RESEARCH NEEDS FOR COMMERCIALIZATION OF FOOD BIOTECHNOLOGY IN DEVELOPING COUNTRIES

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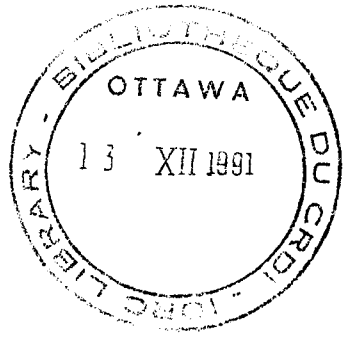

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THE FOOD PROCESSING SECTOR IN DEVELOPING COUNTRIES

The food processing sector in developing countries is characterised by a duality: a few large scale, often sophisticated, corporations pack raw commodities for export and process products derived from these, existing alongside thousands of informal, family and small-scale enterprises which market raw, prepared or processed produce mainly for domestic consumption. Although the domestic population represents a high volume market, the low levels of disposable income in developing countries and the limited infrastructure available for food handling, means that there is only a small market for processed products. Most food is handled in the raw state which inevitably leads to significant losses in quantity and quality, seasonally fluctuating supplies and hence often relatively high prices for scarce and perishable products. The more modern food processing plants generally are producing standard products such as bread, biscuits, dairy products, canned meats or are producing products developed in industrialised countries, under a license arrangement which allows use of the process or formulation and the right to use the international brand name in some cases (soft drinks, confectionary, breakfast cereal, baby foods etc.). These are generally high cost products targeted at the high income sector, with little produced for export.

Thus the food industry carries out little research and development despite often being the major employer of the limited number of food professionals of each particular

country. These technical staff are involved principally with production and quality control. Innovation means copying or importing from abroad. The public sector research and development infrastructure at universities and at national technological research centres is inadequate and underbudgeted and has little relationship with the private sector large or small. This means that the opportunities for technical change are very limited and are essentially in the hands of the private sector - those that have the contacts and the capital necessary to import technology independently.

This situation needs to change if the food industry is to develop the great potential it has in processing for domestic and export markets, to increase the value added and contribute to employment and income generation. Innovation has to be promoted and experimented with, as well as the most effective arrangements to bring this about - strategic alliances with private and public sector groups at the national or international level, vertical linkages between producer groups and processors and marketers (at home or abroad), investment from public and private funds, etc.

OPPORTUNITIES OR NEEDS FOR IMPROVEMENT

All of this has been known for years. There is evidence of major developments in the export agro- and aqua-industrial sectors in several developing countries in recent years, mainly due to the demand in international markets for tropical fruits and shrimps. The sustainability of these sectors is in question due to the lack of local research and technical services available to these new industrial sectors. This is not to undermine the contribution that individual entrepreneurs and technical specialists are making in these

pioneering developments; what is needed is a commitment to develop the necessary services and technical skills and technology which will facilitate the development of more sectors not only for export but also for the largely untapped domestic food markets.

It is here that food biotechnology at this moment could provide a technological jump to stimulate the development of the food sector. There are immediate opportunities to contribute in increasing production of raw materials, custom designed for particular characteristics or levels of desirable constituents; to reduce process time or energy requirements and therefore costs; to improve the separation of desired constituents, preservation of products and, to improve food quality assurance through rapid testing rapid testing for pathogens or toxins. If applied to the tremendously varied natural resource base of tropical developing countries, the potential for development of the food sector is impressive not only on economic grounds but also in dynamising innovation in this essential sector of most developing countries.

