FEED RESOURCES FOR INTENSIVE SMALLHOLDER SYSTEMS IN THE TROPICS: THE ROLE OF CROP RESIDUES.

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Feed resources for intensive smallholder systems in the tropics : the role of crop residues.

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ABSTRACT

The paper focuses on smallholder production systems in the tropics, characterised not so much by the land holding or livestock numbers, which may vary from one ecozone to another, but rather by an integrated crop-livestock production system, which appears to be the common thread among smallholder producers across all ecozones of the tropics. A major advantage of such a system is the production of large quantities of crop residues on-farm. These residues have the potential to contribute significantly to feed requirements. Paradoxically, the major constraint facing this system is a perennial quantitative and qualitative feed shortage which is most manifest during the dry season.

Solutions suggested for correcting the negative feed balance within the system are :

i. the expansion of the feed base to increase available quantities, via the exploitation of aquatic feed resources where appropriate ; the conservation of forage ; and the cultivation of improved fodder such as browse.

ii. the improvement of the quality of the major feed resource of the system i.e. fibrous crop residues and

iii. the development of improved and sustainable feeding systems through nutrient balancing to correct deficiencies inherent in crop residues. A number of successful practical feeding systems are described, and priority research areas including biotechnological applications that might further improve smallholder tropical feeding systems are suggested.

Key words : Crop-livestock integration, crop residues, feeding systems, nutrient balancing, smallholder producers, tropics.

INTRODUCTION

Recent analyses of livestock production in tropical systems revealed a large variety of production systems, such as commercial cattle rearing, nomadic pastoralism, transhumant agro-pastoralism and smallholder crop-livestock systems. Further analysis of smallholder systems, on the basis of ecological zones and social patterns, identified 10 major systems with 22 subsystems in Africa, 10 other major systems in Asia, and 4 in Latin America (World Bank, 1987). This paper will focus on the smallholder systems to permit an examination of the issues of constraints and opportunities for improved production to an acceptable depth.

In many developing countries with tropical or sub-tropical climates, smallholder farmers make up the majority of producers, and also supply the larger share of agricultural products for internal consumption and export. According to Said and Wanyoike (1987), about 80% of dairy cattle population and 53% of sheep and goats in Kenya, are held by smallholder farmers. In terms of product output, the sector contributed 75% and 65% of total milk and meat output, respectively.

Similar figures have been reported from other parts of the tropics, like Latin America, where Seré and Rivas (1987) reported that in 15 of the countries in the region, 70% of the bovine population are dual purpose cattle raised by smallholder farmers, who collectively produce 40% of total milk output.

Given the important contributions by smallholder producers to agricultural output, there is a need to continuously examine and alleviate their constraints, and exploit the opportunities they present for improved production and productivity as a means of improving the agricultural sector in developing countries.

In addressing the issue of feeding animals in tropical systems, this paper will therefore focus on the utilisation of feed resources available to the intensive smallholder producers. The paper will be devoted to a characterisation of smallholder systems, with particular emphasis on the importance of crop residues as feed resources within this system. Constraints to the optimum utilisation of these resources will be examined, followed by consideration of solutions to the constraints and/or opportunities for improving utilisation,

CHARACTERISTICS OF SMALLHOLDER SYSTEMS

Size, in terms of land holdings and/or livestock numbers, is often used as the determinant factor of smallholder production systems. It should be noted, however, that land holdings and livestock numbers observed and reported in the literature vary so much according to agro-ecoregional systems that it is difficult ascribe average figures that reflect norms across the range of countries in the tropical and sub-tropical areas. For example, a summary of published values for sub-saharan Africa, characterises the smallholder farmer as one with less than 10 ha of land, 50 sheep and/or goats, and about half as many cattle. Devendra (1989), however, reported that family sheep holdings may reach 100 to 125 heads in Syria, and in Latin America, average livestock numbers within smallholder systems are usually higher than in sub-saharan Africa.

Thus, a more generally applicable criterion is needed, and we suggest that the integration of crop and livestock production on the same farm unit is a more universal characteristic of smallholder systems, and distinguishes them from such other production systems as nomadic pastoralism, and commercial cattle ranching. Indeed, it is evident that in nearly all smallholder systems and sub-systems, livestock and crop production are closely interdependent and integrated.

According to de Leeuw *et al*. (1990), the typical small scale farmer in semi-arid eastern Kenya cultivates maize, beans, cow peas and pigeon peas, and keeps cattle, sheep and goats. Cattle which constitutes 80% of livestock mass are kept for milk, traction and cash sales, while the small stock are sold for cash.

The systems vary slightly in humid West Africa, where emphasis shifts to crop production, albeit with a small stock component. The typical smallholder farmer cultivates maize, cowpeas, cassava, and yams on nearly all of the average 3 ha holding, leaving little or nothing for grazing. The sheep and goats in the system roam freely, grazing on roadside and fallow lands, but receive crop residues and kitchen wastes as supplements.

In India, landholdings by the smallholders is even smaller, with over 50% of the farmers owning less than 1 ha, on which cereals, pulses, oilseeds, cotton and potato are cultivated. Less than 5% of the land is left for forage crop cultivation to feed buffalo and cattle for milk production.

The one unifying theme within the smallholder system across all of the ecoregional units is the crop-livestock integration. The systems generate considerable amounts of crop residues, which in practice play significant roles in the nutrition of livestock, supplying well over half of feed demand, particularly during the dry season when herbaceous forages, are in short supply.

PRODUCTION CONSTRAINTS WITHIN SMALL HOLDER SYSTEMS

It has been suggested that animal production under the various forms of smallholder production systems is relatively efficient, in terms of the objectives and resources of the farmer (Kaufman and Francis, 1989), However,there is room for improvement, since the potential of animals under these systems is rarely realised, because of a number of constraints.

These constraints can be grouped into 3 categories: ecological constraints such as land availability and climate; socio-economic constraints featuring labour availability, husbandry know how, land tenure and product pricing; and biological constraints which encompass nutrition, health and genotype. Only nutritional constraints will be treated in this paper.

Quantitative forage shortages result from small individual land holdings being used for several farm operations; food crop production usually takes the largest share of arable land. Most of the required fodder for livestock feeding therefore comes from fallow cropland, range and road sides. These sources rarely meet livestock requirements for nutrients.

Forage productivity on communal lands is generally low, particularly during the dry season, which is about 6 months in the sub-humid, and even longer in the semi-arid zones. An example of the low and seasonally fluctuating herbage dry matter yield in the semi-arid region of Kenya, is presented in figure 1 (Thairu and Tessema 1985).

An adequate nutrient supply is further hindered by qualitative deficiencies, as a result of the peculiar growth characteristics of tropical forages; they grow and mature rapidly with the onset of the rains, This rapid growth and early maturity lead to a rapid deposition of fibrous components, a decline in nitrogen and soluble carbohydrates, and increases in the stem:leaf ratio of the forage, with stem containing the less digestible cell walls (Ademosun and Bosman, 1989).

