The role of biotechnology in animal agriculture to address poverty in Africa: Opportunities and challenges

Proceedings of the 4th All Africa Conference on Animal Agriculture and the 31st Annual Meeting of the Tanzania Society for Animal Production (TSAP)

AASAP

Arusha, Tanzania,
20–24 September 2005

TSAP

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Edited by
J.E.O. Rege, A.M. Nyamu and D. Sendalo

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Preface

The current debate on agricultural biotechnology is, at best, confusing—even to the better informed sections of the public. A complex set of issues, all intertwined, combine to complicate the debate. These include, ethical, moral, socio-economic, political, philosophical and scientific points of view being expressed. While champions provide fascinating arguments illuminating how biotechnology could save the world from poverty and hunger, opponents deride it as the doomsday devil of agriculture. The rest of the public remain sandwiched between the two camps either engaged enough to take a semi-informed stand or indifferent to the discussions.

Africa is emerging as one of the frontlines in the battle for acceptance (or otherwise) of agricultural biotechnology. For Africa, the debate is occurring at a crucial time. The local policy makers who will ultimately decide on the future of biotechnology, including genetically modified foods, are being pushed and pulled in both directions. Only a few countries, namely Burkina Faso, Egypt, Kenya, South Africa, Uganda and Zimbabwe are involved in some form of biotechnology research or (at least for South Africa) commercial use, especially in crop agriculture. A few of these countries have introduced regulations to govern transgenic agriculture.

Clearly, biotechnology issues specific to Africa must include crop and animal productivity, food security, alleviation of poverty and gender equity, and discussions must not be allowed to degenerate into political and philosophical battles, usually led by those who are least affected by the plight of the poor in the continent. Like any new technology, the risks and benefits of biotechnology should be assessed in a cost–benefit analysis framework. The final verdict on a well-tested technology should be untainted by views of zealots on either side of the debate, driven by the needs of the people and supported by solid scientific facts taking into consideration social and monetary costs and benefits. In all the debate to date, the application of biotechnology in animal agriculture has received much less consideration than that for crops. With a focus on the animal sector of agriculture, this conference was designed to provide opportunity for experts and policy makers to examine the potential role of the public sector (notably national governments in developing countries and development partners), the private sector and public–private partnerships that could facilitate North–South transfer of relevant biotechnology.

The overall objective of the conference was to provide an opportunity for African scientists and the broader stakeholder groups of the livestock sector to discuss the potential role of biotechnology in animal agriculture to improve the livelihoods of African people. The conference aimed to attempt, through discussions of a series of papers, to answer the questions: Is biotechnology a menace or an opportunity to address the pressing needs for sustainable livelihoods of poor people? What are the potentials and limitations/threats of biotechnology? The conference organisers envisioned that at the end of the conference some of the following questions would have been addressed, at least in part: Are there proven technologies currently available which Africa can immediately take up to address the known constraints? What are the current technical and institutional constraints to livestock biotechnology research and development in Africa? How can Africa organise itself to take full advantage of available opportunities and to minimise possible threats?

The conference was organised by the All Africa Society for Animal Production (AASAP) in association with the Tanzania Society for Animal Production (TSAP). We would like to express our gratitude to the sponsors of the conference. Special thanks are due to the Government of the United Republic of Tanzania which was a major sponsor and also host of the conference, presenters and authors of papers and posters, our colleagues on the organising committee, institutions,

groups and individuals who assisted in one way or the other, and everyone who attended the conference.

While the following pages provide a good coverage of the proceedings of the conference, they do not, indeed could not, cover the sense of enthusiasm and commitment that characterised the conference itself. Contributions were critical, open and frank, but also constructive and objective in content. The conference atmosphere was truly that of a sense of purpose by a people united to accomplish a task, i.e. to translate the potential of biotechnology for Africa into improved livelihoods for Africa's people. The collegial atmosphere also provided opportunity for networking by participants from across the continent and with colleagues from other corners of the globe. Many new friendships were made, old ones strengthened/renewed, and collaborations born. We have made no attempt to summarise the outcomes of the wide array of discussions on the many papers presented in the six sessions of the conference. After the conference, presenters were asked to submit or revise their papers, taking into account the issues raised during the conference discussions. The papers were then subjected to light technical reviews and language editing, thus ensuring that the intellectual content remains that of the authors.

It is our hope that these proceedings will provide useful reference material for those interested in biotech applications in animal agriculture in developing countries generally and Africa in particular.

Ed Rege, President, AASAP
David Sendalo, Chairman, TSAP

Welcome session

Opening statements

Ed Rege, President
All Africa Society For Animal Production

Hon Mohamed Babu, Regional Commissioner, Arusha Region,
Mme Rosebud Kurwijila, Commissioner for Agriculture and Rural Economy, African Union,
Dr Andrea Rosati, Executive Secretary EAAP and WAAP
Representatives of Sponsoring Organizations/Institutions
Dr David Sendalo, Chairman Tanzania Society for Animal Production
Esteemed Guests
Colleagues
Ladies and Gentlemen

The idea of a regional conference on animal agriculture, initially focusing on Eastern and Central Africa, was conceived by a small group of members of the Animal Production Society of Kenya in 1988. This culminated into an Eastern and Central Africa regional conference on animal agriculture which was held in 1989 in Nairobi and was the precursor of the first All Africa Conference on Animal Agriculture held in Nairobi in 1992. It was at that first conference that a decision was made to have such a meeting of livestock sector scientists and stakeholders every 4 years; the second one was held in Pretoria, South Africa in 1996 and the third one in Alexandria, Egypt in 2000. Thus the conference has been held in eastern, southern, and northern Africa. This fourth conference is coming 5 and not 4 years since the third one, and was originally planned for West Africa. The AASAP would like to thank the TSAP for accepting to host this conference at very short notice after we failed to secure a host in West Africa. We are hopeful that a host country for 2009, preferably from West or Central Africa will be identified this week. Having been intimately involved in the conceptualization and evolution to date of the All Africa Conference initiative, I am in a position to talk about challenges associated with such an undertaking, but hasten to add that it is something that needs to be done – a process that allows professionals and other stakeholders to share ideas and experiences from within and without Africa.

The choice of the theme of the 4th conference, '**The role of biotechnology in animal agriculture to address poverty in Africa: Opportunities and challenges'** was principally informed and justified by four related factors: 1) rapid developments in molecular biology and opportunities offered by the new science to address some of the pressing needs for developing countries generally and Africa in particular; 2) relatively little action in Africa to take advantage of these developments; 3) disproportionately little attention (compared to the crop world) given to policy issues in biotech that specifically relate to animal agriculture; and 4) weak human capacity and institutions to facilitate biotech applications and to support development of requisite policies to analyse, utilize and facilitate delivery of appropriate technologies. In animal agriculture, biotech opportunities are particularly evident in the areas of animal health, understanding genetic diversity and improving utilization of the diversity in indigenous livestock populations, improving animal nutrition and feeding, and the inter-phase between animal agriculture and human nutrition and health.

In addition to plenary issues addressing the broad policy and institutional issues, the conference has sessions focusing on specific technical areas, namely – opportunities biotech offers in the development of livestock vaccines and diagnostics, improved understanding of livestock biodiversity, and gene discovery and delivery.

This conference is not designed as a platform for the 'biotech fanatics' to illuminate their fantasies about the technologies, nor is it intended as an opportunity for the anti-biotech groups to deride biotech. Rather, we are expecting sober discussions that will not only improve our understanding of the opportunities, but also identify the challenges that our nations will have to tackle if the opportunities are to be translated into wealth for, and health of, our people. We hope that the discussions at this conference will not be just for the benefit of technical people, but that they will help sensitize African governments on the issues and actions needed at national or regional levels. These actions must, of necessity include the provision of resources to conduct needed, responsible and relevant research and the utilization of results of such research in poverty eradication and wealth creation programme.

This is truly an international conference. We have representation from countries in Europe, North America, and several corners of the African continent. A total of 35 countries are expected to be represented by the 300 participants who will attend this conference.

I would like to conclude my remarks by expression my personal gratitude and that of the entire organizing committee to our sponsors who have made it possible for this conference to take place:

- The African Union (AU)
- Animal Production Society of Kenya (APSK)
- Brookside Dairy, Kenya
- COSTECH, Tanzania
- CTA, The Netherlands
- Eiselen Foundation, Germany
- Food and Agriculture Organization (FAO)
- Forum for Agricultural Research in Africa (FARA)
- GTZ, Germany
- Heifer Project International
- International Livestock Research Institute (ILRI)
- Ministry of Water and Livestock Development, Tanzania
- Swedish International Development Cooperation Agency (SIDA)
- World Association of Animal Production (WAAP)

Thank you for your attention!

It is now my singular pleasure and privilege to introduce our key note speaker.

A scientist in her own right and one who is quite familiar with the science and policy issues around biotech as well as the African region, our key note speaker is known for her forthrightness in discussing difficult issues.

Ladies and Gentlemen, please help me welcome HE Rosebud Kurwijila, Commissioner for Agriculture and Rural Economy, The African Union.

Ed Rege
Chairman of the International Organizing Committee of the Conference
And President, All Africa Society for Animal Production
September 20, 2005

Opening speech

Hon A. Diallo
Deputy Minister for Water and Livestock Development, Tanzania

The President, All African Society of Animal Production
The Chairman, Tanzania Society of Animal Production
Distinguished guests
Ladies and gentlemen

It is my great pleasure and privilege to welcome you to Tanzania and in particular to this very important Fourth All Africa Conference on Animal Agriculture. I can assure you apart from the favourable weather at Arusha, the hosting of this meeting in partnership with the Tanzania Society of Animal Production is a great honour to my Ministry and Tanzania as a whole.

The choice of this year's conference theme 'The role of biotechnology in animal agriculture to address poverty in Africa: Opportunities and challenges' has come at a time when the continent is searching for new ways and means to battle its long-standing development problems. Africa remains plagued by rampant poverty, hunger and famine, poor health, degradation of natural resources and loss of biodiversity.

Africa's economy is heavily dependent on agriculture where its people grow crops and also keep livestock. Agriculture accounts for about 35% of the continent's GDP, 40% of its exports and 70% of its employment. With the exception of a few countries, the sector is characterised by the lowest productivity in the world due to several factors including inappropriate policies, biotic factors (such as drought, high temperatures, poor soil fertility), and biotic stressors (such as pests and diseases) and high costs of inputs (such as veterinary drugs and chemicals).

There is no doubt the underdevelopment of agriculture has resulted into reduced growth of African economies with its negative implications for the people's livelihood. While rural people strive to feed themselves, urban residents spend more than 70% of their earnings on food, leaving only 30% for basic needs such as health, education and shelter.

Today, over 180 million people in sub-Sahara Africa live below the poverty line, and number is expected to increase to 300 million by 2020. More than 200 million people in this region suffer from chronic under-nutrition. Twelve million Africans are currently facing starvation. Acute malnutrition is high as evidenced by the rates among children under five of underweight (27%), stunting (39%) and wasting (8%).

The continent leads the world in major health problems as 80% of global infectious diseases are found in sub-Sahara Africa. Each year, malaria alone reduces the GDP of sub-Saharan Africa by 1%, kills 2 million people and accounts for about 10% to 25 % of direct child mortality. The HIV/AIDS pandemic has worsened the situation. Tuberculosis, a disease considered to be for the poor, has re-emerged and is causing havoc throughout the region along with infectious diarrhoea, pneumonia and whooping cough, sleeping sickness etc.

Let me briefly talk about our natural resources. Africa's natural resources and biological diversity are under fast degradation, threatening economic and physical survival of the people. Escalating soil erosion, declining soil fertility, soil pollution by agro-chemicals and desertification are some of the factors underlying this degradation. Some 500 million hectares of land in Africa have been affected by soil degradation since 1950. An average of 5.5 million hectares of land resources are

lost every year. Biological diversity is thus under threat in Africa unless immediate action is taken to safeguard them.

It is obvious that the underlining solution to the inherent problems in Africa is the availability and use of appropriate technologies. The world has observed major advances in science including biotechnology during the last 100 years. I am informed biotechnology refers to a basket of scientific techniques that are used to modify life forms with the aim of producing products and services. I am further informed that biotechnology itself is not new. Traditional biotechnology applications such as microbial and food fermentation, tissue culture, breeding and composting have been around for some time. What is new is the degree, precision and speed with which living organisms can be altered using advanced molecular techniques.

Despite the advancements in technology, there are serious reservations about the economic, social and ecological value and costs of some of these modern technologies including genetic engineering. This is, however, not surprising because I tend to believe that every technological advance has potential benefits and risks. Sometimes the hidden costs of technologies can be disastrous to the community. You are all aware of the mad cow disease, ozone-depleting substances and the results of Hiroshima and Nagasaki.

Biotechnology products like GMOs [genetically modified organisms] raise economic, environmental, health and social concerns. There are fears that GM foods may cause new allergies, may be toxic or may result in the development of super weeds. Our farmers are afraid of losing their power to save seeds through the restrictive intellectual property regimes that come with biotechnological advancements.

Sometimes the benefits of biotechnology seem to be over exaggerated. Everybody knows that poverty and hunger are caused by a number of economic, social and political factors. I am sure there are a number of interventions that can be used to solve these problems instead of advanced technologies such as biotechnology.

However, biotechnology has played a large role in improving the welfare of the people in the world since there are many biotechnological tools that do not result in GMOs. For example, I am informed that most of our human and animal vaccines are now DNA based. With DNA fingerprinting, we are able to characterise our livestock.

Because of being ill informed, people many times have failed to separate genuine concerns and benefits of biotechnology. People need scientific evidence from systematic research, backed by cost–benefit analyses and transparency. I thus challenge African scientists to develop a coherent biosafety agenda under our own conditions. Many questions have been asked about the safety of GM foods, but very little work has been done to answer them. You need to develop a common agenda to evaluate the potential biotechnology risks and mechanisms to manage such risks. If you do not, I am afraid Africa will continue to be the recipient of unsound science and hence biotechnologies.

The impressive number of participants to this conference is a clear indication that there are enough and competent scientists to make a case for their people. We should not be dependent on outsiders for opinions or positions on matters of such paramount importance. Potential harm can be predicted and its likelihood minimised through systematic scientific research, regulation and institutional support. Outsiders are of course still welcome, but only as equal and smart partners for mutual benefit.

We need to think strategically and act collectively as Africans to defend our resources, develop our capacity to feed ourselves and maintain our dignity. I hope this conference will indeed act as a catalyst to harmonise our thinking, debating, promoting and regulating the safe and responsible use of biotechnology in pursuit of our development goals and priorities.

No country can afford to ignore biotechnology and hope to succeed in this highly competitive global village. Sound policies and not charity will determine whether the new biotechnologies will be a tool for human development in Africa. Countries need to implement policies that encourage innovation and investment in biotechnology research and development. This should be complemented with rigorous biosafety systems harmonised nationally, regionally and globally.

International arrangements such the Cartegena Protocol on Biosafety, the Bonn Guidelines on access to genetic resources and benefit sharing and the International Treaty on Genetic Resources for food and agriculture are a good starting point. They are not adequate. Efforts should be made to develop comprehensive biotechnology regulatory and policy frameworks that cover all biotechnologies. The development of such frameworks should be done with the full participation of Africa. We have been short-changed many times. International frameworks should not be put in place to safeguard the interests of a few economically privileged countries. The development of international policy and regulatory frameworks should be all-inclusive.

Ladies and gentlemen, looking at your timetable I am relieved because challenges and opportunities, policies, genetic resources improvement, trade and marketing as well as issues related to environment are addressed. I am grateful to Tanzania Society of Animal Production for hosting the Fourth All Africa Society of Animal Production conference. This conference will give you an opportunity to meet and discuss these contentious issues. Dialogue such as this one should help you come up with a well thought out position that should strengthen the African place in the global considerations on biotechnology for animal agriculture.

I once again thank you for inviting me to officiate this very important conference. I wish you a fruitful conference, and now declare it officially opened.

Keynote address

HE Mme R. Kurwijila
Commissioner for Rural Economy and Agriculture
African Union Commission

Honourable Ministers
Your Excellencies Ambassadors
President of the All Africa Society for Animal Production
Esteemed scientists
All invited participants and stakeholders
Ladies and gentlemen

I would like to thank you most sincerely for this opportunity to address the 4th All Africa Conference on Animal Agriculture (AACAA) whose theme addresses a very current and important subject on science and technology in our contemporary world. Indeed biotechnology presents to Africa and the rest of the world at large, both opportunities and challenges.

It is a great pleasure for me to be amongst you and participate in this important conference. As the Commissioner responsible for the Rural Economy and Agriculture portfolio in the African Union Commission (AUC), I would like to use this opportunity to emphasise that, from the AU's perspective, this meeting could not be more timely or important. May I therefore express the AUC's profound appreciation for the untiring efforts of the All Africa Society for Animal Production, its President Dr Ed Rege and the entire staff of the AACAA Secretariat for facilitating consultations and for making it possible for experts in the field of animal agriculture from across the entire continent to gather here today.

I would like to start my address by reiterating the AUC's strong commitment to build an integrated continent of Africa amidst a number of challenges. This is reflected in its vision 'to build an integrated, prosperous and peaceful Africa, an Africa driven and managed by its own citizens and representing a dynamic force in the international arena'. The global objective of the AUC is to 'consolidate institutional pillars, build the human network, and strengthen the body work of integration'.

In a bid to translate the vision into concrete action, eight departments have been created in the Commission, one of which is the Department of Rural Economy and Agriculture mandated to implement our collective strategy and actions to tackle Africa's socio-economic development problems with respect to agriculture. This, ladies and gentlemen, is a huge task.

Africa is the only region in the world in which average per capita food production has been constantly falling for the past 40 years. Yet, agricultural sector is of fundamental importance to the continent. It provides 60% of Africa's employment, whilst 70% to 80% of our population rely on agriculture for their livelihoods. Despite this fact, Africa still imports large quantities of food, including livestock products, which it could produce. These imports are accommodated at the expense of other social needs such as education, health and other important economic infrastructure such as roads, electricity and communication. This cannot and should not continue because Africa has enormous potential to reverse this state of affairs.

A common vision of many African countries and that of the African Union (AU) is to achieve accelerated rural development through more efficient exploitation of its abundant animal resources.

In this regard, the AUC has recognised as critical, the role of livestock in the socio-economic development and livelihoods of most farming communities in Africa. This would entail, amongst other initiatives, establishing the institutional frameworks that would promote development and implementation of appropriate policy for livestock development. The AUC therefore has established three specialised technical offices on livestock within its Department of Rural Economy and Agriculture to drive its livestock focused poverty and hunger reduction strategies that are based on:

- the coordination and harmonisation of policies for improved livestock production,
- promotion of cooperation on transboundary diseases and pest control including tsetse and trypanosomosis eradication from Africa
- promotion of drought mitigation programmes for improved livestock and pasture management.
- These are among the key strategies for us to achieve our strategic vision of the AU.

It is in recognition of the importance of livestock that the Inter-African Bureau for Animal Resources (AU-IBAR) was established as a technical body of the AU to deal with all aspects of livestock production, health, trade and marketing. IBAR has a mandate from the Heads of State and Government of AU member states to coordinate activities of all AU member-states and liaise with regional bodies, inter-governmental and international organisations in matters dealing with animal resources in Africa. The directors of animal resources in member states meet regularly to assist in the formulation of IBAR's programmes to ensure their relevance to the needs of member states. Ministers responsible for animal resources in Africa also meet every three years to approve IBAR's programmes. In 1986, IBAR initiated the Pan African Rinderpest Campaign (PARC) to control the major animal diseases that affect the African continent and to eradicate rinderpest from Africa.

In this respect it is worthy to draw your attention to the achievement recorded so far in the implementation of the Pan African Control of Epizootics (PACE) programme:

Eradication of rinderpest and control of major epizootics: There is now a single zone of critical importance to the final eradication of rinderpest from Africa, viz. the Somali Ecosystem (covering north-east Kenya, southern Somalia and south-eastern Ethiopia). In this area, eradication remains the priority but can only be tackled effectively once the behaviour of the persisting virus is adequately understood. Twenty-seven (27) countries have made progress along the OIE [World organization for animal health] pathway; 16 are recognised as free from rinderpest out of which 4 are recognised as free from infection. Twenty-six (26) African countries have submitted their emergency preparedness plans for rinderpest; 18 of these plans have been approved.

East Africa has established the capacity for monitoring wildlife disease and undertaking sero-surveys and there is improved awareness of the methodology in West and Central Africa. Jointly with FAO and International Atomic Energy Agency (IAEA), functional epidemio-surveillance systems have been established and are operational in 29 out of the 30 PACE member countries, and performance indicators have been developed for their assessment. There has been an important improvement in disease reporting rates to both AU-IBAR (67.5%) and OIE (92%) from the African countries.

The programme for improved delivery of veterinary services and assistance, a community based animal health delivery system supervised by veterinarians, was successfully established in remote pastoral areas of Eastern Africa. The development of new concepts to promote livestock trade within and from Africa is also being promoted, especially in PACE countries.

These achievements could not have been possible without the involvement of African scientists and our development partners. Despite the challenges that remain, I can today confidently extend my congratulations to all those who have made these and other achievements in the field of animal agriculture possible.

I would also like to draw your attention to one of the greatest constraints to animal agriculture in the African continent today, the tsetse and trypanosomosis problem. This problem has been widely acknowledged to be rapidly deteriorating since the 1970s. The problem is inherent in 37 countries of Africa. The multinational nature of tsetse and trypanosomosis eradication programme is inherent in the transboundary nature of tsetse infestation and trypanosomosis prevalence, which in turn calls for maximum inter-state cooperation for effective action, and necessitates a central mechanism to guide and coordinate its implementation. In response to this problem, African Heads of State and Government adopted a decision during the July 2000 Summit held in Togo, urging member states to act collectively and embark on a Pan African Tsetse and Trypanosomosis Eradication Campaign (PATTEC) aimed at eliminating the disease from Africa.

The PATTEC initiative is therefore a programme of the African Union, which proposes to accelerate intervention action against trypanosomosis, through inspiring and engaging the commitment of the affected African countries and emphasising the strategic importance of the ownership, leadership and direct involvement of African governments. Some of the key achievements recorded in the implementation of the PATTEC initiative are:

- A strategic plan and plan of action for the implementation of the initiative were developed.
- Convening and managing regional and inter-state meetings of high-level experts and senior government policy officials in affected countries.
- Training manuals on various themes, including the application of geographic information system (GIS) in tsetse control and the sterile insect technique in tsetse and trypanosomosis control interventions, were developed and a number of training courses and workshops were conducted for participants from member states.
- Several countries have been assisted to develop their national plans and strategies on the implementation of the PATTEC initiative and many countries have now developed their eradication project proposals for identified areas.
- In collaboration with the African Development Bank, a framework has been developed through which countries engaged in the implementation of the objectives of the PATTEC initiative will be assisted. In this connection, the African Development Fund (ADF) is funding a multinational project for the creation of tsetse-free areas in six countries (Burkina Faso, Ethiopia, Ghana, Kenya, Mali and Uganda), as the first phase that forms part of a wider programme coordinated by the AUC under the initiative. The project will cover 37 countries affected by trypanosomosis. The second phase of the project, which is currently being prepared, will include several countries (among them Angola, Botswana, Cameroon, Chad, Namibia, Nigeria, Rwanda, Senegal, Sudan, Tanzania, Zambia and Zimbabwe).. These countries are currently in the process of preparing their national plans of action.

Another AU institution dealing with livestock issues is the Pan African Veterinary Vaccine Centre (PANVAC). PANVAC was founded knowing that livestock health in Africa, especially regarding major infectious diseases that are preventable by vaccination, can be dramatically improved by the use of good quality vaccines and good laboratory diagnosis support. PANVAC is an AU Regional Centre with the principal objectives of certification and quality assurance of veterinary vaccines.

During its previous phases and with the technical assistance of FAO, PANVAC has been able to record the following achievements among others:

- Improve vaccine production and quality control methods in the region
- Promote veterinary vaccine biologics standardisation
- Provide training of over 300 veterinarians and technicians from national vaccine production laboratories in Africa
- Provide technical expertise to vaccine producing countries and to vaccine procuring countries.

The current and future activities of PANVAC are directed to reach its strategic objectives that are to:

- Maintain its status of an international and independent centre of excellence for veterinary vaccines and other biologics quality control and certification
- Strengthen African laboratories and institutions capacity in veterinary vaccines and other biologics production and quality assurance
- Ensure the centre viability and sustainability as an African Union agency.

Allow me now to recall one of the recent decisions by the African Heads of States and Government to foster agricultural development and food security in Africa that was taken in Maputo in July 2003. The African Heads of State and Government recognised the need for Africa to utilise its full potential to increase its food and agricultural production to guarantee sustainable food security and ensure economic prosperity for its peoples.

Cognizant of the critical importance of Africa's agriculture, the Maputo 2003 Summit also adopted the Comprehensive Africa Agriculture Development Programme (CAADP) as the framework for the restoration of agriculture growth, food security and rural development in Africa.

Cognizant also of the critical role of livestock in the livelihoods of rural communities, the Maputo Summit also requested the development of CAADP II, a companion document that covers livestock, fisheries and forestry. This document will be presented to the Ministerial meeting of Ministers for Livestock in Kigali, Rwanda, in November 2005. Priority areas for livestock in the CAADP II companion document include:

- the development of practical technologies for controlling animal diseases that limit livestock productivity
- facilitation of access to input and services for effective animal health delivery systems
- extension services and the development of infrastructure

The AUC also adopted the Africa Livestock (ALive) initiative as a platform for the implementation of its livestock development programmes. This was done after a series of consultations with relevant stakeholders, especially on how the platform can be owned and driven by the African livestock agenda. ALive as an initiative of the World Bank was launched in May 2004 and is a partnership for building a sustainable livestock sector to reduce poverty and stimulate economic growth in Africa. The governance structure of ALive has been devised to encourage the contributions of all of the different partners in the programme and to facilitate participation, transparency, accountability and effectiveness.

At its last session of the ALive General Assembly held in Paris, France, in May 2005, the AU was elected President of the Assembly and Chair of the Executive Committee. This will facilitate the harmonisation of policies of ALive with mandates and vision of the African Union. A decision was also adopted at the last session of the ALive assembly to transfer the secretariat of ALive that is currently housed at the World Bank to AU in the next three years.

I would like to turn to the theme of this year's conference, which is also a subject of interest to the African Union. The debate on the role of biotechnology in agriculture appears to involve a complex set of issues that will take a long time to resolve. Biotechnology has an unrivalled potential to offer solutions to the problems of food security and poverty in Africa. Though not entirely, over the past few decades this area of science and technology has been a source of much debate and contrary views. Africa, in particular has been caught between the liberal views of North America and the more cautious stand of Europe. Meanwhile local public opinion in Africa presents yet another challenge requiring a sober, reasoned position on modern biotechnology.

In recognition of public concern for potential adverse effects of modern biotechnology on human health, biological diversity and the environment in general, the Organisation of African Unity published an African Model Law on Safety in Biotechnology (OAU 2002). The model law is based on the precautionary principle, addressing activities related to import, transit, contained use, release or placing on the market of GMOs [genetically modified organisms] and their products.

The AU Executive Council decision in Maputo 2003 on 'Africa-Wide Capacity Building in Biosafety' also called on the AUC to undertake to convene a meeting of experts and civil society organisations to discuss the issue of biosafety and biotechnology and to come up with proposals for an African common position. The AU has appointed and inaugurated a high-level panel of experts of biotechnology that will advise member states on how to take advantage of this new technology. This initiative is currently ongoing.

Agricultural biotechnology, a term which covers a broad range of different techniques ranging from non-controversial tissue culture to controversial genetic engineering, has the potential to increase agricultural yields; improve livestock productivity; reduce yield losses from insects, diseases and drought; and enhance the nutritive value of crops and livestock products crucial to human health. Modern biotechnology has already yielded transgenic food crops resistant to pests, disease, soil salinity and harsh climate. Recombinant animal vaccines, diagnostics kits for plant and animal diseases are the other benefits already being derived. Despite these success stories, the technology is being confronted with unresolved issues amongst scientists, policy makers and ultimate consumers in the food chain, hence the current debate.

Recently, the focus of public attention on the applications of biotechnology has been on the manipulation of animals, often for production purposes, and on the novel pharmaceuticals for medical applications. However, the area where progress to practical application can be made with the greatest public acceptance is probably in the area of control of animal disease. Genomic sequencing and manipulation of the genomes of pathogens has the capacity to deliver vaccines that offer better protection and less adverse consequences. In the longer term high throughput techniques now in experimental use are likely to be adapted for routine diagnostic purposes, and nucleic acid sequencing is likely to find wider application in epidemiological investigations.

Clearly, the content and nature of the biotechnology debate on how to respond to food crises has been fundamentally and irreversibly altered. So too have been those elements of the debate on how to achieve longer-term agricultural growth and food security through self-sustaining process of growth fuelled by technological advance in agriculture. Many stakeholders believe that in the wake of GM food will come GM agricultural technologies. Enduring uncertainties and controversies over the relevance, efficacy, sustainability and safety of those technologies appear to render such a progression, unpalatable to many.

Now, let me now highlight some challenges that surround biotechnology from an AU perspective that should attract your attention during your deliberations in this meeting:

- Development and application of methods of mammalian embryo manipulation for programmes of animal breeding in Africa will permit more efficient selection and so increase the rate of genetic improvement and production of animals with particular traits.
- There is concern expressed by many people about long-term negative health and environmental effects, such as those now debated in developed countries.
- Unequal sharing of benefits of biotechnology is a major concern, especially where the sovereignty over products like seeds resides with the manufacturer, leading to virtual enslavement of the farmer.
- African countries have made insufficient investments in modern biotechnology so far. Currently, these countries spend on average only 0.85% of their agricultural GDP [gross domestic product] on research, a much lower figure than the 2.6% averaged by industrialised countries.
- Sub-Saharan Africa has deployed insufficient capabilities and resources to advance public GM research. Even as the region makes efforts in research and development of GM products, little effort has so far gone into development of legal and regulatory frameworks at local levels, and in educating the public on GM technology and products.
- Public confusion about risks and benefits of biotechnology should be addressed. Small-scale farmers, who are the backbone of food security in Africa, must be engaged so that they are taken on board in the impending GM revolution.

In conclusion, let me reiterate that biotechnology promotion initiatives that the AU has taken need to be complemented by you as scientists because we need an African common position on biotechnology in animal agriculture. As scientists, I believe you will make a distinct mark in contributing to this position.

I wish you a very successful meeting, and on behalf of the AUC, I look forward to receiving the outcome of your deliberations.

Comments by The World Association of Animal Production (WAAP)

A. Rosati

When each of us decided to come to Arusha to attend this 4th All African Conference on Animal Agriculture we considers the pluses and the minuses of such travel. Among the minuses was the cost of travelling and the separation from our home and office. However, for you that are here the negative aspects of attending this meeting were overcome by the many benefits of being here in Arusha. The benefits are not the same for everybody and each benefit carries a different weight for each of us. Attending this meeting is an opportunity to learn new things and hear about new research activities from the presentations. It is also an opportunity to meet our colleagues with whom we will discuss our projects, learn from their projects and maybe find an opportunity to cooperate. Participating at meetings means mainly contact with other scientists who have similar objectives and face similar constraints but live in different countries. We know that there is much to do for Africa in the field of livestock production. Scientists and institutions from the rest of the world will have to do more and more efficiently, but mainly the African scientists must do more for their continent. The large and enthusiastic participation of African organisations and scientists, especially of young scientists, to this meeting shows that we might be heading the right way.

There were many mistakes and failures made in the past on this continent in animal research and production. Few were successful experiences. We will need to learn and start from there. What we should do in every environment, not only in Africa, is to first identify the real needs and the local environment with its possibilities and constraints. Then we can propose a plan of actions having good possibilities to succeed. In the past, the major causes of failure were due to introducing exotic models into the continent. It simply did not work. Every environment has its specifics influencing greatly the success of the projects. Recently, Carlos Sére [Director General, International Livestock Research Centre] commented to me that Africa cannot miss the 'gene revolution' for it has to be a continent where such new technologies will be developed, to have a direct and sound application of them. African scientists should be at the cutting edge of the new genetic technologies. This time Africa should be able to apply its own model and not to import exotic models.

Allow me now only to talk about the organisation I represent on behalf of the President, Dr Assefaw Tewolde. The World Association for Animal Production (WAAP) is a federation of societies and associations from around the world. Policy makers and industries representatives are also involved in the current activities of the WAAP. The WAAP was established in 1965 and promotes high standards of animal science research, technology, education and science-based public policy. The Association also promotes exchange of scientific and educational information among its members and international cooperation for the purpose of reviewing scientific and educational problems and opportunities in animal agriculture. Every five years WAAP organises a world conference on animal production. The last world conference took place in Porto Alegre, Brazil, in 2003. The next world conference, that will be the 10th, will be organised for the first time in Africa, in Cape Town (South Africa).

The policy of the current WAAP five-year period, from 2003 to 2008, is to support the interests of animal scientists and research organisations towards Africa. For this purpose, WAAP is planning to organise short workshops in different regions of the continent before the South African meeting. The goal is to facilitate the attainment of knowledge about African livestock systems for scientists of other continents. The presence at this meeting of WAAP also has the role to support the creation of an African Society of Animal Science, maybe starting from this All African Conference on Animal Agriculture. The success of this plan, which is very important for livestock science in this continent, will depend very much of you.

I wish you a successful meeting.

Plenary session 1

Biotech in agriculture—challenges and opportunities

Biotechnology in animal agriculture and poverty alleviation: an NGO perspective

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Abstract
Biotechnology has only limited potential to alleviate poverty in rural Africa because it does not address the main reasons for poverty such as weak infrastructure, bad governance and unfavourable terms of trade. Looking at the main characteristics of the predominantly small-scale animal farming in Africa, the potentials and limitations for biotechnological applications in food processing, forage improvement, animal breeding and animal health are discussed. Indigenous biotechnology under the control of livestock farmers can be beneficial, whereas—with the exception of some animal health technologies—large-scale and 'high-tech' applications of biotechnology have shown little potential to alleviate poverty. Indeed, these applications can have the opposite effect. Rather than pouring an undue amount of human and financial resources into further refinement of advanced biotechnology, African livestock researchers should develop their own research agenda that addresses the real problems of small-scale livestock keepers and poverty alleviation.

Key words: livestock systems, indigenous knowledge, food processing, animal breeding, animal health, research prioritisation

Introduction
In recent years, biotechnology—especially gene technology—has greatly altered agricultural production in industrialised countries. Some biotechnology advocates also claim that these new technologies have a great potential to alleviate hunger and poverty. This is open to debate. Here, we examine these claims with respect to animal agriculture in Africa. After outlining the main reasons for poverty, we broadly characterise smallholder and pastoral livestock keeping. We then consider which biotechnology options in animal agriculture can contribute to alleviating poverty and who controls them. Finally, we indicate alternative research priorities in animal agriculture to contribute to poverty alleviation.

Reasons for poverty in Africa
Although statistics have their pitfalls, two things are clear: in Africa poverty is widespread and is largely rural. It is therefore understandable that many people think agricultural production must be increased to alleviate poverty. However, a closer look reveals that poverty and famine are rarely due to insufficient production but rather to:

- insufficient access to land and other productive resources
- unfavourable terms of trade for food products, especially for animal products
- remoteness and weak infrastructure (roads, markets, health services, schooling etc.)
- poor health of farmers (HIV/AIDS, malaria etc.)
- civil or international war or conflicts between groups
- external shocks, such as drought
- bad governance, including corruption
- disregard for indigenous knowledge (IK) and local agricultural resource management.

Moreover, female-headed households are much more likely to be poor than male-headed ones. Can biotechnology in animal agriculture help alleviate these reasons for poverty?

Crop and livestock farming in Africa: Main characteristics

In contrast to industrialised countries where farmers are now a small minority—in the European Union 4.5% and in the USA a mere 0.7% (CIA 2005)—farmers make up the vast majority of the workforce in most African countries. For example, 80% in Tanzania, 75% in Kenya, 70% in Nigeria, and even in the industrial giant on the continent**,** South Africa, the livelihoods of 30% of the people depend on farming. African farmers are not only the majority of the labour force they are also the majority of consumers. They could be called 'market-oriented subsistence' farmers.

African farms are generally small labour-intensive operations in which animals serve multiple functions: providing food and raw materials (hides, skins, horns and wool), a savings account, an investment and a means to accumulate capital. If banks are few and far between how can money best be stored—under the bed where it may be eaten by rats or termites or as a productive investment, e.g. in livestock?

Most African farmers still depend primarily on their local knowledge, and this is dynamic. Within their economic possibilities, they are innovators. If they see opportunities they venture into new enterprises such as more intensive goat keeping in parts of Kenya or pig keeping in parts of southern Nigeria. They do this if the circumstances are right; but in many cases it makes economic sense to keep livestock more extensively. Whereas price ratios between meat (beef and mutton) and grain in the North are often more than 10:1, studies in sub-Saharan Africa indicate that the average price ratio of the cheapest grain to live weight is 1:5.6 (McIntyre et al. 1992). Today in parts of Ethiopia, the price of a kg live weight of sheep is almost at par with a kg of grain. Under these economic conditions, there are few 'potentially profitable' technical options to 'improve' in terms of intensifying husbandry—whether through biotechnological or other means. Additionally, external pressures such as drought or disease are common and are beyond the control of poor livestock keepers.

Biotechnology to alleviate poverty?

Agricultural biotechnology is a loosely used term that includes a wide range of processes that change raw material into something edible or longer lasting. In a broad sense, the use of biotechnology in animal agriculture can be differentiated into four groups:

- food processing, such as fermenting milk and making cheese
- forage additives or fermentation (silage making)
- animal breeding, such as artificial insemination (AI) or embryo transfer (ET)
- improving animal health such as through the production of drugs and vaccines.

Many African societies have long used biotechnology in food processing, especially fermentation. As the souring process weakens pathogens of tuberculosis and brucellosis, drinking sour milk products is safer than drinking fresh non-pasteurised milk. Although men may often do the milking, women usually control milk processing and marketing. In Nigeria, Waters-Bayer (1988) found that particularly the poorer women (from households with few or no cattle) benefited from their application of biotechnology, as women from richer households sold unprocessed milk to poorer women who, in turn, fermented the milk and sold it at a profit in a popular mixture with cooked millet known as *fura da nono*.

Drying or smoking of meat and fish (which may or may not be called biotechnology) also contributes to household income. Meat processed in this way comes from not only domestic but also wild animals. As food processing—including meat processing—is often done by women, these practices can strengthen the position of women and projects building on these practices have indeed helped to alleviate poverty (see for example Lemunyete 2002).

Larger-scale processing of milk using standardised cultures, e.g. to produce yoghurt or cheese, often relies on reconstituted milk and the products may compete with indigenous products. Large-scale drying and spicing of venison to make *biltong* as in southern Africa caters primarily for the urban and tourist markets. These larger enterprises create some employment but their contribution to poverty alleviation is minimal.

Biotechnology for forage treatment

Forage conservation includes drying (hay-making), fermentation (silage-making) and feed additives, e.g. urea treatment of straw. In general, if forage can grow year-round it will be of better quality, making forage conservation superfluous. Where forage growth is highly seasonal, forage conservation can offer a way to balance forage supply to animal requirements but moderate weight losses during a dry season are quickly regained through compensatory growth in the next wet season. Hay can be useful for animal survival during a drought, as an extra ratio for sick animals and in urban farming when forage has to be transported to the animals. But in many other smallholder systems, forage conservation is simply not economic, so biotechnology to improve the processes will not benefit them.

Whereas haymaking can make sense for very small animal holdings, silage making and treatment with urea depends on scale. Wetter material is not easy to store; it needs to be covered and kept under anaerobic conditions. Larger units have less waste than smaller pits. Silage and urea-treated straw are better suited for medium-sized or large animal holdings. The biotechnology in these techniques will make little contribution to alleviating poverty among smallholders. Silage and urea-treated straw have a shorter storage life than hay and, because wet material cannot be transported as easily as can dry material, their use is also less flexible.

Biotechnology for animal breeding

Biotechnology in animal breeding includes AI and ET in practical breeding and DNA-level analyses for breed characterisation. There are certainly merits for these techniques. AI was initially developed to reduce the incidence of reproductive disease in animals, but now allows the use of superior male animals on a larger scale than possible with natural service. If breeding or AI centres are available, smallholders, who often prefer keeping female animals, may no longer have to keep entire males. ET makes it easier to introduce exotic animals into countries that have strict quarantine requirements.

There are, however, a number of prerequisites for successful use of AI. Farmers need to recognise whether an animal is in heat; semen and insemination technicians must be within easy reach; liquid nitrogen has to be available etc. This infrastructure is lacking in large parts of Africa and experience with AI has often been disappointing. Even where it seems to work well, there are some dangers. In most cases, the semen is from animals of potentially high production in meat (rapid growth) or milk. Such high-yielding animals are less resistant to disease, more prone to heat stress, require more water than indigenous breeds and need good-quality feed to achieve their production potential. For a dairy cow that produces 6000 to 8000 litres of milk per lactation, straw with a digestibility of 50–55% is not good forage, whereas indigenous breeds that need only to survive as a savings account can manage on this kind of nutrition.

AI can also lead to loss in biodiversity. AI bulls can become semen millionaires, which may be good for the breeders and the AI businesses but has a disastrous impact on genetic variability in indigenous breeds. For example: Holstein Friesian (HF) is the most widely kept dairy cow in the world—currently at least 50 million cows. With current breeding practices, the HF population in the USA will consist of only 60 genotypes by the year 2015 (de Haan et al. 1997). There are currently about 8.5 million HF cows in the USA (WHFF 2005). The push for maximum production means that many bulls are closely related. This leads to an international uniformity among HF dairy cattle. ET will further accelerate this dangerous trend towards uniformity among dairy cattle.

These trends are occurring in the face of the need to conserve animal genetic diversity. The poorer livestock keepers in Africa have to cope with a great variability in ecological conditions and need animals adapted to the local environments. Uniform, high-producing animals cannot serve this purpose. Indigenous animal genetic resources are needed for that purpose (Vilakati et al. 2003)

Although predominantly used among specialised high-yielding breeds, there are exceptions. Nguni cattle semen and embryos are sold in South Africa. The Nguni are known to be well adapted to harsh environment, can cope with low-quality forage, are fairly tick resistant and tolerate a range of diseases (Bester et al. 2003). However, the number of donor animals does not reflect the variability of types found in the larger Nguni cattle population. And this use of biotechnology raises another difficult issue: the Nguni were originally selected by Zulu cattle breeders but the South African Government successfully discouraged the Zulu from keeping Nguni so white commercial farmers conserved Nguni cattle and brought them back to fame. If the Nguni continue to be commercially successful, who should benefit?

The importance of indigenous animals was also highlighted in research in Ethiopia in a study which assigned economic values to the multi-functionality of goats, including their insurance value. The findings suggest that indigenous goats under improved management practices give higher total benefits to the poorer livestock-keeping households than do crossbred goats, even though the crossbred goats produce more milk (Workneh Aleyew 2000).

Thus, it is unlikely that AI and ET can contribute greatly to poverty alleviation in Africa. Both techniques are presently used mainly for high-yielding animals with high demands with respect to feed quality, sanitation and hygiene. These high-input animals are kept on large farms which can out-compete small farms, e.g. in South Africa. If these large farms operate in a labour-intensive way, on-farm employment may contribute to poverty reduction, but this is not always the case. Another consideration is that breeding with the help of advanced biotechnology such as AI and ET takes the control of the breeding process out of the hands of smallholder livestock keepers and puts it into the hands of commercial breeders/firms and breed societies. These modern breeding institutions cater primarily for large farms and generally disregard the specific requirements of small-scale farmers and pastoralists.

A further application of biotechnology is the gene sequencing and modern genetic analysis of livestock genotypes such as recently done for African cattle by ILRI (Hanotte et al. 2002). Findings that prove the uniqueness and high value of indigenous breeds can be a source of pride for poor livestock farmers, but this still does not improve their economic situation. However, the information can help guide public spending on conservation and use programmes.

Biotechnology for animal health

Modern biotechnology can be used for diagnosis (e.g. to differentiate closely related disease agents) and to develop veterinary medicines and vaccines. Ethno-biotechnology in veterinary medicine involves various types of preparations of leaves, bark, roots etc. The recipes for traditional medicines are often not in the public domain; they are the exclusive knowledge of traditional healers, who charge for their services. The process of developing and producing modern drugs and vaccines is not under the control of small-scale farmers or pastoralists—it is an external service, also provided at a price. Experience has shown that, if vaccination can prevent the loss of animals, using these external services is an investment which also small-scale livestock keepers and pastoralists are willing to make.

To control disease in many parts of Africa, however, the problem is not how to develop new, more effective diagnostic methods, vaccines or drugs. Rather, it is their availability at the local level. For this, more effective organisational structures for the delivery of veterinary services are more urgent than further refinement of diagnostic methods or the development of better vaccines. More effective services also include community-based animal health workers, who live within the livestock-keeping communities and provide the local animals with inexpensive 'first aid'.

The way forward

Biotechnology has only limited potential to alleviate poverty, because it cannot remove the main reasons for poverty which are: political instability, bad governance, insufficient infrastructure and services, disregard of indigenous knowledge, and insufficient recognition by government and researchers that smallholder and pastoral farming is a necessary and valuable part of animal agriculture. Research efforts therefore should be directed into: 1) better understanding the existing animal agriculture systems and IK; 2) developing necessary infrastructure; and 3) improving services, rather than into biotechnology developments that require a sophisticated infrastructure (Waters-Bayer and Bayer 2004). The challenge is to find better ways to address the problems of the vast majority of African livestock keepers and to help develop their potential to respond to opportunities and adapt to change. This is the real scientific revolution that African livestock keepers—and scientists—need. And this is the revolution that many NGOs working in Africa are seeking to bring about.

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Agricultural biotechnology for poverty alleviation: One more arrow in the quiver!

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Abstract

Agriculture is the largest contributor to the economies of many African countries, generating more than half of the annual Gross Domestic Product (GDP) for many of these countries. The livelihoods of most rural and low-income communities in these countries are to a large extent based on agriculture. While global availability of food has increased, 35% of the 800 million poor of the world live in Africa, and face food insecurity. And yet agriculture constitutes, for the majority of these poor, the primary means of survival and livelihood sustenance. Agricultural biotechnology, which comprises a wide range of biological disciplines, offers enormous potential to speed up the development of plant varieties with pro-poor traits such as drought tolerance, pest resistance or tolerance, higher yields, increased nutritional value, among others. Similarly in animal production there is substantial opportunity for development of vaccines and diagnostics targeting diseases which constrain livestock production in developing regions of the world. In addition, genetic markers can aid breeding of livestock for important traits such as disease resistance, improved product quality as well as improved productivity. However, to date, the innovation essential to achieve these improvements has largely remained a technology of the North. While biotechnology does not provide the 'silver bullet' for poverty alleviation, it does enhance the effectiveness of other disciplines such as plant breeding, integrated pest and nutrient management, and livestock breeding, feeding and disease management. Importantly, because use of these technologies, as any other, is associated with risks, African scientists need to have access to the knowledge and scientific infrastructure to assess these risks and to contribute to better informed public discussions of the opportunities and challenges of these technologies. Should biotechnology be a preserve for the rich? Can developing nations afford to ignore the potential of biotechnology? Rather than debate on whether biotechnology can meet the needs of the poor, this paper argues that being just one aspect of a complex set of inter-related interventions required to enhance the contribution of agricultural development to poverty alleviation, discussions should be had on how best to take advantage of the opportunities and manage the risks associated with these technologies, for the benefit of the poor. There is need to explore new ways to build the capacity of the public sector - notably national governments in developing countries and development partners, as well as to tap into the resources of the private sector - to enable the continent come up with African solutions to the problem of poverty alleviation. This will require closer collaboration and transfer, between the North and the South, of appropriate biotechnology and the management of bio-safety issues. Thus, risk assessment has to be an integral part of biotechnology research and development. Africa missed out on the 'Green revolution', and should not miss out on the 'Gene revolution' as well.

Introduction

Africa remains the world's poorest continent. Most African countries have economies characterized by slow and declining growth, low and declining per capita incomes, and declining participation in the global markets. The limited exports from Africa are predominantly low value commodities, while hunger, malnutrition and poverty remain widespread in the continent. An estimated 25 to 30 million children are malnourished and the World Health Organization estimates that 54% of child mortality in African countries is associated with malnutrition. About one-third of the children

in sub-Saharan Africa are stunted because of poor diet, while thousands of people die each day from hunger. Another one-third of the continent's adult population, about 200 million, are food insecure and are forced to live below their full potential because they lack the energy and full health to function at their best. If current trends continue, by 2010 Africa would account for nearly two-thirds of the undernourished people in the world. This vicious cycle of hunger and poverty needs to be broken.

Agriculture is the most important economic activity in Africa and offers the means to reverse these trends and to stimulate wider economic growth. This is because 70% of the people in sub-Saharan Africa live in rural areas and are dependent on agriculture for their livelihoods. However, African agriculture is performing dismally: crop production is the lowest in the world. Yields of basic food grains, for example, are one-fifth those of China. Fertiliser use in Africa is 8 kg per hectare; in Latin America, it is over 60 kg per hectare, and in Asia, over 100 kg per hectare. Only 4% of Africa's farmland is irrigated; in the Middle East and Asia, the figures are 29% and 34% respectively. The Green Revolution has had very little effect on the continent's agriculture in the last decade or so. In Asia and Latin America, between 60% and 80% of crop area is planted with modern varieties; in Africa, the figure is between 20% and 30%. As a result, Africa imports more than 25% of the grain it consumes. Ironically, up to 40% of the continient's harvest is lost to post-harvest damage. Moreover, due to rapid increase in human population, there is need to produce more food on less land, with less water, while conserving the environment.

Although the continent's GDP has improved over the years, the proportion of people living in absolute poverty is higher than it was in the 1980s and 1990s (UNDP 2005). While the economies expanded by 3% per annum between 1990 and 2004, the proportion of Africa's population classified as 'absolute poor' increased by 2 percentage points every year. It is estimated that it will take sub-Saharan Africa until 2012 just to restore average incomes to their 1980s levels (UNDP 2005). There is very limited opportunity for poor people to participate meaningfully in the economy as either producers of goods and services or as suppliers of labour.

Potential role of biotechnology

Science and technology are recognized globally as drivers of increased wealth and continuously improving standards of living. The role of science and technological innovation in economic change and sustainable development is receiving attention at national, regional and international levels. There is ample evidence that economic advances in the developed and newly industrializing countries are results of technological and organizational innovations (Mokyr 2002). Scientifically and technologically advanced countries have become continuously wealthier, and their rates of growth have not slowed significantly over time (Pritchett 1995). These countries have succeeded by reinvesting a growing percentage of their gross domestic product (GDP) in further advancement of research. Translation of research into new, more efficient modes of production has brought dramatic benefits. Technological innovation is associated with turning scientific knowledge into products and processes: putting new technologies and their products on the market and incrementally modifying and adjusting them to respond to socio-economic conditions (Juma 2005). Some of the East Asian countries that capitalized on these opportunities have transformed themselves into middle- or high-income economies (Nankani 2005). The key to success has been to focus on improving skills in solving existing and new problems, putting a premium on continuous learning.

Application of knowledge through new technologies will provide opportunities for improving developing country economies and the well-being of the people, and offer a means for increasing agricultural production, improving human health, and addressing environmental degradation. In

this way it creates economic competitiveness and enhances industrialization. However, these benefits can only be achieved if countries formulate appropriate policies to facilitate the development and utilization of requisite human and financial resources and appropriate infrastructure and functioning support institutions.

In agriculture, advances in biotechnology have resulted in improved research leading to: drought resistant crop varieties; increased pest and disease resistance in crops and livestock; new, refined diagnostics and vaccines for livestock diseases (e.g. Foot-and-Mouth disease and East Coast fever); rapid propagation of clean planting material (e.g. flowers, vegetables, bananas etc.).

Current constraints to the research and application of biotechnology in developing countries include: lack of policies; lack of human and financial resources; lack of public and private investments at levels that can make a difference; absence of systems for the delivery of technologies to potential users; lack of awareness, leading to misconceptions about the potential of, and risks posed by, biotechnology.

What is the evidence that biotechnology can benefit developing countries?

There is now ample evidence to demonstrate the opportunities offered by biotechnology in developing economies, and from which Africa should learn. Two examples are given here, from China and India.

China

In the early 1980s Chinese leaders decided that science and technology (S&T), especially biotechnology, would be one of the drivers to improve the agricultural sector, and committed substantial public investments in biotechnology, e.g. rice biotechnology (mapping rice genome) and rice breeding (to develop hybrid rice varieties), cotton biotechnology for insect resistance, production of value-added horticultural crops, and complimentary innovations such as use of nematodes for biological pest control leading to increased export markets. Currently, hybrid rice accounts for over 30% of rice in China and over 5 million small farmers are growing Bt-cotton on 1 million hectares of land. Use of biological control has reduced pesticide use on cotton by 30% nationally. Today, horticultural exports are expanding. Thus, through a deliberate effort to revolutionize agriculture, China is making quantum leaps in agricultural productivity and sustainability improvements. The country is now moving to the 'post-Green Revolution era' towards becoming an industrialised nation. As has been pointed out above, an efficient agricultural sector ensures food security and enables industrial development.

India

India's National Dairy Development Board (NDDB) oversees improved dairy production by millions of smallholder livestock producers, including many women. Success in using increased milk production to generate increased income on a daily basis is the result of investments in S&T targeting: improved feeding and nutrition of dairy cattle; vaccines to control endemic diseases; and improved animal genotypes and their delivery to farmers. The NDDB organizes delivery of services (including biotechnologies) at the points of milk collection. Payments for technical services are affordable and deducted from milk payments to smallholders. In the 1960s and 1970s India regularly had famines and was a net food importing country. The Green-Revolution in crops and the White Revolution in dairy production are the result of investments in S&T and infrastructure, especially irrigation and communications and the formulation and implementation of supportive public policies (prices, trade etc.) to encourage farmers to go into production. India is now using its productive agricultural sector to guarantee food security and is moving towards

industrialisation. Although there are still millions of people living in poverty in South Asia the trends in India and some of its neighbours are heading in the right direction, with millions moving out of poverty each year.

Livestock and poverty impacts: Role of science and technology

Livestock products have for generations been known to be a pathway for income generation by the poor. There is also evidence that small-scale livestock income plays a disproportionately high role in the income sources of poor rural women and other disadvantaged groups in most parts of the developing world (von Braun and Pandya-Lorch 1991). Demand for food products of animal origin is expected to increase dramatically in developing countries (Delgado et al. 1999). The consumption of meat and milk, for example, is projected to grow at 2.9% and 2.7% per annum respectively, between the late 1990s to 2020. This 'livestock revolution' is also expected to result in increases in demand for pork (60%), poultry meat (80%) and red meat (50%) by 2020, with developing countries accounting for two-thirds of global meat consumption and more than half of global milk consumption. The trends in consumer demand for livestock products are driven primarily by growth in human population, increases in income and urbanization and associated changes in consumption patterns. In East Asia, even lower income rural households have begun to shift increasingly to food consumed outside the home, as they have elsewhere in urban areas of the developing world, which typically involves consuming larger amounts of higher quality animal products (Gale et al. 2005).

In Africa, livestock production remains largely in the hands of small-scale farmers who collectively keep approximately 70% of total livestock units. Given this concentration of livestock production, the potential for a viable industry built around these producers provides a significant opportunity for them to escape poverty while supplying the consumer demand. Diseases sharply reduce the productivity of livestock. Conservative estimates of annual losses of US$ 4 billion in meat and milk production have been reported for sub-Saharan Africa—representing approximately one-fourth of the total value of livestock production. These losses have a significant impact both on food security and poverty. Apart from the zoonotic diseases (such as tuberculosis and Avian influenza) that also afflict poor people, who are in constant contact with different livestock species, there are also a number of other livestock diseases (such as Foot-and-Mouth disease, contagious bovine pleuropneumonia, Rift Valley fever and African Swine fever) which preclude livestock and livestock products of the poor from markets.

Concerns about animal disease transmission keep global livestock to less than 10% of the value of global production, whereas it is 40% for fish, a commodity with equally great food safety issues and where trade is overwhelmingly from the developing to the developed countries (Delgado et al. 2003). Implications of animal health issues on trade are, today, receiving increasingly high prominence at a time when developing country producers are recognizing expanded opportunities for international trade in livestock and livestock products. The stakes in effective disease control in developing countries and reliable 'point of transaction diagnostics for disease-free-status certification' have risen considerably as producers in many of these countries have become aware of the possibility of export as an addition to what had been relatively less attractive domestic markets. This is affecting not only those producers immediately capable of supplying export markets, but is also having an impact on all other producers in the these regions. The negative impact of border closures in the Middle East due to an outbreak of Rift Valley fever (RVF) on the price of livestock in the remotest areas of East Africa (Nin-Pratt et al. 2005) is a case in point.

Technological change in animal disease control with associated policy reforms could bring about a major shift in the distribution of world livestock production in favour of developing countries with abundant labour and land resources (Rich 2005). Beyond the development and application of technologies (such as vaccines and diagnostics) to improve animal health and food safety for trade, there is also need for market and policy research to demonstrate the high costs of compliance with traditionally accepted norms and to evaluate the costs and benefits of alternative options for reducing risk of disease transmission, some of which may be more appropriate to particular developing country situations.

Livestock biotechnologies and poverty: Opportunities for Africa

Animal health

Building on a good understanding (based on cumulative knowledge from within and without the continent) of the biology of livestock (hosts), disease vectors and pathogens, research on animal health in Africa should focus on the development of technologies to address the constraints posed by major livestock diseases in the continent to reduce losses (so as to secure the livestock assets), improve productivity and facilitate access to markets (domestic, regional and global).

As pointed out above, diseases such as contagious bovine pleuropneumonia (CBPP), rinderpest, Newcastle disease (ND), RVF, trypanosomosis, gastrointestinal nematodes, tick-borne diseases (such as East Coast fever (ECF), Heartwater and African Swine fever (ASF)), *inter alia*, continue to present significant challenges for livestock keepers particularly the poor small-scale farmers. These diseases affect intensification, productivity and trade. In terms of interventions, while regulatory measures and cost-effective technologies for disease control have been effective in developed countries, this has not happened in Africa.

Rapid advances in classical and molecular epidemiology, molecular biology, immunology and such new sciences as genomics, bio-informatics and proteomics are providing new technological options that can be applied for the control or eradication of animal diseases in Africa. Some of these technologies are on the threshold of being developed into effective new tools such as diagnostics and vaccines, and investment is required in applied research to facilitate this process. For some diseases, for instance, ND (vaccines), ASF (diagnostics) and ECF (vaccines) progress towards developing effective products is at stages where probability of success is high with only modest investments. Conversely, CBPP (vaccines and diagnostics) requires a two-pronged approach: a quick-win option to improve current vaccines and diagnostics and medium- to longer-term research to generate improved and more sustainable 'new generation' products.

Most, if not all, of the investment in research and development (R&D) relating to the above diseases has been obtained from public sources in developed countries with a fair amount of up-stream activities undertaken in the North. However, many of these diseases, e.g. ASF, ECF, CBPP, RFV, trypanosomosis, among others, have little relevance to the developed world and are unlikely to be of continuing interest to development partners in the North, except for scientific curiosity. In the case of ECF vaccine research, a substantial international effort has contributed to the progress toward proof-of-concept for a vaccine. Nonetheless, funding for completion of current and subsequent steps of R&D is not guaranteed. Similarly, research on short-term options for CBPP has benefited from some 'external' funding but there has not been adequate and sustained funding to increase the likelihood of success.

It is increasingly becoming imperative for Africa not only to define the continent's R&D agenda for livestock health but also to mobilize the required resources, including allocation of national resources, to implement the agenda. Recent technological advances, many already being successfully applied to address human and animal health problems in the North and, indeed in some developing countries in Asia and Latin America, provide opportunities which Africa needs to capture. The level of commitment will be needed both to support quick win options that will translate into products and strategies (such as the Pan-African Rinderpest Campaign initiative, improving the ND vaccine, developing ASF diagnostics, improving current CBPP vaccines and diagnostics) in the shorter term, but also to support medium- to longer-term R&D initiatives.

For some of the disease constraints, there are existing technologies previously developed and working for similar diseases or those developed for the same diseases but under different settings (e.g. pathogen strains, delivery infrastructure etc.) elsewhere. In these cases focus should be on the adaptation of these existing technologies to optimize their use or to enhance their strategic relevance to a wider range of users and production systems. In marginal areas, animal health constraints will need to be addressed through a strategy that combines disease control (through development of appropriate vaccines and diagnostics) and use of appropriate livestock genotypes (which combine productivity and adaptability to local environmental stresses). Conversely, in the rapidly changing sub-sectors, such as smallholder dairying in higher potential areas where exotic breeds and crossbred livestock are predominant, technological interventions need to focus on reducing disease risks and improving animal productivity taking advantage of the more benign environmental conditions.

Genetic improvement of livestock

There is little known about the genetic diversity in indigenous livestock breeds and potential for genetic improvement in developing countries. To improve utilization of these resources, information is needed on: how much diversity exists in specific populations; uniqueness of populations; what breeds/populations to conserve; what conservation methods to apply; and how the genetic diversity in indigenous breeds can be utilised to generate greater benefits for the poor livestock keepers, without compromising the diversity. There are no working models for livestock genetic improvement in low input systems in developing countries, nor true equivalents of the seed systems that have been critical for the success in crop production. Furthermore, given the time required to effect genetic change in livestock, it is even more critical that development of breeding objectives take into account ongoing evolution in the production systems, hence there is need to understand the system changes and the key drivers. Indeed, it is now well accepted that, while *ex situ* approaches can support conservation of livestock diversity, a sustainable strategy has to be one in which the diversity is dynamically maintained as a functioning part of the production system. This underscores the need for strategies and breeding technologies that take the issues of systems changes and links to 'genotype-evolution' into account. Progress in livestock species genome sequencing is opening new ways for the identification and improved understanding of economically important traits and genes. These developments are catalysing the emergence of new tools (e.g. bioinformatics and gene expression units, such as micro-arrays) the applications of which represent new opportunities with significant potential for gene discovery research. These are common technologies for both vaccine research (e.g. antigen identification) and genetic improvement. These new technologies are providing newer, faster and possibly more efficient ways to achieving the same objectives (e.g. a specific breeding goal) and exemplify 'value addition' to, rather than replacement of, 'traditional technologies', by new technologies. There are many international efforts focusing on gene discovery for productivity traits in livestock. Efforts in Africa should focus on adaptive traits needed for the unique circumstances in the continent (e.g. disease resistance), adapting and applying methodologies developed in the North to speed the realization of desired outcomes and achievement of impact at local levels. For diseases such as

helminthosis, which affect livestock (especially small ruminants) across the world, there are good prospects for global partnerships.

Feeds and nutrition

Most African livestock production is under traditional systems in which feeding and nutrition is dictated by climatic factors. Thus, there are large cyclical swings in feed availability and quality closely following the rainfall patterns. During a large part of the year, there is inadequate feed and the nutritive quality of whatever is available is generally too poor to support animal maintenance, much less production; a common problem is low protein and high fibre content. There are a number of biotechnologies which use micro-organisms to 'bio-process' feeds/foods with a view to improving nutritional quality, including digestibility. Important feed ingredients such as maize and soya which are commonly used in monogastric feeds can also be nutritionally enhanced through genetic manipulation. Specifically, marker-based technologies are increasingly used to understand the genetic diversity in forages and in food-feed crops; the technology also has potential use in food-feed crops in ways that ensure that food yields and qualities are preserved or enhanced while at the same time improving the feed attributes.

Institutional arrangements to develop and deliver technologies

For both vaccine development and genetic improvement, lack of a working institutional arrangement to facilitate technology development and delivery can be a major impediment. The nature of these technologies requires the engagement of a large number of stakeholders, usually necessitating complex partnership arrangements, not made any easier by need for biosafety and intellectual property management. Consortia or networks of strategic international collaborators (including public research institutions in the North and the private sector) and national partners are almost invariably essential for success. Given the cost involved in putting together such consortia, it is advisable that, while the initial goal may be quite specific, their designs allow the flexibility to address other similar technological constraints. This is the basis of the concept of 'generic research platform' whose aim is to ensure that the best practices (at both technical and institutional levels) can be applied more broadly, for example, in the case of livestock, to multiple diseases, animal genetic resources and in other regions of the world under different settings. The nature of these platforms may vary considerably and will depend on the scope, focus on addressing a national or an international problem. An example of an innovative institutional arrangement of this type is a new initiative known as the Biosciences eastern and southern Africa (BecA).

BecA, an ILRI-NEPAD (New Partnership for Africa's Development) initiative, is a joint venture involving NEPAD, ILRI and stakeholders of countries in the sub-region. It is providing a platform of shared state-of-the-art research facilities and capacity for application of biosciences in agriculture. The generic nature of the technologies and the partnerships and institutional arrangements are allowing ILRI to expand the impact of its expertise—in such areas as immunology, molecular epidemiology and animal genetics—and research outputs focusing on what gets done rather than just what ILRI does, including availing research capacity beyond what is needed just for livestock research. The vision is to enable African scientists and institutions to become biotechnology innovators as well as technology users. This is to be accomplished through the conduct of biosciences research and innovation targeted at issues affecting Africa's development, while accessing and using the best of science available worldwide. The shared research platform hosted by ILRI is open to African scientists—including those from universities and national research institutes—and researchers from the broader international community willing to collaborate with African partners to address African agricultural constraints.

Another example is a recent initiative known as the Global Alliance for Livestock Vaccines and Diagnostics (GALV), the purpose of which is to establish and support public private partnerships

that will speed the development and delivery of vaccines and diagnostic products for use by poor livestock keepers in low income developing countries. It will do this by focusing on promising leads and aiming to develop these into useful pro-poor animal health products. The initiative is borne out of the recognition that academia and the donor community alone lack the expertise, experience and key technology required to turn promising leads, such as vaccine candidates, into new products for less developed countries through the complex and highly regulated development process. However, the private sector, whether big pharmaceutical companies or small biotechnology companies, usually do not have incentive to take on the expensive research and development programmes themselves for markets that are unlikely to provide a return on investment.

Conclusion

Economic development in Africa will, of necessity, have to be initially linked to agriculture (broadly defined to include crop, livestock, forestry and fish). Staple crops and livestock are the most likely to promote economic growth in the continent. To date, public sector investment in biotechnology in Africa has led to few products. This has, in part, been due to lack of viable private sector partners who are able and willing to take new products to markets. There is also a critical need for innovative public/private sector partnerships which will help link public investments in R&D with private 'know-how' and technology for product development. However, similar to what is happening in Asia and Latin America, there is great opportunity for Africa to mobilize science to create wealth for its people and achieve higher economic growth. This requires: strategic investments in science and technology, with time scales in the range of 20 years (from discovery to delivery); investment in physical, human and financial resources to build indigenous science and technology capacity (human and infrastructure); political will to commit the required resources to develop the requisite capacity and to provide a supportive policy environment; vibrant private sector, including facilitating emergence of a critical mass of innovative and enterprising smallholder farmers. In the short-term, some benefits are possible in Africa from previous discoveries, when adapted and adopted in the African context (e.g. Bt cotton). In the longer-term, there will have to be local innovations that focus on critical constraints in Africa (e.g. endemic diseases of livestock).

For biotechnology to create wealth, at least the following must happen: there has to be a clear definition of priorities/targets (participatory research can assist in target identification); the best of *relevant* science regardless of where it comes from around the world must be mobilized and adapted to address the identified targets (a mechanism for proactive identification of new, relevant science must be put in place); and a critical mass of resources (human and financial) must be available for the targets to be met. In addition, the local private sector and communities need to be involved in product development and commercialization so that new technologies can be both affordable and accessible. Further, more delivery mechanisms have to be developed so that new (bio) technologies are accessible to those who need them. Lessons from the rapid uptake of mobile phone technology in developing countries are pertinent: if a new technology is useful and the price is right, the spread is almost unstoppable. Clearly, biotechnology is not a substitute for other technologies, but is an additional arsenal which should be used as and when appropriate to increase the pace of agricultural development. It is simply another arrow in the quiver!

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Applications of genetic engineering for livestock and biotechnology products[1]

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Summary

The influence that biotechnology is having and will have in the future on animal health is now being realised well beyond the researchers' laboratories. An examination of the evolution of reproductive biotechnologies is presented. The latest techniques allow for the use of transgenic farm animals as sources of biologically activated proteins, bio-pharmaceuticals, as donors in xenotransplantations and for further research in gene therapy, all of which are important applications in human medicine. The beneficial applications of embryo transfer include disease control, transboundary movement of livestock and the provision of sexed sperm and sexed embryos. Although cloning of livestock is a multi-step complex process and the technology needs further evaluation, benefits such as the multiplication of desired traits and the conservation of animal germplasm clearly are substantial benefits. With the application of transgenesis in livestock, the benefits of disease resistance, improved meat, milk and wool quality and protein production in milk and meat (biofarm animals) are major benefits. It is predicted that biotechnology-derived vaccines will become common in animal health programmes where they can be shown to have improved efficacy and safety compared to conventional products.

When carrying out risk assessments for genetically engineered animals, conventional techniques and tools will be useful but it is important to be aware that because limited data are available, the actual hazard identification will be a considerable challenge. As the new technologies with their adherent applications evolve, standard setters and regulators will be faced with the challenge of moving in parallel with technological advances.

In response to a questionnaire sent to Delegates of OIE Member Countries, only 40% of respondents indicated that their animal health regulatory administrations have the capability of conducting risk assessments on biotechnology derived animals or products. Likewise, 20% of respondents do not consider the guidelines for risk analysis adequate to help carry out an import risk analysis on biotechnology-derived animals or products. Furthermore, 50% of respondents do not have a regulatory framework in place to govern cloning, transgenic production or products of biotechnology such as vaccines. Public perception in relation to cloning and biotechnology-derived animals will present considerable challenge to Member Countries with 79% reporting no public support for cloning and 52% reporting biotechnology-derived animals perceived as controversial.

There is considerable work that must be initiated by both Member Countries and the OIE to allow appropriate progression in the very important field of biotechnology and animal health.

[1]This paper was first presented as technical item II at the 73rd General Session of the International Committee of the World organization for animal health (OIE) on 23 May 2005 in Paris, France. The PowerPoint presentation given during the 4th All Africa Conference on Animal Agriculture in Plenary Session 1: Biotech in Agriculture—Challenges and opportunities, held in Arusha, Tanzania, 21–24 September 2005 emphasised items, particularly in the questionnaire, which would be of special interest to the African region.

Introduction

The continued challenge that OIE (World Organisation for Animal Health) member countries currently face with the globalisation of agriculture is not limited to the animal health issues arising from infectious and zoonotic diseases. The fact that reproductive biotechnologies combined with genetic manipulations have developed animals with varying traits poses a new and different kind of challenge to the OIE and the scientific community. We are entering an era which will see more widespread use of reproductive technologies combined with gene manipulations to develop livestock and aquatic animals that can propagate superior or desired traits. Central to the idea of genetic improvement of domestic animals by selective breeding or cross breeding, the world today is presented with the scientific opportunity through assisted reproductive technologies and genetic manipulations that could have a positive impact on public health and well being.

The techniques of molecular biology provide great potential for the production of important medical and agricultural products. The production of biotechnology-derived drugs and vaccines relies heavily on recombinant DNA technology for the design of useful products. The production of recombinant proteins in 'transgenic animal bioreactors' is another application of modern biotechnology in agriculture. Preceding the release of any biotechnology-derived animal into the environment, extensive safety evaluations are carried out to verify if it is safe according to currently available expertise. However, as the risk assessments rarely evaluate the risk as zero, biotechnology products in agriculture are regulated, and the purpose of the existing safety guidelines is to assure that these products pose a minimal risk to public health and the environment. The purpose of this OIE Technical Item II is to discuss the technology that is used to develop biotechnology-derived animals, the applications in the fields of animal health and diagnostics, the delicate balance between regulatory frameworks and the ethics of the science, sound risk assessments based on current science and to give member countries an overview of the applications of biotechnology in the global context.

Techniques

The past four decades have witnessed the commercial adaptation of four generations of reproductive biotechnologies, particularly with cattle. It started with artificial insemination and moved to a second level when *in vivo*-derived embryos were harvested and transferred. The third generation consisted of the *in vitro* fertilised embryos, sex sorting sperm, ovum pick-up and cloning and finally we are at a stage when we are using functional deletion and addition of specific genes to the offspring's genome through transgenesis, combined with powerful molecular biology techniques of siRNA (small interfering RNAs) and the use of viral vectors. Recently there have been combinations of transgenics being propagated by somatic cell nuclear transfer techniques, thus taking reproductive biotechnologies a step further.

Embryo transfer of *in vivo*-derived embryos was a huge step to increase the propagation of germplasm of the desired trait. Compounded by the success of multiple ovulation and embryo transfer technology (MOET) there was an upsurge in the transfer of bovine embryos, especially in North America, where 35% of the 538, 312 embryos available worldwide were transferred in 2002 (Thibier 2003). The *in vitro* embryo production system was instrumental in bringing a spurt in embryo transfer activities across the globe. The data collected in 2002 showed that more than 80,000 *in vitro* produced (IVP) embryos were transferred. The IVP embryos provided a window of opportunity for 'invasiveness' in terms of techniques to assess the embryo characteristics. This included obtaining an embryo biopsy to determine prenatal sex. The use of biopsies for pre-natal genetic diagnosis, blastomere assessment for cloning and for other purposes is still used in many settings.

Production of identical offspring with somatic cell nuclear transfer (cloning) was a big step forward, as earlier embryos were split before transfer to achieve the same result. As early as the 1980s Steve Willadsen showed that embryonic cells from 8–16 cell embryos could be used for embryonic cell cloning, but the birth of 'Dolly' in 1996 proved that it was possible to reprogramme adult differentiated cells. Nuclear cloning is, however, currently an inefficient process with a success rate of 6–10% of embryos transferred to the cattle resulting in a healthy offspring. There are concerns related to higher losses in pregnancy, placental dysfunctions, incorrect epigenetic reprogramming and post-natal complications. These abnormalities may be epigenetic errors that can be corrected during gametogenesis. While the technology is still not beyond the infancy stage, the confidence among the researchers that this could result in genetic preservation and disseminating genetic gains, begs attention both from the scientific point of view and other issues related to ethics, welfare and product safety. In contrast to the cloned animal in which some of the anomalies are viewed, the offspring of clones produced following sexual reproduction appear phenotypically normal. Because nuclear cloning can also result in physiologically normal animals, it is anticipated that the initial commercialisation of this technology will focus on producing small numbers of high value animals for breeding purposes, and possibly also transgenic dairy animals capable of producing valuable pharmaceuticals in their milk.

The first transgenic livestock were produced almost 20 years ago by micro-injection of DNA into the pronuclei of zygotes. Pronuclear micro-injection of DNA has been the standard method for producing transgenic animals. However, this is now being replaced by more efficient methods based on somatic nuclear transfer, which also permit targeted genetic modifications. Lentiviral vectors and siRNA technology are also being used for transgenesis. Research has been focussing on chimera generations via injection of pleuripotent cells in early pre-implantation embryos or blastocysts. Transgenesis has also been achieved in livestock by the culture of spermatogonia and their transplantation into recipient males. A novel approach is the use of active siRNA; the simplicity of this has facilitated adoption of this method to generate permanent or transient knockouts for specific genes. The combination of siRNA and lentiviral vector technology may provide enhanced gene transfer efficiency and specificity in gene knockouts for cattle. Transgenic farm animals are important in human medicine as sources of biologically active proteins, bio-pharmaceuticals, as donors in xenotransplantation and for research in gene therapy.

Applications

For ease of explanation, this part will deal with the applications of technologies in current use that have gained importance in the last three or four decades. The first consideration is the embryo transfer technology which is still the backbone of any assisted reproductive biotechnology. The embryo may be produced *in vitro* and may be manipulated or cloned, yet it still has to be transferred to a recipient to bear the offspring.

Embryo transfer: in vivo and in vitro embryos

The embryo transfer industry grew rapidly in the late 1970s, both in terms of the number of practitioners and in the number of donors flushed. North America has continued to be the centre of commercial embryo transfer activity with more than 190,000 bovine embryos transferred annually. The importance of follicle wave dynamics and methods for the synchronisation of follicular wave emergence has simplified the means by which superovulation might be achieved, resulting in increased embryo production per unit time. Some of the applications that are of clear benefit to the embryo industry are:

Disease control

Several large studies have now shown that the bovine embryo does not transmit infectious diseases, if recommended precautions such as those mentioned in the OIE *Terrestrial animal health code*

(the *Terrestrial code*) (OIE 2004a) are followed. In fact the International Embryo Transfer Society (IETS)—an international embryo biotechnologists association—has categorised disease agents based on the risk of transmission by a bovine embryo. None of the infectious diseases studied have been transmitted by *in vivo*-produced bovine embryos, provided embryo handling procedures were done correctly. Consequently, it has been suggested that embryo transfer could be used to salvage genetics in the face of a disease outbreak, which could also be a useful option in the establishment of disease free herds.

Transboundary movement of livestock

The intercontinental transport of live animals costs a lot, whereas an entire herd can be transported, in the form of frozen embryos, for much less. Added benefits of frozen embryos over live animals include reduced risk of disease transmission, reduced quarantine costs, a wider genetic base, the retention of genetics within the exporting country, and adaptation. The procedures recommended by the IETS for embryo handling that have been endorsed by the OIE greatly reduce the possibility of infectious agents being transferred in *in vivo* derived embryos. However, there is still some risk of infectious agent transmission with *in vitro* derived, abattoir retrieved oocytes, and those with zona breaching.

The development of effective methods of freezing embryos has made embryo transfer a much more efficient technology that is no longer dependent on the immediate availability of suitable recipients. Researchers have directly addressed the question of using IVP as a substitute for *in vivo* production of embryos by conventional embryo transfer procedures. However, it is unclear whether IVP is a realistic alternative to conventional superovulation and embryo transfer for production of embryos from reproductively healthy cattle.

Sexed sperm and sexed embryos

Determination of the sex of pre-implantation bovine embryos with the use of the polymerase chain reaction (PCR) is also commonly used in some situations. However, the removal of the biopsy from the embryo requires a high level of operator skill; embryo biopsy is an invasive technique that results in the invasion of the integrity of the zona pellucida and results in some reduction in the viability of the embryo. The flow cytometric technology used to separate X- and Y-bearing sperm into live fractions has been improved over the last 10 years. With a purity of 90%, about 10 million live sperm of each sex can be sorted per hour. In both cases there is a potential to establish embryo banks to obtain the progeny of choice in any setting. This can reduce the unnecessary cost of producing large number of embryos and transfers related to that.

The science and practice of artificial embryo production (*in -vitro* produced and *in vivo* derived) has given us insight into the early embryonic period and the later foetal and neonatal development. By studying in greater detail the aberrant features of artificially produced embryos, one may find that these very same mechanisms lie behind the so-called ‘normal’ foetal and neonatal loss. This will not only help to improve the efficiency but also provide us with the possibility of critically analysing the more invasive procedures (like biopsy, pronuclear injections etc.) that precede the embryo transfer.

Nuclear transfer cloning

Cloning livestock following somatic cell nuclear transfer involves multiple steps, each with potential for disturbing development of the embryo and foetus, and affecting health during adulthood. For these reasons, the technology needs to be thoroughly evaluated to fully appreciate the longer-term consequences on the animals produced. However the application of this technology, although limited at the present time, shows promise of increased benefits:

Multiplication of desired traits
Cloning could enable the rapid dissemination of superior genotypes from nucleus breeding flocks and herds, directly to commercial farmers. Genotypes could be provided that are ideally suited for specific product characteristics, disease resistance or environmental conditions.

Conservation of animal germplasm
Cloning technology can help salvage the germplasm of indigenous species that are near extinction, including intra-species nuclear transfer procedures which can be used to rescue genes from endangered species.

Research model
Animals can be cloned for research to provide a basic research model of genetically identical individuals, reducing variability in the outcome of experiments.

In association with transgenic applications
Cloning can provide a rapid way to increase the population or number of transgenic animals permitting the testing of genetic stability with reduced progeny intervals.

An increasing body of international data indicates that the major abnormalities in clones are probably epigenetic in nature and do not appear to be transmitted to offspring, even when male and female clones are mated. However, there is the need for molecular confirmation of this observation which will be important in providing confidence in large-scale breeding applications of genetically elite cloned livestock. Despite the current limitations in cloning, milk or meat from cloned livestock does not appear to be materially different from that of conventionally bred animals (FDA/CVM 2003). If the acceptability and utility of this emerging technology are to be improved, it is important to understand the biology behind nuclear cloning to improve the health and viability of the cloned animals produced and their surrogate mothers.

Transgenesis
Application of transgenesis in livestock has been instrumental in the development of animals that are: resistant to diseases, have improved meat, milk or wool quality, can increase proteins in their milk or meat (biopharm animals), or which have characteristics which are environmentally friendly. The production of recombinant proteins is one of the major successes of biotechnology. Milk, egg white, blood, urine and seminal plasma can be sources of recombinant proteins. Numerous experiments have shown that the prediction of the expression of transgenic proteins is possible to a limited extent. The purification of proteins from milk or other body fluids is not too difficult except for those present in blood. The available techniques to produce pharmaceutical proteins can be used to add nutriceuticals to milk and to improve carcass quality or meat composition of livestock or farm animals. Antibodies seem to be the kind of proteins that will be most frequently used, as they could be a good alternative to antibiotics for some infectious diseases.

The application of techniques related to the production of recombinant proteins in milk has reached a certain degree of maturity but there is much to do yet. The combination of recent advancements in reproductive technologies with tools of molecular biology opens the horizon to a new era in transgenic biotechnology. The growing amount of data from the human genome project will certainly inspire intense genome sequencing in livestock and somatic cloning will pave the way for the introduction of novel transgenics in livestock.

Xenotransplantation
The possibility that xenotransplantation may offer an opportunity to have an alternative to organ transplantation from human donors is very attractive to researchers. The application of transgenic

technologies can alter donor animals, so that the stimulus to induce immune rejection in recipient patients is much reduced. The research in this area is focussed on the pig genome, to make pig organs and tissues more compatible to humans. Disruption of the gene causing hyperacute rejection response (Galactose alpha 1, 3 galactose), by gene targeting in genetically modified (GM) pigs, has been achieved and further use of nuclear transfer for propagating them is in progress. This provides immense hope for patients awaiting transplantation and needing organs or tissues to fight major medical conditions such as heart disease and diabetes.

Vaccines

There are three major considerations in the registration of vaccines for use in animals and biotechnology-derived vaccines have both advantages and disadvantages in each of these areas. The OIE *Manual of diagnostic tests and vaccines for terrestrial animals* (the *Terrestrial manual*) (OIE 2004b)and the *Terrestrial Code* (OIE 2004a) make mention of these conditions. However, considerations are described in different ways in different regulations, but the key elements that must be demonstrated in any vaccine are efficacy (not worthless, satisfactory potency), purity (not contaminated) and safety (not dangerous or harmful to the environment, humans or animals).

Efficacy is usually determined following a challenge of vaccinated and control animals using a specific disease model. The observed protection from clinical disease or death following a specific dose and route of vaccination is used to formulate a claim for the vaccine product. Subsequent batches or serials of vaccine are compared to the original batch used in this study, and a potency test is developed to enable the prediction that each serial with a satisfactory potency test will lead to the same level of protection observed in vaccinated animals in the study. Biotechnology-derived vaccines which incorporate antigens which are known to be targets of a protective immune response and which present those antigens in a manner to maximise the required type of immune protection may enhance efficacy. These vaccines may also have more thermostable antigens, perhaps plant-derived proteins, allowing this vaccine potency to be maintained in the absence of a cold chain in tropical countries. In many disease models though, the use of live attenuated disease organisms in vaccination leads to the highest level of immune protection, even if there are some residual safety concerns.

Purity is determined by ensuring that the organisms and ingredients used to make the vaccine are not contaminated with other micro-organisms, or toxins, or perhaps prions. With many biotechnology-derived vaccines, the platform expressing the antigens of interest is well characterised, and the vaccine can often be produced with a minimal risk of contamination. Growing more conventional pathogens for the production of killed vaccines often requires the use of materials of animal origin in order to maximise the expression of the antigens of interest, which increases risks of contamination of the vaccine. However, plant-made vaccines grown in open fields risk having undefined contamination such as weeds, fungus or insects, but this may not impact on the safety of the product if administered orally.

Safety is probably the most important potential advantage of biotechnology-derived vaccines. DNA vaccines which do not require oil-based adjuvants are safer to administer by humans and are also safer for animals including fish than some conventional vaccines. Vectors for recombinant vaccines can be selected to minimise any possibility of reversion to virulence which sometime occurs with live attenuated vaccines. Conventional vaccines may also contain toxic elements that are not completely inactivated or removed by the manufacturing process and which may not be necessary for stimulating immune protection in the animal. Removal of these toxins in biotechnology-derived vaccines improves product safety to both humans handling the vaccine or eating vaccinated animals and to the animals themselves. The use of genetically-modified vectors

or plants in the environment does raise some concerns of environmental safety which may be different than the use of conventional live attenuated vaccines. Steps must be taken in the approval process of these products to evaluate and to minimise all of the potential concerns which can be identified.

Ultimately, the usefulness of vaccines will be determined by their availability. This, in turn, is affected by elements such as cost of production and acceptance of a role of vaccination in disease control programmes. Biotechnology-derived vaccines will become common in animal health programmes in cases where they can be shown to have improved efficacy or safety when compared to conventional products, and if they are available.

Risk assessment considerations

Advances in genetic engineering continue to emerge at an accelerating pace, enhancing the potential for its applications. It is anticipated that commercialisation of farm animals genetically engineered to produce unique traits will soon be a reality. Both transgenic and cloned animals raise potentially new concerns about food safety, human health, animal health (and welfare) and the environment. Therefore there is a pressing requirement to develop methodologies to adequately assess the safety of such animals.

To this end, there is a need to bring together scientists, regulators, international organisations, such as OIE, FAO and WHO and other stakeholders to identify and review the science-based data and concerns relevant to science-based risk assessment and management of genetically engineered animals released into the environment. These expert consultations could help design research to solve problems and to identify and develop appropriate management practices to minimise risks associated with genetically-engineered animals.

Risk assessment for genetically engineered animals is not much different than that for conventional animals but because of limited data, general uncertainties and unknowns, the paramount point of a risk assessment, hazard identification, remains an enormous challenge for the risk assessors.

The major difference resides in the identification of hazards from potential genetic abnormalities (phenotypically or genotypically) that can be of possible harm. Since animals exhibiting grossly undesirable effects are likely to be eliminated during commercial development, the areas of concern are those caused by subtle dysregulation of genes.

The following questions, arising from these subtle genetic abnormalities, will render risk assessment more complex and probably, in early stages, result in a high degree of uncertainty:

- How would one detect them?
- How would subtle genetic hazards from genetically-engineered animals differ from the gene dysregulation arising in conventional animals?
- How frequently do they occur compared to conventional animals?
- Would these genetic hazards pose a risk?
- Should they pose a risk, how to measure risks if they happen?

In addition to risk assessment, risk analyses pertaining to genetically-engineered animals involves risk communication (throughout the entire process) and risk management. These other components of the analysis must also take economic, ethical and societal as well as animal welfare factors into account.

At this early stage of the development of genetically-engineered animals, assessments will be based upon data extrapolated from related studies done with other genetic modifications or in other species, often utilising material supplied by the companies marketing the products. In this context, governments must maintain the public trust at a high level through impartiality, integrity and transparency of its decision making process with respect to genetically-engineered animals and their products.

It is perhaps reasonable to believe that in the coming years, the analysis of the risks associated with genetically-engineered animals will become routine, as it has for the import of conventional animals and animal products. Ongoing improvements in the techniques of genetically-engineered animal production will likely reduce the incidence of animal health problems now recognised, and the continued growth of the body of knowledge will reduce the uncertainties that now exist. In addition, new techniques and increased experience will also improve methods of risk management.

Conversely, future research and new techniques will perhaps identify hitherto unknown problems for the risk analyst to deal with—as old issues get resolved, new ones may emerge. It is safe to assume that the challenges presented by animal biotechnology for the risk analyst and other regulatory staff will continue for some time to come.

Regulatory framework

New technologies need to be controlled by guidelines or regulations so as to maximise benefits and minimise risks to humans, animals and the environment. The acceptance of agricultural biotechnology will depend on whether consumers see an obvious personal and societal benefit in the new products. However, the role of the regulators is also to assist the public make an informed decision by critically evaluating the data related to the technology and determining the level of risk to the consumer, the animal population and the environment. Development of legislation and the regulatory provisions do not move as quickly as advances in science. In most cases the regulations are developed to address the concerns of the consumers and society and to provide a much needed level of protection.

Since transgenesis and cloning are relatively new scientific techniques, transgenic animals are new organisms for which there is limited information. The issues associated with the regulation and biosafety of transgenic animals pertain to environmental impact, food safety, animal health and welfare, trade and ethics. To regulate this new and powerful technology predicated on limited background information is a challenge not only for the regulators but also for the developers of such animals, who strive to prove that the animals are safe and merit bio-equivalency to their conventional counterparts. In principle, an effective regulatory sieve should permit safe products, while forming a formidable barrier for those assessed as posing an unacceptable risk.

The regulation of products derived from biotechnology can be based on the principles used for conventionally produced animals. Regulations and standards for determining a responsible use of animal biotechnology in food and agriculture are based on principles that take into account criteria such as benefits and risks, scientific basis of biotechnology and effects on the environment, and must also consider animal welfare and social acceptance (Howard et al. 2001). Transgenic animals may be viewed as most acceptable if the end result of the genetic manipulation applied is to provide better quality of life for humans, or to provide ‘environmentally friendly’ alternatives to ‘factory farms’. The regulations that each country uses to safeguard the public, the animal population and the environment from unintended effects of novel products or technologies are specific to the way the regulatory framework is established. For example, some countries may

have an approach to regulate the technology, while others may be regulating the products of biotechnology. Some of the salient considerations for sound regulation developments are:

- high standards for human and animal health and welfare
- development of clear standards and guidelines for assessments
- provision of sound scientific basis to evaluate associated risks
- consultation and involvement of stakeholders in the development of regulations
- maintenance of genetic diversity and conservation of environment
- building upon existing regulations.

The existing scenario allows us to extrapolate the standards and to develop regulations from the continued research and work being done by international organisations such as the OIE, FAO and IETS. IETS was founded in 1974 with 82 charter members representing researchers, academics and veterinary practitioners. A growing majority of the IETS membership is composed of basic researchers representing government, industrial or academic institutions, including human medicine. However, IETS has played a very important role in the dissemination of basic and applied information, allowing for the rapid growth of the embryo transfer industry in the 1980s and 1990s. In particular, the Import/Export Committee of IETS now referred to as the Health and Safety Advisory Committee (HASAC) has been instrumental in gathering and disseminating scientific information on the potential for disease control by the use of bovine embryo transfer. There was the round table meeting on sanitary issues related to embryo transfers between the IETS and OIE in 1985 (See reference), resulting in the drafting of sanitary procedures for the international movement of embryos in the OIE *Terrestrial code*, and the International Embryo Movement Symposium, sponsored by IETS. These events along with continued close collaboration between IETS and OIE have made the international movement of cattle embryos possible. In this regard, the manual of the International Embryo Transfer Society (Thibier 1998) has become the reference source for sanitary procedures used in export protocols. Today most of the international movement of embryos is based on the recommendations of IETS many of which are endorsed by the OIE *Terrestrial code* and the procedures documented in the manual of IETS are the red book letters for the regulators.

International organisations such as FAO have conducted workshops as technology has progressed, including 'Gene-based technologies' (FAO/IAEA 2003), and the expert consultation on genetically modified animals held in Rome (FAO/WHO 2003. The recommendations of these consultations and workshops form a solid basis for development of regulations in general. The forums where the food safety of cloned animals and international movement, identification and traceability of the embryos is discussed and standards recommended, takes place under the auspices of different subcommittees of IETS.

In essence the regulatory framework may be very specific to the region and the country, yet the consideration is more towards harmonising the approach, so as to facilitate sharing of safety information and to help countries prevent the spread of disease or infections through germplasm. The OIE has therefore an important role to play as a standard-setting body in accordance with its mandate under the WTO-SPS Agreement.

Questionnaire

The OIE sent a questionnaire to the delegates of all 167 OIE member countries to assemble baseline information on some questions relating to applications of biotechnology for livestock and animal health products. Responses were received from 91 countries, including a broad cross section of member countries from all regions. The results are presented as Appendices I and II and are summarised in this preliminary analysis. The questions and tabulated summary results

will be posted on the OIE website. This information will provide a useful baseline to identify topics for discussion in international reference groups and standard setting bodies such as the OIE, and international organisations such as Veterinary International Cooperation for Harmonisation (VICH), and IETS.

The responses to this survey have illustrated a number of common interests and concerns for animal health regulatory agencies and for livestock producers and consumers. There are many potential opportunities for international collaboration in establishing technical standards and risk assessment procedures for these technologies. It is clear that OIE and affiliated standard setting bodies will have a key role to play in facilitating the dissemination of information on development of appropriate risk-based regulatory standards, approval processes and certification procedures for biotechnology-derived livestock and animal health products.

The OIE formed a Biotechnology Working Group in 1989 that was active until November 2000.After the group stopped functioning it was decided that its work would be incorporated into other *ad hoc* groups which would be assigned to study specific topics. It is possible that this survey and the review papers in the Scientific and Technical Review will help to identify issues for further discussion, including some topics which might be referred to *ad hoc* groups for in depth analysis and recommendations.

The following 91 countries provided a response to the questionnaire: Algeria, Andorra, Angola, Argentina, Australia, Austria, Azerbaijan, Belgium, Benin, Bhutan, Bosnia and Herzegovina, Brazil, Brunei, Burkina Faso, Cambodia, Canada, Colombia, Congo (Dem. Rep.), Costa Rica, Cote d'Ivoire, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Eritrea, Estonia, Finland, France, Georgia, Germany, Ghana, Greece, Guatemala, Guinea Bissau, Hungary, Iceland, India, Japan, Kazakhstan, Kenya, Kuwait, Latvia, Lithuania, Luxemburg, Madagascar, Mali, Mauritania, Mauritius, Mexico, Moldavia, Morocco, Myanmar, Namibia, Nepal, Netherlands, New Caledonia, New Zealand, Nicaragua, Norway, Pakistan, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Serbia and Montenegro, Slovakia, Slovenia, Spain, Sudan, Swaziland, Sweden, Switzerland, Taipei China, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, United Kingdom, United States of America, Uruguay, Venezuela and Zimbabwe.

Definitions

Eighty-one of the ninety-one OIE member countries (89%) responding to question 1 agreed with the proposed definitions as applicable to livestock biotechnology. Agreement was consistently high across all geographical areas. Where respondents did not agree with the definitions, the most highly suggested sources for definitions were the Cartegena Protocol on Biosafety to the Convention on Biodiversity and Codex Alimentarius in its Principles for the Risk Analysis of Foods Derived from Modern Biotechnology (CAC/GL 44-2003).

Risk analysis

Fifty-three of the eighty-nine (60%) member countries that responded to question 3 reported that the animal health authority in their country is not capable of conducting risk analysis on biotechnology-derived livestock and biotechnology products. The two main reasons reported for not performing risk analysis on these commodities are the absence of training (53%) and the lack of knowledge (26%).

Eighty-four per cent (75 of 89) of the respondents indicated that they do not have a dedicated unit conducting risk analyses pertaining to biotechnology commodities (question 4). Risk analyses are being conducted by the epidemiology and surveillance unit in 29% of cases, and 37% of

respondents answered that other units conduct these risk analyses. Only 9% use an external consultant to conduct a risk analysis on these commodities. Forty-five per cent of the Asian respondents indicated that risk analyses are conducted by the Import-Export unit.

In question 5, the major factors identified by the animal health authorities as being considered when determining the risk associated with these biotechnology commodities are respectively: food safety (26%), animal health (26%) and environmental impact (23%).

Only 25% of the member countries have conducted (or received a request to conduct) a risk analysis on biotechnology commodities, for a total of 33 requests (question 6). In 52% of the cases (17 cases out of 33), the risk analyses were conducted (or were requested to be conducted) on biotechnology products, whereas only 3 were requested on cloned animals and 7 were requested on transgenic animals. Most of the requests are from countries in the Americas (13 cases).

Only 29% (25 out 89 respondents) of the member countries are willing to make their risk analysis document available for peer review or for public consultation, using official government publication as the main means of dissemination. Peer reviews are mainly conducted internally (45%) within the veterinary services. Only European member states reported having risk analyses peer reviewed internally (37%) or externally (36%) at approximately the same proportion.

Seventy-seven per cent of the respondents (63 of 81) to question 8 considered that the 'Guidelines for risk analysis' contained in the OIE *Terrestrial code* were adequate to carry out an import risk analysis on a biotechnology commodity. Forty-four per cent of the member countries (8 of 18 respondents) that considered that these guidelines were not adequate are from the Americas and these member countries also reported receiving most of the requests (39%) to conduct a risk analysis (question 6).

Regulatory framework

Sixty-four per cent (58 of 91) OIE member countries responding to question 9 reported that they did not produce biotechnology-derived animals or biotechnology-derived products for use on animals. Out of the 31 countries responding 'yes' to this question (note that 2 did not answer), 14 countries (45%) are European Member States.

Respondents to question 10 reported having capabilities in the following fields: cloning (17%), transgenic production (20%) and products of biotechnology for use in animals such as vaccines and/or drugs (28%). Thirty-five per cent of respondents to the questionnaire did not provide an answer to this question.

Approximately half of the OIE member countries responding to question 11 reported having a regulatory framework in place to govern the use of a biotechnology commodity (44 reported having a framework out of 89 respondents). Sixty-two per cent of European members and fifty-three per cent of countries from the Americas responding to question 11 indicated that they have a framework in place to govern the use of such commodities

Research

Slightly less than half (47%) of the 91 responding OIE countries to question 12 reported that there is research being conducted in their country into biotechnology-derived animals and products, including vaccines and drugs. At 64%, Asia had the highest percentage of responding countries engaged in animal biotechnology research activities, followed closely by Europe at 59%, the

Middle East at 50%, the Americas at 41%, and Africa at 25%. Although this question covers a wide variety of activities, the results indicate that this is an active area of research.

Animal vaccines

Forty out of eighty-nine responding OIE Member countries (44%) to question 13 reported that they produced or used animal vaccines in their countries that are biotechnology-derived. This may include experimental products that are not currently licensed for general use, since the question did not ask that countries specify the licensing or marketing authorisation status of products.

Twenty-six of the forty countries who replied said that they produced or used viral vectored vaccines (29% of the responders to this question) which included antigen(s) from unrelated organisms. Sixteen countries (18%) reported using bacterial vectored vaccines which include antigen(s) from unrelated organisms. Twenty-two countries (25%) reported using vaccines which have deleted antigen(s) to differentiate infected animals from vaccinates (DIVA). Twenty-six (29%) of countries produced or used vaccines which included recombinant proteins, and six countries reported using DNA vaccines (7%). One other biotechnology-derived vaccine was reported but not described in the questionnaire.

Eighty-seven countries responded to question 14 which asked how biotechnology-derived vaccines and/or drugs are generally perceived by the public in their countries. Twelve countries (14% of responders) indicated they were perceived as safe, twenty-five (28%) said they were controversial, and thirty-nine countries (45%) said that the public was mostly unaware of biotechnology-derived vaccines. Eleven other countries (13%) made a variety of other comments in response to this question.

When examining public opinion research done in individual countries, it seems unlikely that approximately half of the population in the responding countries are truly ‘aware’ of biotechnology-derived veterinary vaccines and drugs. People can be unaware of products but, when asked, think the products are safe and well-regulated. They can also be aware and think the products are not safe and are not well-regulated. These questions are often separated in detailed polling for that reason.

Technologies

Sixty-six per cent of the member countries that responded indicated that they do not have livestock cloning and/or transgenic animal production facilities in their country. However the European region indicated that 50% of the 34 countries that responded (69%) do have livestock cloning and/or transgenic animal production facilities in there country.

Out of the 91 countries that responded to the questionnaire, 64 (72%) indicated that biotechnology-derived animals or their products are not permitted in the food or feed supply in their country. In the Asian region 43% indicated that biotechnology-derived animals or their products are permitted in the food or feed supply in their country.

Eighty-three countries (83 of 91) responded to question 17; 79% of the responders indicated that there was no public support for cloning of animals. Of the 12% that indicated there was public support for cloning of animals the main purpose chosen was for the rescue of endangered species and generating stem cells (36% each).

When member countries were asked if there are transgenic animals present in their country, out of the 54% that replied to the question 79% indicated that there were no transgenic animals in their country. Of the 24% that indicated there were transgenic animals in that country, 45% reported that the animals were generated for biopharmaceuticals.

Of the 89 countries that responded to this question, 56% indicated that their country does not have the laboratory capacity to identify and detect transgenes in the food/feed supply. However, in the Asian region 50% and the European region 65% indicated that they do have the laboratory capacity to identify and detect transgenes in the food/feed supply.

Public perception

Like question 14 above, this question asked people what they thought about the way other people think. Overall the evidence suggests that, as with most applications, people use the same case-by-case risk/benefit analysis when evaluating these new techniques. In public opinion research on biotechnology, there is a clear hierarchy of support for various applications, and often health applications are at the top of the list, and food applications are nearer to the bottom.

For questions 14 and 20 that asked about public perception, it is very difficult to meaningfully compare data from different public opinion questionnaires (i.e. different questions asked under different circumstances). These questions measure the perception of government workers about public opinion (as opposed to actually measuring public opinion). There are some efforts to create agreed-upon methodology and questions (e.g. by international groups of academics and researchers) and it could be useful if OIE could be informed of the expertise of these people.

Conclusion

In conclusion the OIE may wish to consider further work as follows:

1) Development of a definition for biotechnology which can be agreed by OIE member countries.
2) Development of standards and guidelines for research on containment and environmental release of live attenuated vaccines in animal health.
3) Development of recommendations and guidelines for use of DNA vaccines in food animals.
4) Development of guidelines and recommendations for somatic cell nuclear transfer cloning—guidance for interspecies cloning, recognising that this process has the potential to increase the possibility for transmission of diseases between species.
5) Develop objective criteria for assessing the health of embryos and animals derived from cloning, and associated safety of cloned livestock and their products.
6) Develop policy guidelines for exclusion of unapproved animals and products from the livestock population, and segregation from the feed and food supply.
7) Develop identification, testing, and certification guidelines for international trade in livestock animals and their products for which biotechnology procedures have been used to confer disease resistance.
8) Incorporate standards into relevant OIE documentation such as the *Terrestrial manual* and the *Terrestrial code* and the companion standards for aquatic animals.
9) Development of guidelines relevant to the application of nanoscience/nanotechnology as it relates to animal health.

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Appendix I. Regional membership of OIE member countries.

Africa	Americas	Asia	Europe
Algeria	Argentina	Australia	Albania
Angola	Barbados	Bangladesh	Andorra
Benin	Belize	Bhutan	Armenia
Botswana	Bolivia	Brunei	Austria
Burkina Faso	Brazil	Cambodia	Azerbaijan
Burundi	Canada	China (People's Rep. of)	Belarus
Cameroon	Chile		Belgium
Central African Rep.	Colombia	India	Bosnia and Herzegovina
Chad	Costa Rica	Indonesia	
Comoros	Cuba	Japan	Bulgaria
Congo	Dominican (Rep.)	Korea (Republic of)	Croatia
Congo (Dem. Rep. of the)	Ecuador	Korea (Dem. People's Republic of)	Cyprus
	El Salvador		Czech Republic
Côte d'Ivoire	Guatemala	Laos	Denmark
Djibouti	Guyana	Malaysia	Estonia
Egypt	Haiti	Mongolia	Former Yugoslavia
Equatorial Guinea	Honduras	Myanmar	Rep. of Macedonia
Eritrea	Jamaica	Nepal	Finland
Ethiopia	Mexico	New Caledonia	France
Gabon	Nicaragua	New Zealand	Georgia
Ghana	Panama	Pakistan	Germany
Guinea	Paraguay	Philippines	Greece
Guinea-Bissau	Peru	Singapore	Hungary
Kenya	Surinam	Sri Lanka	Iceland
Lesotho	Trinidad and Tobago	Taipei China	Ireland
Libya	United States of America	Thailand	Israel
Madagascar		Vanuatu	Italy
Malawi	Uruguay	Vietnam	Kazakhstan
Mali	Venezuela		Kirghizistan

Mali	Venezuela	Kirghizistan
Mauritania		Latvia
Mauritius		Lithuania
Morocco	**Middle East**	Luxembourg
Mozambique		Malta
Namibia	Afghanistan	Moldavia
Niger	Bahrain	Norway
Nigeria	Iran	Poland
Rwanda	Iraq	Portugal
Sao Tomé and Principe	Jordan	Romania
	Kuwait	Russia
Senegal	Lebanon	Serbia and Montenegro
Sierra Leone	Oman	
Somalia	Qatar	Slovakia
South Africa	Saudi Arabia	Slovenia
Sudan	Syria	Spain
Swaziland	Turkey	Sweden
Tanzania	United Arab Emirates	Switzerland
Togo	Yemen	Tajikistan
Tunisia		The Netherlands
Uganda		Turkmenistan
Zambia Zimbabwe		Ukraine

APPENDIX II

Results of responses to questionnaire on biotechnology

Do you agree with these proposed definitions as applicable to livestock biotechnology?

Proposed Definitions:

A) "biotechnology" means the application of science and engineering in the direct or indirect use of living organisms or parts or products of living organisms in their natural or modified forms.

1 *B) "living modified organism" means any living organism that possesses a novel combination of genetic material obtained through the use of:*

(i) in vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles; or

(ii) techniques involving the fusion of cells beyond the taxonomic family, that overcome natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection.

	Global		**Africa**		**America**		**Asia**		**Europe**		**Middle East**	
Yes	81	89%	23	96%	15	88%	12	86%	29	85%	2	100%
No	9	10%	1	4%	2	12%	2	14%	4	12%	0	0%
Did Not Respond (DNR)	1	1%	0	0	0%	0	0%	1	3%	0	0%	
If no – suggest an acceptable definition												
Specify	10		1		3		3		3		0	

Key consideration2Please score the following considerations as they pertain to the application of genetic engineering to animals. For each topic listed below circle a score on a scale of 1 to 5, where 1 indicates unimportant considerations, and 5 indicates very important considerations.

	Global		Africa		America		Asia		Europe		Middle East	
	Total	Average	Total	Average	Total	Average	Total	Average	Total	Average	Total	Average
Animal welfare	303	3,33	66	2,75	65	3,82	41	2,93	124	3,65	7	3,50
Economic aspects	334	3,67	99	4,13	68	4,00	51	3,64	109	3,21	7	3,50
Food safety	365	4,01	88	3,67	72	4,24	53	3,79	142	4,18	10	5,00
Environmental impact	353	3,88	87	3,63	74	4,35	47	3,36	137	4,03	8	4,00
Traceability	348	3,82	91	3,79	73	4,29	49	3,50	125	3,68	10	5,00
Nanotechnology	248	2,73	60	2,50	55	3,24	34	2,43	90	2,65	9	4,50
Human health (other than food)	362	3,98	98	4,08	72	4,24	46	3,29	136	4,00	10	5,00
Animal health	384	4,22	106	4,42	81	4,76	51	3,64	138	4,06	8	4,00
Regulatory controls	351	3,86	92	3,83	74	4,35	52	3,71	127	3,74	6	3,00
Xenotransplantation	308	3,38	66	2,75	69	4,06	43	3,07	123	3,62	7	3,50

3. Do the animal health regulatory administrations and/or agencies in your country have the capability to conduct risk analysis (risk assessment, risk communication, risk management) on biotechnology derived livestock and biotechnology products?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	36	40%	4	17%	6	35%	5	36%	20	59%	1	50%
No	53	58%	20	83%	11	65%	8	57%	13	38%	1	50%
DNR	2	2%	0	0%	0	0%	1	7%	1	3%	0	0%
If yes, has a National framework for conducting risk analysis on biotechnology derived livestock and biotechnology products been developed?												
Yes	23	64%	1	25%	4	66%	5	100%	13	65%	0	0%
No	12	33%	3	75%	1	17%	0	0%	7	35%	1	100%
DNR	1	3%	0	0%	1	17%	0	0%	0	0%	0	0%
If no, what are the reasons for not performing risk analysis for decision-making process pertaining to biotechnology derived livestock and biotechnology products?												
Lack of knowledge	22	26%	6	27%	2	13%	6	50%	6	27%	2	50%
Training	44	53%	10	46%	9	56%	5	42%	10	46%	2	50%
Others (specify):	18	21%	6	27%	5	31%	1	8%	6	27%	0	0%

4. Do the animal health authorities in your country have a dedicated unit that conducts risk analysis pertaining to biotechnology derived livestock and biotechnology products?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	14	15%	2	8%	3	18%	3	21%	6	18%	0	0%
No	75	83%	22	92%	14	82%	10	72%	27	79%	2	100%
DNR	2	2%	0	0%	0	0%	1	7%	1	3%	0	0%
If no, which unit is conducting risk analysis?												
Import-Export unit	19	23%	6	26%	3	20%	4	45%	5	15%	1	50%
Epidemiology and Surveillance unit	24	29%	7	31%	4	27%	1	10%	11	33%	1	50%
External consultant	9	11%	3	13%	1	7%	0	0%	5	15%	0	0%
Others (specify)	30	37%	7	30%	7	46%	4	45%	12	37%	0	0%

5. What factors are taken into consideration when determining risk associated with biotechnology derived livestock and biotechnology products?

	Global		Africa		America		Asia		Europe		Middle East	
Animal Health	66	26%	18	25%	11	25%	9	22%	26	28%	2	34%
Food Safety	69	26%	20	29%	10	23%	10	24%	27	29%	2	33%
Environmental impact	58	23%	15	21%	8	19%	9	22%	24	25%	2	33%
Economic consideration	27	11%	11	15%	2	5%	6	15%	8	8%	0	0%
Others (specify)	24	9%	4	6%	10	23%	5	12%	5	5%	0	0%
DNR	12	5%	3	4%	2	5%	2	5%	5	5%	0	0%

6. Have the animal health authorities conducted (or received a request to conduct) a risk analysis on biotechnology derived livestock or biotechnology products?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	23	25%	3	13%	7	41%	4	29%	9	26%	0	0%
No	66	73%	20	83%	10	59%	10	71%	24	71%	2	100%
DNR	2	2%	1	4%	0	0%	0	0%	1	4%	0	0%
If yes, specify what commodity												
Not able to disclose	3	9%	1	33%	1	8%	1	20%	0	0%	0	0%
Cloned animal	3	9%	0	0%	2	15%	0	0%	1	20%	0	0%
Transgenic animal	7	21%	0	0%	3	23%	1	20%	3	60%	0	0%
Biotechnology products (specify)	17	52%	2	67%	6	46%	2	40%	0	0%	0	0%
Others (specify)	3	9%	0	0%	1	8%	1	20%	1	20%	0	0%

7. Do the animal health authorities in your country make their risk analysis document available for peer review or for public consultation?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	25	27%	6	25%	7	41%	4	29%	8	24%	0	0%
No	60	66%	16	67%	10	59%	10	71%	23	67%	1	50%
DNR	6	7%	2	8%	0	0%	0	0%	3	9%	1	50%
If yes, what means of dissemination are used:												
Official government publication	14	38%	4	66%	3	23%	3	42%	4	37%	0	0%
Electronic version	10	27%	1	17%	3	23%	2	29%	4	36%	0	0%
Others (specify)	13	35%	1	17%	7	54%	2	29%	3	27%	0	0%
and who conducts the peer review:												
Internally within the Veterinary Services	18	45%	5	72%	6	40%	3	43%	4	37%	0	0%
External reviewers	10	25%	1	14%	4	27%	1	14%	4	36%	0	0%
Others (specify)	12	30%	1	14%	5	33%	3	43%	3	27%	0	0%

8. Do you consider the "Guidelines for risk analysis" contained in the OIE Terrestrial Animal Health Code, adequate to help carry out an import risk analysis on biotechnology-derived animals or biotechnology-derived products?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	63	69%	19	79%	8	47%	9	65%	26	76%	1	50%
No	18	20%	3	13%	8	47%	3	21%	4	12%	0	0%
DNR	10	11%	2	8%	1	6%	2	14%	4	12%	1	50%
If no, how can it be improved?												
Specify	18		3		8		3		4		0	

9. Has your country produced biotechnology-derived animals or biotechnology-derived products for use on animals?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	31	34%	5	21%	6	35%	6	43%	14	41%	0	0%
No	58	64%	19	79%	11	65%	8	57%	18	53%	2	100%
DNR	2	2%	0	0%	0	0%	0	0%	2	6%	0	0%

10. Do you have the following capabilities in your country?

	Global		Africa		America		Asia		Europe		Middle East	
Cloning	23	17%	1	4%	6	23%	6	23%	10	18%	0	0%
Transgenic production	27	20%	2	8%	4	15%	6	23%	15	26%	0	0%
Products of biotechnology for use in animals (e.g. vaccines and/or drugs)	38	28%	6	23%	5	19%	9	35%	18	31%	0	0%
DNR	49	35%	17	66%	11	43%	5	19%	14	25%	2	100%

11. Do you have a regulatory framework in place to govern the use of the above?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	44	48%	6	25%	9	53%	8	43%	21	62%	0	0%
No	45	50%	18	75%	8	47%	6	57%	11	32%	2	100%
DNR	2	2%	0	0%	0	0%	0	0%	2	6%	0	0%

If yes, briefly please describe the framework and list the Administrations and/or Agencies and pertinent legislation(s) involved

Specify	39	5	8	7	19	0

12. Is research being conducted in your country into biotechnology-derived animals and products including vaccines and drugs?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	43	47%	6	25%	7	41%	9	64%	20	59%	1	50%
No	46	51%	17	71%	10	59%	5	36%	13	38%	1	50%
DNR	2	2%	1	4%	0	0%	0	0%	1	3%	0	0%

13. Do you produce or use any animal vaccines in your country that are biotechnology-derived?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	40	44%	4	17%	7	41%	7	50%	21	62%	1	50%
No	49	54%	19	79%	10	59%	7	50%	12	35%	1	50%
DNR	2	2%	1	4%	0	0%	0	0%	1	3%	0	0%

If yes, what types of biotechnology-derived animal vaccines are available?

Viral vectored vaccines which include antigen(s) from unrelated organisms	26	27%	2	50%	5	28%	4	19%	15	29%	0	0%
Bacterial vectored vaccines which include antigen(s) from unrelated organisms	16	16%	1	25%	2	11%	5	24%	8	15%	0	0%
Vaccines which have deleted antigen(s) to differentiate infected animals from vaccinates (DIVA)	22	23%	1	25%	3	17%	3	14%	14	26%	1	100%
Vaccines which include recombinant proteins	26	27%	0	0%	6	33%	6	28%	14	26%	0	0%
DNA vaccines	6	6%	0	0%	2	11%	2	10%	2	4%	0	0%
Other	1	1%	0	0%	0	0%	1	5%	0	0%	0	0%

14. How are biotechnology-derived vaccines and/or drugs generally perceived by the public in your country?

	Global		Africa		America		Asia		Europe		Middle East	
Safe	12	13%	4	17%	1	6%	3	21%	4	11%	0	0%
Controversial	25	27%	5	21%	5	28%	4	29%	10	29%	1	50%
Public mostly unaware	39	41%	11	46%	7	38%	6	43%	15	43%	0	0%
Others (specify)	11	12%	2	8%	5	28%	0	0%	2	6%	1	50%
DNR	7	7%	2	8%	0	0%	1	7%	4	11%	0	0%

15. Do you have livestock cloning and/or transgenic animal production facilities in your country?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	28	31%	0	0%	5	29%	6	43%	17	50%	0	0%
No	60	66%	22	92%	12	71%	8	57%	16	47%	2	100%
DNR	3	3%	2	8%	0	0%	0	0%	1	3%	0	0%

16. Are biotechnology-derived animals or their products permitted in the food or feed supply in your country?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	22	24%	5	21%	4	24%	6	43%	7	21%	0	0%
No	64	72%	17	71%	13	76%	6	43%	26	79%	2	100%
DNR	4	4%	2	8%	0	0%	2	14%	0	0%	0	0%

Is there a public support for cloning of animals?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	11	12%	0	0%	2	12%	4	29%	5	15%	0	0%
No	72	79%	22	92%	13	76%	7	50%	28	82%	2	100%
DNR	8	9%	2	8%	2	12%	3	21%	1	3%	0	0%
If Yes, would there be a support for cloning for												
Rescue of endangered species	7	39%	0	0%	2	33%	2	33%	3	50%	0	0%
Generating stem cells	7	39%	0	0%	2	33%	2	33%	3	50%	0	0%
Pet cloning	2	11%	0	0%	1	17%	1	17%	0	0%	0	0%
Food product homogeneity	2	11%	0	0%	1	17%	1	17%	0	0%	0	0%

18. Are there transgenic animals present in your country?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	22	24%	0	0%	3	18%	4	29%	15	44%	0	0%
No	67	74%	24	100%	14	82%	10	71%	17	50%	2	100%
DNR	2	2%	0	0%	0	0%	0	0%	2	6%	0	0%
If Yes, what purpose are they generated for												
Altered Nutrient Content	4	13%	0	0%	1	14%	2	22%	1	53%	0	0%
Biopharmaceuticals	14	45%	0	0%	3	43%	3	34%	8	33%	0	0%
Disease resistance	9	29%	0	0%	1	14%	3	33%	5	7%	0	0%
Environmental benefits	4	13%	0	0%	2	29%	1	11%	1	7%	0	0%

19. Does your country have the laboratory capacity to identify and detect transgenes in the food/feed supply?

	Global		Africa		America		Asia		Europe		Middle East	
Yes	38	42%	2	8%	6	35%	7	50%	22	65%	1	50%
No	51	56%	22	92%	11	65%	6	43%	11	32%	1	50%
DNR	2	2%	0	0%	0	0%	1	7%	1	3%	0	0%

20. How are biotechnology-derived animals generally perceived by the public in your country?

	Global		Africa		America		Asia		Europe		Middle East	
Safe	2	2%	1	4%	0	0%	0	0%	1	2%	0	0%
Controversial	53	52%	10	41%	10	50%	8	53%	24	59%	1	50%
Public generally unaware	30	29%	9	38%	5	25%	5	33%	11	27%	0	0%
Others (specify	14	14%	4	17%	5	25%	1	7%	3	7%	1	50%
DNR	3	3%	0	0%	0	0%	1	7%	2	5%	0	0%

	Global		Africa		America		Asia		Europe		Middle East	
English	61	67%	12	50%	6	35%	13	93%	28	82%	2	100%
French	18	20%	12	50%	0	0%	1	7%	5	15%	0	0%
Spanish	11	12%	0	0%	11	65%	0	0%	0	0%	0	0%
Other	1	1%	0	0%	0	0%	0	0%	1	3%	0	0%
Country Questionnaire Received	91	54%	24	49%	17	61%	14	54%	34	69%	2	15%
Member Countries	*165*		*49*		*28*		*26*		*49*		*13*	

Science and technology for our common future: Evolving programmatic initiatives of the New Partnership for Africa's Development

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There is a relatively rich academic discourse on the role that science and technology play in economic change and sustainable development (for example Rosenburg 1982; Freeman 1992). This discourse has exposed the intimate and complex connections between science, technology and development. It has also demonstrated that science and technology are key factors in wealth creation and sustainable development. There is now enough empirical evidence that the gap between poor and rich countries in terms of real income is largely accounted for by differences in the accumulation and utilisation of science and technology. Closing this gap requires deliberate measures to build and/or strengthen capabilities of the poor countries and their people to harness, develop and use science and technology.

Science, especially basic research, and technological development have long been recognised as activities that, by their very nature, are not restrained within national boundaries. The flow of information is vital to the progress of science and technology. Economic globalisation and the rapid growth of information and communications technologies (ICTs) are changing the international context in which science is conducted.

The increasing costs of frontier research in many fields and the growth of the ICTs, including the Internet, have provided both the motivation and the means of intensifying regional and international collaboration in research, at the level of governments, institutions and individual scientists and engineers. At the same time, the increasingly blurred lines between basic research and application and the growing importance of science and technology to economic growth have made policy makers more aware of national interests in research and raised concerns about the risks of collaboration.

The academic discourse is to a large measure responsible for the increasing recognition among politicians and policy makers that science and technology are indeed engines of economic change and sustainable development. At the international level at least three cases demonstrate that political institutions and processes are increasingly recognising the roles of science and technology. These are the Plan of Implementation adopted at the World Summit on Sustainable Development (WSSD), the United Nations Millennium Development Goals (MDGs) and the Group of 8 Action Plan on Science and Technology.

At the WSSD the international community emphasised that development and application of science and technology enables humanity to address such problems as food insecurity, water scarcity, environmental degradation and deterioration in public health. Many of the WSSD recommended actions are about mobilising and directing science and technology for human development. The WSSD Plan of Implementation calls on the international community to '[p]romote technology development, transfer and diffusion to Africa and further develop technology and knowledge available in African centres of excellence; and [s]upport African countries to develop effective

science and technology institutions and research activities capable of developing and adapting to world class technologies" (UN 2002).

The MDGs also recognise that poverty reduction and sustainable development cannot be achieved without investments in science and technology. The UN established a special task force on science, technology and innovation under the Millennium Project to generate a report to inform the international community of strategic actions required to apply science and technology to meet the development goals. The task force is expected to generate recommendations on how best to achieve the goals through the development and application of science and technology. Of interest to African countries will be how the UN will translate the commitment to 'take special measures to address the challenges of poverty eradication and sustainable development in Africa, including debt cancellation, improved market access, enhanced Official Development Assistance and increased flows of Foreign Direct Investment, as well as transfers of technology' (UN 2001) into concrete actions. African countries require programmatic and organisational approaches that will enable them to invoke this commitment.

The meeting of the G8 group of countries added impetus to the political articulation of the role that science and technology play in sustainable development. G8 leaders meeting in Evian, France, 1–3 June 2003, adopted an action plan on science and technology for sustainable development. In the plan the leaders emphasise: 'co-operative scientific research on transformational technologies offers potential to improve public health by cutting pollution and reducing greenhouse emissions to address the challenge of global climate change.' In addition, they note that to meet the objectives of the WSSD, developing countries and countries with economies in transition need to build and strengthen their capacity to assimilate and generate knowledge for sustainable development. They reaffirm their commitment made at the WSSD to assist these countries to enhance their research capacities through international cooperation.

At the regional level, there are several policy and political pronouncements on science and technology. For example, Articles 103, 104 and 127 of the treaty establishing the Common Market for Eastern and Southern Africa (COMESA) are dedicated to issues of cooperation in the development of science and technology. Article 21 of the Southern Africa Development Community (SADC) Treaty recognises the importance of cooperation in areas of science and technology. SADC has also adopted a protocol with provisions aimed at promoting science and technology cooperation. The East African Community (EAC) Treaty devotes its Article 103 to issues of cooperation in science and technology. Similar provisions are found in the treaty of the Economic Commission of West African States (ECOWAS) and the Constitution of the African Union (AU).

Another important forum that has stressed the need to improve regional cooperation in science and technology is the Africa, Caribbean and Pacific (ACP) and the European Union Forum on Research for Sustainable Development held in Cape Town, South Africa, 29–30 July 2002. The Forum, attended by ministers responsible for science and technology, adopted the Cape Town Consensus stressing the importance of cooperation in science and technology. It called upon 'the ACP States, EU Member States, European Commission and the ACP General Secretariat, to make appropriate and timely arrangements for the most effective utilisation of funding instruments in the 6th Framework Programme (FP6) and in the 9th European Development Fund (EDF9), in support of Science and Technology (S&T) Cooperation and research capacity building, respectively.'

The greatest challenge facing African countries now is how to translate the statements of intent and political recognition of the roles of science and technology into concrete activities, programmes and processes. Meeting this challenge requires policy guidance and the support of high-level political institutions. It demands that countries create platforms for political engagement and the formulation and implementation of strategic actions.

The New Partnership for Africa's Development (NEPAD) has been adopted by many African leaders, a growing constituency of civil and academic groups and the UN General Assembly as the framework for organising and promoting socio-economic development of the African continent. In NEPAD there is explicit recognition of science, technology and innovation as sources of social and economic transformation of Africa. Through the NEPAD framework and organisational context African countries aspire to individually and collectively harness, develop and apply scientific knowledge and associated technologies to improve human development and enhance their industrial competitiveness.

The formulation and adoption of the proposed NEPAD strategic framework and action plan on science and technology are knowledge and information intensive processes. Research on specific policy and institutional issues needs to be conducted to provide decisions makers with informed advice on what actions African countries should collectively take to stimulate and enhance the continent's scientific and technological development. A number of key issues that require research and/or additional information were identified by the first NEPAD workshop. These can be clustered into four categories: (a) improving policy development and implementation; (b) mobilising, networking, strengthening and efficiently utilising knowledge institutions or centres of excellence; (c) improving the quality of science and engineering education to build a critical mass of scientists in specific fields; and (d) ways of leveraging additional or increased financial expenditure on research and development (R&D).

Science and Technology in NEPAD

NEPAD recognises that science and technology are central to its goals of promoting economic recovery, poverty reduction, better human health, good governance and environmental sustainability in Africa. One of its overall objectives is to bridge the technological divide between Africa and the rest of the world. It calls for the formulation and implementation of measures to: 'promote cross-border co-operation and connectivity by utilising knowledge currently available in existing centres of excellence in the continent'; and 'generate a critical mass of technology expertise in targeted areas that offer high growth potential, especially in biotechnology and geo-science' (NEPAD 2001).

There are seven main critical factors that currently constrain or undermine efforts to build and/or strengthen Africa's scientific and technological development. First, in most countries of the region there are weak links between scientific enterprise and political institutions. Political parties in the region have not accorded science and technology much attention in their manifestos and parliamentary activities. Technological change is a complex process that is influenced by many political factors. To engage in and manage this process, countries require the support of high-level political institutions. These institutions often determine the nature and levels of resources that go into public research and development activities and the overall governance of science and innovation. The workshop recommended that efforts be made to build strong political constituencies for science and technology development in Africa.

Second, most African countries formulated their science and technology policies in the 1970s and 1980s when development imperatives and technological opportunities were difficult. Many

of the policies are focused on organisational aspects and not on programmatic issues. Countries have for years been preoccupied with the creation of commissions or secretariats to promote science and technology. These institutions have given an administrative outlook to the role of science and technology in national affairs but they never really built the necessary programmes to anticipate and respond to long-term science and technology development issues. Some of these institutions have, over time, lost touch with the reality: it takes more than administrative oversight to promote science and technology development. Awareness of the importance of science and technology must be translated into concrete R&D activities to make a difference in a country's economic life.