There are a long list of constraints and barriers which will limit these developments: the point is that there are now many new opportunities already available or evolving; the task before the developing countries is to choose those that are appropriate and feasible for their situation and facilitate their acquisition and adoption by local industry. This is not a simple technology transfer process. It is no longer tenable that all researchers in the public sector in developing countries (and developed for that matter) have the luxury of carrying out research where there is no direct and explicit linkage with the ultimate user of the results - industry (new or established). Biotechnology is developing so fast, researchers in conjunction with investors,

entrepreneurs and managers must come together in the adaptation of technology to local resources so that new products or improved processes are tested and put into production as quickly as possible. There is already some movement in this direction as biotechnologists are becoming employed by the private sector or, more significantly, are going into business themselves, as we have seen occur in developed countries. This of course is nothing new as traditionally once professionally trained, many LDC graduates enter their family's business or once they have accumulated capital from their wider family, they go into business for themselves. The difference is that in the biotechnology field they carry on researching.

IDRC EXPERIENCE IN RESEARCH FOR DEVELOPMENT IN THE FOOD PROCESSING SECTOR

The International Development Research Centre (Canada) is a public corporation which finances applied research in developing countries aimed at improving the lives of the poor. Projects are identified, executed and managed by indigenous researchers.

While the IDRC has a number of specialist divisions dealing with Social Sciences, Health, Information, Communication, Earth and Engineering Sciences, the work of the Agriculture, Food and Nutrition Sciences Division, particularly in the Post-Production Systems Program focuses on the improvement of the food sector.

Post-Production deals with all activities after farm production or fish capture and so includes harvesting, threshing, drying,storage, processing, marketing and consumer issues relating to quality characteristics etc. Our approach is to encourage researchers to

consider how the whole food system operates and how the solution of the problem they have identified will improve the situation; or what other opportunities for improvement exist or are most needed in order that the desired benefits of income, employment or food are delivered to the target beneficiaries, the rural poor. This is not always possible and certainly is not immediately apparent to researchers who are, in the main, trained in a narrow discipline, such as chemistry, engineering, agronomy or food science with little contact or knowledge of rural contexts. Thus most projects have experimented as much with methodology to improve problem definition, research design, field testing and participation of target beneficiaries as with specific scientific studies such as drying rates, equipment design, product development etc. This has meant that multi disciplinary teams and often more than one institution have become involved throughout or at particular stages of the projects. As there has been little experience of these approaches in research institutes in the past, this has been a process of learning by doing. Our major activity is in the area of agroindustry development in rural areas, where the objective to minimize losses of crops or fish has been expanded to that of generation of additional income and employment through development of a processing enterprise which delivers a stable product for an identified market. The research activity thus incorporates commercialization considerations right from the start as the target is the identification of a feasible enterprise for the produce from the rural areas.

Projects have evolved to four stages:

1. *Prefeasibility*: Market research to identify which product types and forms are required at what price and by whom (rural/urban consumers, other processors); Community

studies to determine volumes of produce, seasonality, organizational and social constraints, current marketing situation; Initial laboratory work on product or process development for the promising options to assess yields, technical problems, estimates of costs of production; Identification of the most feasible options from technical, economic and social points of view.

2. *Pilot plant*: Design and test products, processes and equipment; Optimize processing operations in terms of yields, costs, quality; Testing of products with consumers, markets; Adjustments; Detailed feasibility.

3. *Pilot enterprise*: Establishment of pilot plant or commercial-scale plant in target location; Implementation of processing operations, quality and process control and enterprise management; Test marketing; Monitoring of yields, costs, sales, cash flow, management and organizational conditions; Adjustments for financial viability.

4. *Commercial production*: Transfer to operation by community group or entrepreneurs. Periodic monitoring as required.

I have gone into some detail here to illustrate that the innovation process in such development projects is very slow and inefficient as it has been our experience that attention only to technological research has and will have little effect on its own. Commercialization issues of how technology will be used, where, at what scale, with whom and for whom and how will its costs be covered must continually be assessed and taken into account throughout the project.