Data summarised from the work of Peyre de Fabrègues and Dalibard, 1990; Richard et al (1989); and Xandé et al (1989) on Table 1 illustrate the effects of this growth pattern on nutrient content and availability of some tropical forages.

Crop residues which constitute another major feed resource are produced in large amounts on farm, but only a small fraction of the amount available is used strategically. A large quantity of cereal straws is left on the field for in situ grazing, instead of being harvested, treated and stored for long term feeding. When left on the field, the residues rapidly deteriorate, and a large amount is usually trampled upon and wasted. In addition, the nutrient imbalance which characterises these fibrous residues, is not corrected by appropriate supplementation.

Nutrient supply from forages and crop residues, the main feed resources usually therefore fall below requirements of livestock for acceptable performance. The consequence is a negative feed balance sheet both at the farm and country level, even when all feed resources are taken into account, For instance, smallholder farms in the Siava district of Western Kenya, with land holdings of 1.5 ha, 3 cows with calves, 4 sheep and 3 goats could not procure enough feed from their land, communal grazing, fallow lands and crop residue supplements, to meet the energy requirement of their stock (Onim et al.,1987).

The calculated deficit was most apparent during the 5 dry months of the year. It would be worse if the negative effect of heat and humidity stress on feed intake and efficiency of utilisation of metabolisable energy (Leng, 1989) were considered to vary the energy requirement from one season to another.

At the country level, feed balance sheets reported from a number of countries show varying levels of deficits. Tareque and Saadular (1988), reported that only 44, 26 and 20% of dry matter, protein and energy requirements respectively, were met from available feed resources in Bangladesh. Slightly higher deficit figures of 32.5% energy, and 54% digestible crude protein were reported for India by Devendra (1989)

SOLUTIONS AND OPPORTUNITIES FOR IMPROVEMENT.

We suggest three strategies could be adopted to increase both the quantity and quality of feeds available to the system, in order to improve livestock production and productivity; expand the feed base; improve the quality of major feed resources; and improve feeding systems through better nutrient balance strategies.

Expand the feed base.

The rainfall pattern in many of the humid tropical region is bimodal, with a period of long rains (4-5 months) separated by a dry spell from a period of short rains (1-2 months). In the drier sub-humid areas the pattern is usually unimodal, with a period of 2-3 months of rains followed by a long dry season.

Forage production is often in excess of immediate requirements of livestock during the rains. This excess forage should be harvested and preserved either as hay or silage, to expand the feed base, and ensure a year round supply of good quality fodder.

Given the rainfall patterns described above, hay would be suitable and easier to make in the sub-humid and semi-arid tropics, while silage could be easily made across the tropical ecoregions. A number of potential bottle necks would need to be addressed by research, in order to make silage and hay making techniques attractive and acceptable at the smallholder level. Some of these include technical feasibility as well as availability and cost of required inputs at the small scale level. Some interesting work and results are emerging along these lines.

Onim *et al.* (1986) described a simple grass and legume hay making technique that requires only a wooden box, a grass cutting sickle and sisal twine, all of which are at the reach of small holders. Good quality hay of grasses, and legumes, including browse like pigeon pea, sesbania and leucaena, were successfully made after two to three days of field drying.

The important lesson here is that the technic was not only effective, but also accepted by smallholders who apparently could make four 20 kg bails of hay each day. The authors reported that where hay bailing was adopted, the monthly feed availability pattern no longer fluctuated seasonally between surpluses and deficits, but covered requirements all year round, particularly when combined with forage cultivation.

More recently, Otieno _et al_. (1990) demonstrated the technical feasibility of ensiling a number of tropical grasses with or without molasses in hesian or jute bags. Here again, the technique described appears flexible enough to allow farmers to ensile small quantities of material as and when they become available, and at optimum physiological age, as well as to feed equally small amounts without wastage, as the storage unit had a capacity of only about 40 kg. As with hay, the extra feed provided by the silage, improved feed availability on a year-round basis.

The major inputs - hesian bags and molasses also appear to be within reach of the farmers. These bags are readily available on the market, and fairly cheap. Molasses was apparently also readily available, but could constitute a bottle-neck elsewhere. Hence the need to evaluate other more readily available additives. In this respect, grass-legume mixtures should be evaluated, as there is evidence that the addition of legume forages could improve the fermentative quality of grass silages (Ojeda _et al_. 1990).

Aquatic plants constitute a group of under-exploited resources, which could increase the feed base. For example, the flood plains of large rivers in the Sahel, such as along the Niger delta and Lake Chad are flush with the grass *Echinochloa stagnina*, which could supply feed of moderate quality to the resident dairy cattle owners on a year-round basis if appropriate harvesting and feeding systems are established. Limited studies have shown the value of the plant for goats (Adebowale, 1988).

Another option for expanding the feed resource base, is through the strategic use of browse. Browse in form of fodder trees and shrubs form an integral part of tropical and sub-tropical farming systems, but are yet to play a strategic role in livestock feeding within the small holder systems.A number of browse species such as Leucaena leucocephala, Gliricidia sepium, Sesbania sesban, etc. grow year round, and respond positively to regular pruning. They could therefore be managed to provide fodder during the critical dry periods. Two systems by which browse could be incorporated into the crop-livestock production systems of the smallholder farmer are alley farming and intensive fodder gardens

In alley farms, food crops are planted in alleys formed by hedgerows of the browse. The hedgerow foliage is cut back at crop planting time, and periodically pruned to prevent shading and reduce competition with the associated food crops. The pruned foliage is used as mulch and as animal feed, with a larger proportion going towards animal feeding during the dry non-cropping season, when feed shortages are most acute. A field base model developed by Sumberg et al (1985), showed that the system could contribute towards alleviating feed shortages.

In the intensive fodder garden system, browse only, or browse-grass combinations are planted on a small plot of land to serve as a protein bank for feeding livestock at critical periods of feed shortages. A recent study by Atta-Krah (1989) showed that fodder from Leucaena only intensive fodder garden with an average size of 0.01 ha provided sufficient fodder to meet 12.5% of the daily dry matter requirement of 3-4 West African Dwarf Goats that constituted the average small stock holding of the typical farming house hold in the area of study.

Improve the quality of available feed resources.

Natural forages. In most situations, natural forages do not meet the nutrient requirements of livestock for most of the year, even during the wet growing season when they may be energy deficient. For example, a summary of published nutrient contents of common grasses growing in humid Africa during the rains, show that these grasses contain on average, 25% dry matter, 10% crude protein, 6% ash, and about 43% acid detergent fibre (ADF) (Smith, 1992).

These values change during the dry season with fibre levels of standing hays going much higher (60% ADF), and ash levels falling to below 3%, with a corresponding decline in essential minerals like phosphorus and sodium . With such high fibre levels and extremely low crude protein content (2%), these forages no longer ensure a functional rumen ecosystem, which requires a minimum of 7% protein. Digestibilities and intake in turn fall below the minimum required for maintenance (dry matter intake and digestibility of 1.2-2% of live weight and 50-55% respectively).