Third, African countries have devoted considerably low, and in many cases declining, funding to R&D. Most of them spend less than 0.5% of their gross domestic product (GDP) on R&D. This so despite the declaration—in the Lagos Plan of Action and in national science and technology policies—that each country would allocate at least 1% of its GDP to R&D activities. In such economic areas as agriculture, funding to R&D has declined drastically in the last decade or so to the extent that the region's ability to acquire and sustain food security is being impaired. The low and declining expenditure on R&D is a manifestation of the low priority that countries have given to science and technology. The contribution of the private sector to public R&D is low or non-existent in many African countries. Most governments have not instituted specific policy and legal measures to attract private investment in R&D.

Fourth, associated with the above three factors, there is declining quality of science and engineering training at all levels of educational systems in Africa. Student numbers enrolling into science and engineering subjects at primary, secondary and tertiary levels are also falling. This undermines the continent's aspiration to build up its numbers of scientists, engineers and technicians.

Fifth, Africa is losing some of its best scientific and technical expertise to other regions of the world. Indeed the number of African scientists and technicians who are leaving the continent for employment abroad is growing. This 'brain drain' is caused by a variety of factors including poor research infrastructure and poor remuneration packages. While many Asian (e.g. India) countries have developed and adopted strategies to mobilise and utilise the expertise of their nationals living abroad, most African countries lack such measures. The region can no longer afford to ignore this capital—African scientists and technicians abroad. Indeed, it should tap the enormous scientific and technical talents of Africans abroad and use them for its own scientific and technological development. There is also need to put in place measures that will reduce the brain drain.

Sixth, another challenge faced by African countries relates to strengthening and/or building strong and 'smart' institutions dedicated to scientific and technological innovation for poverty reduction and sustainable development. As a result of the above factors, R&D institutions in many countries are getting weaker. Most countries have not organised and mobilised their institutions in such ways as to efficiently mobilise their scarce financial and human resources in specific fields of scientific and technological development. They tend to spread their resources thinly across the institutional terrain. The region as a whole has not been able to develop 'centres of excellence' in such areas as biotechnology, space science and ICTs.

Seventh, generally there are weak links between public R&D institutions and industry. Research results of public R&D activities are not often accessed and used by local industries. In many cases there is a mismatch between R&D activities and industrial development goals and strategies. For example, while industrialisation policies of most African countries have put emphasis on

building and strengthening small and medium-scale enterprises (SMEs), scientific R&D institutions have weak links to these enterprises.

Lastly, there are a number of other cross-cutting policy issues that impinge on the continent's scientific and technological development. These include such issues as intellectual property protection, biosafety, the role of women in R&D, the impact of new technologies on women, and ways and means of ensuring that foreign direct investment facilitates transfer of new technologies. These issues need to be addressed and where necessary new appropriate policies put in place.

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Plenary session 2

Science and technology policy

Technology-policy gap and impact on application of animal biotechnology in sub-Saharan African countries

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Abstract

The livestock sector continues to play a major role in the economies of many sub-Saharan African countries. Predictions indicate that demand for livestock products will increase in the coming decades due to increasing human population and urbanisation. This calls for enhanced livestock production and productivity, which will require and will clearly involve increased intensification while also ensuring that the systems are resource efficient. Livestock diseases and the need for sustainable natural resource management are among the key challenges that need to be addressed. Although livestock research has over the years been directed at addressing these issues, little progress has been made in sub-Saharan Africa. Conversely, the application of biotechnology, for example in animal health, has significantly benefited developed countries more than African countries. This paper addresses the apparent gap between research and technology generation and adoption of the technologies on farms, especially by smallholders in sub-Saharan Africa. It is argued that science and technology policy if it exists, does not address the constraints faced by the farmers in a way that would facilitate adoption. The constraints include inadequate infrastructure, markets, capacity building, extension, credits, tenure system and institutions among other factors. Governments ought to address these issues at policy level as a way of accelerating widespread application of livestock biotechnologies particularly for increased productivity and profitability in the sub-sector. Moreover, concerted efforts from the national and international community in addressing issues of intellectual property rights, biosafety regulations and rules, fair trade, as well as effective and open communication between researchers, policymakers and technology users would be required.

Key words: biotechnology, research, science and technology policy, livestock sub-sector, smallholder farmer, sub-Saharan Africa

Introduction

Agriculture remains the most important economic sector in many African countries in terms of food and fibre supply, employment creation, income generation and foreign exchange earnings. Over 75% of Africa's population live in rural areas depending heavily on the production and use of natural resources for their livelihoods through agriculture. The agricultural sector accounts for 35% of the continent's gross domestic product (GDP), 40% of exports earnings and 70% of employment and it is expected that reliance on natural resources will remain high at least for the next generation (Dione 2002).

African smallholder farmers pursue a wide range of crop and livestock production enterprises, with considerable diversity across and within the major agro-ecological zones. The importance of the livestock sub-sector to their farming systems in the sub-region is reflected by its contribution to crop production, providing employment throughout the year and dispersing risks, providing funds for buying crop inputs and for financing farm investments through sales, forming a major capital reserve and enhancing the economic viability and sustainability of the farming systems

(Steinfeld and Mack 1995). It is estimated that 70% of the rural poor in sub-Saharan Africa own livestock. Of these, 200 million derive their incomes, nutrition and employment among other services directly from livestock (Sere 2004). It is estimated that in 1988, the livestock sector in Africa raised US$ 11.8 billion, constituting 8% of the total GDP and 25% of the agricultural domestic product (Lahlou-Kassi 1995), due mainly to the large animal population. Statistics indicate that Africa has over 230 million cattle, 246 million sheep and 175 million goats (Knight 2002) as well as 13 million camels (ILCA 1993), millions of poultry and other domestics such as horses, donkeys, pigs and mules.

Demand for livestock products in Africa is on the increase owing to the increasing human population growth, urbanisation, changing lifestyles and increasing incomes (FAO 2000). Currently, it is estimated that 145 million people reside in urban areas and 700 million people will be residing in towns and cities by 2025 (FAO 2000). This will translate into increased demand for nutrient rich and easy to prepare livestock products. Currently, most livestock related food products are obtained from smallholder and pastoral systems despite the production systems being characterised by low production as a result of climatic effects, lack of genetic merit on available livestock, inadequate feed supply and quality, poor animal health, livestock performing multiple functions in the livelihood systems, poor management and lack of credit facilities, especially among poor farm families (Smith and Hunter 1990). This implies that tremendous efforts in prudent structural and technological interventions will be needed to enhance production if demand by 2025 will have to be met (FAO 2000), failure to which massive importation of livestock products will be required (Table 1).

Table 1. Net trade in livestock products ('000 tonnes) in Africa.

Product	1970	1980	1990	2000	2015	2030
Beef	119	63	–32	52	–5	–109
Eggs	0	–3	–5	–17	–9	–22
Meat	142	50	–110	–80	–283	–744
Milk	–913	–2496	–1785	–1971	–3605	–5226
Mutton/goat	29	40	29	59	73	80
Pig meat	–4	–9	–21	–42	–71	–108
Poultry	–2	–43	–86	–149	–280	–606

NB. Negative figures indicate imports.

Source: Seré (2004).

The structural and technological interventions should be directed towards ensuring adequate resource allocation; introduction of new technologies to improve productivity; promoting suitable institutions for research, extension, marketing and credit; and putting in place appropriate policy, both national and at the sub-sector level. This will alleviate the current situation where there is hardly any success story of biotechnology application in developing countries as opposed to developed nations (Rege 1996). This paper highlights some of the bottlenecks relating to institutions and policy that ought to be addressed in order to facilitate effective application of livestock biotechnologies in sub-Saharan Africa.

Status and prospects of biotechnology application in animal agriculture in Africa

It has been argued that conventional technologies are no longer able to increase or provide sufficient levels of the ever-increasing needs for food, fibre and better agricultural environment and therefore the application of agri-biotechnology is vital. Agricultural biotechnologies have been developed as tools/techniques to boost productivity although due to their ownership by private corporations, their usage has mainly been in developed nations with most farmers in

Africa continuing to rely on conventional technologies associated with low productivity and production (Nkamleuet al. 2003).

Biotechnology refers to the scientific application of techniques that uses living organisms or substances from them to make/modify products or improve plants/animals, or to develop micro-organisms to serve specific purposes. The main components used in biotechnology are genomics, bioinformatics, transformation, molecular breeding, diagnostics and vaccine technology (Persley and Lantin 2000) and some of them involve the manipulation of the DNA components of organisms. Modern biotechnology techniques and processes are applied to improve the production potential of plants and animals (Bailey 2003). Cell and tissue cultures are the most commonly used techniques in Africa with genetic engineering being yet to gain profound utilisation due to regulations surrounding its application (Berg et al. 2003) although there have been efforts to produce animal vaccines using the technology both in Kenya and Zimbabwe (Chetsanga 2000).

Globally, the major breakthroughs of biotechnology in the livestock sub-sector have been in the generation of techniques for disease diagnosis and manipulation of selected germplasm for traits such as production, adaptation and improved feed digestibility (Lahlou-Kassi 1995). This has led to techniques such as artificial insemination and embryo transfer as integral part of animal husbandry for many years. Recent applications of DNA engineering techniques target the development of new improved methods of diagnostics and vaccine production, animal breeding and improved nutrition through modification of microbes to improve rumen functions, and in reproductive physiology. However, low annual rate of genetic progress, lack of ways to separate the desirable from undesirable traits of breeding, and the difficulties of transferring genetic information across species (Berg et al. 2003) has hindered some of the intended achievements. It is hoped that with advancing biotechnologies and novel molecular genetics tools, some of these challenges will be overcome.

In sub-Saharan Africa, the application of these technologies at farm level has not been realised. Studies on agricultural innovations show that effective adoption at the farmer and aggregate levels is influenced by several factors. These include: the educational process that extension practitioners use to equip individuals with the knowledge and skills necessary to use an innovation (King and Rollins 1995); supply (institutional process of technology generation and promotion) and demand (reasons for using a technology) of technological innovations (Rogers 1983); relative advantage and compatibility that determine the immediate and long-term economic benefits from using an innovation; access to credit and output prices (Hwang et al. 1994); complexity, trialability, and observability that indicate the ease with which the potential adopter will learn and use the innovation (King and Rollins 1995); nature of farming environment (agroclimatic conditions, nature of prevailing farming systems, degree of commercialisation and factor availability) (Morris et al. 1998); land tenure systems; farm sizes; farmer characteristics (ethnicity and culture); time lag required before getting returns/benefits from adopting the technology; management to maintain the technology working at farm level; initial capital investment; and social factors because farming systems are in some regions highly influenced by social networks (FAO 2001) among many others.

In sub-Saharan Africa, the rate of adoption is not only restricted by the aforesaid causes but also to policy and institutional frameworks at national, regional and international level. The following section highlights some of the areas that require policy interventions to address the challenges facing the application of livestock biotechnologies in smallholder farming systems.

Poverty

According to the World Bank (1996) between 45% and 50% of Africa's population is poor and live in abject poverty. The poor status is a result of limited employment opportunities, inadequate access to markets, low endowment of human capital, environmental degradation, decades of economic mismanagement, corruption, improper governance and conflicts. The GDP of sub-Saharan Africa remains lower than that of other regions of the world. Since multinational companies from the North that conduct biotechnology research are profit oriented, they do not focus their attention on technologies that are relevant to the poor populations in developing countries because these populations cannot afford them. In addition, poverty has driven most governments to accumulate huge external debts, resulting in loan repayment as a priority over investing in biotechnology. This denies the poor smallholder farmer the chance to access improved biotechnologies for increased production. Therefore, there should be efforts to avail cheap but effective technologies and to devise policies for wealth creation, human capacity development to match modern job market, democratic governance and conflict resolution as steps towards ensuring increased biotechnology application in Africa in the future.

Infrastructural development

Infrastructure denotes the materials, institutional, personal facilities and arrangements that facilitate production and movement of goods and services (Karugia et al. 2003). They include roads, storage facilities, research facilities and market centres. In Africa, both the communication and transport systems are skewed in favour of urban centres rather than rural areas. Infrastructural problems date back to the colonial times when the infrastructure favoured settler occupied areas and neglected African reserves. Post-independence governments continued to rely on the colonial infrastructure while expansion or maintenance has been minimal. As a result, transportation of inputs and outputs has become a nightmare in many regions. Poor communication channels and skewed networks that favour urban areas have hampered delivery of information about the latest technologies to farmers in remote rural areas. Although the status is blamed on population distribution patterns, there is need to devise policies for infrastructure improvement as a means of facilitating dissemination and adoption of research recommendations.

Africa also lacks effective research facilities that are compatible with progress in biotechnology, e.g. there are few specialised laboratories where research can be adapted to meet local conditions. In fact, it is argued that only the International Livestock Research Institute (ILRI) is able to undertake livestock biotechnology research in sub-Saharan Africa despite the fact that it cannot manage to address all problems facing the livestock sub-sector in the region. Facilities for procedures such as progeny testing are lacking in many countries. There is need to ensure favourable infrastructure, such as repositories of biotechnology resources, biotechnology information services and centres, biotechnology cooperation service, good roads and communication channels and a strengthened regional technical cooperation network.

Ineffective marketing systems

Agricultural markets in Africa have for a long time been under the control of central governments with limited involvement of private sector players. This meant supply of inputs, market information and marketing of produce by state managed and controlled cooperative societies. Central governments were also responsible for maintaining services that ensured effective delivery, e.g. transport services. However, after the implementation of structural adjustment programmes (SAPs) and liberalisation, government controls over input and output prices, as well as regulatory controls over input and output marketing were considerably reduced or eliminated. Public enterprises were restructured and involvement of marketing boards in agricultural pricing and distribution minimised to improve procurement and distribution channels of key commodities and increase

market efficiency. However, the process introduced stiff competition in provision of services and marketing of agricultural products in many parts of sub-Saharan Africa. Rather than increasing efficiency in the marketing channels, malfunctioning input supply, output marketing systems and inadequate market information resulted due to lack of adequate infrastructure and government support. Costs of inputs increased while product prices went down due to the long chains of marketing transactions involved. As a result, smallholder farm activities were significantly affected by dwindling prices that were lower than could motivate farmers to produce.

Moreover, African countries continue to face external influences from the developed world in terms of trade policies and barriers that negatively affect access to technologies, production and markets for products. First, the global market for biotechnologies is under the control of a few private-sector investors due to mergers and acquisitions. For commercial reasons, these few biotechnology investors target the rich farmer as the main market while giving less consideration to the poor small-scale farmer. Secondly, the subsidisation policies in developed nations (for production and exporting) offsets the real market prices making products from unsubsidised smallholder farms more expensive and unprofitable (Johnson et al. 2003). Thirdly, most products from the region are sold as bulk raw materials with minimal or no value addition. Moreover, any value addition subjects them to escalating tariffs in developed countries (Johnson et al. 2003) which discourages costly and intensive production that relies on advanced innovations. Addressing the plight of farmers in access to inputs, value addition, market information and fair marketing systems, and acting as a cohesive group to negotiate for favourable international trade agreements would be required to promote intensive livestock production through increased biotechnology application.

Research priorities

Due to weak economies, most African states emphasise short- and medium-term research to meet the immediate needs of their populations and industry, such as food security and raw materials. Owing to the fact that biotechnology requires long-term research to allow time for concrete solutions to biosafety and trade issues and is capital intensive, many nations have not developed/initiated effective biotechnology research programmes. This works against the timely availability of biotechnologies to farmers. There is need for sub-Saharan African countries to commit resources and orient towards long-term research to effectively encompass biotechnology research in their programmes as a measure of accelerating the availability of livestock biotechnologies to smallholder farmers in the region.

Extension systems

Extension services are meant to offer advice, help farmers analyse problems, develop opportunities, share information, support formation of groups and facilitate collective action. Extension also allows demonstrations that inform farmers on the best levels of inputs and practices to adopt, especially in the initial stages of technology introduction (Akele et al. 2000) and provides specialists and researchers with valuable information on farmers' needs and efficiency of developed technologies (Damalas 2003). Many African countries and research institutions have traditionally relied on agricultural extension systems to advance their finding to farmers. However, the extension services are no longer effective because most agricultural extension services have virtually collapsed in much of Africa or have been debilitated by structural adjustments and policy reforms. They have experienced operational lapses and lack of follow-up because of low budgetary allocation by national governments. Moreover, most extension systems emphasise crop production and cater less for livestock development. Both the policy makers and researchers have ignored the independence of livestock extension services (Morton and Wilson 2000). Coupled with the effects of the HIV/AIDS pandemic, the system has been further weakened to the extent

that it is not possible to disseminate current research findings to intended beneficiaries (Jones 2004). Hence, research findings and recommendations remain on shelves in research stations where they are inaccessible to potential users.

Access to credit services

The SAPs implemented in many African countries reduced government support for the agricultural sector. Agricultural credit systems were destabilised as privatisation took place, exposing farmers to liquidity problems. The resultant private sector was constrained by inadequate legislation governing commercial relationships or the existence of obsolete legislations that made normal commercial activities technically illegal, thereby undermining the confidence of private institutions in providing credit. The commercial and agricultural development banks, however, have remained uninterested in providing credit to small-scale farmers because of the risk of default, lack of collateral and high transaction costs. With missing or malfunctioning credit markets and liquidity constraints, households surrounded by such a multitude of risks tend to have high discount rates and being risk averse in investment even in current agricultural innovations. There is need for great intervention among African governments to make credit services available to farmers at rates they can afford if agricultural innovations are to find root in farmers' fields. This can be by supporting upcoming farmer cooperatives or providing enabling environment for micro-finance institutions and commercial banks to aid livestock keeping.

Patents and intellectual property rights

Most agricultural biotechnologies are developed by multinational corporations and international research institutions in developed nations (Taylor and Cayford 2003). To recover the cost of research, they seek intellectual property rights (IPR) or patent rights over a certain period of time (Pardey et al. 2003). The implication of this is that IPR and patents limit researchers from developing countries from accessing state of the art technologies for dissemination to farmers (Cruz 2000). Sometimes, the CGIAR (Consultative Group on International Agricultural Research) system and some international research organisations may be allowed to access such knowledge without authorisation to promote agricultural research in the South but this has not been sufficient due to budgetary limitations and diversity of production systems in Africa. Providing an enabling environment for public-private partnerships between research institutions of developed and developing nations where local scientists and national research institutions can access innovations for adaptation would help alleviate the problem. This would enable local research institutions harness their meagre resources to meet local needs rather that strive to conduct research whose results already exist. Moreover, public-private partnerships would avail extra resources for research in local research institutions.

Biosafety regulations and policies and the fear of losing export markets

Given food safety concerns in developed nations, especially in the European Union, biosafety policies and regulations continue to be enacted, inhibiting importation of transgenic products (USDA FAS 2003). Certification and labelling has become common in Europe and Australia although most Africa countries have not adopted such policies. Because biosafety regulations and policies tend to restrict trade in biotechnology-based products, most farmers in developing countries who target developed countries in Europe for their market shy from producing biotechnology related goods for fear of losing profitable foreign markets (Wafula and Sikoyo 2005). This discourages the use of technologies based on genetic modification. For instance, in Namibia, Uganda, Zambia and Zimbabwe there have been cases reported where genetically modified products were denied entry into the countries for fear of contaminating local varieties used for producing export products for the European market (Wafula and Sikoyo 2005). This implies that the growing concern for food safety and the need to produce for markets will limit

faster application of livestock biotechnologies in smallholder farms, especially if it is perceived to pose threat to the international trade.

In other instances, African states lack the regulatory and scientific assessment structures that are necessary to make decisive steps on biosafety application of biotechnology leading to guidelines and policies that are contradictory, thereby hindering the flow of biotechnologies across borders. This calls for harmonisation of policies and procedures for standard testing and enforcement, risk assessment, information and documentation among other issues on safety issues of biotechnology.

Lack of effective communication/dialogue between research, official policy makers, civil society organisations, consumers and farmers

In most cases, researchers generate information and pass it to farmers for adoption with less attention to requirements or needs of farmers. Traditionally, the process of developing technologies has had minimal or no interaction with stakeholders, including policy makers, on what the repercussions of such developments would be in society and on environment. As a result, some of the technologies in the market contravene the policy frameworks on public and environmental safety while farmers and consumers view other technologies with mistrust and lack of confidence. To avoid such situations and develop technologies that are readily acceptable in the market, stakeholders must participate in making decisions about the research and technologies being developed. The decision making process should be based on scientifically accurate information to promote awareness and understanding, transparency, consensus, trust and confidence building rather than being driven by recommendations from the supply side that may be unfavourable or less understood/accepted by policy makers and farmers.

Effect of national food sufficiency policies

Most of the African population depend on agriculture for livelihoods and this makes the agricultural sector quite important in many economies. Hence, agriculture is viewed as the backbone for food sufficiency. However, the aspect of food sufficiency has traditionally been viewed from the point of crop production (especially grains/cereals) while neglecting the contribution of the livestock sub-sector. This has led to policies that emphasise intensive cereal crop production through intensive or irrigation schemes in many arable pockets of marginal areas traditionally used for livestock production resulting in land degradation due to unsustainable use and shrinkage of grazing resources. Consequently, livestock production has been confined to poorer zones where it is not economically viable to apply modern animal biotechnologies. There is need to reconsider the contribution of the livestock sub-sector towards national economies and at household level to integrate it within the national policy frameworks for food self sufficiency.

Lack of policies that emphasis commercial small-scale farming

Most farming systems in sub-Saharan Africa are subsistence oriented and produce for livelihoods with little for markets. In trying to survive in their harsh and difficult environments, smallholder farmers have over time learned how to adapt and tailor their agricultural technologies and systems to work in their unique circumstances and environments. They tend to adapt what works best for them under conditions of limited resources. Africa governments have failed to enact policies that help transform smallholder farming to commercial farming as a means of benefiting from economies of scale (Herbert 2004). This has been reflected by past scientific research that rarely addressed the socio-economic nature of subsistence farming. As a result, most innovations generated through research tend to have relatively limited application under the small-scale conditions found in much of sub-Saharan Africa.

Improper land tenure and property rights systems

Mutema (2003) notes that production efficiency, investment and the adoption of new technologies is highly related to ownership of land rights because it enables users claim ownership and access facilities such as credit for investment. This contradicts many cases in sub-Saharan Africa where land tenure systems are still based on the colonial systems. Through the colonial land policies, small-scale farmers were pushed to poor lands, a situation that was never corrected after independence. The high potential zones where property rights are defined are used for large-scale production of coffee, tea and dairy ranching while most subsistence farmers continue to exploit the poor areas with insecure property rights. Lack of effective property rights is not only a result of traditional land tenure systems but also of contradictions between official land laws and traditional entitlements. However, research over the years has emphasised production in high potential areas while neglecting the needs of a large proportion of small-scale farmers who exploit areas characterised by insecure property rights. Considering the case of Kenya, for instance, marginal lands constitute 80% of the country and carry over half the livestock population. Nevertheless, property rights in most of these areas are mostly held under open access or common property. Farmers lack the incentive to intensify their production or ensure sustainable utilisation. Where land rights are defined based on individual property rights, there is the tendency to use land for more lucrative ventures other than livestock keeping.

Land tenure systems and property rights also determine the natural resource management systems put in place, which has been a major constraint to livestock production. Moreover, land tenure systems determine how various communities claim ownership to the natural resource base. Insecure tenure, multiple ownership, common property and lack of clearly defined and secure property rights result in the overexploitation, underinvestment and general mismanagement of resources due to inappropriate institutions to govern their use. This consequently determines the species and breeds of livestock raised and technologies applied. Traditionally, societies have placed emphasis on breeds of animals that are adaptable to prevailing conditions even though they might not be the best in terms of production. This implies the need for understanding how land tenure systems and resource management policies affect resource use and the consequent effects on application of livestock biotechnologies.

Training and research policies

Having a sustainable livestock production sector requires a variety of skills, which include animal nutritionists, breeders, forage/range agronomists, veterinarians, sociologists, economists and animal physiologists. However, in many countries across Africa, there is a shortage of skilled capacity in many disciplines to engage in research, support extension and ensure economically viable relationships with technology developers for the benefit of smallholder farmers. Under such a scenario, biotechnology production is left in the hands of private firms from the West that mainly produce for profit. In other situations there is lack of adequate funds to support research and establish and/or maintain the necessary research facilities. Effective training-research linkages should be enhanced to ensure the needs of farmers are well matched with research development. Therefore, strengthened linkages between training and research institutions, and with extension systems will be required for the knowledge generated to be of any relevance to smallholder farmers.

Domestic policies

In most African countries, domestic policies such as undervaluation of currencies in order to promote exports have contributed to the squeeze on agricultural prices. Unfavourable prices do not give proper incentives to farmers despite the existence of improved technologies that they can use in production. In other instances, domestic policies on export taxation to raise state revenue leaves lower profit margins for the small-scale farmers. Coupled with attempts to appease

urban populations by lowering food prices or facilitating importation of cheap products, it becomes expensive to produce under small-scale conditions because of limited profitability. As a result, farmers continue to rely on rudimentary technologies rather than investing in improved technologies with limited promise for profits. This calls for formulation of domestic policies that are favourable to small-scale production while rectifying those that undermine it.

Conclusion and the way forward

Although Africa can derive numerous benefits from adopting livestock biotechnologies to increase production, lower disease challenge and meet the deficit in livestock products, there are various areas that require effective policy intervention or review of existing policy frameworks in order to create an enabling environment for the adoption of existing modern biotechnologies. Considerable effort should also be directed at ensuring existence of effective institutions and policy frameworks relating to appropriate markets and marketing systems, infrastructure, training, extension, credit systems, biosafety regulations and land rights among others as a way of promoting biotechnology application at smallholder level for increased productivity and profitability. Globally, addressing issues of intellectual property rights, biosafety regulations and rules, fair trade, and effective and open communication between researchers, policy makers and technology users would be required.

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The role of biotechnology in animal agriculture to address poverty in Africa: The need for appropriate policies

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Abstract

Livestock production currently accounts for about 30% of the gross value of agricultural production in Africa. Seventy per cent of the rural poor in Africa own livestock, including pastoralists living in arid and semi-arid zones. Of these, over 200 million rely on their livestock for income (sales of milk, meat and skins) and manure for growing crop. The livestock sector in Africa, characterised by low productivity, is struggling to keep up with the demand for food from animal sources by the expanding human population. Conventional methods of livestock improvement and agricultural research and development have in the past served the purpose of increasing livestock productivity. However, these options can no longer sustain production hence new intensive techniques including biotechnology are now required to augment productivity.

Modern biotechnology has the potential to provide new opportunities for achieving enhanced livestock productivity in a way that alleviates poverty, improves food security and nutrition and promotes sustainable use of natural resources. While modern biotechnology is and will not be a panacea for solving all the problems of food insecurity and poverty, it could provide a critical component to the solution if it is guided by appropriate policies. This proposition forms the basis of this paper.

Introduction

The challenge facing sub-Saharan Africa today is providing food and alleviating poverty in the ever-growing population without downgrading the environment or affecting the future productivity of natural resources. During the 1990s, the population of Africa constituted 13% of the world population and had the fastest growth rate (Nyira 1995). The population expansion, which puts a burden on economic growth, also decreases food security and environmental sustainability. Poverty is mainly a rural phenomenon in Africa where the rural resource-poor farmers and their families make up more than 75% of the population. Between 55% and 60% of the rural people in sub-Saharan Africa are absolutely poor, subsisting on less than US$ 1 per day (Ndiritu 2000). More than 200 million people suffer chronic malnutrition (Ndiritu 2000). Per capita food production has been declining and today production is less than 70% of the average for the 1960s, when most of African countries attained their independence (Edroma 1992). African countries that were self-sufficient in food 10 to 20 years ago are now importing food through purchases and/or food aid to satisfy demand. Livestock production currently accounts for about 30% of the gross value of agricultural production in Africa. Seventy per cent of the rural poor own livestock; this includes pastoralists living in arid and semi-arid zones. Of these, over 200 million rely on their livestock for income (sales of milk, meat and skins) and manure for crop growing (Seré 2004). However, there are a number of limitations to greater productivity and production of livestock in Africa which include but are not limited to the small size of farms, lack of water resources, poor livestock breeds, diseases and insect pests, poor livestock feeds, lack of rural infrastructure and equipment, and financial constraints.

The low productivity of animal agriculture on the continent will need to be substantially increased to satisfy increasing consumer demand, to more efficiently utilise scarce resources and to generate income for a growing rural population. To increase livestock productivity, we must modernise the rural farming communities through improved breeds, reduce risks such as livestock diseases and insect pests, and improve pastures and forages. This goal can be achieved through innovative and modern agricultural technologies that may include both conventional and modern biotechnology.

Potential uses of modern biotechnology in animal agriculture

Modern biotechnology has the potential to provide new opportunities for achieving enhanced livestock productivity in many countries in Africa in a way that alleviates poverty, improves food security and nutrition and promotes sustainable use of natural resources. In livestock development, modern biotechnology can be utilised to produce cheaper and safer vaccines for animal diseases, prevalent in a given region. It is also possible to produce disease diagnostic kits, and immune boosters for livestock. Recent developments in molecular genetics also allow the identification of livestock with superior traits such as resistance to parasites or diseases and manipulation of rapid animal reproduction using multiple ovulation and embryo transfer (MOET). Applications of biotechnology to animal agriculture include improving milk production and composition; increasing growth rate of beef/meat animals; improving production efficiency, or gain-to-feed ratios, and carcass composition; increasing disease resistance; enhancing reproductive performance; increasing prolificacy; and altering cell and tissue characteristics for biomedical research and manufacturing. Continued development of new biotechnologies also will allow farm animals to serve as sources of both biopharmaceuticals for human medicine and organs for transplantation (NRC 2002).

One of the most prominent developments of modern biotechnology has been the creation of transgenic animal strains and cloning. In the 1980s it became possible to develop a transgenic animal—a mouse (Gordon and Ruddle 1981); the technology has since been applied during the 1990s to some mammals, including cattle, pigs and sheep (Hammer et al. 1985). The creation and use of transgenic animals in research continues to increase. For example, in Great Britain, there were 581,740 procedures in which transgenic animals were used or bred during 2000. Around 99% of these procedures involved mice (Anonymous 2002). A number of applications of genetic modification to farm animals may be possible. As it is with fish, it may be possible, for example, to use genetic modification to create faster growing livestock or produce leaner meat. For example, cloned transgenic cows have been developed that produce milk with a marked increase in â-casein and *k*-casein (Brophy et al. 2003). Transgenic pigs have been produced that over-express the bGH gene, which is associated with a dramatic reduction in carcass fat (85% reduction) and constituent fatty acid classes (Solomon et al. 1994). Genetic modification to change levels of selected nutrients in plants and animals has been, and is, an important objective of genetic engineering strategies to create designer foods (CAST 2003; Falk et al. 2002). From the perspective of modifying the nutrient profile of foods, this has been done to increase beneficial nutrients or to decrease nutrients associated with adverse health effects, such as saturated fatty acids.

Other applications would include engineering resistance to specific infectious diseases within the animal population. An example is Marek's disease in poultry, a virus-induced lymphatic cancer, which is clearly detrimental to the birds' welfare and costs the UK poultry industry alone some £ 100 million a year (Anonymous 2002). It might be possible to make animals resistant to infectious diseases that are also human health risks such as *Salmonella* in poultry or to produce

bovine spongiform encephalitis (BSE)-resistant cows or scrapie-resistant sheep. It is further claimed that genetic modification could be used to improve farm animal welfare by correcting physiological problems which have arisen as a result of conventional selective breeding. Increased knowledge of animal genome sequences has the potential to allow some of the same effects to be achieved by identifying effective genetic maps that will improve marker-assisted breeding techniques.

Transplantation of tissue and organs between different species, and in particular transplantation of animal tissue into humans (xenotransplantation), is foreseen as possible in the near future. There is also a potential for a shortage of human organ donors and some animals, particularly pigs, are being examined as a potential source of suitable organs or cells, genetically modified to reduce the chance of rejection by humans. The recent successful production of cloned pigs is a further step towards efficient genetic modification of pigs and as such is aimed at bringing xenotransplantation closer (Anonymous 2002). There is debate about whether other necessary progress will have been made to allow successful transplants from genetically modified (GM) animals in the next 5 to 10 years. As the general public has become aware of the impact of these discourses, concerns over the use and safety of modern biotechnology have also been on the increase. Besides organ rejection, there remain serious concerns about the possible transfer of animal viruses to humans that will have to be addressed before the technology could be applied; and there are also concerns about physiological compatibility, let alone cultural concerns.

Challenges for biotechnology application

Whereas the developments in biotechnology reviewed above offer potential solutions to most of the problems facing livestock productivity and production, the application of modern biotechnology to research for development systems in Africa requires new investments, changes in resource allocation and new responsibilities for policy makers, research managers and scientists. The new responsibilities include, among other things, deciding how biotechnology is embraced in the national research agendas, setting appropriate policies, determining the benefits and risks of biotechnology applications and use of products thereof and services, ensuring that productivity constraints of the resource-poor farmers are addressed and developing the necessary regulatory capacities (Cohen 2001).

The general policy framework for biotechnology development in Africa should therefore encompass the various stages of transfer of technology and how it relates to decision making. The decision making process should take into account what products and services are needed and how these can be obtained through biotechnology. It is also necessary to identify technologies available and, where such technologies exist, to determine how they can be obtained, whether national expertise is available to source, access, assess, adapt and apply the technologies and to determine what kind of infrastructure is needed for research for development and whether trained manpower is available for the sustainable application of the technologies acquired. The strategy of using modern biotechnology as a component for an overall policy to foster sustainable development in the livestock sector and improve the livelihoods and well-being of the poor will require good political will and governance and leadership of a high order.

The policy framework

Appropriate biotechnologies can improve livestock production on farms of all sizes through improved animal health, reproduction and nutrition. However, to determine if modern biotechnology can benefit the resource-poor farmers in Africa, policy makers at the national, regional and international levels need to analyse the problems that are impeding livestock productivity in the region. Indeed, modern biotechnology is and will not be a panacea to solve all

the problems of food insecurity and poverty. But it could provide a critical component to the solution if it is being guided by appropriate policies. These policies should guide (i) priority setting and capacity building in R&D and desired outcomes; (ii) safe application of biotechnology and use of products and services; (iii) intellectual property management; (iv) financing and incentives for public sector R&D; (v) public-private partnerships; (vi) promotion of regional and international collaborations; and (vii) education and public awareness on balanced, authentic and non-polarised information about biotechnology and biosafety.

Priority setting and capacity building in R&D and desired outcomes

Priority setting must be governed by the need to enhance livestock productivity in a way that improves food security and nutrition, alleviates poverty and promotes sustainable use of natural resources. Governments deciding whether or not to invest in agricultural biotechnology need to identify the most pressing needs and priorities to be addressed and if biotechnology can meet those needs and fit those priorities, and ensure that those priorities are consistent with the government's efforts to improve the livelihoods of the resource-poor people in both rural and urban areas. The key step here is to identify the constraints to agricultural production that conventional research has not been able to overcome and the recent scientific advances that offer new solutions. In recognition of the meagre human and financial resources available priority must be given to those R&D programmes that lead to develop: (1) new breeds of high-productivity, high-quality and disease/insect tolerant/resistant livestock; (2) new medicines, vaccines and diagnostic kits; and (3) biochemical engineering to open up new ways of production in food processing and storage, pharmaceutical industry and agriculture. In determining priorities and assessing the relative benefits and risks of using various technologies a participatory-interactive bottom-up approach involving all stakeholders is highly recommended. This ensures the participation of resource-poor farmers in all stages from priority setting to project development and implementation. The continuous involvement of all stakeholders including the urban and rural poor in R&D ensures development of biotechnology products that are demand driven, thus expecting high adoption rate.

Safe application of biotechnology and of products and services

The term 'biosafety' in the context of biotechnology describes a set of measures used to assess and manage any risks associated with genetically modified organisms (GMOs). Effective and efficient national biosafety systems should be in place before modern biotechnology is streamlined into a country's agriculture. The key components of an effective biosafety system include: (1) guidelines that clearly define the structure of the system, the roles and responsibilities of those involved and the review process; (2) the regulatory mechanism comprised of well trained personnel, confident about decision making; (3) an efficient information system that enables the biosafety evaluation process to be based on up-to-date and relevant scientific information; and (4) feedback mechanisms for incorporating new information and revising the regulatory framework as needed. A science-based assessment of risks on a case-by-case basis and identification of any concerns expressed by stakeholders, enable regulators to find out what risks may be associated with a particular product and to make appropriate recommendations.

In most countries with regulatory regimes, existing institutional arrangements have been adjusted to accommodate biosafety needs. Many developing counties in Africa are now in the process of developing their biosafety frameworks through the support of the UNEP/GEF (Mwinjaka 2004). As a reflection of the need to regulate potential risks posed by transnational transfers of GMOs, efforts are ongoing to negotiate a legally binding biosafety protocol under the Convention on Biological Diversity (CBD). The centrepiece of the Cartagena Protocol is an Advance Informed Agreement (AIA) procedure to be followed before the transboundary transfer of GMOs called living modified organisms or LMOs in the Protocol. While the Biosafety Protocol encompasses

GM semen, ova and animal embryos, animal cloning does not fall within the scope of the Protocol. Under the Biosafety Protocol, any country exporting GM animals for release into the environment will be required to give advance notice to the importing country (www.biodiv.org/biosafety/protocol.asp).

Intellectual property management

Intellectual property rights (IPRs) is a broad term for the various rights granted by law for the protection of economic creation in a creative effort. The main categories of intellectual property relevant to agricultural research and development are patents, plant variety rights or Plant Variety Protection (PVP, also known as Plant Breeders' Rights) governed by an international agreement and organisation, UPOV (French acronym for International Union for the Protection of New Varieties of Plants), trade marks and trade secrets.

The purpose of intellectual property management is to protect local inventions and enable access to technologies developed elsewhere. The Trade Related Intellectual Property Rights (TRIPs) agreement, negotiated as part of the Uruguay Round, requires all members to make patents available in all fields of technology. Under the TRIPs agreement, Article 27 (3b) ['Members shall provide for the protection of plant varieties either by patents or by an effective *sui generis* system or by any combination thereof']. In this sense, it is possible to patent a gene, which typically involves legal claims over the isolated gene and DNA sequences, over the genetic engineering tools that use those sequences, and over plants that have been transformed with such tools. The rights of the patent holder do not extend to plants in which the genes occur naturally. Not surprisingly, the moves by developed countries to protect products of biotechnology have led developing countries to seek to protect their genetic resources. Under the CBD agreement it is clear that nations could enact legislation prohibiting the export of genetic resources unless arrangements were made to share the benefits of financial returns from the exported resources.

The increasing use in research for development of proprietary materials and technologies which are owned by private-sector companies also means greater reliance on licenses, material transfer agreements and other legal agreements. Both national and international public research institutes therefore require suitable institutional and legal frameworks for managing intellectual property. With such legal expertise, research institutions can protect their inventions when necessary and use them to negotiate access to and use of proprietary technologies owned by others.

Financing and incentives for public sector R&D

Creating an enabling policy environment that would allow the application of biotechnology to thrive in national R&D institutions or in the commercial and industrial systems is of critical importance. The issue of financial resources is fundamental to creating this positive policy environment. Policy makers and decision makers need to be informed about the need for and potential of biotechnology so that they are convinced to invest the necessary resources to acquire and develop the necessary capabilities.

In many countries in Africa, R&D institutions and the science and technology (S&T) activities are public financed. Governments are unable to meet their many obligations; consequently, the R&D and S&T activities suffer most. Although governments attach sufficient importance to R&D and S&T functions as integral components of the development strategy, they still stammer when it comes to investments in these areas. This is reflected in the actual budget allocations for R&D and S&T activities. Political support can be built for public sector funding by documenting and publicising research impacts, developing strong and articulate client organisations that have political influence, building closer relations between research managers, scientists and policy makers, and broadening the funding base to include sustainable management of natural resources.

Decision makers and policy makers must establish both short- and long-term policies that will provide incentives for investments in biotechnology to enhance the impact of biotechnology on levels of food security, in the alleviation of poverty and in commerce and trade.

The role of donors including international agencies towards R&D and S&T activities remains crucial in keeping the technological advancement of the society. Their role varies from outright financial input to participation in joint research projects and the supply of equipments and manpower training.

Public–private partnership and private sector investment

Strategic alliances between public and private sector entities must be established to expand the financial resources for R&D in biotechnology. First, and probably most important, private sector research has radically increased, driven in part by the possibility of profits supported by intellectual property rights.

Governments of developing countries could provide incentives to public institutions, non-governmental organisations and local private companies to acquire appropriate biotechnology applications from external sources. These technologies could be used to meet the needs of both the larger commercial farmers and the resource-poor farmers. Several technology transfer organisations and development agencies already have facilitated donations of proprietary products by multinational companies to increase the productivity of subsistence crops and livestock. Much more is possible. Equitable joint ventures between public and/or private sector entities from developing countries and private sector entities in developed countries should be assigned high priority. These ventures can accelerate the adoption of tested technologies by farmers. Developing countries typically will contribute adapted germplasm and the external private sector will provide the proprietary gene that enhances the product. Building trust between parties to ensure equity remains the key challenge. Independent, honest-broker institutions and organisations such as Heifer International, FarmAfrica, African Agricultural Technology Foundation (AATF) and the International Service for the Acquisition of Agri-biotech Applications (ISAAA) can help build trust to achieve the mutual objectives of both the developing countries and the private sector. Both parties can make in-kind contributions to initiate projects and they can agree on their respective returns after the economic value of the enhanced product has been evaluated in the field. Similar strategic alliances could also apply to research carried out by international agricultural research centres.

Joint ventures with multinational agri-biotechnology companies also have great potential for both the public institutions and local private companies in developing countries. They are particularly attractive to private companies, which normally lack the R&D and capital investments to develop their own technology. Joint ventures offer the opportunity to license the technology and gain experience with its use and distribution. The latter activity is one of the weakest links in the chain of crop and livestock production in developing countries. Development agencies should also consider participating in more joint-venture pilot projects.

Officials making decisions about publicly funded agricultural research must first consider whether to modify research foci in order to complement the work carried on in the private sector. The private sector will probably do well at adapting livestock (cattle, sheep, pigs and poultry for example) that middle-income farmers will use in middle-income nations. Private industry probably also will do well at research on livestock exported to the developed world. Conversely, the private sector will pay little attention to the needs of the poorest farmers and it may not be as environmentally sensitive as publicly funded institutions. The public sector, therefore, has an important role to play in areas that complement private-sector activity. Moreover, if mergers

reach the point where competition within the private sector is weak, the public sector should ensure that good public varieties could compete with private varieties so that farmers face reasonable choices. Such choices should be made available even if there are objections that public-sector activity is cutting into private-sector profits. The development of institutional mechanisms, such as competitive funds, could also promote public-private interaction (Kameri-Mbote and Wafula 2000). Promotion of mechanisms that do not require new institutions, such as joint ventures, collaborative research, research levies, and contract research may also be encouraged.

Promotion of regional and international collaborations

Successful biotechnology transfer and application will depend on access to information, positive national policies and most importantly, the recognition by the government of the central importance of S&T in national economic and social development. Biotechnology development has taken new dimensions from traditional technologies to international initiatives. The major investors on biotechnology are international companies, international laboratories and centres of excellence based in developed countries. Policy makers and decision makers must provide a conducive environment and setting to support international and regional initiatives in biotechnology R&D, and promote the creation of partnerships, both public-private and public-foreign investment firms which may also serve to reduce the potential risks in biotechnology developments. Governments must improve climate for creation of private biotechnological enterprises.

Governments must become actively involved in the coordination of the transfer of foreign technology with the development of domestic technological capabilities. Effective technology transfer requires human, scientific, technological, organisational and institutional and resource capabilities. To make technology appropriate for local circumstances, indigenous contribution to technological development is crucial, and this depends on indigenous technological capability. International collaboration and funding are essential, as many of the poor countries in Africa cannot develop successful biotechnology programmes by themselves. Both bilateral and multilateral collaborations are necessary. Regional collaboration and funding can be enhanced through existing organisations such as the African Union (AU), Southern Africa Development Community (SADC), East African Community (EAC), Economic Commission of West African States (ECOWAS) and sub-regional bodies such as Southern African Centre for Cooperation in Agricultural Research and Training (SACCAR), Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) etc.

Education and public awareness on biotechnology and biosafety

Public awareness and understanding of biotechnology has great implication not only in successful application of biotechnology in research for development, but also on the acceptance of products of biotechnology. It has been observed that stakeholders including policy makers and decision makers, research managers and scientists in many developing countries have inadequate knowledge about biotechnology, its impacts and its potential for socio-economic development (Juma et al. 1995).

Recent advances in modern biotechnology and the rapid commercialisation of products, GM crops (James 2005), have led to many questions, deep disquiet and intensive debate. Sharply polarised debates in Europe, have underscored the importance of public participation in decision making on GMOs. GM proponents and GM opponents are continuing to differ on some issues, e.g. the impact of agro-biotechnology on the environment, health of human and animals (biosafety), the ownership and control of genetic resources (IPRs), and the livelihoods and socio-economic futures of the resource-poor farmers in both rural and sub-urban areas. The rapid pace of technological change and the wide-ranging nature of the perceived effects of biotechnology

necessitate much greater public participation in policy making. A number of industrialised countries have launched programmes aimed at including the public in technology assessment and decisions involving the use of biotechnology in agriculture. The issue is not simply one of providing balanced scientific information to the public, but rather of building trust between science and society. Intermediary programmes and institutions concerned with the social aspects of biotechnology could be established to build such trust.

Conclusions

Modern biotechnology has the potential to alleviate poverty and improve food security in Africa, only if it focuses on the problems and opportunities poor people face and only if appropriate policies accompany it. Food insecurity stems from the combined effects of a number of factors; the challenge lies in strategies that tackle all problems comprehensively. Policies must ensure the development of a friendly environment and that biotechnology is oriented toward the needs of the poor, particularly resource-poor smallholders in rural and sub-urban areas. Modern biotechnology is not a silver bullet, but it may be a powerful tool in the fight against poverty and should be made available to poor farmers and consumers.

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Intellectual property rights and public agricultural biotechnology research for the poor: strange bedfellows or partners in crime?

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Introduction

Intellectual property (IP) refers to intangible property resulting from human ingenuity. It describes a wide variety of property including inventions, literary and artistic works, and symbols, names, images, and designs used in commerce, created by musicians, authors, artists, inventors etc. Intellectual property rights (IPR) introduces the concept of legal ownership of intellectual property. Ownership and use of creative works is regulated by IP laws, which recognise legal entitlement to IPR. Intellectual property is divided into two categories: industrial property, which includes patents, and copyright. In general, the holder of the legal entitlement is entitled to exercise various exclusive rights in relation to the subject matter of the IP. IPRs are granted by national authorities, generally for a specified period of time. The two terms, intellectual property and intellectual property rights, are often used interchangeably. In this paper, the term intellectual property is used to mean intellectual property or intellectual property rights as indicated by context.

The basic rationale for protection of IP is that it fosters innovativeness by encouraging authors and inventors to disclose their works in the public domain in exchange for exclusive rights to use of the work for a limited period of time. Thus other innovators can build on the information to develop more innovations. The inventor or author benefits in that he or she has exclusive rights to use or exploit the innovation, oftentimes for a fee, and/or to prohibit non-permitted use.

Changes in intellectual property landscape

A few decades ago, IP was a term that was the preserve for a few lawyers, individual inventors and private enterprises. Intellectual property rights were not considered to be a barrier in public agricultural research whose research products are taken to be public goods. In the recent past, however, the research environment has become more restricted because of protection of research products including basic research tools. National governments are also laying claim to genetic resources found within their bounders and regulating access to those resources. In the past genetic resources were generally considered a common heritage of humankind and were freely distributed and exchanged. Thus, public research institutions have to increasingly take into consideration IP related issues in conducting their research.

The restricted research environment is as a result a combination of factors that have caused tremendous changes in the IP arena. First, there is the dramatic shift from public to private research in the agricultural sector in the developed countries. Historically, agricultural research was a preserve of publicly funded research institutions. In the United States, for example, the Department of Agriculture and the land grant universities were the source of new innovations in agricultural technology. Today, however, the private sector spends more on agricultural research than do public research institutions (Keith and David 2000). In addition, the private sector commits more money into agricultural research than does the public sector. Entry of the private sector into agricultural research has been fuelled to a large extent by the advances made in molecular biology and in biotechnological research. After Mendel's work on genetic inheritance was recognised as

important in 1900, there was steady progress in understanding the genetic makeup of living organisms. This started with the discovery of radiation induced mutation in the 1920s, discovery of the chromosome and gene manipulation in the 1930s and 1940s, and the discovery of the double helix structure of DNA in the 1950s. The quantum leaps, however, are much more recent, notably in development of recombinant DNA technologies and the rapid development in DNA sequencing technology (Serageldin and Persely 2000). The developments in molecular biology and advances in biotechnology have accelerated the development of innovations which are of commercial importance (Jain 1999). Indeed, the entrance of the private sector has been credited as being behind the harmonisation of international IP laws and seeking stronger protection.

Another factor that has brought IP issues to the fore is the expansion of the scope of IP. This has taken various forms, namely expansion to cover new subject matter not previously covered, e.g. databases; inclusion of new 'categories' of subject matter, such that life forms now constitute patentable inventions in a number of jurisdictions; increase in period of protection, especially for copyright protection; and development of a *sui generis* system to protect non-traditional innovations such as new plant varieties. In addition to the expanded scope, there has been increased harmonisation of the IP protection regimes around the world. IP protection laws vary from one jurisdiction to another and generally speaking, registration or enforcement of IP must be pursued or obtained separately in each territory of interest. International treaties such as the World Trade Organization (WTO) Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) have ensured continued harmonisation of IP protection laws amongst members of the WTO. There are other intergovernmental facilities through which protection in more than one jurisdiction can be sought.

The combined effect of globalisation, liberalisation of markets and the shift of the global economy from industry to knowledge-based economy is supported by advances in information and communication technology. Today, information is not only much more readily available and accessible but it is also easier to copy. While there is a remarkable acceleration in generation and dissemination of new knowledge, access, exchange and use of this knowledge is regulated by IP protection regimes including patents, copyrights, trademarks and trade secrets. Not surprisingly, advance in information technology has been paralleled by enhanced and stronger IP protection regimes. The TRIPS agreement sets out minimum standards of protection of intellectual property which member countries have to institute at the national level.

Implications of changes in IP landscape for agricultural public research

Until recently agricultural technologies were unencumbered by proprietary claims and were freely available to all. Agricultural history is an account of innovations spilling across firms, sectors of the economy and countries (Philip and Brian 2001). In the 1970s, advances in molecular biology paved the way for successful genetic transformations. Then the 1980s witnessed an unprecedented protection of products of biotechnology, especially in the agricultural sector, triggered by expansion of patentable subject matter to include life forms. Two events are noteworthy: first is the US Supreme Court decision of 1980 (Diamond v. Chakrabarty 447 U.S. 303, 1980) which concluded that a genetically modified bacterium was patentable. Genetic engineer Ananda Mohan Chakrabarty, working for General Electric, had developed a bacterium derived from the *Pseudomonas* genus capable of breaking down crude oil, which he proposed to use in treating oil spills. He requested a patent for the bacterium in the US but was turned down by a patent examiner, who believed that living things were not patentable. Following a series of actions that finally ruled the case in favour of Chakrabarty, Sidney A. Diamond, the Commissioner of Patents and Trademarks, appealed to the Supreme Court. The court decided that the micro-organism plainly

qualifies as patentable subject matter because the inventors claim was to non-naturally occurring bacterium—a product of human ingenuity.

The second equally significant event is the granting of a patent by the US Patents and Trademarks Office on a genetically modified mouse, the Oncomouse, developed by Harvard University in 1988. The mouse had been genetically modified to carry a specific gene, an activated oncogene, which significantly increases the mouse's susceptibility to cancer, thus making the mouse an important tool for cancer research. This was the first higher animal patent.

The possibility to have proprietary claims on genetic material and life forms constituted an incentive for the private sector to invest in agricultural research and development. While returns from licensing are a blessing to the private sector, the proliferation of patented agricultural technology has increasingly been seen as a research barrier for the public sector. But IP in life form has been criticised for several reasons besides being a barrier to innovation. Those in favour hold that IP plays an important role in stimulating biotechnological innovation, in fostering competitiveness and in advancing medical research including diagnostics, therapies and cures. Those against protection of life forms range from animal rights activists who see patents on animals as aggravating the degradation of animals; environmentalists who fear that genetically modified life forms threaten the integrity of the environment; clerics who see patenting as reducing divinely created creatures to mere objects; and small-scale farmers who are concerned about continued privatisation of agricultural innovations on their livelihoods.

The relevant question for public agricultural biotechnology is broader than the above debate and is founded on the recognition that IP protection for life forms as well as for other innovations, will continue in the foreseeable future. The relevant question is whether the existence of IPR and continued harmonisation of enforcement mechanisms are barriers to research aimed for the poor. Studies done by the International Food Policy Research Institute (IFPRI) can be insightful in answering this question. IFPRI found that IPR embodied in the key enabling technologies used to transform crops were actually not protected in most developing countries because these technologies were held by commercial companies which are interested in profits (Pardey and Wright 2001) while their primary markets are in developed countries. Since IPR are territorial, i.e. they are only enforceable in countries in which protection is sought for and is granted, these technologies can be freely exploited in developing countries in which they are not protected. A problem would, however, arise if products incorporating these technologies are subsequently exported into a country in which the technologies are protected.

The public sector has to consider a number of IP related needs in addressing the challenge posed by an IP saturated research environment. This includes the need to establish collaborative links with advanced laboratories to access technologies, ensure product development and delivery to relevant beneficiaries and the need to guard against misappropriation of technologies developed by the public sector. IP should be used as a tool to meet these needs. Public institutions can use IP as a tool to establish collaborative linkages with advanced laboratories or with the private sector to access the technologies and to form partnerships for product development and delivery. Protecting IP for to promote linkages with the private sector is often seen as one instance where protection makes economic and social sense (Maredia et al. 1999). In each given situation, an enquiry should be made on the research goal, technologies needed to achieve it, accessibility of these technologies, management of the research process whilst respecting obligations to third parties, products developed and their delivery to end users, and, interventions put in place to prevent misappropriation by third parties. This requires that the necessary capacity to deal with matters related to IP be built at the national and research institutional level. At the national level, there is need for developing countries to build capacity to engage in negotiations on matters

relating to IP at global level. In addition, there is need to have capacity to institute policy and legislation and to enforce the legislation. At the public level, there is need to implement policies that are supportive of the public good agenda while at the same time fostering collaboration with a wide range of players including the private sector.

Conclusion

Partnerships with the private sector are becoming increasingly inevitable as public institutions seek to access patented technologies and to deliver research products to relevant beneficiaries. Since the private sector focuses on high return research that is not necessarily relevant for the poor, public sector research will continue to be important in addressing problems of the poor. Intellectual property rights in biotechnological research raise several opportunities and challenges for the public research sector. In addressing the challenges, public institutions should view IP as a tool that facilitates research collaboration and delivery of research products to the poor. In the end IP and biotechnology research for the poor are neither strange bedfellows nor partners in crime. One is simply a means and the other an end.

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Implementing the Cartagena Protocol in West and Central Africa: Challenges and opportunities

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Abstract

Although modern biotechnology holds great potential for agriculture, especially in developing countries, if it is not well regulated and managed, it can be of great disservice to the very people it is intended to serve. The Cartagena Protocol on Biosafety is one of the international instruments that regulate modern biotechnology but some West and Central African countries face many challenges in its implementation. These challenges include, among other things, the lack of biosafety laws, the absence of access and benefit sharing regulations, the absence of clear biotechnology policies, poor government commitment to funding biotechnology research, poor or lack of laboratory equipment, poor public perception of biotechnology and poor access to information and communication technology. This paper discusses how these challenges hinder the proper implementation of the Protocol and proposes a way forward by examining the opportunities that are available for effective implementation of the Protocol in the sub-region.

Key words: implementation, Cartagena Protocol, biotechnology, obligations, challenges, opportunities

Introduction

Experts say agriculture will have to sustain an additional 2 billion people over the next 30 years from an increasingly fragile natural resource base. The need for further increase in production in the future while conserving the resource base of agriculture and minimising adverse effects on the wider environment, calls for ever greater contributions from agricultural research (FAO 2003). Although it has been generally acknowledged that biotechnology holds great promise for agriculture in developing countries, if not well regulated, it can cause a great disservice to the very people it is intended to serve. For this reason there was a need to come up with an international instrument to regulate modern biotechnology. Most developing countries have not yet passed legislation in this field and believe that their limited scientific capacities, their recurrent problems with checking products at their borders, and their restricted ability to make their own assessment of the risks and benefits involved do not allow them to manage properly the challenges that genetically modified organisms (GMOs) and other products of modern biotechnology pose. They therefore called for the establishment of international rules in this field. The Cartagena Protocol on Biosafety, which represents the multilaterally agreed response to these concerns provides the legal framework regulating transboundary movements of living modified organisms (LMOs), adds to the growing number of the multilateral environmental agreements (MEAs) that the international community, especially developing countries, are having challenges to implement nationally.

[1]For details, see http://www.biodiv.org/biosafety/faqs.
[2]Article 37 (1) states: 'This Protocol shall enter into force on the ninetieth day after the date of deposit of the fiftieth instrument of ratification, acceptance, approval or accession by States or regional economic integration organizations that are Parties to the Convention.'

Apart from the fact that this growing body of MEAs suffers from the inability or unwillingness to implement and enforce them, implementation efforts in developing countries are often made more difficult by lack of financial and human resources, the sheer volume and complexity of associated obligations and responsibilities, inconsistency in implementation regimes between countries and occasionally, a lack of political will. In many instances, states recognise an environmental problem, negotiate an MEA to address the problem, and then sign and ratify the MEA, without conducting a serious assessment of whether particular states actually have the financial, personnel, and the required technical resources to implement the MEAs. Today, many states in West and Central Africa are faced with the challenge of implementing numerous MEAs with limited resources. In addition to scarce resources, politicians in the developing countries often need to be convinced of the importance of implementing some MEAs, considering the fact that there are other pressing priorities facing their countries. States are now asking questions about the best way forward (UNEP 2004).

The Cartagena Protocol on Biosafety

The Biosafety Protocol was finalised and adopted in Montreal, Canada, on 29 January 2000 at an extraordinary meeting of the conference of the parties. In accordance with the precautionary approach contained in Principle 15 of the Rio Declaration on Environment and Development. The objective of the Protocol is to contribute to ensuring an adequate level of protection in the field of, the safe transfer, handling and use of LMOs resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements.[1] The 50th instrument of ratification by parties was on 13 June 2003 and in accordance with Article 37 of the Protocol it entered into force on 11 September 2003.[2]

Key features of the Protocol

The Protocol promotes biosafety by establishing rules and procedures for the safe transfer, handling and use of LMOs, with specific focus on transboundary movements of LMOs. It features a set of procedures including one for LMOs that are to be intentionally introduced into the environment (advance informed agreement procedure), and one for LMOs that are intended for use directly as food or feed or for processing. Parties to the Protocol must ensure that LMOs are handled, packaged and transported under conditions of safety. Furthermore, the shipment of LMOs subject to transboundary movement must be accompanied by appropriate documentation specifying, among other things, identity of LMOs and contact point for further information. These procedures and requirements are designed to provide importing Parties with the necessary information needed for making informed decisions about whether or not to accept LMO imports and for handling them safely. The Party of import makes its decisions in accordance with scientifically sound risk assessments. The Protocol sets out principles and methodologies on how to conduct a risk assessment. In case of insufficient relevant scientific information and knowledge, the Party of import may use precaution in making their decisions on import. Parties may also take into account, consistent with their international obligations, socio-economic considerations in reaching decisions on import of LMOs. Parties must also adopt measures for managing any risks identified by the risk assessment, and they must take necessary steps in the event of accidental release of LMOs. To facilitate its implementation, the Protocol establishes a Biosafety Clearing-House for Parties to exchange information, and contains a number of important provisions, including capacity-building, financial mechanism, compliance procedures and public awareness and participation. However, developing countries in general and West and Central African countries in particular have some practical challenges and opportunities to effectively implement the Protocol.

Challenges and opportunities for implementation in West and Central Africa[3]

Sands (1995), says that states implement their international environmental obligations in three distinct phases. First, by adopting national implementation measures; second, by ensuring that national measures are complied with by those subject to their jurisdiction and control; and third, by fulfilling obligations to the relevant international organisations, such as reporting the measures taken to give effect to international obligations. In this paper implementation refers to all relevant laws, regulations, policies and other measures and initiatives that contracting parties adopt and/or take to meet their obligations under the Cartagena Protocol and its amendments if any. In trying to meet their obligations under the Protocol as stated above, countries in the sub-region face common practical challenges, especially as most of them have similar (but distinct) legal, institutional, linguistic and economic contexts. Conversely, there are equally some present and potential opportunities for the countries of the sub-region to seize for their effective implementation of the Protocol.

Challenges

These challenges include, among other things, the lack of Biosafety Laws, the absence of access and benefit sharing regulations, the absence of clear biotechnology policies, poor government commitment to funding biotechnology research, poor or lack of laboratory equipment, poor public perception of biotechnology and poor access to information and communication technology by scientists.

a. Absence of or inadequate biosafety frameworks

The Cartagena Protocol requires a country to allow the importation of a GMO only after it has obtained all the necessary information about it and carried out a risk assessment to evaluate the likelihood of harm to human health, to agricultural systems, to its environment and to its socio-economic conditions. This requires that countries establish what is called a 'national biosafety framework', which includes a policy, a regulatory regime, a system to handle notifications, systems for monitoring and inspections, and systems for public information and participation. According to van der Meer (2003), the establishment of a national biosafety framework is not something that suddenly became necessary because of the Protocol. Since 1992, Article 8(g) of the Convention on Biological Diversity (CBD) has called for the establishment of such national mechanisms. But in the sub-region under consideration, very few countries have developed a biotechnology and biosafety policy document to guide in priority setting, development of laws and identification of the institutional frameworks to promote biotechnology capacity. Apart from Cameroon, that has adopted a Biosafety Law, the other countries in the sub-region are still at the stage of developing their legislations. For effective public involvement, the development of frameworks requires initial public sensitisation and as such funds are needed to organise meetings, workshops, documentation etc. The major challenge here is that these much needed funds are hard to come by, due to budgetary constraints.

b. Lack of or inadequate laboratory equipment for risk assessment

Under the Cartagena Protocol the objective of risk assessment is to identify and evaluate the potential adverse effects of living modified organisms on the conservation and sustainable use of biological diversity in the likely potential receiving environment, taking into account risks to

[3] This paper draws from the outcome of a survey carried out in West and Central Africa in 2002 by Prof. Walter S. Alhassan entitled 'Agrobiotechnology application in West and Central Africa (2002 survey outcome)' which included Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Mali, Nigeria and Senegal. However, experiences from the other Communauté Economique et Monétaire de l'Afrique Centrale known in English as the Economic and Monetary Community of Central Africa (CEMAC) countries have been included.

human health. Risk assessment is, *inter alia*, used by competent authorities to make informed decisions regarding LMO.[4] In the sub-region most biotech institutions are ill equipped to conduct the risk assessment studies, although the techniques required to evaluate risks of LMOs are available. Without risk assessments, governments will be unable to establish and implement the necessary policies and measures to ensure the safe application of biotechnology. The unavailability of laboratory spare parts and trained repair technicians is a major concern in the sub-region. As Alhassan (2003) says, other constraints are associated with staff skills in biotechnology, especially those with knowledge in molecular biology who are not practising their professions for lack of laboratories, such staff are likely to get 'rusty' and therefore frustrated.

c. Poor public perception of biotechnology

The Biosafety Protocol in Article 23 recognises the fact that for public participation to be meaningful, there must be access to information, and public awareness and education. A number of challenges present themselves. For example, how can to present scientific issues to the public in a manner that is understandable by lay people and how to raise public awareness with balanced information and ensure that the uninformed group (which forms the majority) does not fall victim to the mass misinformation that clogs some media? Other challenges are posed by diverse levels of education and literacy across the countries in the sub-region; low understanding of biotechnology among the public; lack of simple communication material; and difficulty in getting biotechnology- and science-based information from local sources. The insufficient dialogue between scientists, industry, policy makers, regulators, civil society organisations and the mass media affect public perception of modern biotechnology and its products. The media culture favours mainly social events, especially political events and science reporting has low priority.

d. The limited access to information and communication technology—BCH

The Biosafety Clearing-House (BCH) was established in Article 20 as one of the key tools to assist countries to implement the Cartagena Protocol. According to Pythoud (2003), there was a common understanding that the BCH should take advantage of the most recent information communication technologies and should therefore be mainly Internet based. The main challenge concerning the BCH in the sub-region is that access to the Internet is still a luxury and this will affect the usefulness of the BCH for the majority that do not have access to the Internet. To present a coherent and relevant view of local concerns and needs at the global level, it is imperative for the public to have access to the information that is available. It is very clear that there is a great need to build human and infrastructure capacity in this area and this needs lots of investment from the states and their partners.

e. Permeable state borders

The Protocol establishes an international, legally binding framework that allows countries, in particular, those that do not yet have in place a regulatory regime for biosafety, to make informed decisions on the import of GMOs into their territory. Therefore countries have the sovereign right to regulate GMOs and their products at the national level and they typically do this by reviewing certain technical information to determine safety. In the sub-region, the porous nature of borders due to the fact that the boundaries have weak control from the state is a major problem. Informal circulation of goods and humans across borders within the sub-region can make inspection and control an onerous task. Moreover, the sub-region is witnessing much ethnic unrest within the states and this forces cross-border movement of people and goods. For instance, at least 23,000 Fulani cattle herdsmen and their animals fled from Nigeria into nearby Cameroon to escape clashes with farming communities on the Mambilla plateau in Taraba State between 1 and 7 January 2002. More than 100 people were killed in the fighting. Some of the Fulani refugees

[4] See Annex III (Risk Assessment) to the Cartagena Protocol on Biosafety.

later returned to Nigeria but the majority remained and were raising their cattle in Cameroon until April 2005 when UNHCR arranged for the voluntary repatriation of some. Such examples are many in the sub-region and things can become very complicated when such situations arise between countries with different GM status.

Opportunities

In spite of the many challenges stated above, there are equally some opportunities that will favour or positively contribute to the effective implementation of the Protocol in the subregion.

a. Similar (but distinct) legal, institutional, linguistic and economic contexts

FAO affirms that 'Intercultural dialogue between developing countries facing similar food and agriculture problems is an important way of sharing expertise and technologies.'[5] Countries of the Central and West African sub-region share similar (but distinct) legal, institutional, linguistic and economic contexts. This is an opportunity in the sense that it is often possible to adapt approaches from one country in the sub-region to the specific context of another country. These shared contexts also facilitate regional, sub-regional and bilateral cooperation and coordination. Countries can learn from the experience of others and avoid repeating mistakes while building and improving on the proven successes. For instance, Nigeria and Côte d'Ivoire are developing their biotechnology policy documents while Cameroon has already adopted her Biosafety Law and the texts of application are at their final stage. These developments have not only been costly but they also required time and consultations. The other countries of the sub-region that are at initial stages of putting their own policies and regulatory instruments in place will have to learn from the weaknesses and the successes of these experiences. Some countries like Mali and Burkina Faso are in the initial process of testing BT cotton; results from their experiences will be useful in developing the policy of the other countries in the sub-region. The Sahel and West African Club (SWAC) says cotton plays an important part in West Africa's development. Between 1 and 2 million households produce cotton in West Africa; up to 16 million people are involved in cotton production in some way and West and Central Africa taken together are the world's second largest exporters of cotton after the United States.[6] Logically it means that the successes or failures of the trials of BT cotton in Mali and Burkina Faso will influence how 16 million people perceive this technology in the sub-region.

b. Favourable environment for regional co-operation

It is recognised that South-South cooperation in the form of sharing expertise and technologies has resulted in the transfer of many solutions suited to local conditions. African scientists and policy makers can gain from the experiences of other countries and regions. Regional networks and international cooperation are effective in sharing information, scientific and regulatory data, and expertise within specific geographic regions. For example, environmental and food safety risk assessments are expensive, and countries may benefit from each other by sharing regulatory data and information. The advances in Internet technology now enable rapid and free delivery of information (Eicher et al. 2005). West and Central African sub-region regional scientific cooperation initiatives are already in existence and only need technical and financial support to be more effective. For instance one of CORAF/WECARD's objectives is to promote cooperation, consultation and information exchange between member institutions and other partners.[77]CORAF/WECARD is a 21-member sub-regional organisation whose mission is to:

The sub-regional economic institutions like CEMAC and ECOWAS (Economic Commission of West African States) have taken the issues of food security, biotechnology and biosafety as a

[5]'Agriculture and intercultural dialogue' is the theme of this year's World Food Day, celebrated every year to mark the day on which FAO was founded in 1945. see http://www.fao.org/wfd/2005/.

priority on their agenda. The diversity of the procedures of analysis and control in this sub-region where the borders are permeable, constrained the states to reflect on the solutions of conformity and harmonisation. It is within this framework that the Heads of State of the CEMAC, came together in N'Djamena (Chad) on 14 December 2000, adopted the Regional Strategy of Food Safety, within harmonisation of the phytosanitary regulations. FAO provided support for the implementation of this strategy and a regional programme for food safety was established.

In addition, during the seminar organised in Nigeria on 1 March 2001 by the Africa Middle East Working Group of the Global Crop Protection Federation (AMEWG/GCPF) (which later became CropLife Africa Middle East), it was recommended to the participants to initiate a procedure of harmonisation of the phytosanitary regulations in CEMAC zone. In the Yaoundé meeting of March 2002, the six CEMAC countries agreed, among other things to establish a harmonised/ common phytosanitary regulation. A committee in charge of preparation and implementation of such legislation within CEMAC zone was created and governments agreed to support the initiative and adopt a harmonised official document. In mid-2005 CEMAC ministers in charge of agriculture met in Douala, Cameroon, to adopt the CEMAC common regulation on the homologation of pesticides. Many observers see this as a giant step towards harmonising regulations in other areas, especially biosafety.

A ministerial conference of ECOWAS states on biotechnology was held on 24 June 2005 in Mali. The objective of the conference was to adopt the necessary conditions defined by the meeting of experts held on 21 to 23 June 2005 for the implementation of the recommendations of the Ouagadougou conference, on the 'mastery of sciences and technologies to increase agricultural production in Africa: West African perspectives'. Some of the major recommendations of the meeting envisaged actions relating to biotechnology and biosafety.[8] On biotechnology, there will be the reinforcement of research priority setting identified by CORAF/WECARD by a quantitative economic analysis and to increase investments through partnership between private and public sectors to drive the best use of biotechnology tools to alleviate the constraints of production. Concerning a regional approach to biosafety there was a call on those countries that had not yet ratified the Cartagena Protocol to do so as soon as possible, so that by 1 July 2006 at latest, all the ECOWAS country members would have adopted their respective national policies and legislations on biosafety, thus, facilitating regional harmonisation of the biosafety system to July 2008. Another objective is harmonise national legislations and establish a regional regulatory framework on biosafety and an independent fund for the assessment of the socio-economic impacts of the use of GMOs. All of these indicate a favourable environment on which cooperation in biotechnology and biosafety issues in the sub-region can be built.

c. Capacity building opportunities

Article 22 of the Protocol requires parties to cooperate in the development and strengthening of capacities in biosafety, including through existing organisations and through private sector involvement. Such cooperation includes, *inter alia*, scientific and technical training and the enhancement of technological capacities in biosafety. By virtue of Article 28 paragraphs 4 and 5, special attention is given to the needs of developing countries. The Conference of the Parties to

[6] For details see SWAC West African Cotton Overview: Draft for comments January 2005 at: http://www.oecd.org/sah.

[7] CORAF/WECARD is a 21-member sub-regional organisation whose mission is to:

- Improve the efficiency and effectiveness of agricultural research in West and Central Africa by contributing to the construction and the consolidation of the capacities of the national agricultural research systems (NARS) through cooperation between its members, development partners, regional and international organisations, the private sector, non-governmental organisations and users of research results.
- Consolidate the position of the West and Central African sub-region within the context of the international agricultural research-for-development.

the Convention on Biological Diversity serving as Meeting of the Parties to the Cartagena Protocol on Biosafety (COP-MOP) is especially required when giving its guidance with respect to the financial mechanism for the Protocol, to take into account the needs of developing country parties in their effort to identify and implement their capacity building requirements. Capacity building for effective implementation of the protocol has been one of the top agenda items of the COP-MOP decisions. At its first meeting, the COP-MOP (in its decision BS-I/5) endorsed an Action Plan for Building Capacities for the Effective Implementation of Protocol and the coordination mechanism developed by the Intergovernmental Committee for the Cartagena Protocol on Biosafety (ICCP). The COP-MOP also considered a preliminary set of criteria and indicators for monitoring implementation of the action plan. Finally the COP-MOP decided to include capacity building as one of the standing items on its medium-term programme of work up to its fifth meeting.

At the second meeting, COP-MOP (in its decision BS-II/3) invited developed countries and relevant international organisations to provide support to developing country parties in capacity building, especially for the development and implementation of national biosafety frameworks. This invitation was particularly targeted at the least developed and small island developing states among them, including countries that are centres of origin and centres of genetic diversity, and parties with economies in transition. This second COP- MOP meeting also reiterated the importance of the roster of experts in assisting developing country parties conduct risk assessment, make informed decisions, develop national human resources and promote institutional strengthening associated with the transboundary movements of LMOs , while reaffirming the need to ensure the regional and gender balance on the roster of experts. It, however, noted with concern the limited use to date of the roster of experts and of the Voluntary Fund for the Roster of Experts, and reiterated the call to parties and governments to use the roster of biosafety experts in accordance with the Interim Guidelines for the Roster of Experts on Biosafety. The countries of the sub-region should capitalise on the fact that the international community is focusing her capacity building priorities on developing countries now and should come up with worthwhile projects and seize the opportunity while it is still there.

Conclusion

Experience has shown that implementation of MEAs in a sub-region like West and Central Africa where emphasis is more on economic development is handicapped by many constraints. Such is the case with the implementation of the Cartgena Protocol on Biosafety in particular and with the application of modern biotechnology that the Protocol seeks to regulate. Despite the potentials of modern biotechnology, the capacity of many institutions in the sub-region to undertake biotechnology research and development lags behind that of developed countries. This is largely due to poor infrastructure, lack of trained manpower and poor support for research and teaching. Successful introduction of biotechnology applications to the region must incorporate strategies that address these constraints. The institutions are ill equipped to conduct the risk assessment studies, although the techniques required to evaluate risks of LMOs are available. Risk assessment is the key feature of the Cartagena Protocol, for without risk assessments, governments will be unable to establish and implement the necessary policies and measures to ensure the safe application of modern biotechnology. All these constraints only point to a key way forward: a sub-regional approach for the effective implementation of Protocol. Some sub-regional initiatives and groupings already existing in the area provide a favourable environment for this approach and should be capitalised on.

[8]For details see 'MAIN CONCLUSIONS AND RECOMMENDATIONS' of the Ministerial conference of ECOWAS states on biotechnology, Hôtel de l'Amitié, Bamako, Mali, 24 June 2005 at: http://www.coraf.org/documents/report/final.pdf

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National Biosafety Framework for Tanzania: Regulatory regime on genetically modified organisms

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Abstract

The Office of the Vice President of Tanzania, in collaboration with national stakeholders and the United Nations Environment Programme (UNEP), has developed a National Biosafety Framework (NBF) for the implementation of the Cartagena Protocol on Biosafety. The process involved the establishment of a system of legal, technical and administrative mechanisms to address safety in the field of modern biotechnology in the country. In the process of developing the NBF, stakeholders' workshops and surveys were conducted in 2003 to ensure public participation. Existing local infrastructure and resources were identified to establish the status of the extent to which Tanzania meets the requirements for safe application of modern biotechnology.

There exists a widespread interest in the use of biotechnology among various stakeholder institutions in Tanzania. The majority of these institutions are engaged in second-generation biotechnologies (e.g. tissue culture and fermentation). A minority are dealing in third generation (modern) biotechnology (molecular diagnostics, genotyping and taxonomy). There is, however, no institution engaged in the application of recombinant DNA biotechnology. At national level biotechnology policy is currently absent. The Environmental Management Act 2004 was enacted in February 2005. The Act provides for the legal and institutional framework for sustainable management of the environment. The Act further provides for the regulation of development, handling and use of genetically modified organisms (GMOs) and products thereof. It empowers the minister responsible for environment, in consultation with sector ministries to make regulations, issue guidelines and prescribe measures for the regulation of the development, handling, and use and the importation and exportation of GMOs and their products. It is on the basis of the Environmental Management Act 2004 that the proposed draft Environmental Management (Biosafety) Regulations will be established and made operational by the environment minister.

This paper details the National Biosafety Framework in Tanzania and the administrative and decision making structure for GMOs. The Vice President's Office is the National Biosafety Focal point whereby all applications concerning GMOs should be addressed. The ministries of agriculture and food security, health, water and livestock development are some of the key competent authorities in their mandate. This paper also elaborates on the application procedures for the export or importation of GMOs, inspection and enforcement, public education, awareness and participation, monitoring, challenges and way forward.

Key words: GMOs, Biosafety framework, Tanzania

Background and context of the national biosafety framework (NBF)

Modern biotechnology is an emerging tool with potential for improving human and animal health, agriculture, industrial and agricultural production and environmental protection. However, the development and application of modern biotechnology have been associated with both opportunities and concerns over the risks of genetically modified organisms (GMOs) to human and animal health, biodiversity and the environment. Concerns raised against modern biotechnology may be grouped into environmental, human health, biodiversity and socio-economic and ethical concerns.

These and other concerns have made it necessary to establish national biosafety frameworks. The necessity emerged as one of the priorities following adoption of the Cartagena Protocol on Biosafety in 2000. Tanzania ratified this Protocol on 16 March 2003.

The National Biosafety Framework is an output of the 'National Biosafety Framework Project', an 18-month project which started in September 2002. This project was funded by the UNEP-GEF and implemented by the Office of the Vice President.

Objectives

The NBF has the following objectives:

- Establish science-based, holistic and integrated, efficient, transparent and participatory administrative and decision making system so that Tanzania can benefit from modern biotechnology while avoiding or minimising the inherent environmental, health and socio-economic risks.
- Ensure that the research, development, handling, transboundary movement, transit, use, release and management of GMOs are undertaken in a manner that prevents or reduces risks to human and animal health, biological diversity and the environment.

Scope

NBF applies to the research, development, handling, transit, contained use, transboundary movement, release or placing on the market of any GMO whether intended for release into the environment, for use as food, feed or processing, or a product of a GMO/product thereof that may have adverse environmental, human and animal health and socio-economic, and ethical and cultural effects on the inhabitants of Tanzania.

Key elements

A national biosafety framework is a policy, legal, technical and administrative instrument established to address safety for the environment and shall include the safety of humans and animals in the field of modern biotechnology. The NBF consists of the following key elements:

a) National policies related to biosafety
b) Regulatory regime
c) Administrative and decision mechanisms
d) Monitoring mechanisms
e) Mechanisms for public awareness, education and participation.

The NBF serves as a basic guide to the implementation of the biosafety system in Tanzania. The NBF shall apply in tandem with two important documents, the National Biosafety Guidelines and the Biosafety Regulations.

Biosafety regulatory regime

Environmental Management Act 2004

The President of the United of Republic of Tanzania signed the Environmental Management Act 2004, in February 2005. This Act provides for the legal and institutional framework for sustainable management of the environment; and the regulation of development, handling and use of GMOs and products thereof. It proposes to empower the minister responsible for Environment in consultation with sector ministries to make regulations, issue guidelines and prescribe measures for the regulation of the development, handling and use, and the importation and exportation of GMOs and their products. The regulations and guidelines will among other things specify:

- Measures to protect environment and human and animal health including socio-economic, cultural and ethical concerns
- Measures necessary to regulate the handling, transport, packaging and identification of GMOs and products thereof
- Measures to regulate, manage and control risks associated with import or export of GMOs and products thereof
- Measures to promote and facilitate public awareness, education and participation concerning the research, development, handling, transit, contained use, transboundary movement, release or placing on the market of any GMO whether intended for release into the environment, for use as food, feed or processing, or a product of a GMO/product thereof.

It is on the basis of the Environmental Management Act 2004, that the proposed draft Environmental Management (Biosafety) Regulations will be established and made operational by the environment minister.

The draft Environmental Management (Biosafety) Regulations

The draft biosafety regulations amply provide for tools to facilitate decision making in terms of risk assessment and risk management. It also provides for liability and redress and places strict liability on the one who carries out activities in relation to GMOs.

The draft Environmental Management (Biosafety) Regulations are arranged in 10 parts:

a) Part one deals with interpretation of various terms used in the regulations. Biosafety, being a new area, necessitates definition of some of the terms.
b) Part two dwells on general principles which give a general direction in implementation. Such principles include precautionary principle, the principle of prevention and strict liability.
c) Part three on institutional arrangement provides for the establishment of the National Biosafety Focal Point (NBFP). It also proposes the establishment of the National Biosafety committee (NBC) and Institutional Biosafety Committees (IBC).
d) Part four is on approval of an activity. This part prohibits any dealings in GMOs and their products without the prior written approval of the NBFP. It provides for an elaborate procedure of notification and approval which includes public participation and a duty to disclose certain information to the public.
e) Part five is on risk assessment and decision making. It is this part which elaborates the powers of the national focal point in decision making.
f) Part six deals with risk management and this includes measures that may be imposed by the NBFP that are necessary to prevent effects of GMOs or their products on human and animal health, biological diversity or the environment.
g) Part seven covers aspects of liability and redress. This part puts in operation the principle of strict liability. Strict liability is imposed on the person carrying out any activity in relation to GMOs or their products when they directly or indirectly cause harm, injury or loss.

h) Part eight specifies offences and penalties. It lists a number of things if committed or omitted constitute offences under the regulations. It also provides for sanctions.
i) Part nine is on schedules. The schedules and any regulations made under or pursuant to this legislation are proposed to be an integral part of this legislation.
j) Part ten is on entry into force. The proposed regulations shall enter into force on the date of its publication in the official gazette.

Biosafety guidelines

Risk assessment and management

Before any release is carried out, an evaluation of the impacts and risks posed to human and animal health and the environment by the release should be undertaken. Tanzania shall base its decision on a risk assessment carried out in a scientifically sound manner taking into account socio-economic and ethical and cultural considerations.

a) The applicant shall carry out or cause to be carried out an assessment of any risks associated with GMOs or products thereof in respect of GMOs in question.
b) No decision on any applicant to import, transit, make contained use of, release or place on the market a GMO or a product thereof may be made by NBFP without the assessment of risks to human and animal health, biological diversity and the environment, including the socio-economic conditions and cultural norms.
c) The risk assessment of a GMO or a product thereof shall be carried out by the applicant or the competent authority as appropriate on a case by case basis and shall be done in accordance with risk assessment procedures as provided in the National Biosafety Guidelines for Tanzania Section 3.0 and Annex VI.
d) The NBFP may require the applicant to bear all the costs for evaluating the risk assessment report or carrying out the risk assessment as the case may be.
e) No person shall be involved in the evaluation of risk assessment in respect of a subject matter in which she/he has any direct or indirect interest of any kind, or if, for any reason, there is, or there is likely to be, a conflict of interest as a result of her/his participation in the evaluation process. A person with a conflict of interest shall declare the fact and withdraw from the evaluation process.
f) If an independent risk assessment cannot be undertaken, or if there is no possibility of verifying the independence of the risk assessment, the NBFP may reject the application.
g) The competent authority shall develop, maintain and use, as the need arises, a risk management strategy for protecting human and animal health, biological diversity and the environment, from the accidents of genetic engineering, the use of GMOs and their products. The risk management should be undertaken in accordance with risk management procedures provided in the National Biosafety Guidelines in Section 4.0 and Annex VII.

Administrative and decision making mechanisms

Institutional structure and administrative mechanisms

The draft Biosafety Regulations proposes the following four institutions for the regulation of GMOs:

- National Biosafety Focal Point (NBFP)
- Competent authorities: ministries responsible for environment; agriculture; livestock; health; wildlife; fisheries; forestry; transport and communication; industry and trade; and science and technology
- National Biosafety Committee (NBC)
- Institutional Biosafety Committees (IBCs)

The NBFP, competent authorities and other concerned agencies should address issues regarding the use of modern biotechnology particularly on biosafety issues, such as health, environmental and socio-cultural and ethical impacts. These authorities and agencies should make consultations, formulate departmental directives and regulations on the access and use of the products of modern biotechnology, coordinate activities and programmes on research and development and their applications and allocate appropriate resources for the upgrading of capacities and capabilities to effectively regulate the GM technology and its products.

The biosafety institutional structure is summarised in Figure 1. At the onset, the proposed structure recognises the mandates of competent authorities in their respective disciplines.

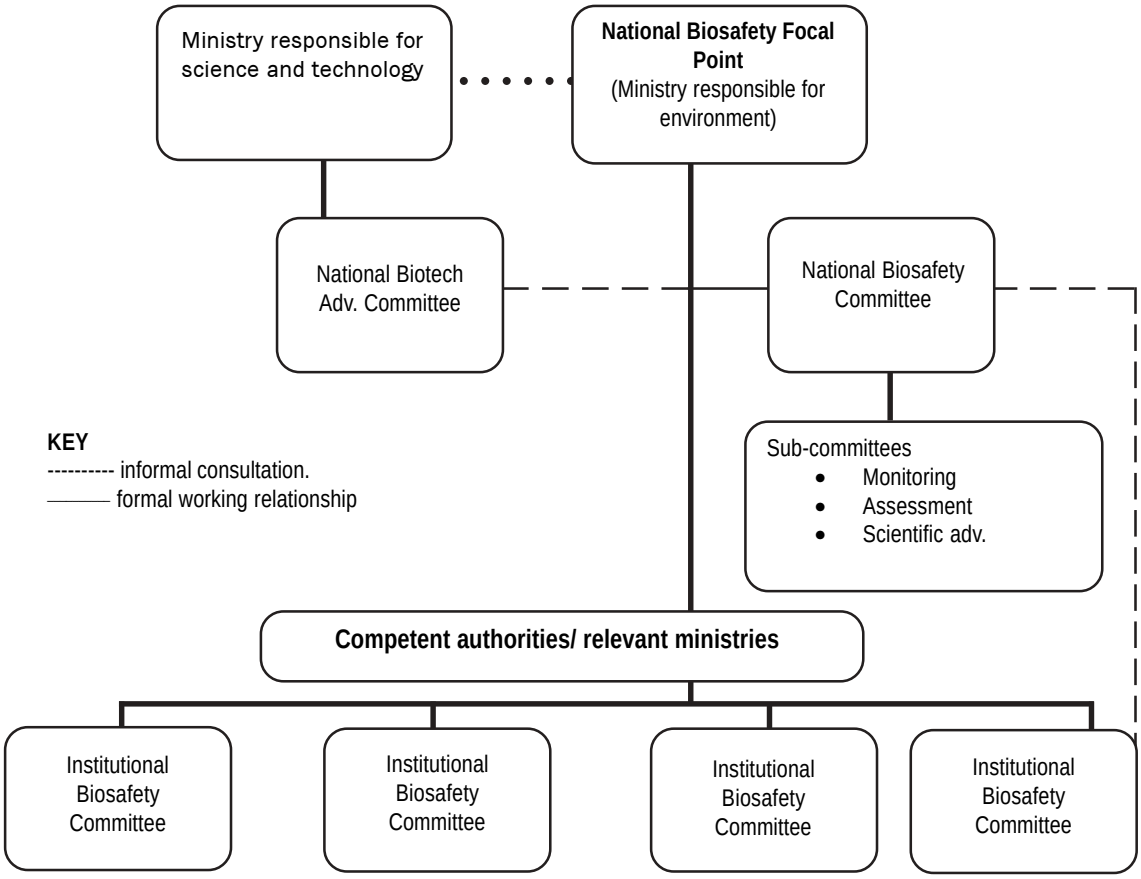

Figure 1. Biosafety institutional structure.

National Biosafety Focal Point (NBFP)

The NBFP should be the ministry responsible for environment. The roles and responsibilities among others are to:

- Review and approve biosafety applications for research, confined release, pre-commercial release or placing on the market, including to receive and forward applications to the competent authorities.
- Establish contacts and linkages with national, regional and international agencies/institutions.
- Establish a database to facilitate collection, storage, retrieval and dissemination of information relevant to biosafety.
- Decide whether to accept or reject an application based on the advice of the competent authority and NBC and to notify the applicant about the results of the review.
- Declare through the Biosafety Clearing-House that a GMO or product thereof intended as

food or feed or for processing (FFP) may be subjected to a full risk assessment.
- Maintain and make available to the public on request, a database on GMO or product thereof intended for direct use as food or feed, or for processing.
- Designate inspectors and undertake inspection and other control measures to ensure compliance with the Biosafety Regulations.
- Establish a list of GMOs and products thereof to be regulated in Tanzania. The list will be reviewed periodically.

The decision making structure of the NBFP is illustrated in Figure 2.

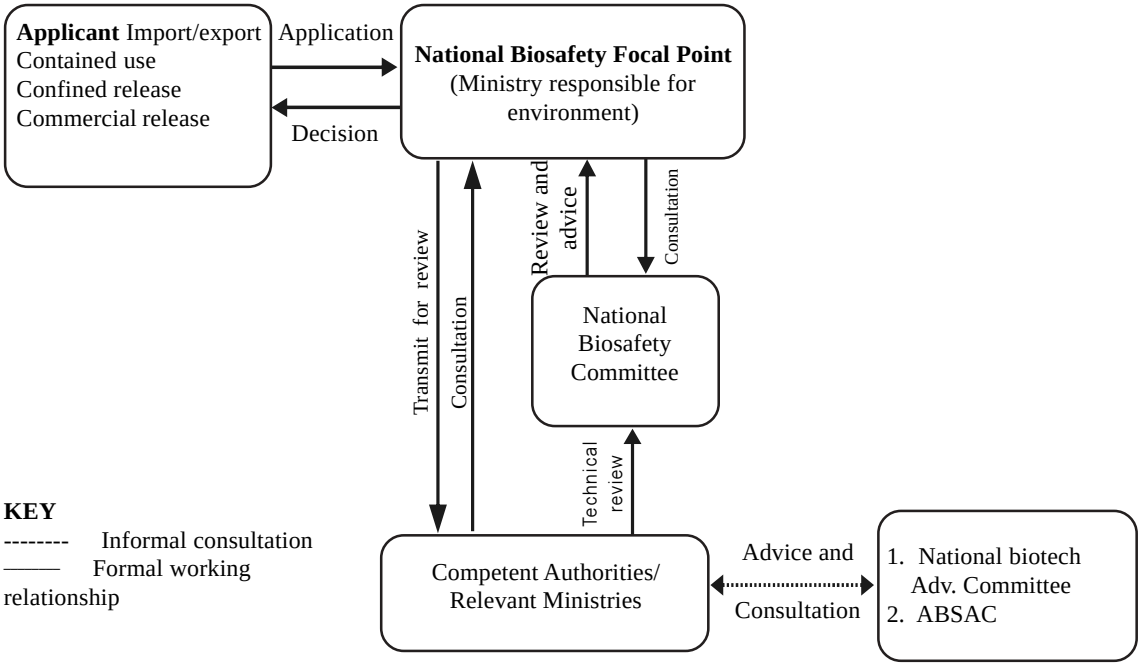

Figure 2. Decision making structure of the National Biosafety Focal Point (NBFP).

The NBFP should designate the National Biosafety Scientific Advisory Sub-Committee comprising of a multidisciplinary team of experts in the field of biotechnology and biosafety. The National Biosafety Scientific Advisory Sub-Committee should be answerable to the NBC. It shall advise the NBC on scientific biosafety concerns. Such functions should include the review and ascertaining of the suitability of both physical and biological containment, confinement and control procedures appropriate at the level of assessed risk involved in relevant research, development and application activities.

National Biosafety Committee (NBC)

The NBC should comprise representatives from governmental and non-governmental organisations and the private sector that are relevant to the issues of biotechnology and biosafety.

The NBC should have the following functions:
- Review relevant applications
- Advise on policies, legislation and other policy instruments
- Undertake study and evaluation of biotechnology research and control and minimise the concomitant risks and hazards associated with the deliberate release of GMOs in the environment and to advise the NBFP and competent authorities
- To ensure that adequate testing of GMOs developed elsewhere has been performed in the country of origin before it is introduced in a local trial programme

- To review biosafety regulations and guidelines from time to time as necessary
- To facilitate the undertaking of socio-economic impact assessment and to initiate scientific and technical review on biosafety applications.

Relevant ministries/competent authorities

The NBFP shall designate competent authorities which shall be responsible for following up, supervising and controlling the implementation of the biosafety regulations, i.e. perform the following roles and responsibilities:

- Review relevant applications or proposals for development, introduction, import, export, transit, contained use, release or placing on the market.
- Review, make or have made risk assessments of GMOs or products thereof. When the GMO or products thereof is to be imported, the cost will be borne by the exporter.
- Advise the NBFP.
- Designate inspectors and undertake inspection and other control measures to ensure compliance with the Biosafety Regulations.
- Undertake assessment of socio-economic impacts and ethical and cultural impacts.

Institutional Biosafety Committee (IBC)

Institutions that are involved in the import, export, handling, contained use, release or placing on the market of GMOs or products of GMOs should establish IBCs to institute and control safety mechanisms and approval procedures at the institutional level. These committees should have multidisciplinary teams whose roles and responsibilities shall include to:

- Review the containment and confinement levels required by the Guidelines for the proposed research
- Hold discussions on the comparative ecological, economic and social impacts of alternative approaches to attain the purpose/objectives of the proposed GMO and other services
- Report immediately to the relevant ministries/competent authorities and appropriate official in the concerned organisation, any significant GMO activities, problems with or violations of the regulations and any significant research related accidents and illness.

Genetically modified (engineered) crops

Currently, there are no GMO products or GMO crops grown in the country either for research or commercial purposes. However, it was indicated that Tropical Pesticides Research Institute (TPRI) in collaboration with ICIPE are planning to introduce B*t*-cotton in the Southern Regions of Tanzania for research purposes. Other institutions such as Mikocheni Agricultural Research Institute (MARI), Animal Diseases Research Institute (ADRI), Sokoine University of Agriculture (SUA) are also ready to undertake research on GMOs if they are required to collaborate with any other institutions at regional or international level. However, it is very important to all applicants who wish to import or export GMOs for research or commercial purposes to follow procedures as stated in the Environmental Management Act 2004 that operationalise Biosafety Guidelines, Biosafety Regulations and Biosafety Framework.

Import of GMOs

Application procedure

Any person who wishes to carry out an import, or transit, or deliberate release, or contained use of, or placing on the market, a GMO or product thereof or intended for direct use as food or feed, or for processing shall submit an application in writing to NBFP. The applicant must have a collaborating partner, and institution recognised by NBFP and the competent authorities. The application form must be completed and submitted by regular mail or courier delivery to the

NBFP.

a) No person shall import, transit, carry out the contained use of, or release of, or place on the market, a GMO or a product thereof without an advance informed agreement (AIA) or the explicit written approval of the NBFP.
b) The application shall include:
    i) The information specified in Annex III of the National Biosafety Guidelines for Tanzania and any other information as may be prescribed by the competent authority
    ii) Assessment report on risks that may be posed by the GMO or product thereof on human and animal health, biological diversity and the environment, including the consequences of unintentional release
    iii) Information from previous or current release of the GMO or product thereof in the country or in any other country
    iv) Information on previous approvals or rejections of the GMO or product thereof by any other country
    v) If the request for approval is for research and development, the recommendations of the IBC
    vi) A clear and sequential description of the steps to be taken in the implementation of the project, the monitoring and evaluation that will be made at the end of each step, and the method of disposing of any waste
    vii) The place where and the purpose for which the GMO or product thereof is planned to be developed, used, kept, released or marketed, including detailed instructions for use and a proposed labelling and packaging scheme
    viii) The applicant shall submit a declaration confirming that the information provided is correct including, where appropriate, an undertaking from the originator of such information affirming its accuracy and completeness.
c) Application should respond to all items listed in the course of action for transboundary movement of GMOs. Application(s) should be submitted four (4) months before importation.
d) If portions of the application contain trade secrets or confidential business information (CBI), each page of the application containing such information should be marked 'Commercial-in-Confidence' or 'CIC Copy' by the notifier.

Inspection and enforcement

In accordance with the Environmental Management Act 2004 and the draft Biosafety Regulations, the Inspectorate of Competent Authorities shall perform inspection and supervision. The authorised party shall pay inspection fees that will be established by the competent authorities. Inspectors have the authority to inspect sites containing GMOs like field trial sites etc. for compliance with terms and conditions of authorisation. Inspectors also have the authority to inspect contained facilities that may be used for research or storage of GMOs. Competences for the inspection supervision will be specified in permits or approvals.

The proposed system has flexibility to appoint different competent inspectorates on a case-by-case basis. Since the competent bodies already have other mandates, separation of the competences will have to be formalised for GMO regulation.

If an inspector during the performance of work or based on a notification establishes that because of unfulfilled required conditions and requirements, the environment, human and animal health or socio-economic and ethical issues are at risk, she/he shall order the following measures:

(a) Prohibit contained use, deliberate release of a GMO into the environment or placing a product on the market
(b) Order the temporary suspension of contained use, the deliberate release of GMOs into the environment or placing a product on the market

(c) Order the rectifying of established irregularities within a time limit that the inspector specifies
(d) Order remediation and other measures to rectify or reduce the consequences of adverse effect that have occurred because of GMO management.

For the inspectors to discharge their duties effectively, it is necessary to:
a) Carry out a capacity needs assessment
b) Develop and implement capacity building programmes including training, infrastructure, equipment and tools.

Monitoring

The purpose of monitoring and evaluation is to gather data concerning the GMOs in order to assess the extent to which transgenics have affected biological diversity, environment and human and animal health. When referring to the environment, the main focus is on confined field trials and commercial release of GMOs. Thus, monitoring would determine effects, which could be categorised as severe, moderate, low, negligible or no harm. In the case of plants, monitoring should be undertaken to determine the level of horizontal gene transfer and to develop a monitoring and evaluation prospectus. Monitoring of the GMOs should be undertaken at different levels. The objective of monitoring plan is to:
a) Confirm that any assumption regarding the occurrence and impact of potential adverse effects of the GMO or its use in the environmental risk assessment are correct
b) Identify the occurrence of adverse effects of the GMO or its use on human and animal health or the environment which were not anticipated in the environmental risk assessment.

Types of monitoring

For the purpose of this NBF, monitoring is used to gather additional scientific data to assist the assessment of risk and decision-making. Monitoring is carried out for specific reasons and at specific times in the development of GMOs. The various types of monitoring that may be used by monitoring agencies are:
1. Case-specific monitoring
2. General surveillance monitoring (see earlier comment)
3. Voluntary monitoring
4. Monitoring by applicants
5. Experimentation
6. Tracking
7. Surveillance.

The competent authorities should implement monitoring of post-emergence following post-emergency time periods established. Post-release/harvesting monitoring is necessary where the risk assessment determines that the continuous presence of the released GMO presents risk of harm. Post-release monitoring will need to concentrate on confirming the removal of the released GMOs. Where appropriate, monitoring should concentrate on detecting and controlling any volunteer GMOs arising form the release. In some cases there may be uncertainty regarding the risk of harm from continued presence of an organism, especially over the long term. Post-release monitoring should then be designed to provide data to enable the uncertainty to be resolved. In case of plants, factors to be taken into account include:
i) Seasonal effects, such as flowering and likely germination times
ii) Post-trial treatment of the release site
iii) Longevity of seed or tubers in soil.

Reporting requirements

The authorised party should comply with the reporting format set in the terms and conditions of

authorisation. However, for every GMO there is a need to determine when to undertake monitoring and when to evaluate the work. The same process would explicitly identify who would undertake the monitoring and evaluation, and who would receive the reports.

Public awareness, education and participation

Tanzania has experienced lively public debates on a wide range of issues related to science and technology but not on GMOs. However, the debates on GMOs coincided with growing public awareness on societal issues such as environment and sustainable development. This reflects the fact that involvement of the general public is crucial in the formulation and implementation of national policies.

The level of public awareness on biotechnology and biosafety in the country is extremely low, even amongst the scientific community. Possible explanations for low awareness include:

a) Recent nature of GMO technology
b) Limited knowledge on GMO technology at all levels
c) Limited access to relevant publications, the internet and other information sources
d) Low level of awareness by the general public on benefits and risks associated with GMOs.

Why public awareness, education and participation?

As biotechnology develops rapidly, more and more GMOs and their products will be released into the environment and may thus pose potential risks to the environment and human and animal health. A proper mechanism should be established to create awareness and enable the public to participate in implementation of the biosafety measures. Awareness and participation are important to:

a) Build consensus on issues that affect people directly or indirectly
b) Build a sense of ownership and collective responsibility
c) Promote sustainable development
d) Promote smooth implementation of the decisions
e) Build transparency and accountability
f) Provide balanced information in terms of pros and cons
g) Harmonise institutions that provide awareness activities.

The competent authorities and other agencies, in making biosafety decisions, should promote and facilitate public awareness, education, and participation concerning the research, development, handling, transboundary movement, transport, use, transfer, release and management of GMOs. They should incorporate into their respective administrative issuances and processes best practices and mechanisms on public awareness and participation.

Right of access to information

The right of the public and the relevant stakeholders to information about applications for the research, development, handling, transboundary movement, transport, use, transfer, release and management of GMOs shall be respected. Concerned government departments and agencies should, subject to reasonable limitations, protect confidential information as provided in the proposed regulations, and should disclose all information on such applications in a prompt and timely manner.

Confidential business information (CBI): All ministries agencies and institutions handling GMO applications shall ensure that they have procedures to protect confidential business information.

In no case shall the following information be considered confidential:

- The name and address of the applicant.
- A general description of the GMOs.

- A summary of the scientific risk assessment conducted by the applicant.
- Where applicable, any methods and plans for emergency response.

For information claimed as CBI, the applicant must provide written justification.

Information on biosafety decisions: The public and relevant stakeholders should have access to all biosafety decisions approving or denying applications for the research, development, handling, transboundary movement, transport, use, transfer, release and management of GMOs. Such decisions need to summarise the application; the results of the scientific risk assessment and the evaluation of socio-economic risks; the public participation process followed; and the basis for approval or denial of the application.

Enabling environment

An enabling environment for public awareness, education and participation is a requirement to ensure smooth implementation of the National Biosafety Framework. There is a need for:

a) Capacity building
b) Establishment and implementation of appropriate programmes and policy guidelines on participatory approaches
c) Networking among stakeholders
d) Regional/sub-regional and global cooperation
e) Effective participation at all levels, public, government and private.

Challenges and way forward

Arguably, to conduct work of a highly technical nature such as modern biotechnology in a manner that is safe and which contributes to sustainable economic development, caution has to be exercised not to perpetuate economic dependency without the necessary local capacity to deal with it.

In that respect, perhaps the key question is, are we ready? Certainly, this review has confirmed the findings from previous studies that, like many developing countries, Tanzania is still under equipped in terms of technical capacity to conduct biotechnology and biosafety R&D while safeguarding biodiversity, human health and the environment taking into account socio-economic, cultural and ethical concerns. Currently, the available resources and capacity are severely limited and donor-dependent.

The issue of market for GMO is very crucial in connection to traditional export. Currently, most of the exported crops are non-genetically modified crops and marketed in the EU and in other countries. Potential market of GMOs is a key prerequisite for Tanzania before commercialisation. Certainly, modern biotechnology brings new challenges for policy and regulatory frameworks in the future. Close cooperation on biotechnology, biosafety issues and trade at national, regional and international levels is very crucial and should be encouraged.

The potential benefits and challenges of agricultural animal biotechnology to pastoralists

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Abstract
The livelihoods of pastoralists revolve around their indigenous livestock. Combining high production with disease resistance using genetic engineering is a biotechnological intervention hailed by some as a promising avenue to mitigate food insecurity and poverty. Considerable human and financial resources have already been devoted to exploring this option. However, the challenges are enormous. It is unlikely that such livestock would survive in the harsh ecosystems where pastoralists live and that it would meet their diverse and breed specific social and economic requirements. Furthermore, the questions of intellectual property rights over genetically engineered livestock need to be resolved otherwise there is the danger of the genetic traits of indigenous livestock being pirated by industrial breeders. The loss of biodiversity and of pastoralist livelihoods might also be possible consequences. Instead of genetically engineered livestock, pastoralists need recognition of their livestock breeds and management skills, the right to their own breeding decisions and improved services to enhance their livelihood and support their breeds.

Key words: biotechnology, livestock, pastoralists, livelihoods, rights, food

Introduction
Occupying arid to dry humid ecosystems that inadequately support rainfed crop production, pastoralists derive their livelihood from keeping uniquely adapted livestock that they manage with their own indigenous knowledge. Most pastoralists are nomadic, with their patterns of movement depending on the season and other factors such as disease outbreaks, the security situation, pasture and water availability, drought and markets (Sanford 1983). Pastoralists' livelihoods are intricately linked to specific species and breeds that provide them not only with food (meat, milk, blood and milk products including butter, cheese etc.) and raw materials (including hides, fur and wool) but also play an in important role in certain rituals, recreational activities and in preserving the dignity of the owners. While pastoralists mainly keep their animals for subsistence, they often sell some of their livestock and livestock products at nearby markets. Thus they also make significant contributions to the gross domestic product (GDP) of their respective countries. At the same time, pastoralists are vulnerable to animal epidemics, unreliable rainfall and frequent droughts leading to low animal and crop productivity, stock theft, inadequate service provision, poor markets for livestock and livestock products, lack of opportunity for adding value to livestock and specialty livestock products, and absence of supportive policies for them. As a result many pastoralists are poor.
In developing countries more than 70% of total poverty is found in the rural areas and although these are the locus of food production, this is also where hunger is concentrated (Dixon et al. 2001).

While the global number of pastoralists is up for debate, there are an estimated 140 million of them in Africa (Dixon et al. 2001) alone where they live in the Sahara, the Sahel, the Horn of

Africa, East Africa and parts of Central and Southern Africa. Since they comprise a significant proportion of Africa's poor livestock keepers, research and development interventions that claim to have the goal of poverty alleviation should take the needs and aspirations of this diverse but distinct group of livestock keepers into account. This paper will examine the potential and challenges for advanced animal biotechnological research to make a positive impact on the livelihoods of pastoralists. It will focus especially on the potential for genetic improvement of pastoralist livestock, keeping in mind that the breeding goals of pastoralists are multifaceted (Köhler-Rollefson 2000). These goals do not only entail productivity 9large body size/weight, much milk, meat, blood etc.) but also encompass other aspects, such as the taste of meat, blood, milk and milk products, agreeable temperament, preferred fur colour, religious and cultural requirements, disease and parasite resistance, good mothering instincts, ability to walk long distances and ability to survive natural calamities including long droughts, extreme cold/heat and flooding.

The potential benefits of agricultural animal biotechnology to pastoralists

Pastoralists would appreciate improved economic returns from their livestock through biotechnology that increased the size and growth rates of their livestock and upgraded the quality of their livestock products quality including food, hides, fur and wool (FAO 2000a).

In the animal health sector, it would be appreciated if biotechnologically developed diagnostics and therapy that could make it possible to rapidly and accurately identify disease-causing agents, besides providing sustainable curative services and carrying out disease control programmes. This would boost the productivity of pastoralist herds. The pastoralists would benefit from vaccines against livestock diseases and could even control parasitic infections (FAO 2000a; Dixon et al. 2001; NARO 2002).

Reproductive biotechnologies (transgenics, embryo transfer and artificial insemination) are said to hold the promise of increasing reproductive efficiency (FAO 2000a; NARO 2002) which would generate livestock with the traits that pastoralists desire.

The challenges of animal biotechnology to pastoralists

Biological challenges

There is a trade-off between production traits on one hand and disease and drought resistance on the other. Animals that are highly productive are more sensitive to stresses. So it is unlikely that agricultural biotechnology could produce animals that survive the often harsh environments of pastoralists and that meet their many breed specific economic and socio-cultural requirements.

Financial challenges

Keeping in mind the often low economic returns of pastoralists and the high cost of agricultural animal biotechnologies, such research is unlikely to be cost-effective. Expensive equipment, facilities and experts are required to carry out biotechnological processes. It can be anticipated that the costs of these technologies would outweigh the intended benefits.

Biotechnology seems to be driven by industries and has been targeted at farmers in developed countries (FAO 2000b) and a small number of wealthy farmers in the developing world. It would be an enormous task for the technology to meet all the diverse breeding goals of indigenous pastoralists.

Challenges of equity and intellectual property rights

Over many centuries of selection by the forces of nature, pastoralists have developed breeds that are optimally adapted to their specific environments. In particular, pastoralists already have worm-resistant breeds, such as the Red Maasai sheep, so research on identifying the genetic basis of this trait benefits exclusively the farmers in developed countries and cannot be considered to be in the interest of poverty-alleviation. Furthermore, it is a general procedure that for any genomic discovery that intellectual property protection is automatically sought to secure future financial returns. It is well known that a small number of companies from the developed countries dominate the biotechnology sector and that the acquisition of patents is the driving factor behind the genomics research by these companies. This is leading to increasing control of the food sector by a small number of companies.

However, the rights of pastoralists over the genetic resources that they have nurtured for generations using their indigenous knowledge are currently not protected. In the interest of fairness and equity, these should also be secured and rendered inalienable rights.

Precedents for biopiracy are known from the plant sector. A case in point is an American company that was granted a patent on the medicinal value of the neem plant, *Azadirachta indica* (native to India), used by traditional indigenous communities for many centuries (FAO 2001). Similarly, medicinal products derived from Brazil's guarana plant, *Paulinia cupania*, have been patented in the United States (Science and Development Network 2005). It can only be expected that similar incidents will happen with indigenous livestock.

Technical challenges

In agricultural animal biotechnology, production of transgenic agricultural mammals is difficult, inefficient and expensive because of their low productive rate and internal fertilisation and development (FAO 2000a; FAO-WHO 2004; FAO 2005).

Food safety challenges

Food related hazards associated with genetically modified animals are diverse, e.g. the morphological and metabolic/physiological abnormalities that may occur (FAO-WHO 2004).
The gene flow from genetically modified animals to non-genetically modified individuals, and resulting in the production of fertile offspring may cause genetic pollution (FAO 2002), as animals with queer characteristics (morphological, physiological, behavioural, diseases etc.), and hence non-productive to the pastoralists, may be inadvertently introduced into the environment.

Trade and marketing challenges

The production of livestock through agricultural animal biotechnology might hinder trade in livestock by pastoralists, as some countries do not permit genetically modified animals and/or their products into their territory (FAO 2002). Similarly, the free movement of pastoralists across regional and international borders in search of pasture and water would be jeopardised by these restrictions.

Genetically modified livestock would also not be compatible with the standards set in organic agricultural animal production, thus destroying the possibility of accessing lucrative markets and the associated income opportunity for pastoralists (FAO 2002).

Biodiversity challenges

The introduction of livestock produced through biotechnology into pastoralists' areas might cause biodiversity erosion as only very few breeds with similar genomes would be used for production.

Discussion, recommendations and conclusion

The world should recognise the unique breeds owned by pastoralists and legally confer upon the livestock keepers inalienable rights over their breeds and the particular genes and/or DNA sequences that the animals contain. Otherwise there is danger that they might lose their treasured well-adapted breeds to industrial livestock breeders. Furthermore, pastoralist community breeding systems that act as custodians of desirable animal genetic resources need to be supported and sustained through appropriate mechanisms by their national governments and the international community.

A legal framework for sharing benefits from animal biotechnology should be formulated in cases where the genetic material from indigenous livestock is used commercially.

Comprehensive research is necessary to determine how best to improve the production potential of the pastoralist livestock systems and to design policies that improve pastoralist livelihoods and conserve their breeds.

Pastoralists need improved and sustainable social and other service delivery systems from their national governments, private agencies and the international donor community that are adjusted to their mobile livelihoods. These should include information, training, infrastructure supportive to their livelihoods and indigenous livestock production. It is not a secret that service delivery in most developing countries targets only sedentary communities.

Some pastoralist areas regularly suffer from lack of protection/law enforcement which hinders livestock production. This is an issue that needs to be more urgently addressed than biotechnology for food security.

Government land policies should accommodate the land rights of the pastoralists and indeed protect their land from undue encroachment by other exploitative land users, including 'investors' (Loquang 2003). This would help them maintain the basis for their livelihood. Myths perpetrated by some 'experts' that pastoralism is not economically viable should be dispelled since it is explicit that pastoralism is the only time proven system for conserving the dry environment in which they live because of their careful movement to diverse pastures while preserving others for later use (Oxfam GB 2004).

The pastoralists need fair markets for their livestock and livestock products. Unjustly low market prices greatly contribute to poverty and food insecurity among pastoralists. Furthermore, pastoralists should be encouraged to explore new avenues for adding value to their products in efforts to alleviate poverty including handicrafts (from livestock horns, hides, wool, fur and bones), livestock food products and ecotourism (Köhler-Rollefson 2000; Köhler-Rollefson 2004a).

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Partnerships do improve smallholder livestock systems: Experience from Limpopo and North West provinces in South Africa

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Abstract
A profit thinking framework was used to select a multidisciplinary farmer support team (FST) to implement a focused participatory approach among livestock farmers in the Limpopo and North Western provinces of South Africa. Farmers were subsequently organised into teams, which meet once in 30 days to identify needs, set objectives, take actions with support from the FST and report every 90 days to measure progress. These meetings are also used to identify new opportunities for future actions.

The results show that farmers recognise that profit maximisation should be the main focus of a beef enterprise with all other activities oriented towards this goal. Farmers were more eager to take actions that improved profit. Accessing new markets, learning pricing techniques and addressing issues such as transport costs, improved prices for beef. The FSTs obtained an in-depth understanding of technical challenges in farmers' operations and assisted farmers to implement appropriate solutions. The results showed that partnerships involving a dynamic mix of scientific knowledge and socio-economic conditions assist researchers and extension workers to considerably improve the performance of emerging beef farmers through participatory methods.

Key words: partnerships, livestock systems, smallholders, livelihoods improvement

Introduction
Conventional farmer development systems assume a top-down approach where extension officers provide logistical support to disseminate technologies to farmers (Kaimowitz 1991). This approach has proved to be both unsustainable and often irrelevant to the needs of farmers (Rivera 1993). Focus is now being placed on strategies to strengthen linkages between research and extension in developing countries (Röling 1990). However, there is growing evidence that alternative methods also have certain disadvantages, especially for small-scale farmers (Rivera 1991). The sustainable alternative would be to adopt a participatory approach that recognises the complex conditions experienced by farmers and is able to demonstrate the benefits of changed behaviour (Gibson 1977; Rogers 1983; Whale 1984). This also necessitates a paradigm shift from a technically-based support system to a system that responds to key issues (Baker and Verma 1993).

The challenge in South Africa is that emerging beef producers perform below potential both in terms of throughput and profit while interventions in current beef systems focus on training in production techniques with little emphasis on business development and the capacity to continuously improve and innovate. Using an outcomes approach to emerging beef business

development, a five-year multi-disciplinary Beef Profit Partnerships (BPP) programme was implemented in 2002 to develop a farmer support method that could enable the South African emerging beef producers to achieve sustained improvement of profit. This paper presents the results of BPP and highlights the impact of a participatory research and development (R&D) approach on the performance of an emerging beef business.

Methods

Eighteen livestock production and marketing specialists, (five from Limpopo, nine from North West and four from the Agricultural Research Council (ARC)) participated in a five-day capacity building workshop on participatory R&D processes and tools in July 2001 and March 2002. Two farmer support teams (FSTs), one in each province were formed to facilitate the formation of a network of farmer teams. Each team consisted of not more than 20 individuals. The focus of each team member was to achieve improved profit. A profit thinking framework was used to enhance the focus of the main drivers of profit (Figure 1).

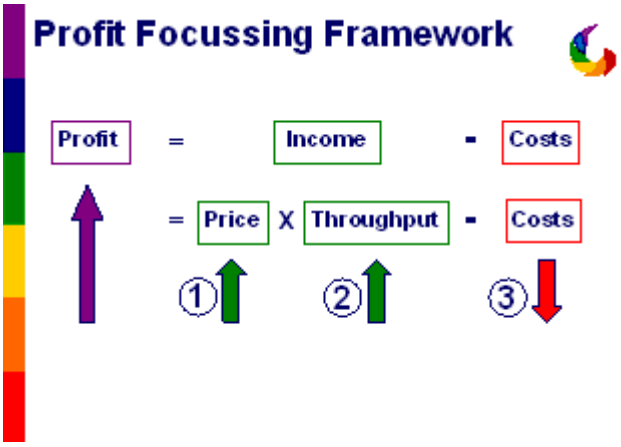

Figure 1. Profit thinking framework for sustainable beef business.

Farmer teams conducted regular focus sessions to do situation analysis, impact analysis and action design, action implementation, performance assessment and creation and synthesis of new opportunities for impact on profit (Figure 2). This spiral of steps was conducted over 30 to 90 days. Responsibilities were shared both by farmers and FST members in partnership. Individual and team action taken and results achieved were reported and supported during the focus session. The reporting involved the computation of measurements such as market prices and herd performance.

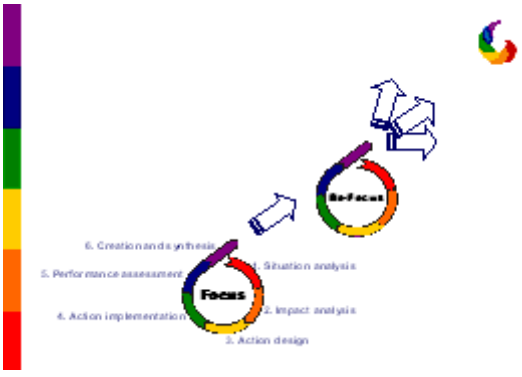

Figure 2. The continuous improvement and innovation process.

Results

Teams

The project leaders agreed beforehand with farmer support teams (consisting of researcher and extension officers) on the number of farmer teams (groups of farmers in one location focusing on beef) that had to be established and participate in the project. The first teams were formed in April 2002. By March 2003 there were 14 farmer teams (Figure 3) consisting of a total of 290 individuals (Figure 4). The expansion of the teams was also determined by extension officers' interest where they joined existing FSTs and assisted by including their current customers in the programme. By March 2003, ten extension officers had joined the FSTs and performed functions as other members.

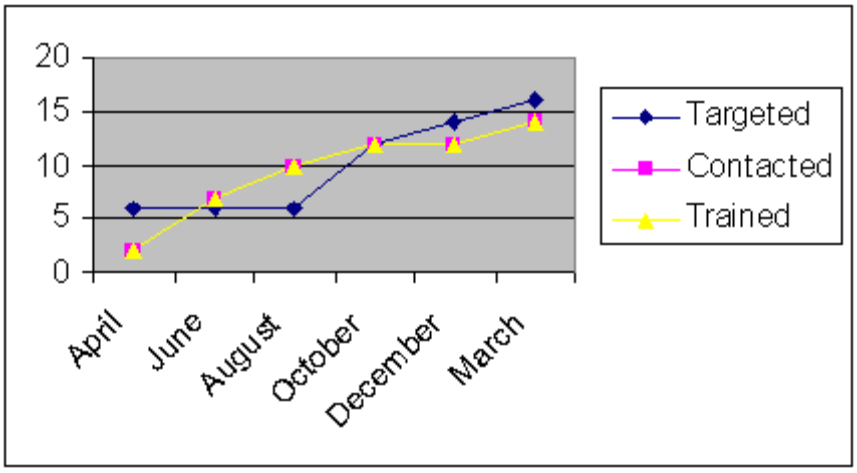

Figure 3. Farmer teams participating in the programme.

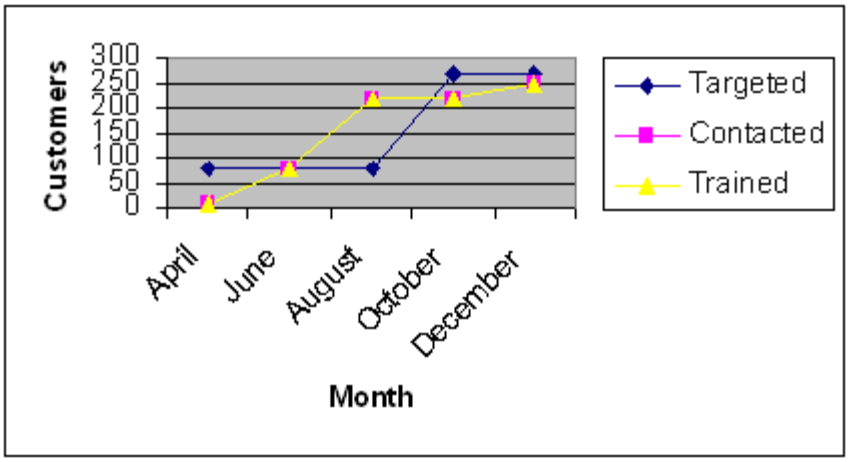

Figure 4. The number of customers retained in the programme.

The action design process

First focus sessions aimed at enabling farmers to determine the focus that would have the greatest impact on their business and identifying the actions that would have the highest impact on profit.

In contrast to the notion that traditional farmers keep cattle for non-economic reasons, the common output at the first sessions was that farmers keep cattle to make profit.

It was found that farmers only use three market outlets with diverse price structures (Figure 5). These outlets did not use appropriate quality assurance equipment such as weighing scales for live animals, and less formal outlets were less economic than formal auctions. Nevertheless, farmers did not realise expected incomes because of a lack of information skills and tools on pricing.

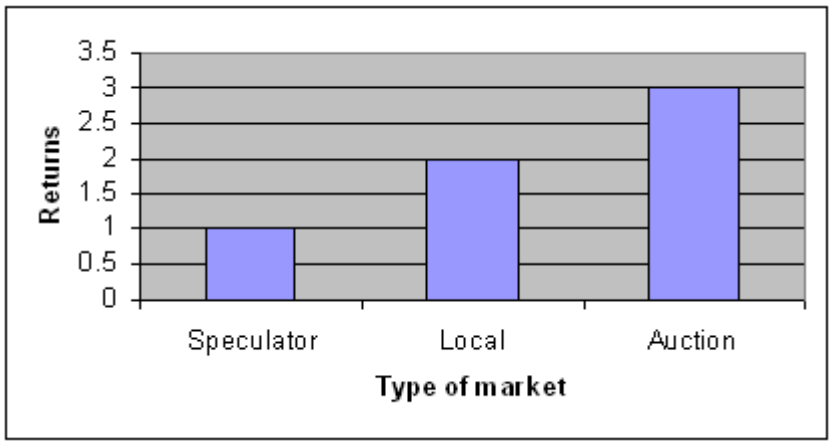

Figure 5. Types of market outlets commonly used by programme customers.

Farmer innovation

Participating farmers took several initiatives to address challenges as part of the action designs agreed upon at focus sessions. In one farmer team at Khomela village, farmers identified a loading ramp as a high impact opportunity for improving access to the market. They built the loading ramp using local materials such as rock and wood, and were therefore able sell their cattle directly to a local feedlot from the village.

In another farmer team at Mmakgatle village, farmers identified the erection of an auction kraal as a high impact opportunity to improve price and reduce marketing costs. After building the kraal, the farmers were able to hold monthly auction sales that included farmers from neighbouring villages.

Another innovation came from a farmer team on Kromspuit farm which had experienced an extremely low calving rate during 2002 (Figure 6). The team identified testing for reproductive diseases as a high impact opportunity to improve throughput. This has led to the introduction of rapid test kits for Brucellosis, which are currently used widely in the area.

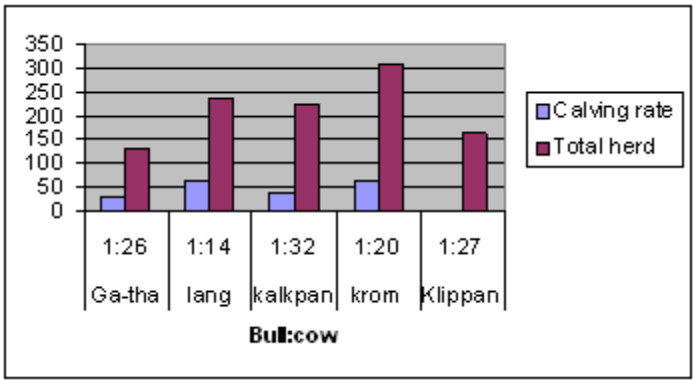

Figure 6. Herd compositions among customers.

In Kuruman, farmers identified communal transport as a high impact opportunity to reduce costs, which, upon implementation, significantly reduced marketing costs as indicated in Figure 7.

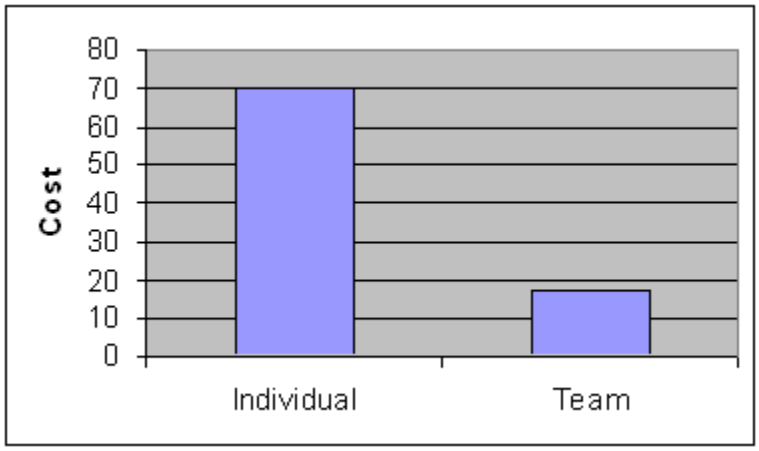

Figure 7. The effect of team marketing on transport costs.

Conclusions

The use of partnerships is a real alternative to conventional top-down approaches because it facilitates farmer centred programmes which enable both researchers and extension workers to participate in a learning process with farmers to identify and address real needs. This has facilitated the use of common conceptual frameworks for profit and to make informed decisions and take actions on different key drivers such as throughput, marketing, pricing and cost. The capacity of farmers to market, develop and monitor key performance indicators (KPIs) such as change in profit, change in price, change in calving rate is gradually improving with a noticeable impact on profits. It is therefore hoped that partners will agree on using a profit-thinking framework to make informed decisions or take any action towards change in the business.