This approach to technological innovation in developing countries has not been easy and has not been widely adopted, as we have seen in the PPS Program and in other

technological fields supported by IDRC. The public sector research system has little relationship to private sectors needs (or to a very small percentage) and the private sector for confidentiality, prefers not to involve the public institutions, thus the output of public system research rarely is utilised and there is little contribution to development, except in the knowledge generated and the experience of the researchers. This situation has been of concern to IDRC and other donors as it became clear that our support was not impacting in any major way to development, particularly for the poor, our target beneficiaries. Hence our recent interest to support experimentation in the pilot enterprise stage and the commercialization stage of projects, with technologies and results from projects we have already funded as well as a concerted effort to ensure that researchers have done enough preliminary study and thinking in the pre-feasibility phase about how the commercialization of the anticipated results could take place.

Therefore in our considerations of harnessing biotechnology for development, a similar orientation is necessary but with a different set of actors. The opportunity raised by the rapidly evolving biotechnology is that of dynamising the innovation process, particularly in the food sector, as major changes in food systems are possible. There must be a shift from public sector led research in developing countries to a stronger role for the private sector, their opportunities and needs. Greater initiatives in the policy area are needed in the promotion of new enterprises in food biotechnology. The emphasis up to now on the scientific research component, the training of scientists, and the establishment of research centres must be balanced by attention to broadening of industry's skills in acquisition of technology, and access to information assisted, where possible, by

government programmes and policies. This will need manpower development at this level too.

POTENTIAL CONTRIBUTION OF BIOTECHNOLOGY

1. Definition

For the purpose of this paper we have borrowed a conceptualized definition of food biotechnology:

Food biotechnology is the technology dealing with the application of the principles of food science for (a) the preservation of active food biosystems such as post-harvest fresh fruit and vegetables and post-mortem fresh muscle systems such as seafood; (b) the production of useful metabolites in food commodities containing active metabolic and degradative enzymes and contaminated with viable environmental organisms and plant cell cultures; (c) the creation of food products through fermentation of food systems; (d) analysis for food constituents and food toxicants using bioactive systems.

2. Potential applications in LDCs for the food sector

A list of potential applications of biotechnology in food processing includes:[1]

* *Production of custom-designed raw ingredients*

Biotechnology offers the potential to manipulate crops to increase the added value for the food processing industry. Custom designed commodities will have characteristics such as increased solids content, increased levels of specific aminoacids and decreased level of saturated fatty acids to improve processing or nutritional attributes.

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[1]. **Harlander, S., *Food Technology*; Sept. 1989, pp. 196-203.**

* *Production of high-value food ingredients by cell cultures*

Production of high-value products such as essential oils, growth hormones, food flavours or colours and alkaloids for medicinal purposes. Secondary metabolites will be produced economically by plant cell suspension cultures, with the added advantage of allowing the control of the quality, availability, and processing consistency of the ingredients.

* *Fermentation and enzymology*

Biotechnology will improve the flavour, quality, nutritional factors and yield of food and feeds, using genetically modified microorganisms and enzymes. Genetically modified food-grade microorganisms will improve bacteriophage resistance, the production of fat modifying enzymes, or production of the natural preservative bacteriocin to help in avoiding losses due to spoilage or contamination, and change dietary components. Modified enzymes will have application in several areas from the production of beer chill-proofing to debittering of fruit juices and flavour development.

* *Natural ingredients*

The demand for natural products is favouring the use of microbial metabolites as natural ingredients in food, including biopolymers, surfactants and antioxidants. In the long-range genetic engineering will be used to improve these components.

* *Animal biotechnology*

The use of growth hormones to increase milk production and feed value efficiency is best-known example, coupled with extraction of bioactive components from animal blood, milk and eggs.

* *Waste management technology*

Conversion of waste to high-value products, aminoacids and antibiotics for animal consumption will increase the efficiency of food processing plants. Examples include biomass utilization for biofuels production and treatment of food-processing by-products as feedstocks.

* *Diagnostic tools and rapid detection methods*

Rapid screening methods for the early detection of pathogenic or spoilage microorganisms, toxins and chemicals in food will be based on detection kits incorporating DNA probes and monoclonal antibodies as an efficient alternative to classical microbiological techniques. These methods will have an impact on quality control and standardization in the food industry throughout the world.

3. Constraints

The food sector in developed and developing countries is characterized by certain factors that make it less attractive to biotechnology investments than say the pharmaceutical sector. These factors are:

- a low value added component for current and possible biotechnology derived products (which will have to compete with conventional products);
- advantages will be in reducing costs, increasing yields and consistency of quality;
- organisms involved are highly complex biological organisms (plants and animals);
- engineering operations are complex and present technical and economic difficulties;
- the issues of industrial intellectual property are less straightforward;
- regulatory concerns can be substantial;
- consumer acceptance and reluctance to ingest products containing recombinant

organisms, nor foods modified by recombinants.

IDRC EXPERIENCE TO DATE: WHERE ARE WE?

IDRC support to food biotechnology activities has been recent, exploratory and minor. Biotechnology on a much broader front has been supported in a number of areas across the Centre. Individual projects have been supported on a number of topics (see Table 1):

1. Policy analysis and priority setting

IDRC is funding activities in the following areas:

- Biotechnology Market Entry and Industrial Policy. This is a comprehensive global study, which incorporates three Latin American country case studies.
- A strategic study is under way in Mexico to develop methodology for priority setting and for research, development and policy implementation in biotechnology that have the greatest potential for delivery of the benefits of improved processed food production, income and employment generation in the food and health sectors. This should lead to specific proposals in these sectors.
- An assessment of the capabilities and needs in engineering aspects of biotechnology implementation in Latin America that would facilitate transfer of results from laboratory to pilot plant to industrial scale.
- A project on Technology Perspectives looks at issues of new technologies in development in order to formulate a long-term scientific and technological strategy for the region. The section on biotechnology focused on the agro-industrial sector.

2. Laboratory level product/process development

The main emphasis at IDRC is currently at the level of product and process development.

- Biotransformation of agricultural waste for the production of pharmaceutical end products in Cuba. This project is an example of collaboration between a Canadian public institution and that of a developing country.
- A project in Bangladesh is developing technologies utilizing microbes in the processing of jute.

In the area of health, there are three main topics:

- Botanical Products - pesticides and herbicides, with concerns for human diseases, including toxicological studies (7 projects).
- Vaccines - development and testing of vaccines (hepatitis B, yellow fever and measles). Very advanced development of a contraceptive vaccine (12 projects).
- Diagnostics - pro-tests and dipsticks. Work on AIDS diagnosis, diagnosis of dengue fever and other epidemiological studies (11 projects).

In the area of agriculture, and more specifically related to crop production, there are a wide range of research activities:

- Cell tissue culture of plant species, including trees (16 projects).
- Pest resistance and biological pesticides (3 projects)
- Biological nitrogen fixation (3 projects)
- Monoclonal antibodies for disease detection (1 project)
- Germplasm conservation (2 projects)

3. Access to technology and transfer

A. Information sources and systems

IDRC is interested in improvements in the flow of information from source to user in order to give researchers, policy-makers, and practitioners in developing countries access to scientific and technical information. IDRC has funded two reviews on biotechnology information sources, in 1985 and in 1989

B. Collaboration

An in-depth review of Canadian biotechnology expertise in agriculture of relevance to developing countries has been completed. A similar study was conducted to assist IDRC in identifying Canadian capability and interest in developing country application of fisheries/aquaculture biotechnology.

Several laboratory level projects include the collaborative mechanism where developing country and Canadian researchers, using their local resources at their home base, work together on solving a problem. This shows considerable promise for adaptation of biotechnology to developing country problems and opportunities.

C. Transfer

Almost all the current R&D in biotechnology is conducted in the industrial world and aimed almost solely at markets in these countries. It is important that the developing countries have access to biotechnology applications, including proprietary products, so that they can decide for themselves whether and how to make use of them.