A number of management strategies have been suggested to improve pasture quality, such as controlled and rotational grazing, bush and weed control, oversewing improved legumes into the natural sward, irrigation and fertiliser application.

These options appear inappropriate for the majority of small scale farmers who have small land holdings or communal lands, particularly as positive results may not be achieved in the short term (Kapinga and Shayo, 1990).

One option which has had some measure of success at the smallholder level is the cultivation of improved leguminous and non-leguminous fodder plants. These options will be treated in detail by another Maraschin and Jacques (1993). It should be pointed out, however, that although the history of research on planted improved fodder is fairly old, and the technology is available, adoption and utilisation in many tropical farming systems is slow and rather unsuccessful. The required labour input, capital investments and expertise are rarely available at the smallholder level, except perhaps under intensive smallholder milk production systems where the necessary investments could be economically justifiable.

It is for the benefit of these producer groups that research should find answers to such pertinent questions as: appropriate fodder species for the various ecological zones, required management inputs for optimum yield and economic viability, and appropriate fodder conservation technology.

<u>Crop residues:</u> Crop residues are fibrous remnants produced after crop harvest or primary processing (Table 2). Their quality is highly variable depending upon the crop species, seasonal growing conditions, extent of processing and post harvesting or processing treatment. They constitute an important, and often the major feed resource available and utilised by smallholder producers in tropical feeding systems.

A number of inventories have been carried out by researchers on national (Aregheore and Chimarino,1992), regional and global (Kossila, 1985) basis. Invariably, these studies all conclude that large amounts of crop residues are available for livestock feeding, supplying over 20% of ruminant energy requirements.

On a regional basis within tropical systems, Asia is apparently the leading producer of crop residues, with a total production of 3.56 tonnes of dry matter/livestock unit of herbivores followed by Africa, 2.20, Latin america, 1.87, and Oceania 1.0 (Kossila, 1985). Within the regions, variations in amount of available crop residues were observed on a country basis, as shown in Table 3, which divides the countries into well and less endowed. These differences could be attributed to a number of factors including climatic factors, agricultural production systems, and land availability (Kossila, 1985).

On a global basis, Kossila (1985), indicated that if all potentially available crop residue could be utilised for feeding, each herbivore would receive over 9 kg dry matter and about 17 Mcal ME /day, thus largely covering their requirements. Unfortunately, a much lower level of utilisation is possible because of problems of collection, transportation, storage and processing, alternative uses, seasonal availability, and perhaps most importantly, an apparently poor nutritional value.

Indeed, most crop residues are deficient in protein, essential minerals like sodium, phosphorus and calcium, and are rather fibrous (40-45% crude fibre). The consequences of such a profile for ruminants are a low intake (1-1.25 kg dry matter/100 kg live weight), poor digestibility of the order of 30-45%, and a low level of performance.

Low intakes and poor digestibility result specifically from high cell wall lignin content, and the chemical bonding between this fraction and potentially nutritious cell wall constituents such as cellulose and hemicellulose.

Physical, chemical and biological treatments can disrupt the bonds between these constituents, causing partial solubilisation of the lignin and hemicellulose fractions, with a resultant increase in the digestibility of the cellulose and hemicellulose fractions. Increased digestibility leads to a shorter feed residence period in the rumen, and hence increased intake.

Poor animal performance on the other hand, results mainly from the unbalanced nature of the nutrients supplied by most crop residues. Evidence exist that increased digestibility and intake of fibrous feeds as a result of ligno-cellulosic bond disruption do not always result in improved animal performance (Brand et al 1991).

A complementary strategy, that of nutrient balancing, through supplementation is therefore required to optimise the efficiency of transforming absorbed nutrients into products. The ruminant should, from a nutritional stand point, be considered as two entities with different nutritional requirements. First, the requirements of the rumen need to be met to ensure a functional ecosystem that will result in a maximum break-down of the fibrous component of the diet by the resident microbes.

The second entity is the whole animal component, which requires pre-formed true protein other than the non-protein nitrogen supplied by the rumen microbes, as well as glycogenic energy precursors. Hence the need to supply by-pass materials - energy and protein to meet these requirements of the whole animal component.

As indicated earlier, crop residues are characterised by the unbalanced nature of the nutrients they supply. Most do not contain adequate soluble nitrogen and fermentable carbohydrates, nor essential minerals, and these need to be supplied to ensure a balance of nutrients. Thus, two approaches need to be used to improve the quality of crop residues.

First to eliminate deficiencies and stimulate efficient fermentative activities that extract the maximum possible amounts of nutrients from the feed in the rumen, and second, to by-pass the rumen and balance nutrients absorbed in the lower gut for maintenance and production. The second approach will be discussed in the feeding systems section.

From a nutritional stand point, plant material is made up of two components - cell contents which are usually highly digestible, and cell wall made up of lignocellulosics and non-cellulosic polysacharides. Complex lignocellulosic bonding prevents easy access of digestive enzymes to cell contents, to the equally digestible non cellulosic polysaccharides such as hemicelluloses and pectins, and to cellulose, the major component of all plant cell walls. Apparently these and other components of the cell wall are bound together into one great macromelecular matrix (Morrison et al. 1989).

Any treatment that can alter and open up the matrix in such a way as to make the digestible components available to enzymatic hydrolysis by celulases complex produced by rumen microbes will efficiently improve digestibility and intake of crop residues.

The various treatment methods tested to date differ in terms of mechanism of action, effectiveness and suitability for the target production systems, as shown in table 4. In general, physical methods such as soaking and wetting which may increase palatability through reduced dustiness; chopping and grinding which reduce wastage, do not significantly affect digestibility.

Exceptions are the newer energy consuming methods such as steaming under pressure, gamma irradiation, and explosion, for which 10 to 31% increases in digestibility have been reported (Hennig et al 1982; Ryu, 1989). These latter methods disrupt cell walls through physico-chemical mechanisms, as exemplified by steaming, which separates and cleaves bonds between cell wall constituents, in addition to a hydrolytic action of acids resulting from the processes (Doyle et al 1986).

Alkalis have been the most commonly evaluated chemicals for treating crop residues. Two other groups of chemicals - acids and oxidative reagents have to a lesser extent also been investigated. All three groups, with some measure of specificity, disrupt cell walls structure by breaking or weakening lignin-carbohydrate bonds, and solubilising lignin and the released carbohydrates.

Reported effectiveness of chemical treatments in terms of increased digestibility are variable, even for sodium hydroxide and ammoniation, the two most tested methods, because of several modifying factors.

The effect of some of these factors were demonstrated by Flachowsky and Schneider (1989), who investigated the effect of ammonia level, moisture content, temperature and duration of treatment on rumen dry matter degradability of wheat straw. They concluded that the optimum conditions which gave an increase in digestibility of 27% units were: 3% ammonia, a straw moisture level of 30%, a treatment temperature of 40-60 °C, for 7-14 days.