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Issues and implications for livestock development policies in eastern and southern Africa

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Abstract
Empirical studies and reviews from eastern (Kenya) and southern (South Africa) Africa have been used to construct a policy framework to guide livestock development in these two regions. Five overarching, integrated elements have been identified. These include food production and security, capacity strengthening for livestock research, livestock and the environment, health and genetics and marketing of livestock and livestock products. The framework that emerges is complex due to the dramatically increasing demand for livestock products and, as a result, the far-reaching changes in the structure of smallholder livestock production. This framework emphasises that many of the policy challenges remain pertinent and important. Significant progress has been made to address some of these challenges, but the fact remains that these macro-policy concerns need to be addressed. This translates into complex, multi-disciplinary and multi-sectoral policy implications for governments, and increasingly, for the private sector.

Key words: livestock, smallholder development, policy framework

Introduction
Sub-Saharan Africa has often been regarded in the development field as a homogenous entity with common problems that require similar strategies. Most countries in sub-Saharan Africa became independent in the early 1960s, but the process of developing agricultural strategies started much earlier. Agriculture plays a significant role in overall development strategies on a continent where, on average, agriculture accounts for 70% of employment, 40% of exports and 33% of gross domestic product (GDP) (Delgado 1997). Evidence from elsewhere in the world, and more particularly from elsewhere in Africa, overwhelmingly demonstrates that smallholder agriculture has been the principal economic driver in rural areas and that smallholder agricultural units have been far more productive over time than large-scale, commercial operations, based on output per unit of labour (Delgado 1997).

Livestock production systems play an important role in the agricultural economy of sub-Saharan Africa. Agriculture contributes between 4% and 5% to the GDP in South Africa, while it contributes 27% to the GDP in Kenya (Kajume and Muthee 1998; Stroebel 2001). Livestock and related products are the major contributors to these figures and there is considerable potential for improving these systems and further enhancing the contribution of livestock to food and livelihood security.

Materials and methods

The study areas
The Nzhelele Area is located in Ward 27 of the Makhado Municipality of the Vhembe District in the eastern part of the Limpopo Province, South Africa. This area was part of the former Venda homeland. It is located at 23°S latitude and 30°E longitude at an altitude of 903 m. The area is

close to the borders of Zimbabwe and Botswana. The population of the Makhado Municipality is estimated at 500,000 people, of whom approximately 11,300 reside in the Nzhelele Area (StatsSA 2003). The education level is very low, with more than 26% of the population having less than a primary education level (Standard Five/Grade Seven). Of the total labour force, 41% of the population is involved in formal agricultural activities. Average temperatures vary between 15˚C and 26˚C. The mean annual precipitation is 780 mm, of which 80% occurs during the summer months (October–March). Livestock and crop farming are the predominant forms of agriculture, practised by approximately 50% of the population in the area (Acheampong-Boateng et al. 2003). Smallholder farms are located throughout the Nzhelele Area, characterised by low levels of productivity and holdings of approximately 1.5 ha per farmer, although this figure varies greatly. Production is primarily for subsistence with little marketable surplus, a situation that farmers and government would like to change.

Baringo is one of the 14 districts in the Rift Valley Province of Kenya. It borders Turkana and Samburu districts to the north, Laikipia to the east, Nakuru and Kericho to the south and Uasin Gishu, Elgeyo Marakwet and Pokot to the west. The district is located between longitudes 35˚30' and 36˚30'E and between latitudes 0˚10'S and 1˚40'N. The Equator passes through the district at the southern tip at Mogotio town. The district covers an area of 10,949 km^2 (Kenyaweb 2004). It is estimated that Baringo District has a population of 242,000 people, with a high annual average growth rate of 3% (CBS and ILRI 2003). The range of people falling below the Kenyan poverty line of US$ 0.53 per day is between 29% and 73%, for a district mean of 46%. This variation is based on the presence of an irrigation scheme, and the irregular rainfall, negatively influencing the livelihood of a large part of the population in the area. The district, like the country, has a very youthful population, with 50% falling in the age category 0–14 years. There are approximately 72,000 households, with an average of 5 people per household. Baringo District has an arid to semi-arid climate, with variations depending on the topography. Rainfall varies between 600 mm to 1500 mm, with 50% reliability. Livestock production activities are found throughout the district, but predominantly in the upper and lower midlands (Kenyaweb 2004).

Data collection and sampling

A non-probability sampling method was used to select a sample of 189 homesteads for the survey in South Africa (Byerlee and Collinson 1984). The selection of the sample was purposive, as it was assumed that most of the homesteads in the selected villages were typical, based on findings of previous studies in the area. Methods of data collection included completion of a structured questionnaire, unstructured interviews and observation. In the case of the Nzhelele Area, key informant interviews, focus group discussions and homestead surveys were conducted. In Baringo District, key informant interviews and focus group discussions were held. Due to the general nature of the data collection in the Baringo District, key informant interviews were the only source of primary data; all the other data were collected from secondary sources. Interviews were organised based on the knowledge of the respondent of livestock systems and policy issues in Kenya. In addition, an experienced extension officer was recruited to provide detailed information on the Baringo District.

Results and discussion

For a detailed discussion of the history of policy development in the two countries, refer to Stroebel (2004).

Similarities and differences between eastern and southern Africa

The assessment of livestock production systems in eastern and southern Africa (with specific reference to Kenya and South Africa) has indicated a number of similarities and differences

between the two sub-regions. Initially, some description of these issues are pertinent as it permits a sharper focus on the nature of the sub-regions, the roles and contribution of livestock, the types of production systems, priorities for research and the strategies required to address the opportunities presented for improvement of smallholder livestock production systems. The major differences between the two sub-regions include:

- Incidence and levels of poverty (percentage of the population living below US$ 1 per day) are much greater in Kenya than in South Africa (50% and 24% respectively), which makes the challenge of poverty alleviation and food security more critical in Kenya (IFAD 2001).
- The main agro-ecological zones in South Africa vary between arid and subhumid, with the predominant area being subhumid, while those in Kenya are predominantly arid with semi-arid and subhumid areas (Blench et al. 2003). In both cases, the majority of the population live in sub-humid areas.
- Increasing human and animal population densities and greater pressures on available land in Kenya, make integrated natural resource management more complex than in South Africa. For instance, the population density in South Africa is approximately 36 persons per km^2, as opposed to approximately 54 persons per km^2 in Kenya (Bhushan 2002; StatsSA 2003).
- A larger area in South Africa (85%) is mainly suited for livestock production than in Kenya (25%) (Bhushan 2002; DoA 2003).
- Smallholder intensive dairy production is more advanced in Kenya (Waweru 1998).
- Landless urban and peri-urban production is more advanced in Kenya than in South Africa largely because there are more non-agricultural employment opportunities in South Africa.
- Systems integrating tree crops and ruminants are much more common in Kenya than in South Africa (Place et al. 2003).
- The size and diversity of animal populations are much greater in Kenya. Furthermore, the number of indigenous breeds within species is larger in Kenya than in South Africa (Rege 1998).
- Animal feed deficits are more critical in South Africa as a result of lower rainfall and temperature limitations (Kajume and Muthee 1998; DoA 2003).
- Feed resource availability varies as a major constraint to production in Kenya, while in South Africa it is consistently a main constraint (Kajume and Muthee 1998).
- The integration of wildlife and livestock is far more advanced in Kenya than in South Africa (Boyd et al. 1999).
- The marketing systems for smallholder farmers in Kenya and in South Africa are not conducive to trade, although it is better developed in Kenya than in South Africa (CTA 1998; Bailey et al. 1999).

The major similarities provide important linkages between the two sub-regions. These include:

- Both Kenya and South Africa are regarded as leaders in their respective sub-regions in terms of livestock production, smallholder development and regional agricultural research capacity.
- The lack of integration of farming system approaches and technology development and transfer in research is common to the two regions.
- Despite the interest in urban and peri-urban agriculture, this sector of the livestock industries, except for poultry, is relatively undeveloped in both countries.
- The integration of animals with annual cropping systems is common to both regions.
- There is limited use of improved forages in both regions.
- Both regions have inadequate socio-economic and policy research and training focusing on livestock.
- There is a need to strengthen the research capacity in the national agricultural research system (NARS) in both Kenya and South Africa.

Towards identifying elements for a livestock policy framework

Based on the previous analysis, the following elements and implications have been identified as core elements of an integrated policy framework for livestock development in sub-Saharan Africa, more specifically in southern and eastern Africa. Elements of this integrated policy framework are spatially represented in Figure 1.

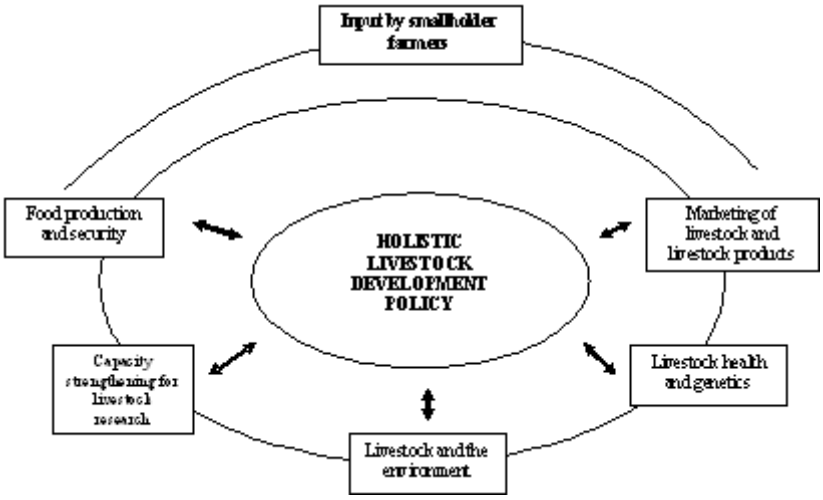

Figure 1. Spatial integration of the main policy issues affecting livestock production in sub-Saharan Africa Source: Adapted from CTA (1998); ILRI (2000).

Conclusion

The elements identified summarise the priority areas for policy research required to compile a holistic, development-oriented framework for livestock development in eastern and southern Africa. It is based on findings from the larger study of the socio-economic complexities of smallholder resource-poor ruminant livestock production systems (Stroebel, 2004) and has been integrated into existing issues and challenges identified by other researchers in previous research analysis as referred to elsewhere. The framework that emerges from these findings is clearly one of urgency and at the same time of complexity. The urgency stems from the dramatically increasing demand for livestock products and, as a result, the far-reaching changes in the structure of smallholder livestock production. The complexity stems from the use of livestock by smallholder agriculture for multiple needs, producing in the process multiple environmental benefits and costs. This framework emphasises that many of the policy challenges remain pertinent and important. Significant progress has been made to address some of these challenges, but the fact remains that the macro-policy concerns that have been identified need to be addressed. This translates into complex, multi-disciplinary and multi-sectoral policy implications for governments and, increasingly, for the private sector.

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Demand-led research, biotechnology and the poor: Issues from the livestock sector

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Abstract

Demand, is the often quoted link between biotechnology development and poverty alleviation. Nonetheless, there is often little evidence as to the exact influence of demand on the research processes. Therefore, the following paper explores the perceptions vs. the reality of demand-led processes using examples from the livestock sector. First, an aspect of the literature, i.e. community-based delivery systems was evaluated using the core issues raised in the wider literature on demand. Second, the perspectives of 190 stakeholders were catalogued and disaggregated. The example from the literature demonstrated that independent views were largely in the minority with the discourse dominated by actors from donor-funded projects and programmes. The exploration of researcher perspectives demonstrated that while the researchers themselves, generally did not account for farmer demands, neither did they themselves appear to be driving research agendas. Thus, on a wider paradigmatic level, the risk is that notions of demand will simply mask the traditional drivers of biotechnology research with little overall impact on the poor.

Introduction

The debate on biotechnology and poverty is frequently framed using arguments of demand, more specifically, the rising demand for agricultural products in the South (de Janvey et al. 1999; Graff et al. 2005; Rolan-Holst 2004):

> Because of population growth and rising incomes, the demand in the developing countries is predicted to increase by 59 per cent for cereals, 60 percent for roots and tubers, and 120 per cent for meat (Perstrup-Anderson cited in Graff et al. 2005).

As such, biotechnologies are increasingly viewed as key to meeting this demand, as Rolan-Holst et al. (2004) notes:

> …biotechnology…can greatly improve the living standards in the developing world. As the touchstone for a new generation of rural development, biotech can increase food output, nutritional quality, and rural employment more quickly than populations will grow, alleviating direct nutritional deficiency and increasing incomes for the world's poor…

Thus, it is argued that biotechnologies will enable the poor to participate in this 'revolution' and help to meet this increased demand for food products by consumers in the South. Consequently, by default, many of these technologies are now portrayed as being developed by research processes which are demand-led. Traditionally, within development, research has been conceived as being driven by the suppliers of research with little consideration for the needs of beneficiaries (Chambers 1983; Lloyd-Jones 2001; Mkandawire 2001). Much of the literature goes even further by pointing the problem squarely at Northern researchers and their institutes (Engelhard 2001; Bastista et al. 2001). Indeed, it is believed that research has failed to bring about sustainable

development largely due to 'the academic orientation of local research and the prevalence of Northern paradigms rather than being orientated towards concrete issues and problems confronting the South' (Engelhard 2001).

Conversely, demand-led research is believed to generate knowledge which is able to reverse these long-standing development polarities (Nair and Menon 2002). As the authors' state:

> Demand-led research can generate knowledge that will empower individuals and enable them to acquire the capabilities necessary to make informed choices on their own, without Northern intellectual inputs.

Hence, within the literature, demand-led research is frequently justified as a means of addressing the patronising and iniquitous relationship between Northern and Southern research partnerships (Bautista 2001; Velho et al. 2001; Engelhard 2001; Nair and Menon 2002).

Therefore, utilising the wider literature on demand as a backdrop, the following questions frame the forthcoming analysis:
1. Do Northern researchers hold a disproportionate sway over the direction of research?
2. Are Southern viewpoints undermined by a Northern hegemony?
3. Is there evidence that current practice has been informed by end-user or receptor demand?

To explore these questions further, the study first examined an example from the livestock literature on community animal healthcare programmes as such workers will likely be key entry points in the delivery of biotechnologies to the poor. Second, the drivers of demand, at the researcher level, are explicated via interviews with 190 animal health stakeholders. Notions of demand are explored in addition to perceptions regarding research priorities. Thus, the paper hopes to answer who is driving animal health research: the decision-makers, the poor or the researchers themselves? All of these issues are relevant to the current debate on poverty and biotechnologies.

Community animal healthcare programmes: Whose demand?

To explore the literature on community animal health workers (CAHW) programmes from a demand perspective, a total of 106 articles, both formal and the grey literature, were reviewed. For each document, the origin of the primary author was catalogued in addition to the overall orientation of the work, i.e. either broadly positive (in support of CAHWs) or negative (critical of the approach). The orientation was derived from the sum of the total arguments presented. As such, while some authors did offer caveats to their assessments, it was the preponderance of the arguments which determined the classification as positive or negative. The majority of the literature was produced by authors from the North (Table 1).

Table 1. The literature on community animal health workers.

Primary author	Positive	Negative	Total
Northern authors (n = 59)	54	5	59
Southern authors (n = 47)	36	11	47
Total	90	16	106

Northern authors were overwhelmingly positive whereas Southern authors were slightly more circumspect in their appraisal of community-based delivery systems (Table 1). However, when a breakdown of the institutions was undertaken the results were more revealing (Table 2).

Table 2. Institutional affiliation of primary author (n = 106).

Institutions	Positive	Negative	Total
Northern-funded projects	30	1	31
Northern NGOs	22	1	24
Northern consultants	7	1	8
Northern universities	9	4	12
Northern professional association	1	0	1
Donor	12	0	12
Sub-total	***81***	***7***	***88***
Southern university	1	2	3
Government	6	2	8

Results showed that the literature is dominated by Northern institutions (Table 2). Indeed, a single Northern-funded institution produced nearly one-third (30 papers) of the total literature reviewed, all of which had a positive orientation. NGOs and consultants were equally positive. Nevertheless, the donor-funded project and NGO authors were generally writing about the impact and uptake of projects implemented by these self-same institutions. Thus, there are few, non-project associated evaluations of CAHW programmes. Consultants, NGOs and donors with a stake in the projects are uniformly evaluating themselves. Thus, the literature on CAHW programmes demonstrates that a neutral mechanism for appraising development research is required.

Conversely, the Southern institutions registered more viewpoints that were negative. A recent report illustrated the open hostility to community-based animal healthcare programmes from veterinary professionals in Kenya (Young et al. 2003). Indeed, the Kenyan veterinarian community has resisted the formal acceptance of CAHW programmes for a number of years. Within the local veterinary community, there has been little natural support for legalising and legitimising these community workers as para-professionals. Indeed, it appears that there has been widespread donor leverage to force the government to accept such projects (Young et al. 2003). As the authors note:

DFID, the EU and OAU-IBAR started to put pressure on the government to support CAHW schemes in the mid-1990s. The EU and DFID supported some of the early CAHW projects being developed by ITDG in Kenya, and the EU as a major donor to KVAPS [Kenya Veterinary Associate Privatisation Scheme], became more directly involved in veterinary service policy issues in the early 1990s.

Hence, the question in this case is: whose demand is being reflected? It is clear that while CAHW programmes are touted as participatory and demand-led many end-users have a measured hostility. Equally, it appears that the evidence to support arguments for community-based animal healthcare providers is owned, almost exclusively, by Northern-funded institutions directly involved in the implementation of projects and programmes. Dissenting voices are few and are often portrayed as minority trouble makers (Young et al. 2003) Hence, it may be argued that Southern researchers and Southern agendas are being suppressed by a paradigm developed in the north, which buttresses its own arguments using the development discourse of participation and demand-led processes.

[1]Respondents were participants in the 10th International Society of Veterinary Epidemiology and Economics International Conference, Santiago, Chile, 17–21 November 2003. The study also canvassed international opinion in an e-mail consultation held during March–April, 2004.

However, it would be a mistake to view these results simply in terms of the polarity between Northern and Southern researchers and institutions. The origins of research projects and programmes are irrelevant to the success. Rather, it is the quality of research and the technologies that are produced that will determine their ultimate value and hence, adoption levels and diffusion. Thus, the larger issues appear to be how to ensure inclusiveness within demand-led processes and neutrality within demand-led assessments.
To further explore current attitudes toward demand-led research and development, the next section explores stakeholder attitudes.

The perceptions of the primary actors in animal health research

To explore perceptions regarding demand, 190 animal health researchers, practitioners and policy makers, whose disciplines and areas of interest ranged from veterinary medicine to livestock economics, production and extension, took part in the study.[1] Participants represented a total of 41 nations from four continents: North and South America, Africa, Europe and Australasia (Table 3).

Table 3. Geographic distribution of study participants.

Geographic location	Number of respondents
Central/South America	49
North America	40
Europe	45
Australasia	21
Africa	35
Total	190

As the objective of the exercise was not to simply solicit expert opinion, but rather to better understand current priorities within the context of demand, participants were asked the following three questions:

1. In your opinion, what are the three largest animal health constraints in Southern countries?
2. What is your understanding of demand-led research and how can current projects be more effective in reflecting demand?
3. What delivery pathways would you suggest for your research outputs?

The questions were open-ended to enable respondents to freely express their opinions. Further, to avoid biases with regard to specialist interests, the first question asked for a rank of three diseases. In this manner, participants would be less likely to simply prioritise their research area. Equally, to avoid influencing respondents the questions were intentionally kept neutral, i.e. without a clear poverty focus.

Livestock disease priorities

Researchers tended to respond to the first question in two ways. Not surprisingly, most of the group mentioned a specific disease or disease complex. Indeed, study participants cited a total of 30 diseases/disorders/syndromes as being the most problematic to livestock keepers in Southern countries. Further, many researchers appeared loath to mention a specific disease but rather ranked groups of diseases, e.g. tick-borne, zoonotic, reproductive disorders etc. Conversely, 15% of researchers, in at least one place in the rank, rather than a disease, offered a larger problem faced by livestock keepers or governments in Southern countries, i.e. access to veterinary services

or the lack of effective policies for disease control. The frequency of mention for the top six disease constraints is illustrated in Figure 1.

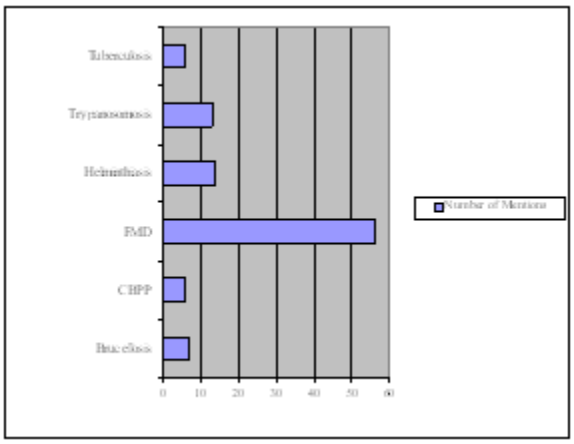

Figure 1. Top six, first order priority livestock diseases (n = 139).

Foot-and-mouth disease (FMD) dominated the ranking, with helminthiasis and trypanosomosis occupying the second and third positions respectively (Figure 1). To explore the finding further, the FMD responses were disaggregated. The first level of analysis explored the geographic area of the researchers involved (Table 4).

Table 4. First Foot-and-mouth disease responses disaggregated by geographic region.

Region	Responses
South/Central America	24
North America	21
Europe	7
Africa	3
Asia	1
Total	56

The highest response rates were recorded from researchers residing in the Americas (Table 4). As the overall responses are evenly divided between Northern and Southern participants, the findings may be viewed as discounting notions of a Northern hegemony in research priority setting. Indeed, perceptions regarding FMD appeared to be the same among a certain sub-set of Northern and Southern participants. Alternatively, it may be argued that notions regarding the importance of FMD are limited to researchers from a single continent and as such, simply display a well-known, geographic bias.

Both conclusions, however, may be too simplistic and offer little insight as to the 'external' demands that may be placed on the providers and clients of animal health research. The majority of the South American respondents worked for their respective governments and national agricultural research centres (NARS) and agricultural research institutes (ARIs). Conversely, most of the North American respondents represented governments and universities (Table 5).

[2]A distinction is required between needs and problems. Oxford Dictionary (1996) defines a need as the 'circumstances in which something is lacking or necessary'. Conversely, a problem is defined as 'a thing that is difficult to deal with or to understand, something that needs to be solved'.

Table 5. First rank Foot-and-mouth disease responses disaggregated by institutional affiliation.

	Universities	Government	NARs[1] and ARIs[2]	International institutions	Total
North	12	10	0	2	24
South	14	9	9	0	32

[1]National agricultural research institutes.

[2]Agricultural research institutes.

Hence, it would be easy to conclude from the results that the demand was driven by governments and echoed by their university providers of research (Table 5). Nevertheless, when the area of research was explored, the study found that far from being a direct relationship, few of the provider institutions were actually involved in FMD research (Table 6).

Table 6. Institutional involvement in Foot-and-mouth disease research.

	Universities (n = 26)	Government (n = 19)	NARs[1] and ARIs[2](n = 9)	International institutions (n = 2)	Total
North	3	6	0	2	11
South	2	8	5	0	15

[1]National agricultural research institutes.

[2]Agricultural research institutes.

Even in the Southern countries involved, only a minority of the provider institutions, i.e. universities, NARs and ARIs were directly involved in research on FMD (Table 6). While many of the Southern governments supported FMD projects and programmes, many of the representatives were from ministries and departments not directly involved in the eradication or control of the disease. As such, the question remains, what are the drivers for FMD prioritisation?

Many countries in South America are seeking freedom from FMD to better participate in a variety of different trade agreements at both the continental and wider international levels. Hence, FMD is a priority disease from an economic standpoint for the countries concerned, both North and South. As such, it may be that these national-level goals are the 'external' drivers influencing the perceptions and priorities of researchers and therefore, demand. Equally, plausibly, within the field of animal health, there is the belief that transboundary diseases are currently on the rise (FAO 2004). As such, some of the Northerners surveyed may be responding to the threat of introducing the disease in the North, rather than the actual impacts of the disease on nations/communities in the South. To accurately elucidate demand, a further understanding of the motivations of the individuals involved is required.

Nevertheless, a global study on the disease priorities of the poor revealed that for 5372 poor farmers on three continents, helminthiasis, rather than FMD was the disease reported with the highest frequency (Heffernan et al. 2004). Interestingly, when asked to prioritise animal health constraints, 29% of farmers, like the experts, were most concerned about FMD. Nevertheless, only 4% of farmers reported the occurrence of the disease in the previous 12 months. The finding was nearly reversed for helminthiasis. Indeed, while 7% of farmers noted the disease to be most important, over 20% of the study sample reported a case or cases during the past year. Thus, the finding demonstrates that simply elucidating priorities and perceptions is insufficient without understanding both the drivers of demand and the reality on the ground. In this case, it would be easy to justify enhanced levels of support for FMD research using the perceptions of the farmers.

Further insight was offered, however, when the drivers of demand for farmers regarding FMD were examined. Indeed, when the same study explored where farmers derived information, over 50% of the households in Bolivia had heard messages about the gravity of FMD from formal sources such as the radio, TV or campaign posters. Interestingly, 41% of households who prioritised the disease did not own a species which could be infected. Therefore, it is clear that the priorities of the experts are influencing the 'demand' of the farmers. Further, while nearly half of farmers linked prevention of the disease to vaccination only 30% of households actually vaccinated their animals. Thus, the behaviour of farmers did not change, regardless of their perception or indeed, knowledge. Consequently, the danger is that perceptions alone will be used to justify agendas under the aegis of a demand-led approach.

Hence, it becomes clear that listing priorities and perceptions in and of themselves is not sufficient and these responses alone cannot be construed as capturing demand. Rather, without an understanding of the type and drivers of demand it is unlikely that decision makers will be able to respond effectively. This is not to say, however, that perceptions regarding disease priorities are not of interest, but rather the multitudinous nature of demand must be accounted for in the interpretation of demand. Indeed, the expert's rank of priority diseases provides an interesting insight into current thinking and a further understanding of present and emerging directions of research. While the rank offered by the farmers, lends further understanding to the complexity involved in the interpretation of disease perceptions.

Thus, given the results the key question becomes, how did the study participants view demand?

Notions of demand

When asked to define demand-led research, participant responses could be generally categorised into two groups. The majority of respondents (64%) related demand-led research directly to the end-users. Conversely, fewer respondents defined demand-led research as a general response to a problem or a need.[2] However, the relationship to the end-user took on a variety of forms (Table 7).

Table 7. Conceptions of demand: The relationship to end-users.

Demand-led research	Responses
Driven/requested/identified by end-users	26
End-user consulted	25
Responds to end-user needs	20
Responds to end-user problems	7
Responds to end-user priorities	8
Responds to end-user aspirations	1
Total	87

Overall, 30% of the respondents viewed demand-led research as being driven or initiated by end-users, as the following examples illustrates:

…the farmer, as a stakeholder, makes a claim that certain issues/diseases are critical to the viability and success of his farming operation.

…demand-led research indicates research that is driven by 'actual' identified demand from the identified beneficiaries of the research...

Conversely, 29% viewed demand-led processes as simply consulting those involved, with researchers having the final say:

…get the right questions enlisted (all stakeholders) and let the researchers make their pick.

Thus, the level of involvement of the end-user in conceptions of demand varied widely. In the former responses, the receptors needs or problems drove the process, conversely, in the latter stakeholders were generally viewed as passive suppliers of information, with the researchers taking the dominant role. However, while participants related demand-led research to the end-user, notions of who the end-user was varied (Table 8).

Table 8. The end-user identified in demand-led research.

End-users	**Per cent mention (n = 131)**
Farmers/communities	42
Veterinarians/veterinary services	4
Researchers	12
Government	12
Commercial sector	13
Unspecified stakeholders/beneficiaries/clients	17
Total	100

The majority of respondents related demand-led research to stakeholders other than the communities involved (Table 8). Indeed, end-users of demand-led processes included national veterinary services, researchers, the government and the commercial sector. Nevertheless, it is clear that the single most frequent response related demand to farmers and communities.

From the above analysis, it is tempting to conclude that researchers broadly understood and/or supported the objectives of such research, given the association between the receptors of research and demand. The conclusion, however, would be misleading. Indeed, the linking of research directly to the farmer was contentious for some study participants for example:

> Demanded by whom? Identification of needs by the people one hopes will be the ultimate beneficiaries of research is important but must be treated with caution.

Although a minority, some participants articulated demand-led processes simply as a donor fad, which had to be accommodated, rather reluctantly:

> …[demand-led research] is research directed by where the money is. This is the sad reality. Ideally, it should be directed to where the needs are.

> …the current fashion is that you have to go to the ultimate beneficiaries and find out what they want…this is only useful in understanding the context.

This perception, however, was echoed more subtly in other responses which ostensibly would appear to be conforming to views that are more ‘acceptable’:

> Technically, greater outcomes may be achieved (in principle) through top-down research but lack of uptake and ‘ownership’ by stakeholders may negate this potential benefit. Demand-led research may lead to simpler outcomes …but greater stakeholders involvement should (again, in principle) lead to a greater ultimate impact.

Thus, demand-led research was viewed as a trade-off necessary to improve research outcomes but ultimately limited in the ability to generate new knowledge. Hence, while it was recognised that use of the term could enhance funding opportunities, the general view was that it offered no new benefits to scientific understanding or indeed, the wider problems facing the animal health sub-sector. Hence, while the objectives of demand-led research were understood its value was questioned, particularly by blue-sky researchers.

Nevertheless, when viewed in relation to the results offered above the finding raises additional issues. From the previous analysis, researchers believed that there were wider constraints inhibiting livestock disease control in Southern countries. These constraints focused upon the farmers, the government and, at least some of the time, on the researchers themselves (Table 8). However, only two of the study participants linked demand-led research to poverty alleviation. Thus, demand-led research was not viewed as a potential solution to some of the wider problems affecting the animal health sub-sector.

Conclusions

Currently, the reality of demand-led research does not match up to the rhetoric. Across stakeholder groups, the study demonstrated the large gap between the perceptions of different actors. Clearly this gap will ultimately affect the future development of biotechnologies and their uptake by the intended clients. Nonetheless, these gaps tended to be among stakeholder groups and not between the different target audiences. For example, both Northern and Southern researchers tended to prioritise the same livestock disease constraint. Farmers were also consistent regarding priority diseases affecting their geographic areas. Unfortunately, the views rarely coincided. To create and deliver sustainable animal health technologies the key question becomes how can these demands be joined up?

At present, the view of demand-led processes as a panacea to enhance development outcomes is unlikely, in the long run, to be effective. Notions of 'demand' appear too easily manipulated to be an effective force for true change. For such processes to be effective, new tools and methods are required to measure demand in a neutral fashion that cannot be influenced by the perceptions of either the experts or the poor. Given the highly polarised debate surrounding many biotechnologies, there is an urgent need to accurately measure the demands of stakeholders to support evidence-based policy and practice.

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Plenary session 3

Institutional arrangements and capacities for biotech applications

Bringing technological innovations to African smallholder farmers through intellectual property and technology transfer management: The AATF approach

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Abstract

Yields of the major staple crops (maize, sorghum, millet, cassava, cowpea and bananas/plantains) of smallholder farmers in Africa have remained stagnant or even declined in the past 40 years. Numerous biotic and abiotic stresses facing these crops in Africa have contributed to this scenario. Local research efforts to overcome these stresses are hampered by declining support for agricultural research, limited access to elite genetic material and other technologies protected by intellectual property rights and absence of commercial interest in these crops by private owners of agricultural technologies.

This paper addresses the intellectual property issues (IP) and partnership arrangements associated with the access, development and deployment of agricultural technologies targeting smallholder farmers in sub-Saharan Africa as addressed by the African Agricultural Technology Foundation (AATF).

AATF is a new initiative addressing these challenges by negotiating access to proprietary technologies and facilitating their conversion into technological solutions deliverable to smallholder farmers in sub-Saharan Africa.

Introduction

The agricultural sector in developing countries is the key source of food, incomes, employment and often foreign exchange. Agriculture is thus crucial in sustaining livelihoods and stimulating overall economic growth. Agricultural progress traditionally occurred through a process of on-farm experimentation, selection and adaptation of crop landraces. This was supplemented by purposive breeding of new varieties of crops, mainly through crossing and selecting varieties with desirable characteristics. In Africa, smallholder farmers constitute approximately 70% and 90% of the population and agricultural work force respectively. Despite the availability of agricultural technologies such as improved seeds and farm inputs, crop productivity in Africa has remained low or stagnant partly due to low use of improved crop varieties resistant to both biotic and abiotic constraints. Technologies like drought tolerant or disease and pest resistant seeds that could mitigate these constraints are not easily accessible, particularly, to smallholder farmers in developing countries, largely due to costs and unavailability of technologies in times of need. This situation is compounded by the introduction of intellectual property rights (IPR) in the form of patents and plant breeders' rights as a means of striking a balance between protecting the rights of the creator of an idea expressed in a material form and providing a benefit to the society as a whole. They often result in raising the cost of access to new plant varieties.

The decline in agricultural productivity and introduction of IPR thus raise the challenge of stimulating development of innovative technologies, e.g. better yielding, drought tolerant and pest and disease resistant crop varieties, while providing mechanisms that support the smallholder farmers' access to these technologies to achieve the goal of improving their livelihoods. Delmer

et al. (2003) described several initiatives designed to meet this challenge, three main ones being the Centre for the Application of Molecular Biology to International Agriculture (CAMBIA), the Public Intellectual Property Resource for Agriculture (PIPRA) and the African Agricultural Technology Foundation (AATF). CAMBIA is an Australian-based initiative that aims at providing technical solutions that empower local innovators to develop new agricultural solutions. PIPRA is a US-based arrangement that seeks to pool publicly owned and patented technologies to be used by research institutions in developing countries. Conversely, AATF focuses on negotiating access to proprietary technologies and facilitating their delivery to smallholder farmers in Sub-Saharan Africa. The first section of this paper gives a brief description of AATF. The second section highlights AATF's policy on the management of intellectual property (IP), with a focus on how this affects specific projects under development by AATF. It also explores the issues encountered and the approaches adopted by AATF to address these issues to advance the projects.

The AATF model

The fundamental rationale for the creation of AATF was to establish links between private and public sector institutions that own technological innovations in developed nations with African stakeholders in agricultural development such as the national agricultural research and development organisations, farmers' associations, non-governmental organisations and national private sector agribusinesses. The goal of AATF is to facilitate access to advanced scientific and technological resources and their adaptation for use in specific projects intended to increase the productivity of smallholder farmers in sub-Saharan Africa. AATF is an African-based and -led entity, registered as a charity under the laws of England and Wales with the specific objective of relieving poverty in Africa by facilitating public-private partnerships for the transfer and use of innovative agricultural technologies by smallholder farmers and, in particular, resource-poor farmers, thus contributing to increased productivity, higher farm output, increased food security and greater income generation potential. AATF was officially launched in June 2004 in Nairobi, Kenya, where it is headquartered.

Operating principles and strategy

AATF's strategy for achieving its objectives is to act as the principal and 'responsible party' in facilitating public-private partnerships on a case-by-case basis. AATF works closely with other African institutions, responding on a project-by-project basis to the expressed needs of African farmers. It endeavours to assemble all the necessary components for each project, balancing concerns for expense, simplicity and effectiveness. More specifically, AATF:

- Consults with African stakeholders to identify priority crops and key constraints for resource-poor farmers.
- Consults with potential technology providers, in both the private and public sectors, to identify technologies that can address those constraints.
- Negotiates with potential partners to develop a project business plan that specifies the role of each partner institution, and determines how and where the technology will be used.
- Enters into license agreements to access and hold proprietary technologies royalty free and ensure freedom to operate for all the components of the technologies.
- Sub-licenses partner institutions for further research as needed to adapt the technologies to smallholder farming conditions.
- Issues sub-licenses to test the adapted technologies for regulatory compliance.
- Issues commercial sub-licenses for production and distribution.
- Monitors compliance with the requirements of sub-licenses to minimise the risk of technology failure.

- Facilitates the work of appropriate partner institutions to ensure that links in the value chain are connected, effective and result in products of the technology getting to farmers and farmers' surplus harvests getting to market.
- Creates partnerships within African countries and with external stakeholders that foster the development of necessary indigenous capacities over time.

As implied above and further illustrated in Figure 1, AATF operates along the entire product value chain, from transfer and adaptation of technology to farmers' access to output markets, with implementation at each step undertaken by the relevant partner organisations. The nature of AATF's involvement varies from project to project.

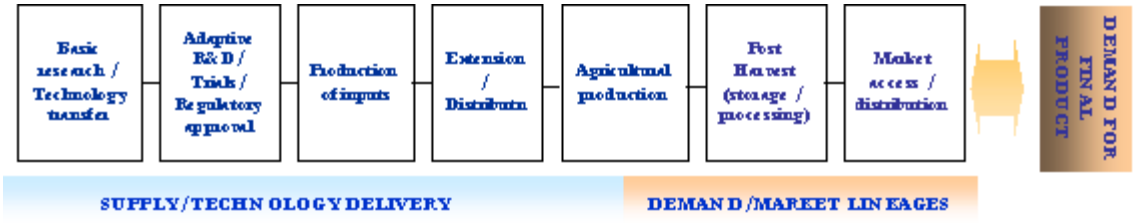

Figure 1. Complete product value-chain.

Source: Cambridge Economic Policy Associates (2002).

Depending on the needs of African farmers, AATF promotes the development and transfer of all types of technology. The choice of technologies reflects African priorities, is demand-led and guided by the potential to improve food security and reduce poverty. AATF prefers technologies that are simple, cost effective and provide sustainable value to the farmer. So far, 10 broad problem areas have been identified as priority targets for intervention by AATF:

1. *Striga* control in cereals
2. Improvement of cowpea productivity and utilisation
3. Bananas and plantain productivity
4. Nutritional quality enhancement in maize and rice
5. Drought tolerance in cereals
6. Mycotoxins in food grains
7. Cassava productivity improvement
8. Insect resistance in maize
9. Building sustainable seed systems in Africa
10. Control of locusts and grasshoppers

AATF's policy is premised on the belief that developing countries in sub-Saharan Africa must make their own decisions on whether or not to adapt and adopt particular agricultural technologies, including genetically modifies organisms (GMOs). AATF expects that these decisions will be based on appropriate national or regional assessments of the costs, benefits and social acceptability of each technology. In the case of GM technologies, AATF will always require that the countries into which technology is licensed have the capacity to manage their safe development and use, through appropriate operational national biosafety regulations and other necessary instruments.

Liability and other concerns

A major concern by multinational companies that affects access to IP-protected agricultural technologies is exposure to liability after such technologies have been licensed to AATF, and subsequently sub-licensed to other parties for use in sub-Saharan Africa. A further concern is the possible misuse of the technology and associated confidential information. Noting that these

concerns could be significant obstacles to the access and ultimate deployment of technologies, AATF has devised the following mechanisms to address them: For each project, AATF (i) develops a business plan that outlines specific uses of the technology, together with management and oversight protocols that will govern and monitor such use; and (ii) conducts risk analyses to aid in the formulation and implementation of risk mitigation plans. Further, where appropriate and reasonable, AATF assumes some risk of liability by indemnifying technology providers for claims resulting from AATF activities. Finally, AATF has been organised and structured to act as a 'responsible party', to protect the interests of technology providers and minimise the risks to users while providing overall stewardship by: (i) ensuring technologies are targeted to specific needs; (ii) ensuring regulatory procedures are in place and followed; and (iii) obtaining the necessary *freedom to operate* thereby safeguarding against IP infringement.

Management of intellectual property (IP)

Formulating an IP policy

AATF firmly believes effective and responsible management of IP starts with the formulation of an IP policy, which sets: (i) clear objectives and principles of conduct in obtaining access to and use of IP and protected technologies; (ii) guidelines as to how and when IP protection will be sought and exercised; and (iii) basic principles concerning the use of IP and protected material by recipients to ensure that this use is consistent with furthering AATF's mission. AATF has therefore formulated a policy (AATF IP Policy) aimed at ensuring that knowledge and products resulting from AATF activities will be used for the maximum public benefit of resource-poor smallholder farmers in sub-Saharan Africa.

Results of activities coordinated by AATF are expected to contribute, through a series of collaborative projects and transfers of technology, to the development of improved technologies used by resource-poor smallholder farmers. Partners in AATF-coordinated projects are required to commit to facilitating the sharing and transfer of technology and research products for both research and commercial use benefiting resource-poor smallholder farmers.

Further, the AATF IP policy stresses the responsible use of IP that belongs to others, in a manner that respects the rights of the IP owners. Additionally, in the acquisition and management of IP, AATF abides by all relevant international laws and treaties, and national laws in the countries in which it operates.

Finally, AATF is guided by its core values of accessibility, accountability, credibility, dedication, transparency and trustworthiness. The AATF approach to IP management is best illustrated in the example shown below from the cowpea project, which is currently being developed.

Obtaining access and rights to use proprietary technology (freedom to operate)

As a responsible party, AATF ensures that proprietary technology is properly acquired and used by the Foundation and its project collaborators to help make the technological advances necessary to further AATF's mission. Before the use and application of such technology, AATF conducts an IP audit to identify any restraints associated with its use or with the distribution of products or processes incorporating the proprietary technology. AATF and its project collaborators always endeavour to develop and deploy products that are 'free and clear' of restrictions imposed by third party IP rights. If not free and clear, the Foundation makes best efforts to disclose any outstanding restrictions that might apply to such technologies and, where possible, obtains any required permissions. The Cowpea improvement project currently under development best

illustrates this: AATF has negotiated with the Monsanto Company (Monsanto) for a royalty-free, non-exclusive license to Monsanto technology in the form of a *cry1Ab Bt* gene for use in the development and deployment within Africa of cowpea *(Vigna unguiculata)* varieties with resistance against the cowpea pod borer *(Maruca vitrata)* for sustainable production of food for and by resource poor farmers of Africa. In line with good IP management practice, AATF coordinated the conduct of a comprehensive Technology Due Diligence, including a Freedom to Operate (FTO) assessment, to clearly determine the ownership rights of the gene, promoters and other component technologies needed to develop the improved cowpea variety. The findings of this assessment will serve as a basis to seek all required permissions to ensure complete FTO.

Preserving the confidentiality of IP and related project information

AATF views as good IP management practice the preservation of the integrity of confidential information contained in third party IP, IP resulting from AATF-coordinated projects and general project information. Therefore, AATF includes a confidentiality clause in all employment contracts and stresses compliance with this clause as a condition of continued employment of AATF personnel. Further, AATF advocates that its project collaborators require all their personnel associated with any project to sign confidentiality agreements as a condition of such association. Finally, AATF routinely enters into non-disclosure agreements (NDAs) with its collaborators to not only facilitate the free exchange of information and materials, including IP, but also preserve the integrity of confidential information at the institutional level.

Defining ownership rights

Good IP management requires that all ownership rights are defined at the start of any engagement. Thus, as between AATF and its employees, these rights are defined in the employment contract, which stipulates, in relevant part, that any rights (intellectual or technical property) in research products, publications and other works created or contributed to by AATF personnel in the course of their normal and assigned professional duties will be vested in AATF.

The ownership rights of AATF and technology providers are negotiated and determined on a project-by-project basis. For instance, in the cowpea project Monsanto will retain its existing IP rights while AATF will own all right, title, and interest, in and to any improvement arising from use of Monsanto's technology under the terms of the license agreement.

The ownership rights of AATF and its project collaborators are negotiated on a project-by-project basis. Consistent with the AATF IP policy, IP rights will be shared equitably, taking into consideration: (i) the intellectual contribution of each partner to the particular project (foreground IP); (ii) the contribution of intellectual property, materials, research effort, and preparatory work of each partner brought to the project (background IP); (iii) the facilities provided by each partner; (iv) the financial contribution of each partner; and (v) other considerations determined by the partners to be relevant.

Further, (i) any rights (intellectual or technical property) in research products, publications and other works commissioned by AATF will be assigned and vested in AATF; and (ii) any rights (intellectual or technical property) in research products, publications and other works jointly commissioned by AATF and the project collaborators will be assigned to and vested in AATF and the project collaborators as joint right holders.

Execution of agreements

AATF believes it is essential and indeed good IP management practice to finalise all contractual terms, set out in writing with the agreement duly signed by the authorised representatives of the parties before beginning any engagement. This involves ensuring that all arrangements with

third parties associated with the access, creation, use or exploitation of IP protected materials are appropriately documented. For instance, for the cowpea project, AATF and its collaborating partners will enter into several agreements. First, AATF has obtained a license from Monsanto, and, with the consent of Monsanto, will sub-license the *cry1Ab Bt* gene to collaborating research investigators and their institutions for introduction of the *Bt* gene into cowpea genome. Further, AATF will sub-license the resulting successful transgenic events to African agricultural research institutions that will introgress the *Bt* gene in cultivated cowpea varieties. These varieties will then be licensed to the commercial, non-government, humanitarian or public institutions responsible for dissemination of improved cowpea varieties in Africa.

Identification of IP assets

The maintenance of IP asset inventories or a register of IP assets is an essential element in an effective plan to manage those assets. Therefore, AATF and its collaborating partners will adopt procedures and practices such as DNA fingerprinting, the keeping of appropriate laboratory notebooks, and controls over the release of information to properly identify, record, safeguard and manage project generated IP.

Publication of project research results

AATF anticipates facilitating access to and use of improved germplasm and research products for the public benefit through publication and public disclosure. Therefore, to the extent determined appropriate by AATF and its project collaborators, research outputs and products from AATF projects will be placed in the public domain.

Statutory protection of IP

In certain cases, statutory IP protection may be necessary to (i) ensure the continued availability of germplasm, inventions, publications and databases to AATF and its research collaborating partners; and (ii) provide AATF with the necessary leverage to negotiate access to other proprietary rights and technologies required for product development. Therefore, in appropriate cases, AATF may seek such IP protection for products generated from its projects (improvements) to which it obtains ownership rights. For instance, as noted earlier, AATF will own all right, title, and interest, in and to any improved cowpea varieties or other improvements developed using Monsanto's technology. In consultation with the project collaborators, AATF may seek to protect these improvements by obtaining IP protection through patents, plant breeders' rights, copyrights, trademarks, statutory invention registrations or their equivalent, and/or trade secrets. In seeking IP rights, AATF will be guided by its commitment to serve the African resource poor smallholder farmer, rather than by opportunities to obtain revenues. To the extent that financial returns are generated through IP licensing, they will be used by AATF and the project collaborators to achieve the charitable objectives of AATF. AATF will ensure that all licenses to third parties to the improvements make provision for:

1. Ready access by others for humanitarian use.
2. The avoidance of possible restrictions arising from 'blocking' patents and to ensure the project collaborators' ability to pursue research without undue hindrance.
3. The transfer of technology, research products and other benefits to the African resource poor smallholder farmer through public channels and, where appropriate, through commercialisation or utilisation of research products.

With regard to the protection of cells, genes, molecular constructs, plants, varieties and traits, AATF and its project collaborators will, to the extent permitted by applicable law, consider the effects that protection has on access to, and the distribution and use of the protected product before proceeding with an application for statutory protection.

AATF and its project collaborators may allow third parties to take IP rights on research products or material derived from research products if it is determined that the public good would be best served by doing so. In such cases, AATF and the project collaborators will ensure that agreements granted to recipients to apply for IP protection do not in any way waive the rights of AATF and the project collaborators to challenge excessive protection, by recourse to administrative and/or court proceedings. AATF and the project collaborators may also reserve the right to retain research products for their own use, and to enter into agreements to deploy research products in a targeted manner to certain partners and/or in certain markets.

Publications

AATF encourages the wide dissemination of publications (printed and electronic) including databases, reports, training material, public awareness material, artwork and audio-visual material, and desires that such materials be used to maximum public benefit. For instance, AATF and its project collaborators have issued publicity materials including press releases in English and three Kenyan local languages—Kiswahili, Dholuo and Luhya—to help publicise the deployment of Imidazolinone resistant (IR) maize technology (named *ua kayongo*, meaning 'kill *Striga*') to help control the parasitic weed *Striga* in western Kenya.

In creating such materials AATF and its project collaborators endeavour to only use the copyright material of others within 'fair use' limitations or with the consent of the copyright owner and properly attribute the source of the material.

AATF and the project collaborator publications (printed and electronic) will normally carry standard copyright convention signs, indicating AATF and the project collaborators as the copyright owner of the compilation, published edition and/or the material published (as appropriate) together with the year of publication.

AATF and the project collaborators will generally incorporate in their publications (printed and electronic) standard copyright notification statements:

1. Permitting, especially in the case of national agricultural research systems (NARS), the making of a reasonable number of copies of such copyright material for non-commercial purposes.
2. Requiring attribution where such copyright material is reproduced in other publications.
3. Prohibiting interference or tampering with the material without the express consent of AATF and the project collaborators.
4. Addressing any other issues relevant to the best use being made of the material such as procedures for the dissemination and recall of material subject to updating.

AATF and the project collaborators may, to the extent available in national laws, enforce the copyright in such publications (printed and electronic) and protect them from unfair competition to:

- respond to a breach of the above terms
- prevent misappropriation of such material for commercial purposes
- protect the fidelity of such material.

To the extent practicable, AATF will develop databases that assist the resource-poor and will make best efforts to keep these databases in the public domain.

Trademarks

AATF and the project collaborators may register all distinctive marks as trademarks in order to protect the goodwill and reputation associated with the exclusive use of these marks by AATF and the project collaborators.

Conclusion

Conventional methods for technology development and transfer have not always contributed sufficiently to sustainable food security and rural poverty alleviation in sub-Saharan Africa. Although there have been numerous attempts in the past to promote public-private partnerships in the region, most have had little tangible or lasting impact. It has become increasingly obvious that new approaches are needed to mobilise new science for application in Africa, and to achieve the potential complementarities of public and private sector research and development efforts.

AATF represents an innovative approach based on forging collaboration between these sectors to identify and transfer proprietary technologies that would otherwise not be available to address the problems of resource poor smallholder farmers. AATF is surely not the single answer or a 'silver bullet'. And it may not be the only or even the best means to achieve the goal of easing access to important technologies for humanitarian purposes. But its African focus, leadership and operational location promise a more comprehensive and realistic appreciation of the constraints to technology transfer in Africa, the design of more feasible solutions and closer follow-up and continuity in implementation. While a wide range of stakeholders in the private and public sectors and in civil society has already pledged their commitment to make the AATF concept work, AATF deems it imperative to retain the confidence of such stakeholders through effective leadership and the responsible management of IP.

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Building the capacity of Africa for biosciences in agriculture

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Abstract

The New Partnership for Africa's Development (NEPAD) has placed agriculture and science at the forefront of Africa's economic development, and has provided support for the establishment of Biosciences eastern and central Africa (BecA) as one of its centres of excellence. The vision is for BecA to capture the immense potential of 'new science' to accelerate agricultural development on the continent and to enable African scientists and institutions to become significant technological innovators as well as users.

The facilities at BecA's hub offers state-of-the-art research laboratories for the biosciences, including genomics, proteomics, gene technology, immunology, bioinformatics and containment facilities for safe genetic manipulation of plants and micro-organisms (e.g. for vaccine development).

The BecA hub also provides opportunities for capacity building and training**,** enhanced by the training partnerships which have been established with African universities, internationally renowned research groups, the CGIAR and a wide range of other appropriate institutions. Financial support for joint training programmes is being provided through agreements with a range of multilateral and bilateral donors. Opportunities exist for fellowships and scholarships to support thesis research for young African women scientists, and scientists from countries engaged in post-conflict reconstruction, visiting scientists, and doctoral and post-doctoral fellows. Support can be offered also for short-term-use of research facilities, short training courses, seminars, workshops and conferences.

BecA's vision and mission

BecA is part of a network of centres of excellence in biosciences being initiated by the New Partnership for Africa's Development (NEPAD) across Africa. NEPAD is doing this to strengthen Africa's scientific and technological development and to mobilise regional resources to solve problems common in sustainable development. BecA is thus a collaborative initiative to support African countries in developing and applying bioscience research to produce technologies that help poor farmers secure their assets, improve their productivity and income and increase their market opportunities.

BecA is being established as a joint venture to provide a platform for the African scientific community to support the activities of national, regional and international agencies as they address agriculturally related problems of the highest priority for alleviating poverty and promoting development.

BecA's vision is that African scientists and institutions become significant innovators as well as users of 'cutting-edge' biological technologies. BecA will allow Africans to undertake biosciences research tackling some of the most severe, high-priority constraints hampering Africa's development. BecA researchers will be able to access and use the best science worldwide. Its mission is to contribute to improving the livelihoods of the poor using new technologies and

strategies for sustainable agricultural production, environmental protection and health improvement.

BecA as a network

BecA consists of a *hub* located at the International Livestock Research Institute (ILRI) in Nairobi, Kenya, that will provide a common biosciences research platform, research-related services and capacity building and training opportunities; and a *network of regional nodes and other laboratories* distributed throughout eastern and central Africa. The network will conduct research on priority issues affecting Africa's development. BecA is being established amongst a group of cooperating institutions that agree to make their facilities available for regional use.

Core competencies of BecA

Based on its vision and mission several areas of scientific and technical core competencies have been identified currently in the network's activities (Table 1).

Table 1. Areas of core competence at Biosciences Eastern and Central Africa (BecA).

Competence	Description
Transformation	Introduction of one or more genes into a species to confer potentially useful traits
Diagnostics	More accurate and quicker identification of pathogens using new diagnostics based on molecular characterisation of the pathogens
Genomics	Use of the available molecular information on all the genes in selected species
Functional genomics	Use of the knowledge that converts the molecular information into an understanding of gene functions and effects
Gene sequencing	The identification of the structure of the genes in an organism
Molecular breeding	Identification, evaluation and expression of useful traits using marker-assisted selection (MAS)
Vaccine technology	Use of modern *immunology* to develop recombinant DNA vaccines for improved control of animal and fish diseases

BecA's bioinformatics platform

Bioinformatics is a branch of information technology that exploits the wealth of genome and expressed sequence tag (EST) data, generated in the last decade, through a multidisciplinary combination of biology, computer science and mathematics. The application of bioinformatics therefore has great potential to underpin research solutions to development constraints. However, research institutes in East and Central Africa currently lack core skills in this crucial new discipline. Whereas computer hardware is relatively inexpensive, and software is frequently open source (users of open source software are generally able to view the source code, alter and redistribute open source software), the expertise required to exploit the wealth of publicly available sequence and functional genomics data are not yet widely available.

The bioinformatics platform aims to provide the expertise that represents a major constraint for bioinformatics development. A BecA stakeholder workshop (January 2004) identified bioinformatics as a major priority among representatives of research institutes throughout the region, indicating substantial demand. A bioinformatics unit has recently been established, availing skills required for sophisticated exploitation of nucleic acid sequence data combined with hardware that has recently been upgraded through a major infrastructure grant from CIDA-Canada to BecA.

This represents the nucleus of a bioinformatics hub that, in collaboration with national research institutions in the countries served by BecA, can be used to drive the establishment of bioinformatics capacity throughout East and Central Africa. The established platform comprises of a 66 CPU High Performance Cluster (HPC) that also incorporates a Gene Matcher 2 system that runs dynamic programming algorithms. The HPC represents an integrated hardware and software solution that can perform most bioinformatics analyses including rapid-whole genome BLAST, computationally demanding Smith Waterman (FASTA) global alignments, sequence assembly and clustering, structural modelling and analysis of micro-array data.

This new facility will allow scientists from universities and agricultural research organisations within the region to pursue projects requiring bioinformatics, with a major initial focus on crop genomics centred on developing resistance to biotic and abiotic stress. Additional future research areas will include environmental genomics, development of novel vaccines and diagnostics and applied arthropod disease vector genomics. These research areas will all require bioinformatics support to exploit EST sequences, through searching public databases and comparative genomics. Analysis of data generated from functional genomics platforms, particularly micro-array and proteomics, which has a strong bioinformatics component, will also be a key element.

Capacity building

BecA also provides opportunities for capacity building and training, enhanced by the training partnerships which have been established. The partnerships include those with African regional universities, internationally renowned research groups, the Consultative Group on International Agricultural Research (CGIAR) and a wide range of other appropriate institutions. Financial support for joint training programmes is being sought through agreements with a range of multilateral and bilateral donors. Fellowships and scholarships will be availed on a competitive basis to young African scientists. Women scientists, those from countries engaged in post-conflict reconstruction and visiting scientists will be particularly encouraged to apply for such capacity building initiatives. A platform can be offered also as a host for short-term-use of research facilities, short training courses, seminars, workshops and conferences.

Revving up the engine for Africa's development: Providing a continental perspective to increase the impact of African agricultural research

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As the predominant industry, agriculture is expected to be the engine of Africa's development. It contributes one-third of Africa's total GDP, about 40% of foreign exchange earnings and provides the livelihoods of about 80% of the population. However, over recent decades agricultural productivity has decelerated causing food insecurity and devastating degradation of the environment.

The situation would be far worse but for the contribution of improved production, health and pest management technologies that have emerged from formal research and farmer innovation. However, the overall impact in increased output has not kept up with increasing demand from growing populations. To meet their needs farm and pastoral families have had to open up increasingly marginal and fragile lands and resort to overstocking even when they are aware of the long-term negative consequences. Their adoptions of improved technologies and access to new markets have remained 'islands of success' with limited local impact. The transfer of technology approach that assumed that interventions developed by researchers could be disseminated to end users by extension agents failed to achieve the scale of adoption required to make perceptible improvements in the livelihoods of the vast majority of farmers.

This failure has been readily attributed to lack of government investment and consequent breakdowns in the extension services and there is still a widely held belief that there are many 'proven technologies' on the shelves of research stations waiting to be extended to the producers. This is a view inadvertently propagated by researchers who tend to forecast formidable impacts by extrapolating positive results obtained in research trials and pilot projects. However, there is growing realisation that adoption is the only valid proof that a technology is successful. There is also considerable evidence that innovations with the attributes of success will be pulled off the shelves one way or another. The adoption of crossbred dairy cattle by Kenyan smallholders happened spontaneously without substantial extension and in some instances even against extension policy which presumed smallholders did not have the necessary skills and resources to keep such demanding animals.

The fact that there has been very little outcry from smallholders, who are the majority of voters, for rehabilitation of defunct extension service indicates that their demise has not been seen as a great loss by the 'beneficiaries'. That does not deny that the transfer of technology model has succeeded spectacularly in particular circumstances such as in the uniform irrigated rice systems of South Asia during the Green Revolution. However, it does not meet the needs of the highly diverse farming systems of Africa that require technologies that are suited to local ecological, economic and social systems.

A new way of doing business is required to make agriculture the engine of Africa's development. It also requires much greater investment to fuel the drive for change on a scale large enough to turn around the decline in living standards and worsening food insecurity and achieve improved

incomes and sustainable wealth creation. To achieve the Millennium Development Goals (MDGs) and its target 6% growth in agricultural productivity by 2025 NEPAD (New Partnership for Africa's Development) is advocating a doubling of investment in agricultural research. However, turning that into a successful investment will require a paradigm shift away from the linear research-extension-adoption approach to a multi-disciplinary, multi-institutional and multi-stakeholder innovation systems approach that empowers all stakeholders to learn together to overcome obstacles and seize opportunities for development. This entails changing the mind-set of people at all levels to forge new institutional arrangements and ways of doing business. To that end, the Forum for Agricultural Research in Africa (FARA) is advancing an integrated set of five continental programmes that are designed to respond holistically to the development needs outlined in NEPAD's Comprehensive Africa Agriculture Development Programme (CAADP). In keeping with FARA's mandate, these programmes are designed to complement and add value to the priorities and programmes of the sub-regional organisations (SROs), i.e. ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa), CORAF/WECARD (West and Central African Agricultural Research and Development) and SADC/FANR (Southern African Development Community/Food, Agriculture and Natural Resources).

FARA's stakeholders recognise that achieving the goals and objectives of Pillar IV of NEPAD's CAADP, which covers agricultural research, technology development and dissemination, will require greater cohesion and value adding between the different actors. This is being addressed by a proposed Framework for African Agricultural Productivity (FAAP) which aims to promote greater impact by:

1. Strengthening Africa's capacity for agricultural innovation and increase investments by African governments in agricultural research, technology dissemination and adoption.
2. Fostering and supporting reforms in African agricultural research, extension and teaching and training institutions and markets.
3. Catalysing formulation of enabling policies for agricultural research, development and capacity building.
4. Linking national, sub-regional and regional programmes and networks with strong international partnerships to achieve efficiency and effectiveness in agricultural research, technology dissemination and adoption.

FAAP will achieve these objectives by providing a cohesive structure for African agricultural innovation that will promote harmonisation of internal and external actions and actors. It will provide a framework within which the roles and responsibilities of the different actors can be negotiated and agreed with minimised duplication, coverage of all vital links in the value chains and assured deliverables.

The drive to find more effective ways of promoting smallholder and pastoral innovation is being spearheaded by the FARA-led Sub-Saharan Africa Challenge Programme (SSA CP). This is bringing the whole African agricultural research community including national agricultural research institutes, CGIAR centres, universities and NGOs into Pilot Learning Teams that will carry out Integrated Agricultural Research for Development (IAR4D). The programme has the following four objectives:

1. To develop technologies for sustainably intensifying subsistence oriented farming systems.
2. To develop smallholder production systems that are compatible with sound natural resource management.
3. To improve the accessibility and efficiency of markets for smallholder and pastoral products.
4. To catalyse the formulation and adoption of policies that will encourage innovation to improve the livelihoods of smallholders and pastoralists.

The following four pillars underwrite the IAR4D approach:

- Promotion of organisational and institutional change to enable cross-disciplinary research and development and multi-institutional collaboration.
- Capacity building for project teams, farmers, and scientists in African institutions.
- Information and knowledge management (including documentation of new methodologies developed) to disseminate widely the findings of IAR4D work.
- Ongoing monitoring and evaluation, and a systemic approach to impact assessment, to track progress towards overall goals, signal the need for mid-course adjustments and document the returns to investment in IAR4D.

Phase 1 will be conducted at three Pilot Learning Sites (PLS) that were selected by the three SROs, one site per sub-region. Each site is characterised by a different but complementary set of constraints to sustainable development. The three sites are the Kano-Katsina-Maradi (Niger and Nigeria; KKM PLS) transect, the Lake Kivu PLS covering the interface of the Democratic Republic of the Congo, Rwanda and Uganda, and a corridor that runs from southern Malawi, through central Mozambique into northeast Zimbabwe (MMZ PLS). The Pilot Learning Teams include multi-institutional stakeholders in three scales of implementation, local, national and regional.

Recognising that human capacity is the single factor without which development is impossible FARA is determined to catalyse and facilitate redress of years of under investment and lack of support for agricultural education at African universities and colleges. A programme for Building Africa's Scientific and Institutional Capacity (BASIC) is being developed through extensive consultations between African and non-African partner universities, CGIAR centres and national agricultural research institutes on what is required to reinvigorate tertiary agricultural education so that Africa will produce the human capacity required for endogenously driven innovation in agriculture. BASIC's ultimate purpose is to raise the quality and relevance of agricultural education at the tertiary level by:

- Providing a means for African colleges and universities to identify and express their common priorities for strengthening their capacities for building capacity.
- Raising the quality of teaching and training provided by African agricultural colleges and universities.
- Linking the universities to agricultural research so that they will have access to up-to-date and locally relevant data and information for inclusion in teaching and training materials.
- Increasing in a significant way Africa's contribution to the global corpus of knowledge and expertise and enhancing the competitiveness of African universities.

The programme has a series of components and the following six are the first selected priorities. These are:

1. Improvement of agricultural curricula and development of learning resources.
2. Soft and hard systems skills required for success in modern multi-disciplinary, multi-institutional and multi-stakeholder innovation systems.
3. Managing risk and uncertainty in agriculture.
4. Biotechnology and biosafety.
5. Agricultural business principles.
6. Agricultural information management and learning methods and tools.

Aware that there are a number of credible technologies that are being successfully adopted but could be out-scaled faster and much more broadly, NEPAD and FARA have developed a programme for Dissemination of New Agricultural Technologies in Africa (DONATA) with the immediate objectives of:

- Disseminating new agricultural technologies across three sub-regions of Africa, namely West, East and Southern Africa.
- Building the capacity of NARS to disseminate new technologies in their sub-regions.
- Institutionalising links between major stakeholders (i.e. regional, sub-regional and national) in scaling-out promising new technologies in Africa.

The first set of projects in the DONATA portfolio includes:
- NERICA rice
- Tissue-culture banana
- Imidazolinone-resistant African maize cultivars – a herbicide seed dressing technology for controlling Striga in maize
- Integrated natural resource management tools that are available for different ecosystems.

The promotion of a portfolio of technologies in a single programme will facilitate learning about dissemination processes and techniques and the sharing of facilities and infrastructures. Thus it is anticipated that there will be a steady stream of new technologies emerging from scientific research and farmer innovation that will add to the DONATA portfolio.

Understanding that improvement of smallholder and pastoral productions systems depends on the acquisition of new knowledge, because they have no unused capacity for investing more labour, FARA is catalysing and facilitating better use of information and communication technology (ICT) to improve African access to global information on agriculture. FARA is equally committed to improving the contribution of African scientists to the global pool of agricultural information. FARA is also aware that information has little utility unless the receiver has the learning tools to turn it into useful knowledge and this aspect has been virtually neglected in rural development with the unsurprising consequences that many technologies have not out-scaled beyond the boundaries of pilot projects that provided means for accessing information and learning. These aspects are being addressed in the development of FARA's Regional Agricultural Information and Learning System (RAILS).

The goal of FARA-RAILS is to enable more equitable access to agriculture information for stakeholders in agricultural research and development, including farmers, by filling critical continental level gaps in information and communication management (ICM) to complement and add value to the sub-regional agricultural information systems such as ASARECA's Regional Agricultural Information Network (RAIN) and the national agriculture information systems (NAIS).

RAILS will emphasise capacity development at national, sub-regional, regional and continental level and integration of the different information systems. It will also facilitate the sharing of experience and expertise from all sources but in particular from other developing regions in promoting rural learning so that smallholders and pastoralists will be able to access the information they need, when they need it, in the form they need it in and with the tools that will make them sufficiently knowledgeable to be able drive their own innovation and economic and social development.

These five programmes respond to different aspects of an integrated approach to revving up the engine of African development. The application of this new way of doing business is most necessary in animal agriculture because it is the largest agricultural sub-sector, contributing about 35% of agricultural GDP. Livestock range over almost 90% of agricultural land in Africa and sustain the livelihoods of 25 million pastoralists. Integrated crop–livestock production is also

the main avenue for intensification of production in the sub humid and humid regions. Animal agriculture is thus the greatest anthropogenic use of land with urgent consequences for the conservation of environmental services on which both rural and urban people depend. Research that is aimed at improving livestock productivity must, therefore, take account of the impact on grazing, forests and water resources and the linkages with crop production in regard to feed grains, crop residues and by-products, nutrient cycling, traction etc. As outlined above, FARA generally takes a holistic system perspective of agriculture that incorporates livestock with other commodities and seeks to facilitate sustainable growth based on the most appropriate mixes of enterprises.

However, recognising that there are some important issues, especially concerning disease and trade, which require dedicated research, FARA is working with the African Union's Inter African Bureau on Animal Resources (AU-IBAR), the International Livestock Research Institute (ILRI) and other stakeholders to advance an African Livestock Research Programme (ALive). The purpose of Alive is to help ensure that Africa does not miss out on the fastest growing global market for animal products. Growing populations, increased urbanisation and higher incomes are giving rise to rapidly growing absolute and relative demand for animal source foods. The prospects for ALive are encouraged by the volume and quality of contributions to this conference from research conducted in Africa. In turn ALive's objective is to source new and additional resources for research in African animal agriculture.

In conclusion, we reiterate that FARA is comprised of all stakeholders in agricultural research for Africa's development. Its programmes are thus owned and implemented by the SROs which established FARA and the whole diverse range of actors including NARS, regional research institutes, universities, CGIAR centres, non-CGIAR international agricultural research centres, NGOs and farmer and community-based organisations and most importantly the smallholders and pastoralists. The programmes described above are designed to enable them to get their feet onto the pedal for revving up the engine of Africa's development.

Facts and emotions in biotech: Towards efficient R&D capacity building targeting Africa's livestock related development issues

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Abstract

There is a growing knowledge gap between poor and rich countries, with a number of well-trained scientists emigrating to the north. Advancement in agricultural biotechnology in developed countries is putting pressure on policy makers to create an enabling environment for experimentation and adoption of biotechnology in Africa. To date knowledge and experiences of commercial biotech R&D capacity is increasingly located in a handful of transnational private companies. Publicly funded livestock related biotech research is rare and scattered. Capacity building is considered the most critical problem on the African biotechnology agenda. The urgent need to build a critical mass of the next generation of African scientists is obvious. Capacity building in biotechnology in livestock development is challenging because of the competing goals of conservation of genetic resources and the need for intensification. It is proposed that a South-South North-North task force mobilising a critical mass of research and development resources should act as a facilitator of change in this process. The paper concludes that only high quality African based research will enable long-term institutional partnerships at a global scale and contribute to development and conservation of the African livestock populations.

Key words: centres of excellence, networking, institutional partnership, quality management, benefits and risks of biotechnology

Introduction

African scientists recognised the critical role of science for development a long time ago (Odhiambo 1967) but investments in research and development (R&D) have remained very low, with sub-Saharan Africa investing only 0.2% of gross domestic product (GDP) relative to 1.7% in Asian countries (UNESCO 2004). Biotechnology, which is a rather complex recent scientific advancement, has been received with either over-optimistic expectations or emotionally driven negative attitudes by various policy makers. The current debate focuses on plant biotechnologies, which are further developed for commercial applications. In contrast, use of biotechnologies in livestock development is not a high priority on the agenda of capacity building efforts in developing countries. From a global perspective African scientists, with the exception of perhaps researchers in South Africa and Egypt, do not play any decisive role in R&D (UNIDO 2003) in Africa. Specifically a recent survey on agro-biotechnology application in West and Central Africa revealed that R&D institutions in plant and livestock biotechnologies (Alhassan 2003) are in their infancy.

Biotechnology in livestock includes established reproductive technologies such as artificial insemination (AI) and embryo transfer (ET), application of molecular markers for marker assisted selection or genetic characterisation as well as future applications (transgenic animals, products applied in nutrition and feed utilisation), vaccine development and disease diagnostics. In contrast to crop production farm animals play multifunctional roles in the African society. The transfer

and adoption of a single technology application may have a cascade of side effects, which need to be thoroughly assessed *ex ante*. For example, the routine application of AI resulted in indiscriminate crossbreeding and loss of identity of local strains through genetic erosion (Wollny 2003) Philippson (2000) observed inbreeding and direct threat to local breeds in wrongly designed development programmes in Kenya and the Sudan. Therefore, research and training for biotechnology in livestock production must be embedded in institutions that understand and facilitate the smallholder intensification process. This is probably one of the major reasons and justifications why ILRI revised its strategy (ILRI 2000) towards a much broader and interdisciplinary approach. The research agenda, the opportunities and challenges for improving efficiency of livestock production and conserving animal genetic resources through application of routine and new biotechnological methods are reviewed in numerous publications (Cunningham 1999; Nene et al. 1999; Ruane and Zimmermann 2001; Madan 2005).

We do not need to discuss whether or not agricultural biotechnologies will be used but how we are going to manage them, which priorities should be set and which alternatives should be promoted for sustainable livestock development in Africa. Assessing the chances and risks of any biotechnology requires sound knowledge and the ability to critically differentiate between scientific facts, commercial interests and public perceptions. This is becoming more and more difficult as research and commercial development in the industrialised and countries in transition are largely being driven by a globally operating private sector.

Can we learn from the genetically modified organisms (GMO) debate?

A critical review of the ongoing global debate on the use of GMOs in crop production may provide some lessons for the discussion on the use of biotechnologies in livestock production. Three major points should be raised. Firstly, we should be aware that the needs and demands for agricultural biotechnology in Africa are different from those of industrial countries which are plagued by food surplus and food safety issues. Secondly, the generally high standard of living allows industrialised countries to debate issues at length without experiencing any negative consequences on basic supplies. Can we then dictate to developing countries how to set their priorities? Thirdly, it is acknowledged that the debate on GMOs and modern biotechnologies is not just a scientific debate but is inherently ethical in nature.

It is obvious that information, knowledge and training on specific and in-depth problem analysis and on interdisciplinary aspects are required. Technical solutions might appear to be obvious and straightforward to resolve persisting development challenges such as food security. Modern biotechnology creates uncertainties about the benefits and risks of existing biotech routines, future technologies or the potential impacts. The underlying dependencies and interactions, therefore, need a thorough and objective assessment. Crucial elements in the public debate are trust and independence. In the seed sector, for example, licensing agreements create new dependencies between large- and small-scale plant breeders and farmers. These issues require, therefore, that scientists and stakeholders get involved in an institutionalised African based bioethical consultation process to develop their own priorities. Scientific entrepreneurs from Ethiopia, Kenya, South Africa or Zimbabwe, which prepared national strategy papers for biotechnology research (Eicher 2003), could jointly initiate such a process. An obvious prerequisite is that knowledge, information and training on critical problem (impact) analysis is provided. The United Nations Environmental Programme (UNEP) has emphasised the need for a public genetic literacy campaign on the implications of GMOs for crop and food security (IAC 2004). FARA (2003a) stressed the need for capacity building in terms of both human and physical facilities in biotechnology and identified the following basic issues:

- The state of knowledge on biotechnology in various regions/countries
- Need versus technological applications
- The state of biosafety regulations/phytosanitary structures
- Capacity for handling intellectual property rights
- Sources of knowledge and information dissemination.

Public knowledge and perceptions

Public perceptions and consumer attitudes are important factors in the decision making process of policy makers in democratic societies (UNESCO 2003). In contrast to industrialised countries no representative surveys on public perceptions of biotechnology in general or in agriculture are available for African countries. Recently, the Department of Science and Technology of the Republic of South Africa published the first representative survey results based on a sample of 7000 interviews on the public understanding of biotechnology (PUB 2005). The survey clearly shows that most of the general public is uninformed and the few who were able to express an opinion were equally negative or positive on the use of biotechnology (GMOs, genetic engineering and cloning). On food labelling only 1% specified that they would like to see information on GMO content and an equal 1% was interested in organic certification. An in-depth analysis of the report results show that weak but positive and significant correlations exist between knowledge of biotechnology and Internet access or income level. Universities (23%) came out as the most trusted institution to provide credible information on biotechnology but media (21%) followed closely. Industry is not trusted and ranked last after government (16%) and religious groups.

The responsibility to educate the public, to inform stakeholders and advise policymakers is a genuine responsibility of the public research sector. A fair, unbiased and scientifically sound debate on existent and future use of biotechnology in agriculture and specifically in livestock development is not possible without a critical mass of well-trained African scientists. A sound knowledge base must be created and coordinated if the research agenda is to be set by Africans for Africa.

Livestock related biotechnology and technology capacity development

Brain drain undermines the capacity building efforts of national, regional or international initiatives and programmes in today's Africa (IAC 2004). It has crippled many African universities that are struggling to build high-quality postgraduate programmes. The successors of the first generation of agricultural scientist are becoming demoralised by the poor conditions of service and low return rate from overseas of many academics. The quality of higher education has declined due to massive brain drain by lecturers, scientists and researchers (World Bank 2002). The underlying causes for the situation may differ in countries such as Ethiopia, Benin, Malawi, South Africa or Zimbabwe but the result is that the overall quality of scientific output of the national agricultural research systems (NARS) is rarely competitive at international level. Initiatives such as the Higher Education Quality Management Initiative Southern Africa (HEQMISA) address quality management in training and research capacity building in the Southern Africa Development Community (SADC) (Wollny 2005).

An estimated 23,000 qualified academic professionals emigrate from Africa each year in search of better working conditions (FARA n.d.). It is estimated that about 30% of highly trained Africans reside outside of Africa. Over the years of economic stagnation or civil unrest the large majority of trained and highly skilled persons have left the continent and will never return (Eicher 2003). For example, the Animal Science Department of the University of Zimbabwe has lost 50% of its

professors and lecturers to other countries over the last five years (Wollny, own observations). A recent internal survey among German universities revealed that there are very few German postgraduate students engaged in development-oriented agriculture (Bosch, German Agency of Technical Cooperation, GTZ, Senior Planner, personal communication). The implications could be that scientific interaction and joint projects will be reduced in future and less development-oriented agricultural research projects will be financed. Future networking and understanding of South-North issues and problems will be negatively affected by this trend at working level. We therefore need to acknowledge that there is a global market for advanced human capital and working terms and conditions are central to the migration of talent.

The current debate on the use of existing and future products and processes of biotechnology in agriculture is characterised by extreme pro- (http://www.ifoam.org) and anti-biotechnology positions (for an example of a very critical statement see Mayet 2004) at the level of scientific research, higher education and training and policy making. Due to the enormous implications of modern biotechnology on social, ethical, environmental, trade and economic issues of the highly diverse African farming systems (Dixon et al. 2001) it is often very difficult to differentiate between facts and emotional arguments. This scenario calls for an informed debate to enable policy makers, farmers and the society to respond to biotechnology developments. As a logical consequence NEPAD (2005) proposes to establish a high-level African Panel on Biotechnology (APB) to facilitate multi-stakeholder dialogue. The implementation of such an ambitious and important plan would require a critical mass of leading scientists and scholars, which does not exist in most countries. The analysis of various directories and compendia on higher education, research and training including agricultural research show clearly the need to enhance the quantity and quality of human resources (FARA 2002; Teffera and Altbach 2003; IAC 2004).

In their analysis of African institutions of agricultural science and technology Roseboom et al. (2003) identified the following six constraints, of which three are directly related to capacity building and knowledge creation:

1. Most African countries have no overall strategy through which agricultural science and technology (S&T) could systematically help to enhance agricultural productivity.
2. Investments in agricultural research have been stagnant for the past 20 years and donor dependency continues to be high.
3. Investments are poorly targeted.
4. Agricultural research capacity is extremely disjointed because of geopolitical and institutional fragmentation, which causes duplication and creates coordination problems.
5. Poor quality management of research and development.
6. Knowledge diffusion among farmers, researchers and extension staff is a very critical bottleneck that dulls the impact of S&T.

The overall picture is that growth rate in research staff in sub-Saharan Africa has exceeded that of expenditures for the past 30 years. In 2000 expenditures were only half of what they had been in 1971 with the exception of South Africa, where indicators show a more balanced pattern.

During the past five years, several organisations specifically addressed in their statements and work plans the need for investments in agricultural S&T capacity building (FARA 2003a; NEPAD 2005). The role that NEPAD can play in facilitating political commitment for investing in agricultural research and capacity building was also recognised. A solution is required that comprehensively addresses the curricula of generations of students and agendas of researchers.

Obviously agricultural biotechnology is an essential part of NEPAD's ambitious continental scale projects.

The human capacity resource

Reliable and recent statistics on agricultural research are difficult to find. Roseboom et al. (2003) estimated that Africa has 18,000 to 19,000 full-time-equivalent (FTE) agricultural researchers, of which Egypt has the largest share with about one-third of the FTE followed by South Africa and Nigeria with some 1,000 FTEs each. In a sub-sample of 13 countries 18% of the FTEs conducted livestock research and about a half were involved in crop research. Government is the most important employer followed by the higher education sector. The currently available statistics provide information on quantitative indicators but not on priorities, output or quality of the research conducted or knowledge created. For some countries information has been made available recently through publications of Agricultural Science and Technologies Indicators (ASTI) (www.asti.cgiar.org/profiles.cfm).

At the time of the independence movement in Africa fewer than 10 universities each had a handful of students enrolled on the entire continent. Starting from scratch African universities experienced impressive growth and in some countries a diversified education sector of higher learning recently emerged. However, the current magnitude of the scientific community could be described as a miniscule fraction of the international mass of scientists in all fields and sectors (Teferra 2003). Therefore, it is not surprising that not one African university is listed among the 100 best universities in international rankings (Teferra, Association of African Universities, Ghana, Director, personal communication). Scientific Citation Indices (see for example ISI, www.isinet.com) reveal that African-based journals contribute to mainstream international science rarely and probably less than 0.5%. An Internet-based search for specific articles published in African journals (www.ajol.info) and related to the topic of this conference yield very few results. Presumably a relatively large quantity of knowledge is in grey literature. The situation becomes even more alarming when we look into at postgraduate training facilities in the biological or agricultural sciences. A survey (Alhassan 2003) of agro-biotechnologies among Central and West African countries revealed that a large percentage of NARS laboratories do not function. The major constraint identified was lack of training and manpower followed by infrastructure problems. In the livestock sector projects, which are related to animal health (vaccine development, molecular diagnostics) and reproduction (embryo transfer in cattle) are negatively affected by non-functioning laboratories due to inadequately trained manpower. An inventory of existing and planned human resources is therefore necessary.

Numerous recommendations and statements emphasise the need to create and retain a new generation of agricultural scientists and to strengthen institutional capacity (IAC, 2004; FARA 2003a, 2003b). There is consensus that more investment is needed and a huge effort is necessary to cope with the complexity of modern science-based technologies. The IAC report (2004, p. 233) recommends targeting national governments, NARS (including universities) and the CGIAR centres for creating and retaining a new generation of agricultural scientists. The time frame for initial impact would be medium term (5 to 10 years). However, a concrete action plan supported by financial commitments or actual programmes is lacking (see reprinted letter by Kofi Annan, IAC 2004).

Institution building

Several African countries started to offer postgraduate programmes in the last 15 to 20 years (Sundstol et al. 2001; Wollny et al. 2002). Therefore, it is not unexpected that within the NARS the importance of university-based research is growing having reached a share of 12% in low capacity countries (<100 FTE) to 38% in countries employing more than 1000 FTE (Roseboom

et al. 2003). Securing funding for university expansion and partnership programmes appears to be highly successful if it can be linked to broader issues such as higher education reform to support democratisation etc. (Eicher 2003).

The IAC (2004) states that more effective institutions are required to improve agricultural productivity and food security. The most promising strategy and the key to innovation are the creation of research centres of excellence. African bodies and fora endorse this concept (FARA 2004), which was previously proposed for Africa by Odhiambo (1967). In tertiary education the concept of 'centres of excellence' improves the capacity of agricultural professionals through better training and more relevant research in Southern Africa. Such centres provide the opportunity to allocate and pool scarce human and financial resources. Successful projects and effects were reported for postgraduate training in SADC by Wollny et al. (2002) or elsewhere in other disciplines (Heyns 2005). The introduction of a new layer of institutions is not sustainable for obvious financial reasons and that is why existing universities or research should host such centres. It is only through such integrated centres of excellence and regional specialisation that the critical mass of knowledge and expertise for training and research can be created. In livestock related biotechnology research ILRI is obviously the best choice for hosting such a centre at the supraregional level. Further centres should be linked to universities or research institutions, which have a record of or the capacity to have a regional impact. The universities of Pretoria, Bloemfontein or Stellenbosch in the Republic of South Africa, which are historically well developed, have the potential to become important and active partners by becoming more involved in the African development process.

What should be done?

Apart from inadequate numbers of high-level African researchers there is also a severe quality problem (Eicher 2003; Ngwira et al. 2003). Lack of political commitment of African leaders on investment in agricultural and livestock related research in combination with erratic donor aid (Wollny et al. 2002) contributed to the low performance of the NARS as mentioned before. Most of the research and many of the university programmes are not internationally competitive thus preventing potential scholars from pursuing rewarding careers. Despite the constraints at various levels (policy, funding, infrastructure, good governance and donor dependencies), Africa-wide efforts are underway to link institutions, to conduct consultations at various levels, to solicit funding and to launch task forces on broad issues and overall themes. To achieve measurable impact some suggestions are given for an action plan, which could be speedily implemented.

Targeting livestock development related issues places research in an application-oriented context. Mutual research partnerships are the method of choice to develop relevant knowledge base and impact-oriented research programmes. Ideally this activity should be driven by mutual interest and decided at all stages on an equal footing. The reality, however, shows that proposals are often designed and evaluated mainly by the North. Impact-oriented research requires a clear definition of the objectives. Understanding of the biology of domestication, origin and development of breeds, characterisation and possible utilisation of biodiversity and conservation programmes requires a large range of biotechnologically derived tool boxes just to a name a few general topics as outlined by Hall (2004). Mutual research programmes built on trust and shared responsibilities avoiding the situation of an unbalanced partnership would be in a position to develop sustained capacities. Comparative advantages of partnerships could serve as 'lighthouses' locally and regain or attract even more and new scientists and researchers. The scale of the programme is probably less important than its quality in achieving momentum. It is recommended to setup a small but powerful group of internationally experienced scientists and scholars to facilitate, advise and monitor a concrete action plan. This committee, ideally an interdisciplinary

task force consisting of outstanding scholars from various developing (South) and industrialised countries (North) could closely cooperate with existing institutions (FARA and NEPAD) to ensure relevant and high-level implementation of existing visionary strategies.

The following innovations are proposed:

- Short kick-off seminar and multi-stakeholder workshops on biosafety and assessment of risks and chances of biotechnologies. These fora should involve excellent residential and non-residential African scholars speaking on themes related to application of livestock biotechnologies and biosafety, to attract and motivate young scientists. They could be in the form of 'summer schools', which are often supported by a number of bilateral foundations.
- Mutual partnership in postgraduate training (MSc and PhD). Strengthen ILRI's graduate fellowship programmes through integrating universities from the North and through active soliciting for funding. Capacity building grants on research and training for livestock development through application of biotechnologies should be offered on a competitive basis.
- Propose a research grant scheme, 'Modern applications of biotechnology' for postdoctoral fellows. In Germany DAAD, Volkswagen Foundation or a private foundation in cooperation with the Federal Ministry of Education and Research are possible partners for mutual research and training projects from 6 to 24 months.
- Develop curricula for MSc and structured PhD modules, 'Biotechnology in Animal Science', which eventually leads to a full degree programme hosted by a regional centre of specialisation in collaboration with leading research centres.
- Integrate North-North and South-South learning experiences to be based on specific problem oriented research issues. Such an experience, which involves international scholars and students from various continents, will create momentum for understanding Africa's challenges in livestock related development.
- Development of comprehensive long-term high-level capacity building programme. Create a symbiotic relationship between postgraduate (overseas) training, incentives, brain drain and capacity building in developing countries. Regaining young scientists and delivery of high quality research can only be successful if there is a comprehensive package consisting of monetary and non-monetary incentives (scientific infrastructure, mentoring, alumni networking, partnership programmes etc.) available.

Funding

The above listed human resource development programmes are not expensive. A PhD student accepted by an innovative sandwich programme (e.g. 18 months conducting research in Africa, 18 months residential at a German university) costs between US$ 35,000 and 40,000, including travel. For one MSc student trained overseas in a sandwich programme or in Africa, 50% of this amount would be sufficient. Africa- or Asia-based regional postgraduate programmes differ widely between US$ 18,000 for an MSc to US$ 50,000 for a PhD student. Such figures, however, do not include development of programmes, infrastructure development, research expenditures or laboratory equipment.

The establishment of competitive and sustainable regional postgraduate programmes in animal science including basic infrastructure improvement requires a modest investment of three to five million dollars over a decade (Wollny, unpublished data). This includes scholarships, equipment, overseas training, staff development, guest lectures and international travel but not specific high-tech equipment (e.g. sequencer). Given the scope and future importance of livestock in Africa (Jutzi 2003) the investment in research and training capacity building should not stress simply estimated returns to investment in livestock related research (e.g. training in molecular genetics

to characterise and develop breeds) but emphasise the strategic aspects of payoffs in extension and higher education. In other words a systems approach must consider African higher education and human capital. Anything else is would not be sustainable and would increase rather than decrease the dependency on commercially or donor driven applications in livestock production.

Conclusions

African policies must support the creation of a critical mass of well-trained African researchers and educators, who are willing and able to work together. Maximising potential benefits of biotechnologies and assessing biosafety through innovative programmes require implementation of an impact-oriented strategy. Training and research programmes built on regional and international mutual partnership and networking programmes could become milestones in an effort to create a fact oriented and emotionally positive climate for further investments in development in Africa. All these are prerequisites for a fair assessment of chances and risks of biotechnologies but also for the fair assessment of alternative approaches.

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Need for the development of regional capacities in biotechnology to improve livestock production in West Africa

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Abstract
Livestock breeding is an essential activity in West Africa. However, its productivity is usually low and it cannot provide enough food to meet the needs of a growing population. To improve livestock productivity, it is necessary to face numerous constraints that could be resolved by research and development activities based in part on biotechnology tools. Different researches using biotechnology tools are conducted in CIRDES on the genetic characterisation of local breeds, parasites and vectors to improve animal health and production. However, all these researches cannot be performed in full at CIRDES or in any other West African institute. Human resources and equipment are not sufficient to achieve the objectives of the research programmes. Building a biotechnology platform in West Africa, with the required equipment and the trained staff in the national agriculture research systems of the sub-region, could solve this problem.

Key words: animal health, animal production, biotechnology, building capacity, training, regional platform

Introduction
Livestock breeding is of great importance in Africa. Livestock provide human populations with food, draft power, livestock products and income. However, livestock productivity is too low to meet the needs of human populations. Indeed, meat and milk production (per kg and per inhabitant) was respectively 9 and 19 in sub-Saharan Africa in 1993, whereas it was 34 and 93 in the world and 21 and 39 for developing countries (Delgado et al. 1999). Furthermore, the average growth rate of 3% in livestock production between 1985 and1994 (ILRI 2000) was insufficient to keep up with human population growth. Other noteworthy data about meat and milk shows the deficit of animal protein production: in 1993, West Africa countries did not export any meat whereas they imported 92,996 t of meat, equivalent of US$ 118 billion. Milk exportation was 722 t (by Senegal) but importation rose to 851,116 t (US$ 276 billion) (ILRI 2000). These figures show the extreme lack of productivity of livestock in western Africa. It is estimated that milk and meat production should increase by 4% to satisfy the demand of a growing population with low income (CTA 1997).

Research and development activities are urgently needed to increase livestock production, which will in turn compensate for the food deficit experienced in much of sub-Saharan Africa. These activities will face the various constraints that hamper production. These constraints are technical (environmental factors and animals genotype), political and institutional.

Constraints to livestock breeding
Technical constraints are linked to environmental factors, intrinsic factors and management practices. Environmental factors that hamper livestock breeding development are climatic constraints, with limited feed and water supply (in quantity and quality), and strong pathologic

pressures from infectious and parasitic diseases. In western Africa, animal keeping is usually extensive and the available resources determine the production level of the livestock. The animals feed on local plants species that are generally of poor quality, with no food supplements. Among the pathological constraints in subhumid areas is trypanosomosis, transmitted by the tse tse flies; this disease strongly limits livestock productivity. The deficit in meat and milk production associated to trypanosomosis is assessed respectively at 0.5 billion tonnes and 1.6 million tonnes per year in sub-Saharan Africa (Winrock 1992). The benefit expected from the control of animal trypanosomosis corresponds to US$ 700 billion worth meat and milk production per year in the region. Moreover, other diseases hamper livestock development such as contagious bovine pleuropneumonia, small ruminant pests and tick-borne diseases. African porcine pest and Newcastle disease must also be controlled to increase pig and poultry productivity.

In addition to these environmental factors, the lack of intrinsic productivity of local breeds is a limiting factor. Western Africa is rich in livestock breeds. For instance, two breeds of cattle exist, the taurine and the zebu, and they are themselves subdivided in numerous local strains. These numerous breeds have different features and assets. Indeed, zebu breeds are well adapted to dryness, low quality forage and have potential for milk production and draft power. However, these breeds are very sensitive to diseases such as trypanosomosis and dermatophilosis in the subhumid or humid areas. Conversely, taurine cattle are able to survive and produce under trypanosomosis pressure but they are not productive from a dairy point of view and their small size makes them less attractive for draft than zebu cattle.

Currently, qualities and inadequacies of local breeds are little-known and their assets are not fully exploited. The use of genetic resources is not optimal and livestock productivity could be improved through a rational use of genetic resources. Moreover, due to this lack of knowledge and poor development some breeds (e.g. Somba, Lagunaire and Kuri) are threatened with extinction. Others, such as Pabli in Benin, have already disappeared. However, breed diversity constitutes biological capital for farming development. Genetic diversity between breeds and among breeds is key to their survival and their ability to adapt to environmental changes—climatic, pathological or socio-economic. Therefore, it is essential to characterise local breeds in western Africa, to preserve and develop them depending on their qualities.

Role of research

Opportunities brought by biotechnologies

These constraints to livestock breeding could be faced by adapted research activities. Strategies for research must focus on these crucial areas: feed supply, animal health and genetic improvement (Winrock 1992).

The ingenious use of biotechnologies, genomic or reproduction technologies, in association with traditional methods in veterinary and animal husbandry sciences, should contribute to raise the constraints on livestock breeding. In developed countries, the increase in livestock production has resulted from the establishment of technologies to increase productivity. Molecular biology brings major tools of research in biology with results in terms of fundamental or applied research. This research area is in constant evolution; tools and methods progress and new perspectives concerning livestock breeding appear (FAO 2004).

Biotechnology brings significant results in various research areas in animal health and production: i) epidemiology by the characterisation of pathogen agents and vectors with consequences on the establishment of fighting methods or control of associated diseases; ii) the establishment of new

diagnosis tools and vaccines; iii) the characterisation of livestock populations to conserve and develop genetic resources; and iv) the characterisation of genetic markers associated to production or resistance to diseases traits to set up markers assisted selection programmes. Reproduction techniques, using artificial insemination, embryos transfer and multiple ovulation, accelerate the genetic progress, allow the import of genetic resources with the limitation of sanitary risks and contribute to the conservation of genetic resources.

Some activities conducted in CIRDES

CIRDES (Centre International de Recherche Développement sur l'Elevage en zone Sub-humide) is conducting research activities using biotechnology tools. Basic techniques in molecular biology and immunology tools are often used for genetic characterisation of livestock populations and its use in conservation decision-making, and also for epidemiology and diseases control purposes. CIRDES performs several molecular biology techniques to improve the diagnosis and characterisation of pathogen agents such as trypanosomes. For instance, the use of PCR-RFLP techniques led to appreciate the extent of the genetic diversity of *Ehrlichia ruminantium,* the causal agent of cowdriosis, one of the major diseases studied in CIRDES. The genetic diversity of strains of *E. ruminantium* is the only obstacle to the development of an efficient vaccine. To overcome this problem, it will be necessary to sequence the strains of interest.

PCR-RFLP techniques are also used to study the mtDNA diversity of various species, like tilapias. Besides, CIRDES is currently performing research on the population genetics of tsetse flies using microsatellite markers. Indeed, populations of riverine species of tsetse flies are strongly fragmented in the subhumid areas by environmental changes due to climatic and anthropic factors like cotton culture. The knowledge of the structure of the population will contribute to assess genes flows between populations and therefore estimate the chance to eradicate tsetse flies locally and help to avoid recolonisation. Such a tool of genetic characterisation is essential in the context of the PATTEC (Pan African Tsetse and Trypanosomiasis Eradication Campaign). Moreover, research on trypanotolerance and gene expression using the SAGE (Serial Analysis of Gene Expression) technique provides the opportunity to understand the genetic basis of trypanotolerance. Initial results provide interesting data on gene regulation during a trypanosomal infection of tolerant and sensitive breeds (Berthier et al. 2003). The final aim of this research is to perform markers assisted selection or crossing programmes to associate trypanotolerance and productivity (for instance milk production traits).

CIRDES has also a strong experience in reproduction physiology of local breeds (Baoule, Zebu and Somba). The technology of animal training, semen and embryo harvest, preparation and storage are mastered. Currently, a lot of semen and embryos are stored in CIRDES.

Insufficiency of the centre capacities

Establishing such research programmes in western Africa is difficult. The required equipment is not available in CIRDES or in a close research institute in the region. The analysis of microsatellite markers for tsetse flies is performed with inefficient and old techniques. Denaturating gels of acrylamide urea are used, with silver nitrate revelation of PCR products. However, this technique is inferior to the use of an automatic sequencer. The technique is also less reliable and requires multiple manipulations (use of families to check the Mendelian inheritance of the guessed alleles). It is expected that, using this technique, 5 years will be necessary to perform work that would require only 1 year in an institution with modern equipment. In addition, other analyses cannot be performed in CIRDES, such as the different steps of the SAGE technique that requires specialised rooms to treat ARN materials and avoid contamination at the various steps. CIRDES staff members are therefore not involved in the molecular biology manipulations denying them the opportunity of any intellectual benefit.

CIRDES also receives requests from national agricultural research systems (NARS), universities or research consortia to carry out genetic characterisation of numerous species. Unfortunately, the Institute does not have sufficient material and human resources to fulfil such large requests. In addition to these research needs, NARS and universities need also to train students. For instance, a masters in biotechnology has been created in Ouagadougou University, but practical work cannot be done because of the lack of sufficient material. CIRDES has students in biotechnology every year, but again the need exceeds the training capacity.

Finally, many analyses using molecular biology tools and reproduction technology cannot be performed in western African. Researchers with the required competencies are based at CIRDES but the lack of capacity building prevents them from running research programmes that could improve livestock production. A scientific gap grows due to lack of investment in developing scientific and managerial capacity (Wilson et al. 1995). Western Africa does not have the research capacities in biotechnologies that are equal to its ambition. This lack of resources has led to some researchers leaving the region to avoid losing their knowledge creating a further challenge to the establishment of research-development activities needed to increase livestock production and therefore food security, and alleviate poverty.

Conclusion

Research and development activities must be undertaken to increase animal production in western Africa, and biotechnology techniques may contribute to this improvement. Unfortunately, western African institutions do not have the required material and human resources to meet the needs of this research.

However, the potential exists; research centres, like CIRDES, have already mastered the basic techniques in molecular biology, immunology and reproduction. Moreover, the international community has a keen interest in biotechnologies and numerous initiatives are ongoing from WECARD (West and Central African Council for Agricultural Research and Development), the African Union, NEPAD (New Partnership for Africa's Development), and FARA (Forum for Agricultural Research in Africa). The NARS are also conscious of the need to develop biotechnology in the region: in the latest ITC (International Trypanotolerance Centre) Newsletter (n°3/4 2004), NARS Directors clearly recommend that the research orientations of CIRDES and ITC include the genetic evaluation and the use of biotechnologies to improve production systems. The purchase of an automatic sequencer would immediately pay for itself through the genetic characterisation studies of livestock species, pathogenic agents (*E. ruminantium*, trypanosomes…) and vectors (tsetse flies). Teams working on human health and agriculture could also use such a tool.

It is time for donors to investment in the establishment of long-term projects, particularly in genetic improvement programmes. Moreover, training needs must be taken into account and supported by fellowships. Western Africa must be supported to develop its own research capacities, in term of human resources (researchers and technicians) and equipment.

It is also necessary to develop and support a regional structure that will provide benefits to the whole region. A network in biotechnology, with a strong association between the regional centre, the NARS, the universities and international centres like ILRI, will stimulate research and contribute to the emergence of strong competencies. CIRDES has already taken initiatives in this direction and proposed such a project of biotechnology network to various donors.

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Capacity of Nigerian national institutions to conduct biotechnology research to improve livestock productivity

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Abstract
Biotechnology development has been the subject of interest in Nigeria over the past decade. As part of the study by the International Livestock Research Institute (ILRI) sponsored by the US Agency for International Development (USAID) to investigate the development and/or prospects of biotechnology tools as applied to animal science research in Nigeria, a survey aimed at assessing biotechnology capacity of Nigeria for animal research was conducted between June and July 2004. The survey used a structured questionnaire, interviews and personal visits to some universities, polytechnics and national research institutions situated in strategic locations in Nigeria. Though a general deterioration of facilities in most universities was noted, there are quite a number of institutions identified to be capable of applying some biotechnology tools to improve animal production in Nigeria. There are well-trained Nigerian researchers in the country who when supplied with tools in biotechnology and financial support to carry out well-focused or coordinated research can help propel the country towards self-sufficiency in animal production. The role of ILRI and development investors like USAID in making significant intervention in the attainment of this goal is highlighted.

Introduction
Nigeria is strategically located in sub-Saharan Africa and its contribution to total agricultural production in the region is very significant. In spite of the growing importance of oil, Nigeria has remained essentially an agrarian economy. Agriculture still contributes a significant share of the gross domestic product and total exports and employs the bulk of labour force.

Nigeria's crops and livestock resources are very diverse. Where there are cattle, there are sheep and goats that have adapted to the ecological constraints of the Sahel and Sudan Savannah zones. The rest of the cattle, sheep and goat population that are made up of the indigenous dwarf breeds are found in the Guinea Savannah and Forest zones. Various local and exotic breeds of pigs are found in different areas of the country. All over Nigeria there is a large population of poultry, especially the indigenous breeds reared under free-range conditions. Commercial production of poultry and pigs takes place throughout the country. Conversely, fishery is mainly restricted the artisanal sector where the coastal and brackish waters constitute the major areas of production followed by inland rivers and lakes. Production from aquaculture is still very low although Nigeria ranks first in total fish production in sub-Saharan Africa. Nigeria's contribution to the annual fish production in sub-Saharan Africa was estimated at 17,700 t (the largest, followed by Madagascar, 5,100 t and Zambia, 4,700 t) in 1997, coming mostly from *Clarias*, *Heterobranchus*, tilapia and carp in small-scale aquaculture farms (Machena and Moehl 2001).

During the last few decades, especially in developed economies, the use of biotechnology has contributed to increased agricultural efficiency. The International Livestock Research Institute (ILRI) recognises that biotechnology can complement traditional animal science methodologies to improve livestock and fish productivity. However, there is a need for baseline information

about Nigeria's work force and infrastructure capabilities to conduct biotechnology research. This survey was therefore conducted to assess the capacity of national institutions to implement work on biotechnological options to improve livestock production and to determine the type of linkages with regional and international institutions that should be promoted to ensure the success of such research.

Methodology

Nigeria has over 30 universities supported by the Federal Government or state governments. There are over 100 research institutions distributed all over the country. A total of 31 national institutions were chosen for the study because of size and corresponding larger government subventions and reported biotechnology facilities or inclination, e.g. federal universities and polytechnics, state universities and national research institutions in 13 states in South West, Middle Belt and Northern zones (Figure 1). Questionnaire surveys combined with institutional visits and interviews of officers and researchers were carried out during the one month period between 28 June and 27 July 2004 to identify:

- Number of personnel involved in livestock biotechnology and related work
- Level of training of the personnel
- Infrastructure in the institutions (laboratories, equipment etc)
- Partnerships or linkages with other national, regional and international institutions

Data collection and analysis

The institutions were sorted into five groups, namely research institutes, state-owned universities, federal universities, polytechnics and the National Biotechnology Development Agency (NABDA, the national biotechnology policy coordinating agency). During the visits, the information obtained was recorded in journals and exhaustively discussed at the end of each day. A summary of the information obtained is presented as 'Consultants' report of field visits'.

Responses to the questionnaires were collated and grouped into the 13 states surveyed. In some institutions, there was more than one respondent. Responses were compared using Microsoft Excel. However, most of the respondents did not completely fill out the questionnaires.

1. NVRI (National Veterinary Research Institute), Vom
2. FIIRO (Federal Institute of Industrial Research), Lagos
3. SHETSCO (National Advanced Laboratories, Sheda Science and Technology Complex), Abuja
4. NAPRI (National Animal Production Institute), Zaria
5. IAR&T (Institute of Agricultural Research & Training), Ibadan
6. NACGRAB (National Centre of Genetic Resources and Biotechnology), Ibadan
7. CRIN (Cocoa Research Institute), Ibadan
8. NIOMR (National Institute of Oceanographic Marine Research), Lagos
9. NIFFR (National Institute of Freshwater Fish Research), New Bussa
10. LAUTECH (Ladoke Akintola University of Technology), Ogbomosho
11. DELSU (Delta State University), Abraka
12. OOU (Olabisi Onabanjo University), Ago-Iwoye
13. AAU (Adekunle Ajasin University), Akungba
14. LASU (Lagos State University), Lagos
15. UNILORIN (University of Ilorin)
16. FUTMINNA (Federal University of Technology), Minna
17. UNIBEN (University of Benin)
18. UNIABUJA (University of Abuja)
19. UNILAG (University of Lagos)
20. UNAAB (University of Agriculture, Abeokuta)
21. ABU (Ahmadu Bello University), Zaria
22. ATBU (Abubakar Tafawa Balewa University), Bauchi

22 a. FEPA ZERI (Federal Environmental Protection Agency/Zero Emission Research Initiative) ATBU, Bauchi

23 UNIJOS (University of Jos)
24 UNAD (University of Ado-Ekiti)
25 UI (University of Ibadan)
26 OAU (Obafemi Awolowo University), Ile-Ife
27 FUTA (Federal University f Technology, Akure)
28 FED POLY (Federal Polytechnic), Ado-Ekiti
29 FED POLY (Federal Polytechnic), Offa
30 FED POLY (Federal Polytechnic), Bida
31 NABDA (National Biotechnology Development Agency), Abuja

Figure 1. Map of Nigeria showing the institutions (box) surveyed.

Results

Consultants' reports and field visits

Personal interviews of researchers from 31 institutions visited and physical inspection of the facilities and equipment were summarised in a detailed report (Omitogun and Osoniyi 2004) submitted to ILRI-Ibadan. The report included photographs of idle biotechnology equipment in the various institutions. The equipment was unused because of lack of funds for maintenance or lack of consumables.

Questionnaire analyses

There were more than 50 respondents from the 31 institutions surveyed, however, not all answered the 10 questions:

1. General information

Everybody gave their names and qualifications and most had an e-mail address. They all wished to be part of a biotechnology research network, to be able to 'stay in touch' or learn about opportunities, e.g. training, workshops or conferences.

2. Biotechnology tools

Only a few answered this question suggesting that there are no facilities for biotechnology tools. The institutions that have biotechnology facilities are listed in Table 1. More details are available in the final report (Omitogun and Osoniyi 2004).

2.1 Other facilities

All the universities, research institutions and state-owned universities have moderate to large animal farms (or houses, e.g. poultry house, pig pens, snailery). However, most of these have been converted into commercial enterprises to generate income for the respective departments. Some have extension services and surgical facilities. Only ABU Zaria and SHETSCO claimed to have containment facilities.

Table 1. The Nigerian institutions among the 31 institutions surveyed that are currently doing biotechnology research.

Institution	Genetic markers	Genetic engineering	Breeding	Diagnostics	Bioin formatics	Others
UNILORIN					Sequence analysis	
NAPRI			Artificial insemination			
NVRI, Vom				PCR-based		Vaccines
OAU, Ile-Ife	Protein markers					Tissue culture
UNAAB	RFLP, Micro-satellites		Artificial insemination			Training
ABU, Zaria				.		Training
FUTA				ELISA for mycotoxins		
Olabisi Onabanjo U		Plasmid isolation				
FEPA/ZERI						Bio-composting Herbal medicine
NACGRAB						Biodiversity Tissue culture

2.2. Biotechnology research application focus

Very few of the respondents answered these questions. The current focus of biotechnology research activities at some of the institutions is listed in Table 2.

Table 2. Nigerian institutions with their livestock biotechnology focus.

Institutions	Biotechnology focus
1. UNAAB Biotech Center	Training
2. UNAAB Animal Breeding and Genetics Department	Marker-assisted breeding, biodiversity
3. OAU Animal Biotechnology Laboratory	Biodiversity, characterisation, conservation
4. NACGRAB	Biodiversity: seed conservation, gene bank storage
5. FUTA	Feed development and enhancement, diagnostics
6. LAUTECH	Biofertilisers, feed development
7. UNILAG	Bioremediation
8. NAPRI	Genetic improvement of livestock breeds
9. NVRI, Vom	Vaccine production
10. Federal Polytechnic, Ado-Ekiti	Feed and food processing, alternative feeds (plasma protein and blood meal)
11. UNILORIN	Diagnostics, marker-assisted breeding
12. FEPA/ZERI	Biogas, insecticide and acaricide extractions
13. UI Department of Veterinary Medicine	Animal diseases diagnostics
14. UNIBEN	Biodiversity, marker-assisted breeding
15. FIIRO	Aflatoxins in food and feeds
16. NIFFR	Hybrid and polyploid catfish, wildlife and range conservation biology

2.3. Animals or micro-organisms you have worked on/are currently working
The research species being used in the different institutions are listed in Table 3.

Table 3. Institutions that were doing livestock research and their research species.

Institutions	Research animals/micro-organisms
1. UNAAB Biotech Center	Fermentation organisms
2. UNAAB Animal Breeding & Genetics Department	Poultry, small ruminants
3. OAU Animal Biotechnology Laboratory	Pigs, *Clarias*, rural poultry
4. NACGRAB	Cryopreservation of sperm of fish
5. FUTA	Bacteria for feed enzyme production
6. LAUTECH	Rabbits, ruminants
7. UNILAG	*Pseudomonas etc*.
8. NAPRI	Cattle, small ruminants, poultry
9. NVRI, Vom	All livestock for disease diagnostics, microbes causing diseases in livestock, e.g. *Clostridium, Staphylococcus*, ectoparasites
10. Federal Polytechnic, Ado-Ekiti	Feeds, animal blood for plasma protein
11. UNILORIN	Ruminants, poultry
12. FEPA/ZERI	Herbal plants, *Pleurotus* (mushroom), *Bacillus*
13. UI Dept of Veterinary Medicine	Poultry, horses
14. UNIBEN	Ruminants
15. FIIRO	*Bacillus, Salmonella etc.*
16. NIFFR	*Clarias* and *Heterobranchus*, wildlife

2.4. Biotechnology projects completed or in progress that have applications to livestock

Although the number of identified institutions was 16, only 4 answered the question on biotechnology projects completed or in progress that have application to livestock namely:

a. OAU Biotechnology Laboratory: Genotyping of indigenous breeds of pig, fish, cattle, small ruminants and fish breeds in Osun State
b. FIIRO: Aflatoxins in maize and sorghum (contaminated feeds for livestock)
c. UNAAB: Biodiversity and breeding studies in poultry, sheep, cattle and goats
d. NVRI: Dermatophilosis, African Swine fever, mycoplasma, brucellosis, ectoparasites, rinderpest seromonitoring, Newcastle vaccine production

3. Research capacity

Most responses were from the departments of animal science, production or health. Nigeria can boast of its human resources, most of them with doctoral degrees (Table 4).

Discussion

There is a general trend of slow development of the application of biotechnology tools in increasing livestock productivity in Nigeria mainly because of poor infrastructure and limited or inadequate funding. There is an obvious lack of coordination of biotechnology research in the country, although it was gathered that the government is harmonising biotechnology research efforts in the country.

Sadly, well-trained scientists who chose to stay in the country have become redundant because of lack of opportunities to do research that will stimulate and motivate them. Modern biotechnology

research is quite expensive and capital intensive, but providing equipment is not enough. Many well-equipped laboratories found in some of the research institutes, universities and polytechnics surveyed have become 'white elephants' because of lack of materials or consumables to fully use the equipment available. Oftentimes, a machine does not function for months because of a small accessory that needs repair or replacement. A SWOT analysis gives an overall view of the capacity for animal biotechnology in Nigeria (Table 6).

Table 4. Available human resources in different states of Nigeria and their respective fields of expertise.

State	Animal Breeding	Immu-nology	Genetic Eng'g	Molec Biol	Biochemistry	Bioinformatics	Micro biology	Parasit Ology	Virol Ogy	Veter Med	Others
Osun	2	6		1	2		1	1		1	2 Nutrn
Oyo	4			2	2		7	3	6	14	
Ekiti					1		5		1		1An Prod
Ondo	1				2			1	1	1	
Ogun	4				3		4	3		2	
Lagos	4	2		1	1	1	11		1		
Kwara	2		1	1	8	1	1	4		1	
Niger	4		1					3		7	
Edo	1				3		1				
Delta		1		2							1 Bot
Plateau	1	3	1	3	4		5	6			1Vet Med
Kaduna	2	2			1						5 Nutrn
Bauchi	4	2			1						5Nutrn/ An Health
FCT	1	1	1	1	2	1	3	1	1	1	

4–10. Biotechnology equipment and other biotechnology facilities, funding and regional and international collaborations, constraints, other research needs, adequacy of funding biotechnology research.

The equipment and facilities available in the different institutions is summarised by state in Table 5.

This analysis from 57 sample survey supports the findings of ASTI (IFPRI/ISNAR 2004) that Nigeria's agricultural research system is marked by institutional instability, declining funding availability and general uncertainty. It was also reported that institutes continue to lack appropriate levels of funding for their research activities and the quality of staff at the government research agencies has deteriorated, with many senior scientists particularly those with PhD degrees, moving into the university sector or abroad. From our survey, it was shown that there is a considerable pool of trained and trainable researchers in the country, many of whom are highly motivated. Many of the institutions also have facilities that can be upgraded or improved, if given the funding.

With the right technological base adapted to sub-Saharan African requirements, investors can get good returns on investments in livestock and fish production. To enable the livestock and fish industry make substantial contribution to the nation's economy requires substantial modernisation, capital for development, trained and competent work force and meaningful additive research results to ensure continuity and progress. ILRI and its development investors can help double livestock production in sub-Saharan African from a low of 750–2500 kg/km^2 to that comparable to Asia and Latin America of 20,000–30,000 kg/km^2 (FAO 2001), thus making 'the livestock revolution work for the poor'.

Table 5. Basic biotechnology equipment availability in the different states surveyed (for DNA extraction and electrophoresis, hybridisation, amplification, Internet connectivity tissue culture etc.) and needs for optimal performance

State	PCR	Sequencer	Computers for database searching	Other biotechnology equipment	Needs for optimal performance
Osun			10 in electronic library, individual staff, cyber cafés	Tissue culture, e.g. but not sufficient	PCR, consumables'water purification
Oyo			Several, cyber cafés	Tissue culture Storage facilities	Equipment, consumables,water, security, electricity
Ekiti			None	Ultracentrifuge Autoclave	PCR, consumables, equipment, water, security, electricity
Ondo			None, in progress	None	PCR, consumables, equipment, water, security, electricity
Ogun	1		Available	None	PCR, consumables, equipment, water, security, electricity
Lagos			Cyber cafés	None, collaboration w/ NIOMR	PCR, consumables, equipment, water, security, electricity
Kwara	1		Available	To be procured	PCR, consumables, equipment, water, security, electricity
Niger			None	None	PCR, consumables, equipment, water, security, electricity
Edo			Available	None	PCR, consumables, equipment, water, security, electricity
Delta			None	None	PCR, consumables, equipment, water, security, electricity
Plateau	2	1	Yes	Available	Consumables
Kaduna			In progress	Available	Consumables
Bauchi			In progress	None	PCR, consumables, equipment, water, security, electricity
FCT	2	1	Yes	Available	Consumables

[1]For DNA extraction and electrophoresis, hybridisation, amplification, Internet connectivity, tissue culture etc.

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Table 6. SWOT analysis of Nigerian animal biotechnology resources.

Strengths	Weaknesses	Opportunities	Threats
1. Capacity (see Table 4 for list of human resources)	Not sufficiently trained in DNA analyses Others who lack training join the biotechnology bandwagon	Trainable scientists and technologists—take less time to train and may have a better scientific outlook of doing things	Brain drain, those who get frustrated ; others given administrative posts that removes them from doing science and creative work Ill-trained technicians and biotechnologists
2. Equipment availability	Too expensive to maintain	Attractive to investors both industrial and development investors	Lack of funds to put to maximum use
3. Infrastructure	Ill-maintained, no structure for fast and less bureaucratic procurement of chemicals and materials Oftentimes too much investment in buildingsLack of reliable water and electricity supply	Space for solar energy utilisationIndustries can rent space and biotechnology innovative collaborations Good sources of genes for insects, diseases, pests, drought etc.; good genetic base for gene isolation and breeding	Government spending too much money on buildings, leaving no funds for maintenance Abandonment after projects funds are exhausted Threat of extinction of endangered species
4. Floral and faunal biodiversity	Underutilisation, facilities for conservation not sufficient Genetic erosion due to indiscriminate breeding with exotic species	Rich indigenous knowledge in biofertilisers, biopesticides, medicinal, insecticidal plants	

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Parallel session 1

Animal health

Genomics and animal health

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Abstract

Over the past decade there has been a paradigm shift in the biological sciences that has important consequences for modern biotechnology. The ability to acquire whole genome sequence data (genomics), advances in computational biology (bioinformatics) and developments in high throughput genomics based technologies have given rise to the ability to predict the molecular composition of organisms and to analyse them at a scale that was not previously possible. Such platform technologies offer unprecedented opportunities to study and understand biological systems, and it is likely that they will revolutionise our approach to solving biological problems. Biotic constraints to the improvement of animal productivity in Africa fall into the major categories of nutrition, livestock genetics and infectious diseases. This paper specifically deals with the positive role that pathogen genomics can play in developing methods to understand and control diseases.

Key words: genomics, animal health, vaccines, drugs, diagnostics

Introduction

The ability to acquire the DNA sequence of the complete genome of a free living organism was demonstrated with the publication of the genome sequence of *Haemophilus influenzae* (Fleischmann et al. 1995) just 10 years ago, and marked the beginning of the genomics era. Since then 256 bacterial and 36 eukaryotic genomes have been sequenced and more than 1500 more are in progress. One highlight of the genomics revolution was the publication of draft sequences of the human genome (Lander et al. 2001; Venter et al. 2001). The genome sequences of a wide range of organisms (bacteria, archaea, protozoa, fungi, worms, insects, plants and mammals) have been determined and information on current and completed genome projects can be found in 'GOLD', the genomes on-line database (http://www.genomesonline.org). Generally, genome sequence data is freely available from publicly maintained databases which can be accessed via the internet (e.g., http://www.ncbi.nlm.nih.gov).

A genome sequence reveals the genetic blueprint of an organism and using bioinformatics it is possible to predict the genes that occur within an organism, the proteins that it might make and the function these proteins may perform. From such data and high throughput technologies, such as transcriptomics and proteomics, it is possible to build an electronic image of the architecture and composition of an organism. A key point to note about genomics research is that genes or their products are studied in the context of a whole genome or sub-set of genes and not at a single gene level, although genomics may eventually lead to the latter. The ability to predict genes is not perfect and prediction of eukaryotic genes is particularly problematic because of the presence of introns that split genes into two or more exons. It is also early days in our ability to assign function to proteins based on their sequence and, in general, about 40% of the proteins encoded by an organism can be assigned to a function. Since 60% of an organism's proteins are of unknown function genomics has highlighted how little we know about the repertoire of genes that dictate the biology of organisms. One caveat to bear in mind is that bioinformatics data are the outputs of statistical analyses and, as in any science, predictions need to be experimentally verified.

Nevertheless, there is a huge repository of genomics data that is relevant to biology and available in an electronic format that may be exploited for research.

Results and discussion

Genome sequences are available for several bacterial, protozoan, fungal and worm pathogens. Many of these cause livestock diseases and such information together with livestock genome sequence data can be used to underpin animal health research.

Diagnostics

To better understand the epidemiology of disease and disease causing pathogens it is desirable to develop highly specific and sensitive strain-specific molecular diagnostic tools, particularly where multiple pathogen genotypes contribute to disease. To this end there has been a shift towards the use of multi-locus sequence typing (MLST) reagents (reviewed by Urwin and Maiden 2003) as they are better markers of isolate composition and are more informative than single marker diagnostic reagents. The ability to develop MLST probes is facilitated by whole genome sequence data.

Novel drug targets

Pathogen genome sequence data can be used to reconstruct their metabolic potential and to infer the presence of novel drug targets. For example, in collaboration with the International Livestock Research Institute (ILRI) TIGR has sequenced the genome of *Theileria parva* (Gardner et al. 2005), a tick-transmitted protozoan pathogen that causes a fatal disease in cattle called East Coast fever. The parasite genome consists of four Mbp sized chromosomes. There is a linear mitochondrial genome that is only 6 kbp in size and a 39 kbp circular DNA molecule found in an organelle called the apicoplast, a chloroplast-like organelle present in a number of organisms in the phylum Apicomplexa. It is thought that the apicoplast was derived by a secondary endosymbiotic event with a photosynthetic bacterium (reviewed by Waller and McFadden 2005). The total size of the *T. parva* genome is ~8.35 Mbp, about the size of some bacterial genomes and the pathogen is predicted to encode 4035 proteins.

Putative functional assignments were made to about 38% of the predicted *T. parva* proteins and those that were assigned enzymatic function were used to reconstruct a metabolic potential of the pathogen (Gardner et al. 2005). We predicted that *T. parva* is able to metabolise glucose via a glycolytic pathway and it can also utilise glycerol as an energy source. It has the ability to make pentoses and pyrimidines and interconvert nucleotides. However, the parasite is missing a number of important biochemical pathways. It cannot carry out b-oxidation of lipids, it does not have a urea cycle, it cannot make essential amino acids and it cannot synthesise haem or fatty acids, revealing its dependencies on the host cell for these compounds. The biochemical function of the apicoplast has generated a lot of interest, due to its evolutionary history. It has retained a number of biosynthetic pathways that are present in plants and bacteria but which are missing in animals. For example, the apicoplast appears to be involved in isoprenoid biosynthesis via a methyl-erythritol phosphate (MEP) pathway while animals use a mevalonate based pathway to synthesise isoprenoids. Thus enzymes of the MEP pathway offer a perfect target for novel drug development as these enzymes are missing in the host. Additional approaches for drug development might involve targeting pathogen enzymes that exhibit different characteristics to those present in their mammalian host.

Subunit vaccine development

Pathogen genomics has resulted in a paradigm shift in the early phase of vaccine development and given rise to a process called reverse vaccinology that results in the identification of candidate

vaccine antigens. This process involves bioinformatic analysis of the entire set of genes present in a pathogen to create a smaller list of genes that may encode antigens. These genes are then subjected to immunological screens to identify candidate vaccine antigens which may then be used in vaccination trial. In general, the kinds of pathogen proteins that are likely to encounter the immune system are those that are directed to the parasite surface membrane or those that are secreted into the environment. Such proteins can be identified using bioinformatics tools, as the vast majority of externalised proteins contain a conserved peptide motif at the N-terminal end that directs them into a classical secretory pathway (Bendtsen et al. 2004). A number of other types of bioinformatics analyses can be overlaid on a primary dataset to further prioritise genes for antigen study, and have given rise to the term 'immuno-informatics'.

The reverse vaccinology approach was pioneered by the Chiron Corporation, a private sector company. Of a total of 2158 proteins encoded by *Nisseria mengitidis*, 570 were identified as candidate antigens (Pizza et al. 2000). Recombinant proteins were produced from 344 of the 570 genes and antisera to them used in *in vitro* assays. Eighty-four novel surface proteins were identified and antisera to 25 proteins have bactericidal activity. By sequencing the 25 genes from different bacterial strains, 7 were found to be highly conserved in sequence and these proteins have gone into further studies. Two points are worth noting. The first is that this novel approach identified several new candidate protein antigens where conventional approaches such as the use of infection sera had failed, and secondly this research was completed over a period of 18 months. While this is a labour and resource intensive approach the rewards are great and the reverse vaccinology approach has been used to identify candidate vaccine antigens from other pathogens (Capecchi et al. 2004), and in a modified format has been used to identify candidate vaccine antigens of *Theileria parva* (Dr Evans Taracha, project leader ILRI personal communication). It is reasonable to predict that reverse vaccinology will become more sophisticated as the characteristics of antigens are better defined and through the process of comparative genomics of related pathogens.

Although reverse vaccinology has lifted one of the constraints to vaccine development, namely antigen identification, the ability to prime long-lived immunity to parasite challenge is still in its infancy and this area of vaccine development tends to be empirical in nature. Part of the problem is that in most diseases there are few if any measurable diagnostic correlates with immunity through which vaccination regimes can be optimised. There has been considerable progress in developing novel protein and DNA delivery vehicles, antigen formulations and molecular adjuvants that provide broad guidelines to prime humoral- or cell-mediated immune responses. But there is much scope for further improvement as in practice several systems require testing to determine which works best for a particular antigen. Genomics technologies could be used to adopt a more systems approach to characterise the host response to infection and vaccination and to use such information to improve vaccination strategies.

Conclusion

The above text provides a few examples of how genomics may be used to underpin animal health research. Genomics will play an equally important role in tackling problems in human health and the environment and we have just started to scratch the surface of research directions that the new sciences will lead us to. It is critical that genomics based technologies be integrated with more traditional biological investigations as they have the potential to greatly reduce research time frames and to provide unexpected solutions to old problems.

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Exploiting host immunity and parasite genomics to develop a robust sub-unit vaccine against East Coast fever in cattle—Where are we?

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Abstract

Theileria parva, a tick-borne api-complexan protozoan parasite, causes East Coast fever (ECF) in cattle. Control of the disease by improved vaccination is believed to provide a sustainable solution. Class I MHC-restricted $CD8^+$ cytotoxic T lymphocytes (CTL) directed at schizont-infected cells constitute the effector immune mechanism against ECF in cattle recovering from a single or multiple infection(s). Schizont antigens recognised by CTL are therefore prime vaccine candidates. We describe a rational approach used to identify 8 CTL target antigens as vaccine candidates. The genes encoding the target antigens have been engineered in plasmid DNA and viral vectors for evaluating their immunogenicity and efficacy in cattle. In a preliminary trial, five of the candidate vaccines demonstrated the capacity to induce CTL responses that correlated with survival and reduced disease severity following a lethal parasite challenge.

Introduction

East Coast fever (ECF) is a major obstacle to the development of a vibrant cattle industry in eastern, central and southern Africa (Mukhebi and Perry 1992). Estimates in 2000 of losses due to morbidity and mortality, costs of control measures and opportunity costs amount to over US$ 300 million annually (Tom Randolph, Henry Kiara, Brian Perry, ILRI, personal communication). Current control measures, which mainly rely on tick control using acaricides, drug-treatment of sick animals and deployment of a live vaccine, are generally effective but do not offer a sustainable

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solution. Immunisation using the live vaccine engenders solid immunity to homologous and occasionally heterologous challenge (Radley et al. 1975). However, the high production costs coupled with the requirements for cold storage and skilled handling make this vaccine inaccessible to most poor livestock farmers who need it most. In spite of this, the demand for this vaccine is on the increase suggesting that an efficacious, safe, inexpensive and easy-to-deliver improved recombinant subunit vaccine would be readily adopted (McLeod and Randolph 2001).

Efforts towards the development of an ECF recombinant subunit vaccine have involved two approaches. The first focused on the infective stage (sporozoite) of the parasite in the tick and yielded a 'first generation' prototype recombinant vaccine, based on one antigen, p67, whose effectiveness was suboptimal (Nene et al. 1996; Musoke et al. 2005). The second has aimed at the schizont, an intra-cellular stage of the parasite that is responsible for causing pathology in the animal. The second strategy builds on observations that cattle recovering from a single exposure to *Theileria parva* infection, either naturally or following chemotherapy (Radley et al. 1975) exhibit the well-characterised class I MHC-restricted $CD8^+$ CTL-based solid immunity targeted at the schizont stage following live vaccination (Morrison et al. 1987; McKeever et al. 1994; Taracha et al. 1995). This has been complemented by the availability of data on the biology of the parasite including the complete *T. parva* genome sequence data (Gardner et al. 2005) which provided a list of selected genes to be screened for candidate vaccine antigens.