IDRC is exploring its role in establishing linkages to facilitate biotechnology access and acquisition as a cosponsor for an organization recently established to act as a broker for biotechnology transfer - The International Service for Acquisition of Agri-

Biotech Applications. ISAAA has a very specific action orientated pragmatic mandate specifically designed to deliver near-term proprietary applications that can be tested in specific agricultural project activities.

4. Intellectual property rights(IPR)

Support has been given to examine the implications of Plant Breeders' and Patent Rights, and evaluate its impact on research in Canada, in developing countries and on farmers. IDRC has also collaborated with the "Keystone International Dialogue Series on Plant Genetic Resources" and hosted a "mini-dialogue" on IPR, with participation of representatives from industry, the research community, NGOs and developing countries.The recommendations from this dialogue series will be presented at the 1992 UN Conference on Environment and Development.

IDRC partially sponsored an International Symposium and Workshop on *Property Rights, Biotechnology and Genetic Resources: Creating Incentives for Innovation, Conservation and Development*, Nairobi, Kenya, June 1991. The aim of the meeting was to develop effective incentives for the developing world to conserve and utilize biological diversity in a sustainable way.

5. Utilization of research results, linkage with productive sector

IDRC supported a series of six regional workshops on university-industry linkages in developing countries as strategies for application of research results. Case studies presented included several biotechnology examples, where university-local industry alliances were established to ensure research was designed to suit local industries' needs.

Cases related to food biotechnology, among others, were presented by: (i) the

University of the Philippines Los Banos (UPLB), where policies and procedures to promote utilization include (a) joint-venture with the private sector in mass producing commercializable technologies/products; (b) Tie-up with government agencies in mass producing non-commercializable technologies; (c) Direct extension to small and medium entrepreneurs; (ii) Chula Unisearch, an autonomous organization of Chulalongkorn University in Thailand, promotes the utilization of knowledge and technology generated by the University to solve problems in commerce and industry. Chula Unisearch develops contacts and contracts with industry, government agencies and communities, acting as a promoter and facilitator, and acts as coordinator when a project is being executed to ensure high quality and timely delivery of products; (iii) University of Zimbabwe; (iv) Centre for Industrial Innovation, Autonomous University of Mexico. Another interesting case is that at BAIF, an Indian NGO which contracts with universities and other institutions in order to develop new enterprises operated by them eg in mycorhizae and cheaper more productive fermentation technology for production of vaccines.

A related project studies communication strategies between users and producers of innovations, in applied and technical fields for bioindustries in Thailand, and it aims to develop a system for evaluating the potential of indigenous research and analyzing industrial innovation potential.

6. Socio-economic impact. Biosafety

Biotechnology is viewed as a promising area with potential to positively affect several areas, as listed above. Concerns about the potential negative impact of biotechnology on developing countries also exist:

-Product substitution and increased danger of dependence on imports

-Genetic erosion caused by the introduction of improved and uniform plant varieties

-Loss of control over genetic resources to the advantage of developed countries

-Control by transnational and loss of indigenous capability to develop adapted technologies

-Restriction in the flow of technical research information through intellectual property rights

-Absence of regulations for biosafety and concern about the testing of new products under lax guidelines

IDRC has participated and sponsored activities and meetings to deal with some of these issues.

A study gathered information on the current status of agricultural biotechnology research in different developing regions to assist in the development and application of a policy in biotechnology commensurate with the Centre's objectives.

This suggested a focus on benefit/risk assessments for evaluating procedures and laws for the responsible testing and release and introduction of recombinant DNA technology and, for dealing with environmental considerations related to the sustainable production of food with, for example, decreased dependency on pesticides. IDRC is funding studies on one of these aspects, related to the control of biotechnology by transnational and loss of indigenous capability to develop adapted technologies. Specifically it examines the impact of patenting of new improved seeds by multinational companies on small-scale farmers.

7. LDC participation at relevant international fora

IDRC in all its Divisions supports the participation of developing country researchers at meetings, conferences, workshops and symposia, where biotechnology issues of relevance to developing countries are being discussed:

African Biosciences Network (ABN) and UNSTCD collaborative workshop on "*Biotechnology for Food Production in Dry Areas, a Regional Assessment*" in Dakar, Senegal, October 1990. The workshop aimed at outlining concrete policy options and strategies available to African countries in the utilization of biotechnology to increase food production in dry areas of the continent.

The International Institute for Tropical Agriculture(Nigeria) Conference on "*Application of Biotechnology for the Improvement of African Crops*" discussed appropriate biotechnologies for use in the African context, in order to enable IITA, national programs, and interest donors like IDRC to set priorities for support to research using these tools.

It should be noted that the areas supported currently are handled by the different divisions and programs independently. We are in the process of establishing the basis for effective coordination of projects with a biotechnology component between the different divisions in the Centre.

OPPORTUNITIES FOR EXPERIMENTATION IN THE FOOD PROCESSING SECTOR

To take advantage of immediate opportunities for food biotechnology, donors should

promote the development of systematic and integrated experiences in selected developing countries. At IDRC, we would be interested to consider collaborating with researchers, institutions, companies,countries and donors in these endeavours.

Specifically in the food biotechnology sector, applied research projects should build on the experience already accumulated in technological innovation, particularly that related to agroindustry development, already highlighted above, ie with the following characteristics:

1. Ex-ante analysis of opportunities, markets and competitiveness.

Researchers should be required to justify their choice of biotechnology research topic with thorough systems analysis on all the options for the particular process or product; assessment of the economic and market competitiveness of the proposed new technology in comparison with the existing or competitive products or processes; evaluation of the opportunities and constraints for commercialization of the technology in the food industry of the country; and, the positive and negative impacts the proposed changes would have on the economy, social progress and equity. This will identify the most attractive opportunities together with the constraints and problems to be overcome. There exists little capability at the research level in developing countries to conceptualize and carry out such complex exercises, let alone operationalize the acquisition of proprietary technology from abroad, negotiate its transfer, adaptation to local industry if this is identified as necessary. Biotechnology researchers cannot be expected to handle this alone. Teams of analysts together with scientists and representatives of industry and appropriate government departments can be encouraged in exploratory projects to work

through these components and develop appropriate methodology which can simplify and accelerate the exercise for future occasions and for other sectors or countries. Such experiences would contribute to methodology development for decision-making and research design, as well as the building of capacity across a range of institutions and actors to work together in the innovation process.

Emphasis here may be in identifying niche markets at home and abroad which are unlikely to be economically or strategically of interest to multinational corporations eg production of unique enzymes, natural colorants and flavours from tropical plants, custom-designing of plants through recombinant DNA technology applied to key crops such as cocoa, coffee, spices etc to improve productivity of desirable functional characteristics, to reduce production costs and increase value in order to compete with cell-culture approaches of developed countries.

2. Technological research.

With the market and industrial opportunity identified together with the constraints and requirements for commercialization, projects on product and process development research can be justified for support. Emphasis here will be in adaptive research using known, or acquired, technology applied to the local resources or products.

Specific attention must be given to bioengineering and pilot-plant research, for producing reduced cost processes and equipment for fermentation, cell culture, separations, purification and preservation. Lack of knowledge and hence research in bioprocessing, is said to be limiting commercialization in developed countries, and hence this component is becoming increasingly protected by corporations in developed countries. Projects will

need to comprehensively evaluate results not only in terms of scientific rigour but also on impacts on production costs, consistency and levels of quality, process and quality control needs, market acceptability, feasibility (including that for the fabrication of new equipment) in order to ensure that the technology being designed will fit the context and constraints identified.