The effect of two other factors that need to be considered - plant and animal species are illustrated in Table 5. In general, however, average improvement in digestibility following alkali treatment could be as high as 30-40%.

Biological treatment through composting, ensilage, fungal growth, fermentation and enzyme addition, have been less well investigated. There is some evidence that while such treatments improve digestibility (Ibrahim and Pearce, 1980; Ryu, 1989), this is usually associated with some loss of dry or organic matter, because many organisms, particularly fungi, in addition to attacking lignin, also have well developed cellulase and hemi-cellulase activities (Morrison et al ,1989).

In order to fully exploit microbial lignin degrading activity, it may be necessary to genetically engineer organisms that have only lignase activity. The production of such microbes is being actively pursued, and the ability of such modified microbes to survive and function effectively in the rumen will be crucial (Morrison et al 1989).

Many of the treatment methods improve the consumption and digestibility of crop residues, but only a few are suitable for the target system under consideration. The most efficient methods, for example sodium hydroxide treatment are also the most unsuitable because of the non-availability of the chemical, health risks, and costs of additional labour.

All things considered, we suggest that the most appropriate methods of improving the feed value of crop residues at the smallholder level should be limited to chopping and grinding, ensiling with urea or animal manure, and ammoniation using urea. Positive effects of these simple treatments on intake and digestibility of wheat (Flachowsky and Schneider 1989), and rice straws (Perdok et al 1982; Khajarern and Khajarern 1985) are summarised on Tables 6, 7 and 8.

Greater efforts should be made to exploit the demonstrated effectiveness of alkalis using resources available to the farmer, such as wood, oil palm bunch, and cocoa pod ashes. Available evidence (Adebowale 1985; Smith et al 1988) suggest that these ashes are as effective as equimolar concentrations of sodium hydroxide solutions, with the added advantage of availability. In addition, farmers are used to handling such ashes for soap making and soil amendments. Some positive effects of treating fibrous residues with such alkali active ashes from the literature (Sudana 1987; Adebowale et al 1991) are shown on figures 2 and 3.

Improve feeding systems

We reiterate that treatment methods briefly reviewed above often result only in increased intake and digestibility of materials that are usually inherently deficient and/or unbalanced in factors required for efficient fermentative digestion and for the efficient utilisation of fermentative products by the ruminants. It is therefore necessary to complement this improvement in digestibility with a supply of nutrients that will correct imbalances in crop residues.

Preston and Leng (1981) suggested the provision of the following factors to optimise fibrous residues utilisation.

i. Fermentable energy

ii. Fermentable nitrogen

iii. Micronutrients especially S, P and B vitamins

iv. Roughage for adequate rumen function

v. By-pass protein and

vi. By-pass energy.

Data in Figure 4 from the work of Leng (1991), appropriately illustrate the concept of supplementation. Cattle weighing 320 kg were fed untreated or ammoniated rice straw supplemented with various levels of by-pass protein meal. In addition, 0.5 kg molasses/urea block supplying fermentable nitrogen, and 0.6 kg rice pollard supplying by-pass energy in form of starch and lipids were fed.

Although the effects of the various supplements can not be easily separated, ammoniation of the straw improved performance from a negative to a positive weight gain, and by-pass protein supplement further effected an improvement in weight gain ranging from 39 to 55%. Some potentially valuable and easily available supplements are shown in Table 9.

The task ahead is then to combine suitable supplements depending on location and cost with available crop residues and evolve viable and efficient feeding systems. A number of such systems, built around multi-nutrient blocks and fodder trees, which are currently in use, and which show promise of success and sustainability, are presented below.

Verma (1990) described a successful system based on urea treated paddy straw or wheat bhusa. Farmers treat straws with urea solutions in well protected stacks, silos or sheds, to heights of 2 m. Three to four weeks later, they start feeding the treated straws, supplemented with green leucaena leaves (1.5-2.5 kg/head/day) or cotton seed cake (300-500 g/head/day, plus mineral salts (30 g/day) with both supplements. In either case, cattle gain up to 450 g/day, the same as they gain when fed untreated straw plus 2 kg/day of an expensive concentrate.

The same system with slight modification is used for feeding dairy cows, and Verma (1990) noted that farmers have been using this feeding system for over 6 years, citing the case of a farmer who soon after adopting the system was able to reduce the area of land under forage crops by 30%, and concentrate feeding by 0.5 kg/cow/day, and yet increased milk yield by 2 kg/cow/day; and decreased age at first calving by 3 months. Annual consumption of paddy straw on the farm was 150 tonnes.

Another promising system featuring the concept of nutrient balance was reported by Smith et al (1991) in Zambia. Cattle grazing unimproved woodland/Hyparrhenia grassland were supplemented with a maize stover and legume residue which they grazed for three hours daily plus 1 kg/cow/day each of maize bran and maize silage, and 250-300 g/cow/day of a urea-mineral lick. This system, in which crop residue served as supplement to poorer quality forage, but with a supply of fermentable nitrogen, energy, roughage and micronutrients resulted in increased milk off take, total daily milk and daily live weight of calves, with the value of the additional milk and weight gains exceeding the cost of inputs.

Successful attempts are being made to prepare supplements rich in required nutrients, and package them in such a way as to facilitate utilisation and acceptance by smallholders. Leng and Preston (1983) reported that the National Dairy Development Board of India has developed multinutrient blocks based on molasses and urea and rich in fermentable nitrogen, minerals, vitamins, amino-acids and peptides.

These blocks, targeted towards dairy buffaloes which consume about 500 g/day/head, promote an efficient rumen fermentation. They are complemented by concentrate feeds with a high content of cottonseed meal as by-pass protein. Similar efforts are on-going in Latin America and the Caribean, and Table 10 illustrates a successful feeding system in Colombia where rice polishings have been incorporated into supplementary feeds (CIPAV 1987). In certain situations, molasses may be unavailable, or too expensive. The task under such situations is to develop efficient feed packages without molasses.

Another simple feeding system that appears appropriate for small holder situations was recently evaluated by Winter (1987) in the Australian semi-arid tropics. The system involved the controlled burning of poor quality native pastures to improve its quality over that of standing dry feed. Cattle grazing the better quality regrowth, which is often still deficient in nitrogen sodium, phosphorus and sulphur are then supplemented with nitrogen as urea, cotton seed meal to supply by-pass protein, phosphorus, and sodium chloride. The results shown on Figure 5, demonstrate the beneficial effects of appropriate supplementation on cattle growth.

CONCLUDING STATEMENTS

Large amounts of fibrous crop residues are available for feeding ruminant livestock, particularly within the smallholder systems. A large proportion of these resources are currently either not being used, or are being used inefficiently.
Given the potential contribution these resources could make to the feed economy of small holder systems, more effort is needed to increase the amounts utilised and the efficiency of utilisation.

The problems associated with the efficient utilisation of crop residues are well known, and solutions to many, if not all of them, have been found since the "residue revolution" which, according to Owen and Jayasuriya (1989) took off in the developing tropics in the 1980s.