The criteria for selection of candidate genes for immuno-screening were based on presence of a signal sequences or transmembrane domains. This was based on the hypothesis that these parasite proteins would access the host cytosol and therefore access the class I MHC processing pathway for presentation to cytotoxic T lymphocytes (CTL). In addition, a high quality unidirectional *T. parva* schizont cDNA library was generated as a complementary source of material for immuno-screening (De Plaen et al. 1997). Underpinning the success of immuno-screening selected and random cDNAs for CTL targets was the availability of a high throughput antigen screening assay. An assay (IFN-g ELISpot) was developed that measures IFN-g release from *T. parva* specific CTL in response to BoLA class I cDNA-expressing COS-7 cells or transformed autologous skin fibroblasts transiently transfected with *T. parva* cDNA (Graham et al. 2006;). This approach has led to the identification of several CTL target vaccine antigens (Graham et al. 2006). Five of these CTL target antigens have been formulated in proprietary technologies including plasmid DNA, modified vaccinia virus Ankara (MVA), and canarypox virus (vCP), evaluated in cattle and shown to induce CTL responses that correlated with resistance against lethal challenge in a proportion of animals (Graham et al. 2006).

Results and discussion

Antigen identification

Eight candidates termed Tp1 to Tp8 were identified using CTLs derived from immune cattle of diverse genetic backgrounds. Five of these genes (Tp1, Tp4, Tp5, Tp7 and Tp8) were mined from the cDNA library. Two others (Tp3 and Tp6) were identified from the selected gene list while Tp2 was identified from both sources. A blast search of global databases revealed that Tp1, Tp2 and Tp3 encode hypothetical proteins and are unique to *T. parva* whereas the rest bear homology to known proteins in other systems (Table 1). Based on this search, Tp4 is eta-subunit of the T-complex protein 1 (chaperon-like protein), Tp5 the elongation translation initiation factor 1A, Tp6 a prohibitin, Tp7 a heat shock protein 90 and Tp8 a cysteine proteinase (Graham et al. 2006).

In addition to releasing INF-g, CTL lines used to identify these antigens were shown to recognise and lyse COS-7 cells and autologous fibroblasts transiently transfected with these genes. To evaluate the relevance of these CTL antigens in immunity to ECF, live vaccine-immunised animals were re-challenged with live *T. parva* sporozoites and the kinetics of $CD8^+$ T cell-mediated IFN-g responses to these antigens analysed.

Table 1. List of *T. parva* CTL target antigens identified through immuno-screening of selected genes and random cDNA library.

Antigen	*T. parva* chromosome number	Identity	Signalpeptide	Anchormotif	mw(kD)
Tp1	3	hypothetical	1-19	Yes	62
Tp2	1	hypothetical	1-23	No	19
Tp3	1	hypothetical	1-16	No	29
Tp4	3	TCP-1	No	Yes	63
Tp5	2	eIF-1A	No	No	18
Tp6	1	prohibitin	1-29	No	31
Tp7	2	hsp90	No	Yes	84
Tp8	2	cysteine proteinase	No	Yes	50

Responses to Tp1, Tp2, Tp5 and Tp8 were boosted on day 8 from pre-challenge levels peaking at between 9–13 days post-challenge. Tp4-specific responses were not observed till 12 days after challenge (Graham et al. 2006). In all, the kinetics of these IFN-g responses coincided with the resolution of challenge infection and were consistent with those of $CD8^+$ CTL observed in previous studies (Morrison et al. 1987; McKeever et al. 1994), suggesting that the antigen-specific responses may contribute to protective immunity against ECF.

Immunogenicity and efficacy of the identified antigens formulated in proprietary technologies

The vaccine potential of five (Tp1, Tp2, Tp4, Tp5 and Tp8) of the identified genes engineered in plasmid DNA, vCP and MVA was assessed in double-blind experiments with cattle immunised and subjected to a lethal *T. parva* challenge and monitored for immune responses and clinical ECF. Twenty-four bovine leukocyte antigen (BoLA)-typed calves were randomised in two groups and immunised with either DNA/MVA (n = 12) or CP/MVA (n = 12) expressing the five antigens individually using the prime/boost regime. Inoculations were done 4 weeks apart. Analysis of immune responses showed induction of significant antigen-specific $CD8^+$ T cell IFN-g responses in 79% of vaccinated cattle. However, antigen-specific CTL were detected in only three immunised cattle following booster immunisation with MVA. Following lethal challenge, 3 weeks after boost, 4/12 DNA/MVA and 6/12 CP/MVA immunised calves developed mild to moderate ECF reactions and subsequently recovered whilst the remaining calves developed severe ECF requiring euthanasia. Of the 10 surviving calves, 7 generated detectable antigen-specific CTL responses to all 5 antigens. However, the specificity of responses from individual cattle was restricted to antigen(s) predicted to be recognised by specific BoLA type. None of the animals euthanised due to severe ECF made a CTL response although most of them mounted antigen-specific $CD8^+$ T cell IFN-g responses. Although only demonstrated in a proportion of vaccinated cattle, the association between CTL responses and survival or reduced disease severity was notably significant as shown in Table 2 ($p<0.001$) and suggested that CTL responses may contribute to protection against a lethal *T. parva* challenge (Graham et al. 2006). These data validate the five antigens as *bona fide* vaccine candidates and provide a good platform to evaluate and identify vaccine formulation technologies that will induce protective CTL responses in majority of vaccinated cattle.

Concluding statement

Based on an understanding of protective immune responses and parasite biology, we have developed a system for identifying CTL candidate vaccine antigens. This study represents key milestones in the development of a CTL-based ECF recombinant vaccine and highlights the

Table 2. Association of CD8+ T cell responses and outcome to challenge; the higher the ECF index, the higher the disease severity.

	CD8+ T cell responses of immunised cattle (n = 24)				
Outcome to challenge	**IFN-g**		**CTL**		**Challenge control cattle (n = 4)**
	Responder (n = 19)	**Non-responder (n = 5)**	**Responder (n = 7)**	**Non-responder (n = 14)**	
Survived	9	1	7*	3	1
Euthanised	10	4	0	14	3
ECF index	7.53	8.04	6.04*	8.04	8.49

* P<0.001

potential implications for similar initiatives to develop vaccines for animal and human diseases caused by intracellular pathogens against which CTL contribute to protective immunity.

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Deployment of a live ECF vaccine in pastoral areas: Lessons learned from Tanzania

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Abstract

After a period of testing and evaluation (1989–1992), Tanzania deployed a live trivalent East Coast fever (ECF) vaccine in the field in 1993. Use of the vaccine was restricted to the dairy sector until 1998, when the first immunisations in pastoral areas were carried out. Problems with ECF vaccination reactors were annulled with the introduction of a 30% long-acting oxytetracycline formulation as the blocking agent, heralding the real inauguration of ECF vaccine field delivery.

Studies in pastoral farming systems in northern Tanzania were carried out between March 2000 and March 2004 to (i) evaluate the efficacy of immunisation against ECF under pastoral management systems; (ii) identify the adoption mechanism; (iii) evaluate the impact of ECF immunisation in pastoral systems; and (iii) evaluate the environmental impact of ITM in pastoral areas.

Results showed that the use of the live trivalent ECF vaccine in pastoral farming systems is a robust and effective ECF control method, even in areas where buffaloes are present given the fact that Endulen site is situated in Ngorongoro area which is a high density buffalo area.

Easy access, availability of the vaccine and the cost of immunisation were the most important causes of delay in adoption. The spill over effects of ITM and farmers' perception of these additional benefits, i.e. greater liveweight gains, higher market value etc., played an important role in the adoption of ITM by pastoralist households. In addition, pastoralists were willing to travel long distances (>60 km), especially cross-border travel from Kenya to Tanzania, to access ECF immunisation sites. No environmental impact has been recorded as increased survival is reflected in increased offtake, especially of immunised animals.

Introduction

Tanzania has the second highest livestock population in sub-Saharan Africa, estimated at 17.9 million cattle (FAO 2002) with indigenous cattle accounting for more than 98% of the national cattle herd. Thirty-six per cent of the 1.027 million households owning cattle are found in the agropastoral and pastoral livestock sector, which account for 70% of the national herd (MWLD 2002). Pastoralism is concentrated in the northern plains and is practised in 'traditional grazing areas' where climatic and soil conditions generally do not favour crop production. Grazing and watering patterns are, of course, highly mobile. Livestock play a central role in Maasai livelihoods, but the productivity of their livestock is said (Field et al. 1997) to be uniformly low throughout the region. Whereas, Humprey and Sneath (1999), write that pastoralism 'far from being a practice associated with the most backward herders, highly mobile livestock herding is often the basis of the most efficient, wide-ranging, well co-ordinated and specialised production, and it is compatible with technologically advanced and profit-oriented economy activity'. They go even further

suggesting that: 'where the pastoral sector is the backbone of the national economy it needs to be supported rather than threatened'.

East Coast fever (ECF) is a devastating disease that kills up to 70% of the annual calf crop within the first 6 months of life in the pastoral (indigenous) herds (Cleaveland et al. 2000; Di Giulio, (unpublished). Acaricide use, especially short interval dipping which is necessary for ECF control, has a number of inherent problems (such as development of resistance by ticks, environmental pollution and high cost). However, foremost among these problems is that dipping facilities are not operational in pastoral areas and the alternative tick-control practices carried out by pastoralists are not implemented correctly and are therefore not effective. Furthermore, after nearly a century of using acaricides it is now accepted that acaricides alone do not provide a practical long-term solution to ticks and tick-borne disease control (Norval et al. 1992), a perception which has long been acknowledge by pastoralists who claim that dipping kills their animals.

The most promising approach currently available for alleviating the impact of ECF is through immunisation by the infection and treatment method (ITM) (Radley 1981). Immunisation involves actively infecting cattle with sporozoites of a known live strain(s) of *Theileria parva*, and simultaneous treatment of the recipient cattle with a long-acting tetracycline (Radley 1981). Tanzania has adopted a trivalent stabilate, comprising *T. parva* (Muguga), *T. parva* (Kiambu 5), and *T. parva lawrencei* (Serengeti transformed), in conjunction with a long-acting oxytetracycline (OTC-LA) at the rate of 30 mg for every 10 kg of animal body weight, for routine field immunisation (Lynen et al. 1999; Di Giulio et al. 2000). Immunisation gives an immunity which last for 2 years in absence of tick challenge. Natural exposure to field ticks will ensure live long immunity after initial immunisation as animals will receive frequent "booster" immunisations from the ticks in the field. Therefore, once immunised, the cattle, if exposed to the parasites through tick challenge, built up a life-long immunity.

ITM was introduced in 1993, initially in the smallholder dairy sector; from 1998 it was made available to pastoralist communities in Northern Tanzania (Arusha Region) and since then its use has spread all over the country. More that 130,000 cattle have been immunised since 1998, with 15 to 20 thousand immunisations carried out annually. For the last two years the immunisations have been conducted on a commercial basis, with more than 80% being carried out in the pastoral sector. The immunisation cost for indigenous calves is around US$ 6 each.

Many pastoral communities span border areas between countries and flexible use of grazing and water resources, and movement responses to drought are the norm (Ndikumana et al. 2000). The related communities in such border areas would adopt disease intervention programmes if they were seen as beneficial.

This paper briefly describes results of longitudinal studies, household surveys and an adoption study in pastoral communities in northern Tanzania. The objectives were to identify and quantify the problem of ECF, the efficacy of ITM and the problems of other transboundary diseases (TBD) after adoption of ITM, to evaluate the impact on pastoralists' livestock production and the adoption process of ECF immunisation within an overall pastoral risk decision-making framework.

Material and methods

Site selection

Studies were carried out in Endulen, Ngorongoro Conservation Area. The area is classified as subhumid-highland (altitude 1993 m, 03°10'32"S, 035°16'96"E) with a human population density of 5–10 people/km^2 and a cattle population of 40–50 head/km^2. The area is highly endemic for

TBD . (Lynen et al. 2000) with high tick numbers, especially from January to June. The area records a reliable onset of the short and long rains and has an average annual rainfall of 800–1000 mm. Low mortality is recorded in the indigenous short-horn Zebu population for all diseases except ECF which causes high calf mortality. Pastoralists practise grazing (mixed herds) with substantial movement of animals, especially in the dry season. Herds in the area are grazed in close proximity with wildlife, including buffaloes.

The second study site, Engare Naibor Ward in Monduli District, Arusha Region, bordering Kenya, is a larger settlement consisting of several main villages and sub-villages. This site is less remote and has better facilities than the Endulen site. The area is classified as medium altitude plains (1450–1750 m altitude) consisting of savannah/grassland, with a human population ranging from 0–5 people per km^2 and cattle population of 10–20 head/km^2 (Ndikumana et al. 2000) and is considered endemic for ECF compared with Endulen area which has lower tick numbers throughout the year except for *R. pulchellus* which is abundant in this much drier environment (annual rainfall 400–600 mm) of mainly sandy soils, short growing periods and less reliable onset of rains (the short rains October–December are often absent).

Sampling frame and data collection

Longitudinal study

One hundred calves, aged between 2 and 6 months were selected, identified and randomly divided in 2 groups (50 immunised and 50 non-immunised). ECF immunisations were carried out at the start of the monitoring period. The herds were monitored for 16 months and all animals were visited twice a month.

Cases of TBDs were diagnosed on the basis of clinical signs, and confirmed on microscopical examination of blood and lymph node smears; treatment was carried out accordingly. Where animals died, post-mortem examinations were performed in the field and specimens collected and examined.

Multi-round household survey, Engare Naibor

A multi-round prospective survey of 49 households across the study site was carried out on 3 occasions. For each of the households a register of individually identified immunised or control animals was established and monitored for births, deaths, disease and transfers. Follow-up visits of these animals and their individually identified offspring allowed evaluation of the impact of immunisation on herd dynamics through systematic recording for approximately 1038 animals. Data on Fertility, mortality, off-take for gift, sale or exchange, TBD impacts and changes in grazing patterns were recorded. The multi-round prospective survey of household economic activity (49 households) collected data including proportional contribution of pastoral, crop and other produce to household economy, income from livestock/pastoral produce, expenditure (animal health, food, education etc.), and cross-investment (cultivation, trade etc.).

Adoption study, Engare Naibor

The study was designed to explain the factors that influence vaccine adoption, and to explore the socio-economic variables that determine buying strategies. The main tools used for the study were structured interviews that included herd count data and focus group studies. GIS readings for all homesteads on the vaccination register (ITTBDCP-2002) were carried out in August 2003.

Results and discussion

Impact of ECF immunisation on mortality

Longitudinal studies

Records indicate much lower mortality rates in immunised calves (Endulen: 4% against 50%, p<0.000, Engare Naibor 2% against 46%, p<0.000). Deaths from non-TBD are also significantly different (4% against 8%, p<0.00) with much higher mortalities due to malnutrition in the non-immunised population. ECF was responsible for 80% of all mortalities in the non-immunised population.

Despite slightly different ECF epidemiological status for Endulen and Engare Naibor, there were no significant differences in the mortality patterns of the two areas for unvaccinated animals. Mortality of immatures/calves ranged between 46% and 50%, while in both groups 80% of all mortalities were claimed by ECF; immunisation had a significant impact on calf survival in both areas. Environmental stress factors in Endulen (drought, malnutrition and predation) weighed more heavily in the non-vaccinated group.

Multi-round surveys

Implications of vaccination for livestock numbers

Survivorship analysis showed significant differences in survival levels of immunised and non-immunised animals and in livestock trade (Figures 1 and 2). There were clear links between vaccination and livestock trade.

Unsurprisingly, survival analysis of the livestock register showed that male cattle were significantly more likely to be sold, than female cattle (Wilcoxon (Gehan) statistic=85.5, df=1, P<0.001). Interviews in local markets indicated that, depending on the breed, an animal that had been vaccinated (and had an ear tag to prove it) could fetch a price up to 50% higher than the equivalent animal without the ear tag.

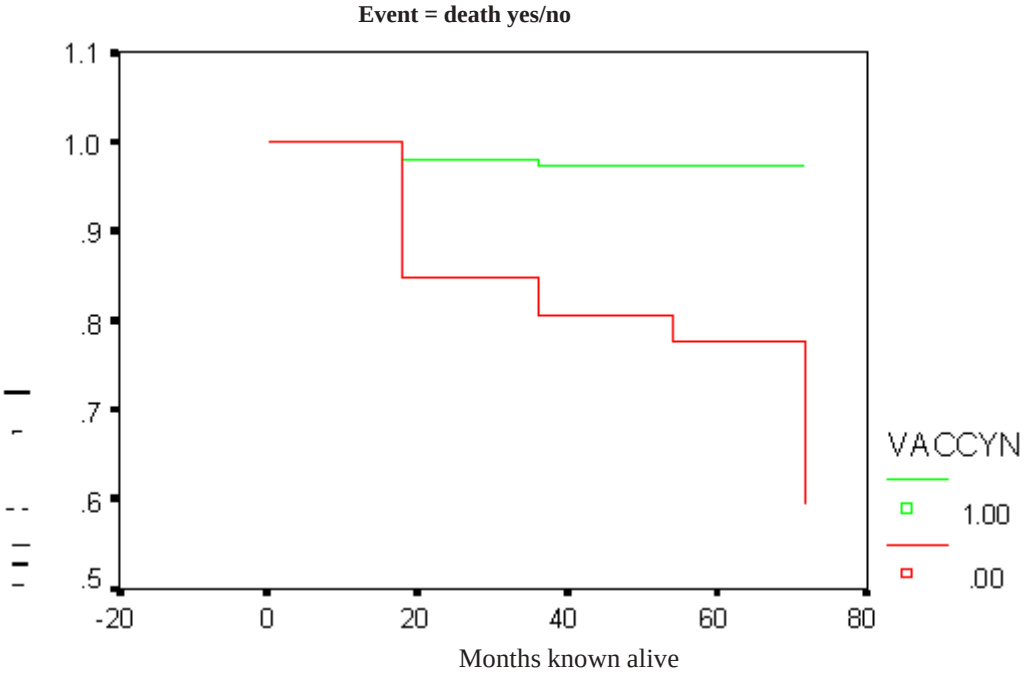

Figure 1. Survival function: death.

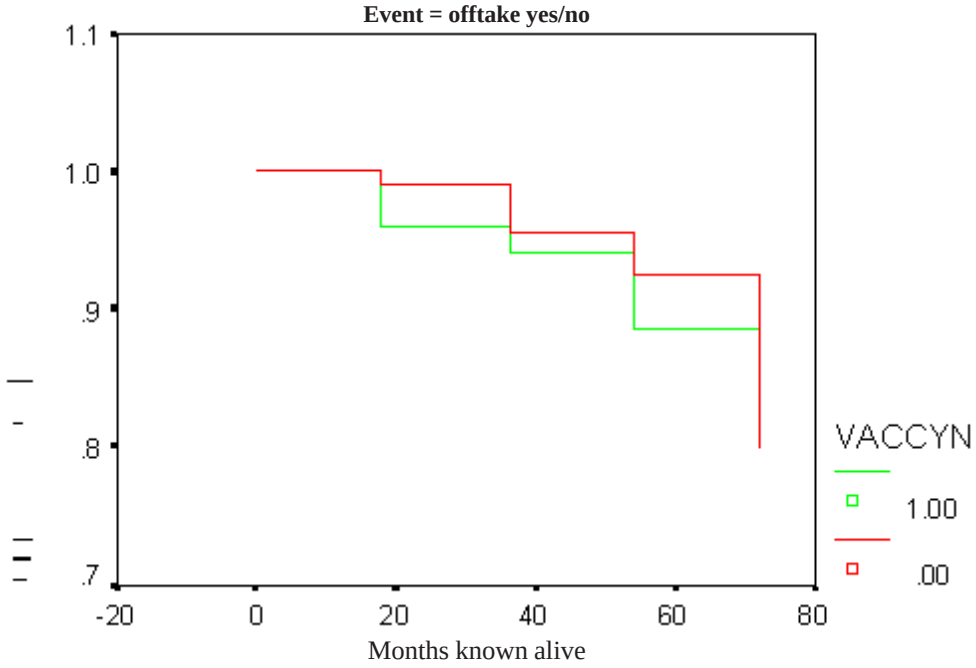

Figure 2. Survival function: offtake.

Implications of vaccination on grazing patterns and farming activities

Other than the expected (and low level) seasonal variation, there was no indication of any progressive change in grazing patterns that could be related to vaccination uptake as yet. No significant interactions could be found between vaccination and farming, which suggests that to date there is little in the way of cross investment, or of direct tradeoffs forcing 'either/or' decisions between livestock and farming enterprises. There was no correlation between acreage and levels of vaccination, whether measured as the presence of at least one vaccinated animal in the herd or as the proportion of animals in the herd that have been vaccinated.

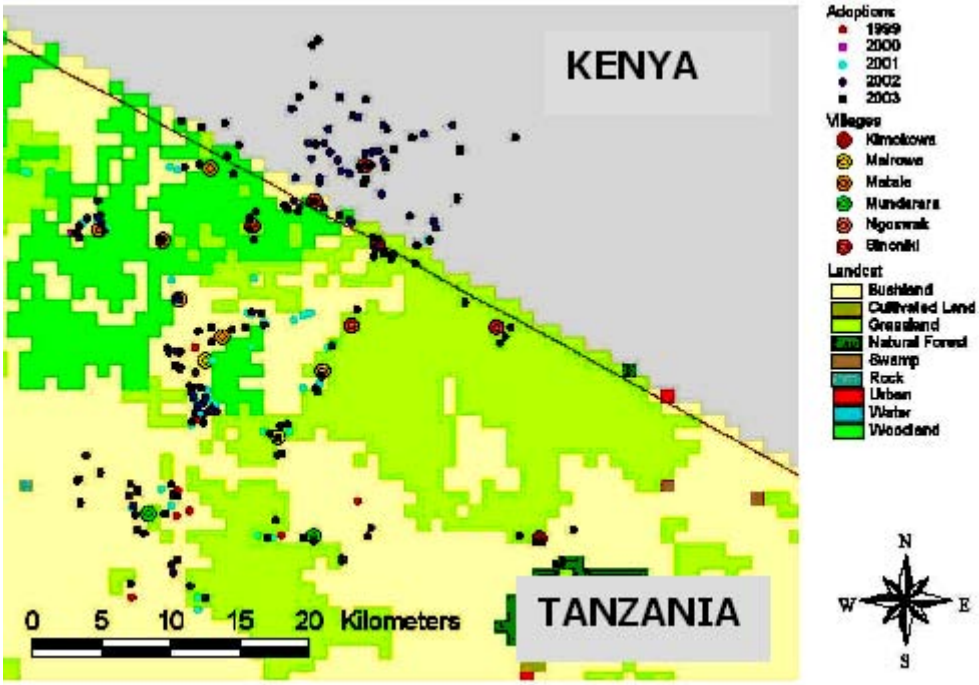

Figure 3. Adoption patterns and spread.

ITM adoption

Geographical spread

After initial introductions of ITM in the pastoral areas of Tanzania it became apparent that availability and access to ECF vaccine distribution centres, was a crucial factor driving the adoption of ITM in the respective areas. With a permanent distribution centre established in September 2001 in Mairowa, several of the smaller sub-villages joined the immunisation activities in 2002 and cross-border service delivery increased with Kenyan pastoralists tracking their calves to the border villages in Tanzania to access ECF immunisation sites. Georeference readings of the actual *boma* locations in August 2003 clearly identified the effort and distances travelled by these households to access ECF immunisation in Sinoniki and other sub-villages. The pattern of adoption and spread is illustrated in Figure 3.

During the first year of adoption calves were immunised at 12 n–18 months, while in subsequent years only the new-born calves are brought for immunisation (see Figure 4 for adoption in Engare Naibor). It is foreseen, that for a single distribution point (1 Livestock Field Officer (LFO), 1 motorbike, 1–2 assistants) the total numbers to be immunised in 1 year will level out at 4–5,000 head because of the logistic constraints in the pastoral areas.

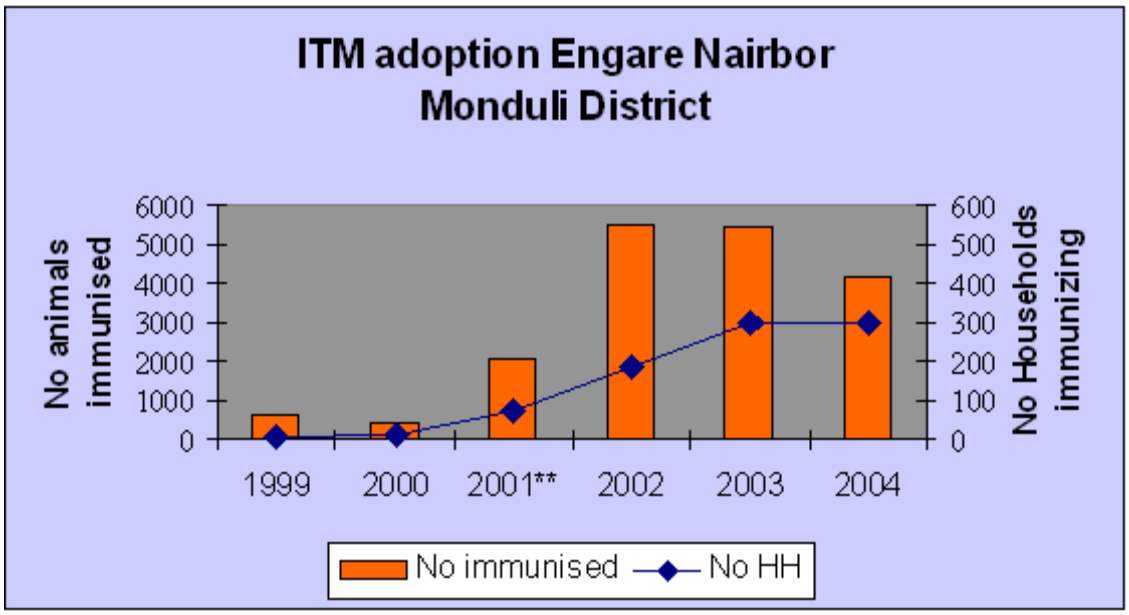

Figure 4. Adoption of ITM by number immunised and number of households participating.

Factors influencing adoption

The livestock register and survey data show no associations between uptake of vaccination and any measure of education or language proficiency (i.e. Maa or Kiswahili speakers). Household wealth in terms of livestock numbers is an important determinant of vaccination uptake. Multiple regression shows the proportions of immatures vaccinated correlate most significantly with total livestock holdings ($F=11.83$, $p<0.001$).

Of the 74 Mairowa interviewees in the adoption-questionnaire-round, 53% of livestock owners admitted that they started vaccinating their cattle after seeing others do so, and almost 40% waited to see that immunised animals were doing well (Figure 5). Herd owners perceived the vaccine as very effective with respect to ECF and as having a positive effect on survival overall, general health and lower risk of other diseases.

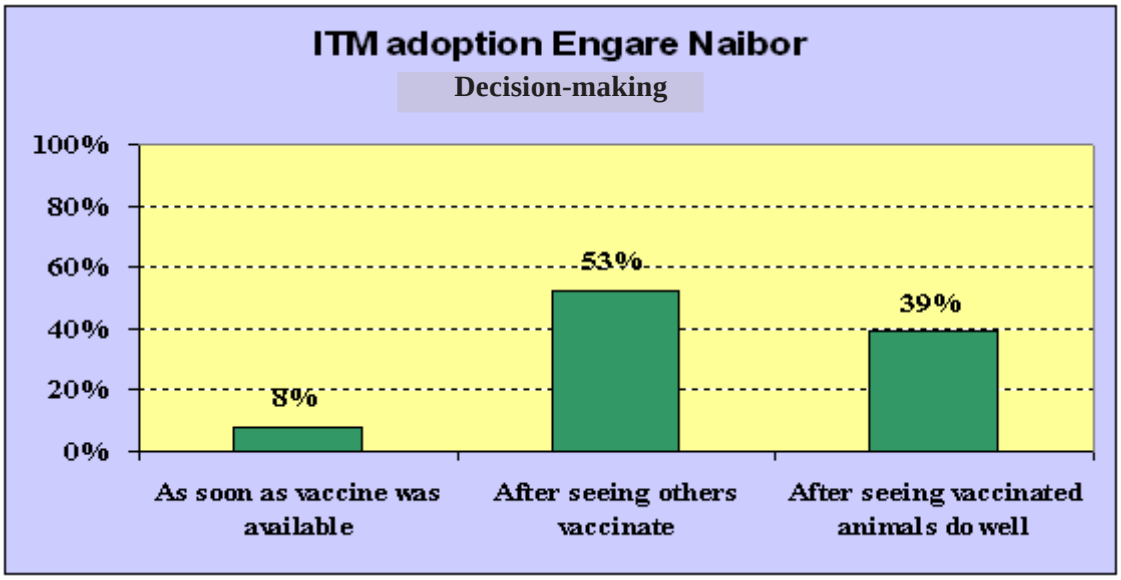

Figure 5. Facts which prompted decision making during period 1998–2002, Engare Naibor.

In October 2001, an exchange visit took place between Maasai livestock keepers from Simanjiro District (an area about to be sensitised) and the livestock keepers from Engare Naibor *bomas*. After 5 days of discussions amongst themselves as per traditional protocol, almost everybody from Simanjiro had been convinced that ITM works, so a completely different picture was observed in Simanjiro District with 70% adoption as soon as vaccine became available (Figure 6).

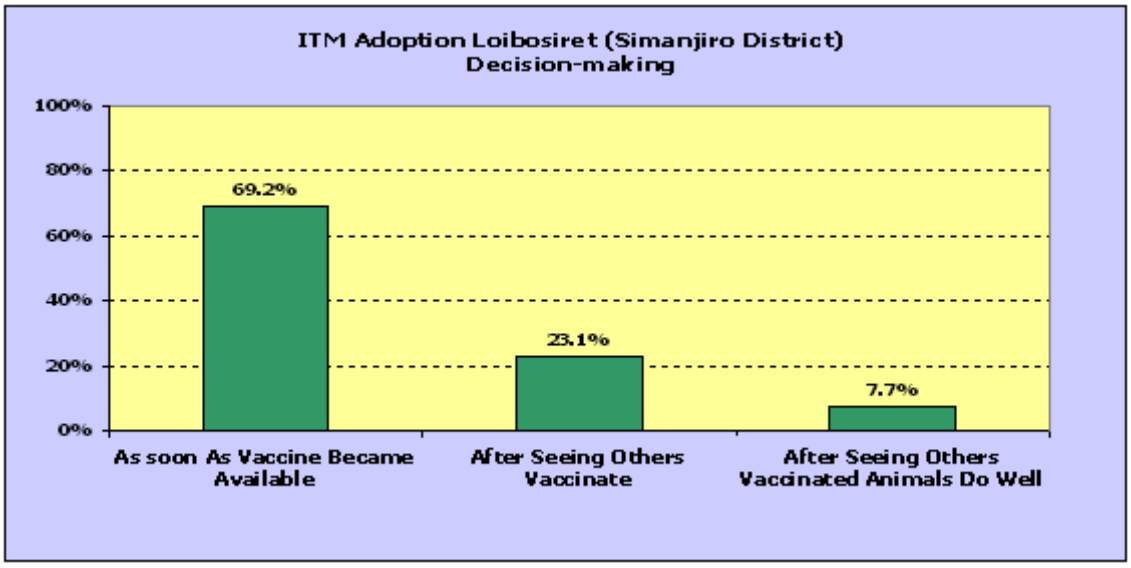

Figure 6. Reasons for adoption in Simanjiro District 2002.

Environmental impact

The actual ITM environmental impact is yet to be determined since ITM was only recently introduced on a large scale in Tanzania. In addition, farmers are still 'busy' recovering from previous losses and it will take time to reach pre-ECF cattle numbers, especially if compared with growth of the population. Already, Cleaveland et al. (2000) pointed out that 'current trends suggest that Maasai are now more likely to sell "excess" livestock that are produced or survive as a result of disease (MCF) control'. While Homewood et al. (1987) said that: 'traditional decision

making probably provides an effective mechanism for appropriate and flexible utilisation of rangelands'.

Looking at the direct impact of ITM, it looks likely that increased livestock numbers will be counterbalanced by an increased cattle offtake as ITM has a huge influence on animal productivity and therefore animals can be sold earlier, while better pricing will also increase the offtake of immunised young stock.

General discussion

While ITM has proven to be a very robust and promising strategy for reducing ECF risk, it has been made available only in recent years to pastoralists in Tanzania and even more recently to selected (restricted) sites in Kenya. Poor adoption of ITM in the region was the norm in the past. Scientists believed that the widespread adoption of ITM was hampered by the lack of information on its impact at a system level, while field workers and livestock owners blamed its poor availability. Stakeholder consultations concluded that the low adoption of ITM was caused by concerns by the veterinary authorities, the private sector and research scientists on a number of issues on the technology and its use, while a conflict of interest by key stakeholders may also have contributed to this delay.

However, despite misgivings and lack of in-depth economic analysis to present to livestock owners in Tanzania, pastoralists in northern Tanzania have increasingly adopted ITM. Experience has clearly shown that ITM is a cost-effective control method allowing a (80–95%) decrease in annual calf mortality and a reduction in tick control to threshold dipping only. Economic returns are visible within 2–3 months after immunisations with no calf mortality recorded in the respective *bomas*.

Vaccinated (male) animals are significantly more likely to be sold at an earlier age, and are reported to fetch a higher price than unvaccinated animals do. There is no clear relation between uptake of vaccination and level of farming activity, however, evaluation of possible changes in grazing patterns needs further long-term monitoring as some pastoral communities (not included in the studies discussed in this paper) deliberately choose ITM as a tool to change previous grazing traditions (Environmental impact assessment 2004- unpublished results)

Adoption of ITM is a gradual process, clearly identifying the early adopters (wealthy households) followed by others within the first year as livestock owners gain confidence that the immunisation *per se* does not harm (kill) the animals, while late adopters join only after they have seen the efficacy of the ITM (increased calf survival and increased productivity). It is encouraging that there is an immediate correlation with increased livestock trading after uptake of ITM, indicating that potentially environmental issues concerning the outcome of this dramatic reduction in calf mortality associated with vaccine uptake in pastoral areas is counterbalanced through increased turnover and offtake.

The deployment of a live ECF vaccine (ITM) is highly effective in veterinary terms, but the logistics and economics of the service delivery still exclude other pastoral areas from adopting the technology. Government promotion of the technology and assistance in remote areas is necessary to allow for fast adoption once the vaccine delivery becomes available. Any policy maker should keep in mind the effect that a wider use of ITM could have on food security, improving people's livelihoods and promoting the country's economic growth.

The ITM market is demand-driven and to solve any potential problem and promote sustainable growth public-private partnership needs to be cultivated so that problems are tackled in the most

effective way. Full privatisation in Tanzania has increased the sustainability of the whole enterprise. Responding to business opportunities, new delivery agents are emerging and their presence in the pastoral areas is driving the increase in ITM adoption. Furthermore, the increase of available delivery agents has had a stabilising effect on the ECF vaccine delivery price at farm-gate.

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Role of plasma lipids in the susceptibility of laboratory mice to trypanosomosis

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Abstract

C57BL/6J mice are relatively resistant to trypanosomosis compared to BALB/c or A/J mice. Bloodstream trypanosomes are partly dependent on the host for lipid supply and the plasma lipid levels differ between resistant and susceptible mice. Furthermore, genes controlling plasma lipid levels are differentially expressed in resistant versus susceptible mice during trypanosomosis. Quantitative trait loci (QTL) studies have co-localised the QTLs for trypanotolerance and plasma HDL-cholesterol levels in mice. We hypothesise that plasma lipids have a role to play in trypanosomosis. We manipulated the plasma lipid levels of C57BL/6J, BALB/c and A/J mice and observed how the mice responded to *Trypanosoma congolense* infection. Significant differences in parasitaemia between the mice with higher and lower plasma lipid levels were observed only in the A/J (P<0.001). There was significant weight loss, following infection, in the mice with the higher plasma lipid levels.

Key words: trypanotolerance, *Trypanosoma congolense*, plasma lipid levels, parasitaemia, quantitative trait locus (QTL)

Introduction

African trypanosomes acquire lipids from the host through the uptake of mainly high density lipoprotein (HDL) and low density lipoprotein (LDL) particles. They require lipoproteins to multiply under axenic culture conditions (Heather et al. 2003). There is a gradual decline in total plasma lipids, which coincides with a rise in parasitaemia, in animals infected with *Trypanosoma congolense*, *T. brucei brucei* and *T. b. rhodesiense* (Traore-Leroux et al. 1987; Katunguka-Rwakishaya et al. 1992). Trypanotolerant cattle and mice have lower plasma lipid levels than the susceptible ones (Ogunsanmi et al. 2000). It is postulated that these low lipid levels slow down parasite multiplication and growth, hence being one possible way by which these animals are able to control parasitaemia and disease pathology. Gene expression studies have shown that genes controlling plasma lipid levels are highly expressed in resistant animals during trypanosomosis than in susceptible animals. This is thought to help clear plasma lipids, depriving the parasite of the much needed nutrients for growth and multiplication. Therefore, in this way, trypanotolerant animals are able to restrict the parasite load in their bloodstreams. Quantitative trait loci studies have also mapped the QTLs for trypanotolerance (*Tir2*) and plasma HDL-cholesterol levels to the same region on chromosome 5. All these point to a possible link between trypanotolerance and plasma lipid levels.

Materials and methods

Animals

Thirty mice each of BALB/c, A/J and C57BL/6J strains 6–10 weeks old were maintained in cages (5 per cage) in a room with a 12-hour light-dark cycle. The had access *ad libitum* to water and either a high or low fat diet for 8 weeks before infection, intraperitoneally, with 10^4 of *T.*

congolense IL1180 clone (Kitani et al. 2002; Naessens et al. 2004). The mice continued with the same feed after infection and were weighed after every 3 days.

Experimental diets

The diets, high fat (23.45%) and low fat (5.16%) were supplied by Purina Mills (UK) and were matched for all nutrients and calories except for the fat content.

Plasma lipid assay

Mice were selected at random from each cage at the time of infection, 8, 21, and 46 days post-infection (DPI) and sacrificed using CO_2. Blood was quickly drawn from their hearts into tubes containing heparin and centrifuged at 2000 G for 10 minutes and the supernatant (plasma) collected into clean tubes and stored at –80°C. Total-cholesterol, HDL-cholesterol, LDL-cholesterol, and triglycerides were then assayed using the CHOD-PAP, immuno-inhibition, selective protection and GPO-PAP assays respectively.

Parasitaemia

The tip of the mouse tail was incised and a blood smear placed on glass slides. Parasites were scored on a scale of 1–5 in wet blood films using the dark ground microscopy.

Results

The mice on the high fat diet showed an increase in body weight before infection whereas those on a low fat diet had no significant weight gain. After infection both groups of mice lost weight, but the mice on a high fat diet lost more weight than mice on the low fat diet within all strains (Figure 1). All three strains of mice on the high fat diet had higher cholesterol than did those on the low fat diet (Figures 2, 3 and 4). Following infection, the lipid levels decreased, but only HDL-cholesterol showed a statistically significant decrease ($p<0.001$).

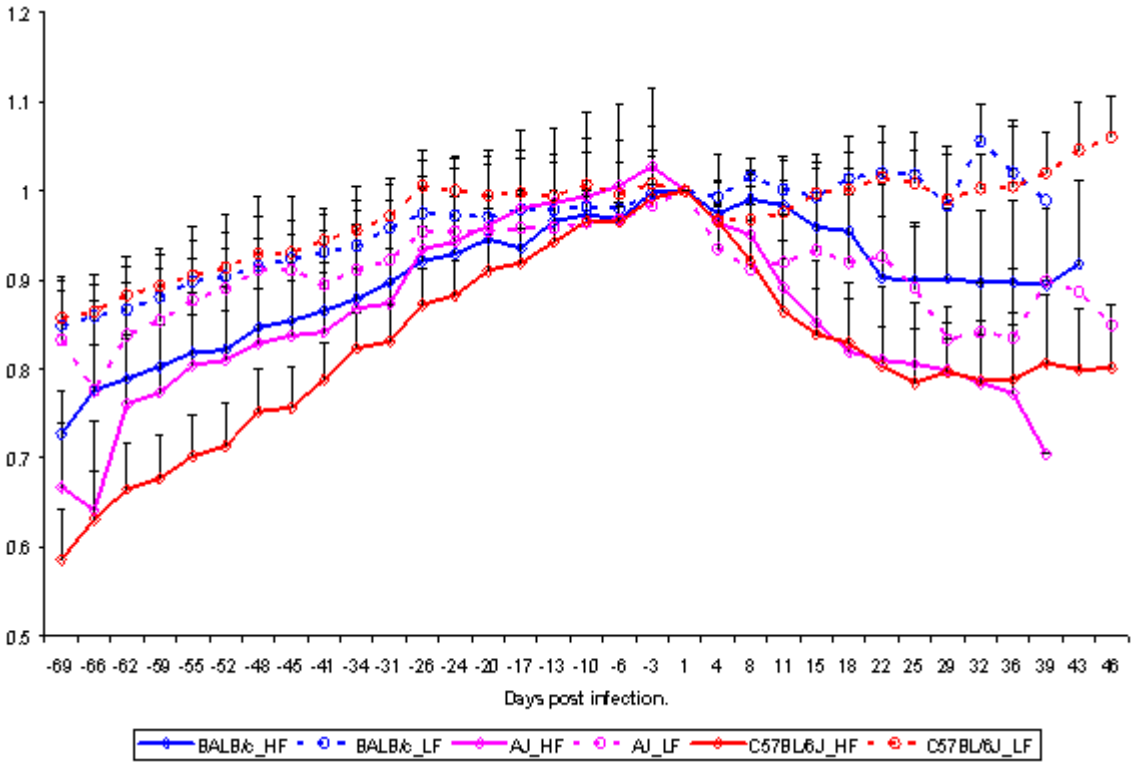

Figure 1. Effect of feeding on either low fat or high fat diet and infection with *T. congolense* on the body weight of Balb/c, C57/BL6J, and A/J mice.

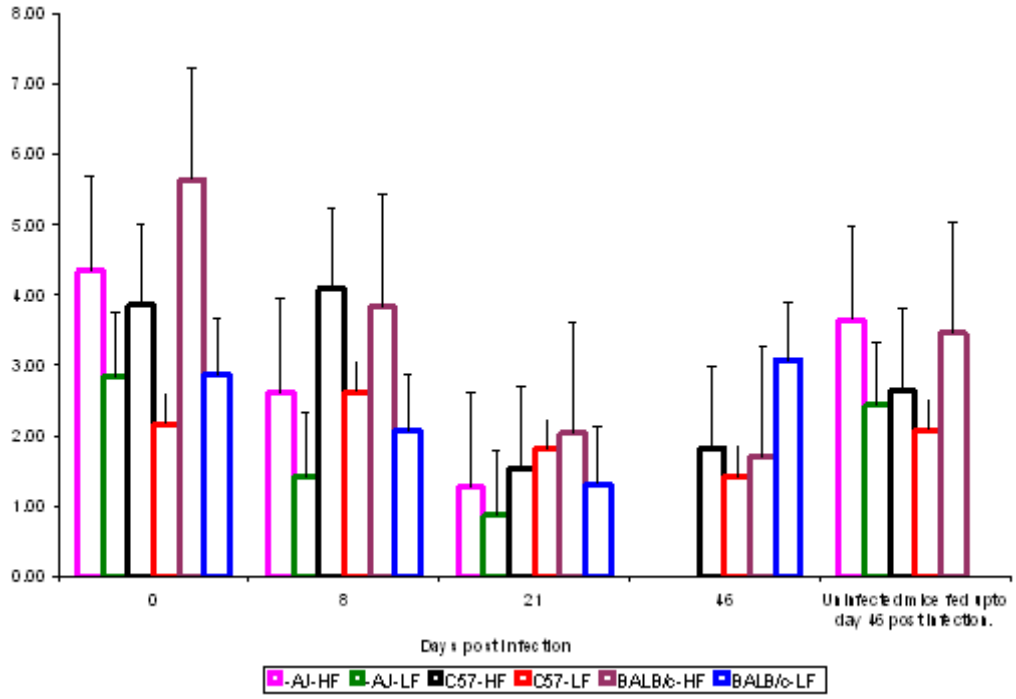

Figure 2. Total-cholesterol levels of Balb/c, C57BL/6J and A/J mice just before infection (day 0) with *T. congolense* and at 8, 21 and 46 days post-infection.

The level of total-cholesterol after 46 days of feeding without the effect of trypanosomes is shown in Figure 2 while the level of LDL-c after 46 days of feeding without the effect of trypanosomes is shown in Figure 3. The level of LDL-c after 46 days of feeding without the effect of trypanosomes is shown in Figure 5.

Only A/J mice showed significantly different parasitaemias between the two dietary groups, with the mice on the high fat diet having lower parasitaemia (mean score of 2 versus a mean score of 3 for the low fat diet group) (Figure 5).

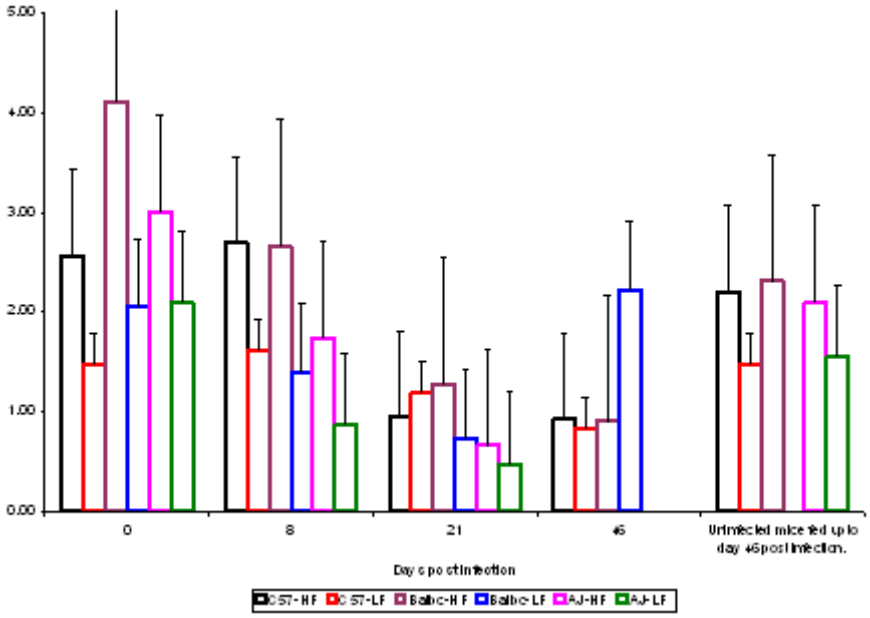

Figure 3. HDL-cholesterol levels of Balb/c, C57BL/6J and A/J mice just before infection (day 0) with *T. congolense* and at 8, 21 and 46 days post-infection.

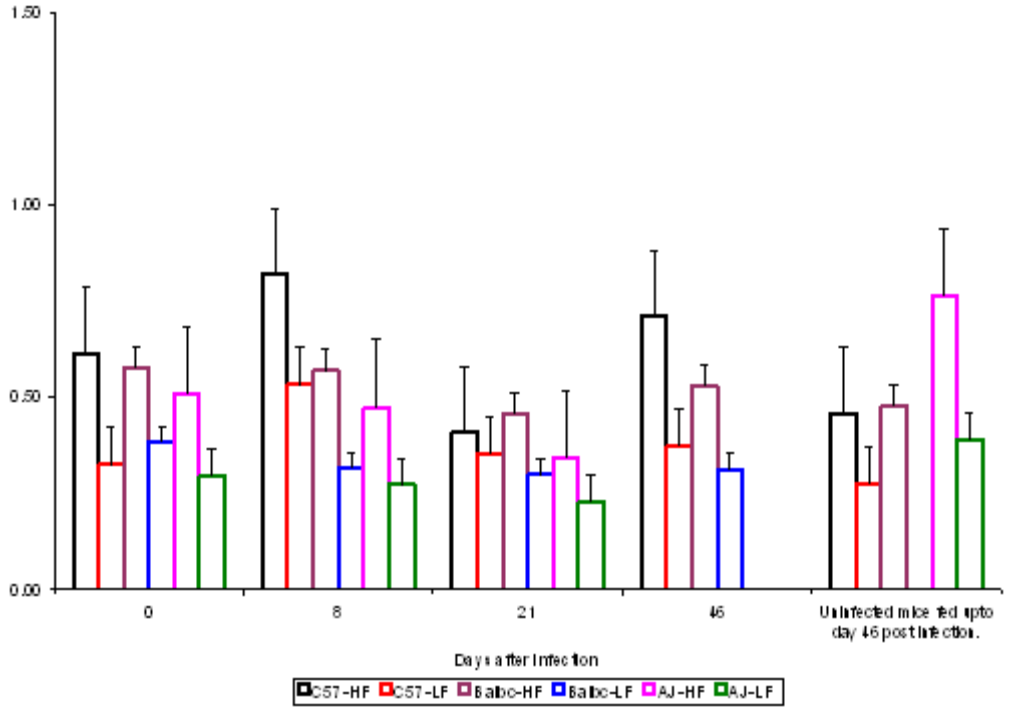

Figure 4. LDL-cholesterol levels of Balb/c, C57BL/6J and A/J mice just before infection (day 0) with *T. congolense* and at 8, 21 and 46 days post-infection.

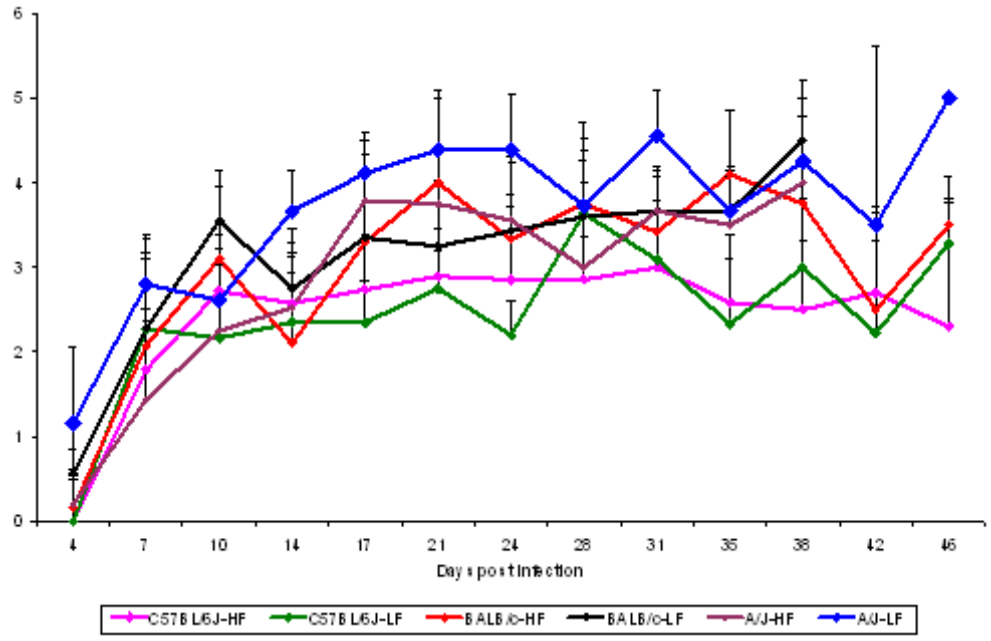

Figure 5. Parasitaemia trends in Balb/c, C57BL/6J and A/J mice infected with ***T. congolense*** after feeding on a low or high fat diet.

Discussion

Following infection, there was a decline in plasma HDL-cholesterol level; this is in consonance with observations made by Ogunsanmi et al. (2000) and could be a reason for the rise in parasitaemia. These results show that increasing the plasma HDL-cholesterol levels does not

raise parasitaemia in the resistant mouse strains. There was a decline in parasitaemia with an increase in plasma HDL-c levels in the A/J strain, raising the possibility of HDL-c having an effect in parasitaemia only in the susceptible strains. There is thus no support for the hypothesis that host lipid levels directly affect parasitaemia in the resistant strains. Possibly, there is up to a certain level of physiological plasma HDL-c concentration that can support parasite growth, beyond which it is detrimental to parasite multiplication and growth. However, the observation that mice on the low fat diet essentially stopped growing does raise the possibility that, despite the diets being calorie-matched, this group may have been suffering from the consequences of an inadequate diet.

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Application of suppressive subtractive hybridisation technique to isolate differentially expressed genes in *Rhipicephalus appendiculatus* ticks following infection by *Theileria parva*

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Abstract

Tick salivary gland proteins are responsible for suppression/modulation of host immune responses and subsets of such genes whose expression is modified by *Theileria parva* infection would be candidates for inclusion in anti-tick/anti-pathogen combination vaccines. We used subtractive hybridisation to screen mRNAs in *T. parva* infected and uninfected *Rhipicephalus appendiculatus* salivary gland cDNA and identified 20 transcripts whose expression was modulated in respect to infection. Out of these, 15 were up regulated and 5 down regulated in response to infection by the pathogen. The identities of the isolated clones were determined by searches on RaGI (www.tigr.org/tigr-scripts/tgi), *T. parva* CDS and nucleic research database on proteins and nucleic acids using BLAST and other algorithms. Based on this analysis, the sequences were divided into three categories: those responsible for modifying host immune responses to the tick, transport molecules (including a putative Na^+/K^+ ATPase) and previously unidentified genes.

Introduction

Humans have a long history of trying to control ticks. At first, attempts focused on modifying the habitat; later efforts relied heavily on the use of chemicals (Norval et al. 1992). Current research is directed at finding a vaccine against ticks. A strategy of targeting 'concealed antigens' succeeded with the first commercialised vaccine against the cattle tick *Boophilus microplus* (reviewed by Willadsen 2001*). Rhipicephalus appendiculatus* is one of the most economically important ticks distributed in south, central and eastern Africa where little progress has been made on attempts to develop a vaccine, unlike the *B. microplus* tick vaccine based on concealed tick antigen (BM 86). Blood feeding arthropods are a major problem to both human and veterinary health worldwide both as debilitating agents and as vectors of diseases (Willadsen et al. 1989). Blood feeding arthropods are not simply crawling or flying hypodermic needles and syringes but they form a complex relationship with the pathogen they transmit. These relationships are believed to either promote the pathogens transmission into the mammalian host or they are defence mechanisms mounted by the arthropod to counter-act the pathogen's onslaught. These invertebrates produce numerous pharmacologically active molecules that help them migrate through the tissues of their host to successfully obtain blood meals.

Theileria parva is the causative agent of East Coast fever (ECF), an acute, tick-borne disease causing high rates of morbidity and mortality in cattle in 12 countries in sub-Saharan Africa. Tick saliva contains pharmacologically active molecules that inhibit the hosts' homeostasis, reduce pain and itch, modulate hosts inflammatory and immune responses and others that are also responsible for transport (Wikel 1996). During feeding, new proteins are expressed by the salivary glands and some are especially transcribed in the ticks' salivary gland in response to infection

(Nene et al. 2004). Molecules in tick saliva that possesses immunomodulatory activities are important for both tick survival and pathogen transmission. However, immune responses have also been shown to interfere with pathogen transmission. An example of such molecules is the *Rhipicephalus* Immuno-dominant Molecule 36 *(RIM* 36) that induces strong antibody responses in cattle in association with tick feeding.

Efforts have been made to catalogue expressed sequence tags (EST) that are expressed in the salivary glands of *R. appendiculatus* whose expressions are modified by the pathogen which resulted in the creation of a gene index (RaGI). This led to the identification of many novel and previously described genes including those that play critical roles in vector and pathogen biology (Nene et al. 2004). However, since that effort only screened less than 0.02% of the cDNA libraries, there were risks of omission of less abundant transcripts. This problem has, however, been overcome by the choice of subtractive suppressive hybridisation, a technique that combines normalisation and subtraction in a single procedure (Diatchenko et al. 1996). This has led to identification of some more novel genes and rare transcripts revealed by the subtraction procedures.

We report here on the identification of *R. appendiculatus* tick salivary gland genes associated with *T. parva* infection, as revealed by subtractive hybridisation and confirmed by slot blot hybridisation and semi-quantitative real time polymerase chain reaction (PCR) analyses. Our results indicate that mRNA transcripts in *R. appendiculatus* were up-regulated or induced more than they were down-regulated in response to theilerial infection.

Materials and methods

Isolation of salivary glands and total RNA

Two batches of adult ticks were fed on rabbits for 4 days and *T. parva* infection rates determined as previously described by Buscher and Tangus (1986). One batch of ticks was fed on rabbits infected with *T. parva* sporozoites while the other batch was fed on uninfected rabbits.

Salivary glands from 30 female ticks were stained with Schiff's reagent on a glass slide and the number of infected acini per tick determined by microscopy. The average infection was approximately 120 infected acini per female tick. Salivary glands from the infected ticks were dissected and placed in 20 ml ice cold L15 medium containing 15% foetal calf serum (FCS). The media was removed following centrifugation at 2000 xg for 5 min at 4°C and salivary glands were dissolved in 35 ml RNA extraction solution (Xie and Rothblum 1991) with vigorous shaking for 2–3 min. Undissolved fibrous material was removed by centrifugation at 2000 xg for 10 min at 4°C; 1/10 volume of chloroform/isoamyl alcohol (24:1) was then added to the supernatant and mixed by vigorous shaking for 10 seconds. The mixture was left on ice for 30 min and then centrifuged at 10000 xg for 20 min at 4°C. RNA was recovered from the aqueous phase by precipitation with an equal volume of 100% isopropanol. The precipitate was again centrifuged at 20800g for 20 min at 4°C to pellet the total RNA, which were washed twice with 70% ethanol, air dried and dissolved in double distilled water (ddH_20). The yield and quality of total RNA was determined by agarose gel electrophoresis and optical density (OD) reading through spectrophotometry.

mRNA extraction

mRNA was purified from each of the *R. appendiculatus* salivary gland *T. parva* infected and uninfected total RNA extracted above. Purification was done using Oligotex poly A+ synthesis kit (Promega, Madison) according to manufacturer's instructions and stored at –80°C until use.

Subtraction hybridisation analysis

Subtraction hybridisation analysis was carried out using the PCR-Select™ cDNA Subtraction Kit according to the manufacturer's recommendation (ClonTech). Double stranded cDNA was synthesised from 2 mg of mRNA from both *T. parva* infected (1) and uninfected (2) *R. appendiculatus* cDNA. Both cDNA were digested to completion with *Rsa* I and then ligated to adaptors 1 and 2R for forward and reverse priming sites respectively. The ligation was done to the cDNA such that each adaptor ligated cDNA, also called tester cDNA, had one set of adaptors ligated, i.e. 1-1 and 1-2R for infected cDNA and 2-1 and 2-R for uninfected cDNA. The adaptor ligated cDNA were then subjected to two rounds of subtractive hybridisation using uninfected cDNA (2) for infected tester fractions and infected cDNA (1) for uninfected tester fractions so as to eliminate mRNA transcripts common to the 1 and 2 cDNA pools. Since the driver cDNA was not ligated to adaptors or PCR priming sites, the tester-driver cDNA hybrids carried only one priming site and were therefore not available for subsequent PCR amplification. Eventually, cDNA transcripts common to the 1 and 2 cDNAs were subtracted from the cDNA pools. In the final hybridisation round, Tester 1 and 2 cDNA pools were hybridised to produce subtracted infected and uninfected cDNA libraries containing differentially expressed cDNA transcripts.

Cloning of differentially expressed cDNAs

To amplify and enrich for differentially expressed mRNAs, 1 ml aliquots of diluted (1:40) subtracted infected cDNA and subtracted uninfected cDNA libraries were subjected to nested PCR using hot start PCR protocol with a slight modification on the number of PCR cycles. The number of PCR cycles was increased to 30 for the initial PCR and 25 for the nested PCR instead of the recommended 22 and 12 respectively. An aliquot of the PCR product was electrophoresed and analysed on a 1.5% agarose gel containing 1 mg/ml ethidium bromide. The PCR products were purified through Qiagen PCR purification kit according to manufacturer's instructions and eluted into 35 µl of distilled water. The elute was then ligated into pGEMT-vectors (Promega, Madison) at a vector to insert ratio of 1:2. The ligation was transformed into competent JM109 cells for purification of transformed plasmids. Insert-positive clones were selected by blue (insert negative) and white (insert positive) colony selection criteria, and in combination with PCR amplification using vector-specific T7 and sp6 promoter primers and finally with adaptor nested primers. Selections of positive clones were sent for dot blot hybridisation.

Dot blot hybridisation

Clonetech PCR select™ cDNA subtraction kit was used to identify differentially expressed genes as per manufacturer's instructions. The screening method chosen was to ensure that even low abundance transcripts were detected by hybridisation. The two subtracted libraries (infected and uninfected) were hybridised with forward- and reverse-subtracted cDNA probes. The forward subtracted probe was made from the same subtracted cDNA used to construct the subtracted library and vice versa. Unsubtracted probes were also made. Clones representing mRNAs that are truly differentially expressed were expected to hybridise only with the forward subtracted probe while clones that hybridised to both may be considered background Wang and Brown 1991).

Results

Clone 1 was not searched against the database because it gave poor sequence results even after repeat sequencing from both the T7 and SP6 ends. From the *Rhipicephalus appendiculatus* Expressed sequence tag (RaGI) database (Nene et al. 2004), clone 3 corresponded to both TC 11, which came from a *T. parva* infected library of *R. appendiculatus*, and TC 1505 that was sequenced from uninfected salivary glands. Clone 02, however, had homologies to cDNA clone TC 1270/1. Their E values (corresponding to a probability of significance of the match) were also highly significant at E-109 and E-149.

Clone 2 was weakly similar to human purine nucleoside but since it was not differentially expressed, it was not processed any further. Clone 4, a homologue to glycine rich proteins had similarity to one singleton in the RaGI database which was sequenced form infected salivary

gland cDNA. This confirmed the results from application of the Suppression Subtractive Hybridisation (SSH) technique. Two groups (Bishop et al. 2002; Trimnell et al. 2002) have studied tick glycine rich (G-rich) tick cement proteins and discovered that they are immunogenic in both rodent models and cattle. Bishop et al. (described the cloning of an *R. appendiculatus* cement protein (a 36 kDa protein, designated *Rhipicephalus* immuno-dominant molecule) containing glycine-rich repeats that induces strong antibody responses in cattle in association with tick feeding.

Clone 7 also had a match with a clone in RaGi library, TC 649, which was sequenced from the infected tick salivary glands. The BLASTX results had significant hits to the Immunoglobulin G histamine release factor and controlled tumour protein homologue.

Another 5 clones (6, 8, 12 and 14) were up regulated and 1 (clone 23) down regulated in response to theilerial infection; they did not show any similarity to known proteins on the database hence could be novel genes. Their E values were significant as were their affiliation to the RaGi. Clone 04 had homology to *Gallus gallus* while clone 13 had significant plasmodium hits. Clone 33 resembled damage specific DNA binding protein homologue while clone 43 was phospholipase C like proteins.

No.	BlastX	E value	Regulation	RaGI affiliation	Comments
1					Poor seq
2	Weakly similar to HUMAN Purine nucleoside phosphorylase (Inosine phosphorylase	0.0	Up regulated (UR)	Infected SG TC 1242 EST 666230 CD794869	
3	AF327439 Na+/K+ ATPase alpha subunit {Callinectes sapidus}, glycine-rich protein (*Triticum aestivum*)	e-109	Down regulated (DR) Up regulated DR	RaGI infected TC 11, RaGI un-infected TC 1505	Responsible for transport, secretions, increases with increase in infection Causes AB response in cattle (Bishop 2002)
4	No hit	1e-57		RaGI infected cDNA	Novel gene?
8				No hits	
9	Sodium-potassium dependent ATPase beta sub unit	e-149	UR	Infected salivary glands cDNA TC 1270/1 & EST ID666121	
10	AF421549 CDH1-D {Gallus gallus}	e-137	UR	Uninfected SG cDNA	
11	Conserved protein Tpchr3	2e-05	UR	No hits on RaGI	
12	No hits		UR	No hits	Pathogen conserved molecules
13	Plasmodium vivax1	3e-94	UR	Infected TC 11	
15	Damage specific DNA binding	e-114	UR		

Discussions

Ticks have an efficient defence system for preventing parasitic infection. *R. appendiculatus* is one of the most economically important ticks distributed in south central and eastern Africa where little progress has been made to develop a vaccine unlike the *B. microplus* tick vaccine based on concealed tick antigen. Blood feeding arthropods are a major problem to both human and veterinary health worldwide both as debilitating agents and as vectors of diseases (Willadsen et al. 1989).

Blood feeding arthropods form a complex relationship with the pathogen they transmit. These relationships are believed to either promote the pathogens transmission into the mammalian host or they are defence mechanisms mounted by the arthropod to counteract the pathogen's onslaught. These invertebrates produce numerous pharmacologically active molecules that help them migrate through the tissues of their host to successfully obtain blood meals. There appeared to have been many more genes that were up regulated than those that were down regulated in the tick vector salivary gland following theilerial infection. An estimated 1000 colonies isolated using the (SSH) technique were screened by adaptor nested primers to 200 colonies out of which 40 were subjected to slot blot analysis.

The immune mechanisms of arthropods are based on humoral factors and on the functions of haemocytes. Additionally, tick defence molecules have been shown to be expressed in haemocytes. While further experimental evidence is required to conclusively state that the genes identified in this study played a role in tick–theilerial interactions, the putative identity of some of the genes isolated here, such as the IgE-dependent histamine release factor, tetraspanin and the clathrin adaptor protein strongly indicates that the results observed here were a consequence of the theilerial infection of ticks. Observations in this study are not specific to theilerial infection in ticks. Mulenga et al. (2003) indicated that similar observations were obtained in theilerial infection of ticks.

Successful attempts on tick vaccination depend on specific antibody-mediated immunoreactions that damage the parasite. Immunoglobulin molecules of vertebrate hosts can pass through gut barriers into the haemolymph of ectoparasites while retaining antibody activity (Wang et al. 1999).

Another set of genes identified in the project is that of Na+/K+ ATPase. In previous studies with *Strongyloides* (Kerepesi et al. 2005), Na+/K+ ATPase induced a significant reduction in larval survival after DNA immunisation. Serum from mice immunised with DNA encoding Na+/K+ ATPase was transferred to naive mice and resulted in partial protective immunity. This work concluded that DNA immunisation with Na+/K+ ATPase induced protective immunity in mice, and it is the first identified vaccine candidate against infection with larval *S. stercoralis*. Given the fact that *Theileria* are obligatory intracellular parasites, successful attachment/adhesion and entry into the eukaryotic host cell is a necessary first step for infection to be established. It was therefore consistent that putative adhesion/receptor molecules like the clathrin adaptor protein be differentially expressed in infected ticks.

Conclusion

For this project, it is clearly evident that there are differences in the expression of *R. appendiculatus* tick mRNAs in *T. parva* infected and uninfected salivary glands that are induced by the pathogen to enhance its survival in tick and transmission into the mammalian host. It is known that tick salivary gland proteins are responsible for suppression/modulation of host immune responses and we propose that the subset of these whose expression is modified by *T. parva* infection would be strong candidates for inclusion in anti-ticks-anti-pathogen combination vaccine.

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Parallel session 2

Human and environmental health

Improving human and animal health using genetically engineered goats expressing lysozyme in their milk

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Introduction

The technology of genetic engineering (GE) is one more tool for use in animal breeding. It is neither a silver bullet to fix all the problems and nor is it a mechanism for replacing good animal breeding practices. What GE does is to allow genetic information in the form of new loci or new alleles at an existing locus to be introduced into the genetic background of any of our major livestock or aquaculture species.

The application of genetic engineering should not be undertaken lightly as it requires extensive infrastructure and inputs before the genetically engineered animal enters a breeding and selection scheme; it does not provide a mechanism for bypassing good animal breeding and selection practices. However, there are instances where GE can provide an opportunity to address a problem in animal agriculture for which the necessary genetic elements cannot be brought into the animals' genome by any other method. Thus, when discussing the role of biotechnology in improving animal agriculture in Africa, GE needs to be included in the discussion, even though the final outcome of that discussion may be that GE is not suitable for application at this time.

Given this background, we would like to present some of our work, and examples from the literature, to illustrate some of the possibilities and to outline the extent of problems in doing this type of work. Genetic engineering can be used to improve animals for use in agriculture, to use animals for pharmaceutical production or for the production of animal (swine) organs for use in human xenotransplantation. Neither pharmaceutical production nor xenotransplantation applications directly affect production agriculture. While both may provide a seemingly economic development potential, caution is needed in that to date no company has brought such a product to the market in the 20 plus years since these applications were first suggested (Palmiter et al. 1982; Jimenez-Flores and Richardson 1988; Yom and Bremel 1993; Maga and Murray 1995). For these reasons, we will focus specifically on aspects of the potential for applying genetic engineering for use in animal agriculture.

Combining various methods for cell transformation (microinjection, viral vectors, electroporation, lipofection etc.) with the components of oocyte/embryo collection and manipulation, including somatic cell nuclear transfer-based cloning (Campbell et al. 1996), it is now possible to make virtually any genetic change in farm animals. The types of changes range from knocking out an endogenous gene to introducing a specific mutation in an endogenous gene to create a new allele (Murray and Maga 2005).

Techniques are now available, even if efficiency is low, to produce genetically engineered or transgenic livestock. The real question now becomes what gene or allele do we change, add or delete to improve our livestock. In other words, are there problems in production animal agriculture for which GE provides the only, or best, potential solution? Such problems can pertain to increasing the efficiency of production, decreasing environmental impacts of animal agriculture, improving animal health and disease resistance, or improving the animal-based products for human use,

including enhancing the safety, nutritional or functional value of the derived food. To illustrate GE approaches in each of these areas we will review three projects.

Enhancing animal production

The knowledge that high production of milk and its components is necessary to allow maximal growth of neonatal mammals leads to the hypothesis that increasing milk production by sows would increase the number of baby pigs weaned, thus increasing the overall efficiency of production (Bleck et al. 1998). The approach was to increase milk production by increasing á-lactalbumin activity in the mammary gland epithelial cells, thus increasing lactose secretion and thereby the volume of milk produced. The transgenic pigs were generated via microinjection of the bovine á -lactalbumin gene, including the promoter, coding region, and 3' flanking sequences. The production of bovine á-lactalbumin in the mammary gland resulted in approximately a 50% increase in the total á-lactalbumin concentration of pig milk. The higher level of total á-lactalbumin correlated with higher lactose percentage in transgenic sows (Bleck et al. 1998).

The expression of the á-lactalbumin transgene was associated with alterations in composition of mammary secretions, with transgenic gilts producing more milk than controls up to day 9 of lactation. Lactose and total solids intake by transgenic sow-reared litters was greater up to day 6 of lactation, with transgenic-reared litters gaining weight at a greater rate than control-reared piglets (Noble et al. 2002). Thus, expression of the á-lactalbumin transgene was associated with increased milk production in lactating gilts and increased growth of transgenic-reared piglets.

Ameliorating environmental impacts

A major environmental problem that accompanies increasing concentrations of livestock, poultry and aquaculture is environmental degradation due to accumulating levels of nitrogen and phosphorus in the soil and surface water. The high level of phytate, an indigestible form of phosphorus, in plant material may result in high levels of phosphate in faeces. Phytase enzymes are lacking in farm animals and cultured fish species, thus genetic variability is not available for selection. To address the problem of phosphorus pollution coming from animal waste, Golovan *et al.* (2001a, b) constructed phytase transgenes composed of the *Escherichia coli* appA phytase gene coding region under the regulation of the rat R15 proline-rich protein promoter or mouse parotid secretory protein promoter. These transgenes directed high levels of phytase expression in the parotid salivary glands that was then secreted in saliva as an enzymatically active protein. Expression of phytase in saliva reduced faecal phosphorus output by up to 75% in transgenic pig manure. Without this enzyme, phytate phosphorus passes undigested into manure to become the single most important manure pollutant of pork production. The phytase transgenic pigs thus offer a unique genetic approach to the management of phosphorus nutrition and environmental pollution in the pork industry and by extension to other forms of livestock, poultry or cultured fish.

Altering the functional and nutritional properties of milk

Lysozyme is a positively charged antimicrobial molecule, existing naturally in avian egg whites and mammalian secretions such as tears, saliva and milk (Jolles and Jolles 1984) that specifically catalyses the cleavage of the peptidoglycan component of bacterial cell walls (Phillips 1996). Lysozyme is naturally present in human milk at concentrations 1600 times greater than in goat milk and is one of the protective compounds responsible for the antimicrobial properties of human milk (Levy 1998). Therefore, the presence of increased levels of lysozyme in livestock milk when consumed by animals or humans would be an efficient way to deliver the benefits of human milk in a continuous and cost-effective manner. The application of GE dairy animals producing lysozyme may benefit animal and human health, as well as food safety and production.

Transgenic goats were generated by standard pronuclear microinjection with a DNA construct consisting of the promoter and 3' regulatory elements of the bovine a_{s1}-casein gene coupled to the cDNA for the human lysozyme (HLZ) gene (Maga et al. 1994; Maga et al. 2003). The human gene for lysozyme was chosen since no allergic or toxic responses are anticipated because it is present in the saliva and milk of humans and therefore is already consumed by all humans daily. To date we have produced a total of 26 HLZ transgenic animals through the F3 generation by natural breeding to non-transgenic goats. Expression of the HLZ transgene at both the mRNA and protein level was confirmed by Northern and Western blot analysis respectively. HLZ protein expression in the milk of hemizygous does was estimated to be approximately 68% of the level found in human milk. Furthermore, there was no gross disruption of the overall composition of milk as milk yield and total fat and protein levels for the transgenic line fell in the same range as the means of our dairy goat herd. The line of goats used for study was hemizygous and produced 1080 times more lysozyme than is normally found in goat milk.

The presence of HLZ in transgenic milk affected several processing properties of milk. The rennet clotting time of HLZ milk was significantly faster and the strength of rennet-induced curd was significantly stronger when transgenic goat milk was used compared with non-transgenic controls of the same lactation (Maga et al. in press).

Goat milk containing HLZ had a bacteriostatic effect on both the *in vitro* and *in vivo* growth of several micro-organisms involved with animal health (*E. coli*) and food safety and production (*Pseudomonas fragi*), while not affecting a strain of *Lactococcus* used in cheese production. Transgenic HLZ goat milk slowed the growth of a clinical isolate of *E. coli* as indicated by a significantly lower mean number of colonies (CFU/ml) on plates with HLZ transgenic milk compared with non-transgenic milk, but did not significantly affect the growth of a mastitis-causing strain of *Staphylococcus aureus*. Transgenic milk was, however, capable of slowing the growth of several bacteria *in vivo*, including *S. cohnii*, indicating that HLZ can act upon gram-positive *Staphylococcus* species. When cultured, transgenic milk had overall lower CFU/ml than did milk from non-transgenic controls. The HLZ transgenic milk also had an increased shelf life as fewer bacteria survived at room temperature for longer periods than control milk before bacterial growth occurred.

A measure of udder health was made by monitoring the somatic cell count (SCC) of milk taken from both halves of the udder. The SCC over a period of 2 years was significantly lower in the HLZ transgenic animals than in our control herd over the same period (Maga et al. in press). High SCC can be directly correlated with mastitis and a decline in milk quality due to associated chemical changes in the milk. While SCC levels in non-transgenic goat milk were not at levels considered unhealthy, they were lower in milk from transgenic does, indicating a healthier udder with fewer sloughed mammary epithelial cells and leukocytes that are indicators of an intramammary bacterial infection. Taken together, these two antimicrobial aspects of HLZ transgenic milk have implications not only in terms of food safety and longevity but also in terms of mastitis prevention.

Additional studies are of great importance in evaluating the potential impact milk of this type may have on the health of the lactating animal and of those consuming the milk. If HLZ is effective in the mammary gland, it could offer a natural defence against mastitis and improve the health and well-being of lactating animals. Likewise, HLZ transgenic milk may have the potential to affect the health of consumers of the milk. Whether a neutraceutical effect such as this has a role to play in African agriculture is an appropriate subject for discussion by animal scientists and producers. Lysozyme can retain activity at pasteurisation temperatures (Shahani et al. 1962), can be active in the environment of the gastro-intestinal tract (Goldman 1993), and can be taken at levels of 5 mg/g body weight with no toxic effects (Osserman et al. 1973). Therefore, it is

possible that HLZ in ruminant milk can act as anti-microbial agent in human milk to result in decreased incidence of gastro-intestinal bacterial infections. In animal studies, feeding of lysozyme has been shown to enhance gut function, promote growth and offer increased resistance to infection (Edde et al. 2001; Humphrey et al. 2002). Indeed, no adverse affects in terms of growth, illness or time to weaning were observed when kid goats consumed the HLZ transgenic milk.

Animal health, milk quality and food safety are important issues for the consumer and the dairy industry alike. Results reported here characterising the milk from transgenic goats expressing HLZ indicate that the genetic engineering of dairy animals to express human milk components does have the potential to affect many of these issues.

Conclusions

As illustrated in each of the three examples given above, GE provides opportunities to improve human and animal health, ameliorate the negative environmental consequences of animal agriculture, and improve the efficiencies of animal production. Genetic changes introduced by GE are permanent heritable changes and thus can be integrated into selection schemes. However, there are a number of significant challenges to be overcome if these opportunities are to be realised.

First, and perhaps the easiest to overcome, is the need to be able to identify appropriate genes and promoters for use in transgene constructs. The real challenge here is to understand the biochemistry and physiology responsible for a desired trait well enough to be able to identify the necessary gene to enhance the trait and the appropriate promoter that will yield the necessary pattern of expression. A corollary to this challenge is that GE should not be used when genetic variation exists for the trait within the species of interest, thus allowing for selection.

Second, the production and study of GE livestock is currently inefficient and thus represents expensive, long-term research. Furthermore, the animal breeding considerations that will be required to introgress a transgene into a national herd, while maintaining a selective breeding programme will also constitute a major research and logistical effort. The final challenge is not a matter of scientific research, but rather one of providing sufficient data to obtain consumer acceptance of GE animals as food. This also requires the enactment of suitable, effective regulations to instil public confidence in the regulatory framework designed to ensure food safety, but it is also important that such regulations should not be constraining and that decisions based on such regulations should be supported by scientific evidence. In conclusion, we would submit that the potential does exist for GE to play an important role in the future development of animal agriculture in Africa, but that such applications should be well thought out and should address regional problems rather than local ones.

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Crop–livestock interaction in the savannahs of Nigeria: Nature and determinants of farmer decision to use manure for soil fertility maintenance

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Abstract
In Nigeria, increased land-use intensity has depressed the use of fallow for soil fertility restoration. Crop yields have fallen, threatening food security. High cost limits farmers' access to fertilisers. Reliance on crop–livestock interaction is plausible because animals provide manure. This paper evaluates the nature of crop–livestock interactions in the savannahs of northern Nigeria, assesses its capability to maintain productivity, and uses a logit model to estimate determinants of farmers' decision to adopt manure for fertility maintenance. Results show that although 86% of the farmers indicated some interaction between crops and livestock, the interaction is weak. Manure is inadequately provided. Only 56% of the farmers applied manure (40–67% of requirement) to their largest upland plot. Results of the logit model indicate that farmers' characteristics and perceptions are the most crucial factors. The paper concludes with recommendations to promote crop–livestock integration and the use of manure for fertility maintenance in the savannahs of Nigeria and similar ecologies.

Key words: crop services, livestock services, manure use decision, Northern Nigeria, savannahs

Introduction
The savannah zone of Nigeria is very important to the agricultural economy of the country because it is where most of the food consumed in the country is produced. In the past, farmers used fallow periods to restore the fertility of depleted lands. Population pressure has reduced the use of fallow periods. Productivity has fallen, threatening food security. The structural adjustment programme has worsened the limited access of farmers to inorganic fertilisers. The search for alternative methods of maintaining fertility led to interest in crop–livestock interactions. Past studies have covered many important topics including the benefits of manure to crop yields in West Africa (Powell et al. 1999). However, little micro-level research has been conducted to demonstrate the nature of crop–livestock interactions in most farming systems in Nigeria (Okike 2000). Previous studies have also failed to establish the link between the increasing importance of crop–livestock systems and the mutual benefits derived from crop–livestock interaction. This study aims to evaluate the nature and manure benefits of crop–livestock interactions in the savannahs of Nigeria, assess the capability of existing crop–livestock interactions to maintain productivity, and determine the factors that influence farmers' decisions to use manure for fertility maintenance.

Research methods

The study area

This study was carried out in 2002 in four villages (Doka and Muriga in Kaduna State and Dan Hassan and Yelwa Danzial in Kano State). While the ecology of Kaduna State is Guinea savannah (GS) with 600–1200 mm rainfall annually, that of Kano State is Sudan savannah (SS) with 300–600 mm annual rainfall. Agricultural activities in the study area are mostly carried out in the uplands. However, *fadamas* (lowland fields) are increasing in importance for food production. In the farming systems, crops and livestock interact mostly through the supply of manure for crop production by livestock and the supply of fodder and sometimes grains for livestock production by crops.

Sample selection and survey

A stratified two-stage random sampling was used to select 160 farm households, 80 each from the 2 agro-ecological zones. Stage one involved grouping villages in each agro-ecological zone into (i) those with primarily upland activities and (ii) those where farmers have upland fields and access to *fadamas*. One village each was randomly selected from each of the groups or list of villages (SF). In stage two, four SFs were constructed of households in each selected village. Forty households were randomly selected from each SF. The heads of the selected households were interviewed using a questionnaire. The index number approach was used to illustrate the changes that have taken place (between 1970 and 2001) in yields of major crops, 1970 serving as the base index (with the value 100). The index numbers were computed with the help of the proportional piling method (see Chianu et al. 2004).

Analytical approaches and models

(i) Average index of crop yield with 1970 as the base year
The model used to compute the average index of yield for the j^{th} crop is given as:

$$AIndex_j = \frac{\sum_{i=1}^{m} Xij}{m}, \quad j = 1, 2, \ldots, 4 \qquad (1)$$

where, *AIndex* = Average yield index of the j^{th} crop, X_{ij} = yield index of j^{th} crop for m surveyed farms, and m = the total number of farms surveyed.

(ii) Computation of tropical livestock unit (TLU)
The number of cattle (*Bos indicus*), sheep (*Ovis aries*), goat (*Capra biscus*), poultry (avian spp.) and other animals kept by households was aggregated into tropical livestock units (TLU) using appropriate conversion factors.

(iii) The logit model
Following Greene (2000), we specify the general framework of the logit model that captures the factors that explains farmers' use of manure as:

$$\begin{aligned} \text{Prob(event j occurs)} &= \text{Prob}(Y = j) \\ &= F[\text{relevant effects: parameters}]. \quad (2) \end{aligned}$$

Consider a model of farmer use of manure for fertility maintenance. The respondent either uses it (Y = 1) or does not (Y = 0) in 2001. Past studies have demonstrated that a set of factors [such

as farmer characteristics ($\boldsymbol{Z}_i$), variables conditional to farmers' decision ($\boldsymbol{C}_{ij}$), and village characteristics ($\boldsymbol{V}$)] gathered in a vector $\mathbf{X}$ influence a farmer's decision to use improved technologies, such that:

$$\text{Prob}(Y = 1) = F(\mathbf{X}, \beta) = F(\boldsymbol{Z}_i, \boldsymbol{C}_{ij}, \boldsymbol{V}, \beta) \qquad \textbf{(3)}$$
$$\text{Prob}(Y = 0) = 1 - F(\mathbf{X}, \beta).$$

β reflects the impact of changes in $\mathbf{X}$ on the probability of use of manure. To estimate this, we need a model that will produce predictions consistent with (2). For a regressor vector, we would expect

$$\text{Lim Prob}(Y = 1) = 1$$
$$\beta' X \to -$$

and

$$\text{Lim Prob}(Y = 1) = 0. \qquad (4)$$
$$\beta' X \to -\infty$$

Partly because of its mathematical convenience, the logistic distribution,

$$\text{Prob}(Y = 1) = \frac{e^{\beta' \mathbf{X}}}{1 + e^{\beta' \mathbf{X}}} = \Lambda(\beta' X) \qquad (5)$$

has been used in many applications (Ramji et al. 2002). $\Lambda(.)$ is the logistic cumulative distribution function. Estimation of binary choice models is often based on maximum likelihood estimates (MLE). We formulate the probability logit model for farmer adoption of manure as:

$$\begin{aligned} E[y/x] &= 0[1- \quad (\beta' X)] + 1[\quad (\beta' X)] = \Lambda(\beta' X) \\ &= \beta[(\beta' \mathbf{Z}_{ij}, \boldsymbol{C}_{ij}, \boldsymbol{V}_{ij})] = \Lambda[(\beta' \mathbf{Z}_i, \boldsymbol{C}_{ij}, \boldsymbol{V})] \end{aligned} \qquad (6)$$

where, $\boldsymbol{Z}_i$, $\boldsymbol{C}_{ij}$, and $\boldsymbol{V}$ are as defined earlier. In (6), ∞_j in $\boldsymbol{Z}$ is dropped because $\boldsymbol{Z}_i$ are not conditional to farmer's decision. Also, $_{ij}$ in $\boldsymbol{V}$ are dropped because $\boldsymbol{V}$ consists of characteristics common to all households and to choice within village. The log likelihood function of (6) is:

$$\log L = \sum_{i=1}^{n} [y_i \log \Lambda(\beta' X_i) + (1-y_i) \log (1 - \Lambda(\beta' X_i))] \qquad (7),$$

and the MLE of β are obtained by Newton's iterative methods in SAS (1999). The details on $\boldsymbol{Z}$, $\boldsymbol{C}$, and $\boldsymbol{V}$ and the dependent variable are given in Table 1.

Variables in the empirical logit model

The dependent variable (ULFY01D) was whether or not the farmer used animal manure for fertility maintenance. It takes the value 1 if yes and 0 otherwise. The independent variables are discussed below.

HHSIZE refers to size of the household. HHSIZE is the main source of labour for farming in Nigeria. Application of manure is labour-intensive and high labour requirements can discourage adoption. HDAGE is age of head of the household. We assume that the older a farmer is, the more likely that he has accumulated resources to acquire livestock. A positive relationship is expected. HDEDUC measures the level of education of head of household. Educated farmers are more likely to use animal manure to enhance crop productivity and sustainability. AA01DS is farmers' perception about changes in availability of manure and takes the value 1 if farmer perceives that manure is more available and 0 otherwise. A positive relationship is expected. MA01DS is farmers' perception about changes in market opportunity for manure and takes the value 1 if an increased market opportunity is perceived and 0 otherwise. A positive relationship is expected.

Table 1. Descriptive statistics of variables used in the empirical logistic model.

Variable	Expected sign	Mean	Standard deviation	Min.	Max.
ULFY01D (1=used animal manure, 0=did not use)		0.56	0.50	0.0	1
HHSIZE (household size)	+	10.11	4.53	3.0	28
HDAGE (age of the head of household; in years)	+	55.79	12.24	30.0	90
HHEDUC (level of education of the head of the household; 0=no education, …, 6=tertiary institution)	+	3.18	1.42	0.0	6
AA01DS (changes in availability of animal manure)	+	0.41	0.49	0.0	1
MA01DS (changes in market opportunity for animal manure)	+	0.42	0.49	0.0	1
RA01DS (changes in restrictions on access to pasture resources)	–	0.37	0.48	0.0	1
NC01P (total number of different crops produced by household in 2001)	+	4.48	1.82	1.0	11
F01INDDS (changes in overall inherent soil fertility)	–	0.61	0.49	0.0	1
RATIO3 (proportion of land cultivated in 2001 devoted to cereal-legume intercrop)	–	0.32	0.37	0.0	1
MONELEV (market development for intermediate products)	+	1.75	0.83	1.0	3
TOPOMIMP (farmers' rating of the importance of animal manure in soil fertility maintenance)	+	1.12	0.77	0.0	2
TLU (total Tropical Livestock Unit possessed in 2001)	+	1.68	2.26	0.0	14.13
ZONE (1 = GS, 2 = SS)	–	1.50	0.50	1.0	2

RA01DS is farmers' perception about changes in restrictions to access to pasture resources and takes the value 1 if increased restriction is perceived and 0 otherwise. A negative coefficient is expected. NC01P is total number of different crops produced by household and measures crop diversity. A positive relationship is expected. F01INDDS is farmers' perception about changes in inherent soil fertility and takes the value 1 if the farmer does not perceive a major decline and 0 otherwise. A positive relationship is expected. RATIO3 is the proportion of land cultivated in 2001 that was devoted to cereal–legume intercrop. Cereal–legume intercropping is an alternative method used by farmers to replenish soil nitrogen (N). A negative relationship is expected.

TOPOMIMP is farmers' rating of the importance of manure in fertility maintenance. It takes the value 2 if rating is 'very important', 1 if rating is 'important' and 0 if rating is 'not important'. A positive relationship is expected. TLU is the total tropical livestock units kept by household. A positive relationship is expected. ZONE refers to agro-ecological zone and takes the value 1 if it is GS and 2 if it is SS. A higher density of livestock (and hence more animal manure) is expected in SS than in GS (Winrock 1992). However, manure pays better in the GS than in SS because of high moisture (Okike 2000). Thus, we let our model determine the sign for zone. MONELEV is the farmers' perception about market development in intermediate products (crop residues, manure

etc.) in the village and takes the value 1 if is 'low', 2 if 'medium' and 3 if 'high'. A positive relationship is expected.

Results and discussion

Crop production

All surveyed households produced crops in 2001, 98% doing so on uplands (about 72% also utilised *fadamas*). A total of 40 and 21 cropping patterns were observed in uplands and *fadamas*, respectively. The number of crops combined ranges from four to eight. The yield survey result based on index number and proportional piling illustrates the deterioration in yields of crops. Between 1970 and 2001, the index of yield has dropped to 65% (for millet), 74% (rice), 76% (sorghum), 86% (maize), 68% (for groundnut), 77% (cowpea) and 80% (soybean). Actual average yields in 2001 were 1258 kg/ha for maize, 793 kg/ha for sorghum, 374 kg/ha for millet, 1378 kg/ha for rice, 602 kg/ha for groundnut, 202 kg/ha for cowpea and 600 kg/ha for soybean. The declining yields of crops are a clear demonstration of a steady decline and long-term deterioration in soil fertility. The households that kept livestock (75% in 2001) kept an average of 1.94 TLU. Farmers applied an average quantity of 2 t/ha of manure in 2001 compared with 3 to 5 t/ha required to maintain cereal grain yields. Sorghum, groundnut, cowpea, and maize are crucial in mutually beneficial crop–livestock integration. A decline in the yields of these crops leads to a decline in manure production by the poorly fed livestock and poses a threat to the sustainability.

Livestock production

About 78% of the households had some history of livestock ownership. In 2001, 75% kept at least one type of livestock or another (cattle, sheep, goats and poultry are the common animals kept). The household livestock statistics from 1970 to 2001 are shown in Table 2.

Table 2. Household livestock statistics in the savannahs of northern Nigeria: 1970–2001.

Year	Statistic	Cattle	Sheep	Goat	Poultry	Other[@]
1970	Households that kept livestock (No.)	8	36	57	54	10
	Total livestock kept, all h/holds (No.)	29	457	803	1181	309
	Average no. of livestock kept	3.63	12.69	14.09	21.87	30.90
1980	Households that kept livestock (No.)	21	46	80	65	20
	Total livestock kept, all h/holds (No.)	85	562	1087	1841	805
	Average no. of livestock kept	4.08	12.22	13.59	28.32	40.25
1990	Households that kept livestock (No.)	28	60	106	87	22
	Total livestock kept, all h/holds (No.)	132	605	1303	2293	597
	Average no. of livestock kept	4.71	10.08	12.29	26.36	27.14
2001	Households that kept livestock (No.)	27	61	105	88	24
	Total livestock kept, all h/holds (No.)	109	478	1185	1838	412
	Average no. of livestock kept	4.04	7.84	11.29	20.87	17.17

[@] For households that kept livestock, other includes those that kept donkeys, pigeons, and pigs; With respect to total livestock kept, other is contributed for the different years as follows: 1970 (84% by pigeons, 16% by pigs), 1980 (88% by pigeons, 12% by pigs), 1990 (68% by pigeons, 32% by pigs), and 2001 (61% by pigeons, 39% by pigs). Donkeys contributed very insignificantly. For the average number of livestock kept, pigeons contributed 61 to 88% and pigs 12 to 39% depending on the year.

Crop services to livestock production and animal services to crop production

When crops are weighted against all the services they provide to livestock, the most important is sorghum (44% of respondents), followed by groundnut (22%), cowpea (15%), maize (11%) and rice (9%). The major contribution of livestock to crop production is provision of animal manure. Goats are the most important in manure generation (49% of the respondents) followed by sheep (29%), cattle (11%) and finally poultry (10%).

Use of animal manure in 2001

The results of the empirical model showing the MLE of the parameters in the logistic regression on farmers' manure use behaviour are presented in Table 3. The value of the function is significant at 1% level and gave 94% correct predictions of users and non-users of manure. The model has a strong explanatory power with 8 factors out of 13 being significant. The factors that are significant and are positively related to the adoption of animal manure are HHEDUC, AA01DS, RATIO3 and MONELEV at 1%; NC01P at 5%; and HHSIZE at 10%. The factors that are significant and are negatively related to the adoption of animal manure are RA01DS and ZONE (both at 1%). For ZONE, this suggests that farmers in the GS zone are more likely to use animal manure than farmers in the SS zone.

Table 3. Logit-model result of factors affecting farmers' use of animal manure in the savannahs of northern Nigeria.

Variables	Parameter estimate	Standard error	Pr>Chi-square
Intercept	0.0597	2.1243	0.9776
HHSIZE	0.1512	0.0793	0.0564*
HDAGE	–0.0273	0.0249	0.2720
HHEDUC	1.2130	0.3192	0.0001***
AA01DS	2.5905	0.8787	0.0032***
MA01DS	1.3961	0.8936	0.1182
RA01DS	–3.5982	1.2046	0.0028***
NC01P	0.4290	0.1802	0.0173**
F01INDDS	0.9447	0.6500	0.1461
RATIO3	6.6220	1.9054	0.0005***
MONELEV	11.8195	2.2571	0.0001***
TOPOMIMP	0.7597	0.4909	0.1217
TLU	0.1178	0.1395	0.3986
ZONE	–19.7174	3.9728	0.0001***

***, Significant at 1%; **, Significant at 5%; *, Significant at 10%
Level of significance of the model (based on Likelihood ratio): 1%
Association of predicted probabilities and observed responses

Concordant	= 94.2%	Somers' D	= 0.885
Discordant	= 5.7%	Gamma	= 0.885
Tied	= 0.1%	Tau-a	= 0.438
(6300 pairs)		c	= 0.942

Conclusions

Crop–livestock interaction is taking place in the savannahs of Nigeria. However, it is functionally weak and unable to adequately support increased productivity. The manure provided has not filled the soil amendment gap due to the farmers' lack of access to sufficient inorganic fertilisers., Given the low level of fertiliser use, the declining yields of most crops show that the manure being applied seems to be insufficient in maintaining fertility., Results from the logit model indicate that farmer characteristics/perceptions and agro-ecology play a key role in farmers' decisions to use animal manure for fertility maintenance. Thus, agricultural policies must address the challenges of declining livestock holding and soil fertility and agricultural expansion (to pasture areas) that limit pasture availability and manure production. A complementary application of organic and inorganic nutrients must be pursued.

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Benchmarking the feedlot performance and meat quality of indigenous cattle genotypes in South Africa

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Abstract

This paper reports on the benchmarking and development of indigenous (Sanga) cattle genotypes for feedlot performance (lean meat yield and meat quality) in South Africa. Animals representing the Bonsmara, Drakensberger, Nguni, Tuli (all Sanga types) and Brahman (Zebu type) were sourced from communal, emerging and commercial farmers. Data on growth rate, individual feed intake carcass/meat yield and meat quality attributes were analysed. After 92 days feeding, no differences in feed conversion efficiency (FCR) were found, whereas the differences in growth rates could be explained by the differences in maturity level. The results also confirmed the good carcass and meat quality characteristics of the Sanga types, with the Brahman having significantly tougher meat. These positive results should open up the market for smaller framed types, such as the Nguni from both the commercial and emerging sectors. With few management (interventions to increase weaning weight, or back grounding them to increase weight at feedlot entry, they can meet the requirements of commercial feedlots.

Key words: Sanga genotypes, growth performance, meat quality

Introduction

Feedlot owner need to produce beef animals with the highest economic returns, i.e. animals that gain the most in carcass weight with the lowest production costs. Therefore, the indigenous small frame Sanga breeds, such as the Nguni and Tuli are being discriminated against as choice to farm without, taking into account other attributes that may be in their favour, such as hardiness and favourable meat quality in terms of tenderness. Being small, these breeds might need different production procedures than their large frame counterparts. Fortunately, there is a growing sector in the meat industry that focuses on total quality management, i.e. production, turnover, economics, meat quality and value for money. This is a good change in thinking because consumer preferences are the most important factors to keep in mind, for without consumer demand, the products will not sell. A trial was conducted to compare the growth performance, lean yield and meat quality of different South African cattle breeds sourced from different farming systems.

Materials and methods

Animals and their management

Treatment (breed) groups consisted of 15 castrated animals described according to its origin (farming system) and breed/type. Eight groups were distinguished in this trial, namely Bonsmara from emerging farmers (BoE), Bonsmara from commercial farmers (BoC), Brahman from emerging farmers (Br), Drakensberger from commercial farmers (Dr), Nguni from communal farming systems (NgCo), Nguni from emerging farmers (NgE), Tuli from commercial farmers (Tuli), and Nondescript (cross-breeds) types from emerging farmers (CrE). These animals represented the typical animal (in terms of type, size and body condition) kept by the different communities and farmers in South Africa. The animals were weighed, tagged, vaccinated, castrated and implanted with Ralgro (36 mg) followed by a Revalor re-implant after 49 days. The animals

were adapted on a commercial feedlot diet. Individual feed intake and weight gain were monitored throughout the feeding period. Real time ultrasound (RTU) measuring back fat thickness and rump fat, marbling in the loin and rib-eye area were performed on all animals 49 days after the trial began. They were again recorded just before slaughter so that these measurements could be verified by means of carcass measurements. Due to problems with the RTU equipment, there were no measurements taken before the first slaughter in November.

Slaughtering and sampling procedures

Animals were slaughtered at the Agricultural Research Council (ARC)-Irene research abattoir after at least a 2-hour resting period. Carcasses were electrically stimulated using 400 volts for 30 seconds after exsanguination. Carcass classification was conducted by a government employed classifier working at the abattoir. Warm and cold carcass weights were recorded.

The muscle pH and temperature of the *M. longissimus thoracis* (LT) were recorded hourly between 1 hour, 4 hours after stunning and after 24 hours post-mortem to describe the course of pH and temperature decline and to determine the occurrence of dark cutters. Back fat (between the last two ribs) and rump fat (P8) thickness were recorded on the day after slaughter. The rib-eye area was traced and measured by means of video image analysis (between last two ribs). The buttock/round was deboned and trimmed of excess fat (to 4 mm subcutaneous). A portion of the LT was sampled and determined for content, fat, water-holding capacity (bound water) and drip loss

Meat tenderness measurements

Two portions of the LL (loin); from the last rib in the direction of the rump of one side of the carcass were sampled for Warner Bratzler shear force measurement (SF). The reported value in kg represented the average of the peak force measurements of each sample.

Histological, biochemical and physical properties

Twelve animals each from five (commercial Bonsmara, emerging Brahman, emerging Nguni, Drakensberger and Tuli) breeds (four animals of each breed at the three slaughter points), were selected from the larger group to investigate the following histological, biochemical and physical properties of their *M. longissimus* according to standardised laboratory methods of the Histological, Biochemical and Physiological Laboratories at ARC-Irene. These were sarcomere length (SL) measurements after 3 days post-mortem myofibril fragmentation length measurements after 2 and 21 days post-mortem by means of a Video Image Analyser (Kontron, Germany), quantification of m-calpain, m-calpain, calpastatin activities and total collagen and % collagen solubility.

Statistical procedures

Data on effect of breed, aging period and time of slaughter was evaluated using analyses of variance (ANOVA) (Genstat 5 1993).

Results and discussion

General breed characteristics

The general carcass condition varied among and within breeds (types), possibly due to the production systems from which the animals were sourced. While the commercial Bonsmara (BoC), Drakensberger (Dr) and Tuli (Tu) groups were within the weaning weight norms set by the National Beef Cattle Improvement Scheme (NBCIS), the Emerging Nguni (NgE) was heavier than breed standard. The weaning weights of Communal Nguni (NgCo), Brahman (Br), Emerging Cross Breed (CrE) and Emerging Bonsmara (BoE) were below the national standard. This variation from the norm could be attributed to both genetic effect and nutritional status of the animals, emp on nutritional status being more important. This is a factor to be considered under commercial

conditions, as it affects not only growth performance of the animals but also their final weight at slaughter.

Growth performance

The different breeds and crosses were at different stages of maturity, hence variation in carcass condition was expected, and sequential slaughtering of groups of animals was followed. After the first stage of 92 days (40 animals slaughtered), the energy content of the diet was increased. Forty-eight days (140 total) later the second group was slaughtered (40) and the last 40 were slaughtered 28 days later (168 days total). On average, the animals were fed for 132 days (after adaptation). The mean values of growth performance and feed conversion ratios (FCR) for the different breeds are given in Table 1.

Table 1. Means and standard error of means (SEM) for selected growth and carcass parameters of the eight breed groups.

	BoC	*BoE*	*Br*	*Dr*	*NgCo*	*NgE*	*Tuli*	*CrE*	*SEM*
Days on feed	132	132	132	132	132	132	132	132	
ADG (kg/day: Total period)[1]	1.70^{c}	1.70^{c}	1.52^{b}	1.76^{c}	1.33^{a}	1.51^{b}	1.70^{c}	1.72^{c}	0.0475
Gain (in 100 days as % of mid-term weight)[2]	48^{a}	53^{ab}	49^{a}	52^{ab}	57^{b}	52^{ab}	56^{b}	53^{a}	0.194
FCR (kg/kg)[1]	5.96	5.60	5.41	5.69	5.51	5.95	5.42	5.59	0.200
Final weight (kg)	467^{e}	434^{cd}	413^{bc}	454de	324^{a}	391^{b}	418^{c}	446^{e}	8.42

[1] Weight after 28 days adaptation. Weights and feed intake recorded after adaptation is used for ADG (average daily gain) and FCR (feed conversion ratio).

[2] Mid-term weight is the mean of the starting and slaughter weight of each breed.

[a,b,c,d] Means in the same row without a common superscript differ ($p<0.05$).

The four larger breeds (BoE, BoC, Dr, Tuli and CrE) gained weight at 1.7 kg per day or more, which was significantly higher than that of the Br (1.52 kg/day) and both Nguni groups (1.33 and 1.51 kg/day). The Tuli and NgCo had a higher proportional gain ($p<0.05$) than the Br, CrE and BoC when animal weights were taken into account. The BoC and NgE were at the lower end of feed efficiency and the long feeding period also penalised the smaller NgE. In contrast, the NgCo and Tuli tended to have better FCRs due to their low starting weight (body condition), although the long feeding period probably negated some of this advantage for the NgCo. The Br had a poor growth rate expressed relative to its size and was also the leanest (together with CrE) at slaughter. This was accompanied by a favourable FCR which was almost 0.4 kg/kg better than the BoE and equal to the Tuli. The Br had the lowest feed intake per body weight unit. The animals appeared calm and well adapted to the self-feeding facility, so the relatively poor growth performance and the lean final condition were not obvious.

Carcass characteristics

Variation in carcass weight was similar to variation in slaughter weight, although there were differences in dressing percentage (Table2). At slaughter, the carcass weight (270 kg) of BoC was almost 100 kg heavier than that of the NgCo (181 kg). The BoC, BoE, Dr, NgE and Tuli dressed out significantly better than the NgCo and Br. The Dr was heavier and fatter than the BoE, which probably contributed to its slightly high dressing percentage. The leanness of both NgCo and Br could have contributed to their low dressing percentage.

Fat class as classified on grounds of visual fat cover of carcass was based on 7 categories from 0 (no visual fat) to 6 (excessive fat cover). Producers in South Africa aim to produce animal in fat class 2 and 3, as there were low penalties for animals in fat class 1, and heavier penalties for animals in fat classes 4 to 6. The BoC, Dr and NgE had 9, 9 and 10 carcasses (out of 15) classed

Table 2. Means and standard error of means (SEM) for selected carcass characteristics.

	BoC	BoE	Br	Dr	NgCo	NgE	Tuli	CrE	SEM
Slaughter weight, kg	467^{e}	434^{cd}	413^{bc}	454de	324^{a}	391^{b}	418^{c}	446^{e}	8.42
Cold carcass weight	270^{c}	256^{c}	235^{b}	265^{c}	181^{a}	227^{b}	241^{b}	257^{c}	5.29
Dressing, %	57.8^{bc}	58.9^{a}	56.8^{ab}	58.3^{c}	55.6^{a}	58.0^{bc}	57.5^{bc}	57.5^{bc}	0.491
Round meat yield, %[1]	72.9^{ab}	72.9^{ab}	72.1^{ab}	72.5^{ab}	72.5^{ab}	71.8^{a}	73.0^{ab}	73.5^{b}	0.546
Trimmed fat, %[1]	10.8^{ab}	10.7^{ab}	10.9^{ab}	11.3^{ab}	11.4^{ab}	12.0^{b}	10.5^{ab}	10.3^{a}	0.556
Bone yield, %[1]	16.4^{a}	16.4^{a}	17.1^{b}	16.2^{a}	16.1^{a}	16.2^{a}	16.5^{ab}	16.3^{a}	0.254
Meat to bone ratio	4.47	4.48	4.25	4.50	4.52	4.45	4.44	4.53	0.0815
Average fat class[2]	7.9	7.1	6.5	7.7	7.1	8.5	8.0	7.0	0.628
Marbling, %	1.43	1.62	1.46	1.73	1.62	1.53	1.52	1.59	0.146

[1] Round meat, trimmed fat and bone as a % of round (buttock) weight.
[2] Mean value of categorical values for fat code scored by official carcass grader in one third of a unit over 6 fat classes – from 1- to 6+ there are therefore 18 subclasses.
[a,b,c,d] Means in the same row without a common superscript differ ($p<0.05$).

as 2 or 3 respectively with none in class 1, and the rest in 4, 5 and 6. The Br and CrE had 13 carcasses each in class 1, 2 or 3 and none in class 5 or 6. The Tuli also had no fat codes 5 and 6 and 11 carcasses in classes 2 and 3 (one carcass short in group). The BoE and NgCo had 12 carcasses in class 2 and 3 and three in classes 5 and 6. The Br had the highest yield of round, significantly higher than any other breed. The NgE had the lowest yield; significantly lower than the CrE and BoE (Table 2). The differences are probably a function of fatness and maturity type.

Feeding the Nguni (both NgE and NgCo), which is an early maturing breed, for a prolonged period resulted in a fatter well-developed carcass with relatively more weight distribution to the fore quarters than to the hindquarters. Although the Br is also a relatively early maturing breed, its development was relatively slow (low growth rate) resulting in a leaner less matured carcass with more weight distributed to the hindquarter. The NgE had significantly less trimmed yield (proportionally) and more fat trimmed off than the CrE, with the other breeds in between. The Br had the highest bone yield, significantly ($p<0.05$) more than all the other breeds, except for the Tuli. Despite these differences, the meat to bone ratio were in a close range between 4.25 for the Br and 4.53 for the CrE and not significantly different among the breeds, despite obvious frame size differences.

Meat quality and related histological and biochemical characteristics

Although slaughter conditions were standardised as carefully as possible, it is obvious that pre- and post-slaughter conditions can never be exactly equal under the different production systems. Animals vary in terms of carcass size and fatness, parameters change from one slaughter date to the next, and temperaments of breeds are different. Consequently, variation in chilling rate between types and/or between slaughter days occurred that influenced the process of rigor mortis, subsequently influencing colour, drip loss and initial and final tenderness. Therefore, apart from inherent (genetic) differences in tenderness between groups (types), environmental factors (trial effects) could also have played a role in variation in tenderness (Table 3).

At 2 days post-mortem, meat from the BoE was the most tender breed group tested (almost 1.4 kg more tender than that of the BrE) followed by the BoC, Dr, and NgE, with shear force (SF) values well below 6 kg. The Tuli and the CrE were less tender with SF values of 5.54 kg and 5.89 kg respectively, and the NgCo and BrE significantly tougher ($p<0.05$) with SF values above 6 kg. The ageing rate between 2 and 21 days was not different, although the tougher breeds tended to

Table 3. Means and standard error of means (SEM) for meat quality characteristics.

	BoC	BoE	Br	Dr	NgCo	NgE	Tuli	CrE	SEM
Shear force, kg									
2 days ageing	5.24^{ab}	5.13^{a}	6.50^{d}	5.23^{ab}	6.12^{cd}	5.23^{ab}	5.54^{abc}	5.89^{bcd}	0.273
21 days ageing	3.51^{a}	3.46^{a}	4.53^{c}	3.38^{a}	4.08^{b}	3.59^{a}	3.77^{ab}	3.64^{ab}	0.166
Moisture characteristics Water holding capacity	0.39	0.39	0.38	0.37	0.39	0.40	0.39	0.39	0.0125
Drip loss, %	2.96^{c}	2.04^{ab}	1.99^{ab}	2.66^{b}	1.89^{a}	2.44^{abc}	2.26^{abc}	1.84^{a}	0.257
pH: temperature ratio[1]	0.44^{c}	0.30^{ab}	0.30^{ab}	0.36^{bc}	0.26^{a}	0.38^{bc}	0.35^{abc}	0.34^{abc}	0.0365
Carcass temperature:									
4 hours	24.1^{c}	23.9^{c}	21.6^{a}	24.1^{c}	21.7^{ab}	23.4^{bc}	23.4^{bc}	22.9^{abc}	0.614
Final pH: 24 hours	5.58	5.77	5.67	5.64	5.72	5.76	5.66	5.69	0.0515

[1] Decline in pH per 10°C decline in temperature.
[a,b,c,d] Means in the same row without a common superscript differ ($p<0.05$).

age slightly more. After 21 days the SF of BrE meat was above 4.5 kg, followed by the NgCo just above 4 kg and all the others below 4 kg. BrE and NgCo meat were significantly ($p<0.05$) tougher than the Dr, BoE, BoC, NgE and the CrE.

The tougher meat of the Bh and Tuli can be as a result of the genetic expression of the proteolytic calpain system, which is reflected in the relatively unfavourable calpastatin:µ-calpain ratio measured in the selected Bh and Tuli animal (Table 4). These measurements were unfortunately not done on the CrE breed. Similar results for Bh (*Bos indicus*) were found by other researchers (Shackelford et al. 1995; Koohmaraie 1996; Frylinck et al. 2003), although Shackelford et al. (1995) also reported that the tenderness of Tuli compared favourably with that of the Hereford (*Bos indicus*). The favourable calpastatin:µ-calpain ratio measured in the BoC, Dr and NgE (Table 4) coincides with the favourable myofibril fragmentation measured in these breeds and correlates with their lower SF values and therefore more tender meat.

Despite electrical stimulation and therefore accelerated pH decline to prevent muscle shortening, the sarcomere lengths of the Tuli and Dr were on the short side. A negative relationship between SF and sarcomere length ($r = –0.39$ and $r = –0.28$ at 2 and 21 days ageing) indicates that this might be a characteristic of the breed and is not an indication of muscle shorting.

Br had significantly less soluble collagen than the Dr, NgE and Tuli ($P<0.05$). However, none of the collagen values had a linear relationship with SF.

Conclusion

The performance of the breeds in this trial was a function of their genetic potential, maturity type and their unique pre-wean conditions. Certain criteria, such as weaning weight (size), body condition, final weight and value adding (carcass gain) determine the suitability of animals and animal types for commercial feeding. Some breed groups performed well as a result of their lean condition, which is unique to their production environment and practices. Under commercial conditions some of the animals would have been excluded for having a too small and too lean starting condition.

Table 4. Means and standard errors (SEM) for tenderness, histological and biochemical characteristics of selected breeds.

	BoC	Br	Dr	NgE	Tuli	SEM
Sarcomere length, mm	1.75^{b}	1.72^{ab}	1.68^{ab}	1.75^{b}	1.65^{a}	0.0321
Myofibrillar fragment length, mm						
2 days ageing	39.5^{a}	45.7^{b}	37.7^{a}	38.3^{a}	43.8^{b}	1.43
21 days ageing	25.6	28.0	25.8	25.4	26.2	0.998
2 vs. 21 days	13.9^{ab}	17.7^{b}	12.0^{a}	12.8^{a}	17.7^{b}	1.51
Proteolytic enzymes activity						
Calpastatin activity, U/g	4.85^{a}	6.13^{b}	4.98^{a}	5.22^{a}	5.40^{a}	0.261
µ- Calpain activity, U/g	1.08^{c}	0.76^{a}	0.96^{bc}	1.02^{bc}	0.95^{b}	0.044
Calpastatin:µ-calpain ratio	4.57^{a}	7.73^{d}	5.30^{b}	5.20^{ab}	6.00^{c}	0.245
Connective tissue properties						
Total collagen, mg/g	3.95	3.83	4.16	4.13	4.06	0.185
Soluble collagen, %	20.9^{ab}	19.7^{a}	22.6^{b}	22.6^{b}	23.4^{b}	0.980

^{a,b,c,d} *Means in the same row without a common superscript differ ($p<0.05$).*

Frame size seemed to be of lower importance when certain performance characteristics, such as growth performance or yield were taken in consideration. However, under commercial conditions factors such as true gain and optimum carcass size are important. Therefore procedures such as back grounding of smaller breeds before feeding should be considered to obtain larger final weights. Alternatively, markets should be selected where smaller carcasses are preferred.

Apart from the difference in carcass weight between commercial and emerging groups, which would have had an influence on the weight of edible yield, proportional yields (%) did not vary much among types.

The Br had tougher meat than the rest of the breed groups even after 21 days ageing. The communal Nguni had tougher meat than its emerging counterpart. Apart from weight and fatness differences no other measurements were performed to explain this phenomenon. Adjustment for pH and temperature decline (mostly due to size and fatness differences) did not influence the tenderness ratings of breeds.

Drip loss was influenced by pH/temperature ratio which indicates that size, fatness and chilling capacity should be taken into account when rigor mortis is managed by means of electrical stimulation.

Considering the inherent size of the indigenous animals and the degree of effort put into the adaptation of the animals in the feedlot, these animals performed very well in terms of growth, edible yield and meat quality. Certain managerial adjustments, such as better back grounding for more adaptable/suitable feedlot animals and control of age at selling could improve their potential as commercial feedlot cattle tremendously.

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Cooking in local alkaline solution as a method for improving the nutritive value of velvet bean *(Mucuna pruriens)* for broilers

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Abstract

Raw unprocessed velvet bean (VB) (*Mucuna pruriens*) meal contains toxic elements, which limit its use as a feed ingredient for livestock, particularly monogastrics. Earlier investigations showed that cooking in water could not improve its nutritive value beyond 20% dietary level for broilers. We examined the effect of whole (W) and cracked (C) velvet bean soaked in water before cooking in maize-cob ash solution on broiler performance in two experiments. In experiment 1, 0%, 25 and 30% of whole and cracked VB were differently incorporated into broiler rations fed at 7–35 day of age. Final weight of the WVB30 group was less ($p<0.05$) than the CVB25 group. WVB30 also exhibited lower ($p<0.05$) day growth rate than any of the other groups, whereas the growth rate of the CVB25 group was higher ($p<0.05$) than CVB30 and WVB25. Daily feed intake increased significantly ($p<0.05$) only with 25% CVB than any of the other groups, but feed conversion ratios were similar. In experiment 2, processed VB was incorporated into finisher broiler rations as in experiment 1 and fed at 28–56 day of age. With 30% WVB, broilers had a lower ($p<0.05$) final weight, weight gain and growth rate. However, feed intake was apparently higher ($p<0.05$) in groups that were fed on WVB25 and CVB30 than the control and WVB30 groups, and the feed conversion ratio was higher ($p<0.05$) in the group on WVB25 than the control group. We conclude that cooking velvet beans in maize-cob ash solution results in improved biological value of the beans and the positive effect is enhanced when the beans are cracked before cooking in the maize-cob solution.

Key words: velvet bean, maize-cob ash, broilers, performance.

Introduction

Velvet bean (*Mucuna pruriens*) is an exceptionally productive black seeded tropical legume that is little known and used as human food or animal feed. In Nigeria, it is valuable only as a green manure/cover crop in the wild but has high potential for exploitation as a protein and energy source for livestock in view of its high yield and protein content. Research into its development as a possible protein feed for the Nigerian livestock and poultry industry has been occasioned by a feed crisis that has almost crippled the poultry and pig industry in the country.

The excellent germination and vigorous initial growth makes the establishment of this legume relatively easy. Total yields of forage of the velvet bean can hit 19 tons dry matter per hectare depending on cutting frequency (Ravindran and Ravindran 1988). Dry seed yields of 2.50–3.85 ton/ha have also been reported in Nigerian (Emanalom and Udedibie 1998). Chemical analysis of velvet bean in Nigeria (Emenalom and Udedibie 1998) and Brazil (Udedibie and Carlini 1998) showed 30–32 and 28–30 crude protein for raw and heat processed beans respectively.

Velvet bean, however, contains toxic substances which limit its use as feed ingredients for non-ruminants. These toxic substances, which included trypsin inhibitors, tannins, phytic acids,

phenols, hydrogen cyanides, and µ-amylase inhibitors and L-3-4 dihydroxyphenylalanine (L-Dopa) (Siddhuraju et al 1996), have been reported to have negative effects on nutrient digestion and absorption (Iyayi and Egbarevba 1998).

To overcome these toxic substances, various heat-processing methods have been used (Siddhuraju et al. 1996; Udedibie and Carlini 1998; Berhe 2001). Mary Josephine and Janardhanan (1992) reported that except for L-Dopa all the anti-nutritional factors detected in velvet bean are heat-labile and could be eliminated by cooking.

Earlier attempts aimed at improving its nutritive value, as a protein and energy supplement for poultry, showed that heat treatment alone (Emenalom and Udedibie 1998; Carmen et al. 1999), pre-treatment with water before toasting (Esonu 2001), soaking in water before cooking (Udedibie et al. 2001) and soaking in calcium hydroxide solution before cooking (Emenalom 2004) did not significantly improve the performance of broilers. However, cracking velvet bean before soaking and cooking produced good results (Emenalom et al. 2005), allowing for dietary inclusion of up to 25% for broilers and layers and 40% for grower pigs. Wanjekeche (2001), however, observed that cooking in local alkaline or acid solutions was effective in removing the L-Dopa content of velvet bean. Meanwhile, velvet bean so processed has not been fed to broilers.

The studies herein reported were therefore designed to determine the effects of whole and cracked velvet bean seeds soaked in water before cooking in maize-cob ash solution on the performance of broilers.

Materials and method

The velvet bean seeds used for these studies were produced at the Teaching and Research Farm of the Federal University of Technology, Owerri, Nigeria.

Experiment 1

The velvet bean seeds were divided into two batches. One batch was soaked in water for 48 hours, rinsed with fresh water, cooked for an hour at 100°C (timed from boiling) in maize-cob ash solution (in 1:150 dilution in water), sun dried and ground into meal to produce whole velvet bean (WVB) meal.

The other batch was cracked into pieces of 2–4 parts per seed using the ASKO A11 motorised grinding mill. The cracked seeds were then treated as in the first batch above to produce cracked velvet bean (CVB) meal. Due to lack of laboratory facilities the anti-nutritional factors in the processed velvet bean meals could not be determined.

The velvet bean meals so prepared were then incorporated into broiler starter diets at 25% and 30% dietary levels respectively; the control diet did not contain velvet bean. The ingredient and analysed chemical composition of the experimental diets are shown in Table 1. At one day old, 250 young broiler chicks of Anak breed were selected from a batch of broiler chicks such that they weighed between 75 and 80 g each as initial weights. The chicks were divided into 5 groups of 50 and each was randomly assigned (using a completely randomised design, CRD) to the 5 treatment diets. Each group was further subdivided into 5 replicates of 10 birds and each replicate was kept in a compartment measuring 2m x 3m. Feed and water were provided *ad libitum.* Feed intake was recorded daily and the birds were weighed weekly. The compartments were heated using kerosene stoves and electric bulbs. Other routine poultry management procedures were maintained. The experiment lasted for 4 weeks. The data collected were subjected to analysis of

variance (Snedecor and Cochran 1978). Differences between means were identified using Duncan's multiple range test (Little and Hills 1978).

Table 1. Ingredient composition of the broiler starter diets (0–4 weeks).

Ingredients	**Control**	**WVB[1]**	**CVB[2]**		
	0%	25%	30%	25%	30%
Maize	55.0	45.0	45.0	45.0	45.0
Soybean meal	12.0	3.00	5.50	3.00	5.50
Groundnut cake	16.0	7.50	5.00	7.50	5.00
Velvet bean meal	—	25.0	30.0	25.0	30.0
Wheat offal	5.00	5.00	5.00	5.00	5.00
Palm kernel meal	2.00	2.00	2.00	2.00	2.00
Fish meal	6.00	6.00	6.00	6.00	6.00
Bone meal	3.00	3.00	3.00	3.00	3.00
Lysine	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
Vit/Tm premix*	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Total	**100**	**100**	**100**	**100**	**100**
Calculated analysis (%)					
Crude protein (CP)	22.3	21.9	21.6	21.9	21.6
ME (Kcal/kg)	2873	2891	2918	2891	2918

* To provide the following per kg of feed: vitamin A, 10,000 iu; vitamin D3, 1500 iu; vitamin E, 3 iu, vitamin K, 2 mg; riboflavin, 3 mg; pantothenic acid, 6 mg; niacin, 15 mg; choline, 5 mg; vitamin B 12, 0.08 mg; folic acid, 4 mg; Mn, 8 mg; Zn, 0.5 mg; iodine, 1.0 mg; Co, 1.2 mg; Cu, 10 mg; Fe, 20 mg.

1. WVB: whole velvet bean.

2. CVB: cracked velvet bean.

Experiment 2

Whole and cracked velvet beans were treated as in experiment 1 above. The velvet bean meals so prepared were then used to formulate broiler finisher diets at 25% and 30% dietary levels respectively. The control diet contained no velvet bean. The ingredient and analysed chemical compositions of the experimental diets are shown in Table 2.

Table 2. Ingredient composition of the broiler finisher diets (4–8 weeks).

Ingredient (% DM)	**Control**	**WVB**	**CVB**		
	0%	25%	30%	25%	30%
Maize	60.00	50.00	45.00	50.00	45.00
Mucuna seed meal	0.00	25.00	30.00	25.00	30.00
Soybean meal	12.00	3.00	3.00	3.00	3.00
Groundnut cake	8.00	2.00	2.00	2.00	2.00
Palm kernel cake	2.50	2.50	2.50	2.50	2.50
Wheat offal	3.50	3.50	3.50	3.50	3.50
Spent grain	6.00	6.00	6.00	6.00	6.00
Fish meal	4.00	4.00	4.00	6.00	6.00
Bore meal	3.00	3.00	3.00	3.00	3.00
L-Lysine	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Vit/Tm premix[1]	0.25	0.25	0.25	0.25	0.25
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Calculated analysis					
Crude protein (CP)	19.46	19.14	20.07	19.14	20.07
Crude fibre (CF)	4.20	5.48	5.86	5.48	5.86
Ether extract (EE)	4.14	3.23	3.06	3.23	3.06
ME (Mjkg $^{-1}$)	2961.75	3334.65	2816.25	3334.65	2816.25

1. To provide the following per kg feed: vitamin A, 10,000 iu; vitamin D3, 1500 iu; vitamin E, 3 iu, vitamin K, 2 mg; riboflavin, 3 mg; pantothenic acid, 6 mg; niacin, 15 mg; choline, 5 mg; vitamin B 12, 0.08 mg; folic acid, 4 mg; Mn, 8 mg; Zn, 0.5 mg; iodine, 1.0 mg; Co, 1.2 mg; Cu, 10 mg; Fe, 20 mg.

At 4 weeks of age, 250 young broiler chicks also of Anak breed were selected from a batch of chicks such that they weighed between 400 and 500 g each as initial weights. The birds were divided into 5 groups of 50 birds each and were randomly assigned to the 5 experimental diets in a completely randomised design (CRD) replicated 5 times. Each replicate of 10 birds was kept in a compartment measuring 2m x 3m. Feed and water were provided *ad libitum*. Feed intake was recorded daily and the birds were weighed weekly. Other routine poultry management procedures were maintained. The feeding trial lasted for 4 weeks.

The data collected were subjected to analysis of variance and compared as in experiment 1 above.

Results

Experiment 1

Data on the performance of the young broiler chicks on the five treatment diets are shown in Table 3. Final weight of the WVB30 group was less ($p<0.05$) than the CVB25 group. WVB30 also exhibited lower ($p<0.05$) growth rate than any of the other groups, whereas the growth rate of the CVB25 group was higher ($p<0.05$) than CVB30 and WVB25. Daily feed intake increased significantly ($p<0.05$) only with 25% CVB than any of the other groups, but feed conversion ratios were similar.

Table 3. Performance of broiler starter chicks fed velvet bean cooked in maize cob ash solution.

Control	**WVB**			**CVB**		
Parameters	0%	25%	30%	25%	30%	**SEM**
Av. initial wt (g)	76.0	76.5	76.1	77.7	76.3	0.90
Av. final wt (g)	895^{ab}	$862.^{ab}$	768^{b}	944^{a}	857^{ab}	5.13
Daily growth rate	39.0^{ab}	37.4^{b}	32.9^{c}	41.3^{a}	37.2^{b}	2.47
Av. daily feed intake	77.3^{b}	73.6^{b}	71.6^{b}	86.2^{a}	70.7^{b}	2.79
Feed conversion ratio	1.98	1.99	2.22	2.14	1.94	0.21
Mortality	2	2	-	2	2	-

^{abc} Means within a row with different superscripts differ significantly ($p<0.05$).
Although one to three birds died within the groups, there was no reason to blame the mortalities on dietary inclusions of velvet bean.

Experiment 2

The data on the performance of the treatment birds are shown in Table 4. In experiment 2, processed VB were incorporated into finisher broiler rations as in experiment 1 above and fed 28–56 day of age. With 30% WVB, broilers had a lower final weight ($p<0.05$) than any of the other groups; weight gain and growth rate per day were also less than for the other groups. However, feed intake was apparently higher ($p<0.05$) in groups that were fed on WVB25 and CVB30 compared to the control and WVB30 groups and the feed conversion ratio was higher ($p<0.05$) in the group on WVB25 compared control group control. Based on the distribution of mortality figures, there was no basis to blame the mortalities on dietary inclusions of velvet bean.