The contribution here will be in making available technologies and equipment for biotechnology applications in food processing and enhancing the capability in engineering schools and industry for process, product and equipment design research for biological industries.

3. Pilot enterprises.

Projects must also explore the linking together of all components of process and product technology designed in an enterprise structure. This enterprise may already exist or it may need to be created, in order to test how the whole innovation performs as an enterprise in the marketplace and to make the necessary adjustments so it is economically viable, technically feasible and socially acceptable. Complementary activities related to evaluation of appropriate policies and incentives for promotion of implementation of the technology, establishment of enterprises and commercialization of the products will be required at this stage.

These activities will encourage the setting-up of alliances between government policy-makers, private industry, consultants, university and public sector researchers, engineers and enterprise development specialists, many of whom will have worked

together in the ex-ante analysis. This will contribute further to capacity building for team work at the national level, but also will provide hands on experience of enterprise development issues in the application of food biotechnology under commercial conditions.

4. Biosafety and regulatory issues.

Since developing countries have minimal, if any, regulations and experience with biosafety and food biotechnology, it will be important to ensure that they are able to access appropriate information and advice on these issues, specifically on the food biotechnology applications identified as priorities for their country. Therefore projects should include provision for collaboration with international agencies working on these topics and access to CODEX Alimentarius discussions and recommendations as they evolve. Under this topic early assessment of consumer attitudes to food biotechnology products in target markets should be undertaken either through access to published studies or commissioning specific studies. This component will require considerable attention to development of appropriate information systems accessible by developing country teams.

In addition projects may be supported on the development or adaptation of biotechnology-based diagnostics for improvement of food quality analytical procedures for safety assessment.

5. Collaboration and Networking

Since it is essential that working experience be gained rapidly and with success, project teams in the developing countries can take advantage of the opportunity to collaborate

with Canadian scientists, government departments and the private sector working in biotechnology, if warranted. This will permit access to Canadian experience, facilities and technology as required to complement the developing country's team capabilities in the project. Since Canada has built up considerable infrastructure and experience in all aspects of biotechnology, this resource could be most effective in contributing to developing countries efforts. Collaboration amongst donors and countries will also be possible, particularly as related to technology acquisition.

Another possibility for strengthening projects which has been effective in other research areas, is the association of a number of projects of similar nature in different countries in a network. Thus teams have the opportunity to communicate with each other and interact at regular meetings so that methodological experiences, problems and information can be shared. Stronger teams can assist weaker ones and new projects can accelerate their activities taking advantage of the experience of earlier teams. The networks may be coordinated by one of the principal workers or lead institutions in order to make the interaction regular and effective. This approach will be particularly useful for food biotechnology projects in order to rapidly accumulate experience across a number of projects, which should lead to more effective work as experiences evolve.

6. Human Resource Development

A characteristic of all projects in this new field, should undoubtedly be a major component related to individual and group training to improve institutional capacity across all the fields necessary. Support for formal scientific training should be limited, with the exception of the field of bio-engineering. Group training in workshops on

integration of all the topics for decision-making and innovation management must be the priority. This task could be effectively be handled through networks.

CONCLUSIONS

1. Currently there exist opportunities for commercialization of biotechnology in the food processing sector. What is needed are creative, practical, efficient, multidisciplinary and multi-institutional programmes for innovation in developing countries to take advantage of these opportunities in the short term.

2. Applied research programmes across all of the issues involved in such innovations, could contribute to the accumulation of experience and capacity building in a number of countries, which could be shared through networks.

3. Collaborative mechanisms with Canadians and other nationals in public and private sectors could be employed to complement developing countries' resources.

4. Donors could collaborate in such programmes with complementary funding to ensure that all the relevant issues are covered effectively but specifically to ensure implementation (promotion of venture capital, credit, technical assistance) at the national level as well as dissemination and application of the results, nationally and internationally, in order to promote rapid adoption of innovation in the South within a short time frame.