So much technology for improving residue utilisation is available that one is tempted to agree with Owen and Jayasuriya (1989) that it is a waste of time and resources to continue developing technologies that are not utilised or adopted by farmers, because they are inappropriate. Yet it is for the same reason of unadopted technologies that one must plead for a continuation of the search for appropriate technology.

Research has an important role to play in defining appropriate and sustainable feeding systems built around crop residues for the smallholder producers. A number of such systems have been briefly described, but many more that are targeted towards particular socio-economic situations are needed.

In this context, the selective feeding system suggested by Owen et al (1989) needs to be further validated and targeted towards situations where there is an abundance of residues to make the generous feeding central to this system feasible.

Although research targeted towards particular socio-economic situations will improve the relevance of technologies, there is still a need for fundamental research that could be beneficial to a larger number of systems. A pertinent example is the current attempts, through genetic engineering, to improve the enzymatic ability of rumen microbes to degrade lignocellulosics or fibre. Leng (1991) suggested that microbes could be produced with enhanced fibrolytic activity, or with fibrolytic enzymes of high specific activity (eg lignase), or with wider spectrum of enzymatic activity, such as combining cellulolytic and xylolytic capacities.

A large number of farmers would benefit from such a fundamental innovation and so it provides an excellent example of the priority research areas that might improve smallholder tropical feeding systems.

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Table 1. Growth pattern and nutrient content of tropical forages

Species	Dry Matter	% DM NDF	Ash	P	DCP	Energy (MJ/kg)
Legume dominated rangeland forage						
Early rains(Sept)	15.3	39.5	13.5	0.2	15.4	9.46
Early dry(Nov)	93.5	66.7	4.0	0.06	4.7	6.36
Cenchrus biflorus						
Vegetative(August)	23.0	30.3*	-	0.16	11.2	9.67
Flowering(August)	28.0	33.2	-	-	4.8	6.07
Seeding(Sept)	39.2	38.9	-	0.13	1.5	5.52
Elephant grass						
Wet season 8wks	15.5	34.6*	10.4	0.25	2.7	9.62
10wks	19.7	37.2	9.2	0.20	2.2	8.74
Dry season 8wks	18.8	30.2	13.3	0.20	4.5	8.91
10wks	20.6	31.9	11.1	0.20	2.4	8.79

*Crude fiber

Table 2. Common crop residues in tropical feeding systems

Crop	Primary product	Field residue	Primary processing residue
CEREALS			
Maize	Grain	Stovers	Cob
Rice	Grain	Stubbles	Straw
Sorghum	Grain	Stovers	-
Wheat	Grain	Straw	-
GRAIN LEGUMES/OIL SEEDS			
Groundnut	Oil	Haulms	Husk
Cowpea	Grain	Vines	Husk
Pulses	Beans	Vines	-
ROOTS/TUBERS			
Cassava	Tubers	Tops	Peels/Rejects
Sweet potato	Tubers	Tops	Peels/Rejects
FRUITS			
Banana/Plantain	Fruit	Tops Pseudostems	Peels/Rejects
Coconut	Copra	-	Husk
Cocoa	Seeds	-	Pods
OTHERS			
Sugarcane	Cane	Tops	Bagasse

Table 3. Regional variation in crop residues availability

COUNTRIES	TONNES OF DRY MATTER/LIVESTOCK UNIT
AFRICA	
WELL ENDOWED	
Nigeria	5.2
Côte d'Ivoire	7.6
Zaire	7.7
LESS WELL ENDOWED	
Ethiopia	0.6
Somalia	0.1
Botswana	0.2
ASIA	
WELL ENDOWED	
Phillipines	11.4
Malaysia	11.6
Indonesia	10.7
LESS WELL ENDOWED	
India	2.1
Bangladesh	1.2
Iran	1.5

Source: Kossila, 1985.

Table 4. Currently available methods of treating crop residues

METHOD	TREATMENT	SUITABILITY[2]
PHYSICAL	Soaking, wetting	++
	Chopping, grinding	++
	Ball milling	-
	Explosion	-
	Gamma irradiation	-
	High pressure steam	-
CHEMICAL	Alkalis and Ammonia Compounds	
	NaOH, KOH	+
	Ammonia, urea, urine	+
	Acids	
	Hydrochloric acid	-
	Sulphuric acid	-
	Hydrogen flouride	-
	Oxidising agents	
	Peroxides, chlorine	-
	Oxone, sulphur dioxide	-
BIOLOGICAL	Composting	++
	Ensiling	++
	Fungal growth	-
	Fermentation	-
	Enzyme-addition (cellulose)	-

[2]Suitability:
++ Suitable at smallholder level
\+ Questionable
\- Not suitable

Table 6. Effect of various treatments on wheat straw digestibility and intake in bulls

Treatment	%OMD	INTAKE	
		Dry Matter (kg/day)	Net Energy (MJ/day)
Chopped	45.0	3.43	11.8
Ground	45.0	3.67	12.5
Chopped + 4% Urea	53.0	4.97	19.8
Chopped + 5% NaOH	59.0	4.04	18.1

Table 5. Plant and animal species effect on response to alkali treatment of crop residues

CROP RESIDUE	IMPROVEMENT IN DIGESTIBILITY (%)
Rice straws	38
Wheat straws	31
Corn cob and stovers	30
Sugarcane bagasse	57
Rice hulls	137

ANIMAL SPECIES	INCREASE (%)	
	Digestibility	Feed intake
Beef cattle	15	35
Sheep	29	35
Goats	40	43

Source: Ryu, 1989.

Table 7. Effect of ammoniation of rice straw by urea-ensiling on sahiwal heifers

Item	Straw	
	Untreated	Treated
Straw Intake (kg dm/day)	2.09	2.84
Total Intake (kg dm/day)	3.84	4.59
Weight Gain (g/day)	73.0	346.0
Feed Conversion (kg dm/kg gain)	53.0	13.0

Table 8. Effect of ammoniation of rice straw by urea treatment on intake and digestibility

Item		Dry Matter	
		Intake (g/kg MW)	Digestibility (%)
Cattle	Treated Straw	95.2	51.5
	Untreated Straw	65.4	42.4
Buffaloes	Treated Straw	98.1	58.4
	Untreated Straw	75.1	49.5

Table 9. Sources of nutritional supplements to crop residues

NUTRITIONAL FACTOR	SOURCE
Fermentable nitrogen	Urea, Animal manure
Fermentable carbohydrate	Molasses, cane juice, cassava chips, cassava peels, reject banana, rice bran, maize bran
Roughage-micronutrients	Cassava tops, sugarcane tops, banana leaves and pseudostems, tree fodder such as gliricidia and leucaena
By-pass protein	Tannin rich fodder such as gliricidia, leucaena, oil seed cakes
By-pass energy	Maize, broken rice, rice polishings, oil seed cakes

Table 10. Cattle growth response to supplementing a range of crop residues with rice polishing

Supplement	Crop residue		
	Bagasse pith	Bagasse	Ammoniated rice straw
	(Wt gain g/day)		
Nil	275	310	170
Rice polishing*	400	500	550

*500g/day rice polishing supplement with ammoniated straw; 300g/day with bagasse and bagasse pith.