Table 4. Performance of finisher broilers feed velvet bean cooked in maize cob ash solution.

	WVB		CVB		SEM	
Control	25%	30%	25%	30%		
Initial weights	431.3	435.5	433.4	456.3	448.0	16.14
Final body weights	1772.8 [b]	1731.7 [b]	1540.0[a]	1770.0 [b]	1773.3[b]	135.2
Weight gain	1341.5 [b]	1296.2 [b]	1106.6a	1313.7 [b]	1 325.4 [b]	137.5
Growth rates (g/d)	47.9 [b]	46.3 [b]	39.5[a]	46.9 [b]	47.3[b]	14.8
Feed intake	3.38[bc]	4.08[a]	2.98[c]	3.96[ab]	4.31[a]	0.22
Feed conversion ration	2.52[b]	3.31[a]	2.77[ab]	3.02[ab]	3.28-[ab]	0.29
Mortality (%)	2	3	-	2	-	-

[abc] Means within a row with different superscripts are significantly (P<0.05) different.

Discussion

Velvet bean seeds have been processed in various ways by different investigators. Their results indicated no more than partial detoxification when fed to broilers (Emenalom and Udedibie 1998; Carmen et al. 1999; Esonu 2001; Udedibie et al. 2001; Emenalom 2004; Emenalom et al. 2005), thus limiting its dietary inclusion levels to 10–25%. Some authors have blamed the toxicity of velvet bean on the L-Dopa content (Prieris et al. 1980; Afolabi et al. 1985).

It has, however, been reported that cooking in local alkaline or acid solution is effective in reducing the L-Dopa content of velvet bean (Wanjekeche 2001). This shows that for velvet bean to be used like other conventional protein supplements, the anti-nutritional factors in it must be subjected to some form of chemical treatment in addition to heat treatment.

The use of maize-cob ash solution (an alkaline) in this experiment may have facilitated the detoxification process, hence the improvement in the nutritive value of the bean so processed. This is reflected in the comparable growth performance of the control group as compared with that of the groups whose feeds were substituted at 25% for whole beans and up to 30% when the beans are cracked.

However, the exact mode of action of maize-cob ash solution on the thermostable anti-nutritional factors in the velvet bean and the extent of removal is not known. But the addition of velvet bean meals so processed significantly (P<0.05) improved the performance of the broilers contrary to earlier reports on whole and cracked velvet beans cooked in water. These effects on performance were seen in both the processing methods and dietary inclusion levels. The growth rates of the birds fed the control and velvet bean diets in the two experiments were not significantly (p>0.05) different except at the 30% WVB diet groups but the results were better than those earlier reported in literature for pre-soaked whole velvet beans cooked in water (Udedibie et al. 2001; Emenalom 2004).

The 84.22% and 95.23%, and 82.46% and 98.75% growth rate recorded in our experiments at 30% whole and cracked velvet bean diets, for starter and finisher broilers respectively, might be ascribed in part to the method of processing which may have rendered the anti-nutritional substances present in the bean ineffective.

We conclude that cooking velvet beans in maize-cob ash solution results in improved biological value and the effect is enhanced when the beans are cracked before cooking in the maize-cob solution.

This approach, which encouraged high dietary inclusion level comparable to the conventional protein supplements, should be used. This may brighten the feasibility of developing velvet bean

as an economic crop since technological processing package can easily be developed for it along this line. More work is, however, required to determine the effect of maize-cob ash treatment on the nutrient compositions, anti-nutritional factors and digestibility of the velvet bean so processed. This will form part of our focus in future investigations.

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Role of animal sourced foods in human health and nutrition

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Abstract
The quantity and quality of the different nutrients in each food group vary greatly. Several nutrients work synergistically to sustain life-supporting tasks. Both inadequate and imbalanced nutrient intakes cause ill effects in the long run. This paper attempts to scan the nutritional adequacy of a vegetarian diet in comparison to animal foods.

Key words: vegetarian, omnivorous, nutrition

Introduction
A prolonged strict vegetarian diet is likely to lead to nutritional deficiencies which may remain undetected until irreparable damage is done (Abrams 1980, Day 2000) unless there is careful planning to provide adequate supplies of nutrients. This is more so for younger children (Erhard 1973; Kerr 1974; Simopoulos 1991; Birch et al. 1998; Hoffman et al. 2000; Birch et al. 2002; Birch et al. 2005), pregnant and breastfeeding mothers (Zmora et al. 1979) and teenagers (Day 2000).

Protein dietary adequacy
Animal proteins[1] are complete because they contain all the eight essential amino acids (EAA)[2] (Abrams 1982) and therefore have high biological value (Singapore 2003). A gram of a complete protein for every 1 kg body weight is required daily for a being to function well (Singapore 2003). To get the equivalent of this, a vegetarian would have to judiciously combine a variety of grains, legumes, nuts and seeds every day[3] (Singapore 2003). Plant proteins are also less digestible and hence intake needs to be increased by a factor of 1.1 to that for milk/egg (FAO 1985), the reference protein in terms of digestibility and bio-availability. For the vulnerable groups whose nutrient requirements are higher, this dietary pattern is likely to result in protein deficiencies.

Fat dietary adequacy
Natural food fats are a mixture of unsaturated and saturated fats. Unsaturated fats include mono-unsaturated fatty acids (MUFA)[4] and polyunsaturated[5] fatty acids (PUFA). Two examples of PUFA are linoleic and alpha linolenic (Lake 2002). These are essential fatty acids (EFAs) (Eritsland 2000; Lake 2002) because they must be supplied from the diet. EFAs are vital to the proper functioning of the body (Eritsland 2000; Lake 2002; Davis and Kris-Etherton 2003) including production of prostaglandins and regulating body functions such as heart rate, blood pressure, blood clotting (Simopoulos 2003; Davis and Kris-Etherton 2003; Oh 2005), fertility, immune function (Kabara 1978; Lake 2002), proper neural development during the intra-uterine stage

[1] Proteins are made of 20 amino acids, 8 of which are referred to as essential amino acids because the body cannot manufacture them and therefore they must be present in the diet.
[2] Isoleucine, leucine, lysine, methionine, phynylalanine, threonine, tryptophan, and valine. Infants additionally need histidine and taurine.
[3] Although not in every meal.
[4] One double bond.
[5] Two or more double bonds.

(Lake 2002; Anderson et al. 2005) and during the first 2 years of life (Simopoulos 1991; Birch et al. 1998; Hoffman et al. 2000; Birch et al. 2000; Birch et al. 2002; Birch et al. 2005). There are two families of EFAs, namely omega 3 derived from linolenic acid and omega 6 from linoleic acid (Lake 2002; Davis and Kris-Etherton 2003). Health problems become more evident if the ratio of omega 6 to omega 3 (6:3) in the diet exceeds 4:1 (Simopoulos 1999; Simopoulos 2002; Davis and Kris-Etherton 2003) because omega 3 and 6 compete for the same enzymes and hence their intake needs to be balanced (Uauy et al. 1996; Birch et al. 1999; Davis and Kris-Etherton 2003).

Omega 3 fatty acids have three derivatives, namely alpha-linolenic acid (ALA), eicosa pentanoic acid (EPA) and docosa hexaenoic acid (DHA) (Davis and Kris-Etherton 2003). Derivatives of omega 6 are linoleic acid, conjugated linolenic acid (CLA), dihomo-gamma-linolenic acid (DGLA), gamma-linolenic acid (GLA) and arachidonic acid (Davis and Kris-Etherton 2003). These are distributed differently in different foods and have different health implications. Sources of ALA are green leafy vegetables, edible oil seeds, phytoplankton and algae (Bartsch et al. 1996) while EPA and DHA are only available in animal foods with cold-water fish oil being its richest source (Koletzko et al. 1992; Davis and Kris-Etherton 2003). EPA and DHA are also the most readily bio-available omega 3 in the body (Koletzko et al. 1992; Simopoulos 2002). ALA may be converted to EPA and DHA (Koletzko et al. 1992; Lake 2002). However, the body is inefficient at converting linolenic acid to DHA and EPA (Simopoulos 2002; Davis and Kris-Etherton 2003; Oh 2005) being negatively influenced by trans-fatty acids,[6] inadequate intake of protein and energy, and deficiency of zinc and copper (Koletzko et al. 1992, Lake 2002). Conversion is also slower in infants, particularly pre-term babies (Koletzko et al. 1992; Uauy et al. 1996) and inefficient in people with diabetes and/or other metabolic disorders (Lake 2002). Breast milk supplies adequate amounts of EPA and DHA (de la Presa-Owens et al. 1996), however, breast milk of strict vegetarian mothers may be deficient (Sanders et al. 1978; Sanders and Reddy 1992) and therefore babies breastfeeding from such mothers are at a higher risk of deficiency of the most readily bio-available omega 3 fatty acids (Fidler et al. 2000; Koletzko et al. 2001).[7]

Linoleic acid is concentrated in green leafy vegetables, fruits, oil nuts and seeds, grain cereals, industrial vegetable cooking oils and margarine, and grain fed and/or zero grazed livestock (Bartsch et al. 1996). CLA is useful in building muscles and body fats;[8] increasing calorie expenditure; maintaining lean muscle tissues; and lowering cholesterol and triglycerides (Pariza et al. 1999). CLA therefore helps keep the arteries clean. CLA has anti-osteoporosis and antioxidant properties, thus making it an anti-tumour/anti-cancer factor (Pariza et al. 1999). However, CLA is primarily found in fatty meat and full fat dairy products of ruminants (Peterson et al. 2002). Avoiding these products may therefore result in increased health risks.

Saturated fatty acids (SFA)

One major criticism against animal foods is the cholesterol contained in it. Cholesterol is a saturated fat that is synthesised within the body; you can also get cholesterol from eating animal foods particularly liver and egg yolks. It is required for several vital biochemical processes (Nygard et al. 1997). Elevated cholesterol in the blood plasma has been associated with atherosclerosis that leads to coronary heart diseases (CHD) (Kannel et al. 1971; Kannel et al. 1979; Gordon et al. 1981; Grundy 1986; Boekholdt et al. 2005). Animal fats and protein have also widely been associated with incidences of heart diseases, colon and breast cancer (Abrams 1982). However,

[6] Most commercially available vegetable edible oils and margarines.
[7] While animal foods are good sources of EPA and DHA, grain fed and/or zero grazed animals may contain higher omega 6 than omega 3.
[8] Observed to reduce body fats in mice by up to 80%.

extensive review of the literature (Yudkin 1972; Abrams 1982; Smith and Pinckney 1991; Mann 1993; Hoffer and Walker 1995; Enig 1995, 2000; Ravnskov 2000; Byrnes 2001) advance that blood cholesterol does not explain mortality incidences due to CHD, colon or breast cancers and most of the degenerative diseases. Had it been so, the incidence of CHD and other degenerative diseases among Eskimos, the Maasai, the Lapps, the Plain Indians and Jamaicans whose staple foods are predominantly fatty animal foods (Eskimos, Maasai, Lapps and Plain Indians) coconut oil (SFA) (Jamaicans), the Aborigines, the Russians of the Caucasus and Lapps would be alarmingly high, but this is not the case (Stefansson 1956; Abram 1982; Pitskhelauri 1982). Rather, Hindus who are predominantly/solely vegetarian have mortality rates from CHD that are similar or greater than rates found in European countries (Sanders et al. 1978; Enas 2000).

Apparently, smoking, stress, excessive weight gain, low dietary fibre intake and overall increased dietary fats,[9] sucrose[10] (Ravnskov 2003) deficiencies of vitamin B_{12} and folic acid (Nygard et al. 1997; Dharmarajan and Norkus 2001)[11] have been associated with increases in CHD rates. Blood lipids also play a key role in the immune system (Alfin-Slater and Aftergood 1980), and also an inflammatory response of the arterial intima to injurious infections is a crucial step in the genesis of atherosclerosis.

Both laboratory and epidemiological evidence supports the protective effect of total serum cholesterol (t-C) and specifically LDL-C against infections and thus against atherosclerosis (Ravnskov 2003). The anti-infective property of high t-C is seen in individuals born with Smith-Lemli Opitz syndrome.[12] Most foetuses with this syndrome are stillborn or die early due to the multiple system malfunctions. A meticulous backward genealogical search of the pedigree of hypercholesterolemic individuals[13] also conferred a survival advantage where the infectious disease was prevalent (Smith and Pinckey 1991). Interestingly, the association of high t-C and LDL-C to CHD has been seen mainly in young and middle aged men (Ravnskov 2003). This observation has been attributed to the fact that most men in those age brackets are at the height of their careers, with the attendant mental stress, a well-known cause of high t-C. Although the highest mortality and cardiovascular diseases are seen in old people, cohort studies of old people do not suggest that high t-C or LDL-C predict CHD or all-cause mortality. In several of these studies the association was inversely associated with high t-C but positively associated with longevity.

Contrary to the long and widely conceived hypothesis that PUFA is not associated with CHDs, available literature exhibited just that (Kummerow 1983; Mann 1994). PUFA, particularly linoleic acid, is also implicated in tumour developments (Mann 1994; Bartsch et al. 1999). The mechanism is believed to involve destabilisation of the cell walls by increased PUFA in the body as a result of changes of the constituency of the cholesterol and body fat making the cell walls weak and porous allowing harmful and pathogens to easily enter into the cells.[14] A study in Sweden involving 61,471 women aged between 40 and 76 years revealed a positive relationship between breast cancer with PUFA, an inverse relationship with MUFA and neutral with SFA (Wolk et al. 1998). Women vegans had also been shown to be at higher risk of dying from heart disease than non-vegans (Montegriffo 1970).

[9] Intake to over 30% of total energy body requirements regardless of the source.
[10] Through raising blood triglycerides.
[11] Homocysteine is an amino acid that is not found in protein as such, but is involved in the metabolism of other amino acids (methionine and cysteine). Higher levels than normal of homocysteine is a risk factor for development of vascular diseases (Dharmarajan and Norkus 2001).
[12] A syndrome seen in individuals born with error of cholesterol metabolism (due to imperfect functioning of 7-dehydrocholestero "7-reductase, necessary for the last step in cholesterol synthesis).
[13] Individuals with very high blood LDL and total cholesterol due to LDL-receptor deficiency.

Most vegetable cooking oils and margarines found in the market are manufactured from vegetable oils and much of this oil is composed of linoleic acid. Linoleic acid as an EFA is required by our bodies to perform life sustaining functions, but is required only in moderation; animal foods supply enough for the purpose. Because of the enormous impact that fatty acids have on human health, an excess of linoleic acid combined with a deficiency of CLA could have far-reaching effects on health and longevity.

Micronutrient content and biological value

Vitamins and minerals are required in trace amounts by the body to perform specific functions. Specifically, diversified intake of foods is necessary to ensure adequate intake of water-soluble vitamins and minerals that must be supplied in daily diets. Of particular concern is deficiency of vitamin B_{12} which occurs in 3–40% of the general population (Dharmarajan and Norkus 2001) and may go asymptomatic for years (Herbert 1999). Vitamin B_{12} is critical for normal neurological development and maintenance (Donaldson 2000) and deficiency has been implicated in hyperhomocysteinemia[15] (Nygard et al. 1997), breast cancer (Sang-Woon 1999), Alzheimer's disease and progression of HIV/AIDS (Miller 2002). Women of reproductive age, infants and young children, teenagers, individuals with gastrointestinal disorders and the elderly are particularly vulnerable (Herbert and Das 1994; Stopeck 2000; Dharmarajan and Norkus 2001). Deficiency is also common among the vegetarians (Herbert and Das 1994) and as evidenced in a number of other studies involving second and third generations of vegetarian (Day 2000). Infants and young children who are exclusively breastfed by strict vegetarian mothers (Higginbottom et al. 1978) and adults who have been vegetarians for a long time (Hokin and Terry 1999; Day 2000) have shown an increased risk of Vitamin B_{12} deficiency. Deficiency symptoms among infants and the young disappear after vitamin B_{12}-rich foods are introduced in their diets (Day 2000). Intramuscular injection of vitamin B_{12} (Higginbottom et al. 1978) or supplementation with vitamin B_{12} has helped reverse the deficiency symptoms although neurodisability remained permanent (van Schenck et al. 1997).

Vitamin B_{12} must be obtained from diets and is found primarily in animal foods (Abrams 1982; Dharmarajan and Norkus 2001). Perhaps the only sources of vitamin B_{12} in vegetarian diets are fermented soya bean products, seaweeds, algae such as spirulina (Dagnelie et al. 1991), vegetables and hands contaminated by soil micro-organisms (Abrams 1880; Herbert and Das 1994). However, these sources are biologically unavailable (Herbert 1988; Lazarides 1997). Reliable sources of vitamin B12 for vegetarians include B12-fortified cereals and soymilks and fortified nutritional yeast (Herbert 1994). Bacteria in the small intestine produce a small amount of vitamin B_{12} but it is too little to prevent vitamin B_{12} deficiency (Albert et al. 1980). Appreciable amounts of this vitamin are also produced in the large intestine but that is too far down the intestine for absorption to take place.

Vitamin D deficiency is also of concern in strict vegetarians (Shinwell and Gorodischer 1982). Ultraviolet light from the midday sunlight is responsible for the production of the vitamin. With reduced sunlight intensity, however, production may not be sufficient. Fortified food sources are the major dietary sources of vitamin D and only foods of animal origin including fish oils (cod liver oil), fatty fish (salmon), mackerel; sardines, eel, eggs and beef liver contain significant amounts of vitamin D (Price 1989). Blood tests of vegetarians have also shown that they are often deficient in other essential nutrients such as fat soluble vitamins A, E and K, vitamin B_1 and B_2, and in certain minerals such as zinc, magnesium, iron and selenium (Jennings 1970).

[14] Cell walls are made of cholesterol.
[15] An independent risk factor for atherosclerosis.

Other positive attributes of animal sources foods

Animal foods can provide multiple micronutrients simultaneously at lower volumes of intake than can plant foods, which tend to be bulk. This is particularly important for young children who have a small food intake capacity per meal and yet have high nutrient requirements. Just 100 g of beef can provide the whole day's requirement of protein, vitamin B_{12} and zinc, and contributes substantially to meeting riboflavin and iron requirements. Likewise, 100 g milk can provide substantial amounts of calcium and vitamins A, B_{12} and riboflavin (Allen 1993; Murphy 1995).

Other concerns about diets predominantly sourced from animals

A major concern is that animals may transmit a multitude of zoonotic diseases (e.g. tuberculosis) (Swabe 1996). Animal fats are also primary vehicles through which pesticides enter the body. To counter pesticides health risks, agricultural practices therefore need to minimise the use of pesticides by using biopesticides and controls.

Another concern is that foods of animal origin are devoid of fibre, necessary for fast and regular bowel movements, thus increasing the risks of CHD (Kapoor et al. 1985). Inclusion of unrefined plant sourced foods, however, can address this problem. Diets made up predominantly of animal protein may also induce ketosis although this is unlikely to occur.

The risk of osteoporosis is another possibility because of the affinity of animal protein to induce acid ash that leads to acidification of urine (Spencer and Kramer 1986). However, including enough fruits and vegetables in the diet can halt this. Excessive intake of very lean animal protein intake (30–40% of calorie intake) may increase the risk of kidney and liver damage, but this is a rare phenomenon (Franz 1997). Muscle meat may raise levels of homocyteine in the blood (Boushey et al. 1995). However, this could be checked by eating folic acid and vitamin B_{12}-rich foods such as liver and green vegetables such as spinach.

Conclusion

The best food is that which adequately supports normal growth; maintains health; and reduces risks of developing illnesses. Several nutrients work synergistically to sustain life-supporting tasks. Animal foods provide a variety of nutrients that are not available or difficult to obtain in adequate quantities from plant sourced foods alone. Careful planning is therefore required to provide adequate supplies of such nutrients in a vegetarian diet. For young children it might be a nightmare to be adequately nourished from a strict vegetarian diet. For healthy living, dietary diversification that includes both plant and animal sourced foods is important and all must be taken in moderation and in their most natural forms.

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Parallel session 3

Livestock genetic diversity—characterization and conservation

Challenges of developing a sui-generis system for the protection of indigenous livestock genetic resources and associated traditional knowledge

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Abstract

The 'Karen Commitment' is a plea by indigenous livestock breeding communities to governments and relevant international bodies to recognise their role in creating and stewarding unique animal genetic resources. It requests legally binding recognition of their right to access, save, use, and exchange their animal genetic resources unrestricted by intellectual property rights (IPRs) and modification through genetic engineering technologies. Furthermore it calls for the right to have breeds recognised as products of communities and therefore remain in the public domain.

With advances in biotechnological research, it may indeed happen that scientists or companies would like to make use of specific parts of the genome of indigenous breeds to genetically improve other breeds. The patenting of such an 'invention' would not only be at loggerheads with the demands of pastoralists and other livestock keepers as articulated in the Karen Commitment. It would also be patently unfair since it would not recognise the traditional knowledge that has been the basis for the expression of the desired genetic trait in the first place.

Ethically, there are strong reasons for recognising and rewarding the traditional knowledge that has been the basis for the conservation of genetic traits long ignored by animal scientists, but now deemed to be of possible commercial importance.

Introduction

The practise of genetically manipulating animal populations by selective breeding is as old as domestication itself. Over the millennia, farmers and pastoralists have developed a wide variety of livestock breeds that suit their economic and cultural requirements and are adapted to their respective environments. The result is the present day diversity of animal breeds. These breeds are recognised as vital stores of livestock genetic diversity by scientists. By continuing to keep animals and by maintaining their herds, small-scale livestock keepers and pastoralists make an important contribution to *in situ* conservation and can even be regarded as guardians of this biodiversity.

Breeds as products of indigenous knowledge

While some livestock keepers might be conserving genetic diversity more or less by default without much attention to breeding, there are also groups or communities among them with highly evolved traditional knowledge systems about animal breeding. These social groups use deliberate strategies to conserve and consolidate specific gene pools (breeds), and ensure a healthy degree of diversity within their herds. For a long time, these breeding strategies remained unnoticed, because their detection requires different 'people-centred' research approaches rather than the animal-focused research methods designed to collect quantitative data that are usually used by animal scientists. In essence, these strategies can only become apparent through

anthropological methods and investing in extended fieldwork. As a result, animal scientists have usually failed to recognise and acknowledge the indigenous knowledge about animal breeding that is or was present among pastoralists and other livestock keeping groups and that is the foundation for all distinct indigenous breeds. Because of the failure to grasp this indigenous knowledge about animal breeding (IK-AB), the assumption that indigenous livestock breeds are merely products of nature or the environment still prevails. However, recent in-depth field research conducted among pastoralists in Africa and Asia (particularly India) has firmly established the character and profundity of the breeding strategies used by these groups to actively influence the gene pool (e.g. Köhler-Rollefson 1997; LPPS 2002; Adams and Kaufmann 2003; Köhler-Rollefson 2003; LPPS 2003; Krätli 2004; LPPS and Köhler-Rollefson 2005; Wu Ning 1998).

Components of indigenous knowledge about animal breeding (IK-AB)

- IK-AB can be systematised into the following components (LPPS et al. 2005):
- Cultural concepts about how to use an animal ('breeding objective').
- Preferences for certain characteristics such as colour, size or behavioural patterns ('breeding goal'). The list of criteria considered in breeding decisions can be quite long. For instance, the Raika sheep breeders in India evaluate nine criteria when selecting a male animal for breeding.
- Diversity conserving practices: pastoralists often do not have the concept of an ideal animal, but try to keep a herd with different types of animals to be prepared for all eventualities.
- Selection practices for certain qualities (castration, culling and offspring-testing).
- Pedigree-keeping.
- Sense of community ownership and stewardship: sharing mechanisms within the community and social restrictions on selling animals to outsiders.

These and other means of influencing the gene pool are practised to differing extents among livestock-breeding groups; among these groups, pastoralists have the most refined knowledge.

Scientific animal breeding practices

As has been shown above, pastoralists consider a wide range of criteria when making breeding decisions. In stark contrast, scientific breeding has always focused on a limited number or even a single production trait, usually milk yield in dairy animals and growth rate in meat stock. This approach resulted in the development of a small number of improved breeds with enormous productivity but reduced ability to cope with environmental stresses and diseases. For many decades, attempts were made to introduce and transfer these high performance breeds to developing countries. Sometimes, these endeavours were successful in temperate climates and among educated farmers but in environmentally challenging conditions and among poor and marginal farmers, the attempts generally ended in failure.

This predominance of a small number of global breeds is a main factor responsible for the severe narrowing of the genetic base of our domesticated animals. According to the FAO which has the global mandate for the conservation of domestic animal diversity, about one third of the approximately 7000 officially documented livestock breeds are threatened with extinction and die out at the rate of almost two per week. While some reports doubt this analysis, it is clear that domestic animal diversity is conserved almost exclusively in remote and challenging areas and by small farmers and pastoralists who remain economically marginalised.

Renewed interest in indigenous breeds

During the last few years, there has been a sea change to the almost dogmatic belief in the inferiority and unproductiveness of local or indigenous livestock breeds. This is due, in part, to

research demonstrating that these breeds are generally more productive under low-input conditions. Another important potential of these breeds lies in the fact that they often possess disease resistance traits that are absent or have disappeared from the genetic make-up of high performance breeds. Disease resistance is important when disease-causing organisms have become resistant to drugs, and to minimise antibiotic applications and residues in livestock products.

The most talked-about example of an indigenous breed with interesting genetic potential is the Red Maasai sheep in Kenya, a breed that is endowed with genetic resistance to internal parasites. Since drenches are increasingly losing their efficacy, this trait is of great interest to commercial sheep farmers all over the world, and particularly to such countries as Australia and New Zealand with their large sheep industries. For almost two decades, ILRI scientists have therefore been trying to identify the genetic sequences responsible for worm resistance in this breed, in the hope of being able to genetically engineer it into high-performance breeds. (Since the Red Maasai is a hair-sheep, it is not suitable for crossing with wool sheep.)

But there are many other examples of indigenous breeds with resistance to disease. The Uda sheep from northern Nigeria is much less susceptible to foot rot (Blench 1999). The Kuri cattle kept along the shores of Lake Tchad are very resistant to insect bites (Blench 1999). N'dama and other humpless African cattle are trypanotolerant. Such disease resistance traits are compromised when animals are selected only for high productivity. For instance, the improved Kenya Boran which has been selected for meat gains over several generations is much less resistant to trypanosomes than the Orma Boran cattle.

Some indigenous breeds are also of interest for their product quality (Köhler-Rollefson 2004b). For instance, the Tuli cattle, a breed that originated in southern Zimbabwe, has excellent beef quality and was voted as having the juiciest meat at breed trials conducted in Clay Centre in Nebraska. Even the adaptation to low-input conditions can be of interest to commercial farmers. The Damara sheep, which hails from Namibia and has a reputation as a no-care breed, has become the base for a new Australian sheep breed ('Meat Master').

Livestock breeds and biotechnology

Leading animal scientists have predicted that 'sequenced genomes, transgenic livestock and cloning will become the norm in the 21st century' (Rothschild et al. 2004). In recent years, research on livestock genetics has indeed experienced a massive shift towards the molecular level. The complete genomes of four domesticated animals (chicken, cattle, pig and sheep) have already been deciphered, either completely or to a significant extent.

Furthermore, micro-array technology now enables scientists to rapidly scan genomes and to systematically map genetic traits (Nene et al. 1997). Using genetic markers, it is then possible to identify animals that have certain wanted traits and selectively use them for breeding. Such desired qualities include resistance to internal parasites and other diseases, high fertility, more efficient metabolisms, or a certain wool or meat quality. Another outcome of genomics is the possibility of gene transfer to create transgenic animals with improved disease resistance, better growth rate and yield and improved reproduction. Not surprisingly, it is expected that genomics will revolutionise the livestock industry to the same extent as the biomedical and plant breeding industries.

Initially large-scale genomics programmes were carried out mainly under the auspices of public funded programmes and instigated by governments of countries with substantial livestock industries. Among these public institutions are the US Department of Agriculture through its

National Animal Genome Programme, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia, and Agriculture and Agri-food Canada. But in anticipation of immense profits, private sector investment has grown rapidly.

The market of the animal industry is estimated to be worth US$ 100 billion in the US and US$ 240 billion in the world. Mapping of genomes is expected by some to create a 5–10% efficiency improvement in the food business (achieved through improved feed conversion rates, faster growth rates and higher retail yield) and this is seen as a 5–10 billion dollar business opportunity for biotech companies (Lipschitz 2002). By now, the majority of livestock breeding organisations in the world are pursuing genomics research to comprehend the molecular constellations that are the basis of important production traits. The situation can be described as a mad scramble for proprietary access because those who discover genes first are likely to have a permanent competitive advantage.

Intellectual property rights

Intellectual property rights (IPR) are exclusive rights usually granted by the state on a temporary basis for the exploitation of intellectual creations. They come in the form of patents, trademarks and geographical indications. Since genomics research is driven by commercial interests, intellectual property rights are exercised as a matter of course and patents are applied for immediately. Patents are applied for not only for the 'discovery' of gene strings and for transgenic animals, but even extend to their offspring, so that farmers would have to pay royalties for these. For example, the Johns Hopkins School of Medicine filed for a world patent on animals genetically engineered to have increased muscle mass. The application claimed not only ownership of transgenic animals and how they are created but also all their food products. This patent application was refused (Grain 2000; New Internationalist 2002). But recently, Monsanto tabled a series of patents in more than 160 countries and territories that pertain to new pig breeding techniques and pig herds and populations with increased frequencies of particular genes. This application is still pending (Shaw 2005).

Even in developed countries where this bonanza is mostly taking place, concerns have been raised that the existing IPR laws are ill-designed for this situation and that new policy frameworks are needed to ensure that not too many barriers are put up against new entrants to the industry and to prevent excessive concentration and monopolisation (Kemp 2001). Some observers recommend enacting statutory and regulatory reforms that safeguard access to plant and animal germplasm for public breeding and research (Center for Rural Affairs 2004).

The Karen Commitment on livestock keepers' rights

In an effort to inform indigenous livestock keeping communities about the issues at stake and discuss their implications, two NGOs, the League for Pastoral Peoples (LPP) and Intermediate Technology Development Group East Africa (ITDG-EA) organised a conference in Karen (Kenya) from 28–30 October 2003, that was attended by about 70 representatives of indigenous livestock keeping communities and NGOs working with them. After intensive deliberations, the participants issued a comprehensive statement that has become known as the 'Karen Commitment' (Köhler-Rollefson and Wanyama 2003). This statement demands an international legally binding recognition of inalienable livestock keepers' rights and the rights of their communities to:

- participate democratically in making decisions on matters related to the conservation and sustainable use of animal genetic resources
- access, save, use, exchange, sell their animal genetic resources for food and agriculture, unrestricted by intellectual property rights and [modification through] genetic engineering technologies that we believe will disrupt the integrity of these genetic resources

- have their breeds recognised as products of their communities and indigenous knowledge and therefore remain in the public domain
- benefit equitably from the use of animal genetic resources in their own communities and by others.

Discussion

There is an obvious conflict between 'traditional' and 'scientific' breeding systems and the institutional set-ups in which they are embedded. There are indigenous knowledge systems and community-owned animal genetic resources whose proponents plead for keeping animal genetic resources in the open domain, although they also assert that breeds should be recognised as products of their communities. Conversely, there are scientists and commercial interests that strongly push for privatisation and IPR. For the sake of conserving genetic diversity and of fairness, ethical considerations and food sovereignty the rights of livestock keepers to their animal genetic resources must be protected. According to the Trade-Related Intellectual Property Rights (TRIPS), countries have the options to create their own 'sui-generis' law and exempt animals from patenting. Unfortunately, most countries lack the resources and interest to develop such laws. But it would be in the interest of all stakeholders, not only livestock keepers, but also scientists and industries to find ways and means of protecting livestock keepers' rights as outlined in the Karen Commitment. Otherwise, the antagonism against animal biotechnology among the general public might become uncontrollable.

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Analysis of methods for efficient biodiversity conservation with focus on African cattle breeds

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Abstract
Methods for biodiversity conservation are reported and applied to 49 African cattle breeds (26 taurine/sanga and 23 zebu/zenga (ZZ) breeds). It was estimated that about half of the breeds and half of today's genetic diversity between breeds would be lost within 50 years. Based on a survey and a literature review, cost and effects of four conservation programmes were assessed: herd books combined with promotion of the breed (HB), *in situ* conservation with sire rotation (IS), cryoconservation of semen (CC) and *in situ* plus cryoconservation (IC). Conservation programmes involving strongly breeders, and giving them part of the responsibility for the conservation of the breed reduce endangerment. In this case Breeders were not just potential sellers of animals for a conservation program, but they participated actively in the program (e.g. take decisions) and took over part of the responsibility for the success of the program. It was shown that allocation of resources to only a subset of breeds is optimal. With US$ 2 million, 64% of the present diversity of the ZZ breeds could be maintained over 50 years, i.e. 13% more than if no action is taken.

Key words: biodiversity conservation, breed, cattle, Africa, efficiency

Introduction
The significance of conservation has been widely recognised, but many countries and organisations are facing problems when deciding on the conservation priorities of livestock breeds or when to assess a conservation programme and its cost. We report methods for assessing breed diversity and its changes, estimating extinction probabilities and conservation cost of breeds and for allocating a given conservation budget optimally to a set of breeds (Reist-Marti 2004). The method is illustrated with data on African cattle breeds.

Material and methods
Diversity and endangerment
To calculate the present (D) and expected diversity (E(D)) within 50 years, Weitzman's (1992; 1993) approach was applied on genetic distance measures between 49 African cattle breeds divided into two groups of 26 taurine (*Bos taurus*) and sanga (*Bos taurus* x *Bos indicus*) breeds and 23 zebu (*Bos indicus*) and zenga (sanga x *Bos indicus*) breeds. The endangerment of the breeds given as extinction probability over a certain time horizon is needed to calculate the expected diversity with Weitzman's (1992; 1993) approach. The extinction probability was estimated considering total population size, change of population size over the last 10 years, distribution of the breed, risk of indiscriminate crossing, organisation among farmers, establishment of conservation schemes, political situation of the countries, special traits, sociocultural importance, and reliability of information.

Design, cost and effects of breeding programmes

Based on an evaluation of six breeding programmes dealing with indigenous and adapted African cattle and a literature review, the following four conservation programmes were modelled (low and high input scenarios for each programme are separated by '/'):

- HB is an *in situ* conservation programme consisting of a herdbook and events (e.g. sales, competitions or courses), which aim at promoting the breed and motivating breeders to keep the breed. It is assumed that 168/252 animals are registered in year 1 with an annual increase in registered animals of 10%. Two/four events are organised per year and the effective population size is assumed to remain constant over the 50 years.
- IS is an *in situ* conservation programme based on a circular mating scheme, where sires rotate between 10/30 cow groups. Each group consists of five cows and one sire. The cows are owned by farmers and the sires belong to the programme. The sires and cows are replaced by one of their offspring every fifth year when the rotation of sires takes place.
- CC is an *ex situ* conservation programme cryoconserving semen from 25/75 unrelated sires. The breed is reactivated by backcrossing from another breed with artificial insemination over 6 generations (27 years) resulting in 58 cows having a 98% proportion of the cryoconserved breed. It is assumed that time to first calving is 4 years, the calving interval is 2 years and the survival rate of the offspring is 70%.
- The IC conservation programme combines *in situ* and cryoconservation. Starting with a base population of 320 unrelated animals (300 cows, 20 sires) of the breed, 25/75 sires not related to this founder generation of the base population are also cryoconserved and used for artificial insemination of half of the cows every fifth year (= one generation). The other half of the cows of the base population are mated with the sires from the base population. Cows and sires are replaced by their offspring.

The cost (given in International Dollar I$ (World Bank 2003)) was also estimated using the data from the survey and the literature review. To acknowledge for economic differences in countries where breeds are conserved, conservation costs for each breed/programme were converted to US$ for allocation of the money:

$$US\$ = \frac{LC}{OER} = \frac{I\$ * PPP}{OER}$$

where *LC* is the local currency of the country where the breed is conserved and *OER* is the official exchange rate from the *LC* to the US$. *PPP* is the purchasing power parity conversion factor reflecting the purchasing power of the local currency on the local market (World Bank 2003). Cost was discounted over 50 years with an interest rate of 3%.

The effects of the conservation programmes are expressed as reduced extinction probability, which considers, among other criteria, the effective population size conserved.

Conservation cost and effects will be illustrated with the ZZ group of breeds.

Optimal allocation of resources

Before the money is allocated, the most efficient conservation programme conditional on a given budget is specified for each breed. Hence, an optimal conservation function results, which links conservation expense in a breed both to a choice of conservation schemes and a quantification of returns in terms of reduced extinction probability.

One million US dollars (Mio US$ 1), 2, 3, 5 or unlimited funds, discounted over 50 years, are allocated to the 23 zebu and zenga breeds conserved with the 4 different programmes. The allocation of resources is done in two steps.
In step 1, the total budget is allocated to N breeds in equal shares. Then, the new extinction probabilities are derived for each breed and the expected diversity is calculated. Going through all possible sets of breeds, we get a certain set of breeds, which yields the highest expected diversity. This is the optimum number of breeds, N_{opt} under balanced allocation.

In step 2, the optimum unbalanced allocation among the breeds selected in step 1 is found by the following algorithm: We start with the total funds allocated equally to the subset of breeds. Among these we chose at random two breeds i and . We then take a small share from the conservation budget of breed *i*, changing $m_i \rightarrow m_i - b$, and reallocate this share to breed *j*, changing $m_i \rightarrow m_i + b$. With the modified conservation budgets, we derive the new extinction probabilities through the optimal conservation function and compute the expected diversity E(D). If this value is larger than the expected diversity given the conservation budgets m_i and m_j, we accept this reallocation, if the newly computed expected diversity is smaller, we undo the reallocation. This step is repeated until there is no more increase in E(D).

Consideration of special traits

The evaluation of breeding programmes revealed that the indigenous breeds were appreciated because of their superiority in climate adaptation, tick resistance, trypanotolerance and ceremonial use, but were inferior in appearance. Therefore, in addition to the allocation described above, Mio US$ 1 was preferably allocated to breeds with special traits. The basic assumption here is that a special trait is a characteristic of entire breeds. This means, that the trait is conserved if at the end of the planning horizon at least one breed has survived that carries this trait, and that the trait is lost if all breeds carrying this trait have disappeared. We suggest two different summary statistics to quantify the amount of special traits in a given set of breeds N_{sp} *J*:

- The variable T_1 reflects the number of breeds in subset *J* showing special traits.
- The variable T_2 indicates how many special traits are present in at least one of the breeds in subset *J*.

Diversity and either of the two special trait statistics can be combined in one objective function by a weighted summation. As suggested in Simianer (2002), we call this a utility function defined as:

$$U_J = w_1 D_J + w_2 T_l \mid J$$

where $l=1$ or 2 and w_1 and w_2 are appropriately defined relative weights of diversity and special traits statistic, respectively. Conditional on an allocation vector *M*, the expected utility can be computed as:

$$E(U \mid M) = \sum_{\forall J} P(J \mid M) U_J$$

The algorithm suggested to find allocation vector *M* maximising the expected diversity can be used straightforwardly to maximise the expected utility.

Results and discussion

Diversity and endangerment

The diversity of the zebu and zenga group ZZ (1.21) was about half the diversity of the taurine and sanga group TS (2.63), mainly because of the lower number of breeds in the ZZ group and

their genetic origin (results not shown). The average extinction probability in both groups was around 40% (results for group ZZ in Table 1), which is in line with the estimation of the FAO World Watch List (Scherf 2000). For both groups, the expected diversity after 50 years was about half the present diversity (ZZ = 0.62 ± 0.137, TS = 1.48 ± 0.290).

Design, cost and effects of breeding programmes

Table 1 shows the cost of the conservation programmes HB, IS, CC and IC and their effect on the extinction probabilities of the breeds. Average annual discounted conservation cost for a breed can be as low as US$ 1000 to US$ 4400 depending on the design of the conservation programme and the economic situation of the country of conservation. Reduction in extinction probability was higher for conservation programmes that strongly involve farmers and give them part of the responsibility for the breeding population. IC was most efficient with regard to cost per effective population size conserved (results not shown). However, if cost per reduction in extinction probability is considered as a criterion for the efficiency of a programme, IS, HB and CC were superior to IC. These findings suggest that decisions on conservation programmes should be based on multiple criteria, and not just on cost per effective population size.

Table 1. Conservation cost (in US$ 1000) and extinction probabilities of African cattle breeds conserved with different conservation programmes.

		Conservation programme[a] (cost and reduced EP)															
		HB				IS				CC				IC			
Breed	EP[b]	Low		High		Low		High		Low		High		Low		High	
ANGONI	0.40	237	0.13	687	0.03	187	0.20	708	0.10	259	0.33	585	0.23	855	0.27	1'480	0.17
ARADO	0.50	152	0.17	438	0.07	119	0.23	257	0.13	165	0.30	374	0.20	546	0.30	945	0.20
ARASHIE	0.53	105	0.27	304	0.17	83	0.40	313	0.30	114	0.33	259	0.23	379	0.33	656	0.23
ARSI	0.53	62	0.17	178	0.07	48	0.30	184	0.20	67	0.37	152	0.27	222	0.37	384	0.27
BALE	0.57	62	0.17	178	0.07	48	0.30	184	0.20	67	0.37	152	0.27	222	0.37	384	0.27
ETHBORAN	0.48	62	0.18	178	0.08	48	0.25	184	0.15	67	0.38	152	0.28	222	0.31	384	0.21
BUTANA	0.43	105	0.17	304	0.07	83	0.27	313	0.17	114	0.30	259	0.20	379	0.33	656	0.23
FOGERA	0.43	62	0.17	178	0.07	48	0.20	184	0.10	67	0.30	152	0.20	222	0.27	384	0.17
GOBRA	0.37	164	0.17	474	0.07	129	0.17	489	0.07	179	0.23	404	0.13	591	0.17	1'023	0.07
HIGHZEBU	0.70	197	0.30	570	0.20	155	0.43	587	0.33	215	0.50	486	0.40	710	0.43	1'228	0.33
HORRO	0.43	62	0.17	178	0.07	48	0.20	184	0.10	67	0.30	152	0.20	222	0.27	384	0.17
IRINGARED	0.60	270	0.20	781	0.10	212	0.33	805	0.23	294	0.40	665	0.30	973	0.33	1'683	0.23
KAVIRONDO	0.47	197	0.17	570	0.07	155	0.27	587	0.17	215	0.30	486	0.20	710	0.27	1'228	0.17
KENYBORAN	0.35	197	0.18	570	0.08	155	0.25	587	0.15	215	0.31	486	0.21	710	0.25	1'228	0.15
KILIMANJA	0.63	270	0.27	781	0.17	212	0.37	805	0.27	294	0.47	665	0.37	973	0.37	1'683	0.27
MALAZEBU	0.50	152	0.13	438	0.03	119	0.23	452	0.13	165	0.33	374	0.23	546	0.30	945	0.20
MAURE	0.40	96	0.13	278	0.03	76	0.20	287	0.10	105	0.27	237	0.17	347	0.27	600	0.17
MBORORO	0.37	195	0.13	564	0.03	153	0.17	581	0.07	212	0.20	480	0.10	702	0.17	1'215	0.07
NUBA	0.57	105	0.23	304	0.13	83	0.37	313	0.27	114	0.37	259	0.27	379	0.37	656	0.27
OGADEN	0.60	62	0.30	178	0.20	48	0.37	184	0.27	67	0.43	152	0.33	222	0.37	384	0.27
ORMABORAN	0.40	197	0.17	570	0.07	155	0.23	587	0.13	215	0.23	486	0.13	710	0.30	1'228	0.20
SOKOTO	0.53	195	0.17	564	0.07	153	0.27	581	0.17	212	0.37	480	0.27	702	0.33	1'215	0.23
MADAZEBU	0.50	180	0.13	520	0.03	141	0.23	537	0.13	196	0.33	444	0.23	648	0.30	1'122	0.20

[a] HB: herdbook; IS: in situ conservation; CC: cryoconservation; IC: in situ and cryoconservation. Low: low input scenario, High: high input scenario. For further description see text.

[b] Present extinction probability taken from Reist-Marti et al. (2003).

Optimal allocation of resources

Depending on the budget, the algorithm allocated the money to different breeds. With a budget of Mio US$ 1, the money was allocated to Arashie, Arsi, Malawi Zebu, Nuba Mountain Zebu and Madagascar Zebu for conservation with HB and to Sokoto Gudali for *in situ* (IS) conservation (Figure 1). Thus, 64% of the present diversity could be maintained over 50 years, which is 13% more than would be maintained if no conservation measures were implemented. Diversity cannot be conserved completely, not even with unlimited resources. A maximum of 92% of the present diversity could be conserved with Mio US$ 10, leaving 8% of the diversity to unpredictable happenings (Figure 2). Breeds with low conservation cost due to a favourable economic situation of the country of conservation had a high chance of getting funds. The choice of the breeds and the optimal conservation programme and the amount of money allocated for each breed depended on many factors such as the amount of funds available, the conservation potential of each breed, the economic situation of the country of conservation, the effects of the conservation programme and its cost.

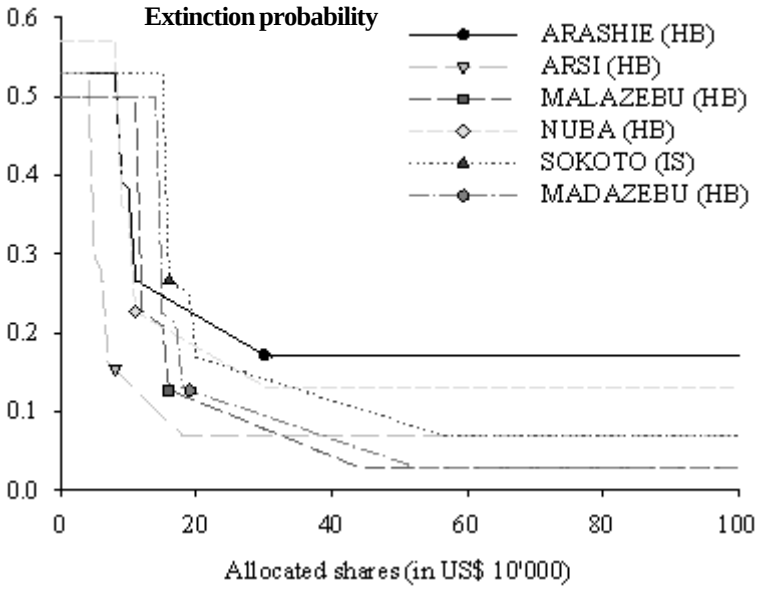

Figure 1. Optimal allocation functions of and amount of shares allocated to each breed conserved with total funds of US$ 1 Mio (for details see text).

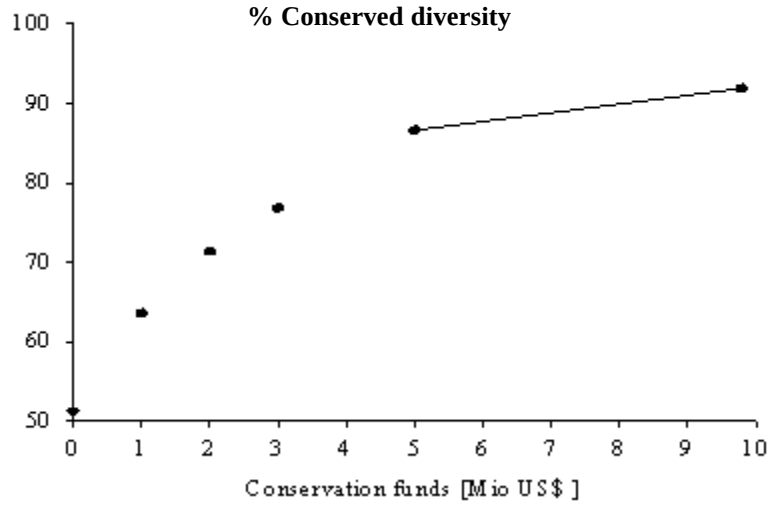

Figure 2. Conserved diversity subject to the invested funds.

Consideration of special traits

When giving a bonus to breeds with special traits, the algorithm allocated money to the Madagascar Zebu, Arashie, Malawi Zebu, Nuba Mountain Zebu, Ethiopian Boran and Maure and the expected diversity declined by 0.0043 or 0.56% to 0.7673. This loss of diversity is highly compensated by an additional 9% of special traits and a gain of 2% in the average probability of conservation of a special trait (Table 2). On this level of investment, 0.56% of expected diversity corresponds to about US$ 120,000 (Figure 2). Hence, the special traits conserved with the bonus scenario do have a value of about US$ 120,000 or 12% of the invested funds. Instead of investing these 12% of funds into 0.56% additional expected diversity, it may be worth to conserve the additional 9% of special traits.

Table 2. Conservation of special traits in African cattle: Allocation of Mio. US$ 1 giving preference to breeds with special traits.

	Presence in the set of breeds		**Probability of conservation**	
Trait	**Without preference**	**With preference**	**Without preference**	**With preference**
Trypanotolerance	1.373	1.373	0.909	0.909
Tick/disease resistance	0.650	0.650	0.650	0.650
Hardiness	2.746	2.743	0.996	0.996
Adapted to local environment	4.828	5.485	1.000	1.000
Docile/calm temperament	3.033	3.433	0.994	0.999
Fertile	0.650	0.650	0.650	0.650
Good mothering ability	1.170	1.570	0.832	0.972
Good product quality	1.503	1.500	0.953	0.952
Total/*Average*	15.953	17.404	*0.873*	*0.891*

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Microsatellite DNA polymorphism of the Long Horned Ankole cattle in Uganda

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Abstract
Nineteen microsatellite markers were used to investigate the genetic diversity, phylogenetic relationships and herd structure of Ugandan Ankole cattle. A total of 304 animals from 8 herds in Mbarara District were characterised. Across all loci, 200 alleles were observed. A high mean number of alleles (MNA) per locus, ranging from 5.89 to 6.79 per herd, was observed. Polymorphic information content (PIC) ranged from 0.403 (*ILSTS013*) to 0.817 (*ILSTS036*), with an overall mean of 0.688. The average observed heterozygosity (*Ho*) was highest in Kaibanda (0.727) and lowest in Kituuha (0.648), while the expected heterozygosity (*He*) ranged from 0.722 (Nshaara) to 0.664 (Kituuha). Significant deviations from Hardy-Weinberg proportions were observed on 8 loci, however, all 152 loci-herd combination tests were in equilibrium after Bonferroni correction. F_{ST} estimates for all loci and between all herds were highly significant (P<0.001), suggesting little if any gene flow between the herds. For all herd pairs, F_{ST} values were generally low, with an overall mean of 0.041 + 0.08. Significant (P<0.01) inbreeding effect (F_{IS}) was detected in the Nasasira herd. The mean number of migrants per generation (*Nm*) across all herds was 3.82. Phylogenetic analysis showed that herds from the same geographical counties grouped together. These results illustrate at the molecular level the fairly wide genetic variation found among the Ankole herds studied and therefore the potential for genetic improvement of these herds.

Key words: Ankole cattle, microsatellite, genetic diversity, pastoralists

Introduction
Ankole cattle, considered to be a zebu × taurine cross (Hanotte et al. 2002), are the main indigenous cattle breed in Uganda; they are used both for milk and meat and comprise between 50% and 70% of the estimated 6 million cattle in the country. This breed is of great importance due to its tropical adaptation, local preferences, cultural and aesthetic value. Indigenous cattle of Uganda are threatened by unplanned crossbreeding and upgrading to exotic breeds, and efforts need to be made to selectively conserve and improve upon their genetic potential for sustainable future performance. Breeding initiatives should focus on evaluation and selective improvement of the production traits of the Ankole breed and its crosses. One of the preliminary steps in selective breeding is the understanding of the current breeding structure and genetic variation available within the breed. Many cattle (Hanotte et al. 2002), sheep (Diez-Tascon et al. 2000), goat (Li et al. 2002), pig (Laval et al. 2000) and horse (Tozaki et al. 2003) breeds have been characterised using microsatellite markers to determine genetic variations within breeds and genetic relationships between breeds. The objective of this study was to compare genetic variability of 8 geographically distinct Ankole cattle herds using 19 microsatellite markers.

Materials and methods

Sampling procedure, DNA extraction and purification
Blood samples were collected from animals from 8 Ankole cattle herds (Kituuha, Kasiisi, Nasasira, Rwokusooka, Kaibanda, Tayebwa, Mwesigye and Nshaara) in Mbarara District of western Uganda

by jugular vein puncture using 10 ml disposable syringes and spread on FTA Whatman® filter paper. FTA purification reagent (Whatman® Bioscience) and Tris-EDTA (TE) buffer pH 7.6 were used to prepare DNA.

Microsatellite markers, PCR conditions and genotyping

Nineteen cattle microsatellite markers recommended by FAO for measurement of domestic animal diversity (MoDAD) were used for analysis: *AGLA293*, *BM1824*, *BM2113*, *ETH152*, *ETH225*, *ILSTS005*, *ILSTS006*, *ILSTS013*, *ILSTS023*, *ILSTS028*, *ILSTS033*, *ILSTS036*, *ILSTS50*, *ILSTS103*, *MGTG4B*, *TGLA53*, *TGLA122*, *TGLA126* and *TGLA227*. Polymerase chain reaction (PCR) amplification was performed in a total reaction volume of 10 ìl on a GeneAmp® PCR system 9700 (*PE* Applied Biosystems). Each PCR reaction contained 20–50 ng template DNA, 1 ìl of 2 mM $MgCl_2$, 0.5 ìl of 0.125 mM of dNTPs, 0.1 ìl of each of the two primers (forward and reverse), 0.5 units of enzyme *Taq* DNA polymerase (Promega). All amplifications included an initial denaturing step of 5 min at 95°C, followed by 35 cycles of 30 sec at 95°C, 1 min at the primer annealing temperature (50–65°C) and 1 min extension at 72°C. Final extension was for 10 min at 72°C followed by holding at 15°C.

PCR products were co-loaded and separated on a 4.5% denaturing polyacrylamide gel using an automated ABI377 DNA Sequencer (Applied Biosystems) Alleles were scored using an internal lane size standard Genescan-350 TAMRA (Applied Biosystems). Microsatellite fragments were analysed using Genescan™, version 3.1.2 software and allele sizes were determined with the Genotyper™, version 2.0 software (Applied Biosystems). The third order least squares was used for base calling.

Statistical analyses

Allele frequencies and mean number of alleles per locus (*MNA*) were calculated and allele sharing matrices for dyads generated using the Excel macros of Microsatellite Toolkit, ver.3.1 (http://www.oscar.gen.tcd.ie). Estimation of average observed heterozygosity (H_O) and expected heterozygosity (H_E) (Nei, 1987) and unbiased estimates of the exact *P*-values, for Hardy-Weinberg equilibrium (HWE) tests at each locus and for each herd, were calculated using a Markov chain randomisation method (Guo and Thompson 1992) using the GENEPOP version 3.3c computer package (Raymond and Rousset 1995). Results were adjusted to control type I error associated with multiple comparisons of data from single sampling sites using a sequential Bonferroni correction (Rice, 1989). An adjusted *MNA* based on 20 individuals per herd was estimated using 250 replicates of re-sampling, to remove effects of unequal subclass numbers. Allelic polymorphic information content (PIC) was calculated from CERVUS 1.0 (Marshall et al. 1998). *F*-statistics (F_{IT}, F_{IS}, F_{ST}) (Weir and Cockerham 1984), *R*-statistics (Rousset 1996) for each locus and pair wise F_{ST} among herds was calculated and tested for significance using FSTAT 2.9.3 software (Goudet 2001). D_A genetic distances (Nei et al. 1983) between herds were estimated using the DISPAN (Genetic distance and Phylogenetic Analysis) program (Ota 1993). The neighbour-joining (NJ) methodology (Saitou and Nei 1987) was used to construct the phylogenetic tree of herd relationships from the genetic distance matrix using the DISPAN program.

Results

Genetic diversity

A total of 200 different alleles were observed at the 19 loci in 304 samples from the 8 Ankole herds studied. The number of alleles per locus varied from 6 alleles at *ETH152*, *BM1824*, *ILSTS013* and *TGLA126* to 17 alleles at *ILSTS036*. Rwokusooka had the highest mean number of alleles (*MNA*) per locus (6.79 + 0.272), while Kituuha had the lowest (5.89 + 0.528) (Table 1). Adjusted *MNA* for 20 individuals sub-sampled from each herd was lower than that for the entire herd, and ranged from 5.50 + 0.451 (Kituuha) to 5.85 + 0.276 (Nshaara). The mean proportion of null

alleles across all herds was 2.9%. The polymorphic information content (PIC) ranged from 0.403 (*ILSTS013*) to 0.817 (*ILSTS036*), with an overall mean over all loci of 0.688. The average observed heterozygosity (*Ho*) was highest in Kaibanda (0.727 + 0.017) and lowest in Kituuha (0.648 + 0.023), while the expected heterozygosity (*He*) ranged from 0.722 + 0.022 (Nshaara) to 0.664 + 0.020 (Kituuha). For all herds, *Ho* and *He* were not significantly different ($\div^2_{(8)}$ = 0.425, P = 1.00). Significant (P<0.01) inbreeding effect (F_{IS}) was detected in only Nasasira herd (Table 1).

Table 1. Within-population genetic diversity expressed as average heterozygosity (ho and he) and mean number of alleles per locus (MNA) and herd and loci confirmation to HWE and inbreeding coefficients (F_{IS}) from 19 microsatellite loci in Ankole cattle.

Herd	n	H_O	H_E	P*	MNA[a]	MNA[b]	Loci in HWE	F_{IS}
Kituuha	26	0.648 (0.023)	0.664 (0.020)	<0.001	5.89 (0.528)	5.50 (0.451)	13	0.025[ns]
Kasiisi	28	0.696 (0.020)	0.710 (0.030)	<0.001	6.05 (0.455)	5.70 (0.429)	14	0.020[ns]
Nasasira	44	0.672 (0.017)	0.710 (0.026)	<0.001	6.37 (0.318)	5.50 (0.256)	14	0.054**
Rwokusooka	52	0.694 (0.015)	0.700 (0.021)	<0.001	6.79 (0.272)	5.72 (0.227)	14	0.010[ns]
Kaibanda	39	0.727 (0.017)	0.699 (0.027)	<0.001	6.58 (0.404)	5.74 (0.327)	15	-0.040[ns]
Tayebwa	42	0.699 (0.017)	0.683 (0.030)	0.06	6.37 (0.378)	5.62 (0.306)	18	-0.025[ns]
Mwesigye	32	0.712 (0.019)	0.710 (0.026)	0.057	6.05 (0.325)	5.55 (0.313)	16	-0.003[ns]
Nshaara	41	0.722 (0.017)	0.722 (0.022)	0.005	6.74 (0.364)	5.85 (0.276)	15	-0.001[ns]
TOTAL	304	0.698 (0.006)	0.727 (0.024)	<0.001	6.36 (0.380)	5.03 (0.323)	10	-

H_O Observed heterozygosity; H_E Average Expected heterozygosity, *P** Probability of herd conformation to HWE, * P < 0.05; ** P < 0.01. [a] for all animals; [b] for 20 animals after 250 re-samplings. Standard error values are given in parentheses. F_{IS} significance level calculated after 152000 randomisations; [ns] Not significant (P > 0.05).

Hardy-Weinberg equilibrium and linkage equilibrium

There were loci significantly deviating (P<0.05) from the Hardy-Weinberg equilibrium (HWE) in all herds ranging from one (*TGLA227*) in Tayebwa to six in Kituuha (Table 1). Three herds deviated significantly (P<0.001) from HWE expectations. No single locus significantly deviated in all the eight herds. A total of 152 locus-herd combinations (19 loci in 8 herds) were tested for conformation to HWE. In total 33 combinations deviated at the 5% level or lower, but after sequential Bonferroni correction, this number was reduced to 7 within the 5% error range allowed.

Population differentiation and genetic relationships among herds

For each pair of herds, the differentiation index values (F_{ST}) and their statistical significance are presented in Table 2. The Ankole cattle herds studied were all highly differentiated (P<0.01) (Table 2). For all the herd pairs, the mean F_{ST} values were generally low, ranging from 0.018 for the Tayebwa-Nshaara pair to 0.073 between Kituuha and Mwesigye herds, and had an overall mean of 0.041 + 0.08. F_{IS} was significant (P<0.001) at *ILSTS023*, *ILSTS033*, *TGLA53*, *TGLA122* and *TGLA227*, while *TGLA126* and *ETH225* were significant at P<0.05. These values corroborate the findings of loci deviations from HWE. Among the herds, only Nasasira herd had a significant F_{IS}. R_{ST} estimates across loci showed a similar trend as F_{ST}(Table 3), supporting the geographical differentiation of the herds. The mean number of migrants per generation (*Nm*) across all herds after correction for herd size was 3.82.

The values for Nei's D_A genetic distances (Nei 1978) between pairs of herds were generally high (Table 4). The smallest genetic distance (0.060) was found between Tayebwa and Nshaara herds while the highest distance (0.153) was observed between Kituuha and Mwesigye herds. The neighbour-joining method based on pair wise genetic distance matrix was used to construct a

Table 2. Pair wise F_{ST} values (Weir and Cockerham 1984)(below diagonal) and their statistical significance (above diagonal) among 8 Ankole cattle herds estimated from 19 microsatellite loci.

	KIT	KAS	NAS	RWO	KAI	TAY	MWE	NSH
Kituuha (KIT)		***	***	***	***	***	***	***
Kasiisi (KAS)	0.056		**	***	***	***	***	***
Nasasira (NAS)	0.068	0.031		***	***	***	***	***
Rwokusooka (RWO)	0.071	0.039	0.046		***	***	***	***
Kaibanda (KAI)	0.060	0.042	0.036	0.041		***	***	***
Tayebwa (TAY)	0.072	0.041	0.042	0.039	0.027		***	***
Mwesigye (MWE)	0.073	0.042	0.039	0.044	0.042	0.032		***
Nshaara (NSH)	0.056	0.028	0.028	0.029	0.028	0.018	0.021	

**P < 0.01, ***P < 0.001. Significance levels were obtained after 28000 permutations. The indicative adjusted nominal level (5%) for multiple comparisons was 0.0018.

Table 3. *F*- and R-statistics (WEIR and COCKERHAM 1984) for 19 microsatellite loci by jack knifing across eight Ankole cattle herds.

Locus	F_{IS}	F_{IT}	F_{ST}	R_{ST}	No.of alleles
ILSTS005	-0.016(0.047)^{ns}	0.009(0.050)	0.024(0.010)**	0.038	9
ILSTS006	-0.078(0.034)^{ns}	-0.031(0.037)	0.044(0.019)**	0.011	10
ILSTS013	-0.039(0.051)^{ns}	-0.027(0.058)	0.011(0.009)**	0.014	6
ILSTS023	0.149(0.101)***	0.206(0.081)	0.068(0.023)**	0.048	7
ILSTS028	-0.044(0.051)^{ns}	-0.015(0.046)	0.028(0.009)**	0.019	16
ILSTS033	0.187(0.067)***	0.231(0.081)	0.052(0.028)**	0.089	7
ILSTS36	0.023(0.016)^{ns}	0.041(0.017)	0.019(0.005)**	0.019	17
ILSTS50	-0.025(0.040)^{ns}	0.012(0.039)	0.036(0.012)**	0.023	10
TGLA53	0.085(0.028)***	0.128(0.032)	0.047(0.016)**	0.033	19
ILSTS103	-0.052(0.018)^{ns}	0.013(0.024)	0.062(0.017)**	0.076	8
TGLA122	0.033(0.040)***	0.093(0.055)	0.062(0.017)**	0.142	11
TGLA126	0.023(0.027)*	0.065(0.029)	0.043(0.014)**	0.095	6
ETH152	-0.085(0.032)^{ns}	-0.043(0.047)	0.039(0.020)**	0.018	6
ETH225	0.032(0.036)*	0.070(0.034)	0.040(0.016)**	0.063	11
TGLA227	0.096(0.048)***	0.148(0.046)	0.058(0.008)**	0.126	14
AGLA293	-0.094(0.040)^{ns}	-0.053(0.038)	0.037(0.012)**	0.054	13
BM1824	-0.022(0.034)^{ns}	0.003(0.029)	0.025(0.013)**	0.053	6
BM2113	-0.054(0.026)^{ns}	-0.031(0.024)	0.021(0.009)**	0.008	13
MGTG4B	-0.007(049)^{ns}	0.042(0.057)	0.048(0.017)**	0.07	11
Mean	0.040(0.017)***	0.045(0.018)	0.041(0.004)**	0.047	-

* P < 0.05, ** P < 0.01, *** P < 0001, ^{ns} Not significant. Significance levels were calculated after 19000 randomisations. Standard errors are given in parentheses.

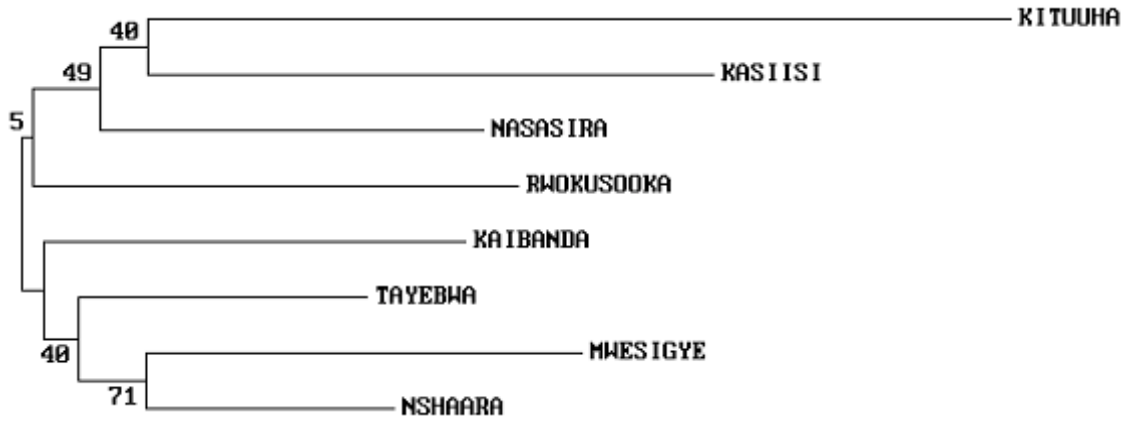
phylogenetic tree to represent the relationships between the herds (Figure 1). The tree indicates that the cattle herds of Kazo County are separate from those of Nyabushozi County. Two main clusters were identified from the tree. The first cluster (Kazo County) consisted of the Kituuha, Kasiisi, Nasasira herds' sub-cluster and Rwokusooka sub-cluster. The second cluster (Nyabushozi County) was made up of Kaibanda, Tayebwa, Mwesigye and Nshaara herds. The bootstrap values for the tree ranged from 55% to 71%. An unrooted UPGMA phylogeny showed a bootstrap value range of 25–56%, with two major clusters.

Discussion

The wide range of genetic diversity observed at the 19 loci assayed agrees with the claim that indigenous cattle have a rich gene pool. The 200 alleles observed across all loci in all the Ankole

Table 4. Nei's (1978) D_A distance matrix among eight Ankole cattle herds estimated from 19 microsatellite loci.

	KIT	KAS	NAS	RWO	KAI	TAY	MWE
Kituuha (KIT)							
Kasiisi (KAS)	0.139						
Nasasira (NAS)	0.132	0.090					
Rwokusooka (RWO)	0.141	0.110	0.094				
Kaibanda (KAI)	0.130	0.124	0.091	0.089			
Tayebwa (TAY)	0.131	0.0103	0.075	0.087	0.069		
Mwesigye (MWE)	0.153	0.113	0.094	0.106	0.098	0.076	
Nshaara (NSH)	0.133	0.098	0.080	0.081	0.078	0.060	0.067



NB: The numbers at the node indicate bootstrap values (1000 re- sampling).

Figure 1. Unrooted neighbour-joining tree showing the genetic relationships among the Ankole cattle herds using D_A genetic distance calculated from 19 microsatellite loci.

herds attest to this. Within population genetic variability (*He*) of 0.648– 0.722 was higher than 0.432– 0.658 (MacHugh 1997) and 0.45–0.69 (Kantanen et al. 2000) reported among African and European cattle breeds respectively. The mean number of alleles per locus (MNA) was 6.36 and average observed heterozygosity, H_0, was 69.8%. These levels of within herd genetic variability are close to the values obtained in other African cattle (MNA 6.7, H_0 = 64.3%, MacHugh et al. 1997), in African goats (2001, MNA 6, H_0 = 64.6%, Chenyambuga et al.) and in Tanzanian sheep (MNA 6.6, H_0 = 71.9%, Stephen et al. 2001). The mean frequency of null alleles observed was lower than in other cattle studies.

Out of the 152 loci herd combinations tested 7 showed significant deviation from HWE expectations. This number is lower than the allowed 7.6. Their distribution in six herds negates herd specific factors. Eight of the 19 loci tested significantly deviated from HWE ($P<0.05$). These deviations are most likely attributed to use of related dyads, inbreeding and herd admixture effects. The genetic differentiation analysis (F_{ST}) showed that the Ankole cattle herds were genetically distinct, with an average of 4.6% of variation being between herds. This value is lower than the 10% observed between European cattle breeds (MacHugh et al. 1998) and 10.5–14.3% (Barker et al. 2001; Li et al. 2002) observed in Asian goats. Inbreeding was detected in the Nasasira herd. This is due to selection of replacement bulls from within the herds. The estimated

number of migrants per generation between herds was generally low, indicating that there is minimal exchange of genetic material. It is also likely that bulls are acquired from specific herds.

The neighbour-joining phylogenetic tree constructed using a matrix of D_A genetic distances among the eight Ankole cattle herds showed that the herds within each county were closer to each other than to the herds, of another county. Interestingly, although the Nshaara herd is in Kazo County, it was included in the Nyabushozi cluster, with which it neighbours. It is possible that the Nshaara ranch herds, which have been recently constituted, contain animals that originated from the two counties studied.

This study demonstrates the usefulness of cattle microsatellite loci for the study of genetic diversity and relationships of Ankole cattle herds. The results show a high within herd diversity and significant between herds genetic differentiation indicating that these herds represent an important resource for future breeding improvement programmes.

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Inference of population of origin of individual animals from different Small East African goat populations using microsatellite markers

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Abstract
A study was conducted to determine the population membership of individual goats from seven Small East African goat strains using microsatellite genotype information. The populations were Maasai, Ugogo, Sukuma, Ujiji, Coastal, Mbeya and Newala goats. The number of individuals per population ranged from 40 to 50 and for each individual, 19 microsatellite loci were analysed. Three approaches were used to determine the affiliation of individuals to their source populations: an allele sharing distance matrix which was used to construct a phylogenetic tree of individual animals based on inter-individual genetic distances, individual assignment tests using a Bayesian statistical approach and maximum likelihood approach. The phylogenetic tree with individual animals as the taxonomic units showed that only individuals from Coastal (83%) and Newala (94%) goats were assigned to their own population cluster. Individuals from Maasai, Ujiji, Ugogo, Sukuma, and Mbeya populations did not show population-specific clusters. For the Bayesian method, the proportion of individuals assigned into their correct population of origin ranged from 85.5% (for Sukuma and Ugogo) to 100% (for Newala and Mbeya). For the maximum likelihood method, the proportion of individuals correctly assigned to their source populations ranged from 64.6% (Ugogo goats) to 100% (Newala goats). The breed assignment test based on the Bayesian method was found to be more efficient in allocating individuals to their source populations, followed by the maximum likelihood method.

Introduction
All the indigenous goats in Tanzania belong to the Small East African goat type. However, the different populations are variously known as Maasai, Ugogo, Ujiji, Sukuma and Newala. It is almost impossible to classify a group of goats into these populations using phenotypic characters commonly used to describe goat breeds (coat colour, horns, physical body measurements and productive traits). This is due to the considerable variability observed within and among the populations, hence, it is difficult to combine different characters in order to have a useful tool for assigning individuals to their source populations. Fortunately, recent advances in the development of nuclear DNA markers, in particular microsatellites, have allowed the determination of differences between closely related populations and the assignment of anonymous individuals to their source populations (Paetkau et al. 1995; MacHugh et al. 1998). Recently, it has been shown that individual genotype information from microsatellite loci can be used to determine the population membership of a single individual (Götz and Thaller 1998; Bjørnstad and Røed 2001; Koskinen 2003). Discrimination among individuals is essential for effective and proper management of livestock breeds for conservation, especially for African breeds which are not adequately characterised even at phenotypic level and have no pedigree information.

Determining the source population of an individual addresses questions of great economic and conservation significance. For conservation it is important to determine the extent of differentiation among breeds since resources are never enough to save everything. Genetic distances are normally used to quantify genetic differences between populations (Barker 1994). One shortfall of genetic distance measures is that it is difficult to get a conceptual grasp of their meaning (Paetkau et al. 1995). An alternative approach is to carry out an assignment test to find out whether sufficient differences exist between populations to make an individual's genotype characteristic or even diagnostic of the population from which it came. Deducing the source population of individuals also answers questions such as: do animals brought to auction markets belong to an endangered breed? Is an animal found at a certain place native or immigrant to that area; if it is an immigrant, where from? In the context of marketing programmes, consumers may have preference for specific breeds and may want to know if a sample of meat at a butcher or supermarket stems from a breed which they prefer. Hence, the ability to assign anonymous animals to the known breeds is important.

The aim of this study was to find out whether we can determine the population membership of a single individual goat from various Small East African goat populations which are phenotypically similar using microsatellite multi-locus genotypes.

Materials and methods

Populations, DNA extraction and microsatellite genotyping

A total of seven populations belonging to the Small East African goat type were sampled in Tanzania. The populations sampled with the number of animals per populations in brackets were: Ugogo (48), Maasai (50), Sukuma (48), Newala (50), Mbeya (48), Ujiji (48) and Coastal goats (48). One African breed from Botswana, Tswana (40), was also sampled to serve as reference breed. For each individual 16 markers (*BM1818*, *BMC1222*, *BMS357*, *BMS1494*, *ILSTS017*, *ILSTS044*, *ILSTS087*, *INRA005*, *INRA063*, *INRA132*, *MAF035*, *MAF209*, *OarAE129*, *OarFCB304*, *SRCRSP003* and *SRCRSP007*) were analysed using the 4200 LI-COR (MWG-BIOTECH) automatic DNA sequencer and three markers (*ILSTS005*, *ILSTS011* and *MAF065*) were analysed using the 377 ABI (PERKIN-ELMER) automatic DNA sequencer. The details of the sampling protocol and laboratory methods, including DNA extraction, polymerase chain reaction amplification and genotyping of the microsatellite markers, were described in Chenyambuga et al. (2002).

Statistical analyses

Three approaches were used to evaluate the potential for breed allocation of individual animals. In the first approach, allele-sharing statistics (Bowcock et al. 1994) were used to determine the affiliation of individuals to their source population. The similarity between individual animals was measured as the proportion of alleles shared over all loci and a distance measure between pairs of individuals was calculated as 1 –Ps (Bowcock et al. 1994) using the MICROSAT program (Minch 2000), where Ps is the proportion of alleles that the individuals share averaged over loci. The distance matrix for the genetic difference between each pair of individuals was used to construct a tree with individual animals as operational taxonomic units (OTUs) using a neighbour-joining (NJ) methodology (Saitou and Nei 1987). The TREEVIEW program (Page 1996) was used to build the tree. In the second approach breed assignment test was performed using the allele frequency distributions of the multi-locus genotypic data. The allocation of individuals to their breeds was done using the WHICHRUN 3.2 computer program (Banks and Eichert 2000) and implementing a maximum likelihood approach. WHICHRUN uses multi-locus genotypic data to allocate individuals to their most likely source population. The likelihood that an individual sample may come from each of the source populations is presumed to be equal to the Hardy-

Weinberg frequency of its specific genotype at each locus in each respective source population. An alternative hypothesis that individual samples in question may come from each source population was evaluated using the jacknife method. In the third approach, the assignment procedure applying a Bayesian statistical approach was carried out using the GENECLASS version 2.0 computer program (Piry et al. 2004). Genotype likelihoods were computed for each individual in each population following the method of Rannalla and Mountain (1997).

Results and discussion

The phylogenetic tree constructed using individual animals as the taxonomic units is shown in Figure 1. The pattern of grouping can be divided into five clusters (Table 1). The distribution of animals from each population shows that 83% of the Coastal goats were found in cluster I at the top of the tree. Cluster II consisted of a mixture of goats, mainly from Ujiji, Ugogo, Sukuma, and Mbeya populations. Out of the 18 individuals in each population, 11 individuals from Ujiji (61%), 8 individuals from Mbeya (44%), 6 individuals from Sukuma (33%) and 6 individuals from Ugogo (33%) clustered together in a single sub-cluster. Cluster III was mainly made up of the Newala goats (94%). In Cluster IV there were two sub-clusters. One hundred per cent of the Tswana goats (reference breed) were clustered in a single sub-cluster while the other sub-cluster was comprised of very few animals (5) from four Tanzanian goat populations. Cluster V at the bottom of the tree was made up of 8 animals; 7 of them were from the Maasai goat populations (38%).

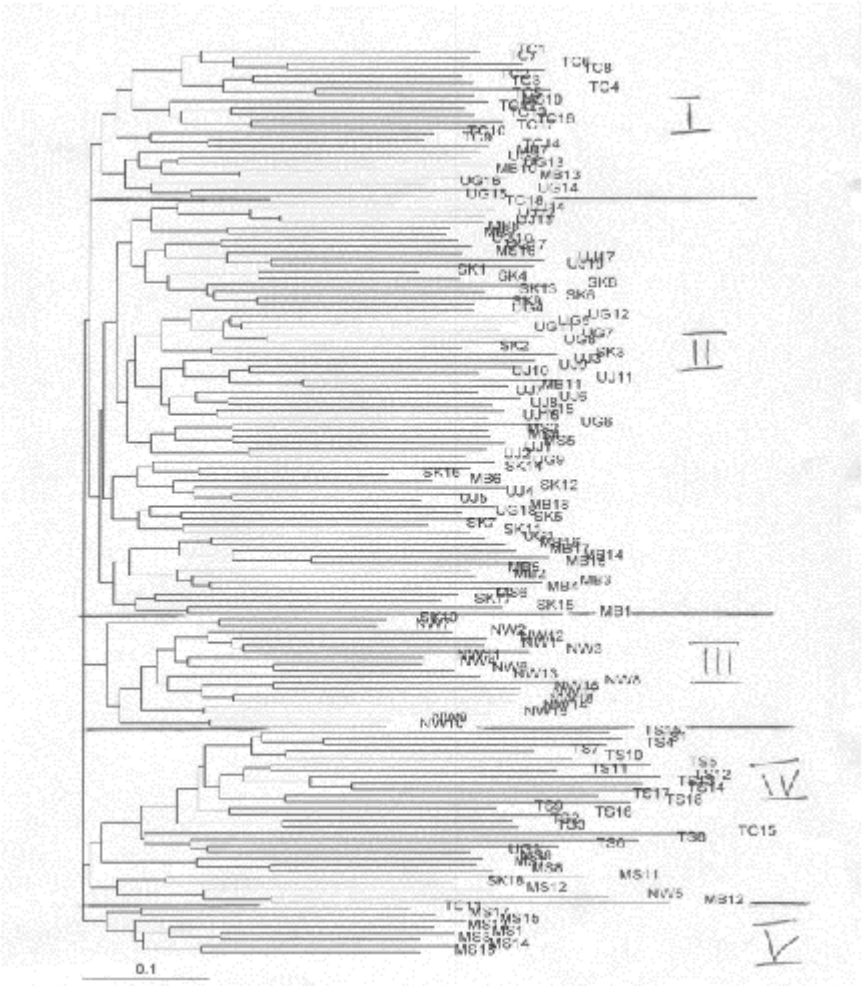

Figure 1. Neighbour-joining dendrogram showing genetic relationships among 144 individuals from seven Tanzanian and Tswana goat populations.

Table 1. Allocation of animals into clusters identified from the individual animals dendrogram of the Tanzanian goat populations.

Population	Clusters					TOTAL
	I	II	III	IV	V	
Coastal	15	1	0	1	1	18
Ugogo	5	12	0	1	0	18
Ujiji	0	18	0	0	0	18
Sukuma	0	16	1	1	0	18
Mbeya	3	14	0	1	0	18
Maasai	1	5	0	5	7	18
Newala	0	0	17	1	0	18
Tswana	0	0	0	18	0	18
TOTAL	24	66	18	28	8	144

The results for the assignment of individual animals to their source populations using the maximum likelihood approach are presented in Table 2. The lowest proportion of individuals correctly assigned to their source population was found in Ugogo goats (64.6%) while the highest proportion was observed in Newala goats (100%). The overall percentage of animals assigned to their source population was 81.5%. In the Bayesian method, on average 94.6% of individuals from the 7 populations were assigned correctly to their source populations (Table 3). When individual populations are considered, the percentage of individuals correctly assigned to the population of origin ranged from 89.5% (Ugogo and Sukuma goats) to 100% (Newala and Mbeya goats).

Table 2. Percentages of animals from each population assigned to each of the seven populations using the maximum likelihood method.

Source population	Assigned population							
	Coastal	Ugogo	Ujiji	Maasai	Sukuma	Newala	Mbeya	Tswana
Coastal	86.7	2.2	0.0	6.7	2.2	0.0	2.2	0.0
Ugogo	0.0	64.6	8.3	14.6	8.3	0.0	4.2	0.0
Ujiji	0.0	4.2	87.5	4.2	2.1	0.0	2.1	0.0
Maasai	4.0	4.0	2.0	84.0	6.0	0.0	0.0	0.0
Sukuma	0.0	4.2	4.2	6.3	70.8	0.0	14.6	0.0
Newala	0.0	0.0	0.0	0.0	0.0	100	0.0	0.0
Mbeya	2.1	10.4	2.1	0.0	6.3	2.1	77.1	0.0
Tswana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100

Generally, all methods were able to identify the source populations of most goats. Under the phylogenetic method, only Newala and Coastal goats formed population specific clusters; the rest of the populations (Ugogo, Ujiji, Sukuma, Mbeya and Maasai) did not show a clear pattern of clustering. The lack of population-specific clustering is an indication of gene flow among these populations. However, for each population, at least six individuals from the same population clustered together in a sub-cluster.

Table 3. Percentages of animals from each population assigned to each of the seven populations using the Bayesian statistical method.

Source population	Assigned population							
	Coastal	**Ugogo**	**Ujiji**	**Maasai**	**Sukuma**	**Newala**	**Mbeya**	**Tswana**
Coastal	91.1	0	0	6.7	0	0	2.2	0
Ugogo	0	89.6	2.1	8.3	0	0	0	0
Ujiji	0	0	95.8	2.1	0	0	2.1	0
Maasai	0	2.0	0	96	2	0	0	0
Sukuma	0	0	4.2	4.2	89.5	0	2.1	0
Newala	0	0	0	0	0	100	0	0
Mbeya	0	0	0	0	0	0	100	0
Tswana	0	0	0	0	0	0	0	100

The maximum likelihood and the Bayesian methods allocated a larger proportion of the goats to their correct population of origin than the phylogenetic analysis. This concurs with the findings of Bjørnstad and Røed (2001) who observed that the phylogenetic analysis, although showing clear differentiation among breeds, is slightly less efficient in identifying the source populations of individual animals than the maximum likelihood method. Between the two methods the Bayesian method was more efficient than the maximum likelihood method in allocating individuals to their source populations. This observation supports the findings of the computer simulation studies by Cornuet et al. (1999), which showed that the Bayesian method is superior to the maximum likelihood and distance methods. The simulation studies (Cornuet et al. 1999) have shown that the efficiency of the Bayesian method may diminish if loci or populations do not conform to the Hardy-Weinberg Equilibrium (HWE), whereas the distance method may perform relatively better under such circumstance. However, this was not the case in this study. The Bayesian method was superior to both the phylogenetic method and the maximum likelihood method, despite the significant HWE deviations observed in most goat populations (Chenyambuga et al. 2002).

Conclusion

This study has shown that there is sufficient differentiation among the Small East African goat populations in terms of genotypic composition across the 19 microsatellite loci analysed. The populations of origin of individual goats were determined with a very high level of statistical confidence based on microsatellite multi-locus genotypes. Even in the phylogenetic analysis it was possible to associate the majority of individuals with the members of their source population. Animals from the Newala population could be relatively easily assigned to the source population using their genotype information compared with the other populations. In general, the genotypes of most individual goats were diagnostic of the population from which it came. This study concludes that microsatellite analysis could be used to determine the populations of origin of individuals from closely related goat populations. The breed assignment test based on the Bayesian method was more efficient in allocating individuals to their source populations, followed by the maximum likelihood method.

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Delivering systematic information on indigenous farm animal genetic resources of Africa

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Abstract
This paper describes the rationale, objectives, historical development, structure, functionality, content, utility and future prospects of the Domestic Animal Genetic Resources Information System (DAGRIS) and its status of development in Africa. DAGRIS aims at delivering systematic information on indigenous farm animal genetic resources of developing countries. It is a public-domain information resource designed to cater for the needs of different stockholders. ILRI developed DAGRIS in 1999 and has been managing it ever since. So far, DAGRIS covers three ruminant livestock species (cattle, goat and sheep) and countries in Africa, and it is being expanded to cover more livestock species (poultry and pigs) of Africa and selected countries in Asia. The database now includes 152, 98, 61 and 127 breeds of cattle, sheep, goat and chicken from Africa and Asia, respectively and about 14,000 trait records. DAGRIS is available free of charge both on the web (http://DAGRIS.ILRI.CGIAR.ORG/) and on CD-ROM.

Key words: AnGR; breeds, characterisation, information delivery; DAGRIS; Africa; ILRI

Introduction
Globally over 6379 documented breed populations of some 30 species of livestock have been developed in the last 12 thousand years since the first livestock species were domesticated (FAO 2000). The majority of livestock genetic diversity is found in the developing world where documentation is scarce and risk of extinction is highest and increasing. More particularly, it is estimated that 35% of mammalian breeds and 63% of avian breeds are at risk of extinction, and that two breeds are lost every week (FAO 2000).

Africa is now known to be one of the centres of cattle diversity and domestication housing a unique set of cattle genetic resources (Hanotte et al. 2002). Recent surveys revealed that some 22% of the known livestock breeds have become extinct in the last 100 years and another 27% are at varying degrees of risk (Rege 1999).

However, there are also opportunities for rapid developments in livestock production because of the fast rising demand for foods of livestock origin (Delgado et al. 2002). The most direct pathway towards achieving the projected increases in demand for livestock products lies in the ability of developing countries to sustainably manage the existing livestock resources (ILRI 2000). Potentially such a change has far reaching impacts for improved livelihoods of poor livestock keepers, hence calling for unprecedented investment in research and extension for broad-based livestock development (Rangnekar and Thomas 2003). This paper describes the rationale, objectives, historical development, structure, functionality, content, utility and future prospects of the Domestic Animal Genetic Resources Information System (DAGRIS) and the status if its development in Africa.

The rationale and objectives for developing DAGRIS

Information has always been an important component of economic development, but it is becoming even more so as the world moves towards an information-based economy. Livestock agriculture is no different; systematic information on the extent of existing genetic diversity, characteristics and use of indigenous farm animal genetic resources in developing countries is the basis for their present and future sustainable utilisation (Ayalew et al. 2003). In recognition of this, ILRI has been developing, since 1999, the Domestic Animal Genetic Resources Information System (DAGRIS). DAGRIS is an electronic source of systematic information on indigenous farm animal genetic resources focusing on cattle, sheep and goats of Africa. Currently the database is being expanded to cover more livestock species (poultry and pigs) and selected countries in Asia. The information system is a product of ILRI's research on livestock to develop international public goods in collaboration with its national agricultural research systems (NARS) partners and other collaborators. It has been part of ILRI's research agenda on the identification and conservation of indigenous livestock genetic resources of developing countries (Rege 1992).

Currently, there are four globally accessible, public domain electronic databases on livestock biodiversity. The first two of these (DAD-IS [http://www.fao.org/dad-is] and EFABIS, the EAAP Animal Genetic Databank of Europe) are related to the FAO global databank on animal genetic resources (AnGR); the third is the database of the Oklahoma State University on breeds of livestock of the world; the fourth one is DAGRIS (http://dagris.ilri.cgiar.org/) of ILRI. DAGRIS differs from the others in at least four ways: 1) it provides essential bibliographic information to all breed-specific information in the database to lead users to more detailed research information; 2) it helps to identify information gaps in characterisation information at breed level; 3) it makes use of available relevant breed characterisation information from unpublished literature (unpublished research reports, field reports, official documentation, theses etc.); and 4) it provides options to summarising available documented information to facilitate decision making in research and policy formulation, which will be strengthened further in the near future through the development of decision support tools.

The development of DAGRIS was prompted by the lack of a comprehensive source of information on the extent and status of existing diversity, characteristics and uses of indigenous farm animal genetic resources in developing countries on the premise that such information is vital to ensure the present and future sustainable utilisation of these indigenous animal genetic resources (Ayalew et al. 2003).

DAGRIS is currently available free of charge, both on the web [http://DAGRIS.ILRI.CGIAR.ORG/] and on CD-ROM (see Table 1 for breed level information for indigenous African cattle breeds). Work is ongoing to develop DAGRIS to include a component on molecular genetic information and a module to allow all users to upload uncovered breed-level research information into the database in available formats to further expand the scope of information dissemination and distribution. This is a plan to assist selected national institutions administer their own versions of country-specific DAGRIS.

Structure, functionality and content of DAGRIS

The new DAGRIS database was developed using the Relational Database Management System (RBDMS) model. In designing the database, specific data elements were identified and grouped into entity types. The relationships between the entities were identified and each of the attributes of the entities and their descriptions defined. Microsoft SQL Server 2000 engine is used to implement and run the database. A total of 15 major tables exist in the structure of the database and these are species, breed group data, general breed data, country-specific breed data, trait

data, population data, environment data, image data, web link, country and region details, trait category, trait type, bibliography (source) and contact (source) tables. In this case, country and region are counted as two separate and activated tables. The core sections of the database are those structures containing organised trait level information by each breed. The web interface of DAGRIS is developed using Active Server Pages (ASP) scripting environment and is served using Internet Information Services (IIS) for Microsoft Windows 2000 Server. DAGRIS has three modules for browse, search (and reporting) and entry. The browse module allows a quick skim through the contents of the database, with options to delimit the browse by species, breed groups or breeds, to speed up the search. The output presents breed description highlights, with direct access to the trait menu for further information. The search and reporting module enables the user to query the database by narrowing the needs to specific breeds, with or without specifying the country and status of the breed. It is also possible to initiate a search of the database from known bibliographic records.

The data entry module is accessible only to the database administrator and data entry personnel. Hence, integrity of the database is ensured, i.e. users cannot add, change or delete data in the database. However, users can download their search output. A new feature under development allows users to upload relevant breed-specific published and unpublished research information to help expand the scope of DAGRIS in its coverage. Other important functions provided by DAGRIS include sort functions on search results, options to specify the number of results to view on screen, access to preset summarised information, print, save, export (to another application) or e-mail search results, hyperlinks to relevant websites for further information on the breed, and help facilities.

The content and functionality of DAGRIS is designed to enlighten all stakeholders, in an efficient way, on the status and on particularly useful attributes of recognised livestock breeds at the level of individual countries, first on cattle, sheep and goats of Africa, and recently on chicken breeds of Africa and selected Asian countries as its scope expands to Asia. Currently the database consists of 14,000 trait records on 152 cattle, 98 sheep and 61 goat breeds of Africa. With the expansion to cover more livestock species and Asian countries, the chicken component of DAGRIS now includes 127 breeds/ecotypes from African and Asian countries and some trait records for 50 of the breeds. Apart from chicken, DAGRIS thus far has the structure and functionality suitable to capture breed-level information for geese, turkey and ducks.

Next steps in the development of DAGRIS

In terms of geographical coverage, DAGRIS currently covers Africa, where about 72% of ILRI's current research activity is directed and the scope of DAGRIS will expand more to Asia, which according to ILRI's global poverty map is home to 57% of the world's poor that are associated with livestock (Thornton et al. 2002). The poverty focus here is relevant not only that most of the existing genetic diversity is found in poor developing countries, but also that sustainable use of the genetic diversity is the most effective way of conserving existing genetic resources.

The next steps in the developments of DAGRIS take NARS as the major players. In the long-term, mandated national institutions need to take charge of the development and administration of public domain information resources such as DAGRIS to serve their own needs and those of other stakeholders. This includes pilot testing of country-modules of DAGRIS in selected African and Asian countries based on which templates will then be made available for other countries to follow. Another major area for development is the georeferencing of DAGRIS for the database to have appropriate GIS linkages. Work is in progress to compile the standard minimum level of detail for all geographic information in DAGRIS for breed distribution and breed characterisation

information. This will open up exciting new opportunities for analysis and generate new categories of breed level information. Biophysical GIS information on climate, ecosystems, landscapes livestock-related resource endowments and disease burdens when overlaid and examined together with breed-level information potentially leads to a more critical and systematic analysis of adaptive attributes of indigenous livestock. Such analysis better serves decisions on selection of suitable exotic or indigenous breeds for introducing and promoting into new areas for sustainable livestock development and effective use of natural resources.

The DAGRIS team will continue with the ongoing data entry and verification, at least in the short-term. The long-term management of the database is under discussion. Meanwhile, additional systems structures will be introduced to handle the following issues: module for uploading and downloading non-curated (any relevant breed-level characterisation information that is yet to be reviewed and validated for inclusion into DAGRIS) breed-level research information from the published and grey literature; module to incorporate decision support tools needed for sustainable use and conservation of animal genetic resources in developing countries; and module for presenting molecular genetic information under DAGRIS-Mol (the molecular genetic information wing of DAGRIS), together with phenotypic information. Apart from chicken, other species of poultry will be covered in DAGRIS. Selected Asian countries will also be covered by DAGRIS in the coming years.

African livestock genetic resources information in DAGRIS

Development of DAGRIS started on indigenous cattle, sheep and goat genetic resources of Africa for two reasons: 1) ILRI and its predecessors (ILCA and ILRAD) have accumulated considerable breed-level research information on African cattle, sheep and goats, and 2) Africa stands out as the priority continent to be served in the development of a public domain information resource on livestock. As a result, to date all of the information on cattle (Table 1), sheep (Table 2), goats (Table 3) and more than half the chicken ecotypes/breeds (Table 4) in DAGRIS come from Africa.

Table 1. Available breed-level information on recognised indigenous cattle breeds of Africa as summarised in DAGRIS (2004).

Breed group	**No. of breeds**	**Per cent of breeds with some trait records by trait categories**				
		Physical	**Production**	**Reproduction**	**Genetic**	**Images**
Commercial composites	7	60	60	50	10	57
Humpless Longhorns	2	100	100	100	100	100
Humpless Shorthorns	15	60	40	47	34	20
Large East African Zebu	16	94	75	63	44	25
North African Humpless Shorthorns	5	60	0	0	0	0
Recently derived breeds	9	67	33	22	0	22
Sanga	31	61	52	29	26	52
Small East African Zebu	47	83	30	19	11	30
West African Zebu	12	100	83	75	42	58
Zenga	8	88	75	50	25	50
Total	152					

Table 2. Available breed-level information on recognised indigenous sheep breeds of Africa as summarised in DAGRIS (2004).

Breed group	No. of breeds	Per cent of breeds with some trait records by trait categories				
		Physical	Production	Reproduction	Genetic	Images
Developed/ composite breeds	25	28	32	20	12	4
Fat-rumped Hair sheep	3	67	67	67	33	0
Fat-tailed Coarse Wool	19	74	58	32	5	11
Fat-tailed Fur sheep	1	100	100	100	0	0
Fat-tailed Hair Sheep	19	53	47	47	21	26
Fine Wool Sheep	2	50	100	100	50	50
Thin-tailed coarse wool sheep	14	57	57	14	0	7
Thin-tailed Hair sheep	15	53	53	53	20	27
TOTAL	98					

Table 3. Available breed-level information on recognised indigenous goat breeds of Africa as summarised in DAGRIS (2004).

Breed group	No. of breeds	Per cent of breeds with some trait records by trait categories				
		Physical	Production	Reproduction	Genetic	Image
Developed goat breeds	4	75	75	75	50	25
Lop-eared goats	27	33	33	22	15	11
Mohair goats	1	100	100	100	100	2
Short-eared Small-horned	27	77	50	68	19	44
Short-eared Twisted horn	3	67	67	67	67	0
TOTAL	61					

Table 4. Available breed-level information on recognised indigenous chicken ecotypes of Africa as summarised in DAGRIS (2004).

Breed group	Number of breeds	Per cent of breeds with some trait records by trait categories				
		Physical	Production	Reproduction	Genetic	Images
Botswana	1	0	100	100	100	0
Burkina Faso	5	20	20	20	20	20
Cameroon	1	0	100	100	100	0
Central African Republic	1	0	0	0	0	0
Chad	7	0	0	0	0	0
Côte d'Ivoire	2	0	0	0	0	0
Egypt	13	8	54	8	23	0
Ethiopia	9	56	100	44	55	33
Ghana	14	0	0	0	0	0
Guinea	1	0	0	0	0	0
Mali	12	0	0	0	0	0
Mauritania	1	0	0	0	0	0
Morocco	1	0	0	0	0	0
Namibia	1	0	0	0	0	0
South Africa	5	40	60	0	40	0
Sudan	3	100	100	0	0	0
Swaziland	4	0	0	0	0	0
Tanzania	7	71	71	0	71	0
Uganda	1	0	100	0	100	0
Zambia	1	0	0	0	0	0
TOTAL	90					

Breeds are presented in evolutionary breed groups, and the breed-level characterisation information therein is organised into logical trait categories: physical, production, reproduction, genetic and image data (Tables 1, 2, 3 and 4). This facilitates the identification of essential information gaps. For instance, at continent level, the database presents much more balanced information on cattle, sheep and goats than on chicken. It also shows that some breed groups of cattle, sheep and goats have more complete characterisation information than others; this is explained by the focus of research so far on a small sub-set of indigenous breeds by NARS and their partners. The specific need for more research information at breed level is also indicated (Tables 1, 2, 3 and 4). NARS and their partners are best placed to lead the search for grey literature available in academic and research institutions and in the relevant government departments. The planned country modules of DAGRIS will help capture such relevant information in the various African countries. The tables do not show the more pressing need for breed-level population figures in Africa. Livestock censuses in Africa seldom provide breed-specific figures. Other available sources are either too crude or are outdated. The range of stakeholders of DAGRIS is hereby requested to assist the DAGRIS team at ILRI by providing missing information on the status, utility and particularly relevant features of indigenous livestock.

Conclusion

A lot more information is believed to be available in the grey literature—unpublished research reports, relevant official documents, and theses and working documents in research and academic institutions. As users and stakeholders of DAGRIS, African NARS should play a more active role in the development of systematic research information to help decisions for livestock development and policy-formulation, and ideally take charge of the development and administration of national databases using the template of DAGRIS in collaboration with ILRI.

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Mitochondrial DNA D-loop sequences reveal the genetic diversity of African chicken

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Abstract
Mitochondrial DNA (mtDNA) displacement (D)-loop sequences were used to study the genetic diversity and relationship of African domestic chicken. A total of 398 individuals belonging to 28 populations were sampled from 12 African countries. The hypervariable 1 (HV1) segment of the D-loop was PCR amplified and subsequently sequenced. The sequences of the first 397 nucleotides were used for analysis. Fifty-two haplotypes were identified from 50 polymorphic sites with polymorphism between nucleotides 167 and 397 contributing to 96% of the variation. Phylogenetic analysis indicates that African domestic chicken mtDNA can be grouped into six distinct clades with one to four clades observed in populations. AMOVA analysis indicates that 64.8% of the total sequence variation between haplotypes was present within population and 35.2% between populations. Our results suggest multiple maternal origins for the African domestic chicken.

Key words: indigenous chicken, genetic diversity, mtDNA, D-loop, haplotype, phylogenetic tree

Introduction
Domestic chicken belong to the class Aves, order Galliformes and family of Phasianidae. The genus name for domestic chicken is *Gallus*. It is widely believed that all populations of domesticated chicken are descended from a single ancestor, the red jungle fowl (*Gallus gallus gallus*), which originated in South-East Asia (Akishinonomiya et al. 1994; 1996). Chicken is by far the most widely distributed of all livestock and poultry species in African countries. It plays a very significant role as a source of income and high quality protein for rural households. Knowledge of the distribution of chicken genetic diversity in Africa would be useful in optimising both conservation and utilisation strategies for indigenous chicken genetic resources. In the past, attempts have been made to characterise local chicken using morphological traits (such as plumage colour, feathering pattern etc.) which have limited utility in the study of genetic variation.

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Mitochondrial DNA (mtDNA) sequences have successfully been used to determine genetic diversity in Asian chicken (Niu et al. 2002; Liu et al. 2004).

Mitochondria have extranuclear DNA called mtDNA which carry genetic information needed for mitochondrial metabolism. Chicken mtDNA has 16,775 base pairs (Desjardins and Morais 1990). MtDNA is highly polymorphic compared to nuclear DNA, evolutionary rate being 5 to 10 times faster than the nuclear genome (Brown et al. 1982). Different regions of the mtDNA evolve at different rates (Saccone et al. 1991), making it a marker of choice for studying genetic diversity within as well as between species. The displacement (D)-loop region is non-coding and evolves much faster than other regions of the mtDNA genome. This makes it particularly useful for phylogeographic analysis (Avise 1994). MtDNA is maternally inherited in most species and does not undergo recombination (Hayashi et al. 1985). These features mean that each molecule as a whole usually has a single genealogical history through maternal lineage. In this study, the sequences of the D-loop hypervariable 1 (HV1) segment of the mtDNA were used to study the genetic diversity and relationship of African domestic chicken.

Materials and methods

Sample collection

Chicken blood samples from a total of 398 individuals belonging to 28 populations were collected from 12 African countries (Botswana, Burkina Faso, Chad, Egypt, Ethiopia, The Gambia, Kenya, Malawi, Mali, Senegal, Sudan and Uganda). Except for the Egyptian samples where blood was collected in Eppendorf tubes and mixed with EDTA as an anticoagulant, all blood samples were collected using FTA® classic cards (Whatman BioScience, Maidstone, UK). The number and geographic location of the samples were as follow: Botswana (n = 55, Semitwe, Motokwe, Malolwane and Gumare) and Malawi (n = 15, central Malawi) for the southern region; Kenya (n = 20, Marsabit and the KARI poultry station in Naivasha), Ethiopia (n = 39, Nekemte, Jimma and Debre Birhan), Sudan (n = 15, Kingdom of Shilluk, Upper Nile) and Uganda (n = 50, Sembabule, Katakwi, Kasese and Apac) for the eastern region; Senegal (n = 42, Koumpentoum, Kolda and Fatick), Burkina Faso (n = 41, Bobo, Seytenga and Djibo), Chad (n = 15, Bagassola), The Gambia (n = 44, Lower Niumi, Wuli and Upper Fulladu) and Mali (n = 45, Mopti, Sotuba and Koulikoro) for the western region; and Egypt (n = 18, Fayoum) for the northern region.

DNA extraction

Genomic DNA was extracted from either whole blood or from air-dried blood spotted on filter paper (FTA® classic cards). DNA was extracted from whole blood using the phenol/chloroform method (Sambrook et al. 1989). For the extraction of DNA from filter papers, the manufacturer's protocol was followed.

Amplification and sequencing of mtDNA D-loop

The primers used to amplify the hypervariable 1 segment were L16750 (52 - AGGACTACGGCTTGAAAAGC-32) as forward primer and H547 52 - ATGTGCCTGACCGAGGAACCAG-32) as reverse primer. This primer pair amplifies a 550 bp fragment between sites 16750 (GenBank accession number NC_001323, Desjardins and Morais 1990) and 547 (GenBank accession number AB098668, Komiyama et al. 2003). The polymerase chain reaction (PCR) reactions were performed in a 30 µl reaction volume containing 2.5 mM of each dNTPs, 14 pmol of each primer, 1.5 mM $MgCl_2$, 1 × PCR buffer comprising 10 mM Tris-HCl (pH 8.3) and 50 mM KCl, and 1.25 U *Taq* DNA polymerase (Promega, Madison, USA). PCR amplifications were carried out on a GeneAmp® PCR system 9700 (Applied Biosystems, USA) thermal cycler. The reaction profiles was: initial denaturation at 94ºC for 2 min, followed by 35 cycles at 94ºC for 30 s, 58ºC for 30 s and 72ºC for 1 min. The last cycle was followed by a

final extension step at 72ºC for 10 min. PCR products were electrophoresed on a 1.5% (w/v) agarose gel stained with ethidium bromide in a 1 × TBE buffer at 100 volts for 1 hour.

PCR products were purified using the QIAquick PCR purification kit (QIAGEN, GmbH, Germany) according to the manufacturer's protocol. Direct sequencing of HV1 segment of the D-loop region was performed using two internal primers CR-for (52 -TCTATATTCCACATTTCTC-32) and CR-rev (52 -GCGAGCATAACCAAATGG-32). Sequencing was done using the BigDye® Terminator version 3.1 Cycle Sequencing Kit (Applied Biosystems, USA) and the purified sequencing products were electrophoresed on an ABI 3730 XL automated capillary DNA sequencer (Applied Biosystems, USA).

Data analysis

MtDNA sequences for the first 397 nucleotides of D-loop were aligned using the program ClustalX 1.83 (Thompson et al. 1997; available at ftp://ftp-igbmc.u-strasbg.fr/pub/ClustalX). The polymorphic sites were identified with the program MacClade 4.0 (Maddison and Maddison 2000; available at http://ag.arizona.edu/macclade/macclade.html). Phylogenetic analyses were conducted using the program MEGA version 3.0 (Kumar et al. 2004; available at http://www.megasoftware.net/). Maternal genetic differentiation was quantified using hierarchical analysis of molecular variance (AMOVA) (Excoffier et al. 1992; http://anthro.unige.ch/arlequin).

Results and discussion

Fifty-two haplotypes were identified with variations at 50 sites. Higher variability was observed between nucleotides 167 and 397 with only two polymorphic sites within the first 166 nucleotides (Figure 1).

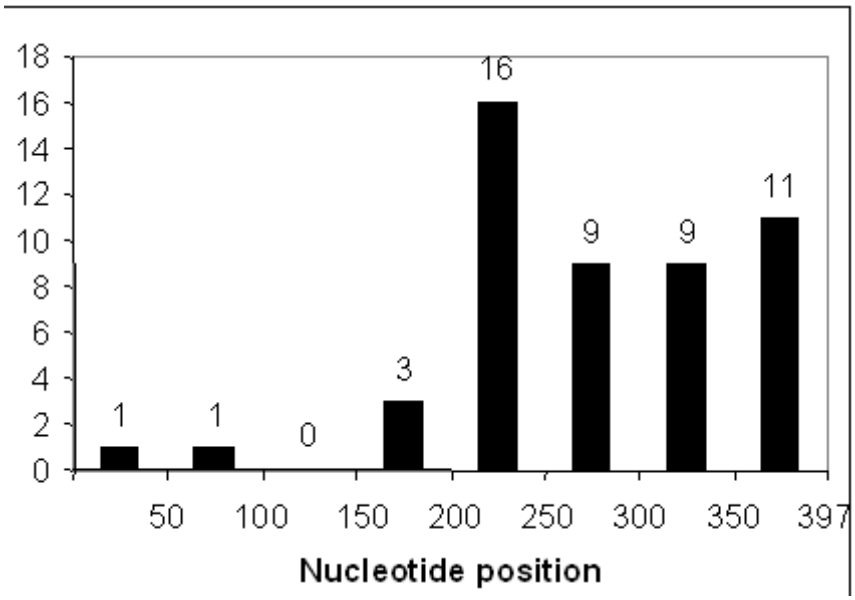
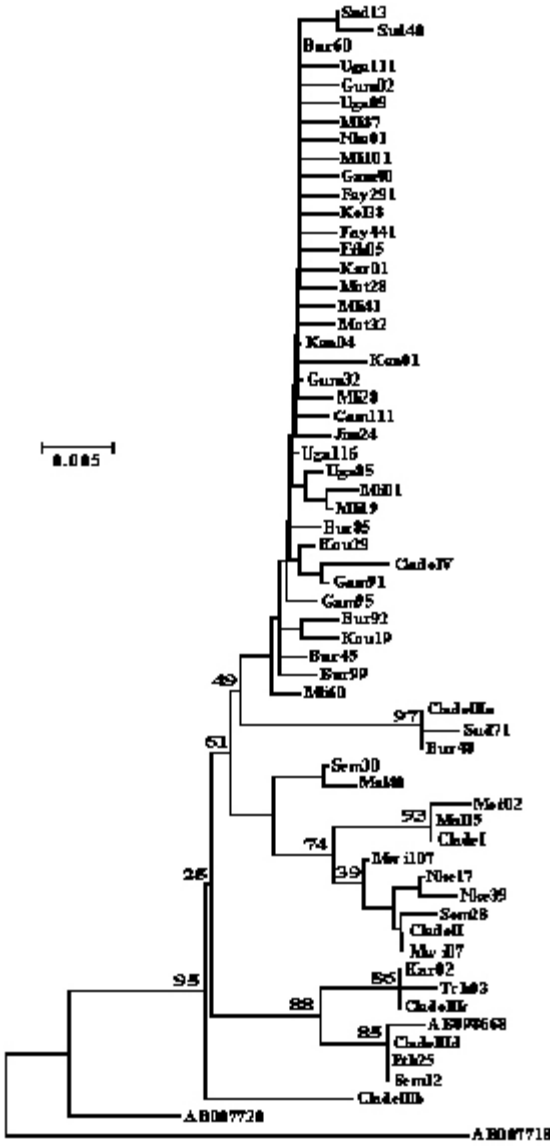


Figure 1. Distribution of sequence variations in the first 397 nucleotides of D-loop HV1 region of domestic chicken from 12 African countries.

Phylogenetic analysis was done with mtDNA reference sequences representing seven different clades (set of haplotypes), as identified in a set of Asian samples (Bjørnstad post-doctoral scientist, ILRI 2003, personal communication). African chicken haplotypes were placed into six of the seven clades observed in Asia (Figure 2).

The numbers of haplotypes observed within populations ranged from one to nine; with one to four clades observed within populations. One of the haplotypes was shared by all the populations except Malawi, suggesting that these populations may share the same maternal ancestor. Analysis of molecular variance (AMOVA) showed that on average 64.8% of the variation in sequences between haplotypes was present within population while 35.2% of the variation was observed between populations (Table 1). More particularly, the West African populations show the highest within population haplotypes variation (Table 1).



NB: The numbers at the major nodes represent the percentage bootstrap values for interior branches after 1000 replications.

Figure 2. Neighbour-joining tree reconstructed using MEGA 3.0 software from 52 haplotypes identified for African domestic chicken, 3 haplotypes of genus *Gallus* retrieved from GenBank AB098668 for domestic chicken, Komiyama et al. 2003; AB007720 for *G. g. gallus* and AB007718 for *G. g. bankiva* submitted by Miyake, T. on the 2nd of October 1997 (Tetsuo Miyake, Wakunaga Pharmaceutical Co., Ltd., Hiroshima Campus Hiroshima, Japan) and 7 clade reference haplotypes (Clade I, II, III a-d and IV, and Bjørnstad post-doctoral scientist, ILRI 2003, personal communication).

Table 1. Analysis of molecular variance between D-loop sequences haplotypes in African chicken populations.

Samples	No. of groups	No. of populations	Variation (%)		
			Within populations	Among populations within groups	Among groups
All 28 chicken populations	4 (regions)	28	63.26	29.42	7.32
All 28 chicken populations	1	28	64.80	35.20	
Eastern region populations	1	9	64.75	35.25	
Western region populations	1	13	93.63	6.37	
Southern region populations	1	5	59.11	40.89	
Northern region populations	1	1	—	—	

Conclusion

Our results indicate that the D-loop hypervariable 1 region of the mtDNA region is highly variable in African domestic chicken with a large number of haplotypes which indicate multiple maternal origins for the African domestic chicken.

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The use of biotechnology in conservation of indigenous animal genetic resources in Mozambique

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Abstract
This paper discusses the potential use of biotechnology in the conservation and improvement of indigenous animal genetic resources. National herds, mostly in the hands of the rural communities, are made up mainly of indigenous breeds. Conservation of indigenous livestock must include cryopreservation of semen oocytes and embryos and associated technologies, besides maintenance of living populations. These should be, accompanied by characterisation studies both phenotypic and generic to better understand better existing breeds and prevent the eradication of breeds due to natural or man-made disasters as already happened in Mozambique and is still happening in some parts of the world. Within a clear livestock breeding policy, this would also ensure sustainable utilisation of the indigenous breeds which can result in poverty reduction and food security taking into account community's intellectual property rights.

Key words: indigenous, biotechnology, AI, livestock, characterisation, conservation

Introduction
Indigenous livestock comprises over 70% of the total livestock population in Mozambique. These breeds have the advantages of being tolerant to diseases, resistant to droughts and food scarcity and they are highly fertile. Mozambique owns three indigenous cattle breeds and various other breeds from other livestock species (Rocha 1985; Maciel et al. 2004).

Water buffaloes introduced in Mozambique in 1969 from Italy, and already an adapted species, need to be improved through the introduction of new bloodlines since inbreeding levels are already noticeable by their decreased birth and growth rates, lowered fertility rates and increased mortality rates (Macamo 1991; Maciel and Muir 1996; Maciel et al. 2004).

In Mozambique application of biotechnology in livestock began in 1951 in experiment stations by crossbreeding the Landim cattle with exotic breeds, either for dairy or meat improvement, through the use of artificial insemination (AI). However, it was in 1962 when the use AI acquired some practical importance. In 1974 a centre for physiology, reproduction and AI studies was established and this brought a new vision to livestock development in Mozambique.

In 1979 the application of AI began intensively with goals of improving milk and meat production by crossing the Landim cattle with exotic breeds and until 1987 there was massive government support both to state and private enterprises (IREMA 1985; Rocha 1985). Parallel to the wide spread of AI some conservation programmes for Landim cattle also began, but it was only for semen conservation. No conservation programmes for other breeds or species were ever initiated or planned. From 1993 to date, almost no AI has been practised in Mozambique either for improvement within pure indigenous breeds or crossbreeding programmes. Nevertheless, the demand for AI is currently increasing, especially for wealthy commercial farmers who require AI

services for improving milk or meat production in their indigenous herds; these farmers are even importing semen from breeds that have not been tested in Mozambique.

During the AI activities several cattle breeds were introduced and various crossbreeding programmes initiated in Mozambique, but there are no productivity data from the progeny which have been reported or existing in a raw form to enable analysis. Some crossbreeding programmes in goats, through AI, were also evaluated with promising results. Fertility results obtained in cattle and goats using AI were comparable to those obtained in other parts of the world; this encourages its reintroduction (IREMA 1985; Maciel et al. 1996).

Besides the use of AI technology, conservation of indigenous livestock must include other technologies such as embryo transfer (ET), *in vitro* fertilisation (IVF), intra-cytoplasmatic sperm injection (ICSI), multi-ovulation embryo transfer (MOET), accompanied by breed characterisation studies on morphology, physiology, reproduction and genetics either *in vivo* or *in vitro* for better conservation and efficient utilisation programmes (Maciel and Manuel 2003).

The objective of this paper is to discuss the potential application of biotechnologies in conservation and sustainable use of indigenous breeds as a tool to reduce poverty and attain food security through increasing the animal's value and considering the community's intellectual property rights.

Materials and methods

The data for this study were collected from published results, existing AI programmes run by specialised technicians and from a private company dealing with water buffaloes.

Results and discussion

Status of characterisation programmes

Mozambique has three native cattle breeds known as the Landim, the Tete Bovine and the Angoni. A population estimate for these breeds is presented in Table 1.

Table 1. Estimated number of native cattle breeds in Mozambique.

Breeds	1998*	2002**
Landim	200.073	600.000
Angoni	85.818	80.000
Tete	27.734	200.000

*Tomo and Macamo (2000).

** Estimates based on total livestock numbers in the country/ by province.

Between 1998 and 2002 the numbers of indigenous breeds generally increased (Table 1), although the great flood that hit Mozambique in 2000 killed a significant number of animals. In the last 2 years, the populations of these breeds might have increased slightly. However, it is difficult to know the exact numbers since the Institute for Statistics, which is responsible for carrying out surveys and livestock census, does not collect data by breed, only by species. It is hoped that the proposed breed survey will capture the actual numbers of different breeds and livestock species.

To date, the Landim cattle is the best known and characterised breed, accounting for more than 70% of the national cattle herd (Macamo and Tomo 1999). As mentioned above, it is the only breed for which there has been an *ex situ* conservation programme, through conservation of its semen from various bulls originated at two public research stations (Chobela, Maputo, and

Mazimuchopes, Gaza). Characterisation for performance and productivity of this breed was performed during the Portuguese colonial period. Milk production varies between 573 and 1793 kg per lactation, but Landim cattle are very suitable for draft power, and they are mostly used for ploughing in the South of Mozambique (Rosinha 1963). This breed is also successfully used for meat production, due to its high calving and weaning rates, associated with a relatively good dressing out percentages, which can reach up to between 51% and 57% with supplementary feeding during the dry season, at 3 to 4 years old. The Landim is the largest native cattle breed found in Mozambique (Morgado 1953/54; Rocha 1985; Catalão and Syrstad 1990; Carvalheira et al. 1995a, 1995b; Maciel 2001).

The Tete Bovine, morphologically similar to the Landim, is smaller in size and has a larger hump. Some authors' state that these cattle might have originated from the Mashona breed in Zimbabwe, whereas others propose that it might be a product of crosses between the Angoni and the Landim cattle, prevalent in the neighbouring areas of Tete Lowlands Province (Tomo and Macamo 2000). Due to its long adaptation to the low rainfall areas (less than 500 mm annually) and high temperatures (average of more than 27°C), Tete Bovine are highly adapted for survival in a very harsh environment; they produce meat and can be used for draft power (Rocha 1985; Maciel 2001). Recent morphological characterisation of this breed was performed within a FAO programme (João and Tomo 2002). Phenotypic characterisation of the Tete Bovine showed that these are small-framed animals adapted to low input tropical production systems, with characteristics such as scrotal circumference and sloping rump highly correlated with reproductive fitness. Based on this data, it has been recommended that programmes for conservation and improvement of this breed should be carried out (João and Tomo 2002).

The Angoni cattle breed belongs to the Small East African zebu group but apparently is more related to the Malawi Zebu than to the Zambia Angoni. Its main use is for meat production and occasionally it is used for draft (pulling carts) and milk production. It is the smallest native cattle breed, very resistant to diseases like trypanosomosis which is endemic in the areas where the breed is prevalent (Rocha 1985). It is a small-framed animal and about 60.5% of the animals are red coated (Tomo 1997). According to Tomo (1997), the very low overall performance shown by the Angoni breed is probably related to high levels of inbreeding. However, this refers only to the data which were obtained from the Angonia Research Station, whose breeding programme was closed due to war and remains closed to date.

The buffalo herd of Mozambique was originally imported from Italy, Naples region, in 1969 to the Zambezia Province. It is now spread to the South, in Maputo and Inhambane provinces (Maciel and Muir 1996). The water buffaloes existing today are crossbreds of the Jafarabadi and Murrah breeds (Serra 1973; Paiva e Serra 1974). Since its first entrance into the country there has been no importation of currently breeding animals. The breed probably has a high level of inbreeding, characterised by decreasing productivity and fertility rates (Macamo 1991; Macamo 1993; Maciel and Muir 1996). The buffalo herd evolution in the last 10 years, in Zambezia Province is presented in Figure 1.

A maximum of 972 animals was reached in 1996 in Zambezia Province; since then the number has been decreasing (Figure 1) and currently there are fewer than 400 buffaloes representing only 37.45% of the number in 1996. This number includes 121 females. Due to their adaptability and the high production attained in performance, these animals are of great importance in the market supply of milk and meat, and there are prospectives for using them for draft power in the rice fields. The data on births, sales and deaths are presented in Figure 2.

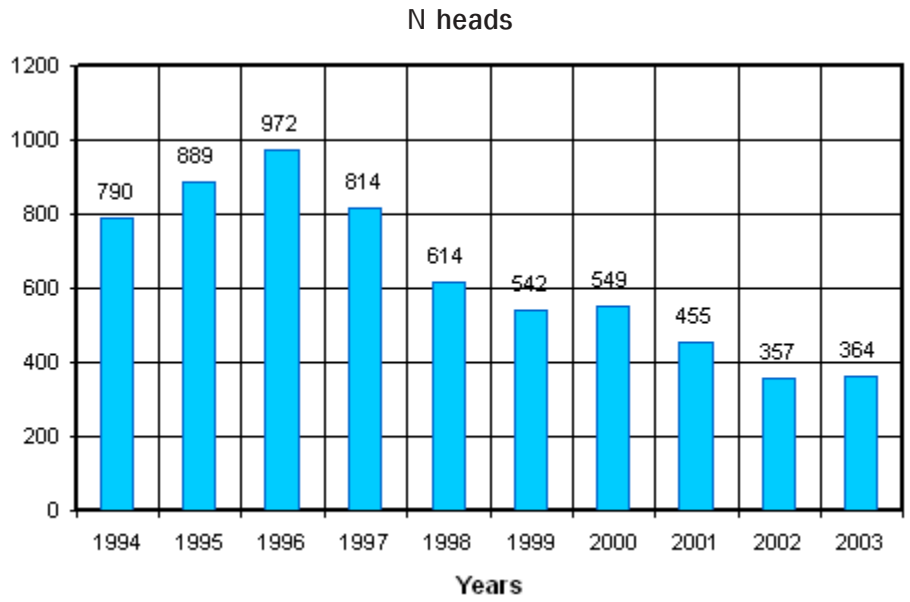
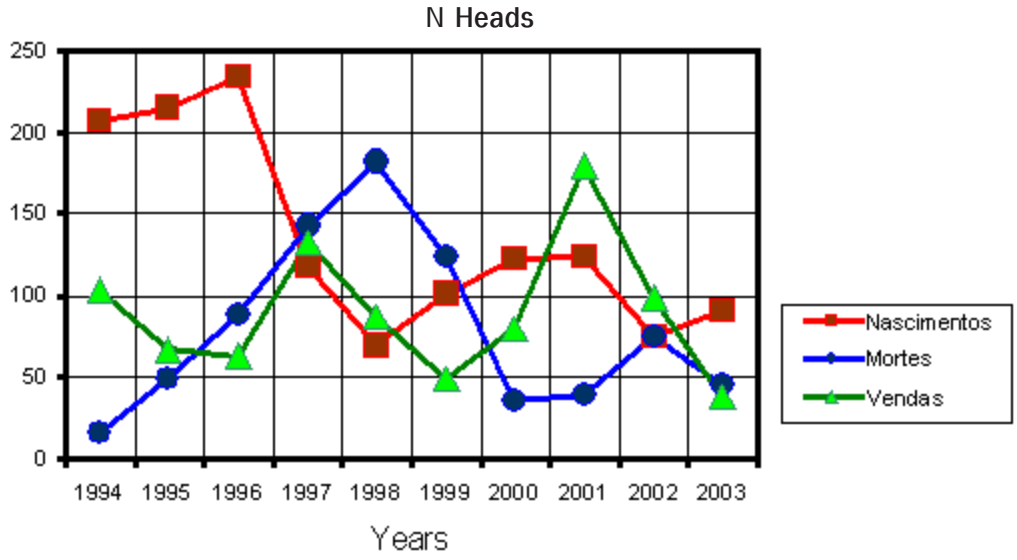


Figure 1: Evolution of water buffalo herd in Zambezia between 1994 and 2003. Source: MADAL (2003).



(Square = birth numbers; Circles = number of deaths; Triangles = number of animals sold).

Figure 2. Birth, deaths and sales evolution in the water buffalo herd in Zambezia. Source: MADAL (2003).

There was a large decrease in the number of births, between 1996 and 1998, followed by a slight increase in birth rate thereafter (Figure 2). Mortality rate reached its maximum in 1998, but then decreased and it has remained low at a level of less than 50 animals per year since 2000. In parallel, the number of animals sold decreased between 1997 and 1999, increased thereafter and reached a maximum in 2001.

In the south, water buffaloes were under an extension programme aimed at promoting draft power and milk consumption in the family/smallholder sector (Maciel and Muir 1996). Although

animals were bred throughout the year, higher calving rates were observed between January and April, with February and March having the highest, calving rate which coincided with the highest rainfall and maximum grass availability (Macamo 1993; Maciel and Muir 1996). Maciel and Muir (1996) concluded that these animals have great potential for development in Mozambique and recommended a study on their potential under various management conditions and introducing them into other areas of the country.

Small ruminants are mostly raised by the smallholder sector which holds over 95% of the national herd. These species are exclusively used for meat production for home consumption and marketing. Various studies have indicated high mortality rates ranging from 30% to 68% (Loforte et al. 1994; Harun and Massango 1996). Animals are raised in an extensive management system, with kraals being either on the ground (60% of farmers) or raised (40%) (Lough et al. 2001).

The Landim goat, the main breed, is spread throughout Mozambique with small variations in size; it is adapted to harsh conditions. In Tete Province animals seem bigger with a higher fertility rate than in the south of Mozambique. The smallest goats are found in Nampula Province and the biggest ones in Pafuri and some of Tete region (Maciel et al. 2004). Apparently, seasonal differences do not affect fertility and survival of the Landim goat, reaching its maximum twinning rate at the third kidding and lowest at the first, having 1.62 kids per kidding and an overall mortality rate of 15% (Mackinnon 1985). The age at first kidding is 390 ± 72 days, the kidding interval average 243 ± 64 days and the percentage of twins is slightly higher in wet than in dry season with an average of 2.3 kids born per doe per year (Loforte 1999).

The Pafuri goat, very typical of a transhumance system in Gaza Province where it is milked during the drier periods of the year (Rocha 1985), is currently spreading out to other southern provinces, such as Maputo (Maciel et al. 2004). It originated in the region with the same name and is probably related to the Matabele goat from Zimbabwe. It is a long-eared type of goat, considered to be a product of the crossbreeding between the Boer goat from South Africa and the Landim goat (Rocha 1985). It is mainly used for milk production (305 to 398 ml of milk/day at peak lactation) and is also heavier than the Landim, at younger ages. The main limiting factor for breeding these animals appears to be its sensitivity to humidity (Rocha 1985).

Sheep are raised in very small numbers, appearing less important than goats, with the proportion of sheep:goats varying between 1:4 and 1:10 depending on the area (Tomo and Vaz 1993; Rocha 1995; Maciel 1996). Sheep are mostly used for traditional and religious ceremonies. As with other species, the Landim sheep is the most common in Mozambique followed by the Black Head Persian. In provinces bordering South Africa, some crosses with South African breeds can be found. The Karakul, an adapted breed, was imported into the country, from Angola. They are currently found in Tete and Manica provinces, in the livestock development centres and surrounding areas (Maciel et al. 2004).