Figure 1. Seasonal fluctuations in the quality and quantity of tropical grasse.

Figure 2. Effect of fire-ash treatment on rumen degradability of rice straw.

Figure 3. Rumen degradability of wheat straw treated with cocoa pod ash

Figure 5. Appropriate supplementation of fire treated native pastures

Figure 4. Effect of straw ammoniation and supplementation on cattle performance.

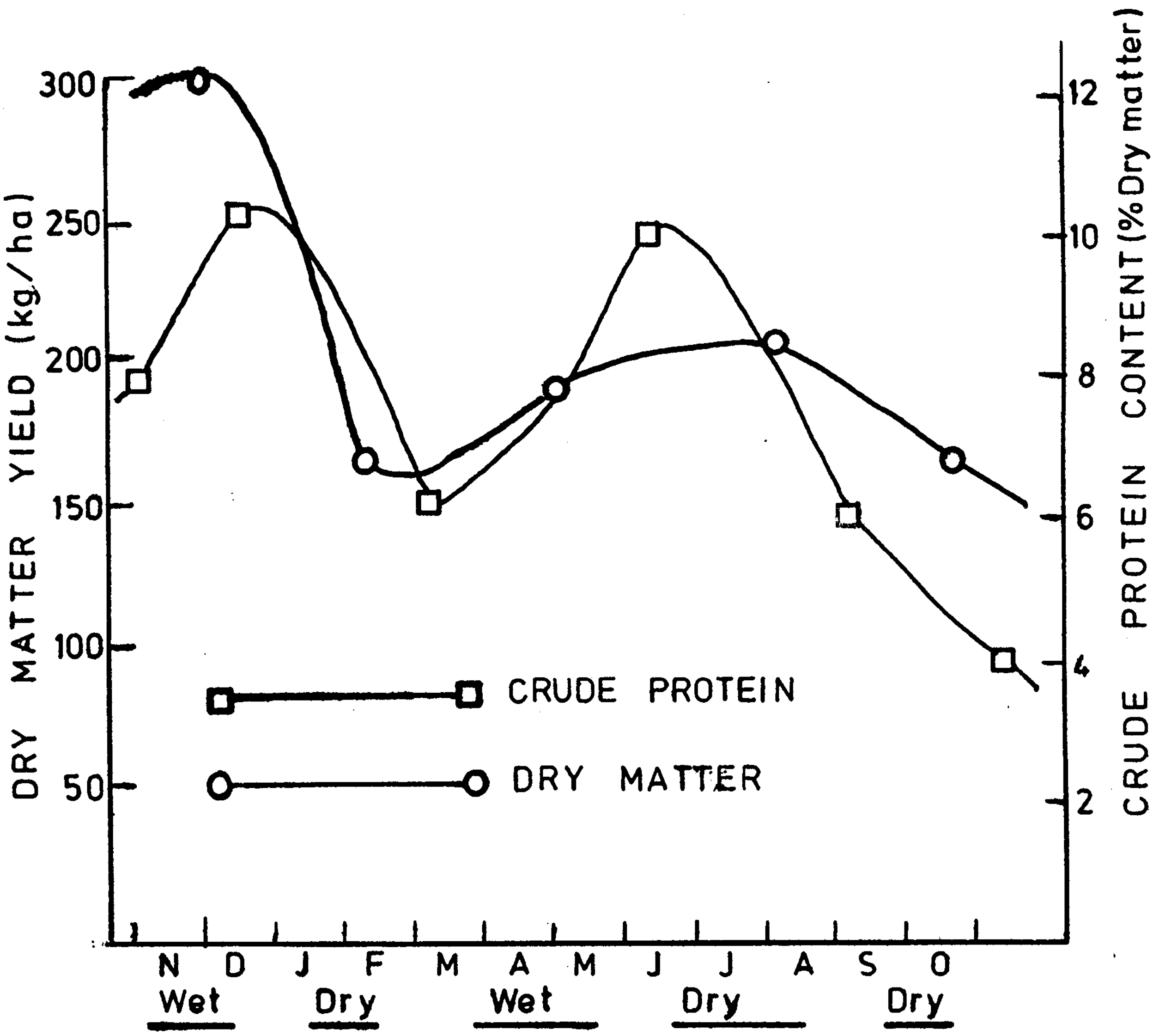


Figure 1: Seasonal fluctuations in the quality and quantity of tropical grasses.