Status of conservation and improvement programmes

Although AI programmes acquired some practical importance in 1962, until 1974 AI was practised without any performance or progeny evaluation programmes. In 1979 a massive AI programme restarted with very clear objectives of milk and beef improvement (IREMA 1985; Rocha 1985; Maciel et al. 1996). However, for several reasons, except for some fertility data and milk production data, no other data from AI progeny are available for evaluation for genetic improvement (Maciel 2003; Maciel and Manuel 2003).

Because of the awareness of the importance of native livestock in Mozambique, preservation of indigenous genetic material, specifically semen, began in the early 1980s at Animal Production Institute (IPA) now the IIAM (Instituto de Investigacao Agraria de Mocambique which means Agricultural Research Institute of Mozambique). Attempts on cryopreservation of the Landim goat semen were made with some success on its post-thawing survival rate. Some experiments on refrigeration of swine semen were performed, but no cryopreservation was attempted. No cryopreservation of embryos from any species has been attempted (Maciel 2001 and Maciel et al. 2004).

Semen conservation of indigenous livestock was focused only on Landim cattle. Imported semen from other breeds, like the Marchigiana and Tarentaise, was never tested in the country. Table 2 presents the breeds tested in dairy and beef improvement programmes in Mozambique. Until 2003, there were about 100 thousand straws preserved at the AI centre from several breeds, from which 14.86% were imported exotic, including the Nguni from South Africa. Landim semen comprised 19.04%, while the Friesland composed 33.17% of the bank. Although semen from the Landim was only processed until 1992, the bulls are still under rigorous breeding control. These bulls originated from 40 years of selection for growth rate at the main breeding station, Chobela Research Station, in Maputo Province.

Table 2. Semen used in the dairy and beef cattle for crossbreeding the Landim in AI programmes.

	Provinces**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Dairy	***H.Friesland***	x	x	x	x	x	x	x	x	x	x
breeds	***Jersey***	x						x			
	B.Swiss	x									
	Normande	x				x					
	Tarentaise	x									
	Montbeliarde	x									
	Saihwal	x									
Beef	***Landim***	x									
breeds	***Brahman***	x					x		x		
	Afrikander	x									
	Simmental	x									
	Limousine	x									
	Boran								x		

**1 = Maputo; 2 = Gaza; 3 = Inhambane; 4 = Sofala; 5 = Manica; 6 = Zambezia; 7 = Tete; 8 = Nampula; 9 = Cabo Delgado; 10 = Niassa.
Source: Maciel and Manuel (2003).

Most dairy breeds were studied in Maputo Province (Table 2), because most technicians are based in this province and consequently better monitoring and evaluation could be performed. Holstein Friesland cattle have been tested in the whole country and it is still the main dairy breed. However, no results from the crossbreeding programmes on its productive or reproductive performance have been published or are available for evaluation. A dairy project on Girolando, from Brazil, is supposed to start soon in Sofala and Manica provinces.

AI programmes for beef cattle have also been carried out mainly in Maputo, probably for the same reasons as for dairy. The Brahman and the Afrikander were the most widely distributed in the country (Table 2). The Landim semen was used to improve growth rates of some beef herds, since the bulls originated from 40 years of selection programmes in breeding stations. In the mid-1990s the Brahman was introduced in Inhambane, by importing animals from South Africa

and Zimbabwe. In Zambezia and Nampula provinces, due to the presence of trypanosomosis, cattle farming is mostly restricted to big commercial companies under strict control programmes. Crossbreeding experiments on the Boran were conducted in Montepuez, a district of Cabo Delgado. The cross breeding was done with the Landim and Afrikander to produce trypanotolerant progeny. However, the crossbreeding results for reproductive and productive performances have not been reported and cannot be recalled for evaluation. The Bonsmara is the most recent introduced breed being used as pure, or for crossbreeding programmes with the Landim or Brahman.

AI results in dairy cattle can be summarized as follows: 52.2% fertility for 1st AI, 83.1% for 3rd AI and 89.5% fertility rate for overall AI, with an average number of AI services per conception of 1.62 (Maciel et al. 1996). Rocha (1985) recommended the use of three-quarters or seven-eighths crossbred Friesland X Landim and reported a good potential of adaptation for the Brown Swiss crosses.

In beef cattle the use of AI accompanied with oestrous synchronisation and heat detection resulted in an average of 56% fertility rate between 1981 and 1984 with an average of 1.2 AI services per cow. This programme was aimed at getting sires for beef breeds and the production of F_1 crossbred dairy cows (IREMA 1985). Although the use of AI stopped 10 years ago, recently 11 thousand straws of semen of South Devon were imported from China but only from one Australian bull. This semen will be used in crossbreeding programmes with the Landim on a private farm.

Reasons for conservation of indigenous livestock

The crossbreeding of indigenous animals with exotic breeds is causing loss of control over the gene pool among the smallholder sector, therefore, posing a risk of the loss of ancient adapted animals. Four basic questions arise about the need to conserve indigenous animal genetic resources.

- What to conserve? To know what we really have there is a need to carry out, both phenotypic and genetic characterisation. The characterisation should include the study of their adaptation to the natural agro-ecological environments and a better understanding of their physiologic behaviour and endocrine profiles both *in vivo* and *in vitro* to determine the best breeding season for the different regions. In addition, the viability of genetic materials (semen, oocytes and embryos) throughout the year should be studied for better cryoconservation programmes.

- Why conserve? There is a need to know the differences and similarities between breeds in Mozambique, within the Southern Afric Development Community (SADC) Region and even within the continent. This will help identify the breeds which have unique characteristics, and those in danger of extinction. There are also social, economic and other reasons for the indigenous breeds to be maintained in the traditional production systems that we need to be aware of.

- For what purpose to conserve? Breed improvement for increased animal productivity is required to overcome poverty and food insecurity. This should be done in parallel with the maintenance of adapted breeds in different agro-ecological regions and production systems. The need to crossbreed indigenous livestock with exotic breeds, taking advantages of the desirable characteristics in the resulting crossbreds should be implemented, bearing in mind the need to prevent breed erosion through preservation of native genetic material.

- How to conserve? Although AI is still the most commonly used technology in improving reproduction, currently there are other potential technologies available, such as ET, through which several other assisted reproductive technologies, like ICSI, IVF, MOET, and

transvaginal ovum pick-up guided by ultrasonography (OPU) could be used for the appropriate conservation and sustainable utilisation of semen, oocytes and embryos accompanied by *in vivo* and *in vitro* studies on endocrine profiles, tissue and cell cultures.

Considering all these questions, attention should be given to what criteria should be used to select breeds for the appropriate germplasm conservation. The conservation programmes should always be accompanied by the registration of genetic material and performance and progeny testing taking into account intellectual property rights, where legislation is still absent.

Conclusions and recommendations

Mozambique has good livestock development potential considering the number of breeds both known and unknown in all species. Although AI is still the method widely used in breeding programmes, other technologies are available and should be used for more efficient conservation. Nevertheless, accurate data recording for productive and reproductive parameters should be instituted for the appropriate development of performance and progeny testing. This is the key for the success of AI and other potential biotechnologies.

The use of these reproductive technologies would allow the conservation and sustainable utilisation of indigenous livestock breeds, as they will enable the implementation of proper selection programmes for increasing fertility, meat and milk production and overall productivity. This will lead to increased income and added value of other animal products such as skin, manure, draft power etc. The overall goal will be that of reducing poverty levels in rural communities and reaching an acceptable food security level. In addition, the smallholder sector would be the main supplier of indigenous breeding stock to the commercial sector for use in crossbreeding programmes with exotic breeds.

Besides conservation of semen for use in AI technology, conservation of indigenous livestock must include embryos and oocytes for the use of other biotechnologies such as ET, IVF, ICSI, MOET, OPU. This should be accompanied by characterisation studies regarding breed morphology, physiology, reproduction and genetics either *in-vivo* or *in-vitro* for planning of better conservation and efficient utilisation programmes and to prevent the eradication of breeds due to natural or man-made disasters as already happened before in Mozambique and is still happening in some parts of the world. With a clear and well-elaborated livestock breeding policy, this would ensure poverty reduction and food security for Mozambique taking into account community's intellectual property rights.

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Parallel session 4

Animal genetic improvement

The role of research and a seed stock industry in the *in situ* conservation of livestock genetic resources

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Abstract
Africa is richly endowed with large numbers of indigenous livestock breeds. However, there is a perception that a major constraint to livestock production is the limited genetic potential of these breeds. This paper uses the Nguni from South Africa as an example, and demonstrates the role of research in addressing such misconceptions. Initial studies on the Nguni in the early 1980s indicated that the Nguni has the shortest calving interval of all beef breeds and its efficiency exceeded that of most breeds. This resulted in a revived interest in the Nguni from the seed stock industry, and the Nguni is currently numerically the sixth largest beef breed in the country. The seed stock industry requires breeds to be competitive, hence a need for selection. This is in contrast to keeping animals in their natural state, which implies a breed should remain the same and be frozen in time.

Introduction
There is a very important difference between Africa and Asia on the one side and other new world or colonial continents such as the Americas, Australia and New Zealand. The new world continents had no indigenous livestock at their disposal and had to rely entirely on imported material to establish a livestock industry. Africa, in contrast, was richly endowed with a large number of indigenous livestock breeds (Scholtz 1988).

Colonists often regarded the performance of indigenous livestock of Africa as being inferior, with little improvement potential. This perception was the result of Africans living in a symbiotic relationship with their animals. The animals were invaluable as they provided for most of the peoples' needs (Matjuda 2005). In addition, the status value of animals resulted in more animals to be kept and overstocking became the order of the day (Scholtz 1988).

A second reason for the earlier ignorance of indigenous livestock stemmed from the variety of colours and colour patterns often encountered amongst animals of the same breed. These wide ranges of colours and colour patterns are in sharp contrast to the general tendency in the Seed stock industry to emphasise uniformity. As a result of this, the Seed stock industry was unable to identify the much emphasised antiquated breed standards (Bonsma 1980), and regarded these animals as an indiscriminate mixture of breeds (Scholtz 1988).

In South Africa, this perception of inferiority led to the promulgation of an Act in 1934 in which indigenous breeds and types were regarded as scrub (nondescript). Inspectors were appointed to inspect the bulls in communal areas (owned by black people) and to castrate them if regarded as inferior. Fortunately this Act was applied effectively only for a few years since it was very unpopular (Hofmeyr 1994).

During the first part of the previous century little or no attention was paid to the improvement or study of the potential of indigenous cattle breeds in South Africa, except for the Afrikaner. Furthermore, the failure in attempts to upgrade these indigenous breeds with exotic European

breeds shifted the emphasis towards improving these breeds (Bonsma et al. 1950). As a result, a committee was appointed to conduct a survey of the nature and numbers of indigenous cattle breeds and their conservation.

The committee recommended that immediate steps be taken to arrest the deterioration of indigenous cattle in black ownerships (native reserves) as a result of the infusion of exotic blood and the use of inferior sires. Their second recommendation was that a purebred cattle herd of not less than 500 Nguni breeding stock be established to investigate the potential of the breed (Bonsma et al. 1950). The name Nguni was derived from the Nguni tribes of people (Swazi, Zulu and Xhosa) who occupied most of the south-eastern parts of Africa.

The Bartlow Combine Breeding Station in KwaZulu Natal was established in 1954 to accommodate the Nguni herd and this herd played a significant role in the development of the Nguni breed and forms the foundation of the initial Seed stock industry (Kars 1993). However, initial research results on the potential of the Nguni breed were only published in the early 1980s (Scholtz 2005) and resulted in a revived interest in the breed.

The Nguni was recognised as a developing breed in 1983 under the Livestock Improvement Act (1977) of South Africa and a Breed Society (Seed stock industry) was established in 1986. This paper will use the Nguni from South Africa to demonstrate the role of research and the seed stock industry in the *in situ* conservation of livestock genetic resources.

Materials and methods

Research results published mainly by the Animal and Dairy Science Research Institute (the predecessor of the Agricultural Research Council, ARC-Animal Improvement Institute) as well as information collected by the National Beef Cattle Improvement Scheme (NBCIS) of South Africa will be used to demonstrate the value and role of research in conservation.

Commercial producers require breeds to be competitive, hence a need for selection, whereas it often happens that the seed stock industry emphasises breed standards. This is in contrast to keeping animals in their natural state, which implies a breed should remain the same and be frozen in time. Own experience and interaction with the Nguni Cattle Breeders Society as well as the FAO publication on farm animal genetic resources (Köhler-Rollefson 2004) will be used to deliberate this issue.

Results and discussion

Performance recording and research

Results obtained from the NBCIS for the periods 1976 to 1985 (Scholtz 1988) and 1993 to 1998 (Scholtz et al. 1999) are used to compare the performance of the Nguni with that of 12 other beef breeds in South Africa (Table 1). Although comparison of performance results across breeds and years must be done with caution, since the results reflect both genetic merit and environmental influences (Scholtz et al. 1999), for this study such comparison can be justified.

In the period 1976 to 1985 the Nguni was the most fertile beef breed of all cattle breeds in South Africa. Its growth rate compared well with that of other breeds such as the Afrikaner and Brahman, which was rather low. Its efficiency (feed conversion ratio), however, exceeded that of many breeds, and compared well with that of the Bonsmara, South Devon, Pinzgauer and Simmentaler.

When the second period (1993 to 1998) is studied, the results look somewhat different. For example, the calving percentage of all breeds increased except that of the Nguni. Cow weight

Table 1. Summary of the results obtained from the NBCIS for the periods 1976 to 1985 and 1993 to 1998.

Breed type	Breed	Cow weight		Calculated calving %		Calf weaning weight		Average daily gain (g)		Feed conversion ratio	
		76/85	93/98	76/85	93/98	76/85	93/98	76/85	93/98	76/85	93/98
Sanga/ Indicus	Afrikaner	459	461	72	77	173	185	1 130	1 267	7.77	7.05
	Brahman	477	491	79	79	197	209	1 156	1 325	7.20	6.99
	Nguni	396	375	87	87	164	155	1 206	1 150	7.07	6.88
Sanga/ Indicus derived	Bonsmara	466	499	81	86	197	214	1 449	1 613	7.02	6.69
	Drakensberger	482	487	72	80	200	206	1 385	1 544	7.32	6.96
	Santa Gertrudis	483	502	75	78	209	225	1 494	1 715	6.95	6.44
British	Angus	455	507	84	88	192	215	1 457	1 804	7.28	6.55
	Hereford	479	507	84	91	183	204	1 422	1 811	6.95	6.27
	South Devon	522	541	79	86	206	241	1 569	1 716	7.00	6.62
	Sussex	555	557	82	88	201	218	1 419	1 598	6.90	6.66
European	Charolais	632	593	75	83	228	232	1 761	1 940	6.69	6.13
	Pinzgauer	474	530	83	85	204	232	1 571	1 779	7.04	6.67
	Simmentaler	507	544	77	85	221	240	1 655	1 898	7.00	6.60

increased or stayed the same for all breeds except the Charolais and the Nguni, where it decreased. In the case of the Charolais this is probably the result of selection for adaptability. In the case of the Nguni this coincides with the development of the Nguni seed stock industry. It is postulated that during this period aspiring seed stock producers collected any Nguni, no matter how inferior. One of the reasons for this is that the traditional custodians of the Nguni hardly ever made the better quality animals available for sale (Kars 1993).

Research conducted included tick resistance of the Nguni (Spickett et al. 1989; Scholtz et al. 1991), the potential of the Nguni as a dam line (Scholtz 1992) and the meat quality of the Nguni (Strydom 1998). Counts of engorged female ticks on naturally infested cattle over a 2-year period showed that Nguni cattle harboured significantly fewer ticks during periods of peak abundance than either Bonsmara or Hereford cattle. Fewer abscesses, associated with tick bite, were also present in the Nguni cattle. The consistently large percentage of Nguni cattle showing high tick resistance according to index determinations indicates a superior level of natural immunity in this breed.

The evaluation of the Nguni as dam line in terminal crossbreeding with the Charolais, Simmentaler and Chianina did not result in any calving difficulties. While the average birth weight was 10% below the mid-parent value, the average weaning weight was 6% above the mid-parent value. The post weaning growth rate of the crosses was 43% higher than that of Nguni, while the feed conversion ratio was 10% better than that of the best purebred. Despite the suppression on birth weight below that of the mid-parent value, the weaning weight and growth rate of the different crosses were close to that of the larger parent. The negative maternal effect on calf birth weight due to the smaller cow size does not seem to persist up to mature age, which makes the Nguni one of the ideal dam lines in terminal crossbreeding.

The study conducted by Strydom (1998) showed that the indigenous southern African breeds (Afrikaner and Nguni) have meat tenderness characteristics similar to or exceeding those of some exotic breeds. A breed such as the Nguni also showed higher proportions of total weight and meat in the high priced cuts compared to exotic breeds at the same subcutaneous fat level.

Role of a breeders' society

Traditionally, stud breeding involves emphasising uniformity and breed standards, whether cattle are exhibited in shows or not, and the Nguni Cattle Breeders Society is no exception. Currently all Nguni seed stock animals are inspected to assure they comply with the minimum breed standards. The minimum breed standards are based on reproduction records and visual appraisal for genetic defects and conformation. There are no minimum breed standards for production traits.

There is always a danger that an over emphasis of appearance may counteract the good results of natural selection that occurred over centuries and resulted in a highly productive breed. In most cases the Nguni seed stock industry is currently maintaining a good balance. However, since not all animals are performance recorded, the effect of the current actions cannot be quantified.

Epstein (1971) and Oliver (1983) described the conformation of heat adapted cattle as having long heads of moderate width, prominent orbital arches over the eyes to protect them from sunlight, an oval shaped trunk to increase the surface area for heat dissipation while a smaller area of the back (which is in direct sunlight) reduces heat absorption, excessive skin area to increase the area for heat loss etc. Any artificial changes to these conformation attributes will affect adaptability to hot climates. According to Oosthuizen (personal communication Nguni Cattle Breeders Society) approximately 20% of the Nguni bulls submitted for inspection fail on breed standards. However, this represents only 30% of the bull calves born, since the breeders seem to cull 70% even before inspection. Of particular concern is the over emphasis on sheath length. If the reduction of sheath length is accompanied by a reduction of excessive skin over the rest of the body, the Nguni is going to lose some of its adaptive attributes. The high prior culling levels also leave very little room for selection on reproduction and production traits.

Genetic resource management

The term 'conservation' has different meanings to different people. In this paper *in situ* conservation is regarded as a collective word for keeping animals in their natural state, sustainable utilisation and global adaptation.

Traditional communities have been the custodians of indigenous breeds from many centuries and they tend to keep animals in a 'pure' state. For them animals fulfil religious, ritual and subsistence purposes (Köhler-Rollefson 2004). Hence the genetic material they conserve is not influenced by the modern breeding programmes, artificial seed stock breed standards or pressure for commercialisation or adaptation. Modern agriculture has caused livestock breeds to be dynamic rather than static entities, and they undergo continual change depending on the needs and priorities of the breeders (Köhler-Rollefson 2004). This puts the different concepts of conservation into conflict, with a third option of global adaptation.

The concept of sustainable utilisation acknowledges that with globalisation, many breeds will only survive if they remain or become competitive. Hence there is a need to improve them genetically through selection. Such selection will not result in the loss of the survival and fitness traits that made these breeds attractive in the first place, as long as this selection is undertaken not out of context, but within constraints of the actual production system (Köhler-Rollefson 2004). This is probably the only strategy that will ensure the long-term conservation of livestock genetic resources.

Global or commercial adaptation is where breeds have been moved outside their natural areas and climatic conditions, and have been selected for specific characteristics to increase its commercial value for specific production systems. An example of such a breed is the Angus that

is currently the most numerous beef breed in the world and which is present in all continents, and in production conditions that are vastly different. Artificial selection is also very prevalent and may result in peculiar characteristics, such as double muscling in the Belgium Blue. Whereas this option makes commercial sense, its role in the *in situ* conservation of livestock genetic resources is limited and where it does occur, it is mostly incidental.

Conclusion

The information from beef cattle recording (NBCIS) and the initial research results led to a keen interest in the Nguni. There has also been revived interest in the Nguni from the emerging small-scale sector. It is now generally accepted that the research and performance results that were published saved the Nguni from the possible threats of extinction. The Nguni has now grown to numerically the sixth largest seed stock beef breed in South Africa. The seed stock industry currently consists of over 18,000 females with roughly estimated 1.8 million Nguni type animals in South Africa (Ramsay, personal communication Department of Agriculture, ARC-Animal Production Institute IRENE). This clearly demonstrates how the important role of production characterisation of indigenous livestock can play in *in situ* conservation.

Much emphasis has been put on the genetic characterisation of livestock using blood groups, iso-enzymes and protein markers, and recently microsatellites. Such genetic characterisations give important information on the genetic history of populations, but do not render any information on the future utilisation thereof. Only the characterisation of the production potential of populations will ensure the long-term sustainable *in situ* conservation of livestock genetic resources. Whereas genetic characterisation has supplied valuable information on the genetic imprints of origins and migrations, the emphasis should now be shifted to characterising the production potential and specific adaptive attributes of indigenous populations.

The seed stock industry can play a pivotal role in the sustainable utilisation of livestock genetic resources, since they can act as the modern custodians for the sustainable utilisation of such breeds. However, they should move away from the antiquated over emphasis on uniformity and artificial breed standards, while ensuring that such breeds remain or become competitive. This will necessitate proper pedigree and performance recording in order to identify any undesirable genetic drift and to ensure competitiveness through proper breeding programmes.

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Will vitrification be the biotechnology to cryopreserve cattle embryos in the future?

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Abstract
Vitrification is a cryopreservation technique that could be an important tool in the application of reproductive biotechnologies in the 21st century. This review summarises recent efforts made in cryopreservation methodologies of cattle embryos. To date, a great deal of effort and experimentation has been devoted to improving assisted reproduction technologies (ART) such as *in vitro* produced embryos (IVPE), nuclear transfer cloning and cryopreservation, due to the increasing global economic importance of cattle. Consequently, large numbers of embryos are generated through IVPE and conventional superovulation without a corresponding number of synchronised recipients; subsequently, these embryos must be either preserved or discarded. Thus, it is essential to cryopreserve embryos for future use, thereby providing an effective method for the conservation of indigenous livestock, global genetic transport, gene banking, breeding line restoration, and for genetic rescue of endangered African indigenous livestock species. Developing an efficacious vitrification technique and improving cryopreservation protocols and their effectiveness for sustaining survival is an essential asset for preserving cattle embryos, both as a routine breeding alternative and to ensure stringent biosecurity.

Key words: vitrification, cryopreservation, cattle, embryos, ultrarapid cooling

Introduction
In cryopreservation, vitrification is the physical process by which liquid solidifies, without the formation of ice crystals, when plunged directly into liquid nitrogen, becoming glass-like. The radical strategy of vitrification is to eliminate ice crystal formation, both within the cells being vitrified (intracellular) and in the surrounding solution (extracellular). Ice crystal formation is often detrimental during cryopreservation of living cells (Palasz and Mapletoft 1996; Nedambale et al 2005). Extracellular ice crystals can develop, collide into each other as they enlarge and cause physical damage to embryos; whereas, formation of ice crystals intracellularly damages an embryo's cells, proteins and membranes, and breaks DNA molecules (Palasz and Mapletoft 1996). To overcome these disadvantages, rapid cooling and warming techniques were developed to avoid the formation of ice crystals during vitrification or warming. Even so, these techniques are variable and remain limited in their ability to cryopreserve embryos that can result in live offspring.

In the mid1980s, vitrification entered the mainstream of animal reproductive technologies as an alternative cryopreservation technique to the traditional slow-freezing method (Rall and Fahy 1985). Since then, vitrification of mammalian embryos or oocytes has been the subject of many investigations and has been achieved simply by plunging the sample directly into liquid nitrogen (LN_2) at –196°C (Rall and Fahy 1985; Arav et al. 2002; Nedambale et al. 2004a; Schmidt et al. 2004). However, recent efforts have been devoted to improving the quality and survival of *in vitro* produced cattle embryos (IVPE) and cloned embryos, and to develop improved cryopreservation methods. These include ultrarapid vitrification, reduction in vitrification solution volumes and incubation times and efforts to eliminate the necessity for expensive programmable freezing equipment.

Large numbers of excess embryos are generated through IVPE and conventional superovulation and nuclear transfer cloning, resulting in a limitation of a corresponding number of synchronised recipients available for embryo transfer (ET). Thus, it is essential to cryopreserve embryos for future use, thereby providing an effective method for the conservation of indigenous livestock, global genetic transport, gene banking, breeding line restoration, and for genetic rescue of endangered species. Developing an improved cryopreservation protocol that is effective for sustaining survival will be another essential tool for the preservation of cattle embryos while ensuring stringent biosecurity. The focus of this review is to outline recent advances in vitrification techniques that are of benefit to embryo cryopreservation by rendering it more accessible and effective, yet less expensive; these innovations will lead to its more widespread use in embryo transfer programmes and other commercial practices.

Source of cattle embryos for cryopreservation

There are two traditional sources of cattle embryos. The first is superovulation followed by non-surgical recovery of embryos that are usually fertilised *in vivo*. However, prolonged use of superovulatory drugs can result in fertility problems. Second, embryos are also generated by *in vitro* maturation and fertilisation of oocytes aspirated from ovaries derived from slaughterhouses. This process requires an appropriate environment so that the early embryo (zygote) can undergo several cleavage divisions to enable it to reach the blastocyst stage 7 days after fertilisation. At this stage (blastocyst), it is ready to be transferred into a recipient cow or cryopreserved for future use (Table 1).

Cryopreservation

Cryopreservation is defined as the freezing of tissues or cells to preserve them for future use; it has become a powerful tool in assisted reproduction technologies (ART) in several mammalian species. There are three methods classified under cryopreservation, namely conventional slow freezing, vitrification and ultrarapid cooling/ultrarapid vitrification (Table 1). These methods are designed to preserve living cells in liquid nitrogen (–196˚C) without decreasing their survival, within certain periods of storage time. Liquid nitrogen is widely used for maintaining cells in a frozen state.

Table 1. Comparison of the three cryopreservation methods.

		Cryopreservation methods	
Parameters vitrification	**Ultrarapid conventional**	**Vitrification freezing**	**Conventional slow**
Embryo storage	Cryovial	Straw	Straw
Treatment temperature	37–39˚C	24–25˚C	24–25˚C
CPA concentration	3.5–5.5 M	5.5–7.5 M	1.3–1.5 M
Time in CPA I	2–5 min	2–5 min	0
Time in CPA II	30 sec	d”1 min	15–20 min
Time required for cooling	<0.1 sec	2–3 min	90–120 min
Ice crystal formation	No risk	No risk	High risk
Osmotic injury	High risk	High risk	Low risk
Toxic injury	High risk	High risk	Low risk
Chilling injury	Low risk	Low risk	High risk
Survival rate after thawing	High	Moderate to high	Low to moderate
Pregnancy rate data	Limited	Limited	Extensive
Offspring born data	Limited	Limited	Extensive
Cost	Low	Low	High
Commercial applicable	Limited	Limited	Extensive

Conventional slow freezing method

Conventional slow freezing involves lowering the temperature of a chamber in a controlled, stepwise manner. This method is widely used for the cryopreservation of mouse, bovine and human embryos (Gardner et al. 2004). Modifications of this method exist but all share the same basic design. Generally, embryos are first suspended in 1 to 2 M of cryoprotectant (CPA) dissolved in a physiological solution (DPBS) at room temperature, allowed to equilibrate for full permeation then loaded into a 0.25 ml plastic straw (Table 1). The 0.25 ml straw is then placed into a programmable freezer at a temperature of –5˚C or –6˚C. The final target temperature at which slow cooling is terminated varies from –25˚C to –45˚C (Table 1). During thawing, the sample is usually diluted with a non-permeating agent (sucrose) before embryos are recovered in a physiological solution (Nedambale et al. 2004a).

Although the mechanisms of cryoprotection are similar, various protocols have been used and modified. For instance, glycerol (GLY) and ethylene glycol (EG) have been widely used for bovine embryos, DMSO for mouse and propylene with sucrose for human embryos (Gardner et al. 2004). Conventional slow freezing has the advantage of using a low concentration of CPA which are associated with chemical toxicity and osmotic shock (Table 1). In contrast, this method lowers the survival rates of IVF embryos and requires the use of a controlled-rate freezer that is expensive. Because of these drawbacks, vitrification becomes a viable alternative to conventional slow freezing.

Vitrification methods

There are two types of vitrification methods, namely conventional vitrification (in straws) and ultrarapid vitrification. Ultrarapid vitrification includes electron micro-grid (EMG), cryoloop (CL), solid surface vitrification (SSV), open-pulled straw (OPS), micro-drop (MD), cryotop (CT) and gel-loading tip (GLT).

Conventional vitrification, in its traditional approach, uses straws (0.25 ml straw) and embryos are plunged into highly concentrated cryoprotectant solutions (Rall and Fahy 1985). This method was found not very efficient for the cryopreservation of *in vitro* fertilisation (IVF) embryos of many mammalian species including cattle (Arav et al. 2002). Further drawbacks of conventional vitrification include the need for fast cooling and uniform or fast re-warming, to avoid de-vitrification.

As a strategy to overcome the embryo injuries in conventional slow freezing and vitrification, a modified conventional vitrification method (ultrarapid vitrification) has been devised in which the cooling and warming rate is markedly increased by minimising the volume of vitrification solution (VS) and the container and increasing the rate of heat transfer, thereby reducing the toxicity of the cryoprotectants (Table 1). Landa and Tepla (1990) demonstrated the first successful report of ultrarapid vitrification techniques, the so-called micro-drop. Six years later, an ultrarapid vitrification technique using an electron microscope grid was described (Martino et al. 1996). Using these techniques, even bovine oocytes that are less cryotolerant could be successfully cryopreserved. Since this discovery, several other ultrarapid vitrification techniques have been reported including open pulled straw (OPS)(Vatja et al. 1997), minimum drop size (MD) (Arav and Zeron 1997), cryoloop (CL) (Lane et al. 1999), cryotop (CT) Kuwayama and Kato 2000), Vitmaster (Arav et al. 2002), gel-loading tip (GLT) (Tominaga and Hamada 2001), and a solid surface vitrification (SSV) technique, which was developed in our laboratory (Dinnyés et al. 2000). Ultra-rapid cooling techniques depend on exposing the embryos to concentrated cryoprotective solutions to dehydrate and concentrate the cytoplasm before cooling (equilibration).

The avoidance of ice by ultrarapid vitrification requires the exposure of embryos to solutions containing high concentrations of permeable cryoprotectants (DMSO, GLY or EG), sometimes supplemented by non-permeable (sucrose or trehalose) solutes to dehydrate the cells, before being cooled rapidly. The time and temperature of exposure to the solution is critical to achieve optimal dehydration with minimal toxicity (Watson and Holt 2001). Ultrarapid vitrification has three distinctive features that have to be taken into consideration for successful preservation: (i) cooling rate; (ii) viscosity; and (iii) volume of vitrification solution (VS). Increasing the viscosity or cooling rate, or decreasing the volume of VS will each increase the probability of successful vitrification. The SSV technique was developed to maximise these features including the risk of LN_2 contamination.

Solid surface vitrification

Solid surface vitrification (SSV) is performed on a metal surface cube cooled with liquid nitrogen (LN_2) inside a styrofoam box (Figure 1). The container-less cooling and small sample volume offer advantages, such as a more efficient heat transfer, and subsequently, increased cooling rates. Since the discovery of this technique, a number of scientific publications have reported higher survival rates of oocytes and embryos with its use (Dinnyés et al. 2000; Begin et al. 2003; Nedambale et al. 2003; Schmidt et al. 2004). However, all these results were evaluated under *in vitro* conditions. Therefore, a large field trial to determine pregnancy rates and births of healthy calves is needed to further verify and confirm the efficacy of this very promising technique for commercial practice.

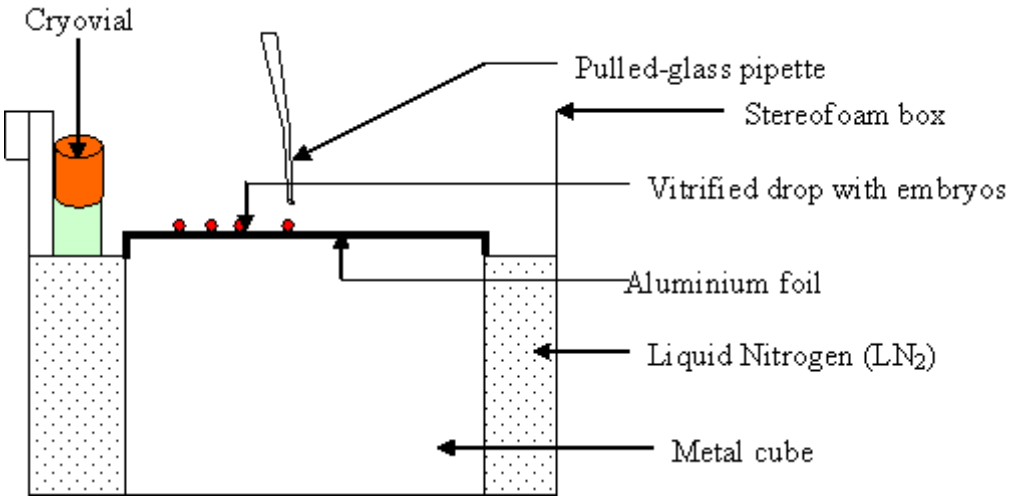

Figure 1. Solid surface vitrification (SSV) device.
Source: Dinnyés et al. (2000).

A metal cube covered with aluminium foil is partially submerged into liquid nitrogen. Micro-drops of vitrification solution, containing the embryos, are dropped onto the cold upper surface of the metal cube with a special pulled glass pipette and are instantaneously vitrified. The drops are then transferred to a cryovial partially submerged into LN_2, and stored in LN_2 tank.

Embryo vitrification challenges

Faster developing embryos *in vitro* are more likely to be male than female. These male embryos are considered more viable and likely to be selected for vitrification because they survive cryopreservation or embryo transfer better than those developing slowly *in vitro* (Hasler 2000; Nedambale et al. 2004b;). This raises the possibility that cryobiologists and embryologists might

be biasing their selection of embryos toward males by using conventional embryo grading techniques based on morphology and the rate of *in vitro* development. This potential skewing of sex ought to be taken into account when preserving beef or dairy blastocysts, where the sex of the progeny is of major economic importance (Nedambale et al. 2004b). Furthermore, gene-banking efforts must develop a strategy for dealing with this effect when preserving various breeds and species. Embryo sexing, before cryopreservation or transfer, might provide one solution by offering selection based upon sex.

Prospects of vitrification

The simplicity and economic advantages of vitrification will provide a more reliable method for cryopreservation of mammalian oocytes and embryos and subsequently revolutionise the cattle industry by offering the availability of global sources of genetic stocks of superior animals to meet the future consumer demands. Furthermore, a gene bank of vitrified embryos will be established wherein lines of elite beef/dairy animals of different breeds will be preserved for future breeding programmes, thereby facilitating the transfer of these animals to farms globally through embryo transfer technology. An additional dimension of vitrification research will be to concentrate on the basics of cryobiology and perhaps expand our knowledge on changing the physics of ice and the biological aspects of living systems during cooling and warming and subsequently maintain higher survival rates of preserved cells, tissues or organs.

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Caprine milk protein polymorphisms: Possible applications for African goat breeding and preliminary data in Red Sokoto

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Abstract

About 70% of all milk consumed in sub-Saharan Africa is imported from other parts of the world. This trend may be reversed by encouraging production through marker assisted selection. Goats are second to cattle in milk production, they require less inputs and their small size make them attractive to smallholder production systems. This paper presents the current knowledge on milk protein polymorphisms in goats, including a_{S1}-casein, a_{S2}-casein, b-casein, k-casein, a-lactalbumin and b-lactoglobulin, and their relationships with milk quality, composition and technological properties. Moreover, the results of a preliminary investigation on milk samples from 48 Red Sokoto goats by isoelectrofocusing (IEF) are discussed. Three main alleles were detected at each of *CSN1S1* and *CSN1S2* loci and two IEF patterns at *CSN3* locus. Finally, the paper makes recommendations for further exploitation of African goats for milk production considering the possibility for the genetic improvement of milk yield and composition, fulfilling both nutritional requirements and technological properties.

Key words: goat, milk proteins, genetic markers, improvement

Introduction

The domestic goat, *Capra hircus*, is the third most numerous ruminant species and the second to cattle in the provision of milk, meat and other products in Africa (FAOSTAT 2004; Table 1). It is widely distributed in the region and this reflects its ability to adapt to a variety of environments, including mountainous terrain and deserts thus making it critically important to the survival and well being of large segments of populations, which often do not have alternative supplies of animal proteins. Goats are smaller in size and easier to manage than cattle and are thus suitable for the smallholder production systems of developing countries. Virtually every farm family can manage a few breeding animals from which they can obtain their proteins, calcium, vitamins and energy. For many people, especially infants, the milk and dairy products from goats and sheep are also a medicinal necessity (Haenlein 1992). Since about 70% of all milk consumed in sub-Saharan Africa is imported from other parts of the world, efforts to reverse this trend may be done through the application of marker-assisted selection (MAS) of milk traits of goats and other milk producing species. The possibility of implementing MAS will, however, rely on accurate molecular knowledge of the genes and their relationships with the traits in question.

Interest in the variability of caprine milk protein genes was triggered by the great variability observed in the bovine species (Formaggioni et al. 1999), the associations of some variants with milk production, technological properties and human health (Hill et al. 1996; Freyer et al. 1999; Lodes et al. 1996; McLachlan 2001), confirmed by quantitative trait loci (QTL) studies (Boichard

et al. 2003; Viitala et al. 2003; Szyda et al. 2005). In the last decade, much attention was consequently directed towards characterising the casein genes of goats, especially in European breeds, showing association of casein variants with unusual quantitative differences in casein synthesis with marked differences between breeds as well as regional tendencies (Grosclaude and Martin 1997; Caroli et al. 2001). Defective alleles, associated with traces or null content of the protein in milk are now known to be present at three casein loci ($á_{S1}$-casein, $á_{S2}$-casein and â-casein). For practical breeding aims and for MAS to succeed for milk trait improvement of African goats, the genes must be characterised for the various breeds and association between the genetic variants and production traits/manufacturing properties determined under the prevailing environmental conditions.

Table 1. Economic importance of goat milk as compared to other milk producing species in selected countries and regions, 2004.

Country or region	Milk in % of milk produced* in country/region				Pop in % of pop of milk producing Species in country/region			
	Goat	Sheep	Cattle	Buffalo	Goat	Sheep	Cattle	Buffalo
Algeria	9.32	12.03	78.17	-	13.50	78.89	6.58	-
Cameroon	22.83	9.24	67.94	-	31.10	26.86	42.05	-
Ethiopia	1.12	1.89	95.51	-	16.92	20.12	62.39	-
Kenya	3.29	1.05	94.82	-	35.45	24.82	37.06	-
**Malawi	-	-	100.00	-	66.28	4.48	29.24	-
Nigeria	-	-	100.00	-	42.29	34.73	22.95	-
South Africa	-	-	100.00	-	13.82	58.73	27.45	-
Sudan	25.27	9.09	63.93	-	32.15	35.98	29.34	-
Sub-Saharan Africa	14.38	7.02	72.45	<0.20	34.62	27.85	35.07	<0.20
Africa	9.40	5.53	72.81	8.54	31.44	33.98	31.98	0.49

*Cattle, goat, sheep, camel, buffalo.
** Records on milk yield of goat and sheep not available for Malawi, Nigeria and South Africa.
Calculations based on FAOSTAT data 2004.

The aims of this paper are to (1) present current knowledge on milk protein genetic variability in goats and their relationship with production traits, (2) present preliminary results of milk protein polymorphism of the Red Sokoto goat and (3) make recommendations on the potential application of milk protein markers in milk improvement breeding in Africa.

Milk protein polymorphism in goats

The proteins found in goat's milk and the milk of other ruminant breeds includes caseins ($á_{S1}$-casein) [*CSN1S1*], $á_{S2}$-casein [*CSN1S2*], â-casein [*CSN2*] and ê-casein [*CSN3*]), and whey proteins (á-lactalbumin [*LAA*], â-lactoglobulin [*LGB*], serum albumin, immunoglobulin, lactoferrin, transferrin and enzymes.

The genes encoding the caseins are tightly linked and clustered on a 250 kb region of chromosome 6 (CH6) in the order *CSN1S1-CSN2-CSN1S2-CSN3* while the main whey protein genes *LAA* and *LGB* are respectively mapped on CH5 and CH11 (Threadgill and Womack 1990; Hayes and Petit 1993; Hayes et al. 1993). Within the calcium sensitive caseins (*CSN1S1*, *CSN1S2* and *CNS2*), the *CSN1S1* and *CSN2* genes are only 12 kb apart and are convergently transcribed (Leroux and Martin 1996). The caseins account for 2.3 to 2.8 g proteins per litre of milk and the whey for 0.6–1.1g/litre.

Using analytical methods at the protein and genomic levels like polyacrylamide gel-isoelectric focusing (PAG-IEF), polyacrylamide gel electrophoresis (PAGE), reverse phase-high pressure liquid chromatography (RP-HPLC), polymerase chain reaction (PCR), restriction fragment length polymorphism (RFLP), single strand confirmation polymorphism (SSCP), real time PCR etc., different naturally occurring forms of caprine milk proteins are now known. The different forms are due to mutations, insertions and deletions of single or large nucleotide sequences, usually with profound effects on post-translational modifications of the mature protein chains. Variations of the casein genes, particularly of those encoding the calcium sensitive caseins are both qualitative and quantitative in nature.

á$_{s1}$-casein (CSN1S1)

The *CSN1S1* gene of the goat presents the highest level of variability of all ruminant casein genes so far studied. Up to 16 alleles, *A, B$_1$, B$_2$, B$_3$, B$_4$, C, E, F, G, H, I, L, M, N, O$_1$* and *O$_2$*, are now known to exist at this locus (see Bevilacqua et al. 2002 for earlier references; Ramunno et al. 2002). The alleles probably evolve after an interallelic event involving four ancestral alleles *A, B$_1$, B$_2$* and *W* (Bevilacqua et al. 2002). *W* is a putative allele. Whereas variability in most of the alleles is the result of single nucleotide substitutions causing an amino acid exchange, deletion events involve the *F* (37 amino acid deleted) and *G* (13 amino acid deleted) alleles. An insertion of a 457 bp segment in the last untranslated exon (19th) of the *E* allele, which has the same single nucleotide substitution events as the *B$_4$* allele, is responsible for a reduced amount of the mRNA of the gene and a lower content of the protein in milk.

The á$_{S1}$-casein alleles are associated with four levels of the expression of the specific protein: strong alleles (3.5–3.6 g/litre) *A, B$_1$, B$_2$, B$_3$, B$_4$, C, H* and *L*; medium alleles (1.1–1.6 g/litre) *E* and *I*; low alleles (0.45–0.6 g/litre) *F* and *G*, and null/traces alleles *O$_1$* and *O$_2$*. Variation at this locus has been studied mainly for goat breeds of central and southern European countries (Grosclaude and Martin 1997). The defective alleles *E* and *F* are widely distributed in this area. The high frequencies of these alleles in the Alpine, Saanen and Toggenburg breeds may have worldwide consequences since they have been used in crossbreeding programmes in many parts of the world (Grosclaude and Martin 1997).

á$_{s2}$-casein (CSN1S2)

The *CSN1S2* locus exhibits a higher level of variability in the domestic goat than in cattle and sheep. Eight alleles corresponding to different levels of the specific protein have been described: normal alleles (2.5 g/litre) *A, B* (Boulanger et al. 1984), *C* (Bouniol et al. 1994), *E* (Veltri et al. 2000) and F (Ramunno et al. 2001a), intermediate allele (1.25 g/litre) *D* (Ramunno et al. 2001a) and null allele *O* (Ramunno et al. 2001b). For the *G* allele (Erhardt et al. 2002) no information is given about the level of expression corresponding to this variant.

The differences between alleles are due to single nucleotide substitutions (Bouniol et al. 1994; Veltri et al. 2000; Ramunno et al. 2001a), except for the *D* allele resulting from a deletion of the last 11 bp of exon 11 and the first 95 bp of intron 11 (Ramunno et al. 2001a). The *A* allele is predominant in German goat breeds (Erhardt et al. 2002).

b-casein (CSN2)

Variations at the *CSN2* locus in the goat are indicated by the existence of five alleles associated with different amounts of the protein in milk. Alleles *A* (Roberts et al. 1992), *B* (Mahé and Grousclaude 1993) and *C* (Neveu et al. 2002) are associated to a normal b-casein content while alleles *O* (Persuy et al. 1999) and *O'* (Ramunno et al. 1995) are associated to a non-detectable amount or traces of the protein in milk. Single nucleotide transitions are responsible for these

variations. Mutations of the *O* and *O'* alleles are responsible for the creation of premature stop codons at respectively 58 (Persuy et al. 1999) and 182 (Rando et al. 1996) amino acid of the protein, consequently affecting their expression in milk.
Recently, a non-allelic variant has been detected at the proteomic level and named as *D* (Galliano et al. 2004). It is most probably the product of an error in the translation process, possibly a differential splicing of pre-messenger RNA.

k-casein (CSN3)

The *CSN3* gene plays an important role in the manufacturing properties and digestibility of milk through the formation, stabilisation and aggregation of the casein micelle. This locus was not considered to be polymorphic until 1990 when Di Luccia et al. (1999) reported variation (alleles *A* and *B*) in an undefined Italian breed. Since then 11 further protein variants (*C, D, E, F, G, H, I, J, K, L* and *M*) and 3 DNA (*B', B"* and *C'*) (silent mutations without a change in the protein) polymorphisms have been described in the domestic goat (Caroli et al. 2001; Yahyaoui et al. 2001; Angiolillo et al. 2002; Yahyaoui et al. 2003; Chessa et al. 2003; Jann et al., 2004; Prinzenberg et al., 2005) and 5 variants in wild goat species (Yahyaoui et al. 2001; Jann et al. 2004). Alleles *X* and *Y* observed by Chessa et al. (2003) correspond respectively to *C* and *M* (Prinzenberg et al. 2005). The actual distribution of the reported alleles in breeds so far screened is not certain due to the inability of separation methods like PAG-IEF and PCR-RFLP to clearly discriminate between some alleles. By the method of PCR-SSCP, Chessa et al. (2003) and Prinzenberg et al. (2005) showed the *B* allele to be the most predominant in some Italian, German and West African goat breeds. The *M* allele has only been found in the Red Sokoto goat (Prinzenberg et al. 2005).

The whey proteins (a-lactalbumin–LAA and b-lactoglobulin–LGB)

LAA and *LGB*, the most abundant whey proteins, are less variable in the domestic goat than in cattle. The existence of two *LAA* variants (*A* and *B*) reported by Maes et al. (1976) is yet to be confirmed in other breeds. Recently, Cosenza et al. (2003) reported a new DNA variant (A^2) involving a C®T transition (silent mutation) of the 5th nucleotide of exon three (80th amino acid of mature protein) as compared to the variant (A^1) seen in most breeds. The frequency of the A^1 allele is above 70% in three Italian goat breeds. Two alleles of *LGB* (*A* and *B*) have been reported in Russian goat breeds (Mancha 1970).

Relationship between goat milk protein alleles with production traits and technological properties

Milk protein genetic variants are candidate genes for milk traits. Goats homozygous for alleles associated with a strong content of *CSN1S1* produced milk characterised by a significantly higher protein percentage, fat and total calcium, a minor diameter of micelles, better parameters for curd firmness, curd firming time and cheese yield compared with goats homozygous for alleles associated with a low or intermediate content (Remeuf 1993; Grosclaude et al. 1994; Mahé et al. 1994). The lowered effects of the defective alleles (*E, F, G,* O_1 and O_2) on the expression of these traits could be explained by the observation of Martin et al. (1999), who after examination of mammary gland tissue sections of goats homozygous for these alleles found epithelial tissue sections with swellings of the rough endoplasmic reticulum primarily due to an accumulation of proteins, thus suggesting a dysfunction in secretion mechanisms. $CSN2^O$ is associated with longer clotting time (Chianese et al. 1993) and less cheese yield (Masina et al. 1993).

Most of these studies, and those in cattle, considered the effects of the individual genes without paying attention to the effects of the other genes in the cluster. Since the casein genes are tightly linked (Threadgill and Womack 1990), it is expected that haplotype form of the genes, determined by the individual casein genes, would be transmitted from generation to generation. Knowledge

therefore of the effect of the casein haplotype of an individual on a trait would be more useful in a selection programme than the single effect of the individual genes. Recognising this fact, recent studies have indicated significant haplotype effects, particularly strong for protein content in the milk of cattle (Ikonen et al. 2001; Boettcher et al. 2004). Another fact to consider here is the multigenic nature of milk traits, implying that further genes may be involved in their expression. Through the availability of highly informative marker maps for several farm animal species (see http://locus.jouy.inra.fr/) anonymous markers (Type II, e.g. microsatellites) that are linked to QTL underlying the genetic variation of multi-factorial traits can be identified. Mapping QTLs influencing economically important traits may lead to more efficient breeding programmes using MAS, especially for breeding males before progeny testing.

Preliminary results of milk protein polymorphism of the Red Sokoto goat

A preliminary screening was carried out on 48 individual milk samples of Nigerian Red Sokoto at the protein level by polyacrylamide gel isoelectric focusing (PAG-IEF), according to Erhardt et al. (2002). Reference milks of known genotypes were used to determine the phenotypes of each sample. PAG-IEF allows a cheap and fast discrimination of the phenotypical expression levels of milk protein genes. More detailed genotype definitions however require molecular approaches. The distribution of *CSN1S1* phenotypes based on PAG-IEF analysis is described in Table 2. As shown by the presence of phenotype B-, further analyses are necessary to give more information about this locus. The phenotype is indicated only for 36 goats since not all samples presented a clear IEF pattern.

Table 2. Distribution of animals according to their *CSN1S1* phenotypes.

Locus	Phenotype	Number of animals
CSN1S1	AB	7
	AE	1
	BB	18
	B-	10

B-phenotype may correspond to BE, BF, BO or EE

The allelic frequencies of the other loci are summarised in Table 3. The highest frequencies were observed for the *CSN1S2* and *CSN2* alleles associated with a normal content of the specific protein. A null allele was evident at the *CSN1S2* and *CSN2* loci. A novel *CSN2* allele, tentatively named as *X*, differed from the *A* and *B* variants respectively for a lower (more acidic) and higher isoelectric point (IP). This new form was identified in two heterozygous individuals. At the *CSN3* locus, the IEF pattern was almost monomorphic for a group of different alleles focusing at 5.29 IP, recently named A^{IEF} (Prinzenberg et al. 2005) and including up to 12 alleles. The B^{IEF} variant (IP = 5.66) including 4 alleles (*D*, *E*, *K* and *M*) was also observed, at a low frequency (0.043). By the methods of SSCP and RFLP, Prinzenberg et al. (2005) resolved alleles *A* and B/B^{I} from the A^{IEF} cluster in the Borno, Red Sokoto and the West African Dwarf goats and the *M* allele from the B^{IEF} cluster in the Red Sokoto goat.

Table 3. Allele frequencies of milk protein genes of the Red Sokoto goat determined by PAG-IEF.

Locus	Allele	Frequency	Locus	Allele	Frequency
CSN1S2	*A*	0.594	*CSN3*	$**A^{IEF}$	0.957
C	0.365		$**B^{IEF}$	0.043	
O	0.042	*LAA*	*A*	1.000	
CSN2	*A*	0.938	*LGB*	*B*	0.979
O	0.042	*X	0.021		
*X	0.021				

*Tentative nomenclature, ** Can be further differentiated by molecular methods.

Monomorphism was found at the whey proteins (LAA^A, LGB^B) except for a new *LGB* pattern, here tentatively named as *X*, which was observed in two individuals in a heterozygous state.

Though the sample analysed was small, these observations are of considerable significance given that very little information exists on the subject for African goats. The presence of the strong alleles at highest frequencies at the calcium sensitive loci is a positive indication for selection for milk traits in the Red Sokoto goat. Initial studies on the milk producing abilities of Nigerian indigenous goat breeds indicate that though milk yields in litres are lower than those of specialised European dairy breeds, the per cent of DM, fat and protein is higher (Akinsoyinu et al. 1981; Ehoche and Buvanendran 1983; FDLPCS 1992). The findings may also suggest a possible relationship between African goat breeds and some breeds of southern Europe with high frequencies of *CSN1S1* strong alleles. The new patterns found suggest the possible presence of milk protein alleles specific of African goats, as observed for African cattle (Mahé et al. 1999; Prinzenberg et al. 1999; Ibeagha-Awemu et al. 2005). Further analyses are necessary to confirm this result.

Potential application of milk protein genetic markers in milk improvement breeding in Africa: Recommendations

Going by available encouraging preliminary results on African breeds and results of associations of milk protein genetic variants and milk traits, faster progress may be achieved in improving African goats for milk traits through MAS. The following steps may facilitate implementation of MAS in African goats:

1. Determine traits of interest and recording: The traits of interest must first of all be determined (e.g. milk yield, protein content, fat yield etc.) followed by adequate recording.
2. Characterisation of milk protein genes (Type I markers): Characterise breeds/individuals for their genotype information of the genes directly involved in the expression of the traits of interest. Available molecular methods now make it possible to obtain genotype information of individuals irrespective of age, sex and physiological condition.
3. Determine marker/trait relationships: Determine through statistical analysis any significant relationships existing between the alleles of the genes and the traits of interest. In the case of the casein genes, the relationship of the haplotypes and the traits will be more useful. Available results obtained for breeds in other regions may serve as a guide but may not apply directly to African goats due to the important effects of the environment.
4. Characterisation of anonymous genes (Type II markers): With the help of information on anonymous markers (e.g. microsatellites) already mapped on the caprine genome, individuals should be genotyped for several of these markers. Detection of significant QTLs for the traits of interest will then follow. Higher genetic progress has been achieved in dairy cattle breeding schemes that included QTL information (Schrooten et al. 2005).
5. Selection index: After careful analysis of the molecular, phenotypic and environmental information on the breeds, a selection index should be established.
6. Implementation: This step requires sustained funding, dedication on the part of researchers and the cooperation of farmers.

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Accuracy of genetic prediction obtained using genetic relationships based on pedigree or marker information

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Abstract

The accuracy of genetic prediction when pedigree ($\mathbf{A}_{P}$) or pedigree and marker-based ($\mathbf{A}_{PM}$) relationships were used in mixed model equations was assessed. Daughter yield deviations (DYD) records for milk, fat and protein yields on Holstein sires (n = 1,811) with DNA marker information were analysed. Three sets of estimated breeding values (EBV) were obtained: (1) EBV-ALL (considered all sources of information and the inverse of), (2) EBV-PED (similar to EBV-ALL but the sire's own DYD was excluded), and (3) EBV-MRK (similar to EBV-PED except that the inverse of was used). Linear and rank correlations were computed between EBV-ALL and EBV-PED or EBV-MRK. The accuracy increased by 4.3% for milk yield but did not change for fat and protein yields when was replaced by for sires without sons. These results suggest that genetic markers may be used to enhance accuracy in genetic evaluation particularly for young animals.

Key words: accuracy, genetic prediction, DNA markers, relationships

Introduction

The animal model best linear unbiased prediction (BLUP) is the methodology of choice for prediction of genetic merit in most livestock species. The BLUP procedure incorporates all available sources of information and accounts for the relatedness using the Wright's numerator relationship matrix. Traditionally, genetic relationships are computed using pedigree information. Recently, advances in molecular genetics have led to the availability of DNA markers such as SNPs and microsatellites. These markers have been used to refine estimates of the additive genetic relationships (Pérez-Enciso et al. 2000; Pong-Wong et al. 2001; Liu et al. 2002; Xu 2003).

A theoretical study using simulation by Nejati-Javaremi (1995) demonstrated that accuracy of genetic prediction could be enhanced through use of genetic relationships calculated from pedigree and marker information. The increase in accuracy from replacing pedigree with pedigree and marker relationships ranged from 0% to 74%. The increase in accuracy was more dramatic under low heritability ($h^2 = 0.1$) compared to moderate heritability ($h^2 = 0.3$). Nejati-Javaremi (1995) assumed a scenario where there was complete genome marker coverage with a QTL within each marker interval. In the current study, we assess the change in accuracy when inverses of the pedigree or pedigree and marker relationship matrices are used in the mixed model equations using a real data set including markers at certain genome locations.

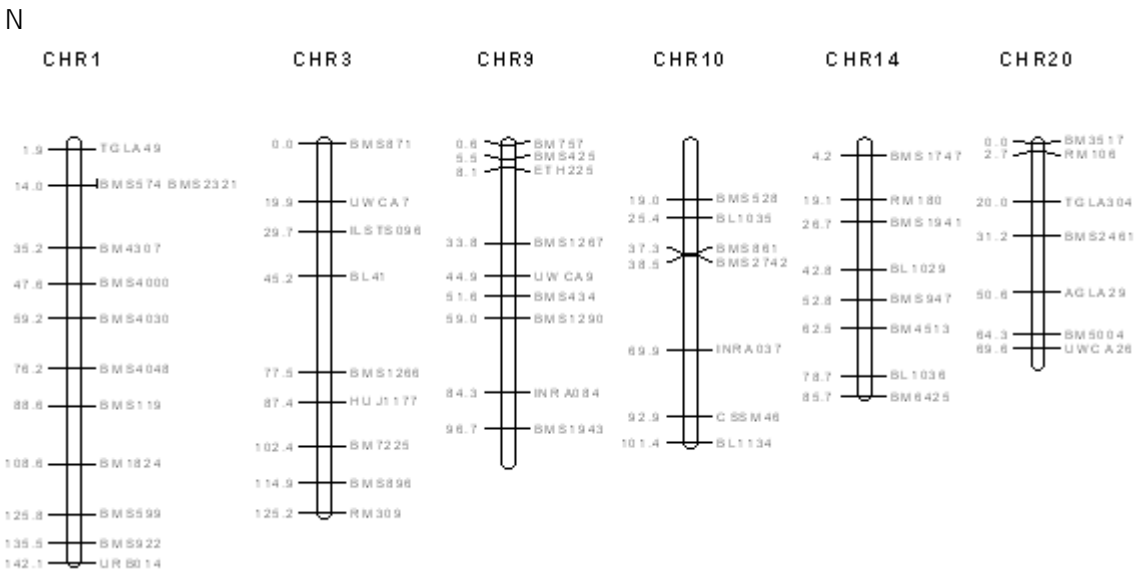
Materials and methods

Data and trait information

A multi-generation dataset comprising 1,811 sires with a different number of sons and daughters was obtained from the Animal Improvement Programs Laboratory (AIPL) of the USDA-ARS Beltsville Research Centre. Each record consisted of the sire's identification (ID) number, its sire and dam ID, date of birth, and daughter yield deviations (DYD) on milk, fat and protein. The

DYD is an average of the daughters' performance adjusted for fixed and non-genetic random effects of the daughters and additive genetic effects of their dams.

Microsatellite marker information on 52 marker loci located on six autosomal bovine chromosomes was also available on all sires (Figure 1). On average, there were nine markers per chromosome. The average distance between adjacent markers across chromosomes was 13 cM. Markers closest to each other were *BMS574* and *BMS2321* located together on chromosome 1 while markers *BL41* and *BMS1266* on chromosome 3 were the furthest from each other (32.3 cM). The average number of alleles per marker was nine. Markers *BMS4048* and *BMS896* on chromosomes 1 and 3 respectively had the least number of alleles (4 alleles per marker) while markers *BL1035* and *CSSM46* on chromosome 10 had the most alleles (20 alleles per marker).



Note: The relative marker position and name are on the left and right of the chromosome respectively.

Figure 1. The relative marker position (in cM) on the chromosome.

Statistical analyses

The following single trait sire breeding value model was used to analyse the data:

$$\mathbf{y} = \mathbf{Z}\mathbf{s} + \mathbf{e} \qquad [1]$$

where **y** is a vector of daughter yield deviations whose i^{th} element represents the average YD of n_i daughters of i^{th} sire, **Z** is an incidence matrix relating the breeding value of the sire to the DYD; **s** is a vector of sire breeding values, **e** is a vector of residuals with the i^{th} element having variance σ_e^2 / n_i. The expectations of the observations and the random variables were mutually zero. The variance-covariance structure of the random effects was assumed to be:

$$\text{var}\begin{bmatrix}\mathbf{s}\\ \mathbf{e}\end{bmatrix} = \begin{bmatrix}\frac{1}{4}\sigma_s^2\mathbf{A} & \mathbf{0}\\ \mathbf{0} & \mathbf{R}\sigma_e^2\end{bmatrix}$$

where is the numerator relationship matrix, is a diagonal matrix with elements $1/n_i$, and are the additive genetic and residual variances, respectively. The set of equations derived from equation [1] are:

$$\left[Z'R^{-1}Z + \lambda A^{-1}\right]\left[\hat{s}\right] = \left[Z'R^{-1}y\right] \quad [2]$$

where, $\lambda = \frac{\sigma_e^2}{\frac{1}{4}\sigma_a^2} = \frac{4-h^2}{h^2}$ is the heritability of the trait assumed to be 0.30, $Z'R^{-1}y$ is a diagonal matrix whose elements are a quarter of the number of daughters contributing to the sire's DYD, $Z'R^{-1}y$ is a vector whose elements are the product of the half the number of daughters and the DYD. Three sets of estimated breeding values (EBV) were obtained from equation [2] using the Animal Breeder's Tool Kit (ABTK; Golden et al. 1992). The first set of EBV, referred to as EBV-ALL, was computed using the sire's DYD and that of its relatives and incorporating the A_p^{-1} in equation [2]. The second set of EBV, referred to as EBV-PED, was similar to EBV-ALL except that the sire's DYD was excluded from the analysis while the DYD on all relatives were included. This analysis simulates young bulls without daughters (or own DYD). The third set of EBV, referred to as EBV-MRK, was similar to EBV-PED except that A_{PM}^{-1} replaced A_p^{-1}. The EBV-ALL was expected to be more accurate compared to EBV-PED and EBV-MRK because of the inclusion of all available sources of information. The Pearson and Spearman rank order correlation between EBV-ALL with EBV-PED or EBV- MRK were computed to evaluate the change in accuracy and ranking of sires when A_p^{-1} or A_{PM}^{-1} was used.

Computation of the additive genetic relationships

Two relationship matrices were constructed. The first relationship matrix was the usual numerator relationship matrix (A_p) based on pedigree information, hereafter referred to as the pedigree matrix, computed following the procedure of Henderson (1976). The second relationship matrix (A_{PM}) was computed using the pedigree and marker information, hereafter referred to as the marker matrix. The marker relationships were calculated using the modification of the procedure proposed by Nejati-Javaremi (1995). Nejati-Javaremi (1995) presented the following formula to compute the relationship between two individuals, say *a* and *b*, conditional on pedigree and marker information:

$$A_{M(a,b)} = 2 \times \frac{\sum_{i=1}^{2}\sum_{j=1}^{2} LS_{ij}}{4} \quad [3]$$

where LS_{ij} is the proportion of the ith linkage segment from individual *a*, in common with the jth [linkage] segment from individual *b*. The takes values between 0 and 1 and thus the marker relationships range from 0 to 2 similar to pedigree relationships. In this study, the linkage segments were constructed using the marker information. The phase of the segments for foundation animals was unknown and thus assigned arbitrarily while the phase of the non-base animals was inferred from the parental genotypes.

Marker relationships based on Equation [3] are accurate when there is full genome marker coverage. Often in practice informative markers may only be available at certain genomic locations and therefore genome marker coverage may be limited. We modified equation [3] as follows to account for incomplete genome marker coverage:

$$A_{PM(a,b)} = \frac{r.A_{P(a,b)} + s.A_{M(a,b)}}{l} \quad [4]$$

where *s* and *r* are the genomic intervals with and without marker coverage respectively, *s* and *r* sum to *l*, *l* is the total genome size in cM; $A_{PM(a,b)}$, $A_{P(a,b)}$ and $A_{M(a,b)}$ are the pedigree-marker, pedigree and marker relationships between individuals *a* and *b* respectively. Equation [4] reduces to equation [3] when there is full genome marker coverage. Alternatively, when no marker information is available equation [4] reduces to the pedigree relationships.

Results

Additive genetic relationships

The number of non-zero elements in the pedigree and marker relationship matrices was the same. However, the marker relationships expressed deviation from the expected relationships computed based on pedigree information alone. The deviation was, however, small because the markers accounted for 20% of the genome such that pedigree information still played a major role in marker relationships. For example, in one of the half-sib families with 79 siblings the marker relationships ranged from 0.231 to 0.278 with an average relationship of 0.256 which is close to the expected relationships among half-sibs of 0.25. The deviation of marker from pedigree relationships provided some knowledge about the actual sample of genes shared between relatives, i.e. the covariance between Mendelian sampling effects.

Pearson linear correlation

There is evidence of significant correlations between EBV-ALL and EBV-PED or EBV-MRK within and across chromosomes (Table 1). There was an increase in accuracy of EBV for milk yield when markers (from all chromosomes) were considered in computing the relationships. The enhancement in accuracy was 4.3%. Conversely, use of marker information led to no change in accuracy for fat and protein yields. Increases and decreases in accuracy occurred when relationships computed from pedigree and marker information within chromosome were used. For example, supplementing pedigree with marker information resulted in the same or higher accuracy than use of pedigree information alone for milk and protein yields while predictions of less, same or higher accuracy were observed for fat yield. Markers on chromosomes 1, 14 and 20 for milk yield and 3 and 10 for protein led to more accurate prediction. However, markers on chromosome 3 provided useful information for computation of relationships. . These results are in agreement with QTL studies that show that QTL for different traits are located at different regions of the genome. On the other hand, markers on chromosome 3 provided useful information for computation of relationships. Considering all the traits, the correlations were consistently higher for protein yield compared to milk and fat yields. In fact, fat yield had the lowest correlations i.e. the least accurate. Given that the same heritability was assumed for the three traits, it is unclear why the protein yield was more accurate compared to milk and fat yields.

Table 1. The Pearson correlation between EBV-ALL and EBV-PED ($r_{ALL,PED}$) or EBV-MRK ($r_{ALL,MRK}$) within and across chromosome.

Trait	$r_{ALL,PED}$	$r_{ALL,MRK}$						
		GENOME[a]	CHR1	CHR3	CHR9	CHR10	CHR14	CHR20
Milk	0.47	0.49[i]	0.48[i]	0.47	0.47	0.47	0.48[i]	0.48[i]
Fat	0.37	0.37	0.37	0.38[i]	0.36[d]	0.37	0.37	0.36[d]
Protein	0.62	0.62	0.62	0.63[i]	0.62	0.63[i]	0.62	0.62

[a] refers to all the six chromosomes, [i] increase, [d] decrease.

Spearman rank order correlations

Rank correlations were consistently higher for EBV-MRK compared to EBV-PED indicating that use of marker information provides better ranking between sires than use of pedigree information alone irrespective of the accuracy of prediction (Table 2). Similar to the linear correlations, rank correlations were higher for milk and protein yield relative to fat yield. Markers on chromosome 1 provided the same rank correlations as using the markers on all the chromosomes.

Table 2. The Spearman rank order correlation between EBV-ALL and EBV-PED ($r_{ALL,PED}$) or EBV-MRK ($r_{ALL,MRK}$) within and across chromosome.

Trait	$r_{ALL,PED}$	$r_{ALL,MRK}$						
		GENOME[a]	CHR1	CHR3	CHR9	CHR10	CHR14	CHR20
Milk	0.38	0.44	0.42	0.40	0.40	0.41	0.42	0.41
Fat	0.27	0.30	0.29	0.31	0.30	0.30	0.30	0.29
Protein	0.54	0.59	0.59	0.58	0.56	0.57	0.57	0.56

[a]*refers to all the six chromosomes.*

Discussion

The improvement in accuracy achieved here was not dramatic primarily due to the relatively limited number of markers considered. In addition, the average distance between consecutive markers was 13 cM, which may play a major role in tracing chromosomal segments through generations. Nejati-Javaremi (1995) using simulation observed change in accuracy from using marker information ranging from 4.4% to 34.6% for a trait with a heritability of 0.3 and the recombination rate between flanking markers of 0.02. The accuracy ranged from 0.0% to 8.0% for a recombination rate of 0.20 indicating that the accuracy declines with an increase in distance between markers. These results were consistent with the 4.3% increase in accuracy observed in our study.

Markers used in this study were not chosen based on knowledge of their association with the traits evaluated but were in interesting QTL regions. When there is evidence of associations between markers and phenotypes, the accuracy of genetic prediction may be enhanced by using **these markers**. For instance, there is increase in evidence of association between markers and QTL on chromosome 1 for milk yield (Khatkar et al., 2004). This may explain the increase in accuracy observed from using markers on chromosome 1 for milk yield.

In the current study, the proportion of the segments in common was weighted by the size (in cM) of the segment. This may not be optimal since the length of the segment does not imply the magnitude of its influence on trait phenotype. Alternately, when information on the genomic regions influencing performance is available, the proportion of variance accounted by the region may be used to weight the relationships.

Conclusions

The results obtained in this study provide empirical evidence of an increase in accuracy when markers were used jointly with pedigree to compute the genetic relationships. The use of marker information resulted in better ranking among sires irrespective of the accuracy of the predictions. The increase in accuracy depended on the trait evaluated implying that different relationship matrices should be considered for different traits. These results suggest that marker information may be used successfully to enhance accuracy of prediction particularly for young sires without

own performance. This will allow for selection among candidate sons to be placed under progeny testing particularly for the dairy industry.

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Application of DNA and protein technology in animal forensics

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Abstract
In South Africa, the increasing incidence of stock theft and poaching, with the accompanying cruelty to animals, affects all sectors of the livestock farming, including the large commercial farmers, stud breeders and the smallholder rural farmers who may own one or two cattle. Animal forensics, which includes DNA and protein technologies, can provide a useful tool for identifying stolen animals. Protein and DNA based methods can be used to establish the identity, ownership, parentage and traceablitiy or origin of the species of individual animals, using samples of blood meat, hair and other tissues collected from crime scenes. DNA microsatellite marker sets are used to obtain DNA profiles. The PCR procedure provides for the analysis of minute quantities of DNA. The analysis of protein profiles provides a simple but powerful means for animal and species identification. The paper discusses cases where animal forensic techniques have led to successful convictions.

Key words: forensics, DNA profiling, species identification, animals

Introduction
Biotechnology has many applications in a variety of fields such as medicine and pharmaceuticals and is now used in animal forensics. This means it can be 'used to detect crime and as evidence in a court of law'. This use is relevant to South Africa where the incidence of stock theft is high. Despite efforts of the South African Police Service (SAPS) to contain the situation animals worth millions of rand are reported stolen annually. For example, during the past year the loss was estimated at over US$ 40 million. Apart from the financial losses incurred, stolen animals are often subjected to cruelty in the form of handling, maiming and inhumane slaughter.

The latest figures obtained from the SAPS for some provinces in South Africa indicate that many animals are stolen but few were recovered in 2003 (Tables 1 and 2).

Table 1. Cattle reported stolen and recovered in South Africa, 2003.

Areas in (# areas)	Stolen	Recovered	% recovered
Eastern Cape (4)	17,518	2,838	16
Mpumalanga (1)	6,567	4,889	74
Free State (2)	9,025	1,564	17
KwaZulu Natal (1)	2,853	942	33
North West (2)	3,412	747	22

Table 2. Sheep and goats reported stolen and recovered in South Africa, 2003.

Areas in (# areas)	Stolen	Recovered	% recovered
KwaZulu Natal (3)	10,183	4,679	46
Mpumalanga (2)	5,131	2,603	51
North West (3)	5,578	2,307	41
Free State (1)	1,751	741	42
Limpopo (1)	1,581	523	33

The data in the tables indicate that animal forensics may have an impact on the economy of the livestock industry in South Africa. It is against this background that the objective of this paper was conceived to review how the different biotechnologies, including protein and DNA technology, have been applied to support crime reduction in South Africa, specifically stock theft.

Applications

There are two main applications of animal forensics in South Africa, namely DNA profiling and species identification. The advent of DNA technology in the early 1980s has revolutionised the identification and genetic characterisation of farm animals. The technology was first applied in humans where it was found to be individual-specific. Trials with mammals soon followed and were based on the same principle: that each animal has a unique DNA profile or fingerprint that distinguishes it from any other, even its siblings. This principle allows for individual identification, parentage verification, traceability and origin of species and includes ownership of animals, all of which are important applications in animal forensics.

In South Africa, the markers of choice for obtaining a DNA profile are microsatellites. These markers are hyper variable tandem repeats, can be easily scored and provide highly accurate and reproducible data. Together with the advent of polymerase chain reaction (PCR) technology, DNA-markers have had a major impact on animal genetic profiling studies (Halverson et al. 2005).

The other important application of forensic science is to identify the origin of the species (species identification) in blood, meat and other biological material that can lead to convictions. When trace amounts of blood are found on clothing, weapons, leaves, soil etc. from crime scenes, an effective and sensitive genetic method for identifying these molecules as being of a certain species are invaluable. In South Africa, the meat industry, including poultry, fish and game, is closely linked with international trade and is experiencing an increase in frequency and substitution of one species for another. Often, the species source of meat is not declared or is falsely declared. In addition, processing complicates the identification of the original species because the external features by which a species can be identified are often removed or obscured. The origin of the animal species for products such as boerewors, viennas, salamis, polony, patties, pies etc. are under constant suspicion. With the import/export of mechanically de-boned meat where external features are also obscured, a species identification test can be invaluable for forensic investigations. The contribution to the successful prosecution and conviction of stock thieves and poachers can be a deterrent to would-be criminals where a forensic application to identify the species origin of biological material is readily available.

Methodology and case studies

DNA profiling

The SAPS Stock Theft Units collect biological samples such as blood, meat, hair or other tissues from crime scenes and other sources implicated in a stock theft crime. The sealed samples are sent to the laboratory where the procedures include DNA extraction, amplification and polyacrylamide gel electrophoresis for separation of the fragments in an automated ABI377 DNA Sequencer (Perkin Elmer, Foster City, USA). Only sealed samples are accepted as this complies with the legal aspects of regulation for the chain of custody. Profiles obtained from different samples using the GENESCAN and Genotyper software (version 2.0, Applied Biosystems) are compared. Results of the analyses are used as scientific evidence in court cases to prove that tissues originated from the disputed animal and, in cases of disputed ownership, the DNA profiles are used to establish parentage (Greiner 2002).

Two case studies are discussed to demonstrate the practical application of DNA profiling in animal forensics.

Case study 1

Three sheepskins from a crime scene, possibly linked to meat found in the house of a suspect, were analysed. In addition, a bloodstained jacket and knife were removed from the same house as possible evidence. DNA profiles were obtained from all the exhibits (Table 3) from which it was established that one piece of meat and the bloodstains on the jacket matched one of the skins. Another piece of meat and a skin matched each other. The DNA profile obtained from the knife was a mixture of DNA, a combination from all the three sheep. These results based on individual identification of the exhibits led to the suspect being charge and sentenced to a prison term.

Table 3. DNA profiles of sheep for matching individual exhibits.

Marker sample	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**	
A	180	184	236	250	151	155	119	119	92	108	146	148	168	170	97	99
B	180	186	236	250	151	155	117	119	92	102	144	148	168	170	97	99
C	182	184	238	250	151	155	119	119	92	110	146	150	168	170	97	99
D	180	184	236	250	151	155	119	131	92	108	146	148	168	170	97	99
E	180	186	236	250	151	155	117	119	92	102	144	148	168	170	97	99
F	180	184	236	250	151	155	119	119	92	110	146	150	168	170	97	99
G	182	184	238	250	151	155	119	119	92	110	146	150	168	170	97	99

A: skin from sheep A; B: skin from sheep B; C: skin from sheep C; D: meat; E: meat; F: jacket; G: knife.

Case study 2

Parentage verification was requested for cattle theft where the external branding identification was altered. Samples included a calf, the alleged mother and a possible father out of four bulls. Using DNA profiles (Table 4) it was proved beyond reasonable doubt that the calf had indeed been sired by one of the bulls.

Table 4. DNA profiles of cattle illustrating parentage verification.

Marker sample	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**	
Calf	131	139	213	217	252	252	77	95	160	160	206	214	143	151	111	121
Cow	131	139	217	217	252	256	93	95	160	166	206	214	137	143	111	115
Bull 1	129	139	209	213	246	252	77	77	160	198	214	214	151	161	115	121
Bull 2	133	135	213	213	248	256	79	89	162	172	196	214	143	149	115	115
Bull 3	131	133	217	221	246	252	77	83	160	182	208	214	151	151	115	123
Bull 4	127	131	217	217	248	260	83	97	166	168	210	218	143	151	115	117

Parentage determination can also be used in cases where ownership has to be proved. Seldom are all the alleged parents available to prove parentage as in this case study. In most cases samples are obtained only from the alleged mothers. This has value because it can be established beyond reasonable doubt that one of the cows can be excluded as the possible mother of the calf in dispute. It cannot also be proved that the other cow is the mother of the calf. Thus, it can only be stated that that cow can be included as the possible mother as this cannot be proved in the absence of a father.

Identification of species

The analysis of general muscle and blood proteins involves a simple but powerful means of species identification with different protein profiles obtained for each species. It is necessary to

utilise reference samples (muscle or blood) stored in a biological bank to compare the general protein profile of unknown samples. The method is based on gradient polyacrylamide gel electrophoresis, a simple, fast and effective way to separate proteins in complex mixtures. Repetitive analysis in the laboratory indicated reproducible, distinct protein profiles recorded for each species. The data collected are truly characteristic of the species and can even distinguish between closely related species and mixtures. Different cuts of single species give identical banding configurations.

Species which are not regarded as edible in South Africa, for example horse meat, can now be identified in products and mixtures. Horse meat obtained from illegal abattoirs is regularly substituted for beef as it is cheaper. The SAPS has a formidable task in tracing these illegal practices. Another interesting case was that of a Hindu priest who had minced meat and a sausage analysed. These samples corresponded to beef instead of mutton. Since the Hindu religion views cattle as sacred, this led to a court case. A contribution was also made in the processing industry where the monitoring of species contents in pies led to the development of a new product on the market. It is now possible to buy a meat pie containing 100% ostrich meat.

Health departments within the greater metropolitan areas in South Africa regularly participate in a monitoring programme of fresh, frozen and processed meat where samples are collected from different butcheries and sent for laboratory identification. These monitoring programmes have succeeded in showing fraudulence where species were substituted and falsely labelled, especially in game products. As part of quality assurance the correct labelling of products is recommended, as there have been several cases reported where meat products are labelled wrongly. Customer satisfaction is an integral part of the consistency of quality. Species identification is an effective way to monitor meat sold from illegal abattoirs as well as informal bush meat that can land on the consumer's table.

Conclusion

Currently, DNA profiling is the most accurate and specific method for individual identification and parentage verification in solving cases of stock theft. The analyst has a formidable task to perform to quantitatively establish the origin of species using protein technology. Both technologies are strongly supported by the SAPS Stock Theft Units and the Department of Justice in South Africa. Expertise and forensic evidence techniques used can withstand legal challenges in courts. Forensic science is dynamic and it is foreseen that the way forward will embrace, for example, new technologies for analysing poor quality or micro-quantities of sample material. Animal forensics is thus a very important tool that can be used in all sectors of the farming community from large commercial organisations to the stud breeders and extends to rural and emerging farmers.

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Importance of infrastructure and system for livestock recording and improvement in developing countries

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Abstract
In many developing countries infrastructure and systems for conventional animal improvement are lacking, and the early speculations that marker-assisted selection will provide a quick solution in the absence of such systems have been proven wrong. Systems of livestock recording and improvement have a wider impact on genetic improvement only. Livestock recording is utilised to establish baseline performance, compare production alternatives, improve animal management and genetically improve livestock. The benefits of livestock recording and improvemen to farmers, rural economy, consumers, government and the nation are discussed. The need to secure long term success of animal recording is also highlighted. This includes aspects such as commitment of governments, financial benefit, role of indigenous breeds, socio-economics and infrastructure. This paper attempts to demonstrate how countries without the necessary infrastructure can gain from using existing facilities that exist within a region. An example of such a facility is the Integrated Registration and Genetic Information System (INTERGIS) in South Africa.

Key words: livestock, recording, improvement, genetic information

Introduction
Most of the developing countries still face the challenges of the generally low input-low output taditional systems of livestock production. On the contrast, the global competition to produce animal products is on the increase, especially in the developing countries. Currently, the developed countries are investing more in research and development of innovative technologies to enhance production efficiency and product properties. In the developing countries there is need to take stock of the existing systems and infrastructure that cater for animal recording and improvement needs. Such systems and infrastructure should provide for the requirements of current practices, baseline performance and biological variation that can facilitate identification of genetically superior animals. Clear definition of breeding objectives and the implementation of efficient breeding systems should form the basis for optimal utilisation of the available genetic resources as recommended by the Food and Agriculture Organization (FAO) of the United Nations (FAO, 1998). Following these strategies can ensure a balanced approach in assessing management interventions needed, determining and rectifying the level of competitiveness and ultimately the identification of suitable animals that would conform to selection objectives. The sharing of human and infrastructural resources in Africa would be essential in achieving these goals and should not be restricted to national borders.

Discussion
Need for sustainable recording systems and rationale for public support
At the Second All Africa Conference of Animal Agriculture, Rege & van der Westhuizen (1996) discussed the possibilities and benefits of a possible multi-country genetic evaluation for Africa. The approach to such an ambitious task included:

- Investigation into current genetic ties among, especially dairy, cattle in the different African or through other countries.
- Documentation of existing infrastructure, including organisations, recording systems, trait definitions, evaluation procedures, human resources and capacities, computing facilities, participation in recording and the proportions of the commercial versus smallholder sectors.
- Establish a coordinating structure to implement joint evaluations.
- Establish genetic ties to ensure proper breeding value prediction across national borders.

It was further recognised that, in order to develop such a system, initial investment will be needed for baseline performance recording that will ultimately lay foundation for genetic evaluations.

Other authors confirmed the general lack of governmental support, direction, diversity in production systems, including smallholder production, land ownership and big commercial enterprises to be catered for, as possible causes of unsustainable animal recording and improvement systems in Africa (Mosi & Mbuza, 1996; Aboagyle, 1996; Moyo & Mpofu, 1996). In the year 2001, majority of livestock were kept in developing countries (FAO Database 2001; Trivedi, 2002). Consumer needs in these countries are also likely to increase rapidly (Trivedi, 2002; Mitaru & Mwai, 2003). In addition, animals in these countries have been exposedto the prevailing environmental and management conditions and should possess adaptive qualities needed to perform efficiently where other breeds will experience stress. This scenario underlines the need for proper evaluation of genetic variation and abilities of individual animals to be used in breeding programmes for enhanced productivity meet the growing consumers needs. Africa is an example of a region where many temperate cattle breeds and strains have been introduced, sometimes with disastrous consequences. To be able to set benchmarks for the current genetic pool as well as introduced animals, proper development of sustainable animal recording systems.

The FAO (1998) identified the following four main reasons for developing and implementing sustainable animal recording:

- To provide baseline performance data on animals.
- To facilitate comparision of production system alternatives.
- To provide requisite data for animal management.
- To support genetic improvement.

Sustainable animal recording systems can partly be realized through sustained and substantial public sector investment. It has been observed that it would require ".. a human generation for a recording scheme to gain full acceptance as an essential part of livestock production (FAO, 1998)." Furthermore, even for farmers' organisations, the commitment has to be nurtured through sustained public support. Public support is more crucial in the developed countries where animal recording systems are considered private. This support is usually channelled through research and academic institutions or incentives to farmers to participat in national recording schemes. Sustained public support is necessary since recording schemes usually benefit both users, primary beneficiaries, as well as a host of other groups and the government secondary beneficiaries. Figure 1 shows the beneficiaries and subsequent benefits of animal recording.

Recording system and other requirements

Advances in technological developments have now made it possible for increased and quick implementation of efficient recording systems. Given the sociological, economical and possibly political limitations, such systems are currently easier to implement than in the past. Animal recording start with basic principles, namely:

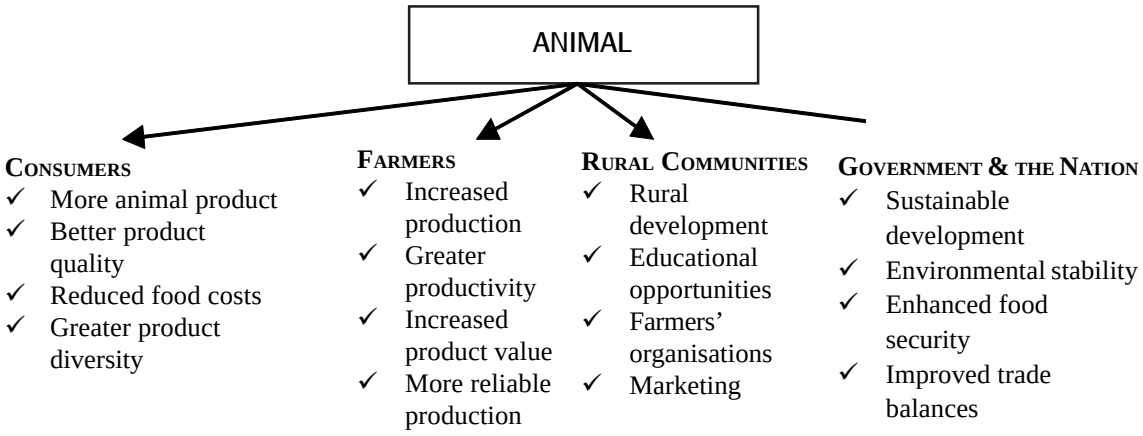

Figure 1. *Beneficiaries of animal recording (FAO 1998).*

- **Unique identification of animals**
  Well established principles have been laid down on the unique identification of animals within national borders or even across borders. The International Committee for Animal Recording (ICAR) and its sub-committee Interbull played a leading role in this regard. Many countries have also adopted legislation to deal with a national identification system laying down the rules of unique identification of animals. The development of systems based on bar coded identification and radio frequency identification (RFID) has also ensured quality control and speed of measurements.

- **Structure and operations**
  Structure implies a network of people, computing capacity and a proper reporting mechanism. In many cases, the network of people needs establishment, either by using existing organisations such as breeding organisations, extension services, research units or tertiary educational institutions, or by establishing new ones. Computing capacity is usually a centralised unit for a country or region, while satellite units can also be used to contribute data, do some preliminary calculations or disseminate information to primary and secondary beneficiaries. In many cases, individual large commercial livestock enterprises fulfil this function on their own. In other cases, a breeding organisation or a co-operative society collect all or some of the records on behalf of members, checks and submits the records to a national unit and also collect and distribute feedback information to members. In all cases, the reporting has to deal with an on-going process of participatory education and training of members.

- **Useful information**
  Participants in animal recording programmes should see the real value in using feedback information to enhance the efficiency of their enterprises, irrespective the size. thereby ensuring long term sustainability. Following the guidelines of the FAO (1998), benchmarking, and adapting to production alternatives and management changes and interventions could have a marked impact on competitiveness of the enterprise. The long term benefit is however linked to the optimal use of genetic resources with appropriate genetic goal based selection and breeding programmes (Mein et al. 2001).

- **Knowledge base development**
  The importance of local knowledge base systems and intellectual property imbedded in communities at local or regional level has only recently been identified as important. The application of participatory approach tools (Lawrence, 2005; Clark *et al*, 2005) and utilisization

of recorded information have both contributed to marked improvements in the economic sustainability of livestock enterprises in South Africa. However, there is a strong need for a permanent and effective linkage between local recording and contiuous research and development in the areas of recording practices, genetics and breeding and economic development (Peters & Zumbach, 2002). Imposition of global systems on developing economies often leads to a drain of human capacities in these fields and investment. In most cases, public funding needs to be sustained.

The South African model

South Africa has established world renowned recording and improvement systems for livestock (Scholtz and Lepen, 1996). Figure 2 depicts this model.

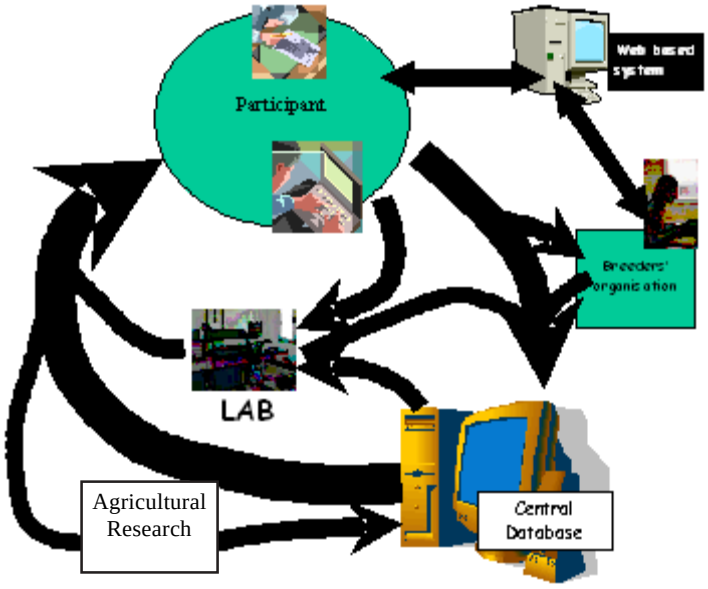

Figure 2. Structure of the the South African National Recording and Improvement System.

Figure 2 shows that all farming and species are accommodated to ensure national participation and storage In a centralised database. The arrows refer to possible data and information flow, except in the case of milk or fibre samples being sent to laboratories for analytical and quality analyses. Close cooperation has also been established with farm computer software developers, while, in some cases, the Agricultural Research Council has developed own packages to enhance data exchange from farm to the central unit. Although the system makes provision for state of the art computing and modelling such as lactation curves based on derived Best Linear Unbiased Estimates of fixed effects and the Wilmink curve, it caters for the most basic level of on-farm recording. The ARC has also embarked on projects assisting smallholders, rural based livestock units and new entrants to take part. These groups are supported and assisted in identification of animals, making scales available when crucial weighing should take place and interpretation of results. The initial project was focussed on beef cattle units in two provinces.Because of its continued success it is currently being expanded to other regions in South Africa as well as other production systems. Through public support of the National Department of Agriculture, the ARC will furthermore embark on a system of training of young technical people in the skills of milk recording to ensure increased participation in the National Scheme.

The balance between the involvement of the emerging economy and the commercial sector remains a challenge. The design of the system makes this possible, as breed societies, supplying genetic material to others, are involved in the system. The ARC applies the latest technology to predict breeding values using the recorded data. The importance of active and topical research and development, linked to the recording system ensures that the local production systems are taken into account when applying models and the human capacity is maintained.

Regional participation

Currently only a few stud breeders and large dairy units from African countries outside South Africa, Namibia, Zimbabwe, Botswana, Zambia and Swaziland, participate in the system. Due to the accessibility and openness of the system, it is possible to extend its regional coverage without major changes. Expansion of such a system in the region or even in the continent will have enhance management of animal genetic resources, traceability as well as joint focussed research and development. In addition, it will facilitate definition of realistic breeding objectives and mating plans. The challenge to ensure that wealth from local knowledge, uniqueness of animal genetic resourcesl and community based intellectual property is channelled to the original source can be faced more effectively

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Use of progesterone in early detection of open cows in smallholder dairy farms in Nakuru District of Kenya

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Abstract
Kenya's smallholder dairy sector produces 85% of the total milk marketed in the country. A major constraint to milk production and number of calves born from the cows is the long calving intervals. Determining non-pregnant cows early by measuring progesterone levels by day 23 after insemination can help reduce calving intervals, thus improving productivity. A sample of 481 cows was inseminated and 10 ml milk samples collected from each cow on day 0, 13 and 23 after insemination to determine progesterone levels using radioimmunoassay and using I_{125} as the tracer. This was to determine timeliness of artificial insemination (AI), cyclicity and pregnancy by day 24 after AI. Rectal palpation was done 90 days after insemination to confirm hormone predictions for non-pregnancy. Conception rates of 53% were recorded. Mean progesterone levels were 0, 5.3 and 10.1 nm/litre at the three stages of sampling respectively for pregnant cows, while non-pregnant cows recorded 0.59, 2.69, 0.46 nm/litres respectively. Of cows inseminated at the right time, 38% did not conceive, showing a problem of cyclicity or early embryonic loss. Embryonic loss was recorded in 32% of non-pregnant cows. The post-partum period averaged 5 months. Breeds were similar for conception while cows inseminated during April to June had higher conceptions than those of July to September. Prediction accuracy of non-pregnant cows was 96%, thus, open cows can be identified early, reducing the time required to re-breed and hence reduce calving intervals.

Introduction
Kenya has a dairy cattle population of 3.4 million head, which occupies 30% of the land in high and medium potential areas and produces 62% of marketed milk while 38% is consumed at home (Waithaka 1993). Smallholder farmers produce 85% of the milk under mixed diversified production systems (Misoi and Namwamba 1987).

The demand for milk is expected to increase due to increased population, incomes and accelerated urbanisation (Mbogoh 1992). This demand can be met through increased production by improving productivity per cow per unit land area.

An important constraint to dairy production is low nutrition as demonstrated by the low average milk yield of 5.8 kg per day (Omore et al. 1994) and lactation curve which does not peak between days 40–70 post-calving (Radostitis et al. 1994). The steep drop and the absence of peaking in the lactation curve shortly after calving is evidence of insufficient dry matter intake (Nelson and Redlus 1989).

The low milk production by cows is an important constraint to optimal calf growth resulting in delayed age at first calving averaging 41 months (Odima et al. 1994). The second major constraint

reported was the long calving interval due to impaired fertility in cows that averaged 633 days (Odima et al. 1994). This results in lactation lengths estimated at 16 months instead of 305 days. On a per herd-year basis a shorter calving interval results in higher milk production and calvings per year. Pregnancy percentage at first insemination, the number of inseminations per conception and the number of days from calving to conception all influence the length of calving intervals (Odima et al. 1994).

The poor reproductive and productive parameters cause losses to farmers as a result of decreased annual milk yield, reduced number of calves over lifetime of the cow and reduced genetic progress in the herd due to few replacements. Under normal grazing conditions, average number of services per conception has been reported at 2.5 in Nakuru District as a result of fertility problems in dairy herds (Lokwaleput et al. 1998).

Early identification of non-pregnant cows after insemination is of economic importance to improve production. During pregnancy, the conceptus inhibits the regression of the *corpus luteum* and prevents the cow from returning to oestrus (Hafez and Hafez 2000). Therefore, an animal not returning to oestrus after service is assumed to be pregnant.

Rectal palpation is used to diagnose pregnancy in cattle between days 60 to 90 after insemination. However, sensitive immunological methods of measuring hormones in biological fluids can identify non-pregnant cows by day 21 after insemination, thus allowing for early rebreeding (Hafez and Hafez 2000).

Radioimmunoassay (RIA) and enzyme immunoassay (EIA) are used to measure pregnancy-dependent hormones like progesterone in plasma and milk. Milk is preferred to blood because progesterone levels are higher in milk than in plasma and samples can be collected without inflicting discomfort to the cow. Due to its lipophilic properties, a considerable amount is accumulated in adipose tissue or transferred into milk fat during periods of high progesterone synthesis. The accuracy of predicting pregnancy varies because in about 20% of the time, high levels of progesterone are exhibited due to the presence of luteal tissues (cysts, endometrities etc.) in the absence of a conceptus (Hafez and Hafez 2000). Therefore, the milk progesterone test helps detect open cows earlier than the conventional 90 days required after insemination.

Objectives

The objective of this study was to use progesterone levels in milk of dairy cattle as a predictor of non-pregnancy by day 24 after insemination and determine probable causes of non-pregnancy.

Materials and methods

Cows from smallholder dairy farmers using community artificial insemination (AI) services in Nakuru District were used for milk sampling; three private large-scale farms and a private AI practitioner were included in the study.

A total of 481 cows comprising of Friesian, Ayrshire, Guernsey, Jerseys and some crosses were randomly sampled as they came on heat and subsequently inseminated. Progesterone levels in the milk samples were determined in the laboratory. The farmers and AI technicians were given 10 ml milk sample collection bottles each containing a sodium azide tablet as a preservative and an individual cow record sheet. Milk was collected from the same cow on the day of AI and on days 12 and 23 after AI. The date of AI, technician, farmer and cow reproductive information was recorded on the individual cow sheet. Three milk samples per cow were submitted to the laboratory for assaying.

The milk was centrifuged at 3000 RPM for 30 minutes to separate fat from skim milk, which was stored at 4°C before extraction. Progesterone levels are less variable in skim milk than in milk fat. The 'self-coating' RIA technique developed by IAEA/FAO (1999) using progesterone 11 hemisuccinate-(2[125] Iodihistamine was used in the assay. A single well gamma counter was used to determine counts per minute and per cent binding used to determine progesterone concentration in the milk samples (IAEA/FAO 1999) derived from a standard curve drawn from supplied progesterone standards.

Progesterone levels at the three stages for each cow sampled were used to determine the reproductive status of the cows and the efficiency of the AI system. Laboratory results were compared with rectal palpation done on days 60 to 75 after AI to determine accuracy of progesterone in predicting non-pregnancy. Amongst other data collected from these cattle was post-partum heat period, hours to AI after heat detection, site of AI, inseminator, time of AI and semen batch. Seasonal effects were also assessed from January to March, April to June, July to September and October to December, which are distinctly different based on average rainfall in Nakuru.

Contingency analysis of this data was done to determine the effects of breed, season, AI time, and site of AI and inseminator on conception rates of inseminated cows.

Results and discussion

Cattle sampled and their breeds (Table 1) are a reflection of the breed preference in this region of the country because of their perceived high milk production.

Table 1. Breed distribution of cattle sampled.

Breed	Number of cows
Aryshire	49
Friesian	401
Guernsey	15
Jersey	16
Total	**481**

Of 481 cows inseminated, conception rates were 53%. The mean progesterone levels for the three stages of milk sampling for 255 pregnant cows is represented in Table 2. The mean basal levels of progesterone at time of insemination was 0 nmol/litre and agrees with the findings of McLeod et al. (1991) who observed increased conception rates when basal levels tend to zero and is an indication of the efficiency of oestrus detection.

Table 2. Mean progesterone levels after AI for pregnant cows (N = 255); progesterone levels nm/litre

Days after AI	Minimum	Maximum	Mean ± SE	Median
0	0	7	0.43 ± 0.02	0
13	0	15	5.31 ± 0.18	5
23	0	26	10.06 ± 0.26	10

After conception, progesterone (P4) levels increased due to the presence of *corpus luteum*, showing mean levels of 5.3 and 10.06 nm/litre on days 13 and 23 after AI respectively (Table 2).

Of the 226 non-pregnant cows, it was found that P4 levels were low with mean levels of 0.59 ± 0.09, 2.69 ± 0.17 and 0.46 ± 0.04 nm/litre on days 0, 13 and 23 after insemination respectively due to cycling problems (Table 2).

It was observed that 38% (N = 185) of the cows inseminated at the right time did not conceive (Table 3). This was attributed to embryonic losses or non-conception. To the contrary, 10% of the cows conceived with P4 levels above 0, while 12 cows comprising 2.5% conceived when P4 levels were above 3 nm/litre in the luteal phase at insemination.

Table 3. Progesterone levels and pregnancy diagnosis at time of AI.

Progesterone levels	Number of cows	Pregnancy diagnosis
0	217	In-calf
0	185	Non-pregnant
Above 0	48	In-calf
Above 0	41	Non-pregnant

At least 84% of the cows were inseminated at the right time, meaning that the process of heat detection and insemination were timely (Table 3).

Embryonic losses accounted for 54% of the cows diagnosed not pregnant (Figure 1) where the profile is normal up to day 13 and drastically drops on day 23. The reasons could be due to environmental stress factors. Luteal cysts accounted for only 1% of the non-pregnant cattle depicted by the relatively high levels of progesterone at all levels.

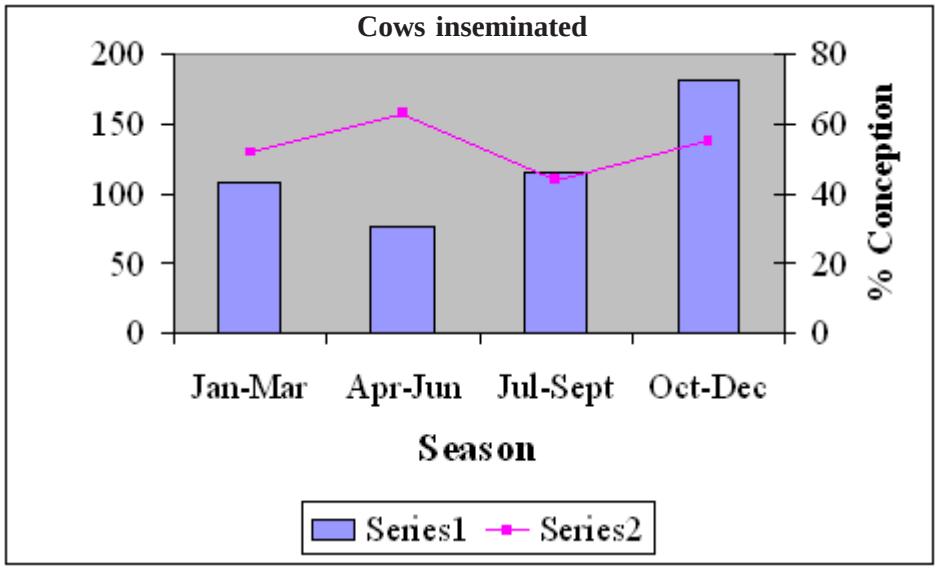

Figure 1. Progesterone profiles for non-pregnant cows.

The non-cycling cows formed 32% of the non-pregnant cows, which had depressed levels of progesterone at all levels averaging less than 0.5 nm/litre. While 13% of the cows were inseminated when they were in the luteal phase, when the progesterone levels averaged 3.9 nm/litre. The depression of progesterone levels after insemination could be due to the interference with the uterus resulting in the loss of conceptus.

Cows were inseminated at an average of 19 hours after heat, but ranged from 4 to 26 hours (Table 4). This is in agreement with the findings of Hafez and Hafez (2002) who indicated that cows should be inseminated 12 to 18 hours after onset of oestrus. The post-partum period to heat averaged 5 months with a range of 1 to 12 months which results in long calving intervals.

Table 4. Heat to AI and post-partum heat for inseminated cows.

	Minimum	Maximum	Median	Mean ± SE
Heat to AI (hrs)	4	26	21	19.2 ± 0.33
Post-partum heat (months)	1	12	4	4.8 ± 0.15

A contingency analysis of conception by breed, season, time of AI, site of AI and inseminators indicated that breed did not show significant differences for conception. However, there were differences in conceptions for the different seasons at insemination (Figure 2). Cows inseminated in April to June showed highest rates of conception compared to July to September, thus indicating that fertility in cattle could be influenced by seasonality. Most inseminations occur in October to December, indicating that this is the time when most of the cows in this region exhibit heat (Figure 2).

Time of AI and site of semen deposition did not affect conception rates, but there were differences among the inseminators, indicating variation in skills, competence and commitment. Out of the 226 non-pregnant cows, the main causes of lack of conception were mainly non-cyclicity, embryonic losses, wrong time of insemination and luteal cysts.

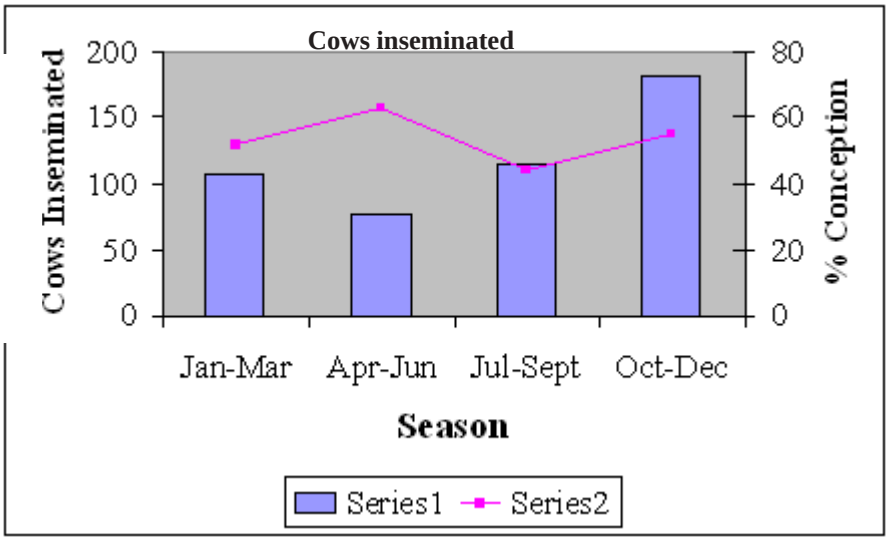

Figure 2. Effect of season on AI service and conception rates.

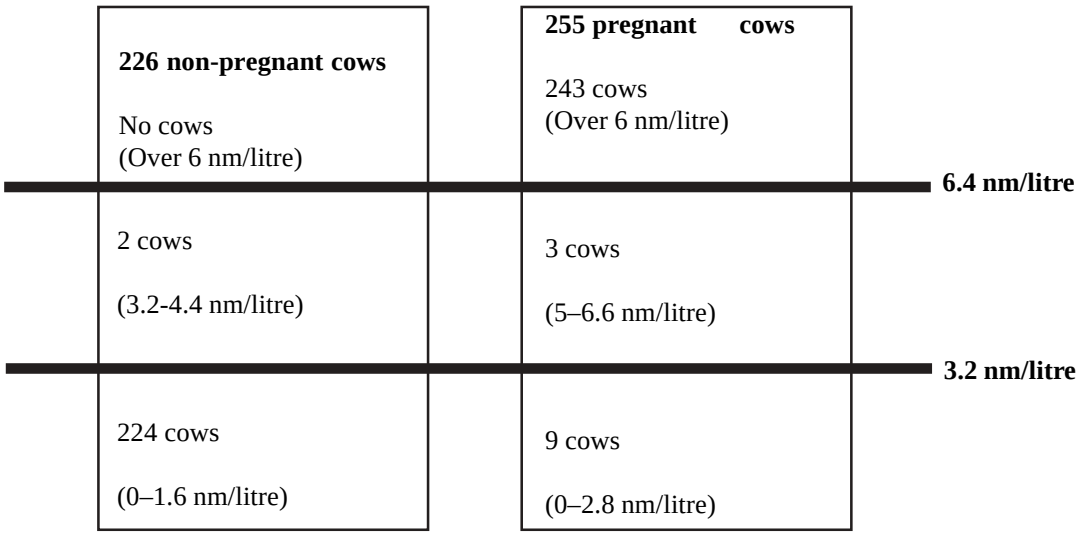

Figure 3. Prediction of pregnancy by progesterone levels.

Of the 481 cows assessed using P4 profiles on day 23 after AI (Figure 3), it was found that the level of prediction for both pregnancy and non-pregnancy varies (Table 5). The cows predicted not pregnant using P4 levels were 224 out of the 226 that were diagnosed not pregnant using rectal palpation.

Table 5. Hormone pregnancy prediction compared to rectal palpation.

Prediction	Rate
No. predicted non-pregnant cows	224
Prediction accuracy for non-pregnancy	99%
No. of cows predicted pregnant	243
Prediction accuracy for pregnant cows	95.3%

This shows quite a high accuracy rate of non-pregnancy prediction and because this system allows for early non-pregnancy detection it saves on the time for rebreeding, thus reducing calving intervals and improving on productivity.

Five cows showed transition progesterone levels of between 3.2 and 6 nm/litre with 3 indicating pregnancy while 2 were not pregnant at rectal palpation.

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Practical application of DNA technology to support livestock breeding in southern Africa

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Abstract
The development of molecular genetics, especially DNA technology, has created the opportunity for animal breeders to make use of the dramatic progress in agricultural biotechnology. The most applicable development in South Africa is DNA profiling. Through the analysis of unique banding patterns, applications such as individual identification, parentage verification, genetic characterisation and the detection of genetic defects and undesirable genes are performed. The results for the different farm animal species are stored in databases for reference. Parentage verification is determined very accurately and the results are used for the registration of animals. Direct information on the genotypes of polymorphic loci allows for the measurement of breed relationships. The screening of animals for genetic defects through the detection of single point mutations is discussed using examples from the dairy and pig industries. The use of DNA technology as a tool contributes to accurate information in breeding programmes that make use of genetically superior individuals while maintaining biological diversity.

Key words: DNA profiling, genetic defects, animal diagnostics, species identification, genetic characterisation

Introduction
Dramatic progress has been made in agricultural biotechnology in the past five years following the advent of DNA technology that has revolutionised the identification and genetic characterisation of farm animals (Beuzen et al. 2000). In South Africa, with our limited financial resources, these advances have been applied directly for the benefit of the livestock industry. Molecular genetics and, in particular DNA technology, is a powerful instrument to use in the diagnostics of inherited diseases and the identification of individual animals with direct relevance to parentage determination.

Applications
Parentage
DNA profiling has replaced blood typing for registration of livestock. The DNA profile of each animal is obtained and stored on a database and remains accessible for future reference. For instance, the information can be used verify future offspring, for registration or to identify individual animals in cases of theft (NRC Report 1996).

The technology rests on the fact that the DNA of an individual is unique and that the offspring inherit half of the DNA from the father and the other half from the mother. This unique DNA is known as the 'DNA fingerprint' or DNA profile of the individual and it can be used to identify an individual beyond reasonable doubt (Pena and Chakraborty 1994).

When establishing parentage, comparing the profiles of the possible parents with the offspring can identify the actual parents (Table 1); in this example the parentage is conclusively proved.

Table 1. DNA profiles to illustrate parentage verification.

Marker	A	B	C	D	E	F	G	H	J	K
Father	J – O	L - L	K - M	R – R	N - N	Q – Q	L - M	O - O	L - M	P - Q
Mother	J – O	K - L	K -K	M - R	K - N	O – Q	L - M	O - O	L - L	N - N
Offspring	O – O	L - L	K -K	M - R	K - N	Q – Q	L - M	O - O	L - M	N - Q

The next case illustrates that alleles found in the offspring have not been inherited from that particular father (Table 2). This means that the alleged father can be excluded as the possible father but the mother has passed on all her alleles to the foal. She is included as the possible mother but, in the absence of a father, this cannot be proved.

Table 2. DNA profiles illustrating the exclusion of a father.

Marker	A	B	C	D	E	F	G	H	J	K
?Father	J – O	L - L	K – M	R – R	N – N	Q - Q	L - M	O - O	L – M	P - Q
Mother	J – O	K - L	K –K	M – R	K – N	O - Q	L - M	O - O	L – L	N - N
Offspring	K – O	L - M	K –L	M – R	K – L	Q - R	L - M	O - O	L – M	N - R

It has been calculated that, for cattle, the chance that there will be two unrelated individuals with exactly the same DNA profile is in excess of 1 in 10 thousand million. The figure for other livestock is similar.

Diagnostics

The number of diagnostic tests using DNA technology is myriad. Breeding programmes rely on DNA testing to select animals with desirable traits. Economically important traits, for example meat quality, stress response and milk proteins are controlled by specific mutations in genes.

Porcine Stress Syndrome (PSS) in pigs

This is a genetic disorder that results in the sudden death of animals that are under stress due to fighting, movement, heat or handling. The cause of PSS is a recessive mutation in the Halothane gene (HAL). The ryanodine receptor regulates Ca++ transport across the cell membrane in muscle cells. Animals that are affected by the mutation in the HAL gene show a higher incidence of stress-induced death as well as poor meat quality. Animals thus develop PSE (pale, soft and exudative) pork with serious implications for the pork industry. Current research indicates that unintentional selection may have occurred because of the superior muscling of the carriers (heterozygotes).

Cytogenetics

Some of the first tests developed in molecular genetics were based on cytogenetic analysis and specifically the typing of chromosomes (karyotyping) where anomalies are identified (Gustavsson 1979). One such example is that found in cattle. The normal cattle karyotype has 60 chromosomes, 29 pairs of autosomes and one pair of sex chromosomes, XY. The most common abnormality occurs when one of the smallest pair of chromosomes, a number 29, becomes attached to one of the largest, a number 1. The effect of this translocation, as with many other anomalies, is important for the breeder as it manifests as reduced fertility in the carrier animal with subsequent financial implications. The 1/29 translocation was first reported in the late 1960s in Sweden when a 10% incidence was found in Swedish Red and White cattle. Since then, the abnormality has been found all over the world in most cattle breeds with degrees of occurrence varying between approximately 2% to as high as 15%.

The cytogenetic technique is employed with great success in the determination of freemartinism where the female twin is infertile and the fertility of the male decreases rapidly after the age of

approximately years. A pattern of mosaicism is found where both the male and female twin exhibit XX and XY cell lines.

Hybrids can also be verified between different species such as horse and donkey, goat and sheep.

Bovine Leukocyte Adhesion Deficiency (BLAD)

This defect of the immune system, as observed in Holstein-Friesland cattle, manifests itself in calves suffering from recurrent bacterial infections, causing early death. Homozygous calves seldom reach adulthood due to infection. The treatment with antibiotics is not very successful.

Deficiency of uridine monophosphate synthase (DUMPS)

This is a monogenic autosomal recessive disorder in cattle which results in the early embryonic death of homozygous offspring. A DNA test for the DUMPS genotype, especially for bulls used for artificial insemination is thus essential in this regard.

Caseins

Genetic typing of dairy cattle for specific milk protein alleles and subsequent selection can enable stud farmers to breed cattle for milk composition optimal for specific needs. This leads to the distinction between different milk types, for example, milk for cheese and yoghurt making, high protein milk or milk particularly suitable for young children. In the past, casein typing was based on milk samples, which meant that only the genotype of lactating cows could be determined directly. The genotype of a bull had to be determined by progeny testing, a lengthy process where the information on the genotype may only be available after a few years. Using DNA technology, the genotype of a bull can be determined at an early age to the distinct advantage of the dairy industry.

Bulldog calves (chrondrodysplasia)

This defect is defined as ‘a calf born with lethal skeletal defects including short limbs, a swollen cranium and a cleft palate’. Such calves are aborted or stillborn. Most of the statistics on bulldog calves comes from Australia where the test for the gene was discovered. The figure for carriers varies from 19% to 46% in Dexter cattle. The condition appears to be inherited in a simple Mendelian manner with incomplete dominance. DNA tests are two-fold: Mutation 1 is available for all Dexters worldwide; Mutation 2 is available for all animals related to Meadowpark Charles. At present, this has been found in Australia only. The possibility exists that a different mutation can occur in South Africa that is not found elsewhere in the world.

Species identification

There has been considerable interest in the identification of species for blood, meat and meat products in South Africa in recent years. The international trade in meat continues to grow. Very often the species of the meat is falsely declared or there is no declaration at all. The consumer in South Africa is then open to the likelihood of meat substitution that, in some cases, could be a health hazard as in the case of meat imported for human consumption, e.g. seal meat.

The possibility of being able to identify the origin of the species in blood and meat also has an application in forensic science. With the increase in stock theft and poaching, the need for a species identification service to solve cases is becoming more important. The identification of the origin of the species in blood, meat and products can monitor and regulate activities in the forensic and meat industry fields and contributes to the inspection and certification of products in the wholesale and retail trade.

Genetic characterisation

To plan a conservation management strategy, it is necessary to define, record and assess the genetic resources. Molecular techniques are used to establish the extent of diversity within a species by quantifying the genetic distance between populations based on differences in their genetic make-up. The data contribute to better knowledge and build the foundation for the improved use, development and maintenance of animal diversity. Microsatellite sets have been optimised for sheep, goats, chickens, pigs and cattle. These adhere to Food and Agricultural Organisation (FAO) and International Society of Animal Genetics (ISAG) standardisation. The laboratory is the focal point in the SADC (Southern Africa Development Community) region for genetic characterisation studies and training courses. Countries already participating are Botswana, Mauritius, Mozambique, Namibia and Zambia.

Biobanking

In addition to the provision of DNA profiling services for a range of domestic and game animals and pets, the Animal Genetics Division has also devised systems whereby biological material can be stored for future applications.

The ARC BioStore™ banks biomaterials from all animals including rare and threatened indigenous farm animals and wildlife. It provides a unique biomaterials banking and information service to a multi-disciplinary research and management audience and co-ordinates the use of such biomaterials on a regional and global basis. Biological Resource Banking (BRB) refers to the collection, validation, value enhancing, banking and distribution of viable biomaterials from wildlife and domestic animal species for conservation, management and research. Biomaterials refer to animal tissue such as blood, serum, hair and skin from live animals other tissue specimens, such as liver, muscle, kidney and other tissues derived from dead animals.

The Livestock identification Catalogue (LidCat™), which is aimed at the protection of livestock, provides a cheap, irrefutable identification system for animals by collecting a biological sample (hair with hair roots or blood) from individual animals (pets, domestic or game animals) and storing it under ideal conditions. In the case of theft or a dispute over parentage, the system can be used to identify the animal beyond reasonable doubt and the sample that has been stored can be used for comparison with the samples found at the scene of the crime.

Conclusion

The use of DNA technology as a tool contributes to accurate information in breeding programmes. The practical applications illustrated in this paper support all aspects of livestock breeding in Southern Africa.

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Parallel session 5

Animal feeds and nutrition

Biotechnology interventions for increasing the feed resource base and enhancing the efficiency of nutrient utilization

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Abstract
The growing of genetically modified (GM) crops became acceptable in a number of industrialized countries and was promoted from the mid-1990s with the resultant generation of feed ingredients and nutrients that have been fed to livestock since then. GM crops enhanced with traits for herbicide tolerance and protection against insects have been the most widely used as animal feeds. The findings of research trials with GM maize, cottonseed and soybean show them to be similar in composition, digestibility and feeding value for livestock production, to their conventional, non-transgenic counterparts when fed to dairy cattle, sheep and finishing beef steers. For sub-Saharan Africa, Bt (*Bacillus thuringiensis*) maize has the greatest potential as a livestock feed while the benefit of genetic modification of plants for practical use in extensive production systems is, for the moment, questionable.

The use of microbial feed additives is conceivable as feed supplements under grazing conditions if local industrial-scale production of microbial cultures can be guaranteed. In intensive smallholder systems of production dependent on poor quality fibrous diets, enzyme preparations incorporating polysaccharidases, are of value in increasing livestock productivity through more efficient digestion of fibre.

Introduction
Food insecurity will continue to be a pressing challenge for the developing world, particularly in Africa where FAO (2000) estimates that an estimated 138 million of the population suffer from malnutrition. There are reports which indicate that in Zambia, Kenya and South Africa, 85%, 50% and 24 % of the population respectively live below the poverty line or US$ 1 a day (IFAD 2002). Much of this poverty is found among rural people, especially those in remote locations, and where the keeping of livestock is the main source of livelihood. Animal agriculture in these areas includes range and pasture based communally driven extensive livestock production systems in the drier regions and integrated crop–livestock systems in more humid and higher rainfall zones. Stroebel (2004) reported that about 40 million rural people are involved in livestock production in the arid and semi-arid grasslands of sub-Saharan Africa. Their contribution to food production is constrained by many factors among them, overgrazing and overstocking resulting in loss of productivity, and lack of technical know-how and services. Other factors include the non-flexible use of grasslands seen in the adoption of questionable models such as sedentarisation and equilibrium oriented solutions. These constraints notwithstanding, the role of livestock in meeting growing food demands from a deteriorating natural resource base will remain significant. This is because the population of the world is expected to grow from 6 to 7.5 billion between 2000 and 2020 (Rosegrant et al. 2001).

A high rate of increase in the demand for food of animal origin in the next 20 years is predicted for the densely populated areas of sub-Saharan Africa (Delgado et al. 1999). The capacity of the region to increase production of meat and milk will continue to come primarily from ruminant animals reared either in rangelands or in mixed farming systems. This calls for the exploitation

of important areas of innovation, which should include technological change that will affect productive efficiency and growth productivity of both plants and animals. Biotechnology provides a viable option in this regard. It is examined in this paper in relation to increased crop yields (hence crop residues), improved plant quality, feed additives and enhanced efficiency of nutrient, particularly fibre utilisation.

Increased feed resources from improved crop productivity

Residues from crop production are a major source of feeds for livestock. Biomass production from crops will depend largely on optimum conditions of soil fertility, adequate rainfall and resistance to disease and attack by pests. In the past agronomic improvements such as crop rotation, selective breeding that promote desired traits and development of hybrids have contributed to increased yields. These conventional methods are, however, not sufficient to meet the ever increasing demand for food and feed. The application of pesticides, herbicides and chemical fertilisers has helped and indeed led to the green revolution but their, sometimes rampant, use has resulted in the development of resistant crop varieties. In India the use of biological control systems and biofertilisers among farmers has not caught on due to inconsistent results and the cost of efficiency when compared to chemicals (Kembhavi 2005).

Biotechnology, as in recombinant DNA technology, has been used to produce transgenic plants that have resistance to pests, stress and competition for soil nutrients in answer to declining productivity from limited land holdings. In 1996 the USA pioneered and has maintained the lead in the growing of transgenic or genetically modified (GM) crops. As sources of livestock feeds, the relevant GM crops in the northern hemisphere include rapeseed, maize, soybean, cottonseed and potato (Agbios 2005). On a world scale, the GM crop area by country is as follows (James 2003): USA, 42.8 million ha equivalent to 63% of global total under GM crops; Argentina, 13.9 million ha (21%); Canada, 4.4 million ha (6%); Brazil, 3 million ha (4%); China, 2.8 million ha (4%); and South Africa, 0.4 million ha representing 1% of the global total. China and South Africa have registered the highest year-on-year growth rate of 33% in GM crop production (James 2003). South Africa grows GM white maize for food, soybean and cotton and has increased its acreage of maize from 6000 ha in 2001 to 84,000 ha in 2003 (James 2003). Using the figures of Abate and Topps (1992) this is equivalent to an increase from 15,678 tonnes to 219,492 tonnes of stover dry matter (DM) that is available for feeding ruminants in just 2 years. Other developing nations engaged in the growing of one or all of GM maize, soybean and cotton include Bulgaria, Colombia, Honduras, India, Indonesia, Mexico, the Philippines, Romania and Uruguay, (James 2003).

Climatic factors and sometimes implementation of wrong policies have put sub-Saharan Africa into a chronic situation of food shortage. On that account alone the growing of GM maize would be appealing. Moreover, the volume of stover that comes with increased acreage under GM maize would add to the much-needed DM in the continent's mixed production systems. The question that needs answering is whether Bt maize with its highly acclaimed resistance to the European maize borer can withstand water stressed conditions. Perhaps, for sub-Saharan Africa, more attention should be paid to the development of a maize variety that is resistant to drought and to the diseases that commonly affect maize such as the maize streak virus in East Africa.

Animal experiments with GM crops

Genetically modified crops are those plants that have been altered by the insertion of selected genetic material to express traits of agricultural importance. Table 1 gives examples of expressed traits and associated genes (Agbios 2005) that have been incorporated in the production of GM crops.

Table 1. Expressed traits and associated genes in GM crops used as animal feeds (after Agbios 2005).

Trait	Genetic element(s)	Gene source
Insect resistance	Cry1Ab, cry1Ac, cry9c, cry3A, cry1F	*Bacillus thuringiences*
Glufosinate herbicide tolerance	Phosphinothricin N-acetyltransferase	*Streptomyces hygroscopicus* or *S. viridochromogenes*
Glyphosate herbicide tolerance	5-enolpyruvylshikimate 3-phosphate synthase (EPSPS)	*Agrobacterium tumefaciens* strain CP4
Modified seed fatty acid profile	Delta-12 desaturase	*Glycine max* (soybean);
Virus resistance	Coat protein helicase/replicase	Potato virus Y Potato leafroll virus

Maize in its various forms (grain, whole plant fed green, maize silage and stover) and soybean or the residue from its processing are the most commonly used genetically enhanced plant products in the feeding of ruminants and other farm animals. Insecticide resistance and herbicide tolerance are the biotechnological interventions that have been imposed on these crops. The feed evaluation criteria of interest relate to assessing for chemical composition including for amino acids and fatty acids; determining digestibility *in vivo* but also *in vitro* and *in situ*; establishing blood metabolite levels; measuring animal performance such as weight gain and milk production and testing for toxicological effects. These nutritive value experiments have been carried out mostly in the USA, Germany and more recently in France and Argentina. The periods of experimentation ranged from 7 days indoor trails to over 4 months grazing/feeding experiments using mainly factorial, switch back, completely randomised and Latin square designs.

Chemical composition and nutritive value

Clark and Ipharraguerre (2001) reported the results of Brake and Vlachos (1998) in which Bt and non-Bt maize grain fed to broilers showed only minor differences in moisture, ether extract, crude protein, crude fibre, ash and amino acid content (Table 2). Similarly, in Germany, Bt and non-Bt grain (Aulrich et al. 2001) and Bt and non-Bt silages (Aulrich et al. 2001; Bohme et al. 2001) were analysed and found to be substantially equivalent in crude nutrients, amino acids, fatty acids, minerals and non-starch polysaccharides. The similarity in feeding value is regardless of the stage of maturity of the ensiled maize as shown by American work summarised by Clark and Ipharraguerre (2001).

Table 2. Nutrient content of maize grain from Bt and non-Bt hybrids.

Parameter	Non-Bt	Bt
Proximate analysis, %		
Moisture	11.62	12.13
Fat	3.00	3.19
Protein	8.87	8.43
Fibre	2.10	2.20
Ash	0.93	1.02
Amino acids, %		
Threonine	0.31	0.31
Cysteine	0.23	0.23
Methionine	0.21	0.21
Lysine	0.25	00.26

Source: Modified after Clark and Ipharraguerre (2001).

Maize grain and whole plant green chop from maize hybrids that were non-transgenic and glyphosate-tolerant were sampled from multiple sites over a year and analysed chemically (see Clark and Ipharraguerre 2001). The results showed no significant differences in composition between grain and whole green chop from the control parental line and the glyphosate tolerant variety (Tables 3 and 4).

Table 3. Nutrient composition of maize grain from a control parental line and glyphosate line collected from multiple sites in 1997.

Parameter	Control	Glyphosate tolerant	Historical range
Moisture, %	16.21	16.86	9.4-15.8
% DM Protein	10.54	11.05	9.0-13.6
Fat	3.98	3.90	2.4-4-2
Ash	1.56	1.38	1.2-1.8
ADF	6.35	6.35	9.6-15.3
NDF	9.80	9.33	3.1-5.3
Carbohydrates	83.79	83.66	81.7-86.3
Calcium	0.0043	0.0040	0.0029-0.006
Phosphorous	0.326	0.326	0.288-0.363

Source: Modified after Clark and Ipharraguerre (2001).

Table 4. Nutrient composition of whole plant green maize chop from a control parental line and glyphosate line collected from multiple sites in 1997.

Parameter	Control tolerant	Glyphosate range	Historical
Moisture, %	68.73	68.83	68.7–73.5
% DM Protein	7.45	7.49	4.8–8.4
Fat	3.21	1.88	1.4–2.1
Ash	4.26	4.29	2.9–5.1
ADF	25.55	23.85	21.4–29.2
NDF	38.92	37.91	39.9–46.6
Carbohydrates	86.06	86.35	84.6–89.1
Calcium	0.2177	0.2304	NA
Phosphorous	0.2179	0.2178	NA

Source: Modified after Clark and Ipharraguerre (2001).

Analysis of Bt and non-Bt silage made by Donkin et al. (2003) produced no significant differences in chemical composition and estimated rumen degradability for a maize crop harvested in 1999 (Table 5).

Table 5. Chemical composition and estimated rumen disappearance of 1999 Bt and non-Bt maize silages.

Parameter	Bt	Non-Bt
DM, %	38.6 ±1.6	38.7 ± 2.9
% DM CP	7.9 ± 0.6	8.2 ± 0.4
ADF	21.9 ± 1.1	21.2 ± 1.3
NDF	36.9 ± 3.9	35.9 ± 2.5
NSC	47.0 ± 3.7	48.0 ± 3.3
Ca	0.23 ± 0.05	0.24 ± 0.04
P	0.25 ± 0.04	0.24 ± 0.03
Mg	0.18 ± 0.01	0.20 ± 0.01
K	0.89 ± 0.01	0.90 ± 0.04
NE_L, Mcal kg^{-1}	1.67 ± 0.07	1.71 ± 0.09
ERD, %	56.2 ± 0.7	60.0 ± 0.7

Source: Modified from Donkin et al. (2003).

Barriere et al. (2001) determined the digestibility of Bt and non-Bt silages using two sets of six sheep over a 7-day period and reported no significant differences in the digestibility of organic matter (OM), crude fibre (CF), neutral detergent fibre (NDF) and the amount of protein truly digested in the small intestine (PDI) among the hybrids (Table 6).

Table 6. Feeding value of Bt and non-Bt whole plant maize silage fed to sheep.

Parameter	Non-Bt	Bt	F
Non-Bt/Bt			
DMI, g $kg^{-0.75}$	40.2	40.3	0.0
Refusal, % diet	0.6	0.4	0.3
DOM, %	67.1	67.6	0.5
DCF, %	52.9	54.2	1.1
DNDF, %	50.2	49.0	0.8
Net energy, MJ kg^{-1}	6.0	6.0	0.6
PDI, g kg^{-1}	60.7	60.6	0.0

Source: Modified from Barriere et al. (2001).

Clark and Ipharraguerre (2001) reviewed extensive analytical work on soybean seeds and toasted meal from a control parental variety of soybean and a genetically enhanced glyphosate-tolerant line. There were statistical differences between the control and glyphosate-tolerant soybean seeds for some proximate nutrients (Table 7) although these were considered small and biologically unimportant.

Table 7. Proximate, amino acid and fatty acid composition of a control parental line and glyphosate-tolerant soybeans from a 1992 US field trial.

Parameter	Control	Glyphosate tolerant	Literature range
Proximate analysis, %			
Moisture	8.12	8.12	7–11
Protein	41.6	41.4	36.9–46.4
Ash	5.04	5.21*	4.61–5.37
Fat	15.52	16.28	13.2–22.5
Fibre	7.13	6.87	4.7–6.48
Carbohydrates	38.1	37.1*	30.9–34.0
Amino acids, %			
Threonine	1.60	1.56	1.33–1.79
Cysteine	0.60	0.62	0.56–0.66
Methionine	0.55	0.55	0.49–0.66
Lysine	2.61	2.56	2.35–2.86
Fatty acids, %			
18:0	4.09	4.14	2–5.5
18:1 *cis*	19.72	19.74	20–50
18:2	52.52	52.31	35–60
18:3	8.02	8.23	2–13

* Significantly different from the control line ($P<0.05$).
Source: Modified after Clark and Ipharraguerre (2001).

Effect of feeding genetically enhanced crops on animal performance

Fresh whole plant green chop from Bt and non-Bt maize varieties were evaluated in diets fed to 12 lactating Holstein cows over a 14-day period (see Clark and Ipharraguerre 2001). No significant differences among treatments were measured in feed intake, milk production and milk composition and milk urea N (Table 8).

Table 8. Feed intake, milk production and percent milk components from dairy cows fed Bt and non-Bt whole plant green chop maize.

Parameter	Isogenic control	Bt hybrid one	Bt hybrid	SEM two
Feed intake, kg as fed d^{-1}	43.4	44.8	47.0	1.0
Milk yield, kg d^{-1}	40.4	39.5	38.2	1.96
Milk nutrients, %				
Fat	3.41	3.50	3.47	0.183
Protein	2.72	2.66	2.80	0.082
Lactose	4.77	4.78	4.88	0.067
SNF	8.18	8.12	8.37	0.117
Total solids	11.59	11.63	11.84	0.289
Milk urea N, mg dl^{-1}	16.9	17.2	19.4	1.38

Source: Modified after Clark and Ipharraguerre (2001).

Folmer et al. (2002) used a 4 × 4 Latin square design to compare the lactation performance of 16 Holstein cows fed on 4 diets containing 40% maize silage and 28% maize grain from Bt or non-Bt maize harvested from early or late maturing varieties. The Bt trait had no effect in either the early or late maturing maize on DMI, milk yields and milk nutrient contents (Table 9). There was also no effect of the Bt trait on rumen pH, acetate:propionate ratio, or *in situ* digestion kinetics of NDF. In a second experiment, the performance of 67 beef steers grazing stover from the late maturing maize hybrids was measured over 70 days. ADG of steers was similar for those grazing Bt and non-Bt maize stover and the steers exhibited no grazing preference between Bt and non-Bt maize stover (Table 10).

Table 9. Effect of Bt vs. non-Bt maize hybrid on DMI and milk nutrient contents of lactating dairy cows.

Early maturing maize		Late maturing maze		
Parameter	**Bt**	**Non-Bt**	**Bt**	**Non-Bt**
DMI, kg/d	22.8	22.4	23.2	22.7
Milk yield, kg/d	29.2	28.6	28.7	28.5
Milk nutrients, %				
Fat	3.80	3.82	3.70	3.73
Protein	3.54	3.55	3.51	3.52
Lactose	4.90	4.85	4.87	4.80
FCM, kg/d	28.3	27.7	27.4	27.3
FCM/DMI, kg/kg	1.26	1.24	1.19	1.20

Source: Modified from Folmer et al. (2002).

Table 10. Performance and grazing preference of growing steers grazing late maturing Bt and non-Bt maize stover.

Parameter	Bt	Non-Bt	SEM
Initial BW, kg	284	284	0.35
Final BW, kg	301	306	2.0
ADG, per kg	0.24	0.32	0.03
IVDMD, %	33.0	36.0	0.7
Grazing preference, %	47.5	52.5	5.2

Source: Modified from Folmer et al. (2002).

The feeding value of a glyphosate tolerant maize variety was compared (Erickson et al. 2003) in three completely randomised feedlot experiments to that of three non-transgenic hybrids (one near-isogenic control and two reference commercial lines). The experiments lasted 92, 94 and

144 days and involved 175, 196 and 200 steers respectively. In all experiments, DMI, ADG and feed efficiency were similar (P>0.30) between the glyphosate-tolerant maize and the reference hybrids. Steers on the glyphosate-tolerant maize and the control were also similar in growth performance. No treatment differences were observed for carcass weight, longissimus dorsi area and marbling scores.

Donkin et al. (2003) used lactating cows in three experiments to determine the effects of feeding silage and grain from glyphosate-tolerant and insect protected maize hybrids on feed intake, milk yield, milk composition and rumen digestion. In addition, measurements of body weight changes and body condition score (BCS) observations were made. In experiments 1 and 2 cows were fed different proportions of silage and grain from Bt and non-Bt maize hybrids in diets that also contained a protein supplement in switch back designs of 3 periods of 21 days each (Experiment 1) and 3 periods of 28 days each (Experiment 2). Experiment 3 was also a 28-day three-period switch back design with the difference being that the cows received diets containing silage and grain from glyphosate tolerant and non-glyphosate tolerant maize hybrids. Data from experiments 1 and 2 indicated similar DMI, milk production and percentages of protein, lactose, SNF and fat in milk (Table 11). Similarly, glyphosate tolerant and non-glyphosate tolerant diets produced no differences in DMI, milk production and milk composition. Rumen degradation of silages and grain from the genetically enhanced maize and their respective controls were similar. These experiments, demonstrated nutritive value and production efficiency equivalence between genetically modified maize and their controls.

Table 11. Effect of feeding maize silage and maize grain from Bt maize and its non-transgenic counterpart on feed intake, milk production and composition.

Parameter	Bt	Non-Bt	SE
DMI, kg/d	24.1	24.3	0.4
Milk yield, kg/d	35.2	35.6	0.5
Efficiency (Milk:DMI, kg/kg)	1.44	1.41	0.5
Milk nutrients, %			
Fat	3.67	3.60	0.04
Protein	3.14	3.10	0.02
Lactose	4.64	4.62	0.02
SNF	7.71	7.67	0.04

Source: Modified from Donkin et al. (2003).

French studies (Barriere et al. 2001) have shown that Bt maize and its conventional isogenic hybrid, fed as whole plant maize silage, were substantially equivalent in feeding value when tested using dairy cattle. In the first trial, 2 sets of 24 Holstein cows were fed silage from the same above sources 9 weeks after calving for 13 weeks. Fat corrected milk (FCM) yield, (31.3 and 31.4 kg/d) protein content (31.7 and 31.6 g/kg) and fat content (36.7 and 37.0 g/kg) in milk were unaffected by maize hybrid source. In the third trial, 5 mid-lactation multiparous Holstein cows were successively fed Bt and non-Bt silages for 2 or 3 weeks without significant effects on protein fractions, fatty acid composition or coagulation properties of milk.

Forty German Holstein bulls, each about 5.5 months old, with an initial weight of about 188 kg were assigned to 2 groups of 20 each to a diet of either Bt or non-Bt maize silage and offered a constant amount of concentrate for a period that lasted until they weighed about 550 kg (Daenicke et al. 1999 cited in Clark and Ipharraguerre 2001). On a DM basis bulls fed the Bt silage consumed significantly (P<0.05) less total feed and energy than those fed non-Bt silage (Table 12). There were, however, no differences between bulls fed the two maize silage sources for average daily gain (ADG), hot carcass weight, dressing percentage and abdominal fat. For more on beef and

sheep performance trials see Agricultural Biotechnology Stewardship Technical Committee (2005).

Table 12. Feed intake and performance of Holstein bulls fed Bt or non-Bt maize silages and concentrate.

Parameter	Non-Bt	Bt
Feed intake		
Concentrate, kg/d	1.78	1.80
Maize silage, kg/d	18.8	18.7
DMI, kg/d	8.00[a]	7.78[b]
MEI, MJ/d	91.2[a]	88.6[b]
Performance		
Final BW, kg	537.0	534.5
ADG, g/d	1487	1482
Hot carcass weight, kg	281.3	282.0
Dressing, %	52.4	52.8
Abdominal fat, kg	49.6	48.7

Source: Modified after Clark and Ipharraguerre (2001).

Castillo et al. (2004) fed rations containing different sources of GM whole cottonseed to 24 Argentinean Holstein dairy cows 53 days into lactation and weighing on average 565 kg to evaluate DMI, milk yield and milk composition using replicated 4 x 4 Latin squares. Treatments in Experiment 1 included 2 Bt cotton varieties, 1 glyphosate-tolerant cotton and a control that was a non-genetically modified but genetically similar cottonseed. In Experiment 2 two commercial sources of cotton, a parental control line and a transgenic cotton containing genes for both insect and herbicide resistance were used as treatments. Cottonseed was included at about 10% in the total ration, which also contained alfalfa hay, maize silage, maize grain, soybean meal and a mineral vitamin mix. DMI, milk yield, milk composition, body weight and body condition score did not differ among treatments (Tables 13 and 14).

Table 13. Effect of whole cottonseed (WCS) from varieties with and without expression for insect resistance and glyphosate tolerance on milk yield and milk composition.

Parameter	Control	Bt_1	Bt_2	Glyphosate tolerant	SE
Milk yield, kg/cow per d	26.9	26.7	27.6	27.4	2.9
Milk yield, %					
Fat	3.59	3.60	3.52	3.59	0.19
Protein	3.15	3.14	3.14	3.13	0.07
Lactose	4.97	5.01	5.04	5.00	0.06
SNF	8.84	8.91	8.96	8.90	0.10
MUN, mg/100 mL	18.77	19.49	20.66	20.01	1.96
BCS[1]	2.30	2.30	2.30	2.34	0.08

[1]BCS of 1 (thin cow) to 5 (fat cow).
Bt_1 and Bt_2 varieties contain different insect resistant genes.
Source: Modified after Castillo et al. (2004).

Table 14. Effect of whole cottonseed (WCS) from an insect resistant and glyphosate tolerant variety and two commercial varieties on milk yield and milk composition.

Parameter	Control	Transgenic[1]	Com_1	Com_2	SE
Milk yield, kg/cow per d	27.5	26.5	26.8	27.4	2.2
Milk yield, %					
Fat	3.32	3.35	3.36	3.24	0.13
Protein	3.16	3.20	3.15	3.11	0.09
Lactose	4.83	4.83	4.86	4.86	0.09
SNF	8.72	8.77	8.73	8.71	0.12
MUN, mg/100 mL	17.10	14.71	15.65	16.63	0.10
BCS[1]	2.34	2.25	2.31	2.36	0.08

[1]BCS of 1 (thin cow) to 5 (fat cow).
Transgenic[1] variety contains both insect resistant and glyphosate tolerant genes.
Source: Modified after Castillo et al. (2004).

The effect of feeding a glyphosate-tolerant maize and a hybrid protected against maize rootworm was compared for DMI and milk production with Holstein cows against feeding a non-transgenic hybrid and two commercial reference lines in replicated 4 x 4 Latin squares (Grant et al. 2003). In Experiment 1 with 16 cows, the four diets contained 40% of either 1) glyphosate-tolerant maize silage, 2) non-transgenic control maize silage, or 3) two non-transgenic reference hybrids and were fed over 28-day periods. Each diet also contained 23% of maize grain from the same hybrid that supplied the silage. There was no effect of the glyphosate-tolerant maize diet on milk composition or efficiency of 4% FCM production that averaged 1.43 kg/kg DMI for all diets. In Experiment 2 16 cows were assigned to 1 of 4 treatments in replicated 4 x 4 Latin squares with 21 d periods. Diets contained 26.7% maize grain from either 1) maize rootworm protected maize hybrid, 2) non-transgenic control maize hybrid or 3) the same two non-genetically enhanced reference hybrids used in Experiment 1. The 4% FCM yield (34.8 kg/d) and DMI (4.06% of body weight) were unaffected by diet as was the efficiency of FCM production which averaged 1.32 kg/kg DMI.

Effect of microbial feed additives, microbial enzymes and ionophores

Live cultures of *Aspergillus oryzae* and *Saccharomyces cerevisiae* microbes and their extracts have recently been used to manipulate fermentation to the benefit of ruminant animals. Improvements in liveweight gain and milk production are in the order of 7–8% because of improved feed intake (Wallace 1994). It is argued that microbial feed additives increase anaerobic conditions and therefore cellulolytic bacteria resulting in an improved rate of fibre digestion and improved protein flow from the rumen (Wallace 1994) (Figure 1).

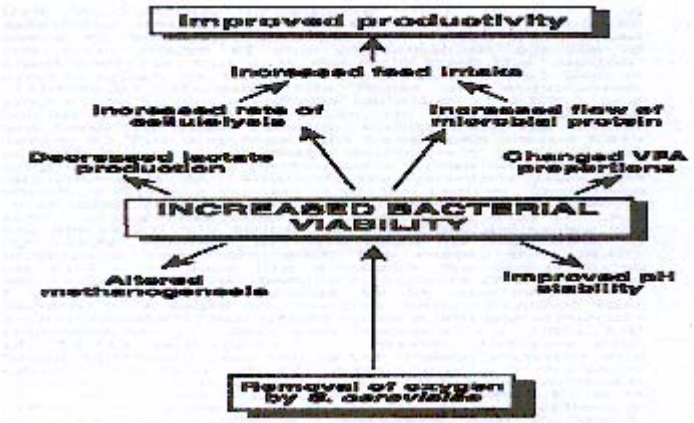

Figure 1. Suggested mode of action of yeast culture.
Source: Wallace (1994).

Similarly, dietary ionophores such as monensin, lasalocid, salinomycin etc. slow down ammonia production and alter ruminal fermentation in such a way as to provide, on average, an improvement in the efficiency of feed utilisation of about 7.5% (Wallace 1994). In the high rainfall areas of Kenya, smallholder farmers using semi-zero-grazing systems feed at least about 0.5 kg DM of an energy concentrate to dairy cows at milking (Abate et al. 1988). Such a concentrate would make an ideal carrier for microbial feed additives and ionophores. However, the investment for a local industrial-scale production of microbial cultures would need to be secured first to make such a proposition viable in terms of cost and availability to small-scale farmers. In extensive grazing systems there are opportunities for the incorporation of additives in compounded feed preparations that may be used as supplements to animals on pasture or range.

It is possible today to produce large quantities of enzymes from GM micro-organisms for inclusion in animal diets. The technology was, however, developed for enzyme combinations that targeted European diets based on wheat and barley (Kembhavi 2005). For sub-Saharan Africa where animals are dependent on unimproved pastures, crop residues and browse, the enzyme products of interest would be polysaccharidases and in particular xylanases, mannanases and endoglucanases because they have powerful fibrolytic activity and ability to hydrolyse very resistant cell wall polymers. The breakdown of fibre will increase the overall nutritional value of consumed roughages through release of more energy and increased protein digestibility as a result of uninhibited access to within-cell nutrients. The incorporation of polysaccharidases into crop residues like maize stover is a development that is worth exploring. Beauchemin et al. (2004) advocate the development of more effective enzyme products for ruminants.

Modifying rumen microflora and plants

Molecular techniques have contributed immensely to the understanding of the involvement of rumen microbial enzymes in feed digestion and fermentation. According to Bowman and Sowell (2003) over 100 different genes encoding enzymes for fibre digestion have been identified in rumen bacteria (e.g. *Fibrobactor succinogenes*, *Ruminococcus albus*) and at least 30 genes in rumen fungi. Progress has also been made in developing suitable gene transfer systems for the introduction of new DNA into rumen species. Because of their high population a number of experiments have targeted bacteria (e.g. *Butyrivibrio fibrisolvens*) for the expression of new or enhanced genetic material from fungal sources (e.g. *Neocallimastix patriciarum*) within the rumen environment. This has usually resulted in the increased ability of the recombinant bacteria to digest fibre. However, their successful establishment in the rumen environment still remains a hurdle to be overcome. Similarly, molecular approaches designed to produce plants with less lignin, increased pectin, moderate levels of condensed tannins and high levels of protein with reduced rumen degradability are yet to be successfully implemented. Indeed, genetic modification of plants is questionable, for the moment, in the extensive production systems of sub-Saharan Africa that are so rich in biodiversity.

Conclusions and recommendations

The experiments reviewed have shown that GM crops expressing insect resistance and herbicide input traits have satisfied the conventional feed evaluation criteria and are the most widely used in the feeding of animals. There is, currently, no evidence of significantly altered chemical composition, nutritional attributes or negative effects on production resulting from the use of GM crops as animal feeds. For sub-Saharan Africa, Bt maize has the greatest potential for use as livestock feed because it is also a direct source of food for humans. Long-term feeding experiments (3–5 years) with the same animals would be more reassuring particularly for policy makers who ultimately have to take the decision on the use of GM crops. For grazing animals, there are opportunities for the incorporation of microbial feed additives as feed supplements. However, local industrial-scale production of microbial cultures is necessary for the technology to be cost

effective. Enzyme preparations incorporating polysaccharidases, if produced cheaply, can be utilised in intensive smallholder systems of production dependent on poor quality high fibre diets such as maize stover. For the moment, the benefit of genetic modification of plants for practical use in extensive production systems of sub-Saharan Africa is questionable.

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Effects of aromatic amino acids and phenyl acids (phenylacetic and phenylpropionic) on rumen fungi, *Neocallimastix frontalis* RE1 and *Piromyces communis* P, fermenting xylan

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Abstract
The influence of aromatic amino acids (AA) as a group and phenyl acids (phenylpropionic and phenylacetic) on growth and yield of the rumen anaerobic fungi, *N. frontalis* RE1 and *P. communis* P, were investigated. The organisms had oat spelts xylan (as the only energy source) and ammonia (NH_3), in the presence or absence of a mixture of 20 AA or the same mixture with aromatic AA deleted but with or without phenyl acids. Highest growth was observed in treatments that had a complete mixture of AA. Acetate was the major volatile fatty acid (VFA) produced by both species. The supply of complete AA mixture increased ($P<0.05$) acetate by 18% and 15%; sugar utilisation by 33% and 22%; and microbial yield by about 22% and 15% in *N. frontalis* and *P. communis* cultures respectively compared to treatments that had NH_3 as the only nitrogen (N) source. Compared to treatment with complete AA mixture, neither the deletion of aromatic AA from the complete mixture nor the supply of phenyl acids influenced VFA production, sugar utilisation and microbial yields in both species. It was concluded that complete mixtures of AA stimulate xylan utilisation, microbial growth and yield of *N. frontalis* RE1 and *P. communis* P, and that these organisms do not have absolute requirement for aromatic AA.

Key words: aromatic amino acids, phenylacetic acid, phenylpropionic acid, rumen fungi, xylan

Introduction
Previous studies indicate that aromatic amino acids (AA) may limit growth and fermentation of mixed rumen micro-organisms (Atasoglu et al. 2003; Guliye et al. 2005). Pure culture studies also suggest that phenylalanine, one of the aromatic AA, to be essential for the growth of bacterial species such as *Ruminococcus* (Allison 1965) and *F. succinogenes* (Allison 1965; Atasoglu et al. 2001). Rumen fungal strains of *Neocallimastix* also showed reduced growth when aromatic AA were omitted from a mixture of 18 amino acids (Onoda et al. 1996), and achieved maximum growth when a complete mixture of 18 amino acids were supplied (Orpin and Greenwood 1986; Onoda et al. 1996).

Xylan, a predominant polymer in hemicellulose, comprises a significant portion of ruminant livestock diets. The bulk of xylan digestion occurs in the rumen, carried out by a number of rumen microbes. The anaerobic rumen fungi, such as *Neocallimastix frontalis* and *Piromyces communis*, contribute significantly to xylan degradation in the rumen (Hespell and Whitehead 1990). The precursors for the synthesis of aromatic AA (notably phenylalanine), phenylacetic acid (PAA) and phenylpropionic acid (PPA), are thought to be beneficial to mixed populations of rumen bacteria and protozoa (Scott et al. 1964; Amin and Onodera 1997). These phenyl acids, PAA and PPA, have also been reported to not only stimulate growth but also improve cellulose degradation by *Ruminococcus albus* (Allison 1965; Hungate and Stack 1982; Morrison et al. 1990). The aim of this experiment, therefore, was to assess the influence of aromatic AA on pure

cultures of the rumen anaerobic fungi, *N. frontalis* strain RE1 and *P. communis* strain P, provided with oat spelts xylan (OSX) as the only energy source. The effect of addition of phenyl acids (PAA and PPA), as substitute for aromatic AA, was also assessed.

Materials and methods

Organisms

The rumen fungal species used were *N. frontalis* strain RE1 and *P. communis* strain P, obtained from the culture collection at the Rowett Research Institute, Aberdeen (UK).

Media and growth conditions

The organisms from stock cultures were initially grown overnight in an incubator (39°C) in 10 ml of anaerobically prepared M2 medium (Hobson 1969), and then inoculated (5% vol/vol) into 100 ml wheaton bottles containing a defined medium of modified Hungate and Stack (1982), modified to include 0.3% (wt/vol) OSX as the only energy source. The cultures were then grown overnight in an incubator at 39°C and used as inoculant. The inoculant cultures were inoculated (5%, vol/vol) into triplicate wheaton bottles with 100 ml fresh modified Hungate and Stack medium, prepared under anaerobic conditions and according to treatment specifications, placed in a shaking water bath at 39°C and grown until stationary phase was reached. All the media (growth and inoculant) contained 0.05% (wt/vol) agar for the fungi to attach to as they grow (Richardson et al. 1998). This was found to prevent clumping, making it easier to sub-sample.

Treatments

There were 5 treatments, based on nitrogen (N) source and addition of phenyl acids: a) ammonia only (no AA); b) ammonia plus complete mixture of 20 AA commonly found in protein (CAA); c) ammonia plus complete mixture of 20 AA with aromatic AA omitted (MAR); d) ammonia plus phenyl acids (no AA+PA); and e) ammonia plus complete mixture of 20 AA with aromatic AA omitted, plus phenyl acids (MAR+PA). The concentration of ammonia, supplied in form of ammonium chloride (NH4Cl) to all treatments, was 10 mM. AA was added to a final concentration of 0.25 g/l for each AA. PAA and PPA were added, where applicable, to a final concentration of 10 mM and 25 mM respectively. Treatments where PAA and PPA were not included had the same volume of distilled water added instead. The N sources for the different treatments, (ammonia and AA) and phenyl acids (PAA and PPA), were added to the solutions during media preparation.

Experimental measurements

Samples were obtained anaerobically (via the septum rubber seal), using sterile needles and syringes, from the Wheaton bottles after shaking at the start (0 h, 10 ml), during (2 ml, at 4, 8, 12, 18, 24 and 30 h) and at the end (10 ml at 36 h) of the experiment. Two millilitres of the collected samples were used for protein determination using the Bradford assay (Bradford 1976), after sonicating and solubilising in 0.5 M NaOH, to monitor microbial growth. The remaining parts of the 0 h and stationary phase (36 h) samples were kept frozen and later used for the determination of volatile fatty acids (VFA), ammonia, sugar utilisation and total cell N (TCN) as described by Guliye et al. (2005).

Data analysis

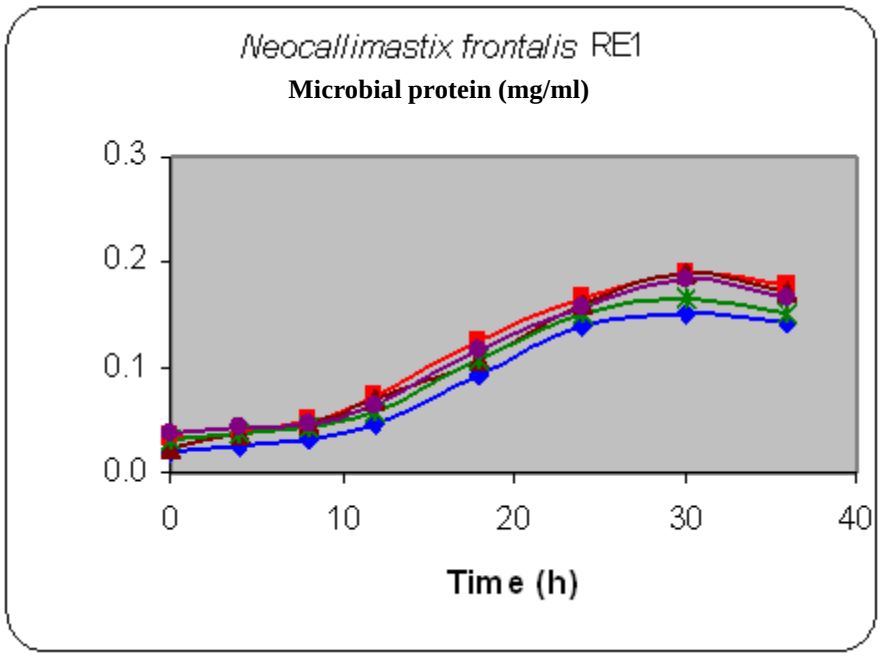
Results are all means derived from the analysis of triplicate cultures. Growth curves were plotted for each organism. Net values were also calculated (36 h concentration–0 h concentration) for VFA, ammonia, sugar utilisation and TCN. Microbial yield (expressed as g N/kg sugar utilised) was calculated from net microbial N synthesis (TCN) and the net sugar utilisation. The data were analysed by ANOVA, with N source and phenyl acids addition as treatment effects, using Genstat

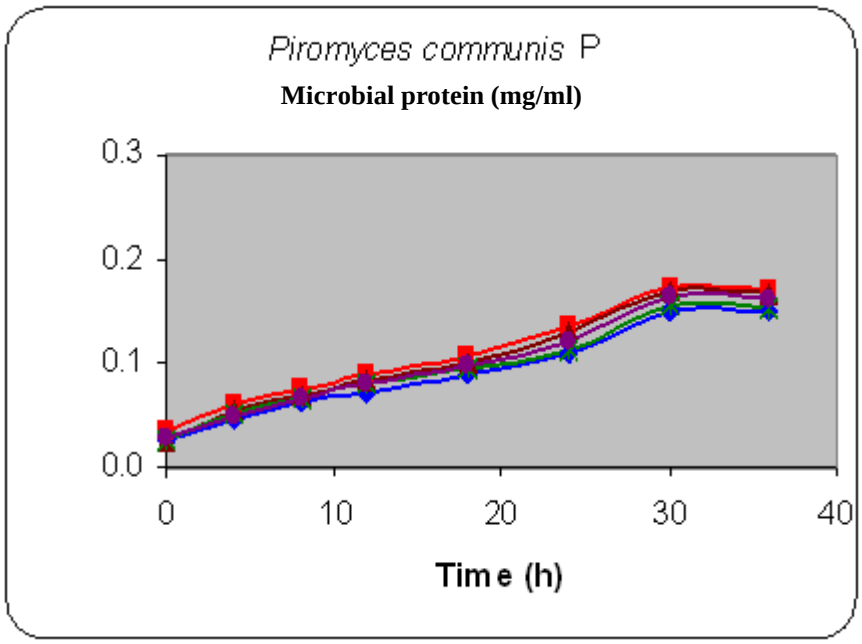
programme 6.1 (Lawes Agricultural Trust, Rothamsted Experimental Station, Harpenden, Herts, UK).

Results

Fungal growth

The fungal species from the stock cultures grew well in M2 medium. Good growth was also observed in the inoculum. Both species were able to grow in the final growth medium of modified Hungate and Stack (Figure 1).





Note: Data points represent mean values from triplicate cultures.

Figure 1. Time course measurement of fungal growth on xylan, in the presence of ammonia only – no AA **(◆)**; complete AA mixture – CAA **(■)**; complete AA mixture minus aromatic AA – MAR **(▲)**; ammonia only plus phenyl acids – no AA+PA **(✳)**; and complete AA mixture minus aromatic AA plus phenyl acids – MAR+PA **(●)**.

Volatile fatty acids and ammonia

Table 1 shows VFA and ammonia produced by the end of the organisms' growth phase. Acetate was the major VFA produced by both fungal species. None of the species produced propionate, butyrate and caproate, irrespective of treatments. The supply of complete AA mixture (CAA treatment) significantly ($P<0.05$) increased acetate concentration, compared to no AA treatment, by 18% and 15% in *N. frontalis* RE1 and *P. communis* P cultures respectively. Although valerate was not significantly influenced by the addition of complete mixtures of AA in *N. frontalis* RE1, there was a threefold increase in *P. communis* P (Table 1). None of the treatments influenced iso-butyrate production by *P. communis* P.

Table 1. Effects of aromatic AA and [1]phenyl acids on volatile fatty acids (VFA) (mM) and ammonia (mg/l) production by species of rumen fungi fermenting xylan.

		Treatments					
Organism	**Measurement**	**no AA**	**CAA**	**MAR**	**no AA +PA**	**MAR +PA**	**SEM**
Neocallimastix frontalis RE1	Acetate	5.58^{a}	6.60^{b}	6.44^{b}	5.67^{a}	6.43^{b}	0.15
	Valerate	$0.01^{a,b}$	0.02^{b}	0.01^{a}	0.02^{b}	$0.01^{a,b}$	0.01
	iso-valerate	0.02^{a}	0.04^{b}	0.04^{b}	$0.03^{a,b}$	$0.03^{a,b}$	0.01
	Ammonia	-16.1^{a}	42.2^{b}	39.3^{b}	-15.7^{a}	40.8^{b}	1.58
Piromyces communis P	Acetate	4.68^{a}	5.37^{b}	$5.00^{a,b}$	4.59^{a}	5.35^{b}	0.17
	Valerate	0.01^{a}	0.03^{b}	0.02^{b}	0.01^{a}	0.03^{b}	0.01
	iso-butyrate	0.01	0.02	0.02	0.02	0.03	0.01
	Ammonia	-13.7^{a}	39.0^{b}	37.8^{b}	-13.4^{a}	35.1^{c}	0.85

[1]Phenyl acids = Phenylacetic acid (10 mM) and Phenylpropionic acid (25 mM). Values are means calculated from triplicate cultures. Means in the same row with different superscripts differ ($P<0.05$). Propionic, butyric and caprioic acids were not detected in all treatments for both cultures.

The deletion of aromatic AA from a complete AA mixture (MAR treatment) did not greatly influence VFA production in both species, compared to CAA treatment (Table 1). Similarly, the addition of phenyl acids to a medium that contained only ammonia as the sole N source did not significantly influence VFA production. Likewise, except for acetate that showed a 14% increase in *P. communis* P, the addition of phenyl acids to a medium that had complete AA mixture with aromatic AA deleted (MAR+PA treatment) did not have significant effect on the yields of the other VFA in both species (Table 1).

Sugar utilisation

The amount of sugar utilised, out of the xylan (3 g/l) provided, is presented in Table 2. The quantity of sugar utilised by the organisms was generally comparable. There was increased sugar utilisation, by 33% and 22% in *N. frontalis* RE1 and *P. communis* P cultures respectively in CAA treatment. However, the deletion of aromatic AA from a complete mixture did not significantly influence the amount of sugar utilised by the fungal species. Also, the addition of phenyl acids, either to no AA or MAR treatments, did not have a significant effect on sugar utilisation by the organisms (Table 2).

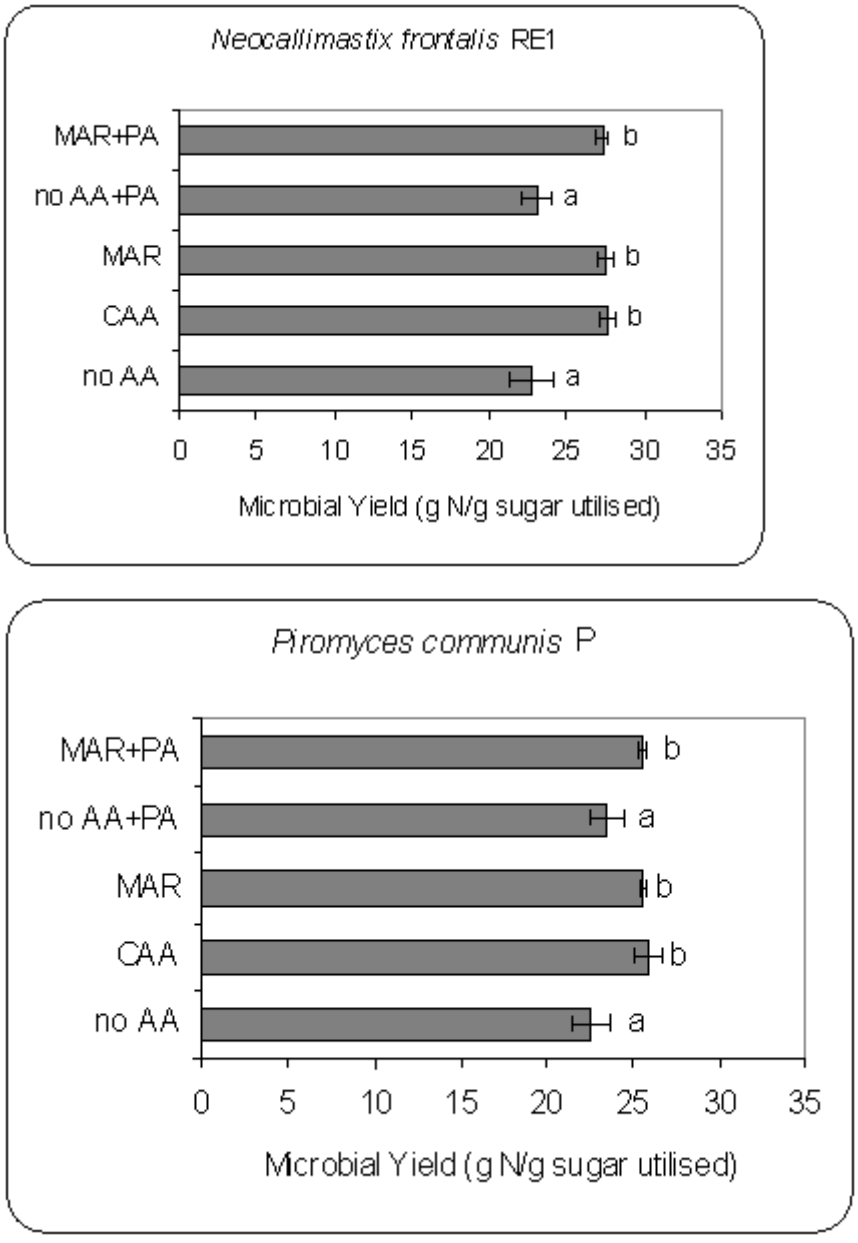
Table 2. Effects of aromatic AA and phenyl acids[1] on sugar (xylan) utilisation by species of rumen fungi.

		Treatments					
Organism	Sugar utilised	no AA	CAA	MAR	no AA +PA	MAR +PA	SEM
Neocallimastix frontalis RE1	g/l	0.91^{a}	1.21^{b}	1.16^{b}	1.00^{a}	1.16^{b}	0.03
	%	30	40	39	33	39	
Piromyces communis P	g/l	0.87^{a}	1.10^{b}	1.09^{b}	0.86^{a}	1.10^{b}	0.02
	%	29	37	36	29	37	

[1]Phenyl acids = Phenylacetic acid (10 mM) and Phenylpropionic acid (25 mM). Initial sugar (xylan) added at 0.3% (wt/vol). Values are means calculated from triplicate cultures. Means in the same row with different superscripts differ ($P<0.05$).

Microbial yield

Figure 2 is a presentation of microbial yield (g total cell N/kg sugar utilised) of the fungal organisms grown to 36 h. The calculated microbial yield values in no AA and CAA treatments were 22.7 and 27.7 for *N. frontalis* RE1; and 22.5 and 25.9, for *P. communis* P. Microbial yield increased significantly ($P<0.05$), by about 22% and 15% for *N. frontalis* RE1 and *P. communis* P cultures respectively when the organisms were provided with a complete mixture of AA (CAA treatment), as opposed to only ammonia as N source (no AA treatment).



Note: The bars (with SE error bars at the top) represent means calculated from triplicate incubations. Bars with different letters are significantly different ($P<0.05$).

Figure 2. The influence of aromatic AA and phenyl acids (phenylacetic and phenylpropionic acids) on microbial yield of rumen fungi fermenting xylan, grown to 36 h.

The deletion of aromatic AA from a complete AA mixture (MAR treatment) did not influence microbial yields of both organisms (Figure 2). Similarly, the addition of phenyl acids to no AA or MAR treatments did not have a significant effect on microbial yields of both species.

Discussion

The study was intended to provide an indication of the importance of aromatic AA and phenyl acids as possible means of improving ruminant nutrition by stimulating ruminal fermentation. The main responses measured in this study were the effects of the aromatic AA phenyl acids of on growth rate, sugar utilisation, VFA and ammonia production and microbial yield.

Growth and sugar utilisation

In this study, both fungal strains were able to grow on the xylan substrate (Figure 1), though *N. frontalis* RE1 showed slightly better growth than *P. communis* P. Previous studies have also demonstrated the ability of both species to utilise xylan as a sole energy source (Mountfort and Asher 1989; Yanke et al. 1996). The supply of complete AA mixtures to a medium that contained ammonia as the only N source appeared to stimulate the growth of *N. frontalis* RE1 more than *P. communis* P (Figure 1), and this may be due to better AA uptake and also higher percentage of sugar utilised (33% vs. 22%, for *N. frontalis* RE1 and *P. communis* P respectively) (Table 2). Although ruminal fungi can use ammonia as the only source of N for the growth (Orpin and Greenwood 1986; Onoda et al. 1996; Atasoglu and Wallace 2002), it has been demonstrated that the provision of AA greatly stimulates growth (Orpin and Greenwood 1986; Onoda et al. 1996).

The deletion of aromatic AA from a complete mixture did not influence either fungal growth or the amount of sugar utilised (Figure 1; Table 2), suggesting these organisms do not have absolute requirement for aromatic AA. This observation is contrary to the findings of Onoda et al. (1996) where aromatic AA omission from a mixture of 18 amino acids led to decreased growth of a *Neocallimastix* spp. N13. The different observations could be attributed to strain differences and type of energy source used. While xylan was used as energy source in our study, Onoda et al. (1996) used cellobiose. The growth curve and sugar utilisation data (Figure 1; Table 2) observed for both species, when phenyl acids were supplied, supports the contention that there is no influence of phenyl acids on growth and sugar utilisation of *N. frontalis* RE1 and *P. communis* P. This perhaps suggests that the organisms do not require these acids to synthesise aromatic AA.

Volatile fatty acids and ammonia

Acetate was the principal VFA produced by both fungal species perhaps suggesting acetyl CoA as the main metabolic route during the fermentation process. Lowe et al. (1987) also reported acetate as the major end product of xylose fermentation by *Neocallimastix* spp. Borneman et al. (1989) observed acetate, formate, lactate, succinate and ethanol as the main end products of anaerobic fungi fermentation of hexoses, and that propionate and butyrate were not produced, an observation also shared by Wallace and Joblin (1985). In addition to the fermentation acids, significant quantities of carbon dioxide (CO_2) and hydrogen (H_2) were also produced during growth. It has been suggested that *Piromyces* spp. strain E2 converted xylose via the combined action of xylose isomerase and a D-xylulokinase, to xylulose-5-phosphate (a key intermediate in pentose metabolism), similar to bacteria (Harhangi et al. 2003). The increase in acetate in this study resulting from the supply of complete mixtures of AA may be a result of increased fermentation and utilisation of the energy substrate (Table 2). Both aromatic AA and phenyl acids seem not to be important in VFA production by *N. frontalis* RE1 and *P. communis* P when fermenting xylan. Perhaps this is a reflection of the lack of effects on sugar utilisation noted before (Table 2).

The ammonia production resulting from the provision of AA, either as complete mixture or mixtures without aromatic AA (Table 1), suggest that both fungal species have the ability to degrade AA. Anaerobic rumen fungi (e.g. *Neocallimastix* and *Piromyces* spp.) have been reported to possess proteolytic ability (Wallace and Joblin 1985; Asao et al. 1993), unlike ruminal

cellulolytic bacteria, that enables them to breakdown the protein-carbohydrate matrix that limits the access of the cellulolytic bacteria to the secondary cell wall (Engles et al. 1985). Ruminal fungi have also been reported to have aminopeptidase activity (Michel et al. 1993), although its significance either to mixed population or to individual fungal species is yet unclear. The study by Atasoglu and Wallace (2002) on *de novo* synthesis of AA by *N. frontalis* RE1 and *P. communis* P utilising cellobiose as an energy source reported small amounts of ammonia produced from the catabolism of AA. None of the organisms tested here appear to be influenced by either deletion of aromatic AA from a complete mixture or supply of phenyl acids.

Microbial yield

Complete mixtures of AA stimulated *N. frontalis* RE1 and *P. communis* P, as shown by the increased yields of both organisms, compared to no AA treatment (Figure 2). However, the yields of *N. frontalis* RE1 and *P. communis* P in treatments that had AA additions, either as complete mixture or mixtures with aromatic AA omitted, were approximately 8% and 14% lower respectively than the mean yield (30 g microbial N/kg organic matter digested) reported by ARC (1980). Treatments that had only ammonia as N source had almost 24% lower yields compared with the ARC (1980) value, though within their range. As noted earlier, the supply of complete mixtures of AA increased sugar utilisation, and might explain the increase in microbial yields, compared to ammonia treatments. Orpin and Greenwood (1986) observed that supplementation with individual AA increased the growth yield of *N. patriciarum* by between 140% and 290%. However, they added AA at a concentration of 5.0 mg/ml, far more than the 0.25 mg/ml in the present experiment.

Xylan degradation was incomplete for both fungal species tested, suggesting that the carbohydrate composition of the residual xylan may be recalcitrant to further hydrolysis and that the growth of the organisms was probably terminated as a result. Studies on the rumen bacterium *R. albus* 8 suggest that xylose accumulation may cause cessation of xylan degradation and growth (Reveneau et al. 2003). However, no xylose measurements were done in this study.

In conclusion, the supply of complete mixtures of AA stimulates xylan utilisation, microbial growth and yield of *N. frontalis* RE1 and *P. communis* P. Neither the deletion of aromatic AA from a complete mixture nor the supply of phenyl acids (PAA and PPA) influences xylan utilisation and growth/yield of *N. frontalis* RE1 and *P. communis* P. The supply of phenyl acids, therefore, could not be substituted for aromatic AA.

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Enhancing the nutritional value of whole cassava root meal by fermentation with rumen filtrate

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Abstract
An *in vitro* study was conducted in which mashed unpeeled whole cassava root was fermented in airtight plastic packs for durations of 0, 24, 48, 72 and 96 hours with nitrogen sources of caged layer waste (CLW), pig excreta (PE) and 1:1 mix of CLW and PE of levels of 0, 25, 50 and 75 g/kg using bovine rumen filtrate as inoculum. Crude protein and ether extract values significantly (P<0.01) increased with fermentation duration. Peak protein yields of 13.58%, 12.46% and 12.87% were obtained for cassava fermented with CLW, PE and 1.1 mix of CLW and PE respectively. Dry matter, crude fibre, ash calcium, phosphorus and HCN were significantly (P<0.05>) reduced with prolongation of fermentation. Based on proximate composition and HCN content, cassava fermented for 72 hours with the nitrogen sources inclusion rate of 75 g/kg were considered as the best three samples out of the 60 samples analysed.

Key words: cassava root meal, caged layer waste, pig excreta, rumen filtrate, fermentation

Introduction
The ever-rising cost and chronic shortages of traditional feed resources have hampered attempts at expanding the animal production industry in the developing nations of the tropics. Seasonal and unreliable rainfall, marginal soil fertility and subsistence farming leave these nations with erratic supplies of locally grown cereals and protein feeds (Ravindran 1993; Baker 1995). In the last 15 years, many research efforts were invested in the search for alternative energy sources for poultry (Eruvbetine et al. 2003). One such alternative is cassava.

The potential of cassava as a feed ingredient notwithstanding, cassava has a low protein content hence the need to find methods of increasing the protein yield of cassava is important. Noomhorm et al. (1992) reported that the conversion of a part of the starch in cassava root mash (CRM) to protein by microbes during the process of solid-state fermentation has great potential as a means of improving the feeding value of CRM. A wide array of micro-organisms, especially fungi, bacteria and yeast has been used by various workers to upgrade the protein quality and quantity of CRM. One way of looking at the issue of micro-organisms available at the farming community level is to investigate potential sources of beneficial micro-organisms. One of these sources is the rumen. Bovine rumen content (BRC) is an abundant abattoir (Adeyemi and Familade 2003). Abasiekong (1991a; 1991b) reported an improvement in the protein content of spent sorghum grain when re-fermented with some selected rumen micro-organisms. The author reported further that a similar result was obtained when fresh rumen filtrate (or rumen liquor) was used directly.

Noomhorm et al. (1992) explained that the addition of nitrogenous sources would provide the necessary nutritional requirements for the micro-organisms introduced into the cassava substrate. Recognising the above therefore, the study reported herein was carried out to investigate the use of caged layer waste (CLW) and pig excreta (PE), which are two readily available farm animal wastes, as nitrogenous sources for enrichment of cassava using fresh rumen filtrate.

Materials and method

Collection and processing of nitrogenous sources

Aliquots of rumen content of freshly slaughtered and eviscerated cattle were collected and the liquid portion filtered through a sieve for immediate use in the fresh state. Droppings from commercial layers devoid of feathers and broken shells were sun dried on a concrete platform to a moisture level of <6%, milled in a blender and stored as CLW. Fresh pig excreta was collected from growing/finishing pigs (60–80 kg live weight) raised in standard pig pens and fed a wet brewers grains/palm kernel cake based diet. The excreta was bulked, sun dried on a concrete platform to a moisture content of <6%, milled and stored till time of use.

Fresh cassava roots (12 months old, variety TMS30572) were washed to dislodge all adhering soil and mashed whole (unpeeled) using a petrol-operated grater. The cassava root mash was placed on a perforated tray, steam gelatinised over a water bath for 30 minutes and cooled. A total of 500 g of the gelatinised cassava root mash were placed in 60 plastic containers of 2 litre capacity mixed with the various nitrogen sources (S) (caged layer waste, pig excreta and 1:1 mix of caged layer waste and pig excreta) at the graded rates (L) of 0, 25, 50 and 75g/kg. The contents of each of the 60 plastic packs were sprayed with 100 ml of rumen filtrate and made airtight with petroleum jelly and fermented for durations (D) of 0, 24, 48, 72 and 96 hours.

Proximate and chemical analysis

The oven-dried samples were analysed for residual moisture and other proximate fractions using the methods of AOAC (1995). Cyanogenic glucoside was estimated by determining the amount of hydrogen cyanide (HCN) released on hydrolysis using the method described by Rao and Hahn (1984).

Statistical analysis

All data collected were subjected to statistical analysis appropriate for 3 x 4 x 5 factorial design using Minitab Analytical computer package (Minitab Inc. 1999). Significant means were separated using Duncan's multiple range test (Duncan 1955).

Results

The main effects of nitrogen source and level of nitrogen source on proximate fractions of whole cassava root mash (CRM) fermented with rumen filtrate are shown in Table 1. The duration of fermentation and the interactive effects of nitrogen source x level of nitrogen source, level of nitrogen source × duration of fermentation, nitrogen source ×duration of fermentation and nitrogen source ×level of nitrogen source ×duration of fermentation are presented in Table 2.

The dry matter (DM) fraction exhibited a decreasing trend ($P<0.05$) with longer fermentation duration. Samples fermented with 0 g/kg nitrogen source had a 14.10% reduction in DM content after 96 hours of fermentation. DM content reduction was more pronounced in samples fermented with 75 g/kg nitrogen sources irrespective of the source (20.57%, 23.53% and 18.61% reduction for CLW, PE and CLW+ PE fermented CRM respectively).

The crude protein (CP) content of the biomasses increased with advancing duration of fermentation irrespective of the type of nitrogen source and level of inclusion of the nitrogen source. All samples fermented with nitrogen sources had higher initial CP concentration compared with samples ($P<0.01$) without nitrogen sources. The CP value of 48.9 g/kg recorded at 72 hours of fermentation for CRM fermented at 0 g/kg inclusion level of nitrogen sources represented a 138.54% increase over the initial CP value of 20.5 g/kg. The interaction effect of source (S) x

duration (D), level (L) x duration and source x level x duration influenced the crude protein yield significantly (P<0.01).

The initial CF content of samples fermented with the various nitrogen sources was higher than that without nitrogen source. Crude fibre value was significantly (P<0.01) reduced with advanced duration of fermentation in samples with and without added nitrogen sources. Fermentation with rumen filtrate significantly (P<0.01) increased the ether extract (EE) content of CRM. The crude fat component increased (P<0.01) with prolonged fermentation. Cassava root mash (CRM) fermented without a nitrogen source had its EE fraction increased from 0.84 at 0 hours to 1.20% by 96 hours of fermentation. All samples fermented with nitrogen sources also exhibited similar increment in the EE values. Strong interaction effects (P<0.01) were observed for source, level and duration of fermentation with respect to EE values.

The terminal calcium (Ca) and phosphorus (P) values for CRM fermented with the nitrogen sources at the various levels were, however, higher than those obtained for CRM fermented without nitrogen source. The type of nitrogen source did not affect the gross energy value of cassava (P>0.05), however, level of nitrogen source and duration of fermentation significantly (P<0.01) reduced the gross energy value of CRM.

For all nitrogen sources and level of inclusion, a marked reduction in the concentration of HCN was observed with increase in the duration of fermentation. Significant reduction (P<0.01) was observed on a daily basis resulting in HCN concentration dropping from an initial value of 52.27 mg/kg to 8.11 mg/kg in 96 hours for samples fermented with rumen filtrate without nitrogen sources. The HCN concentrations were, however, much lower than in samples fermented with the various nitrogen sources. The lowest HCN content of 2.98 mg/kg was obtained in cassava samples fermented with 1:1 mix of CLW + PE after 96 hours of fermentation. Samples fermented with the nitrogen sources of CLW, PE and 1:1 mix of CLW+PE all had slightly lower initial HCN concentration than samples without these sources.

Table 1. Main effects of nitrogen source and level of nitrogen on compositional parameters.

Components	**Source of nitrogen**				**Level of nitrogen (g/kg)**				
(%)	CLW	PE	CLW: PE	SEM	0	25	50	75	SEM
Dry matter	35.58^{a}	34.90^{c}	35.16^{b}	0.061^{**}	32.43^{d}	35.00^{c}	36.03^{b}	37.38^{a}	0.07^{**}
Crude protein	6.64^{a}	6.17^{b}	6.20^{b}	0.072^{**}	3.33^{d}	6.18^{c}	7.27^{b}	8.56^{a}	0.08^{**}
Ether extract	1.59^{c}	1.86^{a}	1.76^{b}	0.05^{**}	1.06^{d}	1.66^{c}	2.07^{b}	2.16^{a}	0.06^{**}
Crude fibre	5.62^{c}	6.45^{a}	6.29^{b}	0.07^{**}	5.01^{d}	6.08^{c}	6.45^{b}	6.94^{a}	0.05^{**}
Ash	5.14^{a}	4.96^{b}	4.45^{c}	0.02^{**}	2.74^{d}	4.49^{c}	5.87^{b}	6.30^{a}	0.02^{**}
Ca	0.24^{a}	0.23^{ab}	0.22^{b}	0.05^{**}	0.18^{c}	0.23^{b}	0.24^{ab}	0.26^{b}	0.06^{**}
P	0.15	0.15	0.16	0.01ns	0.11^{b}	0.17^{a}	0.16^{a}	0.17^{a}	0.01^{**}
HCN/(mg/kg)	21.94^{b}	22.11^{b}	22.62^{a}	0.11^{**}	24.68^{a}	21.09^{c}	22.80^{b}	20.34^{d}	0.13^{**}
Gross energy (kCal/kg)	4286	4309	4321	13.4ns	4505	4414	4158	4145	65.5^{**}

Figures in a row, respective of source and level of nitrogen, bearing different superscripts are significantly different (*P<0.05; ** P<0.01).

Discussion

Fermentation significantly reduced DM and crude fibre while values of CP and EE significantly (P<0.01) increased. The decline in DM content was associated with increased moisture content with advanced fermentation duration. The initial dry matter content of cassava was higher in samples that contained nitrogen sources of CLW, PE and 1:1 mix of CLW and PE. Earlier

Table 2. Main effects of duration of fermentation () on proximate composition (%) calcium (%), phosphorus (%), HCN and Gross Energy (kCal/kg) and the nature of interactions.

Component (%)	Duration of fermentation (hours)						Interactions			
	0	24	48	72	96	SEM	SxL	LxD	S xD	SxLxD
Dry matter	38.42[a]	36.38[b]	35.11[c]	33.82[d]	32.33[e]	0.078**	P<0.01	P<0.01	P<0.05	P<0.01
CP	3.31[e]	4.43[d]	6.38[c]	9.28[a]	8.29 [b]	0.093**	P<0.01	P<0.01	NS	NS
EE	1.59[d]	1.69[c]	1.74[b]	1.81[a]	1.84[a]	0.06**	p<0.0l	P<0.01	NS	P<0.01
Crude fibre	6.96[a]	6.68[b]	6.09[c]	5.59[d]	5.27[e]	0.04**	P<0.01	P<0.01	p<0.0l	P<0.01
Ash	5.14[a]	5.00[b]	4.86[c]	4.72[d]	4.52[e]	0.02**	P<0.01	P<0.01	P<0.01	P<0.05
Ca	0.25[a]	0.23[ab]	0.22[ab]	0.22[ab]	0.20[b]	0.01**	P<0.01	P<0.01	NS	P<0.05
P	0.17[ab]	0.18[a]	0.15b[bc]	0.14[c]	0.13[c]	0.01[x]	NS	NS	NS	NS
HCN (mg/kg)	50.35[a]	25.10[b]	17.05[c]	9.89[d]	5.73[e]	0.14**	P<0.01	P<0.01	P<0.01	P<0.01
Gross energy	4530.71[a]	4457.63[a]	4173.63[a]	4261.92[ab]	4102.04[b]	73.18**	NS	NS	NS	NS

Figures in a row, respective of source, level and duration, bearing different superscripts are significantly different (P<0.05; ** P<0.01).

s = n source; l = level of n source; d = duration of fermentation; ee = ether extract; cp = crude protein.

fermentation reports (Abasiekong 1991a; Abasiekong 1991b; Nguyen and Nguyen 1992; Eruvbetine and Adegboyega 1996; Adeyemi and Familade 2003) indicated a similar trend of reduction in DM content with fermentation. The improvement in the CP content of whole cassava fermented with rumen filtrate with or without nitrogen source is a further confirmation of earlier studies. Eka (1979) reported that fermentation enhances the nutritional value of feeds, especially the protein content. The increase in the CP content is thought to be associated with the proliferation of microbial bodies. Other reports from Shrassen et al. (1970), Gregory (1977), Moo-Young et al. (1983), Ghoul and Engasser (1983), Nguyen and Nguyen (1992) reported an increase in protein synthesis by microbial fermentation of cassava.

The gradual reduction in crude fibre content of the cassava root mash with higher duration of fermentation is similar to earlier reports (McDonald et al. 1998; Abasiekong 1991a; Abasiekong 1991b; Noomhorn et al. 1992). Higher initial crude fibre content of samples supplemented with nitrogen sources is attributed to the crude fibre in the nitrogen sources used in the study that are farm animal wastes which are known to be fairly high in crude fibre content (AAFCO 1982). Abasiekong (1991a) observed that some rumen microbes digest fibre and supply unicellular protein to the rumen. Liener (1982) reported a level of 1130 mg/kg HCN in fresh cassava. Oke (1984) reported a dramatic reduction in HCN content of raw cassava during processing.

The results obtained at the end of the study indicated an improvement in the CP value of whole cassava root mash when enriched with two common farm animal wastes and fermented with bovine rumen filtrate. The values obtained for other proximate components suggest that the product could be a better alternative to cassava root meal and can be readily produced on livestock farms in rural areas. Subsequent studies from this station will evaluate the use of this novel material in monogastric nutrition.

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Effect of feeding feed additives to steers on ruminal methanogenesis and anaerobic fermentation of the resulting manure

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Abstract
The inhibition of enteric methanogenesis using feed additives and anaerobic fermentation of animal manure to renewable energy is beneficial for the environment and to the producers. This experiment was conducted using four steers in a 4x4 Latin square design to investigate the potential effect of monensin, galacto-oligosaccharides (GOS) and L-cysteine as feed additives on enteric and manure derived methanogenesis. Steers were offered high concentrate diets (80% concentrate and 20% hay) *ad libitum* with or without monensin, GOS or L-cysteine. Steers that received monensin and GOS containing diets had lower enteric CH_4 missions. Digesters at 55°C with manure from steers fed monensin-containing diets delayed in the initial CH_4 production. However, after 40 days CH_4 production increased in digesters fed monensin-containing manure. Monensin is a strong inhibitor of enteric methanogenesis, but has a negative influence on biogas energy production at short retention times.

Key Words: monensin, L-cysteine, galacto-oligosaccharides, methanogenesis, biogas

Introduction
The renewed interest worldwide in the need to mitigate methane (CH_4) emission such as the Kyoto Protocol, and the benefits of recycled energy in animal production systems necessitates the use of anaerobic fermentation technology. Recently, there has been an urgent need to produce renewable energy using anaerobic digesters to capture CH_4 (biogas) from animal effluent. Moreover, CH_4 gas is currently recognised as the second most important greenhouse gas emitted from anthropogenic sources. The annual enteric CH_4 emission of about 80 tonnes (t)/g and 25 t/g from manure handling systems to the global atmosphere could be reduced through strategic ruminant production systems and renewable energy production from manure to biogas. One of the mitigation strategies for reduced CH_4 production in ruminant animals is the use of feed additives. The ionophore monensin is one of the most widely used feed additives in feedlot ruminant production, although its effects may be transient.

Due to consumer preferences and some proposed ban on the use of antimicrobial growth promoters in livestock production due to the discovery of some resistance to antibiotics in man, alternative feed additives have to be sort. Natural feed additives such as L-cysteine (Takahashi et al. 1997), galacto-oligosaccharides (Mwenya et al. 2005a) and yeast culture (Williams et al. 1988; Mwenya et al. 2004) have been shown to reduce CH_4 emission in ruminants. The objectives of this study were to evaluate the effects of feeding L-cysteine, galacto-oligosaccharides (GOS) and monensin on enteric and manure derived CH_4 emissions in steers fed on a high concentrate diet.

Materials and methods

Animals, treatments and experimental design

This experiment was conducted to examine the effects of feed additives on enteric methanogenesis and recycled energy production from steers. Animals were confined using stanchions in metabolism stalls in a monitor room with a rubber-padded concrete floor under controlled temperature (21 ± 2°C). The metabolism stalls are equipped with electrical powered mechanical devices that separate faeces and urine automatically.

Four Holstein steers with an initial live weight 291 ± 11 kg were offered a high concentrate diet (20% hay and 80% concentrate) *ad libitum*. Diets were offered without additives (control) or with the addition of 200 g GOS, L-cysteine as a hydrochloride (1.156 g/kg concentrate) or monensin (30 g/kg concentrate). Galacto-oligosaccharides (Yakult Co. Ltd., Tokyo) are non-digestible carbohydrates synthesised enzymatically from lactose by transgalactosidase activity of b-galactosidases derived from *Aspergillus oryzae* or *Streptococcus thermophilus*. Monensin and L-cysteine were incorporated in the concentrate feed by Snow Brand Seed Co. Ltd., Hokkaido, Japan.

Experimental procedure

The 4 experimental periods lasted for 22 days with 2 weeks of adaptation to a new treatment followed by 8 days of data collection. Steers were offered the diets *ad libitum* twice daily (09:00 and 16:00hrs) to allow at least 100 g/kg refusals. On days 1 to 5 of each collection period, total daily faecal and urinary output from individual steers were collected and weighed after mechanical separation. After thorough mixing, the aliquots were put in a cold room (–20°C) for later anaerobic fermentation using batch digesters. On days 6 and 7 of each collection period, enteric methane production, oxygen consumption and carbon dioxide production were monitored by an open circuit respiratory system using the hood over the animal's head (Takahashi et al. 1999).

Anaerobic digesters

The digesters used were 1-litre aspirator bottles with approximately 800 ml working volume. Duplicate batch digesters from manure obtained from each animal fed any of the treatments were started by adding 300 g of inocula (9.3 g of volatile solids, VS) from digesters operated at the same designated temperature fed dairy cow manure and 300 g sample (30 g total solids, TS). The faeces were first diluted with tap water to reduce the TS content to 10% in all the samples. Digesters were placed in a water bath heated at 55°C by thermoheaters (Thermo-Mate, BF 200). The batch digesters were operated for 50 days and hand shaking was done hourly for the first 1 week and periodically thereafter. Granules of iron oxide were used to capture hydrogen sulphide from the biogas. Gas collection bags (AS One, Tedlar bags) were fitted to each bottle and gas volume and composition were measured every day for the fist 2 weeks and periodically thereafter.

Analytical methods

The influent fed to the digesters and the contents after the end of batch trials were analysed for TS using a fan-assisted dry oven (Yamato DX 600) at 105°C for 24 hours, VS analysed using an electric furnace (model FA-21) at 550°C for 4 hours, and pH measured using a pH meter (TOA, Japan). Kjeldahl nitrogen (N) of feed and manure samples were determined using AOAC (1996) procedures. Determinations of neutral-detergent fibre (NDF) were done according to the methods described by Van Soest et al. (1991) whereas acid-detergent fibre (ADF) and acid detergent lignin (ADL) were according to AOAC (1996). Both the NDF and ADF were measured on an ash-free basis. Concentrates were analysed with a-amylase (Wako, Japan) without sodium sulphite. Energy content in feed, faeces and freeze-dried urine were determined with an adiabatic bomb calorimeter (Shimadzu, Japan). Methane and CO_2 concentrations were measured using a gas

chromatograph (Shimadzu GC-8A) with an active carbon column and helium (He) carrier gas supplied at 60 ml/min with an inner temperature 70°C.

Calculations and statistical analyses

Data were analysed using the analysis of variance for Latin square design using the general linear model procedure of SAS (SAS, 1996). Progressive CH_4 yields from each digester collected every 10 days were analysed with the MIXED procedure of SAS for repeated measures. In cases of significant differences in the main effects, contrasts were evaluated and least square means were separated using Fisher's least significant difference test. The overall least square means were declared significant at $P<0.05$ and trends were declared at $P<0.10$, unless otherwise stated.

Results and discussion

Table 1 shows The chemical composition of the diets fed to steers is shown in Table 1; part of the data from the experiment have been reported (Mwenya et al. 2005b). Energy losses as CH_4 (CH_4 conversion ratio (MCR); MJ/100 MJ GE (gross energy intake) ranged between 2.0 and 2.4, and were lower ($P<0.001$) for steers fed on monensin containing diets, and also lower ($P<0.05$) for steers fed GOS diets vs. those fed the control diet. Methane emissions were low irrespective of treatment due to high level of concentrates in these diets. Increasing the concentrate proportion of the diet reduces methane. Another possible reason for lower CH_4 production in this study could be the higher crude protein (CP) content of the diets. Increasing CP in the diet decreases methane emission either due to a direct negative effect of CP on CH_4, or the replacement of dietary methanogenic carbohydrate with protein.

Table 1. Chemical composition of concentrates and mixed hay fed to the steers.

Chemical composition	Concentrate	Hay
Dry matter (g/kg)	867	836
Organic matter (g/kg DM)	934	925
Crude protein (g/kg DM)	176	183
Neutral-detergent fibre (g/kg DM)	197	602
Acid-detergent fibre (g/kg DM)	79	313
Acid-detergent lignin (g/kg DM)	16	26
Gross energy (MJ/kg DM)	20.4	23.0

Ruminal gram-positive bacteria are involved in the fermentation process that produces acetate, butyrate, lactate, hydrogen and ammonia (Russell 1996), fermentation products that are coupled with methane production. Unlike gram-negative bacteria, gram-positive bacteria have less complex membranes thereby making them more susceptible to the antibiotic effects of monensin (Russell 1996). When gram-negative bacteria predominate in the rumen, less CH_4 is produced due to reduced availability of hydrogen and formate. Alternatively, GOS is known to stimulate some microbes, mainly bifidobacteria, that increase propionate at the expense of acetate. Since propionate production is in direct competition with methanogenic bacterium for hydrogen, CH_4 production is reduced.

Methane production in digesters fed manure from steers offered monensin-containing diets was significantly inhibited during the first 40 days. However, the magnitude of the difference was decreasing with time, such that by day 50 no significant difference was observed though the monensin digesters had numerically lower accumulated CH_4 production (Figure 1). Our results concur with those of Hashimoto et al. (1981) who also observed a delay in the start of active fermentation in batch digesters fed manure from monensin-fed beef cattle. Varel and Hashimoto (1981) reported a total inhibition of CH_4 production at 9 days retention time in digesters with feedlot beef waste containing monensin. Three modes of action were proposed: a shift in microbial

population; development of resistance to monensin by mutant strains of bacteria; and deactivation of monensin during the lag period. Varel and Hashimoto (1981) reported that no significant reduction in methanogenic bacteria were observed in slurry of monensin digesters and concluded that monensin primarily affects the production of CH_4 precursors rather than the methanogenic bacteria. This mode of action is also reported in enteric CH_4 reduction by monensin (Russell 1996). About 19.5% of GE intake is recycled through fermentation of manure from steers fed GOS containing diets as compared to 14.9% of GE intake from steers fed a control diet.

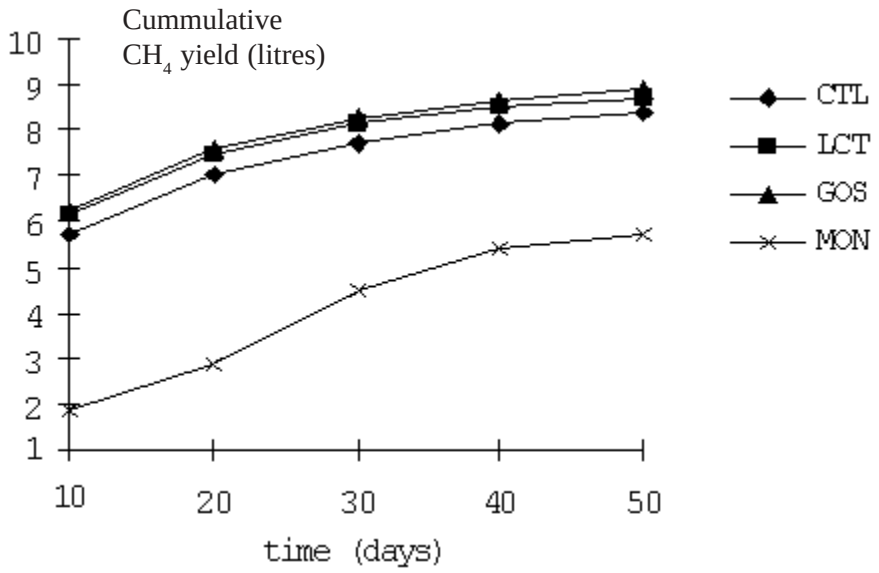

Figure 1. Cumulative methane yield in digesters fed manure from steers consuming non supplemented (control) or monensin, L-cysteine or galacto-oligosaccharides added diets.

Conclusion

Supplementation of monensin, L-cysteine or b1-4 galacto-oligosaccharides to steers fed a very high concentrate diet had positive impacts in this study. Methane energy losses as methane conversion ratio (IPCC 1966) was lower in steers fed the monensin and b1-4 galacto-oligosaccharides supplemented diets. The addition of b1-4 galacto-oligosaccharides to diets of steers resulted in an increased biogas production. Results show that supplementation of L-cysteine and b1-4 galacto-oligosaccharides to feedlot cattle fed on very high concentrate diets have comparable effects on some physiological parameters, as does monensin. However, monensin has an inhibitory effect on the initial methane production in biogas production.

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The role of electrophoresis techniques in ruminant nutritional studies: Developments and challenges

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Abstract
Advances in livestock feeding practices have shown that the conventional crude protein evaluation system is inadequate in expressing the types of proteins specifically absorbed and available to the animal. Currently, emphasis has been placed on quantitative and qualitative determinations of specific protein types in forages and other feeds so as to assess the supply and availability of proteins to animals correctly. The use of sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) technique is given a top priority in the identification of proteins being evaluated by *in vitro* or *in sacco* methods. In this paper, the application of electrophoresis techniques is discussed in relation to protein evaluation for ruminant feeding. General principles to be considered in the development of SDS-PAGE assays are discussed, and limitations of this approach. In conclusion, the paper stresses the use of SDS-PAGE and other electrophoresis techniques that could complement methods for feed analysis and forage improvement for efficient feed formulation and improved livestock productivity.

Introduction
The *in sacco*, *in vitro* and *in vivo* methods used to predict the rate and extent of nitrogen (N) degradability in the rumen categorise the three main fractions of feed proteins. The first fraction is a readily soluble protein that is also readily degraded in the rumen and comprises mostly non-protein N (NPN, i.e. nitrates, amino acids, amides and nucleic acids). The second fraction is comprised of a bound protein which is not degraded in the rumen and is completely unavailable to the animal. The third fraction is that which can escape rumen degradation and yet may be available to the animal. The third fraction (the insoluble fraction) degrades at different rates depending on the protein type, particle size, processing and microbial mass, and it is further categorised into rapidly and slowly degraded protein fractions respectively (AFRC 1992).

Methods for predicting degradability rely mostly on total N (crude protein, CP) determinations in describing the protein value of feeds. Nevertheless, the CP description procedure has been considered to have some deficiencies despite its continued use. As a result, efforts are underway to describe protein N and other NPN fractions using other techniques. Among these are high performance liquid chromatography (HPLC) (Chen et al. 1996) and sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) (Peltekova and Broderick 1996). For a long time, chromatography and electrophoresis techniques have been used in fractionation or separation of biological materials. Although technological developments have accompanied sophistication of these techniques, their valuable success has relied also on the fact that they do not destroy the biological nature of the substances. Essentially, these techniques use the basic physical properties of the molecules dealt with such as their mass, size, shape, charge and adsorption effect (Shaw 1969; Plumer 1971).

General theory

Electrophoresis is used in all life sciences that involve the identification and separation of proteins and individual amino acids or peptides such as clinical or medical biology and similar microbiological studies. Specifically, the electrophoretic technique uses the principle of differences in the charge of the solid particles (Shaw 1969). In this case, charged particles in solution migrate to the electrodes of the opposite charge when an electric field is applied and this results in the separation of the intended substances located as a number of separate, discrete zones or bands in the stabilising media used today (See and Jackowski 1989). The media include filter paper, cellulose acetate, agar gel, starch and polyacrylamide gels. Polyacrylamide is used in most of the analyses mainly due to its low electrical resistance that permits the use of small columns of gel and also due to its transparency characteristics (Plumer 1971).

Summary of the electrokinetic theory

If a particle of charge q is present in an electric field of strength x then the force on the particle causing it to accelerate is qx. This is balanced by the frictional resistance ¦ to give the terminal velocity *v*.

$$qx = fv$$

Now assuming Stoke's law for a spherical particle of radius r moving through a medium of viscosity h, then,

$$f = 6\pi\eta r$$

From these two equations:

$$qx = 6\pi\eta r\nu$$

The electrophoretic mobility Ñ of a particle is defined as the migration per unit field strength so that:

$$\nabla = = \frac{\nu}{x} \quad \frac{q}{6\pi\eta r}$$

The charge q carried by the particle depends on the zeta potential x and radius r of the particle and the dielectric constant of the medium:

$$q = D\xi r$$

Substituting this in the above equation:

$$\frac{D\xi}{6\pi\eta}$$

The zeta potential is the potential of solid surface and the adsorbed layer of ions with respect to the bulk of the solution and is affected by the nature of the particle as well as ions adsorbed from the medium.

The electrophoretic mobility ∇ depends on the charged groups present on the surface of the particle, and the sign and magnitude of the charge carried by ionogenic groups varies according to the ionic strength and pH of the medium in a characteristic manner. Separation of molecules can therefore be affected by selecting the appropriate medium.

Polyacrylamide gel as a supporting medium

Acrylamide (CH_2=CH-CO-NH_2) is a water-soluble substance with a reactive double bond. Polymerisation in aqueous solution in the presence of a bifunctional acrylamide such as N, N'-methylenebisacrylamide H_2C=CH-C=O-NH-CH_2-CH_2-NH-C=O-CH-CH_2 produces a water insoluble gel (Determann 1968). In principle, the presence of a bifunctional reagent results in the formation of cross linkages between two different chains of the polymer (a three dimensional network of carbon chains) and the resulting carboxylic acid amide group on the carbon atoms introduces polarity and thus the ability to swell in water.

Sodium dodecylsulphate (SDS)

In their study, Lillford and Wright (1981) showed that the incorporation of sodium dodecyl sulphate (SDS) and some buffers in the polyacrylamide gel electrophoresis (PAGE) could permit rapid analysis of the soluble and acid sensitive protein fractions of soya bean and other foods and feedstuffs. Actually the use of SDS-PAGE in biochemical and clinical fields, which have shown most of the applications of electrophoretic techniques (Johnson et al. 1982), exploits the advantage of the ability of the SDS to breakdown the proteins into their individual polypeptide chains (Laemmli 1970; See and Jackowski 1989). Separation of the SDS-polypeptide complexes that are formed in these reactions is achieved depending on among other things temperature and the ionic strength of the solution (See and Jackowski 1989).

As it is pointed out later in this paper, there are variations in conducting SDS-PAGE depending on the nature of protein materials and other technical aspects in the working environment (Table 1). Among the areas in which variations exist are in the composition of solutions and methods used in extraction of proteins from sample materials. Nevertheless, care must be taken to minimise technical errors so as to obtain the most reliable results in these protein separation processes.

Table 1. Concentration of SDS in protein extracting solution, time for electrophoresis and power supply in electrophoresis by some workers.

Author	% SDS in protein extracting solution	Total time for electrophoresis (h)	Power supply
Spencer et al. (1988)	0	16	17 mA
Granier (1989)	4	Overnight	120 V
Romagnolo et al. (1990)	2	Not stated	30 mA
Aufrère et al. (1994)	4	4	200 V
Messman et al. (1994)	1	1.75	17.5 mA
Messman and Weiss (1994)	1	1.75	17.5 mA

Estimating molecular weight of polypeptides

Approximate molecular weights (M_r) of the polypeptides separated in SDS-PAGE are determined through methods reviewed by See and Jackowski (1989). Mathematical expressions normally based on the use of a protein whose M_r is known (standard) and accurate measuring the length of the separation gel before and after staining, the distances that the standard protein and the unknown protein migrates during electrophoresis and the distance that the dye migrates. Then, the relative mobility (R_f) of each of the polypeptides is calculated. This is the product of the ratios of the distance of the polypeptide migration to the length of the separation gel after de-staining and that of the length of the gel before de-staining and the distance that the dye migrates respectively. A plot of R_f versus log M_r for the polypeptides of the standard protein may be done. From the R_f value of the unknown and through interpolation the M_r of that polypeptide can be estimated. The choice of standard proteins depends on the purpose of the study and on their commercial

availability. Bovine serum albumin (BSA) and ribulose 1,5-diphosphate carboxylase (RUBISCO) have been reported as protein standards in several ruminant nutritional studies (Faibairn et al. 1988; Spencer et al. 1988)

The use of SDS-PAGE in ruminant nutritional studies

The fractionation of the rumen fluid from sheep conducted by Spencer et al. (1988) was used as a basis for studies that aimed at finding the relative rate of breakdown of individual feed proteins in rumen fluid. However, studies on forage protein breakdown by rumen microflora and subsequent application of SDS-PAGE technique in monitoring the fate of proteolysis of individual molecules had been reported earlier (Nungent and Mangan 1981; Mangan 1982). Mangan (1982) had shown that treatment of fraction 1 leaf protein could dissociate the molecule into two kinds of subunits: a large subunit with a molecular weight (MW) of 56 kilodaltons (kDa) and a small subunit with MW of 16 kDa. In their work, Cherney et al. (1992) applied SDS-PAGE when they determined solubility of alfalfa (*Medicago sativa* L), bird's-foot trefoil (*Lotus corniculatus* L) and other forage proteins in buffer solutions. Their results showed that Kansas state buffer (a phosphate buffer) extracted more high MW proteins from the forage than did other buffers. The results also indicated that proteins soluble in Kansas state buffer were extensively degraded in the rumen within 12 hours.

In contrast, Chaudhry et al. (1992) used gel electrophoresis after sequential extraction of proteins of six concentrate feeds in water, sodium chloride and dilute alcohol, whereas Aufrère et al. (1994) compared degradation of proteins of Lucerne as a green forage, hay and as silage to that measured in a phosphate buffer using electrophoretic profiles. Results from these studies showed that most of the readily soluble proteins (such as those of MW of 55 kDa and 15 kDa) are degraded at short incubation intervals.

In a more recent report, Hancock et al. (1994) studied the expression of SDS polyacrylamide gel electrophoretic profiles. These workers demonstrated that some sulphur-rich proteins are soluble, degradable and digestible at different rates both in the rumen and in the small intestines. The study (Hancock et al. 1994) concluded that proteins with a high percentage of cysteine residues and disulphide bonds are likely to escape rumen digestion and this aspect could be of value in forage breeding techniques and in the nutritional improvement for essential amino acid availability to animals such as sheep and other farm animals (Table 2). Similarly SDS-PAGE was used to relate the protein degradability *in situ* to that degraded when enzymatic methods are used (Fahmy et al. 1991) and also in studies on the quality of protein content of forages when different conservation techniques are used (Messman et al. 1994).

Most of the studies advocated that application of SDS-PAGE and other procedures for identification and characterisation of proteins capable of surviving rumen degradation and factors influencing their accumulation in forages are essential as they may allow for introduction of forages or management practices which could improve the nitrogen status of the ruminants (Hancock et al. 1994). Moreover, the recognition of proteins and nucleic acids using electrophoresis is necessary and valuable for taxonomy studies in plants (Neto et al. 2002).

The gap in the use of SDS-PAGE for forage protein analysis

As with analysis of other protein sources, forage protein analysis with SDS-PAGE relies on appropriate methods of extracting proteins from sample materials. These methods of sample preparation should, among other qualities, not allow proteolytic conditions and must lead to accurate estimates of the molecular weights of the polypeptides (See and Jackowski 1989).

Table 2. Features of some plant proteins rich in sulphur considered as candidates for genetic engineering of plants for essential amino acid improvement in sheep.[1]

Protein type	Size (Kilodaltons)	Sulphur content (mg/g)	Rumen digestion period (h)	Comment on degradability/ solubility
Rice prolamin	10	30	> 24	Highly resistant to degradability[2]Totally insoluble in aqueous buffer[3]
CMTI-1	3.2	24	> 24	More resistant to degradation[2]Extremely soluble in water
Maize zein-10	10	27	24	Highly resistant to degradation[2]Totally insoluble in aqueous buffer[3]

Although efforts have been underway to develop methods of extracting plant protein, the lower concentration of protein in plant tissues compared to animal tissues and the nature of plant cells in general pose specific problems in plant protein extraction (Granier 1988). As a result, there is paucity of information on reliable methods for extracting proteins from forages and other animal feeds. For example, propanol was used at various concentrations in studies conducted by van der Aar (1983) but extraction of albumins and prolamins using water and alcohol respectively has more often been reported with protein concentrates such as soybean meal than with forages.

Nevertheless, Messman and Weiss (1993) described protein extraction procedures in which a borate-phosphate buffer (pH 9) containing various concentrations of SDS (0.1%, 1%, 2%, 3% and 10% w/v) and involving sonication for 1, 2 or 5 minutes respectively were tested. The method in which SDS content was 1% and sonication was done for 2 minutes extracted up to 85% of Kjeldahl CP and was later applied in electrophoretic studies of protein concentrates conducted by Messman and Weiss (1994) (see Table 1). Likewise, Makoni et al. (1993) proposed a sequential procedure of fractionating proteins of wilted and unwilted grass silages. Although these workers did not directly use the method for electrophoretic studies, their procedure (Makoni et al. 1993) showed no significant differences ($P<0.05$) when it was repeated six times. Conversely, the method described by Granier (1988) was adopted by Aufrère et al. (1994) and involved initial grinding of sample materials and subsequent extraction of proteins with a solution containing 4% SDS, 5% 2-mercaptoethanol, 5% sucrose and 20% of insoluble polyvinyl pyrrolidone (PVP). Before electrophoresis, the mixture was boiled for three minutes and the proteins were precipitated in acetone. However, Faibairn et al. (1988) extracted protein from ensiled alfalfa samples using a buffer solution (pH 7). These workers not only inhibited formation of protein-tannin complexes by adding PVP to the buffer but also their extraction procedure involved the use of ascorbic acid and sodium metabisulphite at a concentration of 1.32 and 0.13 g/100 ml respectively so as to maintain reducing conditions. Extraction was also carried out under a stream of N gas.

It is obvious therefore, that there are variations in methodologies among and even within laboratories. Nevertheless, it is essential that an efficient and reliable method of protein extraction particularly in forages is needed. Through this development other advantages in the application of the SDS-PAGE technique may be fully realised.

Summary and conclusions

Apparently, it is acknowledged that the use of SDS-PAGE technique would have profound effects in animal feed evaluation. Equally, this may improve the scientific knowledge in other areas in ruminant feeding aspects such as forage breeding studies. However, the potential of the technique depends not only on developments in biochemical studies but also on other areas in applied science and technology.

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Body weight changes and reproductive performance of crossbred cows fed maize-lablab stover *ad libitum* and supplemented with graded levels of lablab hay

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Abstract
Twenty-four multiparous Zebu × Friesian crossbred cows, were fed maize-lablab stover as basal diet and allocated to four graded levels of lablab hay (0%, 0.4%, 0.8% and 1.2% BW) treatments in a study to investigate effects of levels of lablab supplementation on body weight changes and reproductive performance. Supplementation during the first 60 days post-partum resulted in reduced weight loss ($p<0.05$) of the cows from –82.9 g/day to a gain of +7.1 g/day. Mean interval from calving to first post-partum ovulation improved by 19.4% but the supplemented treatments were not significantly different. Intervals from calving to first observed post-partum oestrus averaged 51 (range, 43–60) days and decreased ($p<0.05$) with increasing levels of lablab supplementation. Calving to conception interval was highest (95 days) for unsupplemented treatment and was reduced by supplementation although the supplemented diets were not significantly different. For optimum reproductive efficiency, it was recommended that crossbred cows fed ML stover should be supplemented with lablab hay at 0.5% BW but required additional energy supplements to meet the ME requirements for maintenance, milk production and reproductive efficiency.

Key words: intercropping, lablab, supplementation, cattle, live weight, reproduction

Introduction
The reproductive performance of tropical cattle is less than optimum and this is attributable to late age at first calving, low conception rates and long calving intervals (CIs) (Mukasa-Mugerwa 1989). The main determinant of these long CIs is a prolonged post-partum anoestrus interval and the main constraint to productivity is generally accepted to be the low nutritional status of the animals (Payne 1970). In general, poor feeding post-partum reduces luteal function and responsiveness of the ovaries to luteinising hormone (Rutter and Randel 1984). Cattle in the tropics mainly subsist on low quality pastures and crop residues but are generally unable to meet the nutrient requirements for milk production and reproduction (Brumby and Gryseels 1985). Lactating cows fed these feeds are unable to meet their nutritional requirements and lose weight and condition during lactation; this prolongs the lactation anoestrous period and cows tend to calve in alternate years (Mukasa-Mugerwa 1989).

Animal nutrition in the tropics could be improved by the use improved crop residues from intercropping cereals and forage legumes (Umunna et al. 1995; Mpairwe et al. 2002), and supplementing with forage legumes (Matizha et al. 1997; Mpairwe et al. 2003). However, Umunna et al. (1997) noted that although intercropped feeds were of better quality than their respective

pure stand cereal crop residues, they were still deficient in crude protein (CP) and energy and should not be used as sole feed. The most economic way to improve energy intake and performance of animals eating crop residues is to supplement them with good quality forage, including forage legumes (Topps 1997; Mpairwe 1998). This paper reports a study conducted to investigate the effects of supplementation with graded levels of a forage legume (lablab hay) on body weight, body condition score and the reproductive performance of crossbred (*Bos indicus* ×*Bos taurus*) cows fed intercropped feeds (maize-lablab (ML)) stover basal diets.

Materials and methods

The study was conducted at the International Livestock Research Institute (ILRI) Debre Zeit Research Station, located 50 km south east of Addis Ababa in the Ethiopian highlands (8˚44'N and 38˚58'E) at an altitude of 1850 m above sea level.

Feed production

Maize-lablab stover was obtained by intercropping hybrid BH 660 maize (*Zea mays*) with lablab (*Lablab purpureus*) variety Rongai, mixed in a ratio of 3:2 by weight and planted at a seed rate of 50 kg/ha of the mixture. After harvesting the mature dry maize cobs, maize-lablab stover was obtained by harvesting a mixture of maize stover and lablab which was later chopped to an average length of 5 cm using a tractor mounted Chaff cutter. Lablab hay was acquired from sole stands of lablab planted at a seed rate of 30 kg/ha, harvested at 50% flowering stage and dried into hay.

Animal management and experimental design

Twenty-four cows approximately 60 days pre-partum with mean live weight of 445 SD + 57 kg were selected from a herd of 72 multiparous (parity 2–4) Friesian (*Bos taurus*) ×Zebu (*Bos indicus*) crossbred cows. The cows were blocked according to their previous lactation daily milk yield, body weight and body condition score into six blocks of four animals each. Within a block, the animals were each randomly allotted to one of the four dietary treatments comprising of maize-lablab stover (ML) basal diet fed *ad libitum* and supplemented with graded levels (0%, 0.4%, 0.8%, and 1.2% body weight) of lablab hay. The experiment was a randomised complete block design with four dietary treatments and six animals per treatment. The cows were then allocated to individual tie-stall pens according to treatments in a roofed concrete floored barn. The cows had free access to water and mineral blocks (1.39% N, 5.54% P, 26.54% Na, 3.31% K, 14.38% Ca, 0.23% Mg, 719 ppm Fe, 1087 ppm Mn, 2178 ppm Cu and 2377 ppm Zn). At calving, the calves were separated from their dams about 2–3 hours after parturition, kept in individual pens and bucket-fed. Cows were hand-milked twice daily, starting at 0700 hours and 1600 hours. The experiment lasted 200 days with each cow covering 60 days pre-partum and 140 days post-partum.

Body weight and body condition score (BCS) were determined fortnightly from the start of the experiment (2 months before calving) until end of the experiment. Body condition score was determined using a 9-point scale (1 = emaciated, 9 = fat) according to Nicholson and Butterworth (1986). After calving, cows were under continuous observation by technicians with the assistance of a teaser bull for oestrus manifestation while either in the holding pens of the milking parlour or in the exercise lot. An observed oestrus was when a cow was either seen standing to be mounted by a herd-mate or displayed at least two secondary signs of oestrus (Peters and Ball 1987).

Blood sampling and ovarian activity

Blood samples were collected twice weekly from each cow starting from day 21 post-partum until pregnancy was confirmed (60 days post-partum) or until the end of the experiment in cases

where pregnancy was not manifested. Additional blood samples were also collected on the day of observed oestrus and insemination and on the next day. Blood was collected via jugular venipuncture into vacutainer tubes containing heparin (10 IU/ml blood) as an anti-coagulant. Immediately after collection, the blood samples were centrifuged (4000–5000 rpm for 5 minutes) to separate the plasma. Plasma samples were then kept frozen at –20°C until analysed for progesterone concentrations. Plasma samples were assayed for progesterone concentration (P4) by the enzyme-linked immunosorbent assay (ELISA) technique (Boland et al. 1985; Parker et al. 1988) using Ovucheck Plasma Progesterone EIA kits (Vetoquinol Diagnostics S.A, France). Procedural details of the ELISA technique were as described by Mukasa-Mugerwa et al. (1989).

Plasma progesterone concentrations and profile of individual cows provided an index of ovarian activity, periods of oestrus and pregnancy status of the cows. Plasma progesterone of <1 ng/ml later verified oestrus with a subsequent increase over the next week. The interval from calving to first ovulation was calculated from observations of oestrus behaviour and results of plasma progesterone analysis. Ovulation was taken to have occurred 1 day following an observed oestrus or, if oestrus was not observed, ovulation was estimated to have occurred 3 days before an increase in P4 concentration >1 ng/ml. Unobserved oestrus consisted of a progesterone value <1 ng/ml with a subsequent increase unaccompanied by an observed oestrus.

Cows were artificially inseminated and the intervals from calving to oestrus and conception were calculated from observed oestrus and the results of plasma progesterone analysis. Conception date was verified by pregnancy diagnosis (PD) by palpation per rectum 45–60 days after insemination, and interval to conception was calculated based on calving date the subsequent year.

Statistical analysis

Data were subjected to the analyses of variance (ANOVA) procedure for randomised complete block design experiments using the general linear models (GLM) in SAS (Statistical Analysis Systems) (SAS 1989).

Results and discussion

Feed composition, nutrient and metabolisable energy intake and apparent digestibility

Maize-lablab (ML) stover comprised of 890, 550, 354 and 93.1 g/kg of dry matter (DM), neutral detergent fibre (NDF), acid detergent fibre (ADF) and CP respectively. Lablab hay consisted 907, 441, 228 and 157 g/kg DM, NDF, ADF and CP respectively. Calcium, phosphorous, magnesium and potassium composition was respectively 10.1, 4.5, 2.7, and 25 g/kg DM for ML stover and 17.4, 5.4, 2.9, and 26 g/kg DM for lablab hay. Estimated nutrient content of rations requirement for dairy animals indicated that both the ML stover and lablab hay met the mineral requirements (4.8, 3.4, 2.0 and 8.0 g/kg DM Ca, P, Mg and K respectively, while lablab hay alone met the CP content (140 g/kg DM CP) required for a dairy cattle weighing 400 kg and producing between 8 and 13 kg of milk with a butter fat content of 4% (MAFF 1987). This indicated that ML stover needed supplementation to meet the CP requirements of dairy animals.

Total DM intake of the basal diets before and after calving for the supplemented cows was significantly higher ($p<0.05$) than for the cows fed ML stover alone (Table 1). Similarly supplemented cows had higher CP intake than cows fed ML stover alone and increasing levels of lablab hay supplement significantly ($p<0.001$) increased the CP intake by the supplemented cows both before and after calving. The higher total DM and CP intake during the post-partum period than before calving was attributed to the increased nutrient demands of lactating animals for maintenance, lactation and repair of the reproductive organs.

Dry matter digestibility was significantly ($p<0.001$) improved by lablab hay supplementation during the pre-partum period but was similar during the post-partum period (Table 1). However, the DM digestibility after calving (704 g/kg) was higher than before calving (658 g/kg). Lablab hay supplementation significantly ($p<0.001$) improved CP digestibility and was higher (740 g/kg) during the post-partum period than before calving (700 g/kg).

Supplementation with lablab hay significantly ($p<0.05$) improved the metabolisable energy intake (MEI) of the cows but there were no significant differences among the supplemented treatments (Table 1). ME intake after calving was higher than before calving but during the pre-partum period the supplemented cows had significantly ($p<0.01$) higher ME intake than that of the cows fed ML stover.

Table 1. Nutrient and metabolisable energy (ME) intake and apparent digestibility by crossbred cows fed *ad libitum* maize-lablab (ML) stover basal diets supplemented with graded levels of lablab hay.

	Treatments					
Basal diet	**Maize-lablab (ML)**					
Lablab level (%BW)		**0**	**0.4**	**0.8**	**SED 1.2**	**Significance (n = 6)**
Before calving						
Nutrient intake						
Total dry matter (kg/day)	8.7b	9.7a	9.2ab	9.6a	0.59	*
Crude protein (kg/day)	0.90c	1.13b	1.22b	1.40a	0.07	***
ME (MJ/head/day)	74b	96a	95a	99a	8.08	**
Digestibility (g/kg)						
Dry matter	573c	688ab	646b	728a	19.18	***
Crude protein	577e	720bc	714bc	788a	29.14	***
After calving						
Nutrient intake						
Total dry matter (kg/day)	10.3b	11.5a	10.7b	10.9ab	0.60	*
Crude protein (kg/day)	1.09c	1.32b	1.37b	1.52a	0.07	***
ME (MJ/head/day)	102	118	107	111	8.92	ns
Digestibility (g/kg)						
Dry matter	687	712	705	713	17.81	ns
Crude protein	698c	740b	750ab	771a	12.78	***
MEI MJ/day (200 days)	95.2 b	111.7 a	107.4ab	102.1ab	7.92	*
MEI balance 1	-9.8	6.7	-58	-112		

ME =Metabolisable energy intake [calculated from metabolisable energy of feed (MEF) = 0.15 x DOMD % (MAFF, 1987)]; * = $p<0.05$; *** = $p<0.001$; ns = not significant; SED = Standard error of difference.

[1] = *ME balance after taking into consideration the requirements for growth and milk yield.*

Body weight and condition score

Body live weight and condition score changes during pregnancy were affected by level of lablab hay supplementation (Table 2) and during this period, all the dietary treatments tended to increase body liveweight gain and improve body condition score. This was an indication that feeds supplied the dietary nutrient requirements of pregnant crossbred cows. Calf birth weight ranged from 30.0 to 33.8 kg; although not significant, the highest calf birth weight (33.8 kg) and weaning weight (55.7 kg) was achieved at the level of 0.4% BW lablab supplementation.

Table 2. Mean body weight and body condition score of crossbred cows fed *ad libitum* maize-lablab basal diets supplemented with graded levels of lablab hay.

	Treatments					
Basal diets	**Maize-lablab**					**Significance**
Lablab level (%BW)	**0**	**0.4**	**0.8**	**1.2**	**SED**	
60 days pre-partum						
Initial (week 0) LW (kg)	436	441	453	441	5.61	ns
LW at week 8 (kg)	443c	465b	477ab	487ab	10.23	ns
LW change 0–8 weeks (kg)	27.4	23.5	23.8	28.8	7.34	ns
LW gain 0–8 weeks (g/day)	284	232	251	283	64.62	ns
Calving weight (kg)	415c	422bc	438abc	452a	11.74	*
140 days post-partum						
LW at 60 days	380c	392bc	415ab	424a	13.23	*
LW at 140 days	389d	404bcd	428ab	438a	12.46	**
LW change (kg) from						
calving-60 days	-8.8	-9.3	-5.9	-0.2	7.10	ns
60 - 140 days	9.9	10.6	14.1	14.0	4.75	ns
calving - 140 days	1.1	1.2	8.1	13.8	8.48	ns
LW gain (g/day)						
calving-60 days	-82.9	-52.4	-54.2	7.1	65.55	ns
60–140 days	59.3	64.2	106.9	111.9	44.40	ns
calving - 140 days	5.4b	40.2a	39.8a	45.8a	32.21	*
Body condition score						
Initial		4.8	4.8	5.0	5.1	-
At calving	4.5	4.6	4.8	5.2	0.33	ns
Change (pre-partum)	0.51	0.53	0.49	0.53	0.29	ns
At 140 days post-partum	4.9	5.1	4.7	5.0	0.33	ns
Change (post-partum)	0.2	0.7	0.2	0.2	0.38	ns

abc = In a row, means with different superscripts are significantly different: * = $p<0.05$; ** = $p<0.01$; ns = not significant; SED = Standard error of difference.

All cows lost body weight at varying rates during the first 60 days post-partum and thereafter the body weights increased (Figure l) but the weight changes were not different ($p>0.05$) among the treatments (Table 2). However by 60 days (8 weeks), lablab hay significantly increased body weight of the supplemented cows at 60 days ($p<0.05$) and 140 days ($p<0.01$) post-partum.

The losses in body weight and condition score of cows during the first 60 days post-partum were attributed to the high nutrient demands during the early stages of lactation and have been reported in other studies (Tegegne et al. 1994; Muinga et al. 1992, 1995; Garnsworthy 1997). Stage of lactation and genetic merit of the animal affect both the milk yield and live weight response by partitioning energy toward milk production at the expense of body fat reserves (Garnsworthy 1997). Therefore, the increased DM intake and metabolisable energy intake (Table 1) during the first 60 days post-partum period could have been utilised for increased milk yields at the expense of body fat reserves.

The tendency of cows fed ML stover alone and those supplemented with lablab hay at 0.4 and 0.8% BW to have lower body weights during the post-partum (lactation) period was attributed to the higher milk yield than the cows supplemented with lablab hay at 1.2% BW (Mpairwe et al. 2003).

At high levels of lablab hay supplementation (0.8 and 1.2% BW), cows were in positive weight gain much earlier (5 weeks after calving) than at 0.4% BW lablab hay supplement. Unsupplemented

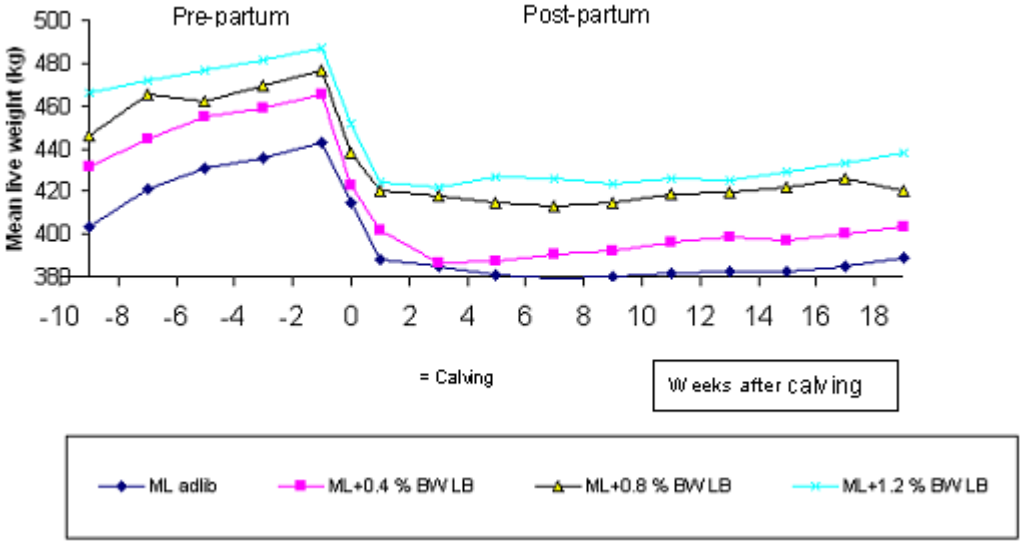

Figure 1. Effect of supplementation with lablab hay (LB) on mean body weight of crossbred cows fed maize-lablab stover (ML) basal forages.

cows delayed gaining weight up to 7 weeks post-partum. Pre-partum and post-partum body condition scores followed a similar pattern (Figure 2) with body weight and there were no significant treatment differences (Table 2). All dietary treatments exhibited positive body condition score changes during the pre-partum and post-partum periods. Garnsworthy (1997) noted that in later lactation, when appetite is greater and milk yields less, partition of energy switches more toward body reserves so increased energy supply results in greater fat deposition in body reserves. Therefore, in this study, during the period 60 to 140 days after calving, when milk yield was less (Mpairwe et al. 2003) while DM intake was high (Table 2), the increased ME intake could have resulted in fat deposition for body reserve build-up and hence the animals gained weight and improved in body condition score. The high metabolisable energy intake in this study could have counterbalanced energy release from tissue thus reducing net tissue mobilisation. The reversing of liveweight losses during early lactation by lablab hay supplementation was also associated with increased supply of nutrients (Table 1), especially protein resulting from the lablab which in turn increased ration digestibility and/or energy intake.

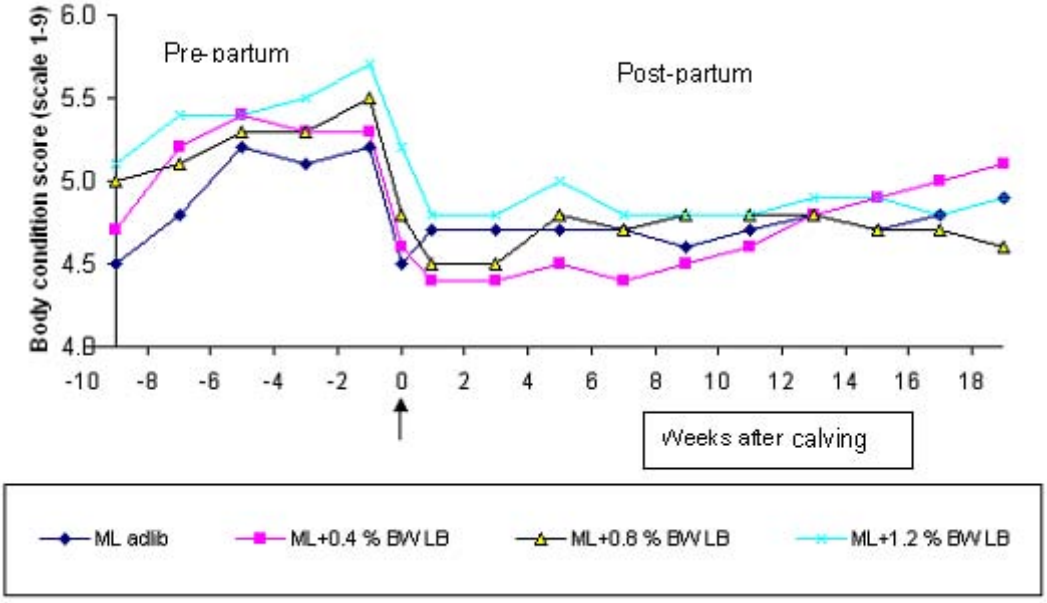

Figure 2. Effect of supplementation with lablab hay (LB) on body condition score changes (B) of crossbred cows fed maize-lablab stover (ML) basal forages.

Reproductive performance

The first post-partum ovulation ranged from 20 days to 63 days with the highest post-partum ovulation occurring among the unsupplemented cows (Table 3).). The mean interval from calving to first post-partum ovulation averaged 32 days for cows fed ML stover alone. Although there were no significant differences among the supplemented treatments, lablab hay supplementation reduced the mean interval from calving to first ovulation by 19.4% from 32 to 25.8 days. The interval from calving to first observed oestrus was significantly reduced by lablab hay supplementation from 60 days for the unsupplemented cows to 43 days for the cows supplemented with lablab hay at 1.2% BW. The intervals from calving to second and third observed oestrus were not significantly ($p>0.05$) different but tended to have a wider range for the supplemented cows at high levels of lablab hay supplementation (Table 3).

The post-partum anoestrus interval (calving to first oestrus) averaged 51 (range, 43–60) days. The first observed post-partum oestrus was significantly ($p<0.05$) higher for the unsupplemented than the supplemented cows and decreased with increasing levels of lablab hay supplementation. Cows fed ML stover alone delayed the post-partum anoestrus interval by 60 days. In addition, plasma progesterone levels in this study indicated that 9.5% (4 of the 42 first post-partum ovulations) were associated with silent heats and therefore unobserved oestrus could have accounted for the long interval from parturition to first observed oestrus especially with the unsupplemented treatments.

The long intervals from parturition to first observed oestrus recorded for the unsupplemented ML stover diet and for supplemented ML stover at 0.4% BW lablab hay level were attributed to loss in weight of the cows during the first 60 days after calving mainly due to the negative energy balance (Table 2) as a result of high milk yield during the first 60 days post-partum (Mpairwe et al. 2003). Large weight losses during early lactation, as was the case in the unsupplemented diets of this study, may prejudice the chance of conception and seriously affect subsequent productivity (Mutsvangwa and Hamudikuwanda 1994).

The interval between calving to conception averaged 88 (range 75–95) days and was highest (95 days) for unsupplemented ML stover. This interval was reduced ($p<0.05$) by lablab hay supplementation at 0.4% BW. However, supplementation of cows fed ML stover with lablab hay at 0.8% and 1.2% BW had similar negative effects on reproductive efficiency by extending the mean calving to conception interval. The majority of intervals between oestrus days (Table 3) were within the normal range (18–25 days) reported for dairy cows (Donkin 1980).

Negative energy balance during late pregnancy and in early lactation reduces ovarian function by suppressing gonadotrophin release (Dobson and Alam 1987). Therefore, the reduced calving to conception interval at 0.4% BW supplement level was attributed to the positive energy balance while the high calving to conception intervals in cows fed the ML alone and for cows supplemented with lablab hay at 0.8 and 1.2% of BW was attributed to inadequate ME intake which resulted into negative energy balance (Table 1).

The range of calving to conception interval was wide for cows supplemented with lablab hay at 0.8% and 1.2% BW and the majority of the cows on these diets conceived after 2–3 inseminations. This could have been due to the high CP intake (Table 1). Negative influence of CP on fertility is that excessive CPI leads to increased ruminal and blood ammonia and urea N concentration, resulting in a local toxic effect on the reproductive system (sperm, ovum or developing embryo) (Howard et al. 1987; Eldon et al. 1988, Carrol et al. 1988). Therefore the tendency for negative effect of high levels of lablab hay supplementation on fertility of cows in this study calls for caution and for a more strategic approach to supplementation to avoid toxic ammonia effects on the reproductive system.

Table 3. Reproductive performance of crossbred cows fed *ad libitum* maize-lablab (ML) stover basal diets and supplemented with graded levels of lablab hay.

Basal diets	**Treatments Maize-lablab**					
					Significance	
Lablab level (%BW)	0	0.4	0.8	1.2	SED	
1st post-partum ovulation1 (days)						
(n)		5	6	6	5	
Mean	32.0	26.3	24.8	26.2	6.62	ns
Range	20-63	20-47	19-40	21-35		
Calving to 1st oestrus2 (days)						
(n)		5	6	6	5	
Mean	60.2a	58.0ab	43.2b	43.0b	11.49	*
Range	42-106	47-72	19-86	32-52		
Calving to 2nd oestrus2 (days)						
(n)		4	4	6	5	
Mean	77.0	72.5	65.7	77.2	10.82	ns
Range	67-86	69-78	40-107	55-111		
Calving to 3rd oestrus2 (days)						
(n)		3	1	3	4	
Mean	99.3	93.0	86.6	97.5	23.22	ns
Range	87-106	93	62-94	73-129		
Calving to conception (days)						
(n)		5	6	5	5	
Mean	95.2ab	75.5b	89.2ab	93.2ab	13.24	*
Range	72-106	60-93	60-111	74-129		
Interval 1st to 2nd oestrus (days)	28.2	17.7	22.5	34.2	8.10	ns
Interval 2nd to 3rd oestrus (days)	20.6	17.0	31.0	19.7	18.57	ns

*1 = based on blood plasma progesterone concentration (P4) analysis; 2 = based on observed oestrus and confirmed by plasma P4 analysis; abc = within row, means with different superscripts are significantly different: p<0.05; ** = p<0.01; *** = p<0.001; ns = not significant; SED = standard error of difference.*

It is generally accepted that the optimum calving interval for commercial dairy cows is 12 to 13 months (Pelissier 1972) and to achieve this calving interval the calving to conception interval should not be more than 80–85 days (Peters and Ball 1987). In this study, the lowest mean calving to conception interval (75.5 days) was obtained by cows supplemented with lablab hay at 0.4% BW. In addition, it was noted that both the ML stover and lablab hay met the mineral requirements while lablab hay alone met the CP content required for a dairy cattle (MAFF 1987). The results of this study thus demonstrated the importance of using intercropped forages (ML stover) in satisfying the CP and mineral (Ca and P) requirements for gravid and lactating crossbred dairy cows and the importance of supplementing with lablab hay. Traditionally, smallholder dairy farmers hardly provide mineral supplements to animals. Therefore, the adoption of the technology of feeding intercropped forages (ML stover or OV hay) supplemented with forage legumes (lablab hay) would provide adequate minerals to dairy cattle especially the two most limiting minerals, Ca and P, often encountered in roughage-based feeding systems.

Conclusion

Based on the results of this trial, it was recommended that for optimum reproductive efficiency crossbred cows fed ML stover basal diets should be supplemented with lablab hay at 0.4% BW. Higher levels than these would result in detrimental and inefficient reproductive performance of the cows. The optimum levels of supplementation were associated with post-partum anoestrus interval of 36 days and a calving to conception interval of 72 days. However, it should be noted that although lablab hay supplemented cows satisfied CP intake requirements, they were deficient

in dietary energy to supply adequate ME requirements for maintenance, milk production and reproductive efficiency. It was therefore concluded that additional high energy supplements to lablab hay are required for higher milk production and improved reproductive efficiency of cows fed forages resulting from intercropping maize and lablab (ML stover) based diets.

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General characterisation of traditional small-scale livestock farmers in the peri-urban areas of Bloemfontein, South Africa

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Abstract

A questionnaire-based survey was conducted among peri-urban small-scale livestock farmers in Bloemfontein, South Africa. The production systems were characterised and the most important husbandry and management practices adopted by the small-scale livestock farmers described. Similar to other traditional small-scale livestock production systems in Africa, these farmers use communal grazing pastures, show poor adoption of modern livestock husbandry and management technologies and low productivity. The poor management of the pastures resulted in poor body condition of the animals reflected by low reproductive rates and low milk production. Most farmers use medicinal plants and traditional remedies to treat animal ailments; these valuable indigenous knowledge applications need to be further researched. The access to markets, extension services and other information sources need to be improved. Only then can biotechnological advances achieved by African animal scientists, have a positive impact on the livelihood of peri-urban small-scale farmers.

Key words: cattle, sheep, goats, small-scale, farming

Introduction

Over the past few decades, South Africa, like all other sub-Saharan African countries has undergone rapid population growth, particularly in peri-urban areas. The phenomenon results in a growing demand for food, particularly protein of animal origin. This emphasises the need for more efficient resource utilisation regarding livestock production. In South Africa, unlike the other southern African countries, small-scale farming contributes less (only 30%) to the national economy than commercial farming does (ARC 2004). Nevertheless, the importance of small-scale farming to help improve food security and provision of animal protein should not be underestimated. The sustainability of small-scale farming systems is threatened by low productivity, caused to a large extent by communal grazing practices (Webb et al. 2003), poor adoption of modern animal husbandry technologies and poor access to inputs and markets (Nell 1998). The globalisation phenomenon puts further pressure on small-scale farmers in South Africa who, under such disadvantageous conditions, have to compete with commercial farmers, both locally and internationally without the aid of modern technologies and benefits from government subsidies. The challenge to small-scale farmers is to develop adapted biotechnologies and evaluate the indigenous technologies which have the potential to improve animal productivity. The purpose of this study was to characterise the livestock production systems and evaluate traditional animal husbandry practices utilised by small-scale farmers in the peri-urban areas of Bloemfontein.

Materials and methods

The study was conducted in peri-urban areas of Bloemfontein (Botshabelo and Thaba-Nchu) between October 2001 and November 2003. A questionnaire-based survey was conducted among 90 cattle farmers and 28 sheep/goats farmers. The most important socio-economic characteristics, animal husbandry practices and the access to resources and markets were studied. Data were analysed using Statistics Package for Social Sciences (SPSS 1994), version 12.

Results and discussion

Most small-scale farmers (74.4% and 71.4% cattle and small ruminant farmers, respectively) were more than 51 years old (Table 1).

Table 1. Brief description of the personal characteristics and land tenure amongst small-scale livestock farmers in the peri-urban areas of Bloemfontein.

Parameters	Cattle farmers		Sheep/goat farmers	
	Frequency	Percentage	Frequency	Percentage
Gender				
Male	76	84.4	23	82.1
Female	14	15.6	5	17.9
Age				
21–30	3	3.3	4	14.3
31–40	6	6.7	1	3.6
41–50	14	15.6	3	10.7
³ 51	67	74.4	20	7.4
Land tenure				
Own	25	28.4	9	31.0
Communal	49	55.7	12	41.4
Rent	2	2.3	2	6.9
Open access	12	13.6	6	20.7

These results are in line with the findings of Mahanjana et al. (1996) who reported a mean age of 56 years for small-scale goat farmers in the Eastern Free State. In most African countries the relatively old age of farmers is a major reason for low productivity in the small-scale farming systems, as elderly people are less active and less willing to adopt new husbandry technologies (Feder et al. 1985). A high percentage of farmers (55.7% and 41.4% cattle and small ruminant farmers respectively) use communal land for grazing. Similar results have been reported in other African countries in (Mugabe et al. 2001; Webb et al. 2003).

The majority of the small-scale farmers in the peri-urban areas of Bloemfontein do not keep farming management records (76.7% and 74.1% of the cattle and sheep/goats farmers respectively) (Table 2). This is characteristic of small-scale farmers in South Africa (Marfo 2000; Webb et al. 2003). Most small-scale farmers (64.4% of the cattle and 75.0% of the small stock farmers) supplement their animals, mainly in winter and particularly in years of drought. Almost all small-scale livestock farmers use year-round mating, as the males run with females throughout the year. The use of communal grazing areas makes controlled breeding impossible. Webb et al. (2003) reported similar observations in communal goat production systems in South Africa. Most small-scale farmers do not test their animals for pregnancy (89.7% and 75.0% cattle and small ruminant farmers respectively), due to ignorance and lack of awareness and resources. Very few small-scale cattle farmers (21.0%) in the study area wean their calves (Table 2). Those who wean calves do it at about 12 months of age; similar weaning age was also reported in communal farming systems in Zimbabwe (Barrett 1991). These results indicate that small-scale cattle farmers in the peri-urban areas of Bloemfontein are not aware of the advantages of early weaning and the recommended age at which calves should be weaned (i.e. 6–8 months).

Most cattle farmers offer milk (36.6%) and live animals (34.5%) for sale. These products are mostly sold in informal markets (78.7%), due to poor access to formal markets (Table 3). Cattle are usually not slaughtered for home consumption, except if animals are dying or have fractured limbs. Similar results have been reported from West Africa, where calves and adult bulls or old cows are normally sold to generate income and are not slaughtered, except when animals are very sick (Smalley 1996). Cows of any breed are milked for home consumption. Similar results

have been reported in Mozambique, Zimbabwe and in the former Transkei (Bembridge 1984; Rocha et al. 1991).

Table 2. Management practices adopted by peri-urban small-scale livestock farmers around Bloemfontein.

	Cattle		Small stock	
Parameters	**Frequency**	**Percentages**	**Frequency**	**Percentages**
Using record keeping	21	23.3	7	25.9
Using Supplementary feeding	58	64.4	21	75.0
Supplements used				
Crop residue	9	7.5	5	11.1
Hay	43	35.8	17	37.8
Grains	13	10.8	7	15.6
Salt licks	44	36.7	16	35.5
Other	11	9.2	0	0
Breeding season				
Use limited breeding season	2	2.5	3	10.7
All-year-round	79	97.5	25	89.3
Using pregnancy diagnosis	9	10.3	7	25.0
Weaning of offspring				
Yes	17	21.0	2	7.4
No	64	78.0	25	92.6
Weaning age				
Few days after birth	1	5.3	—	—
8 months	7	36.8	—	—
12 months	11	57.8	—	—

Table 3. Animal products sold, milk production, processing of products and type of markets used by small-scale livestock farmers around Bloemfontein.

	Cattle		Sheep and goats	
Parameters	**Frequency**	**Percentages**	**Frequency**	**Percentages**
Market				
Informal	59	78.7	18	78.3
Formal	16	21.3	85	21.7
Products for sale				
Live animals	67	34.5	20	48.0
Beef	26	13.4	—	—
Milk	71	36.6	—	—
Manure	30	15.5	—	—
Mutton	—	—	7	17.1
Wool/mohair	—	—	14	34.1
Milk produced per cow (litres)				
1-2	19	29.7	—	—
3-5	26	40.6	—	—
6-10	13	20.3	—	—
>10	6	9.4	—	—
Processing of products				
Yes	14	15.6	—	—
No	76	84.4	—	—

In general, animal products are not processed. Few cattle farmers (15.6%) make sour milk and a similar custom was reported by Rocha et al. (1991) in Mozambique. The mean milk production per cow per day in the area was 2.1 ± 0.1 l (Table 3). This production level is much lower than the 3.5 to 4 l in the same study area reported by Moorosi (1999). However, this production level is

higher than 1.5 l and 1.8 l obtained by smallholder farmers in Zimbabwe (Matsvangwa et al. 1989). Sheep/goats are kept mainly for wool and mohair production and for sale as live animals in the informal markets (Table 3). Mainly goats, but sometimes sheep in this area are slaughtered and used for traditional ceremonies. Similar results have been reported in the Eastern Cape Province by Madikizela (1988).

In the survey 59.0% and 77.0% of cattle and small stock farmers respectively, have no formal training in animal production practices or access to extension agricultural services (Table 4).

Table 4. Formal training, access to extension service and disease control practices adopted by peri-urban small-scale livestock farmers in Bloemfontein.

	Cattle		Small stock	
Parameters	**Frequency**	**Percentages**	**Frequency**	**Percentages**
Training /external information				
Yes	33	40.7	6	24.0
No	48	59.3	19	76.0
Type of assistance needed				
Training	52	36.4	20	31.7
Technical advice	48	33.6	19	30.2
Financial support	24	16.8	14	22.2
Better market	19	13.2	10	
Need of technical support	65	92.9	23	100
Use of remedies for disease and parasites	78	90.7	26	100
Method of treatment				
Traditional	56	54.4	10	31.3
Veterinary	47	45.6	22	68.8
Reasons to use traditional remedies				
Cultural	4	8.5	1	7.7
Veterinary remedies too expensive	6	12.8	5	38.5
Better than veterinary remedies	19	40.4	3	23.1
Readily available	11	23.4	4	30.8
No reason	7	14.9	—	—

Similar observations have been reported in Kenya and are seen as major constraints to livestock production (Mason 1998). As a result of ignorance and lack of awareness of general modern animal husbandry practices, there is a need for technical support and training, extension and information services and access to markets. Most small-scale cattle farmers (54.4%) use traditional remedies to treat animal diseases, as they believe that these treatments are better than the conventional veterinary remedies or affordable. To the contrary, most small stock farmers (68.8%) use conventional veterinary remedies. The use of traditional remedies readily available is supported by the high prices of conventional veterinary remedies and lack of access to suppliers of inputs. Similar observations have been reported for small-scale sheep and goat farmers in Qwaqwa (Nell 1998).

Conclusions

Small-scale livestock farming in the peri-urban areas of Bloemfontein is an activity led mainly by elderly people, with little knowledge of basic modern animal husbandry practices like record-keeping, the use of a limited breeding season, weaning of calves/lambs and pregnancy diagnoses. The poor access to agricultural extension services, agricultural supplies and markets are limiting factors for sustainable production systems. The reproductive and productive performances realised by small-scale livestock farmers in the peri-urban areas of Bloemfontein are sub-optimal when compared to those of the commercial farming systems. It is, however, in line with other traditional production systems in Africa. The use of indigenous knowledge as traditional veterinary remedies

and medicinal plants should be further investigated. The results of this study show that unless access to relevant extension services and suppliers of agricultural inputs and markets is improved, small-scale resource poor farmers in rural areas of Africa will not reap the potential benefits of the biotechnological advances in the world.

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Drought outlook and veld condition assessment as an integrated part of livestock production

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Abstract
Rangeland condition describes vegetation in relation to its long-term potential for livestock production. It is the most important aspect of sustainable rangeland management systems, as it affects the utilisation potential of the rangeland and therefore has major economic implications. Droughts, however, as a natural phenomenon in arid and semiarid rangelands, have an equal detrimental effect on livestock production. Monitoring the development and extent of a drought together with an accurate early warning system provides valuable information to the agriculture industry. The PUTU production simulation model was used in a geographical information environment to quantify the production potential and climate risk for grasslands and to delimit drought severity. The prediction of approaching *El Niño* events were monitored monthly and farmers used the results for both long-term planning and short-term strategic decisions. A system was developed which simulated production potential for the grassland biome.

Key words: drought, veld condition, animal production

Introduction
The climate of southern Africa fluctuates widely, putting pressure on water resources and food security. Climatic extremes such as the droughts of the early to mid-1980s were reported to have adversely affected more than 40 million people in sub-Saharan Africa (Office of Foreign Disaster Assistance 1990). Approximately 65% of South Africa's rangeland is in the arid and semi-arid areas, with a mean annual rainfall of 500 mm or less (Schulze 1979).

One of the lessons from Africa and elsewhere is that climatic extremes (like drought) result in significant impacts regardless of the level of development, although the character of these impacts differs profoundly (Benson and Clay 1998; Wilhite 1999). Currently, over 20% of the population are under-nourished. Within a decade, 80 million people will face water scarcity (Petersen 1997).

Natural physical resources such as precipitation and soil characteristics (depth and texture) largely determine the production capacity of planted pastures and natural ecosystems. Grazing animals produce food for human consumption and thus contribute to food security; they convert radiant energy captured from the sun in pastoral ecosystems.

If rangeland is in good condition, there is usually a significant relationship between seasonal rainfall and plant production with an index value of prediction (D) (Wilmott 1982) of as high as 0.97 for the grassland biome of South Africa (Snyman 1993). In contrast, as rangeland deteriorates the same relationship is very poor (Snyman 1993) and can be ascribed to insufficient utilisation of rainfall.

Mean annual rainfall is inversely correlated with its coefficient of variation. For example, the coefficient of variation varies from 40% in a semi-arid summer rainfall area of South Africa with a mean annual rainfall of 400 mm to less than 10% for areas with an average rainfall of 700 mm (Tyson 1986). The result of this is that more arid climatic regions are characterised by extreme inter-seasonal variations in plant production (Snyman and Fouché 1991). The average and dry season production in the grassland biome of South Africa can vary by almost 400% (Snyman 1993). As grazing capacity in southern Africa is closely related to rangeland condition (Danckwerts 1982; Danckwerts and King 1984; Snyman 1994) the result of this variable rainfall is major inter-annual fluctuation in grazing capacity. As a result, the short-term stocking rate of a farming unit requires thorough planning for sustainable animal production which becomes more complicated with veld degradation.

Regardless of the quantity of rainfall received by rangeland in poor condition, it is usually ineffectively converted into plant production and contributes towards increased intensity and frequency of seasonal droughts (Snyman and Fouché 1991). Moderate levels of defoliation can further increase the rain-use efficiency of *Themeda triandra* swards (Snyman and Opperman 1983). In the arid and semi-arid rangeland areas of southern Africa productivity is higher and more constant in soils deeper than 750 mm, and able to store limited rainfall, while 2–6 kg dry matter (DM)/ha can be produced from rangeland in good condition for every mm of rainfall used (Snyman 1988; Snyman and Fouché 1991).

Table 1. Hydrological characteristics, production, water-use efficiency and income from Merino sheep on three veld conditions in a semi-arid climate (mean annual rainfall 530 mm).

	Veld condition		
	Good	**Moderate**	**Poor**
Evapotranspiration (mm/day)	1.73	1.61	1.55
Runoff (% of annual rainfall)	3.50	5.55	8.71
Dry matter (DM) production (kg/ha)	1238	768	368
Water-use efficiency (kg DM/ha per mm)	2.50	1.58	0.78
Grazing capacity (ha/LSU (large stock unit))	0.87	1.39	3.23
Income (@ Rand (R) 90 gross margin/LSU)			
R/ha	104	48	28
R/ha per mm	0.20	0.10	0.05

Actual rain-use efficiency figures throughout the arid zones of the world may vary from less than 0.5 kg in depleted sub-desertic ecosystems to over 10.0 kg DM/ha per mm in highly productive and managed steppes, prairies or savannahs (le Houérou and Hoste 1977; le Houérou 1984; le Houérou 1994; le Houérou et al. 1988).

The Free State Department of Agriculture (FSDA) recognises the need to assess the impact and spatial distribution of drought. The Pasture Section of the department has successfully used geographic information systems (GIS) to describe drought severity spatially. Lourens and de Jager (1997) demonstrated the use of GIS to determine drought severity for maize crops in the Free State.

Methodology

The production potential of the *Themeda*-veld could be computed from measured annual harvest yields as done by Snyman (1997). The problem in assessing the overall potential of this veld lies in how to extrapolate results to other localities (Snyman and Fouché 1993; van der Westhuizen 1994; Snyman 1997). Variation exists not only in rainfall and temperature, but also in soil and species composition. By taking these factors into account deterministic models like PUTU15

(Fouché 1992; Howard 1993) make extrapolation possible. The PUTUVELD production model and the GIS were used to quantify the production potential and climate risk (De Jager et al. 1999) for grasslands and to delimit drought severity.

The prediction of the approaching *El Niño* event was monitored monthly and farmers used the results of this project for long-term planning and to make short-term strategic decisions. A system was developed which simulated production potential for the grassland biome.

Using the Southern Oscillation Indices and sea surface temperatures, climatic outlooks were made. Analogue years with similar developments were used to construct an expected rainfall year. The data were used in the PUTU model to simulate the expected veld production and thus animal production for the coming season. Information generated from the model is used as an early warning and decision support system for livestock farmers.

Results and discussion

Veld condition is one of the main factor's determining productivity. With this in mind a simulation of rangeland production as determined by climate was made and compared to the long-term potential (Figure 1).

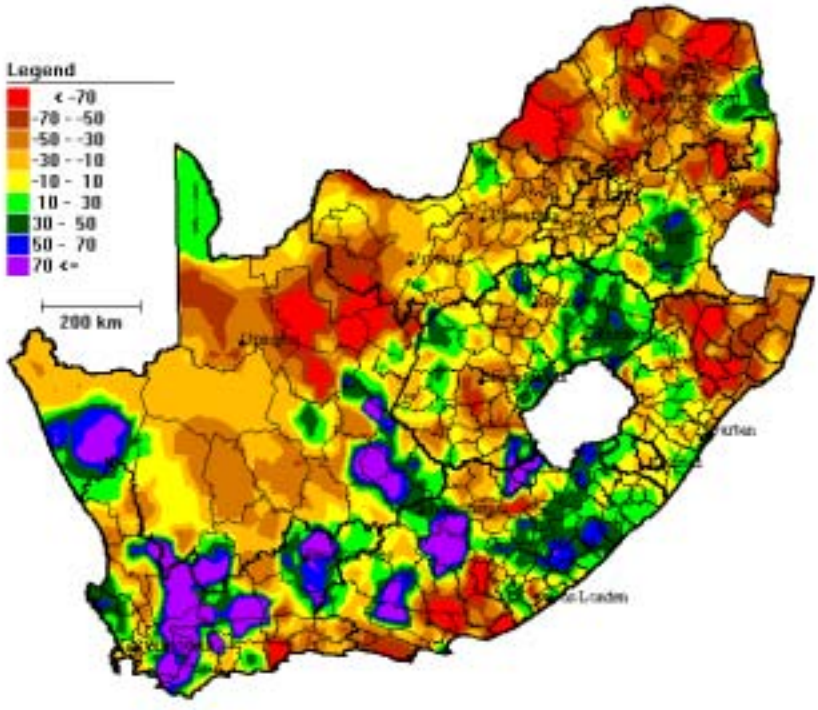

Figure 1. Simulated expected veld production at the end of May 2005 as a percentage deviation from the long-term average pasture condition for the coinciding months.

Areas of low production compared to the expected for that time of the year could easily be seen in the map (Figure 1). Generally, the northern parts of South Africa are dryer than the southern parts, with the exception of the Eastern Cape. A calculation of the areas of different production classes for the central province (Free State) was made (Figure 2). In less than 30% of the area the

veld production for the season was less than 40% of the expected. About 10% of the area experienced serious drought conditions (Figure 2).

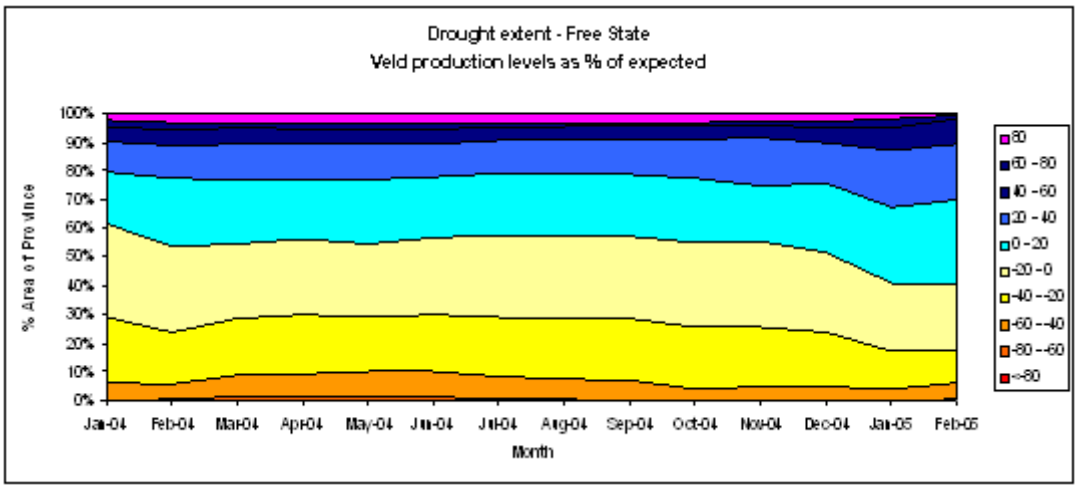

Figure 2. The drought extent and intensity indicated by the deviation from the expected (%) for the Free State Province.

The expected rangeland production for 3 months from February 2005 was simulated with the PUTU model (Figure 3). No dramatic change on a national scale was forecast. The implications of areas going into a winter with very low production reserves must be quantified in terms of animal production.

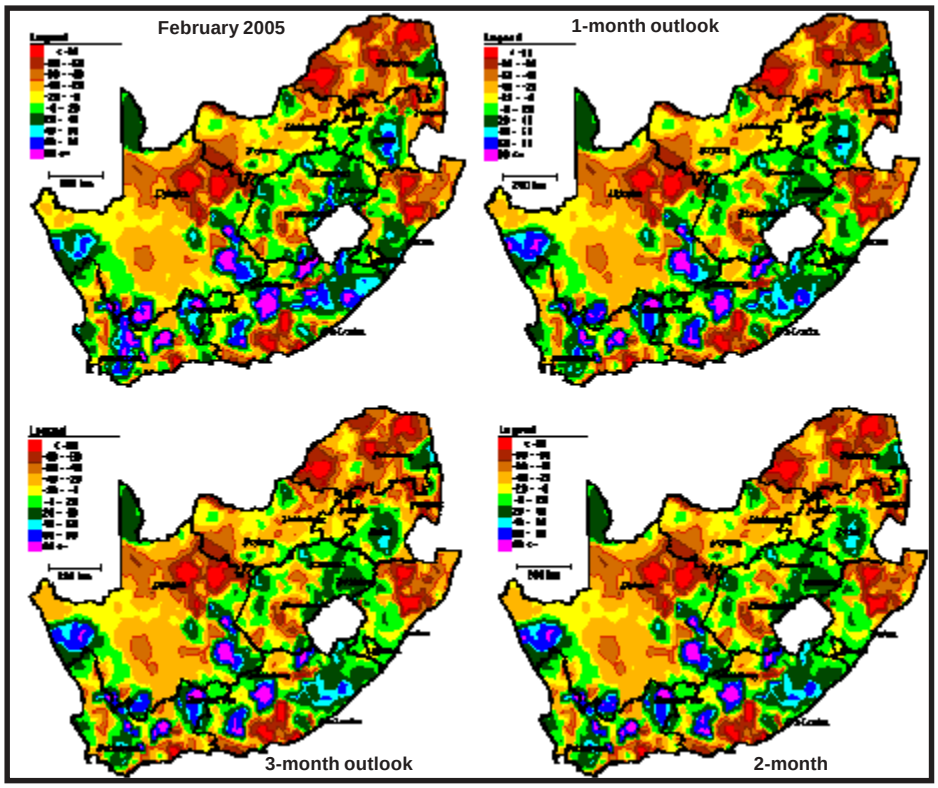

Figure 3. One, two and three monthly outlook of expected veld production deviations from February 2005.

The outcome of the decision on stock numbers, and therefore on available grazing days, are illustrated in Figure 4. A difference of 6 months in encountering fodder shortages exists between a stocking rate of 4 and 7 ha/LSU (livestock unit).

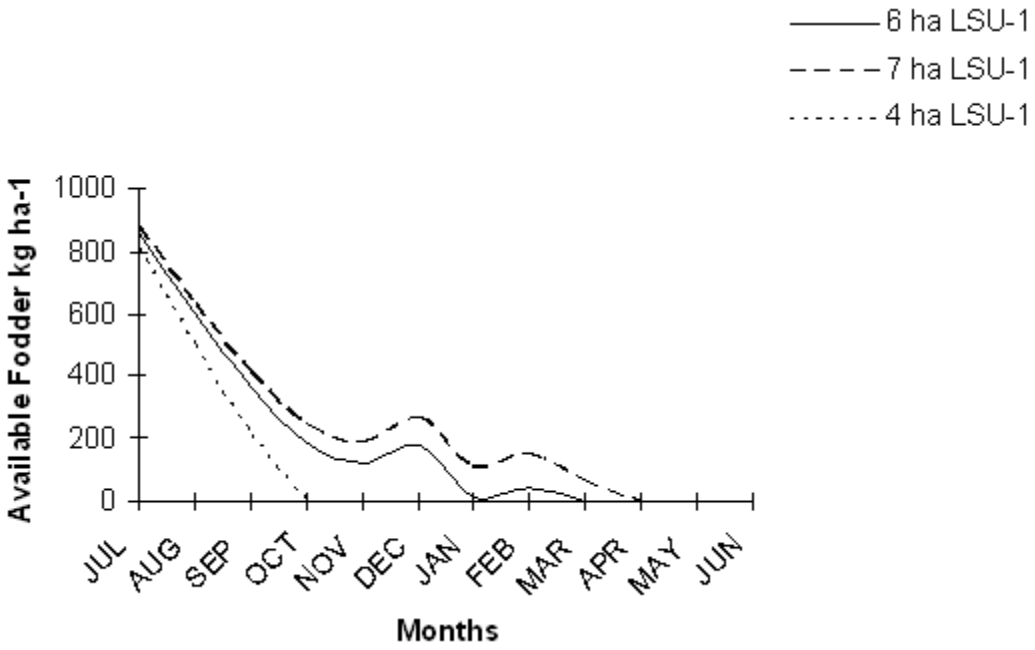

Figure 4. The effect of three stocking rates on the available grazing days for the 2001/2002 growth season.

Conclusion

Veld condition has a major impact on drought vulnerability as it affects the productivity of rangeland. Regardless of the quantity of rainfall received by rangeland in poor condition, it is usually ineffectively converted into plant production and contributes towards increased intensity and frequency of seasonal droughts (Snyman and Fouché 1991). Veld condition as a manageable factor also has an impact on the economy of livestock production.

Livestock production systems must be in harmony with the long-term production potential of an area. This system must absorb the normal climatic fluctuations making it less vulnerable. Short-term tactical strategies must be in place to manage exceptional climatic conditions like droughts. A reliable early warning system could give the stock farmer an advantage in terms of markets, avoiding losses and reducing risks.

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Analysis of three goat production systems and their contribution to food security in the semi-arid areas of Tanzania

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Abstract

Three goat production systems in semi-arid areas of Tanzania using Gairo Division as a case study were characterised in terms of their productivity, contribution to dietary protein and farm economics. System A involved keeping dairy goats only (various blood levels of resultant crosses between Small East African goats (SEA) and Norwegian land race), system B involved keeping SEA purely for meat production and system C involved keeping both milk and meat goats. In system A, meat was a by-product through slaughter or sale of excessive males and culls while in system B, milk was not a by-product as the goats were not milked in the area of study. Information on the production systems was collected using a semi-structured questionnaire in a cross-sectional research design. A purposive sampling procedure was used to ensure that sample households selected represented the three goat production systems. A total of 91 (28, 33 and 30 from systems A, B and C respectively) households were visited and interviewed. Gross margin analysis was used to assess the three goat production systems. The average herd size was 4.3, 10.4 and 5.3 goats for system A, B and C respectively. Over 90% of farmers under system B (meat only) grazed their animals outdoors while more than 50% of farmers in production systems A and C either confined their goats under zero grazing or practised restricted grazing on fields close to homesteads. Age at first kidding, litter size and mortality rates were higher ($P<0.05$) in A than in B and C production systems. The *per capita* consumption of animal protein was three times higher in households in production system A and more than one and a half times in system C compared to system B (meat only). Farmers under production systems A and C gained about 2 times higher returns to labour and had gross margins 10 times higher than farmers under production system B. Although all the 3 systems had positive gross margins, the high mortality rates of 29.0%, 18.0% and 21.5% observed for production systems A, B and C respectively greatly affected the profitability of the systems.

Key words: goats, farm economics, food security, smallholder farmers, Tanzania

Introduction

The livestock sector makes an important contribution to the livelihoods of smallholder farmers in Tanzania although its potential has not been fully exploited. The sector is estimated to contribute 30% to the agricultural gross domestic product (GDP) (Shem and Mdoe 2002). Its role in food security and income generation of most rural dwellers is substantial, with small ruminants providing about 23% of the meat consumed in the country (Mtenga et al. 2004). Of the small ruminants, goats are more popular in Tanzania and therefore their contribution to household economies and the *per capita* supply of animal protein among smallholder farmers is relatively high. In recognition of this importance, crossbreeding of high potential dairy goats with the indigenous breeds of goats of low genetic potential for milk has been practised mostly in Mgeta, a high potential area of Tanzania (Nordhagen et al. 2003). In the semi-arid areas, the first attempt at crossbreeding was in 1999, when the Norwegian breed was introduced in Gairo.

The crossbreeding programme aimed at increasing productive and reproductive performance of the Small East African goats (SEA) to improve nutritional status at household level. The introduction of dairy goats has led to emergence of two production systems apart from the traditional one. The first involves keeping of dairy goats only (various blood levels of resultant crosses between SEA and Norwegian land race). The second consists of both dairy and meat goats managed on the same farm. Each system is expected to be different from the other in terms of management, input and output flows, and how the two breeds in the latter category for example, would possibly complement each other. The perceived differences therefore, led to classifying goat production into three categories rather than based on breeds only.

Although previous studies have acknowledged the role of goats in rural societies, there have been only few quantitative evaluations of their contribution to food supply and livelihood aspects in general. Thus, the objectives of this study were (1) to characterise the three existing goat production systems in the semi-arid areas of Tanzania in terms of production and farm economics and (2) to assess their contribution to human dietary protein supply.

Materials and methods

Three goat production systems in the semi-arid areas of Tanzania using Gairo Division as a case study were characterised in terms of their productivity, contribution to dietary protein and farm economics. System A involved keeping dairy goats only (various blood levels of resultant crosses between SEA and Norwegian land race), system B involved keeping SEA purely for meat production and system C involved keeping both milk and meat goats. In system A, meat was a by-product through slaughter or sale of excessive males and culls while in system B milk was not by-product as the goats were not milked. Average herd composition of the three production systems was obtained by physical counting of the animals at each household. Other information about the production systems was collected using a semi-structured questionnaire. A cross-sectional research design using a purposive sampling procedure as described by Bryman (2001) was adopted to ensure that sample households selected represented the three goat production systems.

A total of 91 (28, 33 and 30 from systems A, B and C respectively) households were visited and interviewed. Gross margin analysis was used to assess the three goat production systems. The questionnaire was structured in such a way that information on goat management and productive and reproductive performance could be obtained. The reproductive parameters assessed included age at first kidding, kidding intervals and litter sizes while productive parameters were mainly mortality rates, off-take, milk yield and lactation length. Diseased incidences were also assessed.

Animal protein output in each system was obtained using the following procedure:

Meat: $(p_{mt}) = (45n \times 1000w \times 8.5e)/100$

Milk: $(p_{ml}) = 35q$

$P_t = (p_{mt}) + (p_{ml})$

where P_t = total protein in g from milk and meat in a production system, n = number of goats slaughtered, w = average live weight of goats at slaughter from a given breed (kg), e = percentage edible parts taken as 81%, q = quantity of milk in kg produced in the household and p_{mt} and p_{ml} = protein from meat and milk respectively. Constants 8.5, 35 and 45 are equivalents of protein in g per 100 g of meat, proportion of protein in g per 1 kg of milk and dressing percentage respectively. The amount of milk produced per household as stated by farmers was converted into protein equivalent using a conversion factor obtained by actual determination of protein using AOAC

(1990) procedures. To estimate daily amount of protein made available per person, information on the amount of beef and chicken meat consumed by each household was obtained through the questionnaire.

The herd composition dynamics of goats, costs and benefits in each household for 2004 were assessed. These included annual births, purchases and transfer-in[1] as inflows while slaughters, deaths, losses in the field and transfer-out[2] formed outflows. The costs and benefits were converted into monetary terms using either 2004 market prices or derived prices as stated by farmers during the study. Reproductive data from the three goat production systems were analysed using GLM procedures of SAS (1998). Flock productivity index was obtained by assessing flock development using the model developed by Peacock (1987).

Gross margin (total revenue – total variable costs) analysis was carried out using the system described by Nyaribo et al. (1990) which involves the use of variable costs only as key components for decision making in day-to-day operations. The variable cost items of the systems included labour, veterinary services, feeding, purchase of live animals and losses due to mortality. The benefits were consumption of milk and meat, animal sales, skins, exchange with relatives and the net change in flock inventory calculated over 2004. The capital value of the stock was obtained by multiplying the average herd size with the average purchase and sale price per animal. Returns to labour (US$/hour) was calculated by subtracting non-labour output from the gross value of outputs divided by number of hours spent in rearing goats.

Results and discussion

More than 80% of the households owned at least two species of livestock which mainly included chickens and guinea fowls. Goats were kept in small flocks, ranging from 1 to 24 animals, with an average of 9 goats per household. Apart from keeping animals, a wide diversification of activities was noted in almost every household, especially those without regular incomes. There were at least two off-farm activities, the most common being small-scale trading and seasonal labour. Such activities can be seen as a strategy to reduce risks of failure in agricultural activities. The concept of diversification as a risk reduction strategy between livelihood components has been extensively covered elsewhere (Valdivia et al. 1996; Ellis 2000; Chambers 2003).

With respect to goat farming, feed scarcity was identified as one of the main challenges. Over 90% of farmers under system B grazed their goats outdoors. In the dry season when goats and other animals are subjected to shortage of browsing/grazing material, a number of strategies were adopted. The strategies varied with the type of production and in some cases with the flock size. Few goats were tethered or provided with supplement feeds. In years with a long dry season, some households with large flocks moved goats to the mountains or to their second homes in the field where they also had farms for crop cultivation. In addition, traditional labour exchange (*kiwili*) was practised by 27% of the farmers under this system. More than half of the farmers under systems A and C either confined their goats under zero grazing or practised restricted grazing on fields close to homesteads. Restricted grazing was reported as a strategy to avoid breeding with unwanted bucks.

The following measures were taken to secure enough feed mainly by farmers under system A: conservation of feeds such as potato vines (10%), tethering (56%) and cut-and-carry of fodder (60%). Thirty per cent of these farmers hired labour to cut-and-carry fodder. Under systems A and C, concentrates were provided with priority being given to the lactating goats. In these systems, mineral blocks were also availed in the goat houses. In contrast, none of the meat

[1, 2] Transfer-in and -out refer to exchange of goats received or given as gifts often between close relatives.

production farmers ever bought mineral blocks. Average time per day spent in taking care of goats was 3, 2.5 and 3.5 hours for systems A, B and C respectively. About 72% of respondents faced labour shortages, especially during the cropping season.

There were variations in flock structure across production systems. Male to female ratio was low and similar for systems A and C, but high in system B (Table 1). This variation reflects differences in production objectives. Over 90% of farmers in system A reported that milk production was the main reason for keeping goats followed by income. Similar priority was made by 75% of farmers under system C. For 62% farmers under this system, having meat goats in their herds was important as they could have other utilities such as traditional functions, festivals and funerals with less expensive goats (meat goats). The observed low proportion of bucks to does can also be seen as a necessary strategy of minimising costs associated with husbandry in systems A and C in order to maximise system output. In system B, the flock compositions were still in favour of the breeding females. However, compared to system A, bucks were more important in system B because they could still serve other production objectives such as liquidity reserve for emergence.

Table 1. Average herd composition of the three production systems

	System A	System B	System C
Herd structure (no. of goats)			
Kids (0–4 months)			
Males	0.40 (9)	1.00 (10)	1.10 (21)
Females	0.30 (7)	1.20 (12)	1.24 (23)
Young (4–12 months)			
Males	0.60 (14)	0.90 (9)	0.54 (10)
Females	1.10 (26)	1.30 (13)	0.80 (15)
Adults (above 1 year)			
Males	0.10 (2)	1.40 (13)	0.02 (0.4)
Females	1.80 (42)	4.60 (44)	1.60 (30)
Total	4.30	10.40	5.30*

*20% constitutes meat goats.
A = milk goats only, B = meat goats only and C = both milk and meat goats on the same farm.
Figures in parentheses are percentages.

A high rate of productive efficiency is often pointed out to be the most important prerequisite for the production of meat, milk, skins and breeding stock (Wilson 1989). In this study, some of the biological parameters denoting productivity are presented in Table 2. Mean litter size of 1.10, with 12% as the overall probability of twinning rate was recorded in system B, being the lowest compared to other systems (1.40 and 1.32). This value is much less than the production objective of 1.5–1.8 kids/doe suggested by Hary (1999). Higher litter size under systems A and B suggests higher meat output from the systems if mortality rates can be reduced.

All farmers with crossbred goats practised a partial suckling system in which kids were allowed to stay with their dams during the day but separated at night. Milking was usually done in the morning. Under system A, average milk yield in the first 3 months of lactation was 1 kg/day, between 4 and 6 months, 0.75 kg/day and in the 7th and 8th month 0.5 kg/day. After 2 months of rest, the new lactation started, 10 months after the onset of the previous one (Table 2) where milk yield was again 1 kg/day. Thus, the average milk yield per doe per year was about 233 kg. With 1.8 milking goats, average milk yield per year per household was 432 kg. In system C, milk production from 1.3 milking goats was estimated at 315 kg/year. These values are slightly below the 0.6–1.4 kg/day reported by Nordhagen et al. (2003) from the same genotype in Mgeta, Tanzania. Mgeta is a highland area, which experiences cool temperatures throughout the year. This

environment seems to be predestined for milk production because of the low stress on animals; this is likely to be an important factor contributing to the higher milk yields. The performance of milk production in the semi-arid areas recorded in this study is also encouraging, as the problem of low consumption of animal source foods was evidently reduced since in almost all cases, goat milk was being consumed at home. Given the high availability of maize bran coupled with its low price (US$ 0.2–0.3 per 20 kg [US$ 1 = TSh 1000 in 2004]), milk production in Gairo is a feasible undertaking.

The mean value for the age at first kidding was lowest (13.6 months) in system A (Table 2). This value is lower than 16.2 months observed by Eik et al. (1985) but similar to the 14 months obtained at the Sokoine University of Agriculture farm (Mtenga and Kiango 1992). Highest age at first kidding (16.6 months) was under system B, being close to 15.8 months reported by Karua (1989) for the Malawian local goats. Differences in management may, to a large extent, account for this variation. Under system A, farmers tend to facilitate mating at an earlier age in an attempt to begin milking earlier and to compensate for the relatively higher variable costs.

Table 2. Productive and reproductive performance of the three goat production systems.

	System A	System B	System C
Age at first kidding (months)	13.6 [b]	16.6 [a]	15.1 [b]
Kidding interval (months)	10.6	11.6	10.3
Litter size (no.)	1.40[a]	1.10[b]	1.32 [a]
Mortality (%)	29.0[a]	18.0[c]	21.5[b]
Annual milk yield/lactation/doe[2] (kg)	233	-	220
Lactation length[3] (months)	10.1	-	10.0
Off-take (%)	46	26	39.7
Herd development index	1.3	1.1	1.2

[2, 3] Calculated from crossbred goats only and excludes milk suckled by kids.
Within rows, values with different superscripts differ significantly ($p<0.05$).
A = milk goats only, B = meat goats only and C = both milk and meat goats on the same farm.

The results show that herds taken in terms of slaughter and sales ranged from 30% in system B to 57% in system C (Table 3), the rate at which, the average herd size could still be sustained as indicated by the positive herd development index in Table 2. Off-take rate in system B was about a half that in systems A and C in spite of the higher number of goats in system B. A possible explanation for this tendency is that system B involves minimal use of cash as opposed to systems A and C. By choosing to include crossbred goats a farmer has to dispose of a few goats from which part of the revenue is used to maintain the flock. Under typical traditional systems, the off-take rate of goats would depend on specific needs for cash. Weather and disease outbreak would also influence the off-take indirectly.

The role of goats

Goat production in Gairo is at subsistence level involving a few goats to meet household needs for meat and/or milk and for family cash income. In this study, farmers received an average contribution of 13% to their total income from goats. However, the value of goats is much higher when non-market values are taken into account. Ayalew et al. (2003) described the subsistence goats as a low-cost and inflation-proof alternative of saving and that their value provides asset (financing) and security (insurance) functions. For example, for the 70% of the meat goat farmers in this study, stock was mainly meant to meet uncertain requirements while over 80% of households in system A, did not milk their goats with the aim of selling the milk.

Table 3. Flock changes within production systems

Descriptors	System A	System B	System C
Annualised average flock flow			
Stock 1 year ago (*a*)	5.20	14.00	9.00
Inflow			
Births (*b*)	2.60	4.60	3.60
Purchases (*c*)	0.30	0.01	0.90
Transfer-in [4] (*d*)	—	0.02	0.10
Out flow			
Slaughters (*e*)	1.00	1.40	1.60
Deaths (*f*)	1.40	2.50	1.90
Losses during grazing (*g*)	—	2.00	1.00
Transfer-out [5] (*h*)	—	0.12	1.30
Sales (i)	1.40	2.20	2.50
Standing stock = (*a*+*b*+*c*+*d*)-(*e*+*f*+*g*+*h*+*i*)	4.30	10.40	5.30
Change in stock	0.90	3.60	3.70
Average herd size between 2 yrs (herds)	4.75	12.20	7.15
Average herd size that can be taken (%)	50.50	30.00	57.30

[4, 5] Goats received or given as gifts.

A = milk goats only, B = meat goats only and C = both milk and meat goats on the same farm.

Previous studies have indicated inadequate supply of animal protein in most regions in developing countries. In their study in Morogoro, Tanzania, Kinabo et al. (2003) found that, of the children under the age of five, 25% were underweight and 52% were stunted. Earlier studies elsewhere had consistently reported high levels of protein deficiency as an outcome of low intake of animal protein (Schäfer et al. 1997; Arene 2002). In the study area, goat meat, chicken and beef are important animal food sources. However, consumption of protein is low because invariably, farmers do not easily slaughter their animals. Goats for instance, being small in size, are generally assumed to be convenient to dispose of (Bett et al. 2004; Lebbie 2004). Instead, farmers in Gairo did not sell goats readily, neither did they slaughter them except during ceremony and/or when a goat was sick or had an accident.

Conversely, milk from a milking animal is a more certain source of protein than meat, especially for children and the elderly. Its usefulness among infants who very frequently face lactose intolerance from cow milk is well known (Haenlein 2004). An additional advantage of goat milk, as some literature shows, is high quality due to small fat globules present on greater surfaces (Jandal 1996). This characteristic makes it more digestible as lipases in the gut are able to attack the lipids more rapidly. Its composition is also characterised by low levels of short fatty acids, which have recognised medical value for many human disorders and diseases (Haenlein 2004). However, goat milk at least in the Tanzanian context, has gained popularity only recently. In other societies such as the pastoral society in Kenya, goat milk has been reported to be highly valued (McCabe 1987). The importance of goats is linked with their ability to provide an alternative source of protein in the dry season when cows produce less milk as drought affects them more than it does goats.

Influence of production systems to protein supply

The results from the milk samples showed that protein contents in goat milk ranged from 3.0–4.2 g/kg with an average of 3.5 g/kg. This value was used to estimate annual protein from goat milk. Crossbred goats produced approximately eight times as much protein as pure SEA (Table 4). The amount of animal protein in families with crossbred goats was threefold higher than that of those with pure SEA when other sources (beef and chickens) were included. These findings imply that milk from at least two milking does for example, would provide sufficient amount of protein (21

g/person/day) for two individuals all year round. In calculating protein from meat, dressing percentage was used as a reduction factor. This method may have underestimated the values in the context of Africans where almost all parts of animals are virtually consumed. All the same, milk protein is expectedly more available because milk would be consumed nearly every day.

Table 4. Annual contribution of animal protein in the three production systems.

Particulars	System A	System B	System C
Protein from goat meat			
Number of goats slaughtered (no.)	1.0	1.4	1.6
Average weight (kg)	40	25	30
Total meat produced (kg) = a	4.6	11.4	17.5
Protein produced from a[6] (g) = (*x*)	1283	1178	1158
Protein from milk			
Milk produced per year (kg) = b	432	-	315
Equivalent protein (g) in 1kg	35	-	35
Protein produced from b[7] (g) = *y*	15120	-	11025
Protein from milk and meat (g) = (*x*+*y*)	17744	2296	14174
Available protein from goat milk and/or meat (g/person/day)	8.1	1.3	7.0
Available protein from chicken and beef (g/person/day)	1.7	2.0	1.6
Total available protein at the household (g/person/day)	9.8	3.3	8.6

[6] Based on 8.5 g protein/100 g of meat (Syrstad 1993) and 45 % as dressing percentage.
[7] Reduced from 35 g of protein/ 100 g of milk.
A = milk goats only, B = meat goats only and C = both milk and meat goats on the same farm.

Major costs in goat production systems

Results of the gross margin analysis are presented in Table 5. In general, major costs in systems A and C were labour, feeding and veterinary services in that order. In system B, feeding cost was the lowest contributing to 16.7% of the total variable costs. Meat production farmers bought neither concentrates nor block minerals. Goats in this system could find for example maize bran during processing of maize for home consumption. The feeding cost in this system is the cost foregone to sell the maize bran, but costs due to lack of adequate feeds may present a much higher proportion. In the dry season, as a result of reduced forage availability, animals lose weight and their body conditions become poor. The expression of this effect is more evident at the beginning of the wet season. This is another cost dimension which results from reduced milk production or income apart from low prices in the wet season due to forces of demand and supply in the study area reported by Mushi et al. (2004).

Overall, prevention and/treatment costs accounted for about 20% of the annual input flows across production systems. Common health problems encountered in crossbred goats in the order of importance were helminthiasis, contagious caprine pleuropneumonia (CCPP) and tick-borne diseases. For the meat goats, CCPP was more important followed by helminthiasis, tick-borne diseases and Foot-and-Mouth disease. Disease prevalence is one of the major constraints that hinder productivity of small ruminants accounting for nearly a half of small ruminant losses in Tanzania (Kusiluka et al. 1998).

In this study, mortality rate was of the order of 18% to 29%. Mortality rates of similar crossbred and local goats in the high potential areas were reported to be 17% for the crossbred goats and 8% for all genetic groups studied (Mtenga and Kifaro 1992). This is lower than 23% for the crossbred and meat goats obtained in our study. The observed variations in mortality rate within groups between households may be explained in part by the differences in management. Free ranging meat goats are more exposed to risk factors than the restricted crossbred goats. While

crossbred goats were kept in elaborate structures, meat goats were relatively less secure as they were confined mostly in open kraals that may have rendered them more susceptible to disease. Poor housing conditions (e.g. dampness in rainy season and chilling effects at night) in system B may explain the higher mortalities due to CCPP. Its influence, nevertheless, did not lead to higher mortality rates than that of crossbred goats. The average annual loss per herd due to mortalities in the three production systems were estimated at US$ 84, 37.5 and 57 for systems A, B and C respectively. This leads to the rather obvious conclusion that increased benefits to the systems can be realised if more efforts to reduce mortality rates are in place because high mortality reduces the number of surplus animals available for off-take and the number of young stock available for replacement.

In general, data in Table 5 suggest minimal involvement of cash in system B. When costs of hired labour are considered, the total cost of goat rearing per annum is less than US$ 2 per goat, which shows that the subsistence agriculture follows a rather low-input production system. In this study, gross margins appeared to be related to the level of income of the household. The results showed that in families with lowest income (average less than US$ 200 per year), the average gross margins were also lowest. Neither did the families with highest income (greater than US$ 500 per year) have high gross margin from their enterprises. Lack of adequate cash to meet necessary costs such as health care may well represent a limiting factor for improving goat keeping for the low income farmers while among the high income earners, goat rearing is likely to be a sideline activity thereby receiving less attention. Across production systems, the highest gross margins were on average recorded from households with medium income levels. The overall implication is that it would be more appropriate for farmers with low incomes to engage in goat meat production. Although variable costs per goat were approximately five times higher for system A than B and about three times as much for the C as for B, the corresponding gross margins in systems A and C were about tenfold higher than in B. The returns to labour for systems A, B and C were 0.13, 0.06 and 0.16 US$/hour respectively. Generally, the three systems are profitable as indicated by positive gross margin and could be attractive engagements in pursuit of employment apart from food supply and income generation. The choice of a system would, however, depend on available resources at the farmer's disposal and the availability of dairy goats.

Conclusion

The introduction of dairy goats increased access to animal protein significantly, being approximately eight times higher than protein obtained from pure SEA. Although all the three systems had positive gross margins, the high mortality rates of 29.0%, 18.0% and 21.5% observed for production systems A, B and C respectively greatly affected the profitability of the systems. However, gross margins in systems A and C were about 10 times higher than that of B. Thus, this study underlines the potential of goats, especially crossbred goats, for improving food security at the household level in the dry marginal areas of Tanzania.

Table 5. Mean values of annual input and output (US$) for three production systems in 2003/2004.

Descriptors	System A	System B	System C
Value of change in stock[8] (*a*)	48.6	64.6	144.3
Value of milk (*b*)	125.6	—	90.7
Skins (*c*) 0.7	0.9	0.9	
Gross value of output ($a + b + c$) = (*d*)	174.9	65.5	235.8
Cost of hired labour[9] (*e*)	32.0	27.0	41.6
Feed costs (*f*)	21.0	4.0	19.0
Veterinary services (*g*)	16.0	9.0	12.5
Total variable costs/herd ($e+f+g$) = (*h*)	69.0	40.0	73.1
Total variable costs/goat	13.3	2.9	8.1
Gross margins/herd (*d*-*h*)	105.9	25.5	162.7
Gross margins/goat	24.6	2.5	30.7
Returns to family labour (US$/hour)	0.13	0.06	0.16

[8] Average prices per goat in system A, B and C are US$ 54, 18 and 39 respectively.
[9] Measured in cash and/or in kind.
A = milk goats only, B = meat goats only and C = both milk and meat goats on the same farm.

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Parallel session 6

Trade in livestock and livestock products: national and regional policies to improve market access for the poor

Improving market access and terms of trade for economic growth of poor livestock keepers: Opportunities, constraints and strategies in Eastern and Southern Africa

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Abstract
A salient feature in the poverty reduction strategy programmes in Eastern and Southern Africa countries is the focus on the commercialisation of agriculture. The macro-policies in the agriculture sector in Ethiopia, Kenya, Uganda, Tanzania and Zambia all focus on transformation of subsistence farming to market oriented agricultural production. There is empirical evidence of a strong relationship between poverty and the distribution of livestock. Livestock keepers constitute over 60% of the rural poor in Eastern and Southern Africa. At the same time recent analysis of livestock development trends has predicted a large increase in livestock production and consumption and also has shown that livestock sub-sector is an important livelihood source. This paper gives an overview of recent development trends in the livestock sector and looks into the aspect of improved access for the poor to domestic and regional livestock markets as a way of scaling up production and escaping the poverty trap.

Key words: poor livestock keepers, livestock trade, livestock marketing, market access

Introduction
The terms 'poor' and 'poverty' are currently the key words in the human development arena. They are simple terms that we all think we know, but defining them is complex. Poverty is a multidimensional social phenomenon. It ranges from food and material deprivation to the psychological experience of multiple deprivations (LID 1999; Morton and Meadows 2000; IFAD 2004).

In recent years researchers and development workers in the livestock sector have studied and discussed the role of the livestock resource in Africa in the war on poverty. Africa carries about 20% of the world's cattle and 25% of the world's sheep and goats and has about 34 million equines and camels as well. In 2002 the livestock sub-sector in Africa provided over 11 million tonnes of milk and about 4 million tonnes of beef for domestic consumption and export, valued together at about US$ 19 billion. The estimated market size of the countries, which fall under the Common Markets for Eastern and Southern Africa and the East Africa (COMESA) bloc is over US$ 120 million per year. Africa imports US$ 3 billion worth of livestock and livestock products but exports only US$ 1 billion worth of the same, with net imports rising by 4% every year. Over 90% of the COMESA and East African Community (EAC) dairy market is serviced from extra regional imports.[1] These statistics indicate that there is a viable but unsatisfied market for processed livestock products, which can be catered for if the local capacity to produce competitively priced livestock products was increased and/or the quality of locally produced livestock products matched that of the imported products.

[1] COMESA/EAC/RATES/ECAPAPA Regional Dairy Trade policy paper September 2004.

The work of Thornton et al. (2002) on 'Mapping poverty and livestock' provides a guide to better understanding of poor sedentary livestock keepers and poor pastoral/agropastoral livestock keepers. This work indicates that poor livestock keepers constitute over two-thirds of the total number of poor out of which 75% are sedentary small-scale farmers (Figure 1). The pastoral/agropastoral community constitutes less than 10% with over one-third of this group falling under the poor in Ethiopia, Kenya and Tanzania. Paradoxically, two-thirds of the rural poor are livestock keepers despite the fact that livestock is an enabling asset and an important source of livelihood. Poor market access of livestock keepers to domestic and regional markets, lack of supportive policy and legal framework and unfavourable terms of trade are among the main causal factors identified in recent analyses on livestock development and poverty.

This paper presents an overview of the livestock sector in Eastern and Southern Africa as a source of wealth and discuss the various factors that restrict the access of the poor to livestock and livestock products markets. The effects of the emerging global, regional and national trends and strategies to improve access and terms of trade in the livestock industry are also discussed.

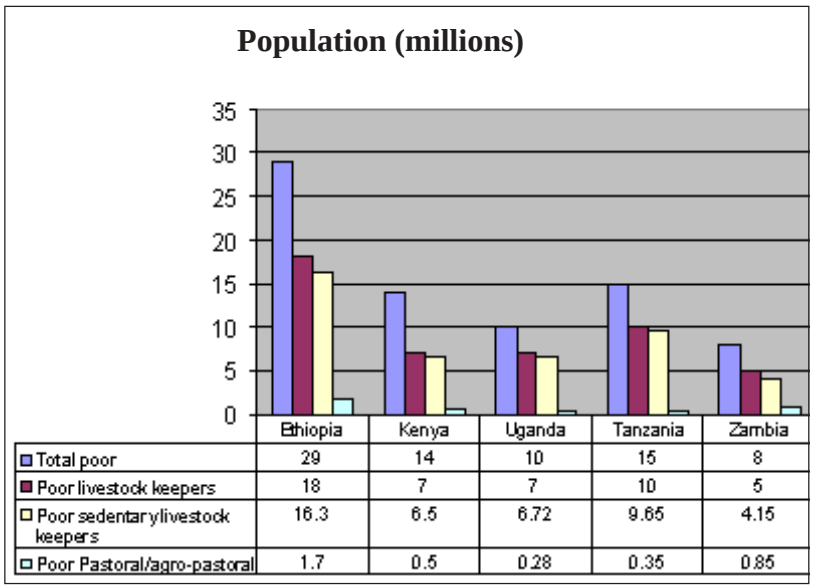
Livestock and wealth creation—national, regional and global outlook

Analysis of assets through a framework of five types of capital: natural, human, financial, physical and social has been rated as a good approach in analysis of the holistic view of the poor (Carney 1998). However, there is no clear definition of what sort of capital livestock are. Morton and Meadows (2000) describe livestock under natural capital, financial and social capital supporting the multi-faceted nature of livestock (Box 1). In addition to the multiple functions described in Box 1, livestock play a significant role to the national economies in the region (Table 1).

Box 1. Livestock have multiple functions among poor households

- Livestock provide an important dietary component animal protein—meat, milk and eggs—thus contributing to household food and nutrition security.
- Livestock are the main and often the only source of steady income.
- Livestock diversify smallholder production systems and thereby increase food and income security.
- Livestock provide draft power, which contributes to increased crop production and reduces human drudgery, especially for women (fetching water, forages and fuel wood).
- Livestock contribute to increased farm production efficiency through integrated nutrient management.
- Livestock keeping is one of the few activities through which the poor can accumulate capital.
- Livestock are one of the few natural capital assets owned by the poor.
- Livestock allow the poor to gain private benefit from common property resources.
- Livestock act as a buffer capital in lean seasons.
- Livestock give social status security and cultural identity.
- Livestock make arid and desert regions with sparse vegetation habitable for humans, where a sedentary agricultural lifestyle is impossible.
- Livestock supply building material for shelter, e.g. the Gabbra community (camel herding nomads in northern Kenya) use camel skin for building mobile houses and as beddings.

The main avenue for wealth creation is through trade of both live animals and their products. In the beef sector, it is evident that trading live animals in the region is big business involving huge transactions of money. The terminal markets in cities such as Addis Ababa, Dar es Salaam and Nairobi are known to handle large volumes of animals and much money. Kera market in Addis Ababa slaughtered 155,459 cattle valued at over US$ 75 million in 1999/2000 (Aklilu 2002). In Kenya the value of red meat production is estimated at KSh 43.2 billion. However, producers and particularly the poor get a dismal share of what is accrued in the business. Aklilu's (2002) analysis of the situation in the Horn of Africa reported a declining trend in the producer's share of the retail price. The same report noted that in Sudan, which is characterised by a long marketing



	Ethiopia	Kenya	Uganda	Tanzania	Zambia
Total poor	29	14	10	15	8
Poor livestock keepers	18	7	7	10	5
Poor sedentary livestock keepers	16.3	6.5	6.72	9.65	4.15
Poor Pastoral/agro-pastoral	1.7	0.5	0.28	0.35	0.85

Figure 1. Poor sedentary livestock keepers and pastoral/agropastoral communities in the five countries based on World Bank rural poverty rate.
Source: Thornton et al. (2002).

chain with many middlemen, livestock prices in terminal markets end up at 2 to 4 times higher than that of producer's price. The high transaction costs have been associated with poor infrastructure, poor access to services and markets, low public sector investment and frequent conflicts and insecurity.

Recent analyses in the dairy sector have also identified dairying as a potential poverty exit and wealth creating enterprise among sedentary smallholder farmers. Dairy activities provide regular income to the poor to address immediate household needs. However, as for the beef sector it remains a question of whether poor livestock keepers get a fair share of the retail price. Poor infrastructure is a major constraint. Research within the smallholder dairy project in Kenya has shown that each additional kilometre of poor feeder road separating a farm from main road reduces the price of milk by about 3% (Staal et al. 2003). The same study has shown that the informal milk sector plays a significant role in wealth creation and improving access to markets.

In international trade, livestock and livestock products account for about one-sixth of all agricultural trade by value while the value added by livestock in the global farm economy is around 40%. However, Africa's contribution to global livestock trade is dismal. Today, Africa accounts for only 2% of the total value of world trade in livestock and livestock products, with imports of the same being greater than exports as noted above.

Table 1. Livestock sector and national economies in Eastern and Southern Africa: Contribution of the agriculture sector and that of livestock component (%).

Country	Contribution of agriculture to national GDP	Livestock component in agriculture	Livestock component in national GDP
Ethiopia	55	40	20
Kenya	30	40	10
Uganda	29–58	20	8
Tanzania	45	13	10

[2] Pro-Poor Livestock Policy Facility, Project Memorandum, start date October 2001, end date October 2007.

Africa's ability to increase livestock exports is limited by several factors. These include its inability to increase domestic production because of biotechnical, economic, socio-cultural and political problems. Even when there is surplus production that can be exported, it is often difficult to meet the technical standards, regulations, rules and procedures set by international organisations such as the World Trade Organization (WTO) and the World Organisation for Animal Health (OIE). These are referred to as the sanitary and phyto-sanitary measures (SPS) and can constitute barriers to trade if they place unjustifiable discriminatory demands on exporters/importers. Thus, Africa remains marginalised in a competitive global environment. A recent analysis of the situation commissioned by African Union (AU) concluded that few sub-Saharan African countries would be able to fully satisfy the general international requirements, i.e. to comply in full with the minimum standards, guidelines and recommendations of the OIE terrestrial animal health code and the Codex Alimenatarius (Brückner 2004). Among the key issues raised in the AU report were: importing countries require standards for compliance that are not attainable in sub-Saharan African countries; there is inadequate technical, policy and institutional support to sub-Saharan African countries in the process to realise and maintain minimum standards; and there is poor participation of sub-Saharan African countries in setting standards.

The predicted livestock revolution by year 2020, which is demand driven, is expected to provide income growth opportunities for many rural poor (Delgado et al. 1999). Africa has a large potential to tap from the predicted demand. Meat and meat products in Africa are largely produced under natural conditions (organic conditions) and therefore likely to attract the health conscious consumers who form the bulk of the rich members of a society. In an improved economy, there will be a predictably higher consumption of animal based proteins, namely meat, eggs and milk.

Technical, physical, institutional and policy barriers impinging on market access for the poor

Technical barriers constrain small producers from efficiently supplying a safe and relatively uniform product to the market. The lack of appropriate infrastructure for the preservation of perishable products affects the negotiation power of small production units, particularly if these are distant from the consumption centres. In addition, technical barriers exist in the form of sanitary requirements (including animal welfare) as a prerequisite to trade. A perceived or real low animal health status may exclude countries or groups within countries from international, regional and local markets. Small producers are also currently excluded from the market because of lack of technologies, goods and services that allow for the implementation of innovative product standards and safety norms. Technical barriers to market access for the poor in sub-Saharan Africa include:

- Trade sensitive diseases and zoonoses (Foot-and-Mouth disease (FMD), lumpy skin disease (LSD), Rift Valley fever (RVF), African swine fever (ASF), contagious bovine pleuropneumonia (CBPP), peste des petits ruminants (PPR), New Castle disease (NCD) and zoonotic diseases such as anthrax, tuberculosis, brucellosis and cysticercosis).
- Poorly functioning veterinary services, especially at the grassroots in terms of (surveillance, diagnostics, risk analysis and mitigation procedures, disease reporting and control quarantines and quarantine facilities).
- Stringent livestock movement regulations (bureaucracies in acquisition of permits/no objection chits).
- Low technical capacity for appropriate grading systems for quality (classes of animals, facilities etc.).

Physical barriers to market access for the poor

- Inadequate, dilapidated, poorly equipped or inconveniently located holding grounds/ quarantine centres for inspection, isolation and treatment.
- Inadequate watering facilities or watering points along stock routes.
- Stock movement routes are not clear, reliable and safe in some cases.
- Remoteness of the localities of the producers making it difficult to reach them.
- Poor infrastructure in terms of road networks, bridges for efficient communication between producer and buyer.
- Poor market infrastructure at primary, secondary and tertiary levels.

Other barriers

- Insecurity (this has a drawback on the purchase, transport or the production process of the livestock).
- Transportation (high costs, time, security etc.).
- Market information not available to most producers and some traders.
- Attitude change to produce for marketing, especially for the pastoralists.

Institutional and policy barriers impinging on market access by the poor

The Pro-poor Livestock Policy Facility programme[1] led by the Food and Agriculture Organization of United Nations (FAO) has identified a combination of global, regional and national level policies, regulations, norms and values that have resulted in the poor not being able to take advantage of the opportunities presented by the demand led growth for animal protein. These issues are described as institutions that provide a framework for access to and control of capital assets that influence the political effectiveness of economic interests and control the political agenda. The manner in which these factors shape collective outcomes through the organisational enforcement of these rules at a national and international level therefore supports or prohibits the development of the poor. Such rules are said to translate into barriers, lack of competitiveness and risks, all of which prevent the poor from taking advantage of the available development potential. The institutional and policy support barriers in livestock trade in sub-Saharan Africa can be summed as:

- **Financial and asset barriers** prevent small farmers intensifying their production because the investment required often exceeds their capital wealth. The absence of innovative forms of targeted small- to medium-scale credit is restricting the involvement of the poor in the commercialisation of livestock production and product processing.
- **Social and cultural barriers** restrict access to assets, goods and services, including the market, due to ethnic grouping, class, gender, language, education or lack of property rights. A lack of appropriate mechanisms and information campaigns has thus far prevented the equitable participation and empowerment of the most vulnerable groups in the development process.
- **Lack of competitiveness** resulting from a combination of higher production and transaction costs often disadvantage the small producers who do not benefit from the economies of scale associated with large-scale units.
- **Production costs** are usually higher in small-scale production enterprises, outweighing any cost advantages from the discounted value of family labour. Furthermore, there is a lack of objective data to inform policies and institutions about the impact of hidden and overt subsidies that facilitate the supply of cheap animal products to the cities, on small-scale producers, public health and the environment. In addition, the public sector has thus far not

acted to adapt or disseminate new technologies for small-scale use. The absence of policies and institutions that enable small production units to benefit from the cost advantages of large-scale production skews the playing field further.

- **Transaction costs** can be prohibitively high for small-scale producers because of the small quantities of marketable product produced and the absence of adequate physical and market infrastructures in remote areas. Transaction costs are also increased where producers lack negotiating power or access to market information and remain dependent on middlemen. Moreover, the lack of facilitation in the formation of producers associations or other partnership arrangements makes it more difficult for smallholder producers to reduce transaction costs through economies of scale.
- **Market risks** include price fluctuations for both inputs and products and are often associated with a weak negotiating position. Many small-scale producers evolved from subsistence farming with sound risk coping mechanisms but lack the assets or strategies to sustain full exposure to market risks. The absence of safety nets in the face of economic shocks, invariably present in such markets, will restrict the full participation of the poor.
- **Production risks** relate to resource degradation and asset control, to climatic variations such as drought and floods, and to infectious diseases. Although both small-scale and intensive livestock production systems are at risk from the predations of epidemic diseases and droughts, the poor are particularly vulnerable to these types of shocks due to their limited assets and the lack of insurance schemes. Public and private services in disaster-prone poor countries almost invariably lack the capacity to plan for such risks or to respond in a timely manner.

The role of regional and international institutions in promoting livestock trade and marketing

International development trends in line with globalisation call for regionalisation and formation of trading blocs as trading of all commodities becomes increasingly competitive. There are three main regional development blocs within Eastern and Southern Africa, namely: the Inter-governmental Authority on Development (IGAD) comprising seven countries in the Greater Horn of Africa, he EAC and the Southern Africa Development Community (SADC). A bigger regional economic bloc including nearly all the countries in Eastern and Southern Africa is COMESA. Major developments emanating from these regional economic communities or regional coalitions are growing economic integration, establishment of preferential areas of trade and formation of a custom union. These developments led to an increase in intra-regional exports of dairy products between 1999 and 2003 and much of it has been attributed to launching of COMESA Free Trade Area (FTA) in 2000, which rendered regional exports cheaper than extra-regional trade.

Another institution of much relevance to promotion of livestock trade in Africa is the Inter-African Bureau for Animal Resources of the African Union (AU-IBAR). This pan-African institution was created in 1951 and became a technical organ of the Organization of African Union. IBAR has played a large role in addressing livestock trade barriers, which are of transboundary nature. In collaboration with African national governments, regional economic communities (RECs) and development partners, AU-IBAR has successfully implemented several livestock development programmes in Africa within the last 50 years.

[3] To quote from U.S. Agricultural marketing Agreement Act. 1937. Secure fair exchange value for farm products by establishing orderly marketing conditions for farmers while accounting for consumers interests. And Canadian Dairy Commission Act 1966. provide efficient producers with the opportunity for fair returns to their investment and labour while providing consumers with a continuous and adequate supply of quality dairy products

These regional initiatives have enabled some member countries to break through some of the barriers to trade and are participating in the global market for livestock and livestock products. However, more needs to be done particularly to enable Africa to talk with one voice at the WTO and OIE if it is to break through any artificial barriers to the world market. There is a need for Africa to have regional bodies that will defend the interest of their member states at the WTO, OIE, multilateral and bilateral talks. Networking among IBAR, RECs and national governments is particularly essential for promoting continent-wide livestock development and trade.

National and international research institutions

The inception of the poverty reduction strategy programmes in the region has resulted in a major policy review process in most countries. In the agricultural sector there is a new thrust on commercialisation of agriculture or a move toward market oriented agriculture. Focussed and country or region specific research agendas are crucial if national and international research institutions are to play their rightful roles in this global agenda on poverty reduction. Some of the areas of concern being addressed by national and international research institutions are highlighted below:

- Conservation of indigenous livestock and wildlife genetic material
- Community-based approach to integrated utilisation of the livestock/wildlife interface
- Repackaging and disseminating appropriate messages: Retooling extension messages to better target livestock producers through appropriate information and communication technologies (ICTs)
- Development of new/better quality vaccines for common and economically important diseases including contagious bovine pleuropneumonia (CBPP) and Rift Valley fever (RVF)
- *Mitigation against environmental and land degradation associated with irrational use of rangelands*
- Development of a replicable model for management at the livestock-wildlife interface in African traditional pastoral production systems and dissemination
- Increasing livestock production through improved feeds and feed resources and access to water
- Improving productivity of emerging livestock
- Development of a livestock marketing and trade information and communication system
- Policy research on rationalisation and harmonisation of livestock policies.

These noble goals, however, cannot be achieved as the national institutions continue to be starved of funds by the public sector while the private sector (livestock) in Africa does not believe or appreciate that it has a role to play in funding research (or cannot afford to) for their own good. It is important that the public sector re-investment into the livestock sector, which is currently between 0.2–1% in most countries in Africa, is increased.

Public–private sector partnership development in the sector

Public–private sector partnership is critical for the development of livestock trade and markets following trade liberalisation. Major areas of partnership include, but are not limited to:

- Financial services—Livestock trade, especially live animal exports, requires huge capital resources. Many African traders and aspiring exporters lack this capital. The provision of financial services for the livestock sector, be it for production, trade or transport, is therefore essential (e.g. Sudan has established a special bank for the livestock sector, the Livestock Resources Bank).

- Privatisation of traditionally government-managed service provisions—Past experiences show that government-managed services such as veterinary services and the management of certain infrastructure involving ranches, stock routes, watering points etc. have not been successful due to poor management, corruption, neglect etc. While initial government investments are still required for such services, the management of such services is better contracted to private entities so that they can provide services at a cost. Governments should limit themselves to playing regulatory roles.
- Cutting through unnecessary red tape—Governments should strive to facilitate trade rather than be an impediment. Livestock trade should not suffer from lengthy bureaucratic export procedures some of which are obsolete and unnecessary.
- Joint government–private sector forums—the formation of joint government-private sector forums (livestock and livestock products trade associations) will be instrumental in tackling issues on time. Such issues may include SPS, taxation, transport, industry code of conduct, export procedures, credit extension, internal and external promotion etc.

Conclusions

The African livestock sub-sector is largely traditional and dominated by pastoralists and smallholder mixed crop–livestock producers. These producers have limited individual capacity to penetrate markets and to increase and sustain market share in an increasingly competitive global environment. African governments and development partners have realised the need to address the institutional and policy issues, which are directly linked to economic growth. The main issues for consideration on the basis of the ongoing national and regional programmes include:

- Critical review and analysis of the need for and benefits of participating in international standard setting, including increased commodity-based livestock trade and the concept of disease free zones.
- National policy and legal framework review process—support for pro-poor policies in the livestock sub-sector.[2] Key questions arise about the policies supporting producers to get fair returns from the business. What about access to inputs for production of quality products?
- Rationalisation and harmonisation of policies, and regulations that will create an enabling institutional environment for livestock markets.
- Public–private sector partnership. At national level a strong public–private sector partnership is a prerequisite for delivery of livestock services to poor livestock keepers. Access to regional and international livestock markets will depend on a strong public–private sector partnership.
- High transaction costs: In the beef industry the remoteness of producers from the main markets is reported to lead to high transaction costs. Use of producer association/groups is mentioned as one of the strategies that can be used to alleviate this problem. Lessons from RELMA in ICRAF project in the area of farmer organisations and more recently contract farming could provide options for reducing transaction costs. High transaction costs could also be due to small or low volumes of produce, which can be addressed through cooperatives or associations.
- Information dissemination: Given the literacy level of most of the poor livestock producers, information dissemination has to be addressed in a wider perspective. Information communication has to be demystified and producers be empowered to know how to analyse the information.

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The development of a computer management program for small- and medium-scale egg producers

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Abstract
The Agricultural Research Council (ARC) released the latest version of the [EGGS 2000™] computer program in February 2005. It aims to assist small- and medium-size egg producers to effectively manage egg production in their enterprises. This program uses relevant data and information that influence egg production in an egg enterprise. Firstly, production data is stored in a structured query language (SQL) database on the farm and could be used by the farmer to generate production reports and graphs on a daily, weekly or monthly basis. Secondly (and most importantly) it gives the farmer an opportunity to contribute to the national and regional comparisons of production efficiency parameters of the different flocks (comparisons are anonymous), thus assisting the producer to make more accurate management decisions. This paper discusses the role of this programme in improving egg production, minimising risk and increasing the financial viability of the producer.

Introduction
The egg industry represents a very important part of agriculture in South Africa, representing some 16 million laying hens, owned by approximately 300 producers. Although egg production embodies factory and industrialised farming (which optimises biological objectives, efficiency ratios and application of the learning curve), a comprehensive drive to simultaneously combine production management, financial efficiency and interactive training is still lacking. The development of this encompassing package [EGGS 2000™] serves as the impetus to the above-mentioned drive. [EGGS 2000™] is a comprehensive egg laying computer program designed to monitor the efficiency of flocks on a daily basis. It is aimed at assisting small- and medium-size egg producers. The first version of this package was developed successfully over the last 10 years by the Poultry Performance Testing Scheme of the Agricultural Research Council (ARC)-Livestock Business Division in consultation with the Software Development Company, *Felix Solutions cc*, and culminated in a registered trademark end-product [EGGS 2000™]. [EGGS 2000™] is a Windows driven computer package that runs from a Pentium computer with all the accessories. This programme is aimed at assisting producers to improve egg production, minimise risk and increase the financial viability of the producer. The objective of [EGGS 2000™] is to expose and equip egg producers with the latest technology and science in the field of computerised/electronic farming, thus enabling them to operate efficiently and profitably.

Materials and methods

[EGGS 2000™] as a management tool
[EGGS 2000™] uses all relevant data and information that would influence egg production in an egg enterprise. Firstly, production data is stored in a structured query language (SQL) database on the farm and could be used by the farmer to generate production reports and graphs daily, weekly or monthly. Secondly (and most importantly) the farmer gets an opportunity to contribute to the national database at the Irene Livestock Business Division. This database is used for

national and regional comparisons as far as production efficiency parameters of the different flocks are concerned (all the comparisons are anonymous).

[EGGS 2000™] enables egg producers to collect production data on the layers pertaining to egg production, feed usage, mortality, egg distribution, hen mass, lighting programmes etc. This information is recorded in the computer for each hen house unit. The program automatically performs the complicated calculations for over 20 production parameters including hen house production, percentage hen day production, average egg mass, feed used per hen day, egg grading profile, percentage mortality, production efficiency measures etc.

[EGGS 2000™] easily generates a detailed production report within flock and between the flocks (houses) daily, weekly and monthly. The daily production report gives production figures for the selected date and preceding six days. The weekly total and total production figures to date are also available. The information outlined below is available from the report.

Hen days and production section

- Hen days (cumul)—the cumulative hen days from the start of production.
- Hen days (since prev.)—is the hen days on a specific date. If there was no production data input on a previous day and the data input for the specific date is the total for the two days, the 'hen days since previous' is the cumulative hen days for the specific two days.
- % prod/hen day—the percentage production per hen day.
- % prod/hen house—the percentage production per hen house.
- Eggs/h. house—the number of eggs produced by a hen house for a day or week.
- Eggs/h. house/cumul—the number of eggs produced by a hen house from start of production.

Egg production by grades

- Cracks, small, medium, large, xlarge, jumbo—the number of eggs produced by each grade (small, medium, large, extra large, jumbo and cracked eggs).
- Total egg production—the total of cracks, small, medium, large, extra large, jumbo eggs.

Percentage distribution by grade (cracks excluded)

- Gives the percentage of the different grades excluding the cracked eggs.
- Cracks—the percentage cracked eggs of the total eggs produced.

Mortality section

- Lost—number of birds stolen in the flock for a day, week and to date.
- Dead—number of birds that died in the flock because of sickness or disease per day, per week and to date.
- Culled—number of birds culled in the flock for a day, week and to date.
- Birds in flock—number of birds remaining in the flock after all the lost (stolen), dead and culled ones are subtracted.
- %mortality—the percentage mortality for a day, week and to date.

Egg mass section

- Average egg size gms—the average egg size in grams.
- Total egg kg—the total mass of egg produced (kilograms) by the flock per day, per week and to date.
- Total egg kg/cumul—the cumulative total mass of egg produced by the flock per day, per week and to date.

- Egg gms/hen day—the average mass of egg in grams produced per hen day.
- Egg kg/hen housed—the average mass of egg produced by a hen per day, per week and to date.
- Egg kg/hen house/cumul—the cumulative total mass of egg produced by a hen house from start of test for a day, a week and to date.

Feed section

- Feed type code—the type of feed used, the code exists in the library.
- Feed used (tonnes)—the tonnage of feed used by the flock on a day, week and to date.
- Feed used/cumul—the cumulative quantity of feed used by the flock from start of production until the report date.
- Gms/hen day/cumul—the average quantity of feed used by the hen per day, per week and to date.
- Feed kg/dozen—the average mass of feed used by the average hen in the flock to produce one dozen of eggs.
- Feed kg/dozen/cumul—the same as feed kg/dozen but the cumulative feed usage and cumulative dozen of eggs from start of production are used to do the calculation.
- Feed kg/egg kg—the average mass of feed used by the average hen in the flock to produce one kilogram of eggs.
- Feed kg/egg kg/cumul—the same as feed kg/egg kg but the cumulative feed usage and cumulative egg mass from start of test are used to do the calculation.

Financial summary—at standard cost and egg prices

- Feed cost/tonne—feed cost per tonne, for feed type used, at standard feed cost.
- Feed cost/usage—feed cost, for feed quantity used, at standard feed cost.
- Feed cost/dozen—feed cost to produce one dozen eggs, at standard feed cost.
- Feed cost/egg kg—feed cost to produce one kilogram of eggs, at standard feed cost.
- Standard sales—the egg income, at standard income for each grade.
- Sales/hen day—the egg income per hen day, at the standard income per dozen for each grade.
- Sales/hen house—the egg income per hen house, at the standard income per dozen for each grade.
- Net inc/hen day—the egg income minus feed cost per hen day, at standard income and standard feed usage.
- Act inc/hen day—the egg income minus feed cost per hen day, at standard income and actual feed usage.
- Net inc/hen house—the egg income minus feed cost per hen house, at standard income and standard feed usage.
- Act inc/hen house—the egg income minus feed cost per hen house, at standard income and actual feed usage.
- Point-of-lay price—standard point-of-lay cost per bird, for the strain.
- Profit/hen house—net income per hen house, minus point-of-lay cost per bird, at standard price per bird.

The period production report is the same as the daily production report, but with weekly summaries in place of daily figures. Production graphs could also be generated. This will keep the egg producer informed of all the production events.

Results and discussion

[EGGS 2000™], as the first and only registered/trademarked egg laying computer programme in South Africa, has already been developed in to a marketable programme. Currently, 20 producers are using the programme in South Africa and 3 in other Southern Africa Development Community (SADC) countries. Results obtained from [EGGS 2000™] are promising and extremely existing.

Milestones

- [EGGS 2000™] is fully internationalised thus opening up vast opportunities on the global market and Internet.
- More than 20 production parameters are being monitored.
- More than 13 eggs grades are included, allowing international clients to use the programme.
- Four versions of the programme have been released to date.
- Requests for inter active training at universities, technikons and colleges level had been received. Tertiary institutions represent seven universities, ten agricultural colleges and Pretoria Technikon.
- Batch loading enables the client/student to load data of various production traits on one screen.
- The package also has a wide potential for application among consultants, nutritionists, commercial feed representatives, pharmaceutical officers, extension officers and researchers.

The development of this package as an open source database technology made provision for a much sought after industry database. The package has a proven record of rendering support and creating knowledge and goes beyond software thus enhancing its economic impact and competitiveness. The establishment of this package has resulted in a new, tangible and competitive end product with vast opportunities for the commercialisation of the egg industry as far as research and development are concerned.

Conclusion

[EGGS 2000™] measures the effectiveness of egg production and is able to monitor the daily production in the enterprise, thus assisting the producer to make more informed or accurate management decisions. The egg production of the enterprise will indirectly improve production, minimise risks and make the enterprise financially viable. The data sent to the ARC-Livestock Business Division at Irene can be analysed statistically (it should be noted that only production data are exported to ARC for backup and analysis, since maintaining confidentiality of each enterprise is important). Scientific conclusions are made to the benefit of the egg producers. Anonymous comparative national and regional reports are made available to the participating egg producers in future.

The outcomes of using continuous improvement and innovation method to improve livestock marketing for the resource poor farmers in South Africa

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Abstract
South Africa needs 'focusing' methodologies to improve the capacity of emerging farmers in risk management and profitability. This study evaluates the use of the continuous improvement and innovation system as a methodology to achieve sustainable improvement in beef cattle marketing by resource-poor farmers. The methodology was tested on 23 pilot projects involving 450 farmers in the Limpopo and North West provinces in an initiative called 'Beef Profit Partnerships'. The methodology enabled farmers and support teams to focus on identifying the key drivers of marketing of beef cattle by rural producers and prioritises actions to achieve greater efficiency. The results show significant improvements in local market access, prices and marketing costs. Village farmers organised regular and frequent auctions in their villages to reduce transport costs and improve prices, e.g. prices of weaners increased by R 2.47/kg and mature animals by R 1.33/kg. On average, village auctions achieved sales of 56 animals, village incomes of over R 100,000.00 and transport cost per head of cattle and per trip reductions that ranged from R 18.00 –to R 73.00 and R 300 –to R 1,300.00 respectively.

Key words: continuous improvement and innovation, livestock marketing, resource poor farmers

Introduction
South Africans tasked to develop the 'second' agricultural economy into the 'first' economy need to look at innovative models to develop nationally and internationally competitive businesses and industries. There is a need to look at models used in other sectors like manufacturing and engineering to drive their continuous improvement (Gieskes and ten Broeke 2000). Special skills and practices are needed to achieve sustainable improvement in agriculture profitability, risk management and entrepreneurship. South African agriculture commodity chains are the most advanced in sub-Saharan Africa and supply very developed markets. In the South African livestock industry, most products go through the feedlot sector before ending up on a consumer's plate (70% for beef and almost 100% for pork and chicken). South Africa also has a vast number of farmers with limited market access that are referred to as the emerging sector. These farmers barely understand their commodity marketing chains. They own about 40% of the South African beef cattle breeding herd but contribute only about 5% directly to the formal market chain. They are amongst the poorest people in South Africa as it is not possible to subsist as a beef cattle farmer. Market access, throughputs and costs are some of the challenges that affect the profitability of their enterprises and thus their livelihoods.

The Agricultural Research Council (ARC) Livestock Division has developed a methodology called continuous improvement and innovation (CI&I) in partnership with emerging beef farmers, local governments, Limpopo and North West provinces, the Australian Centre for International Agricultural Research (ACIAR), the University of Queensland and the Australian Beef Co-operative Research Centre (Beef CRC)in an initiative called Beef Profit Partnerships. The methodology was used to tackle problems relating to market access (pricing), throughput (which includes number available to sell, growth performance and mortality) and costs that affect emerging farmers' profitability in South Africa.

This article focuses on a system for marketing improvement for these farmers. Emerging beef farmers in South Africa on average get prices that are 50% less than the national market price. The costs of selling their animals, especially those related to transporting the animals to the formal markets, are very high and discouraging. Negative perceptions about these animals also cloud their direct access to the feedlot market, a situation commonly exploited by speculators and middlemen.

Methods

Clarke and Timms (2001) defined continuous improvement and innovation as individuals in teams, networks and partnerships regularly and frequently focusing their thinking and action to achieve improvement and innovation, now and in the future. Improvement in this methodology means enhanced practices, processes, systems, products, services, outputs and outcomes. Innovation means new practices, processes, systems, products, services, outputs and outcomes in the marketplace, workplace and/or community. The methodology is based on the application of the principles of Better Practice Process of the CI&I approach, a six-step ongoing cyclic technique (Figure 1).

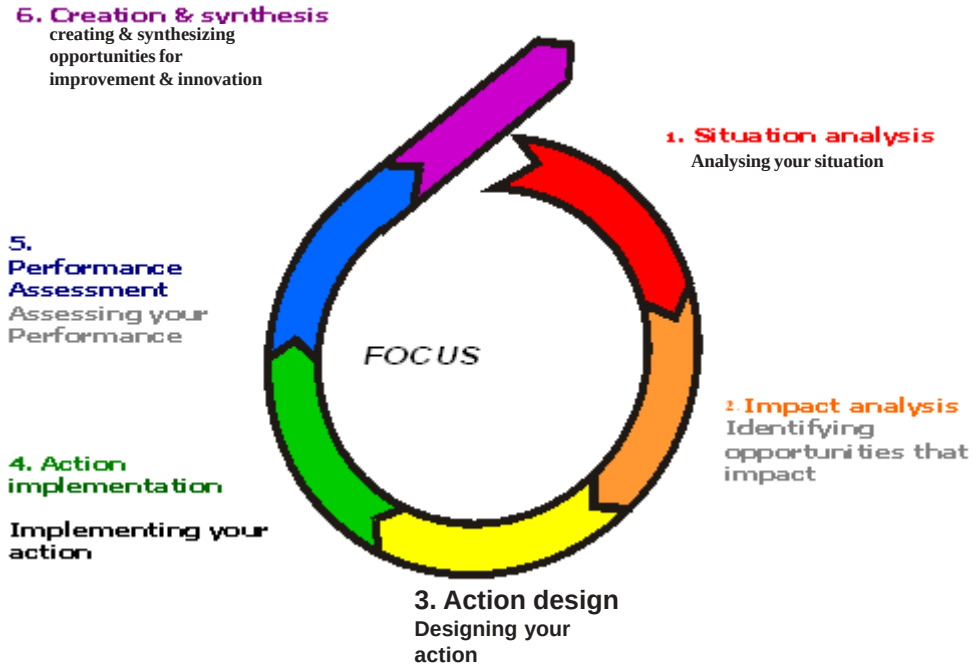

Figure 1. Six steps of the Better Practices Process of continuous improvement and innovation.

The key features of the CI&I methodology processes are that it:

1. Focuses on how to make a real difference to performance in a given situation.
2. Incorporates set principles and values.

3. Has a sequence of six key steps (Figure 1) which are designed to deliver specific outputs and outcomes. Every time these six steps are completed, a new level of performance is created from which further improvement and innovation is possible. The CI&I process is therefore an upward spiralling process rather than simply a cyclical process (Figure 2).

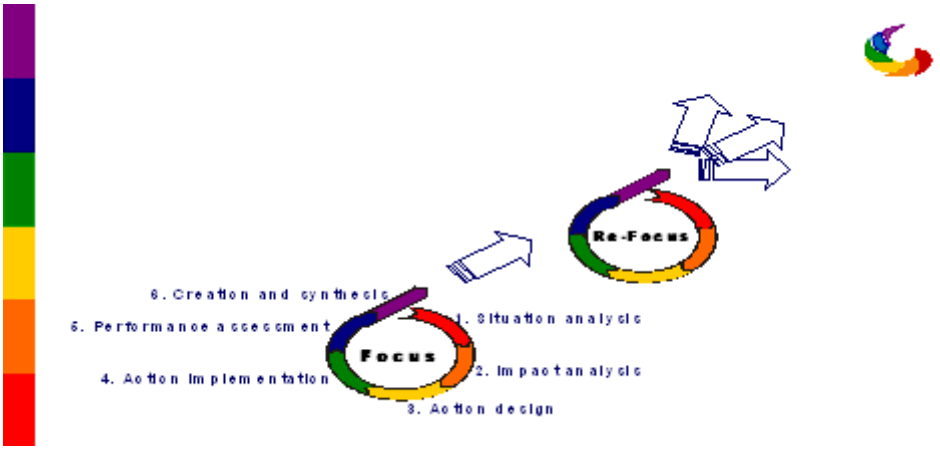

Figure 2. The continuous improvement and innovation process.
Source: Clarke and Timms (2001).

1. Has focusing questions to enable thinking and action to be focused on the purpose of each step.
2. Has recommended tools for each step. Some of the tools have been designed and developed specifically to support steps in the process. Tools from other sources are also used.
3. Enables flexibility in thinking and actions, and should not be applied in a linear or recipe-like mode.
4. Has five stages of engagement to support continuous improvement and innovation of performance.
5. Consists of running four types of sessions—start-ups; 30-day action support sessions; 90-day performance improvement sessions; and 180-day refocusing sessions.
6. Is specifically designed to enable improvement of the process itself and is therefore continually improving.

The profit thinking frameworks tool was used for these farmers (Figure 3). Profitability in simple terms is affected by the total income minus the costs of production. The profit thinking framework ensures that every aspect that affects profit and could be influenced gets all the attention to maximise its contribution to the enterprise profitability. The farmer and support teams' conception of this thinking framework formed the basis of this project.

Farmer teams and support teams agreed to identify issues to focus on that would improve their prices. They agreed to keep records of their costs, marketing related costs, market prices, actual price sale and animal's age. The farmers' support teams organised different buyers and auctioneers, provided scales to weigh animals before the sales, recorded market prices of the day and trained farmers on price determination. The scientists agreed to focus on clearing negative perceptions about cattle from the emerging farmers of the biggest buyer of live cattle, which is the feedlot sector. A study was designed to evaluate feedlot performance of animals bought from the emerging sector compared to the commercial sector. Their feed intake and weight gain were recorded to calculate their average daily gain and feed conversion ratio. They were also quarantined and

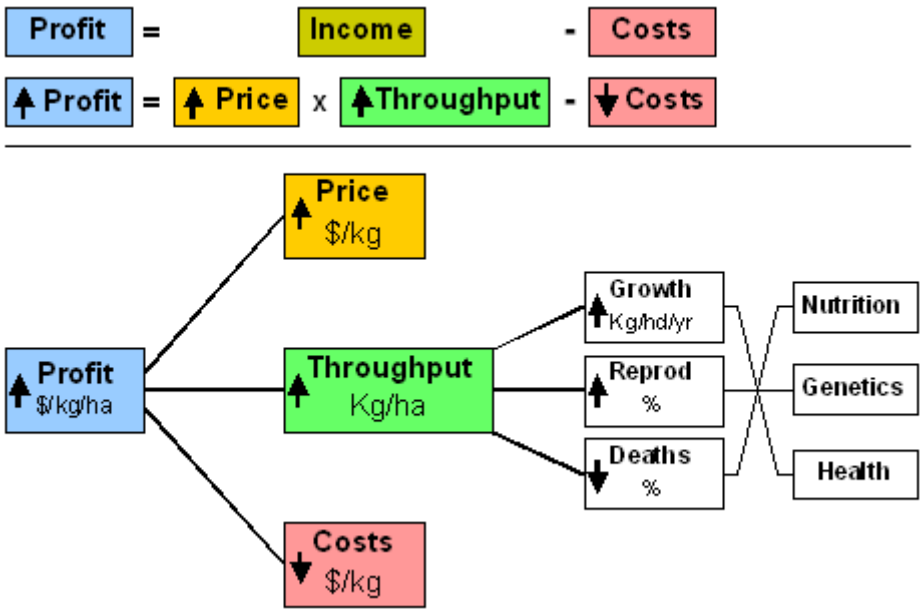

Figure 3. Profit thinking focus framework tool.

tested for a series of diseases including tuberculosis (TB), Contagious Abortion (CA) and measles. The meat quality was also studied for meat tenderness, marbling and colour. The animals were also tested for presence of marbling and tenderness genes. A database was established in 2002 with values deduced from the situation analysis used as the benchmarks. The information recorded was the market average price of the day, the actual price recorded by each farmer, the animal class, number of buyers and date of the auction.

Results and discussions

Market access, price and market costs were the prime focus for all 17 teams under the pilot scheme. Prices before the project intervention where deduced from data collected during the situation analysis. Benchmarking of prices was based on comparing the trends over the years.

Table 1. Percentage increase in prices due to the Better Practices Process intervention in 2003/ 2004.

	Weaner prices (R/kg)	Mature prices(R/kg)
Before BPP	4.56	4.5
After BPP	7.03	5.8
Difference	2.47	1.33
% increase	54.2	29.6

Exchange rate of South African Rand to dollar during the study r7.50 = $1

A communal village managed to organise four auctions in 2003 where on average 56 animals were sold. A similar number of auctions were held in 2004. The prices of weaners and mature animals shifted by an average of R 2.00 and R 1.33 per kilogram respectively towards the market price in all 17 teams.

Emerging farmers generally continue to get weaner prices below the market prices; however, some teams received prices that were not significantly different from the market prices. This indicates that farmers were using market information and is illustrated by the reduction in the difference between actual and market prices following the intervention. The trend shows that weaner prices followed the market trend. They also organised their sales only when prices were good and withdrew their animals when offered very low prices, e.g. at one auction in Khomele,

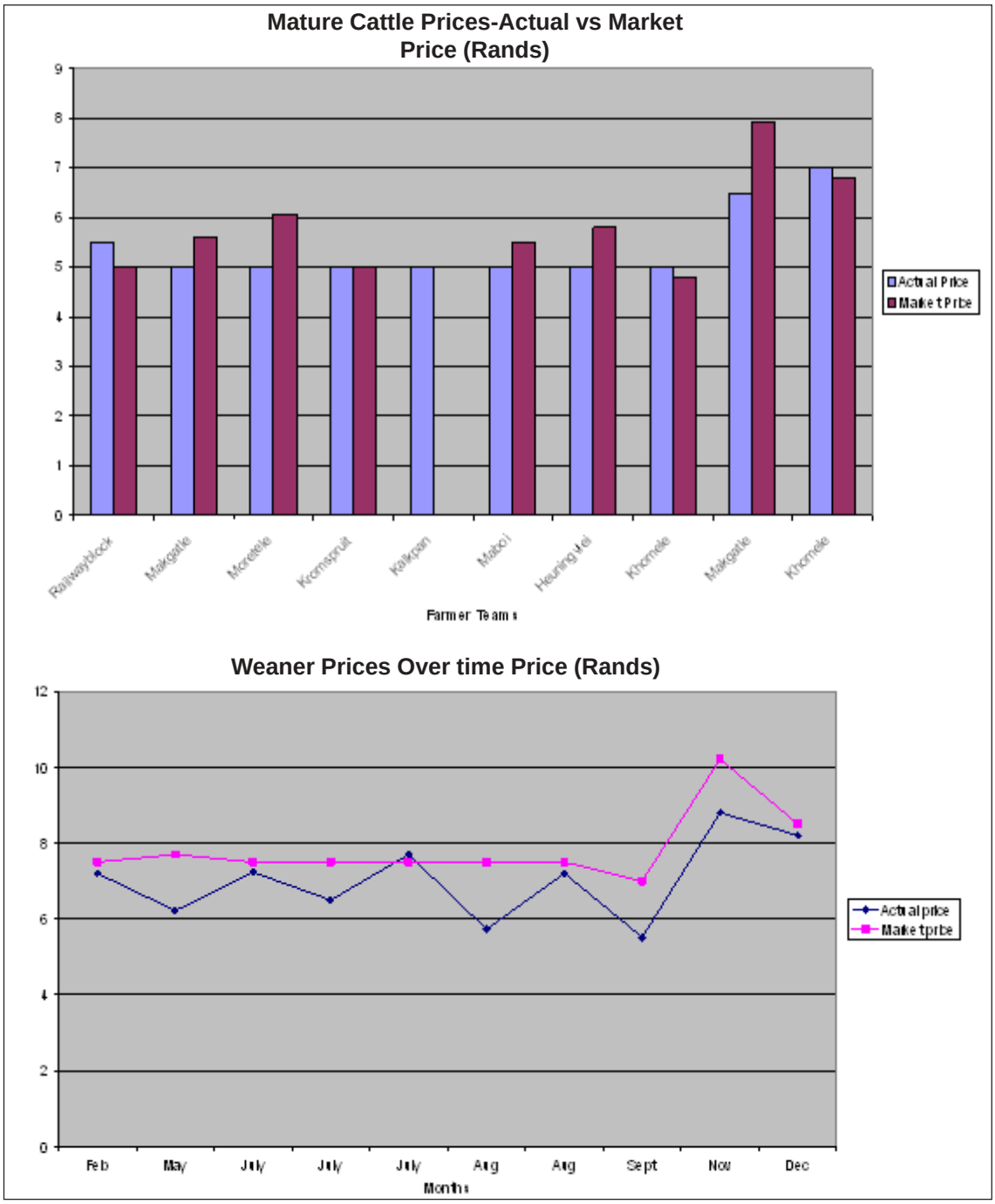

Figure 4. Graphical comparison of market prices differences.

21 weaners were withdrawn from the market and an auction was cancelled with 87 animals in Mmagatle.

Farmers saved thousands of rand on the costs of transporting animals to the nearest selling points (see example in Table 2). The new focus of these teams has been turning towards throughput as market issues are improved.

Table 2. Costs saved by organising on-farm or village sales.

Team	Sale pens	Distance from village/farm [b]	Rands saved per trip [a,b,c,d]	Total rands saved
Magatle village	Bela-Bela	200	1,300	12,264.00
Maboi 3CT farm	Polokwane	50	375	378.00
Khomele village	Mapani	100	625	4,964.00
Kromspruit farm	Zeerust/Northum	60	313	791.00
Railwayblock	Vryburg	180	1,125	7,812.00
Total				26,209.00

[1]Assume they pay 3.50 per kilometre.
[2]Assume kilometres to and from the farm or village.
[3]Assume the truck loads 18 mature livestock unit per trip.
[4]Assume they organised joint transport, which was not the case.

The market focus helped farmers realise their herds' performance levels as they wished they had more and heavier animals to sell. The financial benefits of this focus for emerging farmers has been tremendous, i.e. buyers have been spending about R100,000 in villages auctions; feedlot performance trials cleared perceptions that animals from emerging farmers will have high disease prevalence, poor growth and low meat quality, which lead to feedlot companies buying directly from some of these teams at the actual market price.

Conclusion

Village incomes increased significantly once CI&I was used to focus on improving market price in all pilot sites. A village auction of 56 animals will leave on average about R100,000 with the communities, which is a promising way of increasing incomes through livestock. The support teams provided a useful service to these farmers. Service providers and recipients who practise CI&I developed a culture of performance monitoring. CI&I stimulates thinking outside the box beyond existing systems of research, extension, and other support to farmers. Practising CI&I encourages uptake of available technologies by emerging farmers. The methodology also inculcates the culture of being systematic in dealing with identified problems by both the emerging sector and its support structure. The emerging sector needs a culture of self-propelled continuous improvement which develops when CI&I is practised. The Republic of South Africa needs to look for such methodologies to support our agricultural sectors, both the established and the emerging sub-sectors.

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Technologies for enhancing value addition, quality and safety of milk produced by smallholder farmers in Africa

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Abstract

FAO 2003 data indicate that Africa imported over 5.6 million tonnes liquid milk equivalent worth about US$ 1.8 billion or 29% of the world dairy import trade. Part of this demand-supply gap for value added dairy products could be filled by processed dairy products from within the African region. While Africa produces about 28.7 million tonnes of milk annually (26.7 kg/per capita), in most countries more than 85% is sold as raw milk thus raising quality and food safety concerns. The paper reviews and discusses technologies that have been developed to address these problems including improvement of milk handling by informal milk traders, traditional fermentations, butter and cheese processing, milk preservation using lactoperoxidase (LPS) and in-pouch pasteurisation of liquid milk. It is concluded that Africa's dairy industry needs to grow from an industry dominated by informal actors to small and medium enterprises answering the needs of the changing socio-economic landscape of African countries.

Introduction

Among the major regions in the world, Africa's dairy industry is the least developed in terms of productivity per cow, milk supply per capita and proportion of industrially processed milk and dairy products. A large proportion of the 28.7 million tons of milk produced annually is by traditional cattle keepers and smallholder dairy farmers of whom more than 80% are concentrated in Eastern and Southern Africa (Tambi et al. 2001). FAO data show that in 2003 Africa as a whole imported 5.633 million tonnes liquid milk equivalent worth US$ 1.766 billion or 29% of world dairy import trade worth US$ 6 billion. The imports are necessary to fill the ever growing gap between supply and demand for milk and dairy products and to compensate for the low internal capacity to collect and process domestically produced milk into preserved dairy products. The challenge for Africans is to apply appropriate technologies and economies of scale to fill the gap from domestic and regional supply chains.

From the mid-1990s in most African countries, the state-owned dairy parastatals have given way to private sector operated milk marketing and processing ventures. In Kenya, Tanzania and Uganda the number of dairy plants increased from less than 10 in each country to more than 30 small- and medium-scale dairies in each country. In spite of this, more than 80% 95%, and 85% of the milk produced is marketed as raw milk respectively in Kenya, Tanzania and Uganda (Lore et al. 2005). Reasons why informal milk marketing dominates the dairy industry of most sub-Saharan African countries are weak infrastructure for milk collection and processing and the fact that most poor urban consumers cannot afford the added cost of processing and packaging of pasteurised milk (Staal and Omore 2003). Recent studies in Kenya and Tanzania have shown that a significant proportion of informally traded milk does not meet microbiological and composition specifications set forth by national bureaus of standards and adulterations are quite common (Omore et al. 2004). Post-harvest losses due to milk spoilage and spillages have been estimated at 2.7%, 5.6% and 3.0 % in the entire marketing chain in Uganda, Tanzania and Kenya (Lore et al. 2005). Reasons for high microbial loads in raw milk and spoilages include poor hygienic practices and the lack of cooling facilities at the farm and in the entire marketing chain. To address some of

these problems affecting smallholder dairy farmers and informal milk traders, various milk preservation and processing technologies have been investigated or promoted in various countries in Africa. The objective of this review is to present appropriate technologies and discuss their implications for dairy marketing and processing industry development in Africa.

Milk preservation at the farm level

Most smallholder farmers and milk traders operate in rural areas without access to electricity. Milk marketing chains are in most cases short involving direct sales of raw milk to consumers or milk vendors (itinerant milk traders) who act as intermediaries between producers and consumers in some cases. Due to the high perishability of milk, these warm milk market chains are limited to the sale of morning milk within 2–3 hours travel distance from the farm. Beyond these time and spatial limits, some form of preservation has to take place. Cooling is the technology of choice where electricity is available; the use of generators can be justified by the quantities of milk that can be bulked at a milk-cooling centre. While bulk coolers are common and the preferred mode of chilling milk, the use of locally fabricated ice banks can enable small quantities of milk to be cooled in 30–50 litre milk cans. In Tanzania, the Sokoine University of Agriculture has in the past several years promoted the fabrication and use of this technology by some smallholder farmers groups with considerable success (Figure 1). Using this technology milk can be preserved for up to 24 hours and the ice block formed can still keep the milk below 10°C for at least 12 hours following breakdown of electricity. Due to technical and economic limitations attempts to use solar refrigeration in milk preservation has not been commercially applied anywhere in Africa.

The ice bank is double walled, galvanised mild steel tank measuring 86 cm wide x 218 cm long x 82 cm deep (1.45 m^3) insulated with styropol sheeting (5 cm) in between the two walls. Two 0.75 hp single phase compressors are installed on one side of the box (Figure 1). Copper pipes (3/8" diameter) from each compressor are lined 9 cm apart along the tank walls and bottom surface to function as the evaporator that absorbs heat from the water. The tank can accommodate 10 milk cans each holding up to 50 litres of milk (Figure 1). Alternatively, the tank can be constructed out of smooth finished concrete or fire bricks insulated with styropol held in place by chicken wire on the outer wall and finished by a smooth layer of cement plaster.

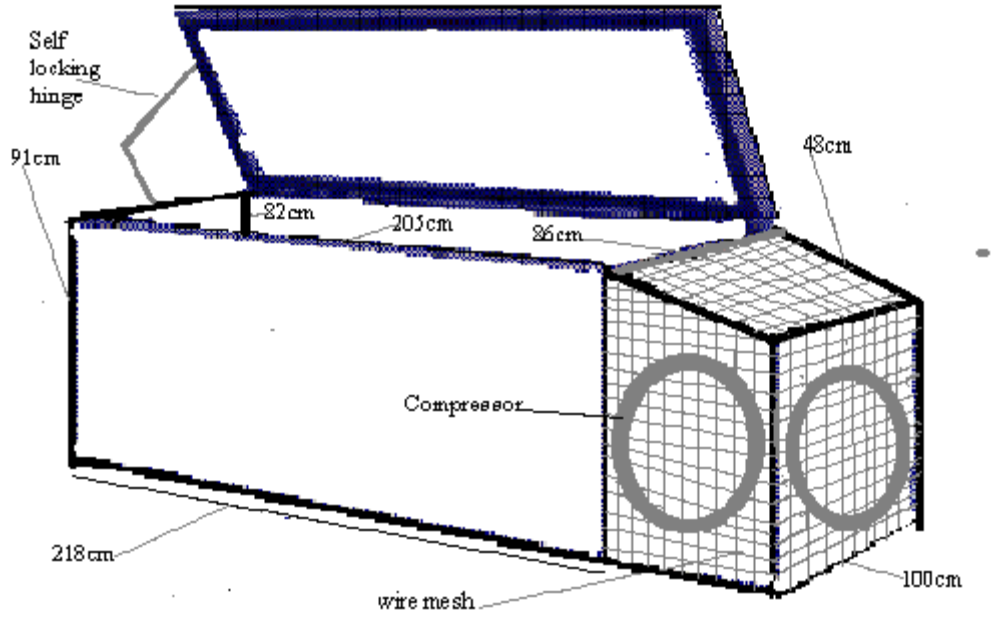

Figure 1. Simple design of a 500 litre ice bank milk cooler.

Milk preservation without electricity

Preservation of raw milk without electricity has proved to be of considerable technological and ethical challenge. In 1956, FAO approved the use of hydrogen peroxide for preservation of milk in warm developing countries where refrigeration was not possible. It has not been widely applied commercially due to a number of drawbacks including presence of impurities such as trace amounts of iron, copper and arsenic acid, the need to remove excess H_2O_2 by catalase treatment and oxidation of proteins, aldehydes, ketones and vitamins A and C and more seriously, the splitting of a minor component of the casein complex which affects the ability of rennet to coagulate milk during cheese making (Scott 1981). Moreover, this method cannot be regarded as a safe method in respect of pathogens in milk such as *Mycobacterium tuberculosis* that can survive H_2O_2 treated milk for longer than 24 hrs. For these reasons, the use of H_2O_2 for the preservation of raw milk has now been replaced by the activation of the naturally occurring lactoperoxidase system (LPS) (IDF 1981; Claesson 1995; FAO 1999).

The activation of LPS in the milk is achieved through addition of 14 mg of sodium thiocyanate (NaSCN) and 30 mg of sodium percarbonate ($2Na_2CO_3.3H_2O_2$) to give an initial concentration of about 15 ppm of thiocyanate (SCN^-) and 8.5 ppm (H_2O_2) respectively in the milk. This treatment, when done within 2 hours of milking and to milk of good hygienic quality, prolongs the bacteriostatic effect of the natural antibacterial systems for a further 6–24 hours depending on the (ambient) temperature of the milk thereby enabling milk to be marketed for longer distances and time interval after milking (Table 1).

Table 1. Effect of temperature on efficacy of the lactoperoxidase system.

Temperature (°C)	Shelf life (time, h)
30	7–8
25	11–12
20	16–18
15	24–26

Source: FAO (1999).

The technical and economic efficacy of the LPS system has been the subject of considerable interest and investigations in recent years. Field trials conducted in Ethiopia showed that the lactoperoxidase preserved milk for 3 hours longer than the untreated control, but failed to do so after 7 hours (Taye Tolemariam et al. 2000). Under tropical environments in Africa, it appears that the usefulness of the LPS system to preserve the quality of milk is limited to 6–7 hours (IDF 1988) but it is still cheaper than conventional cooling is (Wanyoike et al. 2004).

High ambient temperature and initial quality of raw milk are important factors to consider where it is desirable to use LPS to prolong the shelf life of evening milk (Kurwijila and Mwaikambo 2003). An added advantage of the LPS treatment is the extension of shelf life of pasteurised milk which has been preserved by LPS (Kamau et al. 1999; Nicholete et al. 1999; Mwaikambo et al. 2005). The results of a recent study (Mwaikambo et al. 2005) showed a clear advantage in shelf life extension of LPS activation over the control sample for milk pasteurised within 3–6 hours following activation and storage at ambient temperature (24–25°C) (Figure 2). All pasteurised milk samples were subsequently stored in a refrigerator maintained at 5–8°C. This has positive implications for marketing of pasteurised milk by small-scale milk traders and retailers as it would reduce losses due to spoilages. To date the major drawback to commercial application of the LPS treatment is a clause in the guidelines which requires such milk not to enter international trade (IDF 1981).

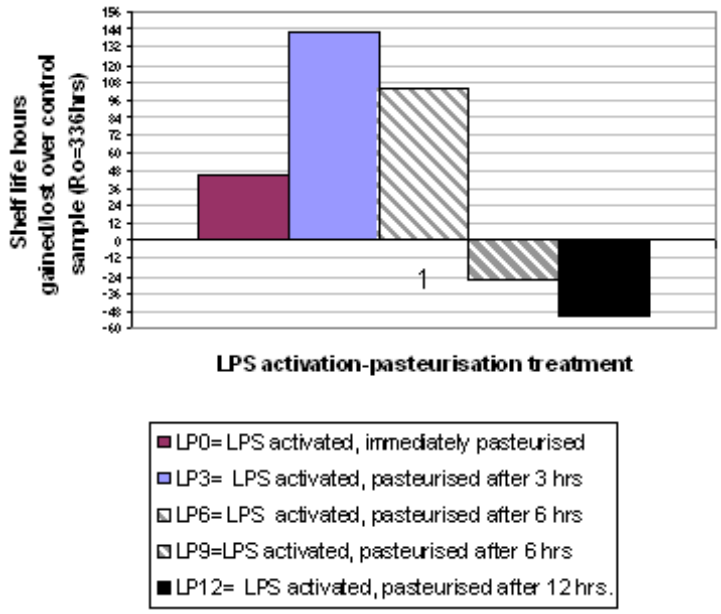

Figure 2. Effect of storage period after LPS activation on extension of shelf life (pH=6.4) of in-pouch pasteurised milk stored at 5-8°C.

Milk fermentation

Throughout Africa, naturally fermented milk is the most common milk food. Various societies have evolved fermentation processes that produce products with specific flavours and taste. The end products of spontaneous fermentations have a tart acid flavour while Zimbabwean *amasi* also has a malty flavour which is preferred by the local population (Narhvus et al. 1998). The fermentation is effected by naturally occurring lactic acid bacteria present in the milk and in the pores of older vessels. Occasionally addition of previously fermented milk—'back slopping'—is practised (Gonfa 2001). Work done on traditional fermented milks in Africa over the last two decades show that both thermophilic and mesophilic lactic acid bacteria take part in the fermentation depending on the environmental temperature and other factors. Yeasts also play a role in the later stages of the fermentation, contributing to the flavour of the end products (Gonfa 2001). The vessels used differ from community to community. Clay pots, calabashes and gourds, wooden and woven vessels and smoking of these vessels are common (Shallo and Hansen 1973; FAO 1990; Bekele and Kassaye 1987; O'Mahony and Peters 1987a, 1987b; Shallo 1987; Coppock et al. 1992; Gonfa 2001, Abdelgadir et al. 2002). Wood of different species is used including *Olea africana, Acacia busia, A. nilotica, Cordia gharaf, Cordia ovalis, Combretum molle, Balanities aegyptica* in Ethiopia (Bekele and Kassaye 1987; FAO 1990; Gonfa 2001) and *Combretum* spp., *Diplorhynchus condylaccarpon* and *Olea africana* in Tanzania (FAO 1990). The application of smoke slows down the fermentation process, improves flavour and slows down the growth of coliforms (Ashenafi 1996) thereby contributing towards safety and extended shelf life of the fermented products.

Amongst most pastoralist communities who have to walk long distances in search of pastures and water for their livestock, the shelf life of the milk products is of paramount importance for food security. Hence, over hundreds of years, these communities have evolved processes to make concentrated dairy products with long shelf life. Products such as *ititu* prepared by Borana pastoralists in Ethiopia and *biruni* made by the people of the Nuba Mountains of western Sudan, have been reported to have a shelf life of 90 days (Coppock et al. 1991) and up to one year (Abdelgadir et al. 2002) respectively. Another product, *mish*, related to *biruni*, is made by the people of Darfur State (western Sudan) and the nomadic tribes in northern Sudan and the Dinder

Region (Ethiopian border). This product is reported to undergo fermentation for 1 month. This has to be compared with commercial, western type yoghurt or cultured milk which, without the benefit of refrigeration, has a shelf life of less than five days and not more than 20 days with refrigeration (Tamine and Robinson 1988).

In recent years, great interest has therefore been directed at isolation and characterisation of lactic cultures from traditional African fermented milk products. Nearly all commercially known lactic acid starter bacteria have been isolated from traditional African fermented milk products (Feresu and Muzondo 1990; Isono et al. 1994; Abdelgadir et al. 2001; Savadogo et al. 2004). A number of species of lactic microflora have been isolated from a variety of traditional African fermented milk products (Table 2). These microbial species represent a vast range of biodiversity that remains to be exploited in the formulation of starter cultures that could be formulated to suit the special flavours and tastes that have been the cornerstone of many a traditional fermented milk of various communities on the African continent. The challenge that remains is the commercial development of fermented milk products that simulate the characteristics of traditional African products in the same way yoghurt and *kefir*—traditional products in the Balkan states—were developed 100 years ago.

Table 2. Isolates of lactic acid bacteria from traditional fermented milks in Africa.

Species	Products from which isolated	Author
L lactis ssp. *lactis*; *L. lactis* ssp.*lactis biovar*. *diacetylactis*; *Lb. confus*; *Lb. delbrueckii*; *Lb. plantarum*; *Leu. citreum; Leu. lactis*	Bukina Faso fermented milk	Savadogo et al. (2004)
L. lactis; Lb. fermentum; *Lb. acidophilus*; *Streptococcus salivarius, Sacharomyces cereviiae* and *Candida kefyr*	Sudanese fermented milk *rob*	Abdelgadir et al. (2001)
L. lactis ssp *lactis*; *Lb. acidophilus L. lactis* ssp. *lactis biovar. diacetylactis* strain INF-DMI	Naturally fermented milk (*amasi*) in Zimbabwe with malty flavour	Mutukumira (1996); Narvhus et al. (1998)
L. lactis/lactis; biovar *diacetylactis*; *maltigenes;lactis/cremoris Lc. mesenteroides/mes* spp *cremoris*;ssp *dextranicum*; *lactis Lb. plantarum*; *curvatus*; *brevis*; *casei*; *Enterococcus spp Lb. plantarum*; *curvatus*; *brevis*; *casei*; *Enterococcus spp*	Isolates from Ethiopian fermented milks	Beyene (1994)
S. cerevesiae	*Nono*, a Nigerian fermented milk; *mbanik*-Senegalese cultured milk	Okagbue and Bankole (1992); Gningue et al. (1991)
S. thermophilus	*Iria ri matti*- a fermented milk from Kenya	Kimonye and Robinson (1991)
Lb plantarum, Lb curvatus, L. lactis ssp. Lactis ; *Leu.mesentroides ssp. mesenteroides* *Lactoacillus spp., Lactobacillus spp*; *Leuconostoc spp;. Streptococcus spp*. + yeasts	*Maziwa lala*, at traditional fermented milk from Kenya *Ergo* and *ititu* – fermented milk from Ethiopia	Miyamoto et al. (1989)

L.lactis, Streptococcus thermophilus, Lb. Bulgaricus, Lb helveticus, Lb fermentum; Yeasts: *Sacharomyces globus*; *S. exigus*; *Kluyveromyces bulgaricus* and *K. lactis*	Sudanese *rob* collected from the market	El Mardi (1988)
L lactis ssp.lactis biovar.diacetylactis. Leu. Lactis, Leu mesenteroides ssp. *cremoris*; *Leu. dextranicum*	*Laban*, a Moroccan fermented milk	Tantaoui-Elaraki and El Marrakchi (1987)

Traditional butter making

In Ethiopia, fermented milk is often churned to produce butter and the buttermilk is filtered off and used as a drink or eaten with other foods (Bekele and Kassaye 1987; Gonfa 2001). Scientists from the International Livestock Research Institute (ILRI) in Ethiopia developed an agitator mechanism for clay pot churns that greatly reduces the churning time and improves efficiency of fat recovery. Hundreds of the improved churns are now widely used in Ethiopia. Similar improvements can be applied to traditional gourds used widely in churning of sour milk to produce butter. The results obtained by O'Mahony and Bekele (1985) working with the improved clay pot butter churn in Ethiopia are summarised in Table 3.

Table 3. Churning efficiency of traditional clay pot butter churns in Ethiopia.

Type of churn	No. of trials° (litres)	Quantity of milk	% TA	in Churning WM (min)	Time taken	%BF BM	in% recovery	fat
Traditional clay pot	25	10	0.88	4.4	18	90	1.00	75
	11	8	0.86	4.9	17	139	0.57	77
	10					134	0.90	
Local wooden butter churn	10	-	-	-	-	56	0.86	-
Imported wooded butter churn	10	-	-	-	-	44	0.90	-
Improved clay pot butter churn	16	16	0.83	4.3	16	61	0.40	90

% TA = titratable acidity; BF = butterfat; WM = whole milk; BM = buttermilk.
Source: O'Mahony and Bekele (1985).

Traditional cheese making

Except in Ethiopia, West Africa and North Africa traditional cheese making is not very common on the continent. In Ethiopia, *ayib*, a soft cheese is made from buttermilk, which is a by-product of butter making. In West Africa, Fulani pastoralists make a traditional cottage cheese called *wagashie* (*woagashie*) using a coagulant from Sodom apple (*Calotropis procera*) (Awor and Nakai 1986). In Ghana the processing of *wagashie* is done mainly by women who purchase milk from Fulani herdsmen (Kees 1995; Omore et al. 2004). Due to the high moisture content, the product's shelf life is just 3 days, which artisanal producers attempt to extend by repeatedly dipping the curds in boiling water every day until sold. This gives the cheese a fibrous texture and results in loss of desired flavour (Gilmore et al. 1997; Omore 2004). Although generally not practised in West Africa, recent studies have shown that immersing the cheese in a 10% brine solution for 12 hours will prolong the shelf life and quality of *wagashie* for up to 14 days (Padmore 2001; Sunu-Atta 2001; Omore et al. 2004).

In Egypt and Sudan, pickled cheese is made using rennet as coagulant. It is known as *domiati* in Egypt and *gybna beyda* (white cheese) in Sudan (Osman 1987). Other minor cheeses include dried cheeses such as *aoules*, a sun dried cheese (87–92% dry matter) made by heat coagulation

of sour buttermilk protein in Algeria. The curd is subsequently dried to form a flat cylinder, 2 cm thick, and 6–8 cm diameter. *Takammart*, another Algerian sun dried cheese, is made from goat milk using crude rennet extract from kid stomachs. From Niger, *tchoukou* is a sun-dried cheese made by rennet coagulation (FAO 1990). These traditional products provide valuable avenues for milk preservation and value addition that can be used as stepping stones towards specialised small-l and medium-scale milk processing by informal milk traders and women provided they have access to credit and improved technologies. The challenge is how to promote the commercial application of the technologies, identifying the size and growth of potential markets for the traditionally processed products and to what extent they can compete with imports of similar products. This will be a subject of an ASARECA funded collaborative study between Sokoine University of Agriculture and Animal Diseases Research Institute (ADRI) in Tanzania, ILRI, the Kenya Agricultural Research Institute (KARI) and Kenya Bureau of Standards (KEBS) in Kenya and the Ethiopian Agricultural Research Organization (EARO) in Ethiopia.

Improvements in milk handling hygiene and food safety

One of the major concerns of public health regulatory authorities regarding informal milk traders and small-scale milk processing is the risk of infection of consumers with zoonoses and other pathogens and the frequency of adulteration of milk with water. Studies done in Kenya and Tanzania show hygiene indicators among raw milk traders vary from acceptable levels to unacceptable levels of coliform counts, presence of *Brucella* antibodies and presence of drug residues and adulteration with added water (Table 4).

Table 4. Proportion of unacceptable milk samples from informal milk traders.

	Proportion above acceptable limit (%)			
Quality criteria	Kenya (SDP 2004)	Tanzania (Omore et al. 2004)	Ghana (Omore et al. 2004)	Public health implications
Adulteration with added water	10	20–60	37	Farm-market chain critical control point. In conflict with public interest and regulators
Coliform counts	52	55–58	23–27	Inactivated by boiling, pasteurisation; indicates poor hygiene; recontamination of heated ready to eat products
Prevalence of antimicrobial drug residues	6	35–40	35	Farm level critical control point. Not removed by pasteurisation
Prevalence of *Brucella* antibodies	5	20–23	22–29	*B. abortus* destroyed by pasteurisation; may survive milk fermentation (pH>4.2)
Prevalence of *Mycobacterium bovis*	0	0	0	Inactivated by pasteurisation/boiling; survive milk fermentation (pH>4.2)
Mycobacteria other than tubercle bacilli (MOTTs)	n.r.	10	Not investigated	Inactivated by pasteurisation/boiling, recontamination; pathogenesis in immuno-compromised persons
Prevalence of haemorrhagic *E. coli* 0157:H7	<1	0.24	<1	Inactivated by pasteurisation/boiling, recontamination

Generally the extent of informally sold milk samples adulterated with water was higher in Tanzania than in either Kenya or Ghana. High levels of antimicrobial residues and *Brucella* antibodies could be attributed to non-observance of withdrawal periods and bulking effect. The proportion of milk samples with unacceptable levels of coliforms is indicative of poor hygienic practices which include the use of plastic containers and non-cooling of milk. Introduction of metal containers and training market agents in better hygiene has been shown in Kenya to improve the proportion of milk meeting the set criteria for good microbiological quality (SDP 2004).

In Kenya, Tanzania and Uganda small-scale processing has expanded in the last 10 years. Processing adds value to milk by reducing spoilage, increases the variety of products that meet specific consumer demand and enhances the safety aspects of milk and dairy products when good manufacturing practices (GMP) are used. In Uganda open pan boiling of milk has given way to batch pasteurisation in water jacketed vats (Balikowa 2003), ensuring both good the hygiene and nutritional quality of the heated (pasteurised) milk if adequate measures a taken to avoid recontamination during packaging. Among the technologies that reduce contaminations are in-pouch pasteurisation of milk, which avoids post-pasteurisation contamination, and hot filling of pasteurised milk into plastic sachets. One small-scale dairy in Tanzania has been using these simple technologies and recording a shelf life of at least 10 days under cold storage which is standard for industrially pasteurised milk. The same plant produces fermented milk by inoculation of milk with mesophilic starter cultures followed by immediate filling and sealing in plastic sachets. Incubation takes place in an air conditioned room at 22˚C and the resulting product has a shelf life of 20 days, which is comparable to similar products made by large-scale dairies using automatic filling machines (Driessen and Puhan 1988).

Fermentation of milk generally renders such milk safe for consumption, especially when combined with prior heating of the milk. While fermentation *per se* may reduce public health risks by killing off pathogens such as mycobacteria when sufficiently soured for at least 66 hours and attaining pH below 4.2 (Minja 1998), a significant proportion of naturally fermented milk in milk bars in Nairobi was found to be inadequately fermented to render it safe (Mutave et al. 2004) while 19% of the fermented milk samples had not undergone any prior pasteurisation or boiling. Such products present risks of consumers being exposed to potential zoonoses and therefore measures need to be taken to educate both milk handlers and consumers on the inherent risks of inadequate fermentation or not boiling milk sufficiently to eliminate potential pathogens. This can be achieved through participatory market chain (PMCA) approaches whereby different chain actors, often with competing interests, can work together to find solutions for each other's problems. This can foster cooperation and co-innovation in the entire market chain for the benefit of all actors. For example, if consumers want better quality dairy products and are willing to pay for the added cost and processors want better quality raw milk and willing to pay a higher price to producers, then farmers might benefit by investing in technologies that enable the production of better quality milk that satisfy the processors' demand for quality raw milk and consumers demand for quality dairy products and regulatory authorities will have reasons to feel *affaire compli*.

Conclusions

The technologies described can be easily adapted by informal milk traders and small-scale milk processors. Mostly lacking to support the adoption of these technologies is enough exposure, training, awareness creation and access to financial resources in the form of credit. Traditional technologies in particular can form the basis for development of products that meet the consumer preferences for flavour and taste, especially of fermented milk products. This should enable a stepwise transformation of the informal dairy sectors into small- and medium-scale enterprises that manufacture nutritious and safe dairy products. This can be achieved through participatory

market chain (PMCA) approaches whereby different chain actors, often with competing interests, can work together to find solutions for mutual benefit.

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Institutional and technological innovations to transform informal milk markets in the Eastern and Central Africa region: Preliminary lessons from action research

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Abstract
This paper discusses preliminary lessons from action research to promote institutional and technological innovations aimed at transforming informal milk markets in East and Central African countries. Regulations affecting the dairy sectors in five selected countries were reviewed and factors limiting cross-border dairy trade documented. Dialogue among dairy experts and regulatory authorities was then undertaken to arrive at minimum standards of competence, build consensus on a regional guideline and curriculum to certify informal dairy traders and ensure cross-border recognition of certification by counterpart regulatory authorities and freer trade. The consultative process has fostered sharing of valuable experiences in improving the quality of informally marketed milk, and has helped influence changes in mindset among regulatory stakeholders, who are now more willing to support the development of informal milk markets. Generic work plans will be developed to facilitate the required actions.

Key words: informal milk markets, East and Central Africa, action research, dairy regulation, policy and institutional environment

Introduction
Inappropriate regulations or the poor implementation of well intended ones have long been identified as the most important factors constraining enterprise development in developing countries. In agricultural markets, traditional or informal dairy markets perhaps suffer the greatest burden of stifling regulations or neglect due to perceived quality and safety concerns. This has been the case in Eastern and Central African countries where, although informal small-scale milk traders handle over 85% of marketed milk, their market participation has long been ignored or discouraged by public policy largely due to safety and quality concerns. Private firms with vested interests in milk processing and packaging also actively promote this perception without sufficient scientific evidence, thereby contributing to the stifling of small-scale milk traders. Furthermore, the capacity of responsible national authorities to directly regulate the dairy sector is largely inadequate.

Comprehensive dairy systems research by the International Livestock Research Institute (ILRI) and partners in Kenya and Tanzania (www.smallholderdairy.org; Omore et al. 2004) and ensuing wider consultations in the region by the Eastern and Central Africa Program on Agricultural Policy Analysis (ECAPAPA) of the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) identified removal of policy barriers against informal milk traders as key to the continued development of respective dairy sectors. The evidence generated further demonstrated that bridging the regulatory gap between informal and formal markets is feasible without endangering public health. One alternative and potentially effective mechanism for achieving this is through proactive engagement of the traders and promotion of certification

schemes involving training in milk quality control, and enforcing the use of appropriate milk handling equipment, through business development services (BDS).

The rationale for accommodating and improving informal milk markets is: They flourish because they supply cheaper milk for poor consumers, satisfy traditional tastes and offer better prices for milk producers (www.smallholderdairy.org). These traditional milk markets also contribute significantly to income and employment generation (Omore et al. 2004), and to the nutrition of millions of poor consumers who cannot afford to pay higher prices of formally processed and packaged milk products. If encouraged, these markets can form a solid bedrock for the growth of the dairy industry in the region.

ECAPAPA and ILRI have in the past undertaken relevant research and promoted institutional environments in which small milk traders in eastern and central Africa countries can market their milk more efficiently within individual countries and across borders. This engagement has used action research to monitor progress and learn lessons for wider application in the region. The preliminary lessons learnt thus far from the processes are presented and discussed.

Process towards policy change

A policy change cycle involving first, a data collection and analysis phase and subsequently, a dialogue and action phase, was followed. The first phase, conducted in 2004, involved a comprehensive review of policies, rules and regulations affecting the performance of the dairy sub-sectors in five selected countries in the region and documented factors limiting domestic and cross-border movement of dairy inputs and products. The second phase was implemented during 2005; it aimed at promoting dialogue and action among scientists and dairy sector development and regulatory agencies, to realise pro-poor institutional reforms in milk marketing by small-scale milk traders in the region.

The dialogue was promoted by engaging national experts with experience in dairy technology and training, to collect and collate the needed background information in each participating country and to compare the information across countries. The experts worked in close consultation with the national dairy regulatory authorities to define minimum requirements for competence and hygienic handling of milk, for inclusion in milk training guidelines and curricula. This information formed the basis for developing a harmonised generic guideline and curriculum for certification of small milk traders that outlines the minimum competence requirements agreed upon. A key objective was cross-border recognition of the ‘stamps of approval’ issued by counterpart regulatory authorities and thereby, greater market access. The over-arching aim was that the generic training materials would be availed for adaptation and adoption by other ASARECA countries not directly participating in the initial exercise.

A more sustainable quality assurance strategy, involving the use of BDS was proposed to be a central component of a work plan to institute the proposed policy and technological changes (Figure 1). This was in light of the limited capacity of the regulatory authorities to effectively provide the needed services directly, and allow them to concentrate on facilitating the provision of the services.

The proposed milk quality assurance scheme to be facilitated by the regulatory authority through privately provided business services involves:
The BDS providers:

- Provide milk traders with training on milk safety, quality control and hygienic handling and other services

- Issue certificates of competence to trained traders
- Report their activities to the regulatory authority.

The milk traders:
- Pay cess fee to the regulatory authority upon showing a certificate of competence
- Conducts his/her business within norms accepted and approved by regulatory authority.

Figure 1. A schematic diagram for applying institutional and technical approaches in a quality assurance scheme involving business development services.

The regulatory authority:
- Accredits BDS providers based on agreed minimum standards of competence for trainers
- Monitors compliance of accredited BDS providers to approved trainers competence level
- Issues licences to trained traders based on the evidence of a certificate of competence
- Monitors compliance of certified milk traders to approved minimum standards for milk handling.

Preliminary lessons and discussion

Regular meetings by those involved have provided a useful forum for learning from each other's experiences in streamlining the activities of informal milk markets. The engagement of top-level regulatory stakeholders developing informal milk markets through a more effective quality assurance scheme also indicates a willingness to transform the sector. This is particularly evidenced by the action taken by the Kenya Dairy Board (KDB) to include the project's outputs in its recently released Strategic Plan to 2009. Already, the KDB has partnered with a local non-governmental organisation (NGO) to implement a quality assurance scheme based on the institutional framework outlined here. This noteworthy attitudinal change being witnessed among the top-level staff at KDB is encouraging but still needs to trickle down to the level of field staff, some of whom still carry out their activities with an 'anti-raw milk marketing' mindset. This pilot project is being monitored through qualitative and quantitative approaches to evaluate both technical and behavioural changes among project implementers and boundary partners, through outcome mapping (Earl et al. 2001) to learn lessons that would inform the development of generic work plans for the other countries in the region.

One of the experiences that is positively influencing adoption of 'good practices' is Uganda's experience in improving quality in its informal milk markets after the dairy sector was liberalised. Before the establishment of the Dairy Development Authority (DDA) in 1998, milk quality control among small-scale traders and regulatory systems tailored for their needs were non-existent and raw milk was commonly handled in plastic containers and heated by open-pan boiling, often under unhygienic conditions. Following appropriate sensitisation and training by the DDA, informal traders have formed groups and acquired hygienic water jacketed batch pasteurisers to replace the open-pan boiling system. Plastic containers for handling milk have increasingly been replaced with metal containers, thus improving milk quality. One of the key factors contributing towards this high level of quality compliance among informal traders within the relatively short span of DDA's existence has been its adoption of a 'peer pressure' approach to sensitise groups of traders to join training programmes, with rewards for attendance. The traders now regard DDA as a partners working for their good, as long as they adhere to the set code of hygienic practice. This progress forms good ground for further dissemination and uptake of appropriate milk handling technology among other informal sector cadres and offers vital lessons for other countries to adopt.

Since the uptake of the quality assurance scheme depends on active participation of traders and regulatory authorities, the current consultation with them will be extended to meetings among them and exposure to promising pilot projects in the region. This is expected to make them more willing to openly engage in activities geared towards the development of informal milk markets.

An important underlying factor to the positive changes in mindsets is the value of evidence-based knowledge in influencing policy changes. In this case the risk analysis studies on milk-borne public health risks from milk markets in Kenya have been critical. This shows the benefits of integrating research with development projects.

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Side event

Animal health and poverty in Africa

Harnessing the new science in biotechnology for animal health in Africa

Introduction

Demand for food products of animal origin is expected to increase dramatically in developing countries. Meat and milk consumption, for example, are projected to grow at 2.9% and 2.7% per annum respectively between the late 1990s and 2020. This 'livestock revolution' is also expected to result in increases in demand for pork (60%), poultry meat (80%) and red meat (50%) by 2020, with developing countries accounting for two-thirds of global meat consumption and more than half of global milk consumption. In Africa, livestock production remains largely in the hands of small-scale farmers who collectively keep approximately 70% of the total livestock units. Given this concentration of livestock production the potential for a viable industry built around these producers provides a significant opportunity for them to escape poverty while supplying the consumer demand. Diseases sharply reduce the productivity of livestock. Conservative estimates of annual losses of US$ 4 billion in meat and milk production have been reported for sub-Saharan Africa, representing approximately one-fourth of the total value of livestock production. These losses have a significant impact on both food security and poverty. Apart from the zoonotic diseases that also afflict the poor, who are in constant contact with different livestock species, there are also a number of livestock diseases which preclude the poor from markets.

Several diseases continue to present significant challenges for livestock keepers, especially poor small-scale farmers. These diseases include contagious bovine pleuropneumonia (CBPP), rinderpest, New Castle disease (ND), Rift Valley fever (RVF), trypanosomosis, gastrointestinal nematodes, and tick-borne diseases such as East Coast fever (ECF), heartwater and African Swine fever (ASF). They affect intensification, productivity and trade. While interventions such as regulatory measures and cost-effective technologies for disease control have been effective in developed countries, this has not happened in Africa.

Rapid advances in classical and molecular epidemiology, molecular biology, immunology and such new sciences (such as genomics, bio-informatics and proteomics) are providing new technological options that can be used to control or eradicate animal diseases in Africa. Some of these technologies are on the threshold of being developed into effective new tools such as diagnostics and vaccines. Investment is required in applied research to facilitate the required research that can lead to the development of effective vaccines and diagnostic tools. For some diseases, for instance ND (vaccines), ASF (diagnostics) and ECF (vaccines), progress towards development of effective products is at stages where probability of success is high with only modest investments. However, CBPP vaccines and diagnostics require a two-pronged approach: a quick-win option to improve current vaccines and diagnostics and medium- to longer-term research to generate improved and more sustainable 'new generation' products.

Most of the investment into research and development (R&D) relating to the above diseases has been obtained from public sources in developed countries with a fair amount of up-stream activities undertaken in the North. However, many of these diseases (e.g. ASF, ECF, CBPP, RVF, trypanosomosis among others) have little relevance to the developed world and are unlikely to be of continuing interest to development partners in the North, except for scientific curiosity. For ECF vaccine research, a substantial international effort has contributed to the progress toward proof-of-concept for a vaccine but funding to complete current and subsequent steps of R&D is not guaranteed. Similarly, research on short-term options for CBPP has benefited from some

'external' funding. However, there has not been adequate and sustained funding required to increase the likelihood of success. This is despite several recommendations from CBPP control expert meetings by FAO (Food and Agriculture Organization of the United Nations), IAEA (International Atomic Energy Agency), AU/IBAR (African Union/Inter-African Bureau for Animal Resources) and African national veterinary authorities.

It is increasingly becoming imperative for Africa not only to define the continent's R&D agenda for animal health but also to mobilise the required resources to implement the agenda. Many of the recent technological advances are already being successfully applied to address human and animal health problems in the North and indeed in some developing countries in Asia and Latin America. These advances provide opportunities which Africa needs to capture. A high level of commitment will be needed both to support quick win options that will immediately translate into products and strategies (such as the PARC initiative against rinderpest, improving the ND vaccine, developing ASF diagnostics and improving current CBPP vaccines and diagnostics) and to support medium- to longer-term R&D activities. Africa's direct and significant financing of such activities would represent a major paradigm shift allowing it to take leadership in funding of science and technology of priority diseases of the poor. This is the only way Africa can conquer poverty through livestock R&D.

The purpose of the side event was to bring together key stakeholders in the livestock sector, including development agencies, policy makers and researchers, to discuss how opportunities provided by recent technological developments can be harnessed to address key animal health constraints in Africa. The objective was to define a strategy and to agree on steps to realise its implementation. It was envisaged that the outcome of this conference would feed into a planned Ministerial Conference scheduled for October in Rwanda.

The International Livestock Research Institute (ILRI), the Inter-Africa Bureau on Animal Resources of the African Union (AU-IBAR) and the Forum for Agricultural Research in Africa (FARA) co-convened this side event of the conference to discuss major developments in the field of biotechnology which can be utilised to improve animal health technologies and provide easier access to regional and international markets. The side event also focused on emerging initiatives in animal health research and development, priority animal diseases that affect trade in livestock and livestock products, and how regional organisations and research institutions can mobilise resources to support high priority research and development (R&D).

Summary of deliberations

New opportunities presented by recent developments in biotechnology

Significant progress in the biological sciences has been made over the last few decades as a result of developments in modern biotechnology. Genome sequencing projects for animals and their pathogens have yielded whole genome sequence data (genomics). In addition, tangible advances have been made in bioinformatics, developments in functional genomics/gene discovery and in applied immunology. These developments have offered opportunities and approaches in development of novel or improved diagnostics, vaccines and novel therapeutic drugs.

In the field of diagnostics, tests that afford early, accurate and rapid detection of a variety of priority diseases have been developed. Such tests include enzyme linked immunosorbent assays (ELISA), conventional and real-time polymerase chain reaction (PCR and RT-PCR). These tests have further been improved by developing rapid 'penside' tests that can be used in the field and more importantly tests that can differentiate between infected and vaccinated animals (DIVA).

The vaccines area has also benefited from advances in biotechnology, especially in the area of antigen identification and in development of novel vaccine formulation and delivery. A good example is the development of a sub-unit vaccine for ECF. This disease is a major obstacle to the development of a vibrant cattle industry in eastern, central and southern Africa. Efforts towards the development of an ECF recombinant sub-unit vaccine have benefited from the sound knowledge that has been generated based on protective immunity and generation of tools and tests that can be used to identify potential vaccine candidates. Availability of data on the biology and genome sequence of the parasite *Theileria parva* genome has provided a list of selected genes to be screened for candidate vaccine antigens. With these developments and approaches, eight vaccine candidates have been identified in a relatively short period of research. The genes encoding the target antigens have been engineered in plasmid DNA and viral vectors and other vaccine delivery systems for evaluating their immunogenicity and efficacy in cattle. Another major contribution of biotechnological advances is the development of marker vaccines which allow the use of the DIVA technology to differentiate between infected and vaccinated animals.

Genome sequence data of infectious agents can also be used to understand biochemical and metabolic potential that can reveal presence of novel drug targets.

Emerging initiatives in animal health

To address the issue of mobilising resources that will be used to fund strategic livestock research and to identify constraints along the marketing chains, several animal initiatives have been initiated. One such initiative is African Livestock or the ALive platform which has been formed to implement the CAADP/NEPAD (Comprehensive Africa Agriculture Development Programme/New Partnership for Africa's Development) programme to enhance livestock productivity. A related initiative is the Forum for Agricultural Research in Africa (FARA), which is the technical arm of NEPAD. FARA is a multi-institution and multi-stakeholder initiative established to complement sub-regional organisations such as the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) in livestock research.

Several donor agencies and research organisations with interest in livestock vaccines and diagnostics have formed the Global Alliance on Livestock Vaccines (GALV) to mobilise financial resources to fund development and application of novel animal health technologies.

Priority animal diseases and their impacts on trade in livestock and livestock products

It is imperative that livestock production and disease control practices adhere to OIE (World organization for animal health) and to *codex alimentarius* standards. To enhance compliance to these codes of practice, African scientists need to participate in setting the standards to ensure that the unique factors in this region are taken into account. To access export markets, African countries should focus more on disease surveillance rather than eradication. Exploitation of the African (or regional) markets is key in livestock trade as most of the disease constraints are similar. Issues addressing animal health in the region should also go together with improving production.

There is an urgent need to identify and address the animal health constraints to international livestock trade. Some of these constraints include the diseases of trade which include CBPP, Foot-and-Mouth disease (FMD), RVF, ASF, highly pathogenic Avian Influenza (HPAI) virus etc. There are also other regional endemic diseases such as ECF and other tick-borne diseases which are major constraints to improved livestock productivity. The main challenge for the continent is to institute procedures for recognition of disease freedom. This is hampered by lack of new tools

and approaches such as diagnostics, vaccines and surveillance techniques for disease control. Where these technologies are available there is lack of adoption by farmers and animal health workers. Another major concern which is increasingly included in the agenda of livestock trade is the issue of food safety which includes food borne diseases and pesticides which might gain entry into the value chain either at the farm or at the point of food handling.

Mobilising resources to support high priority R&D

To mobilise resources to support R&D in animal health, there is a need for livestock researchers to engage policy makers to encourage African governments to fund research on priority diseases rather than rely on external funding. However, the packages of R&D issues to be addressed have to be discussed and prioritised. There is also need for African governments to take up donor funded animal health initiatives such as the Pan African Control of Epizootics (PACE) programme to ensure sustainability.

Issues for consideration by national governments

African governments must do whatever is required to ensure that the continent is not left out by the 'gene revolution'. A regulatory policy environment should be created for the application of new science in animal agriculture. In animal health, vaccine and diagnostic research present the greatest opportunities. Adequate investments by national governments in livestock-related science and technology would remove major constraints related to the ability of the continent to leverage additional resources from international sources. To achieve this objective, the top priority should be in capacity building in agricultural science and technology. Furthermore, involving the private sector is one way of ensuring that science produces tangible, relevant products and technologies which are both accessible and sustainable.

Sub-regional organisations and livestock R&D initiatives, such as the Biosciences east and central Africa (BecA), GALV and ALive, are seen as important and cost-effective ways of creating the requisite capacity/platform to harness biotech opportunities.

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