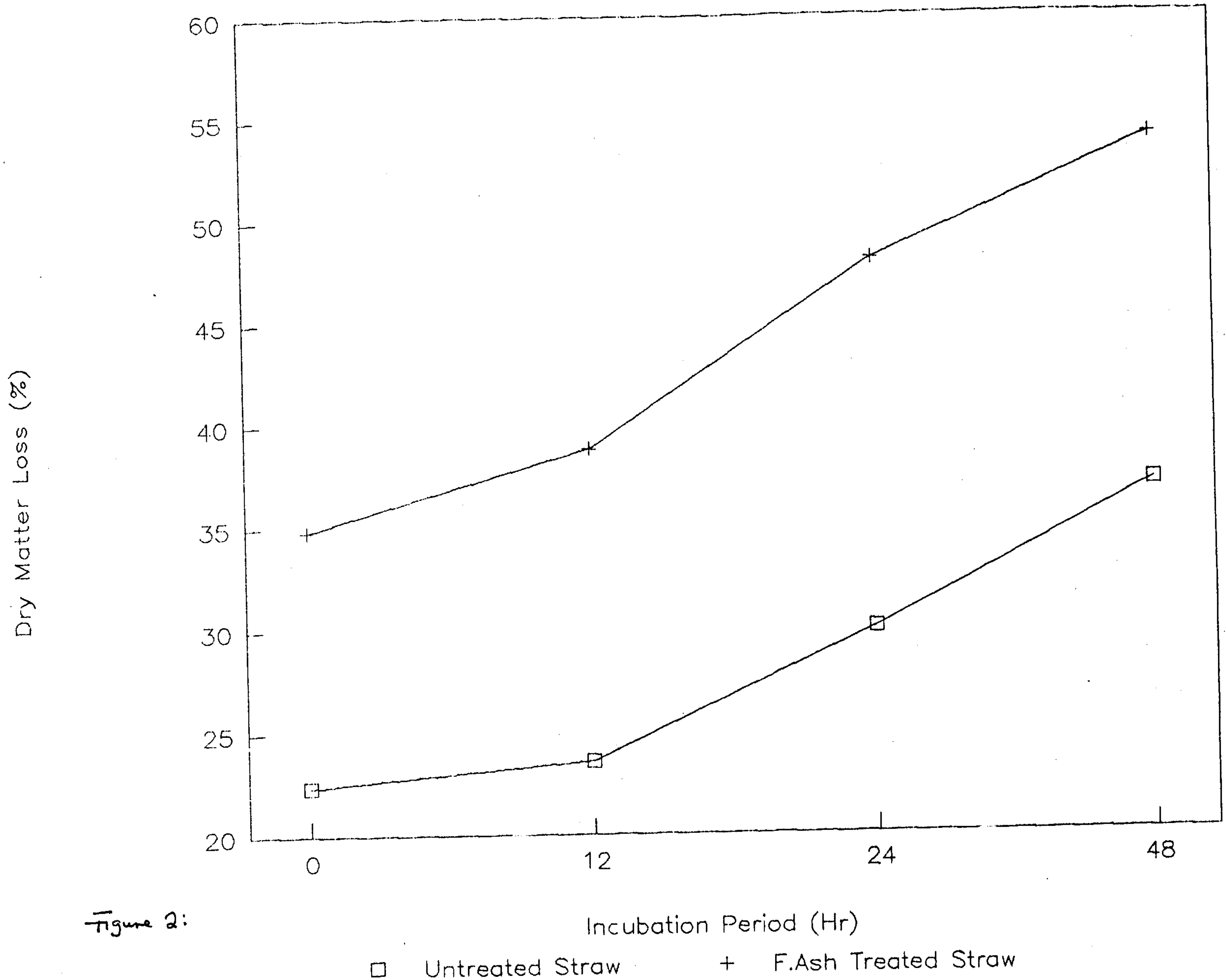
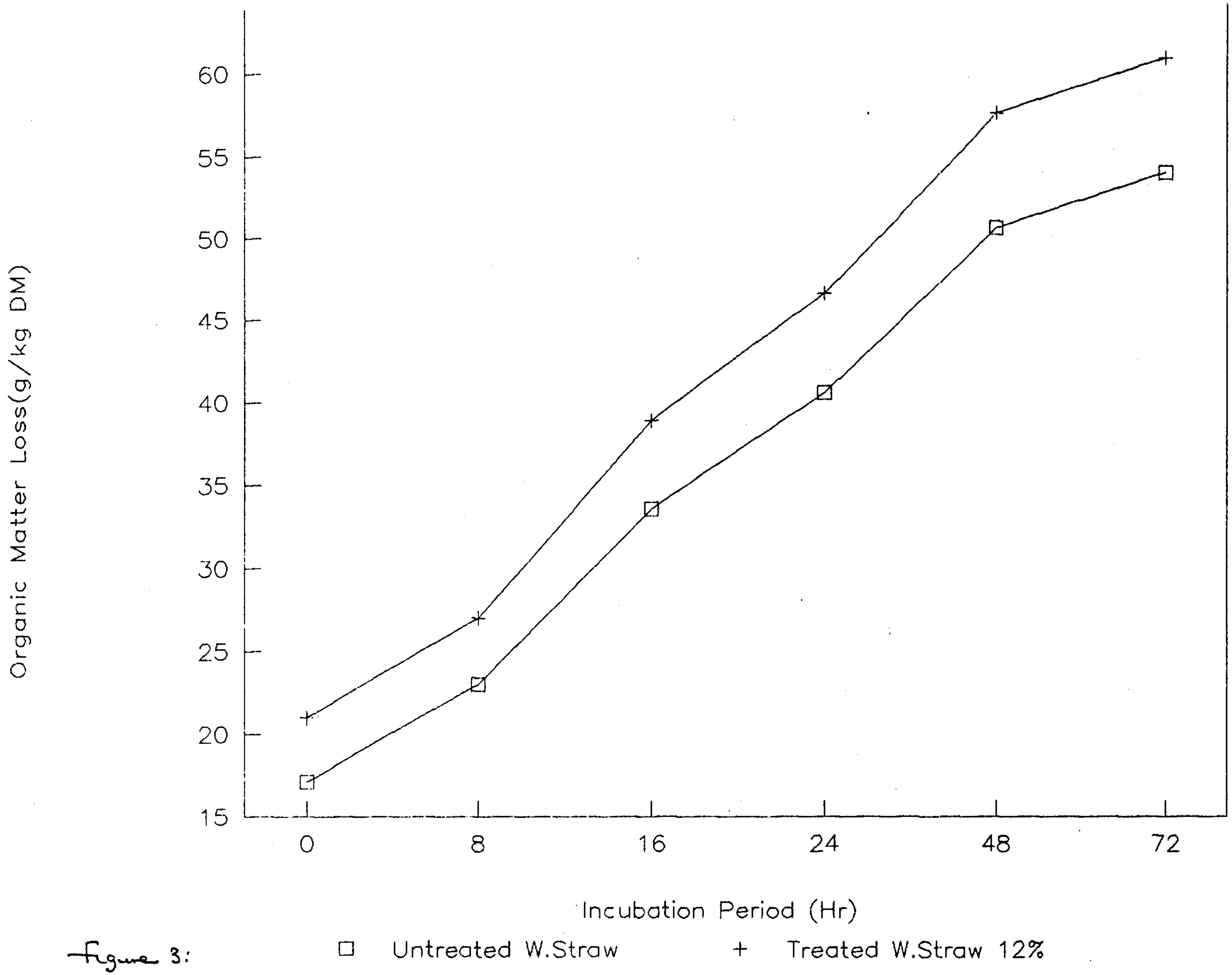

Dry Matter Loss (%)
60
55
50
45
40
35
30
25
20
0
12
24
48
Incubation Period (Hr)
Untreated Straw
F.Ash Treated Straw

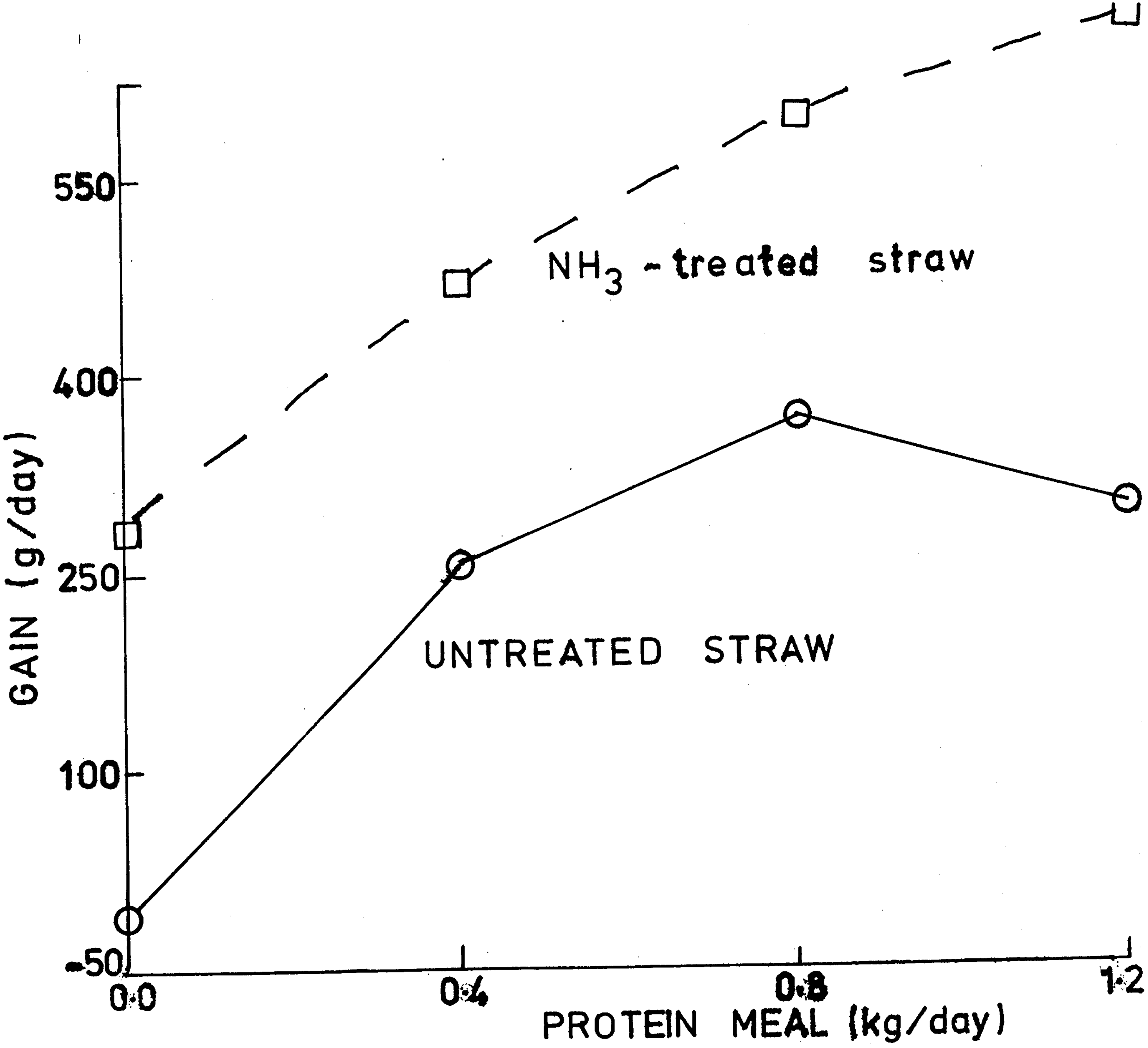
Figure 2:



Organic Matter Loss(g/kg DM)
60
55
50
45
40
35
30
25
20
15
0
8
16
24
48
72
Incubation Period (Hr)
Untreated W.Straw
Treated W.Straw 12%

Figure 3:

Figure 4:



550
400
250
100
-50
GAIN (g/day)
NH_3 - treated straw
UNTREATED STRAW
0·0
0·4
0·8
1·2
PROTEIN MEAL (kg/day)

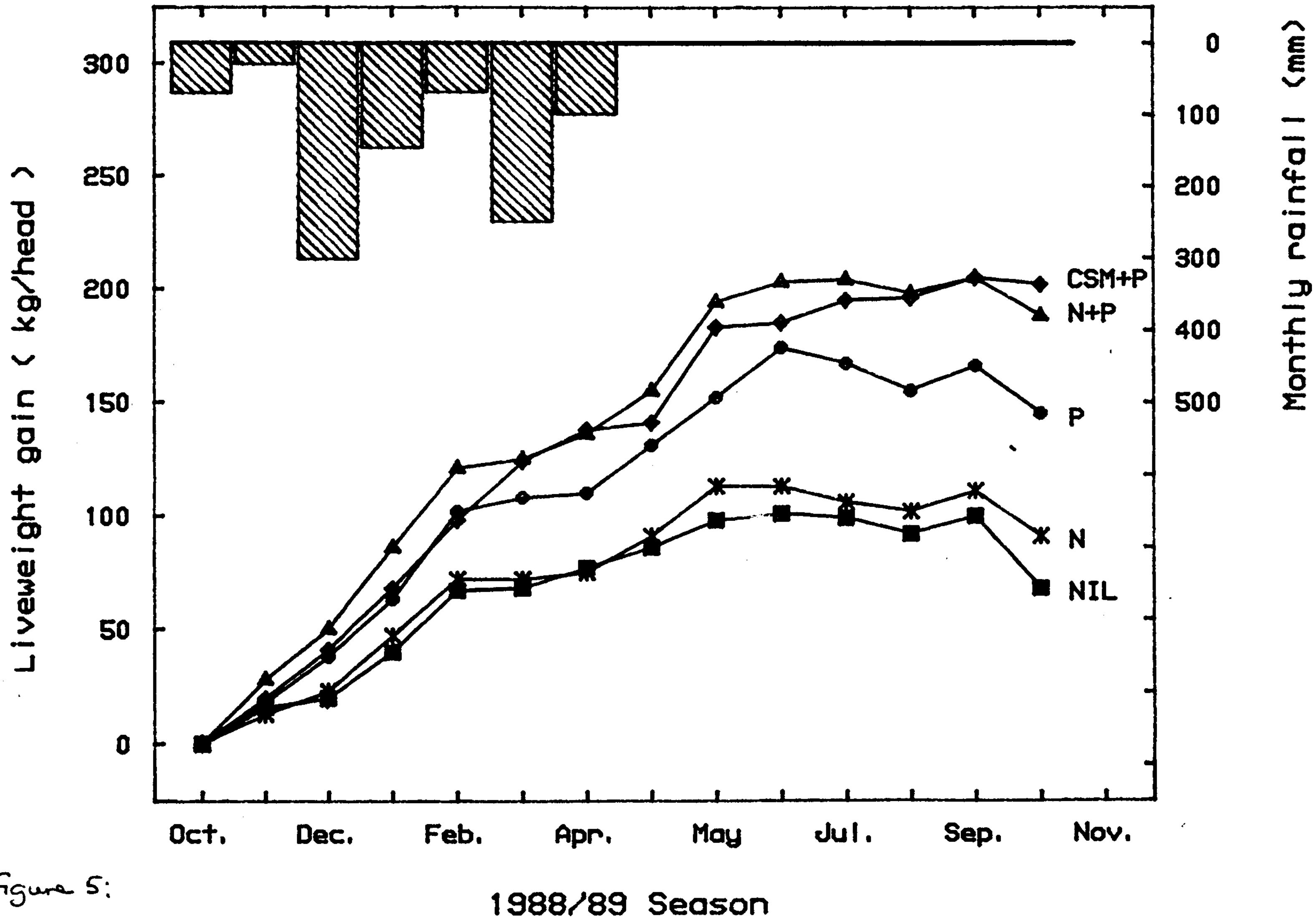

300
250
200
150
100
50
0
Liveweight gain (kg/head)
0
100
200
300
400
500
Monthly rainfall (mm)
CSM+P
N+P
P
N
NIL
Oct.
Dec.
Feb.
Apr.
May
Jul.
Sep.
Nov.
1988/89 Season

figure 5: