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Development and field evaluation of animal feed supplementation packages

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FOREWORD

Inadequate nutrition is one of the major constraints limiting livestock production in African countries. The ruminants in the smallholder sector depend on natural pasture and fibrous crop residues for their survival, growth, reproduction and production. Since quality and quantity of the natural pasture vary with season, animals dependent on it are subjected to nutritional stress in the dry season when feed resources are senesced and in short supply leading to decreased animal productivity.

The main objective of the IAEA Technical Co-operation Regional AFRA Project II-17 (RAF/5/041) was the improvement of ruminant livestock production in AFRA Member States. It had two main components: (a) the development and dissemination of cost-effective and sustainable feed supplementation packages which are based on locally available feed resources; and (b) establishment of the "Self-coating Radioimmunoassay" technique for measuring progesterone in the milk and blood of ruminants.

The project has developed a number of feed supplementation packages using feed resources available on-farm and by-products from agro-industrial processes. The packages involve the use of multi-nutrient blocks containing molasses and urea or poultry litter, ensilage of fibrous crop residues with poultry litter, leguminous fodder, mineral blocks etc. These packages have been evaluated on-station and on-farm to assess their potential to enhance productivity of ruminants. The cost–benefit ratio for feeding supplementation packages has been established. As a result of their use, income of the farmers has been shown to increase substantially. Needless to say, the scientists, agricultural extension officers, policy makers and the governments must work hand-in-hand to capitalize on this and ensure wider application and extension of the packages, and develop strategies for sustaining them.

Radioimmunoassay for progesterone has been used in this project mainly for the assessment of ovarian activity in order to evaluate reproductive performance in animals that are subjected to different feed supplementation strategies. It was, however, realised that this technique has potential to monitor and improve existing support services to livestock farmers such as artificial insemination and to introduce new services such as early diagnosis of non-pregnancy and infertility. In order to ensure future sustainability of the RIA for use in such applications, the work on the second component has now been taken under a new project (RAF/5/046).

This publication contains the results presented by the scientists of National Agricultural Research Systems of African countries who participated in the Final Review meeting held in Cairo, Egypt from 25 to 29 November 2000, which dealt with only the nutrition component, Development and Field Evaluation of Feed Supplementation Strategies. This publication also contains some selected papers presented at the National Training Workshop on Field Evaluation and Development of the Dry Season Feed Supplementation Packages for Ruminant Animals in the Traditional Smallholder Farms organized with financial assistance from the IAEA, from 25 to 29 July 1999, in Lusaka, Zambia. The contributions from experts associated with RAF/5/041 have also been included. It is hoped that this publication will help stimulate further research and development into ways of improving the efficiency and productivity of livestock, leading to higher incomes of smallholder farmers.

This publication was compiled by H.P.S. Makkar with the assistance of M.C.N. Jayasuriya and T. Smith. The IAEA officer responsible for this publication was H.P.S. Makkar of the Animal Production and Health Section of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture.

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PROJECT SUMMARY

DEVELOPMENT AND FIELD EVALUATION OF ANIMAL FEED SUPPLEMENTATION PACKAGES (AFRA PROJECT II-17 - RAF/5/041)

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1. BACKGROUND

The basic reason for the poor performance of livestock in developing countries is the seasonal inadequacy of feed, both in quantity and quality. These deficiencies have rarely been corrected by conservation and, or, supplementation, often for lack of infrastructure, technical know-how, poor management, etc. In addition, many feed resources that could have a major impact on livestock production continue to be unused, undeveloped or poorly utilised. A critical factor in this regard has been the lack of proper understanding of the nutritional principles underlying their utilisation.

The Joint FAO/IAEA programme has supported animal production research in Africa for many years through country Technical Co-operation (TC) Projects, Regional Projects (AFRA) and Co-ordinated Research Project (CRP). These activities have helped to build up the infrastructure needed in the countries concerned to conduct much of the research in animal reproduction and nutrition. In the past the Agency has provided technical assistance in defining reproductive indices of ruminant livestock species and identifying nutritional constraints to productivity of animals maintained on smallholder farms under various topographical and environmental conditions.

During the period 1993–1996, activities of AFRA Project VIII, 'Radioisotopes in Animal Reproduction and Nutrition', have been aimed at consolidating these past experiences and establishing the relationship between productivity, feeding, and management in order to develop strategies to raise sustainable output. The development of feed supplementation strategies was to be based on locally available and affordable feed resources. Radioimmunoassay for progesterone was to be used to assess the status of animals prior to and following changes in feeding and management strategies.

Activities carried out under the AFRA Project VIII, have identified poor nutrition and poor reproductive performance as two major constraints limiting livestock production, especially in peri-urban dairy production in Africa. Therefore, the ***introduction of improved feeding practices*** *based on* ***strategic supplementation*** *using* ***locally available feed resources*** (e.g. urea-molasses multinutrient blocks, tree legume leaves, mineral supplements, high quality forage, brewer's grain, etc.) was expected to not only enhance milk production but also to introduce a sustainable farming practice that will ensure a continuous supply of milk and milk products.

The major achievements of AFRA Project VIII are summarized as follows:

- *Poor nutrition and poor reproductive management* are two most important constraints to livestock productivity in Africa.
- Past technical assistance from the IAEA has been *useful in characterizing the indigenous species of livestock* in many African countries, in relation to their productive and reproductive parameters.

- A considerable amount of *information has been generated on the feeding value* of many local feed resources that are not in direct competition with man or monogastric animals.
- Many countries in the region have recognized the *importance of developing supplementary feeding strategies* for improving the productivity of ruminant livestock. Attempts have been made to use locally available feed resources for developing such feeding strategies. A number of *Member States have developed feeding packages* that required field validation and testing under existing smallholder farming conditions in the respective countries.

2. SCOPE AND OBJECTIVES OF THE PRESENT PROJECT

In view of the satisfactory progress of AFRA Project VIII in identifying the major constraints to livestock productivity in the region, and the recognition of many Member States of the importance of supplementary feeding for improving milk and meat production, a regional strategy was proposed for developing affordable and sustainable supplementation packages for improving productivity from smallholder farms using locally available feed resources.

The new Regional Project was initiated in 1997 with the following objectives:

- To produce a supplementary feed in the form of a convenient and easy-to-use package for improving milk and meat production in peri-urban areas
- To promote the uptake of this technology through demonstrations of its advantages in terms of increased productivity and benefit:cost ratio
- To maximize the use of locally available feed material such as molasses, cereal bran, legume tree leaves, oil seed meals, etc. for feeding ruminant livestock, thereby reducing the use of high cost concentrate feeds
- To promote technical co-operation amongst developing countries (TCDC) in the region and take advantage of established infrastructure and available human and technical resources to solve problems of common interest.

From 1997 until 2000 the project has been operational with 13 Member States participating in various project activities. The project activities included Research Planning and Review Meetings, Expert Visits, Regional and National Training Workshops, Fellowship Training and Scientific Visits to National Agricultural Research Systems.

The Final Review Meeting of the Project was held from 25 to 29 November 2000, in Cairo, Egypt under the auspices of the Egyptian Atomic Energy Authority. The meeting was attended by 9 of the 10 nominated Project Co-ordinators from 10 AFRA Member States (Cameroon, Egypt, Madagascar, Mauritius, Nigeria, Sudan, Tunisia, the United Republic of United Republic of Tanzania and Zambia).

3. TECHNICAL SUPPORT

The technical assistance and cooperation for the Project was oriented towards:

- providing technical advice on developing feed supplementation strategies, e.g. the production of urea-molasses-multinutrient blocks, mineral supplementation packages, legume tree leaf and/or agroindustrial by-products based practices, etc.
- supporting the organization and execution of regional technical meetings and training courses

- providing training on radioimmunoassay (RIA) for progesterone, development of supplementation strategies using *in vitro* and *in vivo* approaches, and methodologies for technology transfer, to professional staff, through regional training workshops, fellowships and scientific visits
- providing RIA kits for progesterone togetherwith appropriate standards, the assay protocols, and external quality assurance services for use in the project to evaluate reproductive performance of animals in response to supplementation strategies being developed and tested by the participating groups
- promoting the establishment of specific agreements for the provision of technical expertise, biological material and financial resources between countries
- encouraging countries in the region to adopt technological strategies which are well proven and cost effective.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. General

- All participating Member States have developed feed supplementation packages based on locally available feed resources and have completed on-station and on-farm studies.
- Those Member States that extended the packages to the farmers have been able to determine the cost effectiveness of the packages.
- Six regional training workshops have been completed as programmed.
- National workshops were organized by 90% of the participating Member States.
- A training Manual on “Guidelines for Development of Feed Supplementation Packages” was compiled and is available to AFRA Member States.
- Some participating Member States have compiled a database on "Feed Resources and Reproductive Parameters of Livestock".
- Radioimmunoassay (RIA) facilities have been upgraded in all participating Member States and the solid state RIA technique has been established.
- All participating Member States have successfully participated in the external quality assurance programme for RIA.
- The project has lead to the successful co-operation between scientists from AFRA Member States and the willingness to plan together for the future.
- All participating Member States who have completed on-farm studies should ensure wider application and extension of the packages.
- All Project Coordinators who successfully developed and tested supplementation packages should develop strategies for sustaining them by establishing suitable mechanisms such as establishment of a revolving fund system or entrusting the manufacture of the package to a private industry.
- Where applicable Project Coordinators should incorporate the project activities into their national R & D programmes.

4.2. Scientific

- Feeding standards as practiced in developed countries could be misleading when non-conventional feed resources are used in formulating rations for ruminant livestock in developing countries. The alternative approach to the use of feeding standards would be to ensure that the production system matches the available resources. The development of feed supplementation strategies based on locally available feed resources should take into account the nutrient needs of the two-compartment system represented by the micro-organisms in the rumen and the host animal.

- The nutritional value of cereal crop residues to ruminants is constrained by low N and high fibre contents. These constraints can be alleviated by treatment with alkali, the most suitable of which, for smallholder use, is urea. Technical interventions and adaptation procedures suitable for a range of conditions, imparting flexibility to the urea treatment, have been identified. These will lead to widespread adoption of this technique in Africa.
- The *in vitro* gas production technique enables selection of a feed for high efficiency of microbial protein synthesis in the rumen along with high dry matter digestibility, and provides a basis for development of feeding strategies to maximise substrate fixation into microbial cells. The microbial protein production can be determined using the isotopic (^{15}N, ^{32}P, ^{35}S incorporation) and non-isotopic (DAPA, purines, 16S RNA). Introduction of this technique in Animal Nutrition Laboratories in the region is suggested.
- Up to 90% reduction in tannin levels could be achieved by anaerobic storage of tannin-containing feeds in the presence or absence of urea, by the use of oxidising agents, by the treatment with white-rot fungi or by the use of polyethylene glycol, preferably in a slow release form. These approaches enhance the biological value of tannin-rich feeds.
- The crop-livestock mixed system has the advantages of allowing diversification of risks, using labour more efficiently, recycling wastes thus preventing nutrient losses, adding value to crops and crop products while providing cash for purchasing farm inputs. The major constraints in most crop-livestock mixed systems on smallholder farms in African countries are: the negative soil nutrient balance, and low digestibility of feeds especially in the dry season. In Zambia, the technologies have been identified that can be introduced to smallholder farmers to improve quantity and quality of feeds and to increase animal productivity. These are: improving soil by mulching, conservation tillage, introducing multipurpose fodder shrubs, grasses and legumes to reduce soil erosion and as animal feed, improving feed quality through treatments of crop residues, reducing nutrient losses from manure by stall feeding, strategically supplementing specific classes of animals (e.g. lactating animals) to improve efficient use of limited feed, and using multi-nutrient feed blocks.
- Poultry waste has been successfully used in ruminant rations in Egypt. The total bacterial count was considerably lower in sun dried poultry waste compared to the oven dried waste. Aflatoxins were not detectable in the concentrate mixtures containing poultry litter. Both feed intake and milk production in ewes was not affected by the inclusion of 14% poultry waste as a dietary supplement, suggesting that cottonseed meal and other high protein feed ingredients could be, at least partially replaced, by poultry waste without any loss in productivity. The weight and age at puberty of lambs fed a ration containing 17% poultry waste was similar to those given a ration without any poultry waste. Similarly, poultry waste up to 20% in the diet had no detrimental effect on growth in cattle and buffaloes and on the reproductive performance in buffalo heifers evaluated. The inclusion of 15% poultry waste in mixed concentrate feed decreased the cost of feed by about 10%.
- In Ghana, cows fed 1.5 kg concentrate generated the highest net income from milk sales. They produced 53% more milk and 16% more milk revenue than the control cows. A sustained means of information dissemination was considered vital for the growth of the emerging dairy industry in the Kumasi area. Farmers should be encouraged to form and sustain their own trade associations which could raise funds to ensure that member farmers receive vital information for their efficient operation.
- The daily consumption of 0.6 kg urea-molasses minerals blocks (UMMB) resulted in an additional 30 to 55% milk production during the dry season in Madagascar, with a cost:benefit ratio of 1 : 4 to 1 : 5 and an extra income of US$ 0.365 per litre of milk.

- Supplementation of forage with feed concentrate and with UMMB increased milk production by 1.26 and 1.5 litres per cow/day respectively, and significantly improved body condition score and body weight change. Both supplementation strategies had no significant effect on reproductive performance, as judged by RIA for progesterone. However, there was a slight reduction in the number of days postpartum (DPP) to first progesterone rise (65.3 vs. 77.6 days), DPP to conception oestrus (120.2 vs. 128.7 days), and calving interval (400 vs. 414.5 days) in the block supplemented cows compared to non-supplemented control animals. Conception rate improved from 48% to 68% in the supplemented cows. The increase milk production gave a profit of US$ 0.11–0.29 per cow/day, which was a considerable increase in income for smallholder farmers in United Republic of Tanzania.
- Leguminous browses; *Calliandra calothyrsus, Leucaena leucocephala,* and *Gliricidia sepium* have been successfully incorporated into the diets of West African Dwarf Goats in areas around Dschang in Cameroon. The supplementation improves growth and body conformation of the animals, giving an additional revenue of at least 4500 CFA without incurring any additional costs.
- In Tunisia, mineral supplementation in the form of di-calcium-phosphate significantly increased the body weight (by 1.67 kg) and the average milk fat content (by 5.6 g/L); and decreased the inter-calving interval by 38 days. The body condition score of the cows and the milk quantity and quality (protein and density) tended to be higher in the mineral supplemented group.
- The supplementation of lablab to diets of Bunaji cows in Nigeria increased milk by 79% and body weight by 224%. The gross benefit of supplementation was Nira 3458 per cow with the cost:benefit ratio of 1:1.5.
- Supplementation using the UMMB improved milk yield of cows giving a net financial benefit of Rupees 450 per cow per lactation, under Mauritius conditions. Cows that calved resumed ovarian activity earlier in the block supplemented animals (67 vs. 73 days).
- In Sudan, poultry manure-molasses mixture used as a complete diet in the sedentary system, and molasses as a substituted diet in transhumance system significantly increased milk yield. In sedentary, migratory, and transhumance production systems, the cost: benefit ratio from milk sales increased by 75%, 67%, and 162% respectively after the supplementation.
- A large quantity of crop residues is available in African countries for livestock feeding. The low protein/fibrous materials (crop residues and natural grazing) have a pivotal role in dry season feeding, and, therefore, a modest improvement (5–10%) in their feeding value would substantially reduce the effects of underfeeding on both survivability and production. The nutritive value of residues can be improved by correct harvesting and storage, supplementation with N and physical and chemical treatment. Further work is required on conservation of fodder, as silage, for milk production.
- Of the tools suggested here, a combination will probably be most effective. It is for the extension worker and farmer to decide on the options most appropriate for a given set of circumstances. Availability and costs of off-farm inputs, together with the perceived value (sales and outputs used within the household) should be the determining factors. The options presented here should not be seen as definitive. Further research is needed, particularly at the farm level. Closer collaboration between those in development within the Africa region is called for.

REVIEWS

PRINCIPLES OF RATION FORMULATION FOR RUMINANTS

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Abstract

PRINCIPLES OF RATION FORMULATION FOR RUMINANTS.

Feeding standards as practiced in developed countries could be misleading when non-conventional feed resources are used in formulating rations for ruminant livestock in developing countries. They tend to reject the poor quality feeds that are available in vast quantities. The non-availability of good quality forage throughout the year and the need to optimise the efficiency of utilisation of locally available feed resources have lead to the application of basic nutritional principles when considering ration formulation. The alternative approach to the use of feeding standards would be to ensure that the production system matches the available resources. The development of feed supplementation strategies based on locally available feed resources require the understanding of the relative roles and nutrient needs of the two-compartment system represented by the micro-organisms in the rumen and the host animal.

1. INTRODUCTION

The relevance of using feeding standards in the formulation of rations for ruminant livestock in developing countries of the tropics has been questioned for many years [1], especially after the publication in 1980 of "Who needs feeding standards?" by Prof. M.G. Jackson of the University of Pant Nagar, India [2]. Jackson argued that feeding standards as practiced in developed countries are misleading when non-conventional feed resources are used in formulating rations for ruminants in developing countries. He pointed out that the level of production achieved might be considerably less than what is being predicted by the feeding standard. More importantly, he emphasised that feeding standards lead to the rejection of many locally available feed resources which were apparently poor in supplying the digestible energy needed for production although they could be the main or the sole feed resources available at the smallholder level. Feeding standards also encouraged researchers in developing countries to copy feeding systems from the temperate countries, which required resources that were often inappropriate on socio-economic grounds. They also ignored the value of rumen non-degradable protein; in many instances although nutrient requirements were satisfied according to traditional standards the responses did not correspond to the predicted level of performance.

The smallholder farmers in developing countries have limited resources available for feeding to their ruminant livestock. They are unable to select the basal diet according to the requirement for production unlike their more fortunate counterparts in developed countries, but use whatever is available at no or low cost. Therefore, the strategy for improving production should be to optimise the efficiency of utilisation of the available feed resources, and thereby attempt to maximise animal production.

2. FEED RESOURCES AVAILABLE FOR RUMINANT LIVESTOCK

The availability of feed resources is determined by the land utilisation pattern. This reflects the demand of the human population and the nature of the ecosystem which in turn is a function of land and soil characteristics including terrain, availability of water, rainfall, soil fertility, etc. Due to the ever increasing human population and the consequent increase in demand for food, livestock feed tends to be derived from residues and by-products of the food industry.

The major problems with feeding of livestock occur in those areas subjected to long dry seasons, when there is insufficient plant biomass carried over from the wet season to support domestic livestock population. The situation becomes more acute as the dry season becomes established, when protein content of the natural grazing falls, often from 12–14% to about 6–8%. The fall in crude protein content is also accompanied by an increase in fibre content. Thus, the animal is faced with insufficient amounts of a low quality and relatively indigestible feed. The situation is intensified by drought.

In most developing countries, the major feed resource is natural grazing, often in communal ownership. Over the past 50 years a rapidly expanding human population has markedly increased pressure on land, causing arable land to encroach on the best of the grazing land. In some areas this has made zero grazing a necessity, especially for dairy cattle production, in place of the traditional grazing systems. Feed resources available for livestock production in the tropics can be categorized into four groups.

2.1. High fibre-low protein feeds

These include fibrous residues arising from crops grown for human consumption, such as straws and stovers from rice, millet, sorghum and maize, and sugarcane bagasse.

The production of crop residues and by-products can be estimated fairly accurately from estimates of the primary product (e.g. grain), using multipliers which assume grain:residue ratios. The uncertainty of such ratios can be judged by the different multipliers used by different people [3, 4]. Not withstanding such discrepancies in grain:residue ratios for estimating residue yields, it is quite evident that vast quantities of residues are produced as a result of crop cultivation. A conservative estimate would be over 5 billion tonnes of dry matter (DM) per year.

Crop residues are characterised by their high fibre content (>700 g of cell wall material/kg DM), low metabolizable energy (<7.5 MJ/kg dry matter), low levels of crude protein (20–60 g of crude protein/kg DM) and mineral nutrients and low to moderate digestibility (<30–45% organic matter digestibility). Their daily intakes are often limited to less than 20 g dry matter/kg live weight. Most residues are also deficient in fermentable carbohydrates, reflected by the relatively low organic matter digestibility.

Chemical treatment increases the potential feeding value of crop residues. Alkali treatment of fibrous residues has been well researched and the possibility of using urea as a source of ammonia led to the expectations of rapid adoption of the technology in developing countries. However, for various reasons this has not been realised [5].

2.2. High fibre-high protein feeds

By-products derived from crop production (tops and haulms from ground nut, sweet potato vine, cassava leaves, bean straw) and industrial processing (bran from cereal milling — rice, wheat and maize bran, brewer’s grain), fall into this category of feeds. They are generally less fibrous (below 700 but above 400 g of cell wall material/kg of DM) than those in the first category but have relatively high amounts of crude protein (> 60 g/kg DM). Leaves from tree legumes and browse plants such as *Glyricidia, Leucaena* and *Erythrina*, that have around 250–350 g/kg of crude protein in DM, can also be considered in this category.

2.3. Low fibre-low protein feeds

These include feed resources derived from crops grown for renewable energy such as sugarcane by-products and root crops. They are generally rich in energy and low in protein content. Examples of this category would be molasses, oil palm juice and waste material arising from the fruit processing industry (citrus pulp, pineapple waste) and root crops (cassava waste).

2.4. Low fibre-high protein feeds

These are the feeds traditionally called *concentrates* and include oilseed meals and cakes (coconut cake, soybean meal, cotton seed cake, groundnut meal/cake) and animal by-products (fishmeal, blood meal, feather meal). They are valuable sources of good quality protein for both ruminant and non-ruminant animals.

Oil seed meals and cakes may contain variable amounts of crude protein: coconut meal contains around 200 g crude protein/kg of dry matter while decorticated oil seed meals such as groundnut meal, and cotton seed meal (or cake) may contain as much as 400–500 g of crude protein/kg of dry matter. The amount of oil contained in the by-product may affect the keeping quality of the feed. It varies according to the method of extraction of the oil; solvent extracted meals or cakes will contain less oil than expeller extracted meals or cakes.

Animal by-products are very good sources of high quality protein and can improve the nutritive value of low quality forage based diets for ruminants. Fishmeal is often used for balancing the amino acid content in monogastric feeds. Even for ruminants, fishmeal can provide a high proportion of rumen non-degradable protein acting as a reservoir of amino acids for high levels of production.

Natural pastures fall into the first and/or the second category depending on time of harvesting, the nature of the pasture species, climatic conditions, etc.

The proximate composition of some common feeds found in developing countries and classified according to the above criteria are shown in Table 1.

3. RATION FORMULATION FOR RUMINANTS — AN ALTERNATIVE APPROACH

If one considers that the use of traditional feeding standards as practiced in developed countries are inappropriate for developing countries with limited resources, then there must be an alternative approach when formulating rations for ruminants. This alternative approach would require that the livestock production system is matched with the resources available and optimises the utilisation of locally available feed resources. Such an alternative approach for formulating rations for ruminants should consider that:

- the efficiency of the rumen ecosystem cannot be characterised by any form of feed analysis currently in use. This raises the question: can the feed support optimum rumen function? What are the nature, amount and proportion of end products of fermentative digestion?
- feed intake on some diets bear no relationship to digestibility of the feed
- feed intake is often influenced by supplementation
- the availability of amino acids cannot be inferred from the crude protein content of the diet. This reflects the potential escape of nutrients from the rumen and their digestibility in the small intestine

- the energy value of a diet and the efficiency of its utilisation are largely determined by the relative balances of glucogenic energy, long chain fatty acids and essential amino acids absorbed by the animal

Therefore, as described by Leng and Preston [6] and Preston and Leng [7], when considering ways to optimise the utilisation of feed resources for ruminants it is necessary to apply two basic concepts.

a) ensure optimum conditions for microbial growth in the rumen to make the digestive system of the animal as efficient as possible
b) supply deficient nutrients to balance the products of digestion to requirements, optimising production
c) any further increases in production should be by the use of supplements of protein, starch and lipids.

This entails that the ruminant animal must be considered as a two-compartment system having a digestive system with an efficient rumen fermentation optimising microbial growth. This implies a requirement of nutrients for the microbes. The animal ought to rely on the products of fermentation of those feed components that escape rumen fermentation but are digested in the intestines for the supply nutrients for maintenance and production purposes.

The two systems are mutually supportive. Efficient rumen fermentation ensures that the host animal receives the maximum amount of digestible nutrients from a given feed. The rumen microbes need protein (amino acids, peptides), glucose and minerals, in particular sulphur, potassium and phosphorous, as pre-cursors.

Maximum efficiency will occur when a continuous supply of fermentable carbohydrate is matched with the correct amount of ammonia and amino acids so that microbial protein is formed without waste of the major substrates (microbial cells contain 40 to 60 percent protein on a dry matter basis).

3.1. Feeding the rumen microbes

The two compartments system requires that the rumen microbes are adequately fed so that they could perform at their optimum level. When feeding the rumen microbes the following are important.

- free choice of basal diet to ensure maximum intake. Ideally, offer the animal over and above its requirement — offer ENOUGH — to facilitate selection by the animal of more digestible components.
- the need for ammonia is in excess of 200–250 mg per litre of rumen fluid to maximise digestibility as well as intake. This is especially important when considering fibrous crop residues and by-product feeds. It can easily be achieved by allowing access to a highly soluble source of nitrogen such as urea in urea-molasses multinutrient blocks.
- macro and micro minerals. Macro minerals phosphorus and sulphur and the micro mineral cobalt are considered essential for optimum microbial growth. They can be supplied through multinutrient blocks and/or mineral supplements or small amounts of green forage.
- macro nutrients such as peptides and amino acids come from rumen degradable proteins given in the basal diet.
- an optimum ecosystem that will promote the rapid colonisation of the basal diet. When possible, provision of a small quantity of highly digestible green forage (say 2 kg of fresh material/100 kg live-weight) is the best way of supplying this.

TABLE I. PROXIMATE COMPOSITION OF SOME COMMON FEEDSTUFFS FOUND IN DEVELOPING COUNTRIES IN AFRICA AND ASIA (g/kg DRY MATTER)

Feed Resource	Ash	Crude Protein	Crude Fibre	Neutral detergent fibre	Digestibility
	(range — g/kg dry matter)				(%)
High fibre-low protein	low to moderate	low	high	high	low to moderate
Cereal straw/stover	40–120	20–60	>300	>800	30–45
Bagasse	30–40	<30	>450	>800	20–30
Sugarcane tops	50–60	50–70	>300	>700	
Corn cobs	15–20	30–40	>300	>800	
Cottonseed, groundnut hulls	30–60	40–60	>300		
High fibre-high protein	low to moderate	moderate to high	moderate to high	moderate to high	moderate to high
Leguminous tree leaves (meal) *(Gliricidia, Leucaena, Erythrina)*	10–15	100–300	100–150		60–70
Haulms and tops (bean, ground nut, soybean, sweet potato vine)	60–150	60–195	120–300	>600	50–65
Cassava leaf meal	70	120–250	150		
Brewers grain	30–40	200–250	150–210		50–70
Cassava peels	70–120	50–120	100–300		
Low fibre-low protein	low to moderate	low	low	low	low to moderate
Molasses	70–100	<60	-		
Citrus pulp	30–120	<60	120–200		40–60
Low fibre-high protein	low to moderate	moderate to high	low to moderate	low to moderate	moderate to high
Oil seed cakes (coconut cake, groundnut cake, cottonseed cake, sun flower cake, soybean meal)	50–80	250–500	30–300		60–70
Brans (rice, wheat, maize)	20–90	80–160	70–180		70–80
Animal by-products (blood meal, fishmeal)	20–160	>600			
Poultry waste (offal, hatchery waste, feather meal)	50–200				
Cage layer manure	120–250	200–400	170–300		

3.2. Feeding the host animal

When feeding the host animal the aim should be to increase the protein:energy ratio in the nutrients absorbed. This is generally achieved by:

- increasing the efficiency of rumen fermentation to maximise microbial protein production
- supplying rumen non-degradable protein (e.g. from cotton seed meal, sun flower meal) to meet the deficit protein between that is synthesised in the rumen and that is required by the host for a given level of production.

While the first above can be achieved by way of the basal diet supplying adequate nutrients for optimum functioning of the rumen microbes the latter needs to be addressed by way of supplementation.

When considering supplementation a number of factors have to be born in mind. The purpose of supplementation would be to provide nutrients that are deficient in the basal diet and additional nutrients needed for production. The selected supplements should not reduce intake and utilisation of the basal diet but instead have the potential for enhancing them. The ideal supplement will facilitate maximum utilisation of the basal diet and will be of limited value as a feed for man or other monogastric species. The supplements should also be easily available, cheap and require minimum labour for storing and feeding. At the same time they should improve animal productivity, compatible with on-farm feeding practices and offer minimum chances of poisoning or ill health to the animal.

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ON-FARM TREATMENT OF STRAWS AND STOVERS WITH UREA

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Abstract

ON-FARM TREATMENT OF STRAWS AND STOVER WITH UREA.

The nutritional value of cereal crop residues to ruminants is constrained by low N and high fibre contents. These constraints can be alleviated by treatment with alkali, the most suitable of which, for smallholder use, is urea. However, it has not widely been used in Africa. Whilst in some areas, cost and availability of urea will be a factor, it may also be that the flexibility of the technique is not appreciated. The scope for adaptation at each stage of the procedure is reviewed, showing that the farmer does have options to develop a system suitable for a range of conditions.

1. INTRODUCTION

Farmers accept that fibrous straws and stovers from cereal grain crops are a poor feed resource because their crude protein (CP) content is low and fibre levels are high. When offered to livestock both dry matter intake and palatability are low. However, these residues are often the only livestock feed available in smallholder mixed crop and livestock systems, especially in areas characterised by a defined dry season or with high land pressure resulting from a high human population.

The total amount of fibrous residues available in Zambia has been estimated as 2–4 tons per livestock unit [1]. This suggests that if these materials were used optimally, so that a small improvement in the nutritive value was obtained, there would be a marked reduction in dry season feeding stress in livestock in developing countries [2].

2. WHAT CAN BE DONE TO IMPROVE THE NUTRITIVE VALUE OF THESE RESIDUES?

The answer to this question is addressed in other contributions to these proceedings. It is the on-farm application of one of these tools, treatment with urea, which needs further consideration.

3. WHY USE UREA?

Of the three chemicals (sodium hydroxide, ammonia, urea) most tested as improving agents for residues, urea is the best qualified for use in smallholder systems in the tropics because:

- It is usually available as a product (ammonium nitrate) with which farmers are familiar.
- Sufficient urease to ensure breakdown of urea to ammonia does not appear to be a problem in a warm climate.
- Urea breaks down the ligno-cellulose bonds of the residue, increasing rate and extent of rumen microbial digestion.
- It improves the nitrogen status of the residue.
- It is relatively safe and easy to use.

- It is easy to transport, if necessary in small quantities.
- There are no recorded social or cultural reasons (as could be a constraint to widespread use of urine) prohibiting its use.
- There is no damage to the environment

4. DIGESTIBILITY AND INTAKE

The objectives of treating residues are to increase the proportion of their gross energy available to the animal as metabolizable energy and to raise intake. Urea treatment has been found effective with all the major sources of crop residue (barley, rice and wheat straws; maize, millet and sorghum stover). Table I gives an indication of typical responses in nitrogen enrichment, digestibility and intake after urea treatment, for the major residues available in Africa.

TABLE I. EFFECT OF UREA TREATMENT ON NITROGEN CONTENT (N, g/kg DM), DRY MATTER DIGESTIBILITY (DMD, g/kg DM) AND DRY MATTER INTAKE (DMI, g/kg$^{0.75}$/DAY) (FALL ET AL. [3], FALL [4]).

Residue	N	DMD	DMI
Rice straw			
Urea (5%)	12.6	540 ± 40 (n=6)	61 ± 10 (n=6)
Control	7.2	430 ± 40 (n=6)	48 ± 3 (n=5)
Maize Stover			
Urea (5%)	23.8	570 ± 50 (n=6)	53 ± 10 (n=6)
Control	6.2	490 ± 20 (n=6)	40 ± 5 (n=5)
Millet stover			
Urea (5%)	22.6	490 ± 60 (n=5)	31 ± 7 (n=4)
Control	13.4	390 ± 60 (n=5)	31 ± 7 (n=4)
Sorghum stover			
Urea (5%)	23.4	650 ± 30 (n=6)	68 ± 3 (n=6)
Control	6.7	470 ± 50 (n=2)	50 ± 6 (n=5)

5. WHY IS UPTAKE, PARTICULARLY IN AFRICA, DISAPPOINTING?

The original work on treatment of residues was carried out in Northern Europe, based on the use of sodium hydroxide [5], as much to preserve straw, which was damp at the time of collection and storage, as to improve its value, the possibilities for which became apparent as the technology developed. This technology has been applied to tropical residues in laboratory conditions, but is not suited for use by resource poor farmers, who need an easy and safe treatment procedure which will both upgrade the residue and add N. The use of urea, already familiar to many farmers as a fertiliser and feed, is currently the most widely acceptable. Interest by farmers varies, but has been high, especially in some Provinces in China. In Africa uptake has been disappointing. However, the following points need considering [6].

- Cost and availability of urea (conflict in using resources to treat residues or as a fertilizer?). In some countries urea has to be imported, thus having to compete for limited availability of foreign currency.
- Cost and availability of sealing materials (e.g. plastic sheeting or bags) and stores.
- Labour constraints. In many areas it is normal to leave residues *in situ,* for grazing, rather than gather and store them.
- Seasonal variation in feed supply.
- Benefits are not always obvious.
- Residues produced some distance from livestock, necessitating the use of transport (expensive with bulky feeds).
- Lack of knowledge and training. Both farmers and extension workers need practical demonstrations and appropriate fact sheets to assist with the treatment procedure.
- Rigid procedures for applying treatment.

In summary, it is predictable that use of urea for treating crop residues will be most acceptable where urea is cheap and can be purchased locally. The cost of sealing can be reduced, but labour may be needed to dig pits. The technique will probably not be attractive following good rains, when there is a carry over of alternative feeds. The process costs time and money, for which the farmer needs to see some reward, suggesting that strategic feeding (e.g. draught, pregnant and milking animals) of treated residues should be encouraged. Adequate explanation and demonstration is necessary, together with help in adaptation to local conditions.

6. ARE TREATMENT PROCEDURES TOO RIGID?

To assess the benefits of urea treatment, loss of urea/ammonia, through extraneous factors must be eliminated. This necessitates guidelines for mixing the urea solution, method of sealing for incubation (this must be as tight as possible so that ammonia is not lost, thereby reducing the effects of treatment) and the time of incubation (the aim is usually to obtain the full benefit of the urea). However, is simplification of the system to promote adoption by farmer's possible, especially in Africa. Is there any scope to produce a system, which meets technical requirements and is 'farmer-friendly' in its application.

7. IS THERE SUFFICIENT FLEXIBILITY TO MAKE UREA TREATMENT WORK IN PRACTICE?

7.1. Economics

Economics of purchasing urea to treat residues or use as fertiliser will depend on the unit cost, expected returns, severity of the season/other available feed resources and the farmer's access to financial support. Intensive land pressure and a poor growing season will always increase the dependence of livestock on crop residues. Orskov [6] suggested an economic price for one kg of urea as costing no more than two kg of high quality concentrates. The cost of extra nutrients derived from processing must be compared with the cost of nutrients from other sources [7].

7.2. Labour requirements

It can be managed by varying the size of batch to be treated, from a daily task to one which is undertaken once or twice during the season. This requires forward planning.

Convenience will depend in part on treatment time, availability of resources and the number of animals to be fed.

7.3. Storage before treatment

Residues destined for treatment need collecting and storing as soon after grain harvest as possible to reduce leaf-loss: however, in the semi-arid areas of Central and Southern Africa there is increasing interest in conserving them (S. Ncube, personal communication). Methods of collection and storage of residues vary [8]. Local materials are being used to build structures to prevent post-harvest losses, through the effects of weathering, in a semi-arid environment [9].

7.4. Urea requirement

It is accepted that crop residues need to be offered with supplementary nitrogen to improve their fermentation in the rumen. Urea is often the cheapest source and can either be added at the point of feeding (often in conjunction with a soluble energy source such as molasses) or used as a treatment agent. Saadullah et al. [2] noted that DRY MATTER DIGESTIBILITY (DMD) was increased by six units when urea was added as a supplement at the point of feeding but by 11% units when it was added to the straw 10 days previously. The amount of urea added, as a percentage of the weight of residue, has varied between three and five (see review; [10]). Smith et al. [11] found no advantage in treating maize stover with 7% urea, compared to 5%, although 2% was insufficient to prevent moulding in wheat straw when added with 20% (w/w) water (Manyuchi and Smith unpublished data). Results similar to those of Smith et al. [11] were obtained for wheat straw by Singh and Makkar [12]. Orskov [6] recommended 'around' five per cent urea (w/w basis).

Once the amount of urea has been determined for a given amount of residue, it can be measured using a container of known volume. Residues will probably also be ‘measured’ (e.g. a known number of armfuls). Check weighings should be done when possible.

7.5. Amount of solution (water)

The amount of water used has also varied. Munthali et al. [13] used 1.5 litres of solution per kg maize stover, as in earlier work [14] they found inadequate wetting when one litre of solution per kg stover was applied. However, in Bangladesh, Dolberg et al. [15] found one litre of solution adequate when treating dry rice straw. This is the amount recommended by Fall [4]. Orskov [6] recommended 40–50% solution (w/w basis), but also pointed out that in dry areas water supply (both flow rate and total supply) can be a major problem. This could result in the quantity of solution being reduced or the size of individual treatment batches being reduced. Smith et al. [11] added 20% solution when treating maize stover. For relatively small batches the solution is best applied using a watering can with a rose.

7.6. Preventing loss of ammonia from freshly treated material

Ammonia loss can be prevented by wrapping the treated material in plastic sheeting. The disadvantages with this are, assuming the plastic is available, cost and damage from birds and animals. Disposal of torn plastic sheeting may cause a pollution problem. Cheaper, readily available materials are needed to create the airtight conditions needed. Ibrahim et al. [16] (quoted by Sundstol and Coxworth, [10]) stored urea-treated rice straw in earthen pits, polyethylene bags, coconut leaves, urea bags, ‘big bags’ and in an open stack. The most efficient, measured by the lowest incidence of mould and increased digestibility and intake, were earthen pits and polyethylene bags. Saadullah et al. [17] found similar improvements in urea-treated rice straw, either stored in earthen pits lined with a mixture of soil and cattle dung with a covering of banana leaves, or bamboo baskets. Dolberg et al. [15] lined the sides of pits with banana and coconut leaves and covered them with the same materials topped with 30 cm of soil. In one village the authors observed treated straw stacked and covered with the leaves, which were tied to keep them in place. Where earthen pits have been used a variety of materials have been employed to seal the tops, including plastic sheeting; plastic and jute bags; soil; cow dung. Plastic (sheet or bags), when available, is usually laid between the residue and other materials to avoid contamination.

7.7. Length of incubation period

Oji and Mowat [18] found that treatment of maize stoker with ammonia resulted in a higher intake and digestibility after 12 hours incubation at 90°C, compared to 30 days at 60°C. As ammonia is the treatment agent released from the breakdown of urea by urease of microbes which are present as contaminant in straw [19], it is reasonable to assume that ambient temperature will be an important factor in the process. However, whilst some manipulation of temperature may be possible (e.g. selecting site for incubation, storage under a metal roof), supplying heat to speed up the process is not feasible. The same workers, Oji and Mowat [20], found that urea treated maize stover, with a dry matter content of 55–65% stored in polythene bags and kept at room temperature, 70% of the urea was decomposed after two days. All the urea had disappeared after 20 days. Temperature dependent hydrolysis of urea and increase in dry matter digestibility of wheat straw have also been observed by Makkar and Singh [19] and Singh and Makkar [12]. Saadullah et al. [17] found that the N content of rice straw was similar after 20 or 40 days incubation. In another trial an 11% unit increase in the digestibility of rice straw was noted after 10 days incubation [2]. Smith et al. [11] found that *in vitro* digestibility was unimproved after seven days incubation, but was improved after 21 or 35 days. Ambient temperatures ranged from a minimum of 4°C to a maximum of 31°C over the treatment period. Orskov [6] suggested 14–28 days incubation time, depending on ambient temperature, whilst Fall (1990) recommended 14 days in a tropical environment and up to 42 days in cooler regions.

Dolberg et al. [15] noted that treated straw absorbed more moisture than the same straw untreated, with the result that it may have a reduced shelf-life when atmospheric humidity is high.

8. ADAPTATION OF PROCEDURES FOR THE LITTLE FLOWER LEPROSY WELFARE ASSOCIATION FARM IN NORTHERN BIHAR

A herd of 25 milking cows and their followers were considered to be under-performing, with poor nutrition as a major factor. Roughage, largely from wheat and rice straw, was in short supply (each cow received about 6 kg straw per day) and budgetary constraints limited the amount of concentrates which could be purchased.

Chopped straw was delivered in daily. This suited the transport (ox cart) and also the limited storage space. Regular labour was available, with routine work relatively easy to fit into the system. Urea was readily available in 50 kg bags, at 4 rupee/kg (milk retailing at 17 rupee/litre). It was decided to store the treated material in woven plastic meal bags (available on the farm) and measure the response, before purchasing plastic bags. Initially it was decided to treat 25% of the total straw intake with 5% urea. Bags held about 7.5 kg straw and this was treated with 3 litre of solution, which was added as the straw was packed into the bag. Bags were stored in a low building with an asbestos roof for 10 days (warm season).

To allow a sample to be brought to UK for analysis, the first bag was opened after only eight days. The colour had changed from dull brown to bright yellow and there was a lingering smell of ammonia (this was present in the storage shed, indicating that the woven bags were allowing some ammonia to escape). Gas production [21] from the two straws showed that the treated material produced more gas in the first 48 hours than the untreated, although total production at 96 hours was similar. *In vitro* organic matter digestibility [21] was increased from 41 to 48% at 48 hours. The increase in N was disappointing, up from 0.64 to 0.78%, possibly reflecting the short incubation time and relatively open weave of the bags.

9. CONCLUSIONS

Saadullah et al. [2] concluded that for Bangladesh the attractions of treating residues with urea are the relative simplicity of the process and the competitive price of urea. Both these aspects are essential for widespread adoption in Africa. Fall [2] suggested on-farm research to devise suitable practical procedures for urea treatment. The evidence presented here suggests that farmers do have choices. They need to be made aware of them and the potential benefits that could be realised.

At every stage of the process of treating residues with urea there has been variation in the procedures used. Farmers should select the options that will best suit their particular circumstances (size of individual batches; amount of water to use; method of storage; time of incubation, etc.) (Table II). There is little the farmer can do about the cost of urea, but whatever the cost the outlay is best justified when there is a production objective (e.g. milk or draught power)

TABLE II. SUMMARY OF OPTIONS FOR APPLYING UREA TREATMENT TO CROP RESIDUES.

	Range	Recommendation	Comment
Pre-treatment Storage		Covered store with air circulation	Prevent mould formation and leaf loss
Batch size	Daily or less often (e.g. once /season)	Depends on labour, urea and water supply, place/room available for storage of treated material	With high relative humidity a short storage period indicated
Incubation period	2–40 days	10–30 days in tropical regions.	Higher the ambient temperature, quicker the reaction
Urea requirement	3–7%	5%	Costs money: weigh or measure known volume
Amount of solution	20–150%	40–50% up to 100%	Water availability; thorough wetting, with residue 'holding water'
Storage/ Covering	Pits/bags/baskets	Cheap, locally available materials	If covering with soil, put leaves/bags between residue and soil
Tools	Depends on scale of operation	Water drum/bucket/ watering can/scales (or appropriate measures)	Elaborate equipment unnecessary. If measuring volumetrically, check weigh when possible.

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APPLICATIONS OF THE *IN VITRO* GAS METHOD IN THE EVALUATION OF FEED RESOURCES, AND ENHANCEMENT OF NUTRITIONAL VALUE OF TANNIN-RICH TREE/BROWSE LEAVES AND AGRO-INDUSTRIAL BY-PRODUCTS

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Abstract

APPLICATIONS OF THE *IN VITRO* GAS METHOD IN THE EVALUATION OF FEED RESOURCES, AND ENHANCEMENT OF NUTRITIONAL VALUE OF TANNIN-RICH TREE/BROWSE LEAVES AND AGRO-INDUSTRIAL BY-PRODUCTS.

A major constraint to increasing livestock productivity in developing countries is the scarcity and fluctuating quantity and quality of the year-round supply of conventional feeds. In order to meet the projected high demand of livestock products, and to fulfil the future hopes of feeding the millions and safeguarding their food security, the better utilisation of non-conventional feed resources which do not compete with human food is imperative. There is also a need to identify and introduce new and lesser known food and feed crops capable of growing in poor soils, which can play a vital role in control of soil erosion, bring economic benefits to farmers, enhance biodiversity, create jobs and bridge the wide gap between supply and demand for animal feeds. This paper highlights the potential of a novel approach using an *in vitro* rumen fermentation technique for evaluation of nutritional quality of non-conventional feed resources; many of the considerations discussed also apply to conventional feeds. This technique enables selection of a feed for high efficiency of microbial protein synthesis in the rumen along with high dry matter digestibility, and provides a basis for development of feeding strategies to better synchronise energy and nutrient release to maximise substrate fixation into microbial cells. This could lead to increase in the supply of protein to intestine and reduce methane production from ruminants. Tannins are the most widely occurring anti-nutritional factor in non-conventional feeds. General approaches for detanninification and increasing nutritional value of tannin-rich feed resources are also discussed.

1. INTRODUCTION

A major constraint to livestock production in developing countries is the scarcity and fluctuating quantity and quality of the year-round feed supply. These countries experience serious shortages in animal feeds of the conventional type. Food grains are required almost exclusively for human consumption. The world population is increasing at a very high rate and most of the population growth is occurring in developing countries. With increasing demand for livestock products as a result of rapid growth in the world economies and shrinking land area, future hopes of feeding the millions and safeguarding their food security will depend on the better utilisation of non-conventional feed resources, which can not be used as food for humans. In addition, a large area of land in the world is degraded, barren or marginal and the amount is increasing every year. This also calls not only for better utilisation of already known non-conventional resources but also for identification and introduction of new and lesser known plants capable of growing in poor soils, which can play a vital role in the control of soil erosion, bring economic benefits to farmers, create jobs and bridge the wide gap between supply and demand for animal feeds. An important class of non-conventional feeds is by-product feedstuffs which are obtained during harvesting or processing of a commodity in which human food or fibre is derived. The amount of by-product feedstuffs generally increases as the human population increases and economies grow. The role of ruminants must increasingly be one of scavenging to make use of by-products, residues and other non-conventional feeds. In developing countries, ruminants are fed low quality roughages in various proportions depending on the type of animal and season. These feeds are poor in protein, energy, minerals and vitamins. Addition of foliage from tree spp. *Leucaena, Glyricidia, Calliandra, Acacia*, etc. in ruminant diets can improve the utilisation of low quality roughages mainly through the supply of protein to rumen microbes, but the presence of tannins in these tree foliages prevents not only their optimal utilisation but also that of the roughages and by-products. Tannins are generally present in high amounts in tree foliage and agro-industrial by-products [1, 2].

This paper highlights the potential of a novel approach using an *in vitro* rumen fermentation technique for evaluation of the nutritional quality of conventional and non-conventional feed resources, and to describe general approaches for improving the nutritional quality of tannin-rich non-conventional feed resources such as agro-industrial and forestry by-products and tree and shrub foliage. The reason for choosing tannin-rich non-conventional feed resources is that tannins are the most widely occurring anti-nutritional factors found in plants.

2. EVALUATION OF FEED RESOURCES

Recent advances in ration balancing include manipulation of feed to increase the quantity and quality of protein and energy delivered to the small intestine. Selection of fibrous feeds based on high efficiency of microbial protein synthesis in the rumen along with high dry matter digestibility, and development of feeding strategies based on high efficiency as well as high microbial protein synthesis in the rumen will lead to higher supply of protein post-ruminally. This concept of feed evaluation has the extra element of efficiency of microbial protein synthesis in addition to the more conventional one of dry matter digestibility. The limited supply of protein post-ruminally under most feeding systems in developing countries is an important limiting factor which prevents an increase in animal productivity.

There are a number of methods used to determine net microbial protein synthesis in the rumen based on the use of microbial markers. They require the use of post-ruminally cannulated animals to determine flow rate of digesta. The cannulation approach is tedious and has several limitations [3] to its applicability under most research conditions in developing countries. A simpler technique for determination of microbial protein supply to the intestine is based on the determination of total urinary purine derivatives [4]. This approach is being thoroughly investigated under a joint FAO/IAEA Coordinated Research Project [5]. Although the method is based on the collection of urine for determination of purine derivatives (allantoin and uric acid for cattle, and allantoin, uric acid, xanthine and hypoxanthine for sheep), the approach is being further simplified using spot urine samples. This technique does not require cannulated animals, but it involves feeding the diets under investigation to animals and therefore is not suitable for screening large numbers of samples or for developing feed supplementation strategies using various feed constituents.

2.1. *In vitro* methods

In vitro methods for laboratory estimations of degraded feeds are important for ruminant nutritionists. An efficient laboratory method should be reproducible and should correlate well with actually measured *in vivo* parameters. *In vitro* methods have the advantage not only of being less expensive and less time-consuming, but they allow one to maintain experimental conditions more precisely than do *in vivo* trials. Three major biological digestion techniques are currently available to determine the nutritive value of ruminant feeds:

1) digestion with rumen microorganisms as in Tilley and Terry [6] or using a gas method [7], 2) *in situ* incubation of samples in nylon bags in the rumen [8], and 3) cell-free fungal cellulase [9]. These biological methods are more meaningful since microorganisms and enzymes are more sensitive to factors influencing the rate and extent of digestion than are chemical methods [10].

2.2. *In vitro* gas method

Several gas measuring techniques and *in vitro* gas methods are in use by several groups. Advantages and disadvantages of these methods are discussed by Gatechew et al. [11]. The *in vitro* gas method based on syringes [7, 12] appears to be the most suitable for use in developing countries. The *in vitro* gas method is more efficient than the *in sacco* method in evaluating the effects of tannins or other anti-nutritional factors. In the *in sacco* method these factors are diluted in the rumen after getting released from the nylon bag and therefore do not affect rumen fermentation appreciably. In addition, the *in vitro* gas method can better monitor nutrient-anti-nutrient and anti-nutrient-anti-nutrient interactions [13].

A simple *in vitro* approach is described below which is convenient and fast, and allows a large number of samples to be handled at a time. It is based on the quantification of substrate degraded or microbial protein produced using internal or external markers, and of gas or short chain fatty acid (SCFA) production in an *in vitro* rumen fermentation system based on syringes [7]. This method does not require sophisticated equipment or the use of a large number of animals (but one or preferably two fistulated animals are required) and helps selection of feeds or feed constituents based not only on the dry matter digestibility but also on the efficiency of microbial protein synthesis.

In the method of Menke et al. [7], fermentation is conducted in 100 mL capacity calibrated glass syringes containing the feedstuff and a buffered rumen fluid. The gas produced on incubation of 200 mg feed dry matter after 24 h of incubation together with the levels of other chemical constituents are used to predict digestibility of organic matter determined in vivo and metabolizable energy.

For roughages, the relationships are:

$$OMD\ (\%) = 14.88 + 0.889 * Gv + 0.45 * CP$$
$$ME\ (MJ / kg\ DM) = 2.20 + 0.136 * Gv + 0.057 * CP$$

where, OMD is organic matter digestibility (%); ME, metabolizable energy; CP, crude protein in percent; and Gv, the net gas production in ml from 200 mg dry sample after 24 h of incubation and after correction for the day-to-day variation in the activity of rumen liquor using the Hohenheim standard.

The method of Menke et al. [7] was modified by Blümmel and Orskov [14] in that feeds were incubated in a thermostatically controlled water bath instead of a rotor in an incubator. Blümmel et al. [12] and Makkar et al. [15] modified the method further by increasing the amount of sample from 200 to 500 mg and increasing the amount of buffer two-fold. As a result the incubation volume increased from 30 mL in the method of Menke et al. [7] to 40 mL in the modified method. In the 30 mL system, the linearity between the amount of substrate incubated and the amount of gas produced is lost when the gas volume exceeds 90 ml because of the exhaustion of buffer of the medium. In the 40 mL system, the linearity is lost when the gas volume exceeds 130 mL [16]. The exhaustion of the buffer decreases pH of the incubation medium; consequently the fermentation is inhibited. If the amount of gas production exceeds 90 mL in the 30 mL system and 130 mL in the 40 mL system, the amount of feed being incubated should be reduced.

The main advantages of the modified method (the 40 mL system and incubation in a water bath) are:

- there is only a minimum drop in temperature of the medium during the period of recording gas readings on incubation of syringes in a water bath. This is useful for studying the kinetics of fermentation where gas volume must be recorded at various time intervals,
- because of large volume of water in the water bath and also its higher temperature holding capacity, drastic drop in the temperature of the incubation is prevented in case of a power failure for a short duration,
- an increase in amount of sample from 200 to 500 mg reduces the inherent error associated with gravimetric determination needed to determine concomitant *in vitro* apparent and true digestibility (see below).

When a feedstuff is incubated with buffered rumen fluid *in vitro*, the carbohydrates are fermented to produce short chain fatty acids, gases and microbial cells. Gas production is basically the result of fermentation of carbohydrates to acetate, propionate and butyrate. Gas production from protein fermentation is relatively small as compared to carbohydrate fermentation. The contribution of fat to gas production is negligible. When 200 mg of coconut oil, palm kernel oil and/or soybean oil were incubated, only 2.0 to 2.8 mL of gas were produced while a similar amount of casein and cellulose produced about 23.4 mL and 80 mL gas.

The gas produced in the gas technique is the direct gas produced as a result of fermentation and the indirect gas produced from the buffering of short chain fatty acids (SCFA). For roughages, when bicarbonate buffer is used, about 50% of the total gas is generated from buffering of the SCFA and the rest is evolved directly from fermentation. At very high molar propionate levels the amount of CO_2 generated from buffering of SCFA is about 60% of total gas production. Each mmol of SCFA produced from fermentation releases 0.8–1.0 mmol of CO_2 from the buffered rumen fluid solution, depending on the amount of phosphate buffer present. A highly significant correlation has been observed between SCFA and gas production (see below).

Gas is produced mainly when substrate is fermented to acetate and butyrate. Substrate fermentation to propionate yields gas only from buffering of the acid and, therefore, relatively lower gas production is associated with propionate production. The gas which is released with the generation of propionate is only the indirect gas produced from buffering. The molar proportion of different SCFA produced is dependent on the type of substrate. Therefore, the molar ratio of acetate:propionate has been used to evaluate substrate related differences. Rapidly fermentable carbohydrates yield relatively higher propionate as compared to acetate, and the reverse takes place when slowly fermentable carbohydrates are incubated. Many workers reported more propionate and thus a lower acetate to propionate ratio in the ruminal fluid of cows fed a high grain diet. If fermentation of a feed leads to a higher proportion of acetate, there will be a concomitant increase in gas production compared with a feed producing a higher proportion of propionate. In other words, a shift in the proportion of SCFA will be reflected by changes in gas production.

The gas produced on incubation, of cereal straws [14], a wide range of feeds including many dairy compound feeds and their individual feed components, whose protein and fat contents vary greatly [17], and tannin containing browses [18] in the absence or presence of polyethylene glycol (a tannin complexing agent) in the buffered rumen fluid, was closely related to the production of short chain fatty acids (SCFA) as per Wolin [19] stoichiometry, which is as follows:

Fermentative $CO_2 = A/2+P/4+1.5*B$; where A, P and B are moles of acetate, propionate, and butyrate respectively.

Fermentative CH_4 = [A+2*B]-CO_2; where A and B are moles of acetate and butyrate respectively and CO_2 is moles of CO_2 calculated from equation.
Assumption: one mole of SCFA releases one mole of CO_2 from bicarbonate-based buffer described as buffering CO_2 and therefore, mmol of buffering CO_2 is equal to mmol of total SCFA generated during incubation.

Gas volume = mmol of gas*gas constant (R)*T;
where
R = the ratio between molar volume of gas to temperature (k) [22.41L/273 = 0.082],
T = incubation temperature; 273 + 39°C = 312 k.
Total volume of gas (ml) calculated from SCFA production = [BG + FG]*CF
BG = gas volume (ml) from buffering of SCFA,
FG = fermentative gas (ml) [CO_2 + CH_4],
CF = correction factor for altitude and pressure which is 0.953 for Hohenheim [17].
(The volume of 1 mmol of gas at 39°C in Hohenheim would be; 1*0.082*312*0.953 = 24.4 mL).

The origin and stoichiometry of gas production have been described in details by Blümmel et al. [12] and Gatechew et al. [11].

The *in vitro* gas production measured after 24 h incubation of tannin containing browses in the presence or absence of PEG was strongly correlated with gas volume stoichiometrically calculated from SCFA. The relationship between SCFA production (mmol) and gas volume (ml) after 24 h of incubation of browse species with a wide range of crude protein (5.4–27%) and phenolic compounds (1.8–25.3% and 0.2–21.4% total phenols and total tannins as tannic acid equivalent) was [18]:

In the absence of PEG; SCFA = –0.0601 + 0.0239 * Gas; R^2 = 0.953; n = 39; P <0.001
In the presence of PEG, SCFA = 0.0521 + 0.0207 * Gas; R^2 = 0.925; n = 37; P <0.001
Overall, SCFA = –0.00425 + 0.0222 * Gas; R^2 = 0.935; n = 76; P <0.001
These relationships are similar to that obtained for wheat straw [20].

The SCFA production could be predicted from gas values using the above relationship. The level of SCFA is an indicator of energy availability to the animal. Since SCFA measurement is important for relating feed composition to production parameters and to net energy values of diets, prediction of SCFA from *in vitro* gas measurement will be increasingly important in developing countries where laboratories are seldom equipped with modern equipment to measure SCFA.

The stoichiometric balance also allows calculation of the CH_4 and CO_2 expected from the rumen fermentation if the molar proportions and amount of SCFA are known.

2.3. *In vitro* gas production with concomitant microbial mass measurement

2.3.1. Need for determination of microbial mass

Lately, the surge of interest in the efficient utilisation of roughage diets has caused an increase in the use of gas methods because of the possibility of estimating the extent and rate of gas production in one sample by time series measurements of the accumulating gas volume. *In vitro* gas tests are attractive for ruminant nutritionists since it is very easy to measure the volume of gas production with time, but the measurement of gas only implies the measurement of nutritionally wasteful and environmentally hazardous products. In most studies the rate and extent of gas production has been wrongly considered to be equivalent to the rate and extent of substrate (feed) degradation. Current nutritional concepts aim at high microbial efficiency, which cannot be achieved by measurement of gas only. *In vitro* gas measurements reflect only SCFA production. The relationship between SCFA and microbial mass production is not constant and the explanation for this resides in the variation of biomass production per unit ATP generated. This can impose an inverse relationship between gas volume (or SCFA production) and microbial mass production particularly when both are expressed per unit of substrate truly degraded. This implies that selecting roughages by measuring only gas using *in vitro* gas methods might result in a selection against the maximum microbial mass yield. Blümmel et al. [12] have demonstrated how a combination of *in vitro* gas production measurements with a concomitant quantification of the truly degraded substrate provides important information about partitioning of fermentation products. The *in vitro* microbial mass production can be calculated as:

Microbial mass = Substrate truly degraded — (gas volume × stoichiometrical factor).

For roughages, the stoichiometrical factor was 2.20.

2.3.2. Partitioning factor

The parameters in the above equation also allow the calculation of a partitioning factor (PF). The PF is defined as the ratio of substrate truly degraded *in vitro* (mg) to the volume of gas (ml) produced by it. A feed with higher PF means that proportionally more of the degraded matter is incorporated into microbial mass, i.e., the efficiency of microbial protein synthesis is higher. Roughages with higher PF have been shown to have higher dry matter intake. Different *in vitro* PF values are also reflected by *in vivo* microbial protein synthesis as estimated by purine derivatives (the higher the PF, the higher the excretion of urinary purine derivatives; [21]) and in methane production by ruminants (the higher the PF, the lower the methane output; [22]). These results show that the PF calculated *in vitro* provides meaningful information for predicting the dry matter intake, the microbial mass production in the rumen, and the methane emission of the whole ruminant animal.

The procedures for the determination of truly degraded substrate and the calculation of the stoichiometrical factor; stoichiometrical relationship between SCFAs and gas volume; and relationship between SCFA production, ATP production and microbial mass yield can be obtained from Blümmel et al. [12] and Getachew et al. [11]. It may be noted that these procedures and relationships are valid for substrates consisting predominantly of structural carbohydrates, and the findings might not extend to substrates such as those high in soluble carbohydrate, protein or fat. Rymer and Givens [23] have shown that, as observed by Blümmel et al. [12], good quality feeds (grass silage, wheat, maize, molasses sugarbeet feed and fishmeal) which produce large amounts of gas and SCFA yield small amounts of microbial mass per unit of feed which is truly degraded.

It seems therefore justified to suggest that feeds or feed ingredients should be selected that have a high *in vitro* true degradability but low gas production per unit of truly degraded substrate.

2.3.3. Role of incubation time in PF determination

Another study by Blümmel et al. [24], in addition to once again describing the importance of measuring microbial mass, has highlighted the importance of the fermentation time at which the microbial mass should be measured. In this study, substrate degradation and kinetics of *in vitro* partitioning of three hays, with similar *in vivo* digestibilities, into SCFA, microbial mass yield, and ammonia, carbon dioxide and methane production was examined at 8, 12, 18 and 24 h of incubation in the gas method under both low and adequate nitrogen levels. Microbial synthesis was quantified gravimetrically [12], by nitrogen balance [25] and by purine analysis [26]. SCFA and gas production were positively correlated ($P < 0.01$) and cumulative at all times of incubation under both low and adequate nitrogen levels. On the other hand, microbial mass, microbial nitrogen and microbial purine yields declined after 12 h of incubation while ammonia production increased. Per unit of substrate degraded gas and SCFA production were always inversely ($P < 0.05$) related to microbial mass yield regardless of incubation time and medium (low or adequate nitrogen). At later incubation times, continuously more SCFA or gas and less microbial mass were produced reflecting microbial lysis and probably increasing microbial energy spilling. All three hays differed ($P < 0.05$) consistently in how the degraded substrate was partitioned into SCFA and gas and into microbial mass in both the low and adequate nitrogen medium. Purine analysis indicated substantial differences in microbial composition across treatments, which might be one explanation for these different microbial efficiencies [24].

The efficiency of microbial growth was higher for 16 h incubation than 24 h for tannin-rich feeds when these were incubated in the presence or absence of PEG, a tannin-inactivating agent. Additional nitrogen in the medium also affected the efficiency of microbial protein synthesis from tannin-tannins feeds both at 16 h and 24 h [27]. Approaches need to be developed for measuring the PF at the incubation time at which the lysis of microbes is minimal. Some possible approaches worth investigating to identify this incubation time are:

i) the time at which half of the maximum gas is produced, and
ii) the inflection point at which the rate of gas production is maximum (the rate increases up to a certain incubation time and thereafter decreases as the incubation progresses).

Both these parameters can be mathematically calculated from the gas profiles. The effect of the nitrogen level in the medium on the PF and the significance *in vivo* of these PFs also need to be investigated.

2.3.4. Digestion kinetics of neutral detergent-soluble fraction

The gas measurement method has also been used to study digestion kinetics of the neutral detergent soluble fraction of forages, starch-rich feeds and other highly digestible carbohydrate components, which was obtained by subtracting the average gas production curve for the digestible neutral detergent fibre (NDF) from that of the unfractionated whole feed [28]. The subtraction procedure might give some useful information relevant to low-NDF fibre feeds, e.g., corn grain [28], but it is not suitable for forages rich in NDF [29]. Blümmel et al. [29] examined the rate and extent of fermentation of whole roughage and extracted NDF, dry matter degradability of extracted NDF and the PF for whole roughage and the extracted NDF of 54 roughages. The 24-h degradabilities of extracted NDF were higher than NDF degradabilities in whole roughages, and the PF values were lower for extracted NDF than for whole roughages (2.5 vs 3.1; i.e. the efficiency of microbial protein synthesis with extracted NDF was lower). Both the higher degradability and lower PF contributed to higher gas volumes obtained from extracted NDF compared with whole roughage. Supplementation of amino acids and sugars, which essentially constitute the solubles, may increase the efficiency of microbial synthesis from cell walls during fermentation (a situation similar to that in unfractionated forages) and the removal of solubles may result in lower microbial efficiencies. A considerable effect of cell solubles on partitioning of nutrients from the NDF raises doubts as to the significance *in vivo* of the kinetic parameters calculated using the subtraction procedure [29].

2.4. Evaluation of silages and by-products rich in acids by the gas methods

Caution is required in the evaluation of acid-containing silages and by-products using the gas methods. Some silages [30] and by-products such as citrus pulp and distillery by-products can contain a substantial amount of acids. Since the gas methods [11, 12] are based on incubation of the feed in a bicarbonate-based buffer, the acid present in the feed will release carbon dioxide from the buffer, which might be mistaken for fermentation gases, leading to erroneous results. This acid-base reaction is spontaneous and the gas released due to the neutralisation of acids can be measured within 5 to 10 min of the start of the incubation. It should therefore be subtracted from the total gas production volumes measured at different times of fermentation before these gas values are used for evaluation of such feeds.

2.5. Protein degradability using the gas method

A method, based on the gas method [12] and that of Raab et al. [31], which measures gas production and ammonia in the medium has also been developed for measuring rumen degradability of nitrogen from low quality feeds [11]. This method could be useful in developing sound supplementation strategies and increasing the efficiency of utilisation of non-conventional feed resources.

Although the 24-h *in vitro* degradable nitrogen values obtained from tannin-rich browse and herbaceous legumes were lower than those reported for low quality roughages [11, 25], the relatively high crude protein content of these browses and herbaceous legumes could play a significant role in supplying rumen degradable nitrogen. In the presence of a tannin-inactivating agent, PEG, their *in vitro* degradable nitrogen values were raised. The difference between these values observed in the presence and absence of PEG indicates the amount of protein protected by tannins from degradation in the rumen [25]. Whether the protein protected by tannins from microbial degradation is fully available to animals post-ruminally requires further research. Raab et al. [31] reported a close relationship between *in vivo* and *in vitro* values when incubation was terminated after 17 h. When normal protein feeds were tested about 80% of the 24 h value was degraded in the first 8 h incubation whereas in protected protein feed only 60% of the 24 h value was degraded in this time [31]. The appropriate incubation time for *in vitro* degradability studies in the presence and absence of PEG for tannin-rich feeds may depend on the nature of protein and tannins, which should be identified. Also, this method for quantifying feed proteins that have been protected by tannins from degradation in the rumen needs to be validated *in vivo*.

Measurement of feed proteins during fermentation using polyacrylaminde gel electrophoresis coupled with the use of an image analyser could be another attractive approach for measuring the rumen degradability of nitrogen, and for studying the influence of various natural plant products (e.g., tannins, saponins, alkaloids [32]).

2.6. Evaluation of tannin-containing by-products and forage

2.6.1. The need to determine microbial mass using internal or external markers

The approach mentioned above used data from the gas method and the detergent system of fibre analysis to calculate the microbial mass produced during the fermentation of fibrous feeds. Unfortunately, this method did not work at all for tannin-rich feeds. The PF for tannin-rich feeds (calculated as mg truly degraded substrate needed to produce one-ml gas) ranged from 3.1 to 16.1 [25] which is well above the theoretical range of PF (2.75 to 4.41) [12]. The high PF could be due to: a) solubilization of tannins from the feed. These tannins would make no contribution to gas or energy in the system but would contribute to dry matter loss, b) the cell solubles contributing to dry matter loss but not to gas production because the gas production is inhibited by tannins or c) a combination of a) and b). In addition, the appearance of tannin-protein complexes as artefacts in the true residue also makes the gravimetric approach [12] of quantification of microbial mass redundant [33]. The presence of tannin-protein complexes in faecal samples (the origin of proteins could be microbes, feed or endogenous secretion from the gastro-intestinal tract) from animals fed tannin-rich forage and their non-removal by the detergent system of fibre analysis [34] leads to misleading values of fibre and also causes problems in the *in vivo* evaluation of tannin-rich feeds [35, 36]. Therefore, caution is required in interpreting results obtained from *in vivo* or *in vitro* experiments on the evaluation of tannin-containing feeds using the detergent system of fibre analysis.

For the *in vitro* evaluation of tannin-rich feeds, the microbial mass should be quantified using diaminopimelic acid or purines as markers, or by ^{15}N incorporation into the microbes [32], and the PF for tannin-rich feeds can be expressed as the microbial mass determined by these markers per ml of gas produced (or per mmol SCFA produced). The system developed for evaluation of tannin-containing feeds depends on incubation of the feed in the presence and absence of polyethylene glycol (PEG MW 4000 or 6000 preferably of 6000; [15]) and measurement of gas (or SCFA) and microbial mass using the above-mentioned markers. PEG has a high affinity for tannins. Addition of PEG results in the formation of PEG-tannin complexes which inactivates tannins. The changes in gas (or SCFA) and microbial mass as a result of PEG addition represents 'in totality' the tannin effects (biological) as a function of the rumen fermentation parameters. This bioassay based on an *in vitro* rumen fermentation system coupled with the use of a tannin-complexing agent, polyethylene glycol (PEG) could be complementary to other tannin assays [37, 38] in evaluating the nutritional quality of tanniniferous feeds.

2.6.2. Significance of bound tannins and the efficiency of microbial protein synthesis

The above approach of incubating tannin-containing feeds in the presence and absence of PEG also enables studies to be made on the nutritional significance of both extractable and unextractable (bound) tannins. Addition of PEG during the incubation of tannin-rich NDF led to an increase in gas production, suggesting that tannins released as a result of NDF degradation by rumen microbes are biologically active and have the potential to influence rumen fermentation [39]. Similar results were obtained on incubation of tannin-rich browses made free of extractable tannins by repeated use of 70% aqueous acetone. Another application of this method is to study the effect of tannins on the partitioning of nutrients between microbial protein and SCFAs or gases or to study the efficiency of rumen microbial protein synthesis. Using DAPA, purines and ^{15}N approaches for measuring microbial mass it has been shown that in the presence of PEG, the degradabilities of substrate and microbial mass production were higher, the efficiency of microbial protein synthesis was lower. Similar results have also been obtained by another approach based on the gas method in which the rate of ammonia uptake is taken as the efficiency of microbial protein synthesis [32]. Conversely, efficiency of microbial protein synthesis is expected to be higher in the presence of tannins. The net microbial mass production would depend on the balance between decreased degradable dry matter and higher microbial mass production per unit of dry matter digested in presence of tannins.

3. ENHANCEMENT OF FEEDING VALUE

Various studies have been conducted aimed at the detanninification of tannin-rich feeds. Two types of approaches were developed, one for farmers and the other for small-scale industries. The capabilities of farmers and small-scale industries were kept in mind so that the approaches could be easily adopted by the end users.

3.1. Farmers-based approaches

Oak and pine wood are generally used as fuel in rural areas of the Himalayan region in India and adjoining countries. A 10% solution of ash (pH, 10.5–11) decreased tannin levels in mature oak leaves by up to 80% [40]. Magadi soda (sodium sesquicarbonate, sodium carbonate and sodium bicarbonate), another unrefined material containing alkalis has also been shown to reduce assayable tannins in sorghum by 40–50%. Wood ash solutions have also been used traditionally for the treatment of high-tannin containing sorghum and millet for human consumption (for references see [40]). The use of wood ash, a cheap source of alkali holds potential for the detanninification of tannin-rich feedstuffs.

Other major findings were: i) a substantial reduction in the tannin content (72–89%) on storage of fresh leaves, containing 55% moisture and 4% urea, for five days, and ii) a reduction in tannin content of 46–60% on storage of chopped leaves for 10 day [41]. The 'chopping of leaves followed by storage' can find practical application for the farmers and can be adopted easily as it requires only a slight change in normal management practices. Instead of feeding the leaves on the same day as they are lopped, chopped and stored for about five to ten days before feeding. The use of urea calls for resources and some degree of education, the lack of which has hindered the adoption of this approach. The higher extent of inactivation of tannins by chopping leaves could be due to oxidation of tannins by phenol oxidases present in leaves because chopping should increase the availability of tannins to the enzyme. In addition, inactivation of tannins during storage is due to their polymerization to higher 'inert' polymers [41, 42]. Another factor responsible for enhanced effects observed on addition of urea could be the higher pH caused [43] by the evolution of ammonia from urea. Similarly, inactivation of tannins observed when using wood ash is also mediated by high pH-mediated oxidation of tannins.

3.1.1. Approaches for small-scale industries.

Drying under different conditions [44], steaming and autoclaving [45] were found to be not very effective for oak leaves. Extraction with organic solvents (acetone, methanol, ethanol) and treatment with oxidising agents (potassium dichromate, potassium permanganate and alkaline hydrogen peroxide) were very effective and removed/inactivated up to 90% of the tannins in oak leaves [46] and up to 99% in agro-industrial and forestry by-products [1]. The use of oxidising agents holds promise for the large-scale detoxification of tannin-rich feedstuffs because of its low cost. These approaches are very simple, do not require complex equipment and are likely to be adopted by the feed industry in the future both in developing and developed countries. In addition, potassium permanganate can be made easily available in villages in developing countries (generally used for cleaning water in wells) and is non-corrosive. Hence farmers can use this chemical at home for detanninification of tannin-rich feedstuffs. The use of organic solvents for extraction of tannins has an advantage over oxidising agents because the solvents can be largely recycled and the tannins can be recovered for the tanning of leather or for other industrial applications. The oxidising agents convert tannins to quinones, which are not capable of forming complexes with proteins under normal physiological conditions. However, the use of organic solvents is expected to be more expensive, unless the value of tannins recovered is higher than the cost of organic solvents used in the treatment.

The white-rot fungi (*Sporotricum pulverulentum, Ceriporiopsis subvermispora* and *Cyathus steroreus*) which degrade lignin, were also found to decrease tannin content by about 60% in 10 to 20 days of fermentation [47, 48]. This approach though presently in its infancy, may also find a place in industry in the future.

The above technologies for the detanninification of tree leaves on a small scale industrial level do not seem to be economically viable because large quantities of leaves are seldom available in one place (unlike agro-industrial by-products) and the cost of collecting them is high. There is a lack of information on the effects of judicious lopping of tree leaves and strict control, especially in developing countries, on the extent of lopping. Even if the information were available, its application would seems to be difficult, particularly when the interests of industries in detannifying or making protein supplements from trees or shrubs are at stake. However, the detannification technologies presently available may well set the stage for the utilization of agro-forestry by-products including tree pods.

3.1.2. Use of PEG by farmers and by the feed industry

Addition of a tannin-complexing agent, PEG to tannin-rich diets is another attractive option to enhance the feeding value of such diets. This approach can be used both by farmers and by the industry. Farmers can give PEG directly to animals through water, by mixing it with a small amount of concentrate, by spraying it on tannin-rich feedstuffs or better still as a part of nutrient blocks (see below). Industry can incorporate PEG in a pelleted diet composed of ingredients including tannin-rich by-product(s). Amongst various tannin-complexing agents investigated, PEG of molecular weight 6,000 was the most effective in binding to tannins at near neutral pH values [15]. Incorporation of PEG has been shown to have beneficial effects in monogastrics and both beneficial and adverse effects in ruminants. The incorporation of PEG had beneficial effects for feedstuffs such as *Quercus calliprinos, Pistacia lentiscus, Ceratonia siliqua* [49–51], *Zizyphus nummularia* [52], *Hedysarum coronarium* [53], *Acacia aneura* [54–56], *Lotus pendunculatus* [57–58], *Desmodium ovalifolium* and *Flamingia macrophylla* [59], and *Acacia saligna* [60] which are rich in tannins (condensed tannin content: 5–10%). Inactivation of tannins through PEG increased the availability of nutrients and decreased microbial inhibition, which in turn increased degradability of nutrients leading to better animal performance. On the other hand, for *Lotus corniculatus*, the condensed tannin content of which varied from 2 to 4%, addition of PEG decreased wool growth, weight gain [61–62] and milk yield [63]. These decreases were attributed to a substantially lower absorption of amino acids from the intestine resulting from increased digestion of proteins in the rumen [64]. Addition of PEG to a diet based on *L. corniculatus* which containing 1% condensed tannins did not have any effect [65], suggesting that 1% condensed tannin from *L. corniculatus* may be insufficient to protect feed protein from degradation in the rumen. The lower performance of ruminants whose diets are supplemented PEG could also be due to lower efficiency of microbial protein synthesis in the rumen ([32]; see above). Not only the concentration of tannins, but also their nature influences the response of animals to PEG incorporation. A diet containing 1.8% condensed tannins from *L. pedunculatus* caused significant reduction in the levels of rumen ammonia and SCFAs and reduced nitrogen digestibility, whereas the same level of condensed tannins (1.8%) from *L. corniculatus* had lesser effects [64]. The effect of PEG also depends on the level of proteins in the diet. Proteins mimic the effect of PEG — the higher the level of proteins, the lesser the effect of PEG [66]. It is evident from the literature that addition of PEG is advantageous when the tannin content of the feed is high and is deleterious when the tannin content is low. There is some evidence that activity of tannins from tropical plants (expressed as protein precipitation capacity per unit of tannins) is much greater than those from temperate plants [2], and therefore for tropical plants the addition of PEG might be beneficial even when the levels of condensed tannins are low. Characterising tannin-containing feeds in terms of parameter(s) representing the biological activity of tannins, such as protein precipitation capacity, will give a better insight into the role of tannins and will be more useful in the development of approaches for their inactivation than simply measuring the condensed tannin contents alone.

PEG has been incorporated into the diets at a level from 3 to 120 g per day, with varying responses. Supplementing sheep and goats, fed *Ceratonia siliqua* leaves, with 25 g of PEG/day seems to be the optimal amount in terms of the cost-benefit response under Israeli conditions [49]. Although this technique is quite effective, the likelihood of its adoption will depend on the cost-benefit ratio.

The effect of the manner of application of PEG (MW 6000) on some fermentation parameters after 24 h of incubation of tannin-rich feeds in the *in vitro* rumen fermentation system (mentioned above) has also been studied. PEG was applied as a single dose (51 mg) or in split doses (7 doses of 7.3 mg at 2 h interval starting at 0 h) in incubations containing *Calliandra* leaves (protein precipitation capacity: 0.45 mg BSA precipitated/mg feed). The gas and SCFA production increased substantially on addition of PEG. Purine as a marker for microbial mass was similar for the control and single application of PEG but with the split application it was higher. Efficiency of microbial protein production was also higher with the split application of PEG [37]. The implications of these results are that PEG given to animals on tannin-rich diets in the form of a molasses-mineral block (leading to a slow consumption of PEG) would lead to better animal performance than the currently used approaches which are based on a single dose in the drinking water or in a small amount of concentrate feed. Ben Salem and Nefzaoui [68] have shown that sheep fed nutrient blocks containing PEG have a higher intake of *Acacia* leaves, higher nitrogen retention, and greater urinary excretion of allantoin (a marker for microbial protein supply to the intestine) than controls without PEG. But it would be interesting to compare these parameters when PEG is fed as a part of nutrient blocks or given as a single dose mixed in water or in a small amount of concentrate. Under the auspices of the IAEA, projects are now being planned for improving the utilization of tanniniferous forages by feeding PEG-molasses-multinutrient blocks. When the animals lick these blocks the PEG will be released slowly, and this is expected to supply higher microbial protein post-ruminally as a result of higher efficiency of microbial protein synthesis mediated probably via better synchronisation of ATP production and release of nutrients.

Addition of PEG to tannin-containing feeds increased *in vitro* gas and SCFA production, and *in vitro* degradation of nitrogen. Therefore, there appears to be a potential for improving the utilisation of tannin-containing feeds by the use of tannin-binding agent such as PEG without altering the genetic pool of tannin-containing plants. Inclusion of energy sources with the aim of synchronising nitrogen degradability and availability of energy increased the efficiency of microbial protein synthesis in the presence of PEG [25]. A rapid degradation of nitrogen not matched to the availability of energy could lead to high absorption of NH_3N from the rumen *in vivo*. *In vivo*, the NH_3N not captured in the rumen is absorbed into the blood and converted into urea in the liver which requires expenditure of energy; each mole of urea requiring four moles of ATP. The loss of nitrogen as urea in urine is energetically costly, is a loss of a valuable nutrient and causes environmental pollution.

4. CONCLUSIONS AND FUTURE RESEARCH

Research and development efforts are required to establish a feed library for non-conventional feedstuffs that includes information on nutritive values in addition to routine composition analysis. In the case of tannin-containing feedstuffs, there is a need to incorporate approach(s) measuring the biological activities of tannins as well as measuring tannin levels by chemical methods.

The *in vitro* rumen fermentation method in which gas production and microbial mass production are concomitantly measured has several major advantages:

- ♦ it has the potential for screening a large number of feed resources, for example in breeding programmes for the development of varieties and cultivars of good nutritional value
- ♦ it could also be of great value in the development of supplementation strategies using locally available conventional and non-conventional feed constituents to achieving maximum microbial efficiency in the rumen
- ♦ it has an important role to play in the study of rumen modulators for increasing efficiency of microbial protein synthesis and decreasing emission of methane, an environmental polluting gas
- ♦ it provides a better insight into nutrient-anti-nutrient and anti-nutrient-anti-nutrient interactions. The method is also being used increasingly to screen plant-derived rumen modulators. These products have a lower toxicity to animals and humans, and are environmentally friendly. Consequently, they are becoming increasingly popular with consumers.

Further studies are required on:

- ➢ the development of simple approaches for identifying the incubation time in the *in vitro* gas system at which the PF (a measure of the proportion of fermented substrate which leads to microbial mass production) is maximum,
- ➢ the effect of nitrogen in the incubation medium on the PF, and
- ➢ the *in vivo* significance of the PF so obtained.

The results of the limited experiments conducted so far have shown that simple models employing gas kinetic parameters and the PF are capable of predicting the dry matter intake of roughages and level of emission of methane by ruminants. Experiments also need to be done to test whether, for any given feed, the microbial protein synthesis as derived from digestion kinetic parameters (including PF) *in vitro* is sufficient to explain the observed microbial protein supply to the small intestine *in vivo*. At present, the simplest way of determining the latter parameter is to calculate it from the level of urinary purine derivatives. This validation exercise should be conducted for a wide range of feed constituents and diets which should enable the above mentioned simple technique of measuring gas and microbial mass to be a routine and powerful tool for feed evaluation thus avoiding the need for time-consuming, laborious and expensive feeding studies. Lately, much emphasis has been given to the development of statistical or mathematical models, which fit best the gas production profiles and describe the gas evolution with high accuracy. Experiments must be designed to understand the biological significance of the various statistical and functional parameters being calculated using these models, and also to incorporate a measure of microbial mass into these mathematical descriptions.

Enhancement of the feeding value of tannin-rich feeds can be achieved by anaerobic storage in the presence or absence of urea, by the use of oxidising agents, by the treatment with white-rot fungi or by the use of PEG, preferably in a slow release form. PEG can be added to forages rich in tannins along with an energy supplements or to tannin-rich by-products low in energy with the aim of synchronising nitrogen degradability and availability of energy and thus increasing the efficiency of microbial protein synthesis. PEG is best given as an ingredient of ‘nutrient blocks’ so that not only will it enhance the incorporation of the feed nitrogen into microbial mass but will also allow the livestock to self-regulate the intake of PEG, thereby decreasing the cost of the treatment. The aim of future studies should be to explore the potential of these approaches for a wide range of tannin-containing feeds, and then to develop simple and economically viable detanninification approaches for use by farmers for feed resources such as foliage from trees and shrubs and for other available by-products. Other techniques will be required for use by small-scale industry to treat agro-industrial and forestry by-products which are available in large quantities in one place. These approaches will help to alleviate the problems posed by the disposal of various agro-industrial by-products and the shortages of conventional feeds.

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COUNTRY REPORTS

THE USE OF POULTRY WASTE AS A DIETARY SUPPLEMENT FOR RUMINANTS

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Abstract

THE USE OF POULTRY WASTE AS A DIETARY SUPPLIEMENT FOR RUMINANTS.

The use of poultry waste as a dietary supplement in ruminant ration could have a considerable effect on reducing costs, insufficiency of protein in diet, and on solving disposal problems. The chemical composition of poultry waste and its safe use in ruminant nutrition were investigated prior to its use as a dietary supplement. No appreciable differences in chemical composition were noted in poultry wastes between oven and sun dried forms. The high content of protein, energy, and minerals in poultry waste indicated its importance as a partial substitute for concentrates in the diet. The numbers of total bacteria and pathogenic microorganisms such as *Salmonella* and *E. coli* detected in poultry waste were within the acceptable limits. Farm testing of rations containing poultry wastes were carried out on sheep (ewes and lambs), Friesian cattle and buffalo heifers. In ewes fed during late pregnancy and lactation, milk yield and performance did not show any significant changes. Lambs suckled from ewes fed on poultry waste did not show any significant difference in weaning weight, average daily weight gain or feed efficiency (kg feed used/kg weaned weight). However, the poultry waste group had shorter age at weaning than the control group. In another feeding trial on growing lambs after weaning, mean daily body weight gain was higher in lambs fed on a ration containing poultry waste than the control ration. In Friesian and buffalo calves, no significant differences in average daily body weight gain were found as a result of inclusion of poultry waste in the ration. In buffalo heifers various estimated reproductive parameters indicated no appreciable differences due to the inclusion of poultry waste in the diet except that the number of ovulations and number of services/conception were both higher in the group fed with poultry waste.

1. INTRODUCTION

The productivity of livestock in terms of milk yield or the annual red meat off-take from an animal unit in Africa including Egypt is considerably low, when compared to other developed countries. Poor nutrition, both in quantity and quality and poor reproductive performance are recognized as major factors limiting animal production. In general the animal feed base in Egypt is insufficient, especially in feed ingredients of high protein content.

There are about 2.5 million heads of cattle, 3.1 million buffaloes, 3.5 million sheep, 2.8 million goats and 144 thousand heads of camels that are mainly fed on berseem during winter. However, summer feeding depends mainly on a variety of poor quality field crop residues, which are nutritionally imbalanced and do not cover the requirements of the animal either in protein or in energy. In addition cottonseed meal, which is the main source of protein in concentrate feed mixtures in the country, is in short supply. Improved feeding systems based on supplementation of locally available feed resources will enhance milk and meat production at a considerably low cost and partially fill the gap in protein and energy shortages.

The approach in the use of poultry waste as a constituent in ruminant rations was motivated by the shift of the poultry industry from extensive to intensive system of production. This lead to a significant increase in the production of poultry wastes (PW). The amount of collectable poultry waste was found to be 750 000 tons/year during the last five years. The poultry waste is rich in protein (about 25% protein equivalent), Total Digestible Nutrients (TDN) (about 50%) as well as minerals.

Although poultry waste is mainly used as a fertilizer, it has been shown to be a potential source of both nitrogen and energy for ruminants in providing low-cost feed components [1, 2]. The use of poultry waste in feeding ruminant livestock decreases the cost of feeding and also minimizes the effects of its contribution to environmental pollution in areas of intensive poultry production. More importantly, it solves partially the shortage of the animals' requirements of protein and/or energy during the dry season. Chemical composition and nutritive value of poultry waste has been studied by a number of workers [3–7], indicating its potential use as an inexpensive nitrogen, energy and mineral supplement.

The present paper reports some experiments on the utilization of poultry waste in ruminant rations and its effects on productive and reproductive traits. The paper also attempts to identify possible problems, which may be associated with its inclusion in rations.

2. MATERIALS AND METHODS

2.1. Collection of poultry waste

Poultry waste was collected from at least 10 farms in each of the following three locations: i) Cairo and Kalubeia governorates, ii) Sakha and adjacent cities and Kafr El-Shikh governorate and iii) Giza governorate.

Samples from each location were subjected to sun drying for at least 2 weeks or oven drying at 75°C for 48 h in specialized laboratories.

2.2. Nutritive quality of poultry waste

The chemical composition [8], mineral content and pathogenic microorganisms [9] of poultry waste were determined in the following laboratories: i) Faculty of Agriculture laboratory, Ain Shams University, ii) Sakha Agriculture Experiment Station laboratory, Animal Production Institute, Ministry of Agriculture and iii) Agriculture Experiment Station laboratory, Radioisotope Applications Division, Egyptian Atomic Energy Authority, Cairo. The extraction as well as the determination of aflatoxins [10] using high performance liquid chromatography [11], were carried out at the Agriculture Experiment station, AEA.

Based on dryness and tests for pathogenic microorganisms, sun dried poultry waste was considered most suitable for use in the feeding trials.

2.3. Feeding trials

2.3.1. With sheep

An on-farm feeding trial was carried out at Sharkia province where a diet containing 14% poultry waste was compared with a control diet without poultry waste (Table I). Barki ewes, six per treatment, were fed the two diets ad libitum during the last 3 weeks of gestation and up to 12 weeks after lambing. All animals had access to drinking water at all times.

The milk yield of ewes fed on the two rations was recorded. The lambs were weighed before and after suckling at 9.0 and 16 h and milk consumption by lambs was calculated by difference. Body weight of lambs was recorded weekly from birth to weaning.

2.3.2. With male lambs

Twelve male Rahmani lambs were assigned to two groups. The treatment group was fed with a diet containing 17% poultry waste (PW) and the control group without PW (Table II). From the first day of the feeding, lambs were examined twice weekly for libido, separation of penis from the prepuce, erection and ejaculation.

TABLE I. COMPOSITION OF EXPERIMENTAL DIETS (ON DM BASIS) GIVEN TO SHEEP

Ingredient (%)	Control Diet	PW Diet
Crushed yellow corn	74	66.5
Cotton seed meal	15	11
Poultry waste (PW)	-	14
Soybean meal	5	3.5
Wheat Bran	5	4
NaCl	0.5	0.5
Mineral mixture	0.5	0.5
Total	100	100
Chemical composition (on DM basis)		
Organic matter (OM)%, on DM basis	96.5	93.8
Ash	3.5	6.2
Crude protein (CP)	14.2	14.1
Ether extract (EE)	3.9	2.9
Crude Fiber (CF)	9.9	10.2
Nitrogen free extract (NFE)	68.5	66.6

TABLE II. COMPOSITION OF DIETS (ON DM BASIS) USED IN THE FEEDING TRIAL WITH MALE LAMBS

Ingredient (%)	Control Diet	PW Diet
Yellow corn	10	24
Poultry waste (PW)	0	17
Concentrate feed mixture (CFM)	70	39
Berseem hay	20	20
Total	100	100
Calculated chemical composition (%, on DM basis)		
Ash	8.8	9.5
Crude protein (CP)	18.6	18.8
Ether extract (EE)	2.6	2.4
Crude fiber (CF)	15.3	14.4
Nitrogen free extract (NFE)	54.7	54.9

2.3.3. With Friesian calves

An on-farm trial was conducted at Kafr-El Sheikh governorate using growing Friesian calves. The average daily weight gain was determined after 240 days of feeding with a ration containing either 10 or 20% PW.

2.3.4. With buffaloes

Experiments carried out at Milk Replacer Research Center, Faculty of Agriculture, Ain Shams University focused on some reproductive traits of buffalo heifers. Radioimmunoassay of milk/plasma was used to determine the progesterone concentration for detecting non-pregnancy and ovulation, amongst other reproductive parameters.

A feeding trial on buffalo calves to determine the effect of PW as a dietary supplement on average daily gain, was carried out in a farm in Sharkia province.

2.3.5. Acceptance by end users of poultry waste in their animal feeding system

Sarkia governorate, 100 km from Cairo, was chosen for assessing the acceptance by farmers of PW as a dietary supplement in ruminant rations. The farmers were classified into three categories based on their ownership of cattle and/or buffaloes. They were requested to respond to a questionnaire.

3. RESULTS

3.1. Chemical composition and mineral content of poultry waste (PW)

The average chemical composition and the mineral content of sun dried samples of PW collected from the three locations is given in Tables III and IV. The crude protein equivalent was similar and ranged from 19–23%. However, the ash content was relatively high in samples from location 1 (Table III).

3.2. Pathogenic microorganisms and aflatoxin concentration

The total bacterial count (CFU/g) of sun dried PW was 174.6×10^4 while that of the oven dried PW was 508.9×10^4. Salmonella and E.coli were not detected in both sun dried and oven dried PW.

Aflatoxin G_1 was found in both sun and oven dried PW (109.5 and 132.3 ng/g, respectively) while B_1, B_2 and G_2 were not detectable.

TABLE III. CHEMICAL COMPOSITION OF POULTRY WASTE USED IN THE FEEDING TRIALS

Location	DM (%)	OM	CP	EE	CF	NFE	Ash
		(% IN DM)					
1	90.5	41.3	19.4	1.2	8.1	42.6	28.7
2	94.5	81.0	20.2	3.3	12.7	45.0	19.0
3	88.0	85.4	23.0	-	-	-	14.6

Locations: 1. Faculty of Agriculture, Ain Shams University.
2. Sakha Agriculture Experiment Station, Animal Production Institute, Ministry of Agriculture.
3. Agriculture Experiment Station, Radioisotope Application Division, Atomic Energy Authority.

TABLE IV. THE MINERAL CONTENT OF POULTRY WASTE

Location	1	2	3
Percentage			
P	na	2.11	1.93
Ca	na	3.1	6.5
Na	na	0.44	0
K	na	2.08	1.78
Mg	na	0.52	0.44
Zn ppm	na	158.2	338
Cu PPM	27.05	38.8	123
Fe PPM	na	1422	na
Mn PPM	na	158	na
Pb PPM	10.7	7.7	na
Cd PPM	0.15	0.97	na
Cr PPM	na	0.93	na
As PPM	308.2	na	na

Locations: 1. Faculty of Agriculture, Ain Shams University.
2. Sakha Agriculture Experiment Station, Animal Production Institute, Ministry of Agriculture.
3. Agriculture Experiment Station, Radioisotope Application Division, Atomic Energy Authority.
na — data not available.

3.3. Feeding Trials

3.3.1. With Sheep

Milk production in ewes and the productive performance of suckled lambs are presented in Table V. There was no significant difference between the diets in terms of milk production and feed conversion efficiency in lactating ewes, and age at weaning and average daily body weight gain in the suckled lambs.

3.3.2. With male lambs

The age and weight at puberty and mean daily gain of male lambs fed a diet containing 17% PW is given in Table VI. There was no significant difference between the two diets in relation to age at weaning and weight at weaning. The average daily body weight gain was higher in the PW supplemented group as compared to the non-supplemented group, though this difference was not statistically significant ($P < 0.05$).

3.3.3. With buffalo and Friesian calves

Both buffalo and Friesian calves supplemented with diets containing PW showed similar daily body weight gain as compared to the control ration without PW, indicating its the supplementary feeding value (Table VII). Similarly, PW supplementation had no significant influence on reproductive parameters, including the plasma progesterone profiles, of buffalo heifers as compared to the control diet (Table VIII).

3.3.3. Acceptance of poultry waste by farmers

Of the 30 smallholder farmers interviewed none used PW as a feed supplement. Only 20–30% of the medium (4–10 animals) and large-scale (over 10 animals) farmers used PW as a feed supplement. However, they all used it as a fertilizer for crop production.

TABLE V. EFFECT OF DIET CONTAINING POULTRY WASTE (PW) ON DRY MATTER INTAKE (DMI) AND MILK PRODUCTION IN EWES AND PERFORMANCE OF SUCKLED LAMBS

Parameter	Control	PW Diet
Percentage of PW	0	14
DMI		
g per head/day	1346.90	1369.77
g/kg LW/day	31.38	30.90
g/unit MBS	80.32	79.73
Milk production		
g per head/day	660.37	740.58
g/kg LW/day	15.39	16.71
g/unit MBS	39.38	43.11
Feed efficiency		
kg DMI/kg milk yield	2.04	1.85
Performance of lambs		
Birth Weight (kg)	3.84	3.80
Weaning Weight (kg)	20.58	20.18
Age at Weaning (days)	87.7	79.9
Average daily gain (g)	191	206
No. of kg weaned/kg LW of ewe	0.48	0.53
No. of kg feed/kg weaned weight	5.73	4.65
Mortality	0	0

DMI = dry matter intake; LW = live weight; MBS = Metabolic Body Size

TABLE VI. AGE, WEIGHT AT PUBERTY AND DAILY BODY WEIGHT GAIN OF MALE LAMBS FED A RATION CONTAINING POULTRY WASTE (PW)

Item	Experimental diets	
	Control diet	PW diet
Percentage of PW	0	17
Number of days on feeding trial	224	224
Age at puberty (days)	311.5	286.0
Weight at puberty (kg)	36.4	40.9
Mean daily gain (g)	129.4	164.7

TABLE VII. AVERAGE DAILY BODY WEIGHT GAIN OF FRIESIAN AND BUFFALO CALVES FED DIETS CONTAINING POULTRY WASTE (PW) FOR 240 DAYS

	Level of PW	Initial weight (kg)	Final weight (kg)	Daily weight gain (g/day)
Friesian	0	180	381.7	840
Calves	10.1	179.5	375	815
	20.5	179	379.8	837
Buffalo	0	110	215	438
Calves	15	89	182	388

TABLE VIII. REPRODUCTIVE PERFORMANCE OF BUFFALO HEIFERS ON A SUPPLEMENTARY DIET CONTAINING POULTRY WASTE (PW)

Parameter	Control Group	PW Group
No. of ovulations/conception	3.25 ± 0.9	3.25 ± 1.0
No. of 'silent' ovulations/conception	2.00 ± 0.7	1.50 ± 0.8
No. of ovulations associated with heat/conception	1.25 ± 0.2	1.75 ± 0.3
No. of services/conception	1.25 ± 0.2	1.50 ± 0.2
Age at first ovulation (months)	17.2 ± 0.3	17.7 ± 0.4
Weight at first ovulation (kg)	316.0 ± 10.8	330.3 ± 33.8
Age at fertile service (month)	18.6 ± 0.8	19.1 ± 0.5
Weight at fertile service (kg)	340.0 ± 16.0	351.0 ± 12.0
Age of heifers at 1st calving (month)	28.8 ± 0.7	29.3 ± 0.5
Weight of heifers at calving (month)	501.2 ± 16.0	484.6 ± 23.6

4. DISCUSSION

The marginal differences in the nutrient content of poultry waste between the three locations (Tables III and IV) could be attributed to the difference in the type of bedding, degree of contamination between the excreta and the bedding, the type of rations used, method of handling and method of processing and storage of excreta [12].

In relation to the safety aspects of using poultry waste in ruminant diets, the results obtained indicated that sun-dried waste was better than oven dried waste. The total bacterial count was considerably lower in sun dried poultry waste compared to the oven dried waste. This was possibly due to the action of ultra violet rays of the sun affecting the microorganisms. *Salmonella* and *E. coli* were both absent in sun and oven dried wastes. The survival of microorganisms in dietary ingredients varies widely with its moisture content. The higher the moisture content the higher would be the bacterial count. The decrease in viable bacterial cell count noted in dried PW may also be due to a reduction in the moisture content [5].

Aflatoxins were not detectable in the concentrate mixture that contained crushed yellow corn. It has been reported by Jones et al [16] that mixing with poultry waste would destroy aflatoxins in contaminated corn. Therefore, it is apparent that even if aflatoxins were present in the crushed yellow corn it would have been destroyed by the PW.

Both feed intake and milk production in ewes (Table V) was not affected by the inclusion of 14% PW as a dietary supplement. This is a clear indication that cottonseed meal and other high protein feed ingredients could be, at least partially replaced, by PW without any loss in productivity. Part replacement (up to 14%) had no effect on feed efficiency, similar to results obtained with buffaloes [17].

The weight and age at puberty of lambs fed a ration containing 17% PW was similar to those given a control ration without any PW (Table VI). Similarly, PW up to 20% in the diet had no detrimental effect on growth in cattle and buffaloes (Table VII) and on the reproductive performance in buffalo heifers (Table VIII).

The fact that none of the smallholder farmers used PW as an animal feed may be mainly due to its use as a fertilizer in crop production. It may also be due to lack of space for sun drying (over 2 weeks) and a lack of appreciation of its nutritive value as an animal feed.

5. CONCLUSIONS

The establishment of demonstration farms, organising farm visits and setting up discussion groups may be the most effective way of demonstrating to smallholder farmers the beneficial effects of poultry waste as a supplementary feed for ruminant livestock. These should be followed by training of livestock farmers and agriculture extension personnel, in the preparation and proper use of poultry waste in ration formulation. The collection of poultry wastes at different locations and subjecting them to suitable treatment also need to be accomplished.

The economical aspects in the use of poultry waste as a dietary supplement in ruminant rations in Egypt may be viewed as follows. The inclusion of 15% poultry waste would cost 24 Egyptian ponds. It would save the cost of 15% of concentrate in the feed mixture, amounting to 75 Egyptian pounds. The difference per ton will be about 51 Egyptian pounds. In other words, poultry waste mixed concentrate feed will cost about 10% less than the cost of a ton of concentrate feed presently available in the market.

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THE ECONOMICS OF FEEDING CONCENTRATE TO PARTIALLY-MILKED SANGA COWS IN THE DRY SEASON

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Abstract

THE ECONOMICS OF FEEDING CONCENTRATE TO PARTIALLY-MILKED SANGA COWS IN THE DRY SEASON.

An experiment was carried for 120 days during the dry season of 1998/99, to assess the sustainability of dry season feed supplementation in an emerging peri-urban dairy production system in the Kumasi district of Ghana. Fifty three Sanga cows were divided into four treatment groups T1, T2, T3 and T4, and were fed 0, 1, 1.5 and 2 kg respectively, of a home-made concentrate supplement containing 18% crude protein. The treatment groups contained 12, 14, 12 and 15 cows, respectively. The cows were milked once a day in the mornings and allowed to suckle during the day. Daily partial milk yield was 1.7, 2.1, 2.6 and 2.7 L for cows supplemented with 0, 1, 1.5 and 2 kg concentrate, respectively. Cows fed 1.5 kg concentrate generated the highest net income from milk sales. They produced 53% more milk and 16% more milk revenue than the control cows. Their-daily partial milk yield was not significantly different ($P > 0.05$) from that of cows fed 2 kg concentrate supplement, but was significantly higher ($P < 0.05$) than that from other groups. It was found that feeding 2 kg concentrate supplement a day to Sanga cows in the Kumasi district may not be economical even though milk yield may be increased. It is suggested that given the large variability observed in individual cow performance, selection of more productive cows or culling of less productive ones could be used in conjunction with feed supplementation to improve the productivity of Sanga cows in less endowed environments.

1. INTRODUCTION

Most farmers in the Kumasi district of Ghana are crop farmers. In recent years, however, many of them have started rearing animals on a commercial basis, even though most of the animal enterprises in the district remain sideline activities. Cattle rearing is now becoming popular with many traders and office workers as well.

The cattle are often left in the care of hired labour, usually Fulani herdsmen. The owners usually consider cattle rearing as an additional business, which becomes important only if their main businesses run down or after their retirement from office work. They, therefore, resort to a low-input-low-out put production system and do not spend much money to improve the productivity of the animals, which is usually low.

In Ghana, the objectives of the cattle improvement programme have been to seek improvement in production of meat, manure and draught power. Milk production on any scale has never been considered to be of prime importance. The demand for milk and milk products has, however, been growing over the years due to increased urbanization. In certain communities the demand for animal protein is so high that even hides are consumed. The cattle herds in the Kumasi area are usually a combination of the West African Shorthorn (WASH), N'Dama, Sanga and Zebu types. At present most cattle in the Kumasi district are not milked. Those milked produce very little because they are essentially of beef type and are also not fed well during their lactation period. Total milk sales could however be high for herds which could easily sell milk to the Kumasi city. It is believed that substantial amounts of money could be realized from local milk production if farmers would properly feed their cows and milk them.

The N’Dama and West African Shorthorn are reported to produce between 120 and 360 litres of milk per lactation, which usually lasts between 120–300 days. The two Zebu breeds, Sokoto and White Fulani, which are used mostly for crossbreeding in Ghana produce between 450 and 1300 litres per lactation of length varying between 190–360 days [1]. The Sanga which are crosses between the N’Dama or WASH and the Zebu form the bulk of milk-cattle in the Kumai district. While the above figures would be discouraging in Europe, they emphasise the importance of the measures, which could be taken to increase productivity of cattle in Africa. In the interests of the African people and their national economies it is important that African livestock should be improved. The low milk yield of cattle being milked in the Kumasi district means that both the maintenance and production nutrient requirements could be met by feeding good quality grass without concentrate supplements. But the Kumasi cattle are free-range grazers on low quality natural vegetation or scavenges of stubble and crop residues of low nutritional value. Like much of Africa, it is usually difficult to get enough quality feed for the cattle during the dry season in the Kumasi district. Grasses grow rapidly during the rainy season and quickly lose their nutritional value as they advance in maturity [2]. The situation adversely effects productivity and may result in little or no production during the dry season.

Many of the Kumasi cattle owners do not own the land on which they rear their stock. They usually squatter on public land. The number of cattle is rapidly increasing in the area and so is the human population. The result is that grazing areas are being progressively reduced. At the moment farmers are unlikely to be able to raise money to acquire their own farm land in the area, But unless and until the cattle farmers acquire their own land and produce high quality green fodder for their stock, other, perhaps more expensive measures will have to be taken to improve the productivity of the stock, especially during the dry season.

The negative effects of dry season on cattle productivity could be reduced by maintaining small herd sizes, hand feeding calves or feeding edible shrubs or tree branches but such practices are usually uneconomical and cannot move the animal husbandry beyond the subsistence level [2]. One way of improving the performance of grazing cattle during periods of scarcity of feed would be to use concentrate supplementation. The supplements increase the feeding value of the entire diet by direct addition of nutrients over and above supplied by the pasture and other roughages. They usually increase the supply of energy from the roughage due to increased intake and/or digestibility of the herbage on offer [2]. Protein or non-protein nitrogen supplements can also prevent a decline in voluntary feed intake resulting from low protein content in the grazing diet. Improving feeding through concentrate supplementation could therefore, promote the increase in the amount of milk extracted by the stockman for human consumption and that suckled by calf in systems where partial milking is done [3]. It could also put the lactating cow in a relatively good condition, which would enhance reproductive efficiency [4, 5, 6]. Since milk sale is carried out daily and the response to supplementation is almost immediate, feed supplementation strategies could be embarked upon without a large initial capital outlay.

The positive effect of supplementation on milk production has been widely reported [5, 7, 8]. Little et al. [3] reported that cotton seed cake and sesame oil meal fed to lactating N’Dama cows in the Gambia significantly increased milk yield. It has also been reported that the use of supplementary urea molasses blocks during the cold season in China resulted in milk yield increases of 14% in black yak cows and 20% in white yak cows [6]. Concentrates have also been used to achieve improvements in milk yield [9]. However, the low genetic potential of tropical livestock and high prices of grain and oil cakes in many tropical countries call for a careful analysis of the economic implications of concentrate feed supplementation before farmers are advised to resort to such supplementation. The objective of the present study was therefore to assess the economic feasibility of supplementing lactating Sanga cows with home made concentrate during the dry season.

2. MATERIALS AND METHODS

2.1. Experimental site

The experiment, which lasted from November 1998 to February 1999 was carried out at Kentinkrono in the Kuimasi district of Ghana. Kumasi is located at an altitude of about 290 m above sea level and 06°43' N and 01°36' W of the equator. The vegetation is semi-deciduous forest, and the climate is described as hot and humid. The months of November to February inclusive, constitute the dry season. Monthly precipitation drops from November to January and starts to rise in February. The mean monthly precipitation for the dry season months is 42 mm, 23 mm, 5.6 mm and 65 mm for November, December, January and February, respectively. The respective relative humidities were 95, 89, 83 and 41% during the morning (06.00 h) and 57, 50, 40 and 41% during the afternoon (15.00 h). The mean daily temperature for the dry season is about 26°C, but may vary from 18°C in the night to 35°C in the afternoon. The duration of sunshine for the period was about 5.8 h [10].

2.2. Herd management

Sanga cows belonging to two cluster herds were used in this experiment. Each cluster herd comprised of animals belonging to different people, but kept on the same grazing land under different herdsmen. Cows in an area were treated as if they were under one person and distributed among the four treatment groups. All the experimental animals in an area were managed essentially the same way. They were grazed in the same area, usually between 08.30 and 17.00 h. The animals were provided with adequate water both in the morning and in the evening. Breeding was not controlled and occurred throughout the experimental period. Calves were grazed with their dams, although very young calves less than 2 weeks old were not grazed.

All herdsmen practiced partial milking. Under this system calves were separated from their dams in the evening to prevent suckling till the next morning. The calves were brought to suckle for a few minutes to stimulate milk let down before milking. Milking was done only in the morning, usually before 07.00 h. Milking usually started two to three weeks after calving.

2.3. Experimental design and analyses

Fifty-three Sanga cows lactating throughout over a period of four months, from November 1998 to February 1999, were used in the experiment. The cows were in two cluster herds (Herd I and Herd 2) at Kentinkrono in the Kumasi district of Ghana. Cows in each of the cluster herds were grouped into four treatments T1, T2, T3 and T4 in a completely randomized design, which took their body weights into consideration. Treatment groups T1, and T3 contained 12 cows each while T2 and T4 groups contained 14 and 15 cows, respectively. Cows in treatment T1 received no concentrate (control). Cows in treatments T2, T3 and T4 received 1, 1.5 and 2 kg concentrate per animal/day, respectively. The concentrate contained about 18% crude protein and consisted of rice bran (50%), cottonseed cake (30%), maize (16%), common salt (2%) and oyster shells (2%). The mean daily partial milk yield for the week preceding the experiment was calculated for each participating cow and used as a covariant in the statistical analysis. The recording of the daily partial milk yield was continued for each cow throughout the experiment.

Milk samples from individual cows were taken twice a week for progesterone assay. Samples were kept on ice until they were centrifuged in the laboratory at 2,000 *g* in a refrigerated centrifuge (40°C). The skimmed milk samples were kept at –18°C until assayed for progesterone. The FAO/IAEA solid-phase technique [11] was used for the progesterone assay. The intra and inter-assay coefficients of variation were 6.3% and 8.7%, respectively. Progesterone levels >2.0 nmol/L in 2 or more consecutive samples were deemed to indicate ovarian cyclicity. A cow which maintained high (> 2.0 nmol/L) progesterone levels for more than 3 weeks was considered pregnant [12].

The proximate analysis of the concentrate used was determined by the AOAC method [13]. Calves were weighed at the beginning and at the end of the study to estimate body weight gain.

The statistical analyses of the data was carried out using Systat computer statistical package [14]. The data were subjected to analysis of covariance. The terms for the covariance analysis were treatment, herd, treatment × herd interaction and the covariant was initial (first week) partial milk yield. The monthly means for daily partial milk yield were also calculated. Using the technique of regression analysis, the rate of change in monthly milk yield was determined for each cow and then for the treatments and herds. The Pearson chi-square test was used to determine the significance of proportion of cows cycling versus those not cycling as well as pregnant versus empty cows between the treatments.

3. RESULTS

Table I shows the proximate analysis of samples of the experimental concentrate. Results of the covariance analysis are presented in Table II. The overall treatment means for the daily partial milk yields were 2.62, 2.24, 2.14, and 2.24 L for November, December, January and February, respectively. The monthly mean milk yield for treatments in November was significantly ($P < 0.05$) higher than the means for the other months.

Table III presents the rate of monthly milk yield decline according to treatment and herd. The partial milk production and net income derived from the sale of partial milk extracted during the 120-day period are presented in Table IV.

The postpartum ovarian function of the cows and the body weight gain of calves are reported in Table V. Both Pearson chi-square (X2) tests on cows showing cyclic ovarian activity versus those not showing cyclic ovarian activity (X2 = 0.752; DF = 3), and those pregnant versus empty cows (X2 = 0.464; DF = 3) were not statistically significant ($P > 0.05$).

TABLE I. CHEMICAL COMPOSITION OF EXPERIMENTAL CONCENTRATE (ON DM BASIS)

Constituent	Percent
Crude protein (CP)	18.1
Ash	10.3
Acid detergent fibre (ADF)	40.9
Neutral detergent fibre (NDF)	48.8
Ether extract (EE)	5.7

Dry matter (DM) of the concentrate was 91.3%.

TABLE II. MEAN DAILY PARTIAL MILK YIELD OF SANGA COWS FED VARYING LEVELS OF CONCENTRATE SUPPLEMENT FOR 120 DAYS

Category	LS Mean (L)*	SE	n
Treatment			
T1	1.71^{a}	0.11	12
T2	2.14^{b}	0.10	14
T3	2.61^{c}	0.11	12
T4	2.70^{c}	0.10	15
Herd			
1	2.28	0.10	22
2	2.30	0.10	31
Treatment × Herd			
T1 × Herd 1	1.8	1.6	5
T1 × herd 2	1.6	1.4	7
T2 × Herd 1	2.1	1.5	6
T2 × Herd 2	2.1	1.3	8
T3 × Herd 1	2.6	1.6	5
T3 × herd 2	2.7	1.4	7
T4 × Herd 1	2.6	1.5	6
T4 × Herd 2	2.8	1.2	9

*Treatment means with different superscripts are significantly different ($P < 0.05$).
SE = Standard Error; n = Number of observations.

TABLE III. RATE OF DECLINE IN MONTHLY MILK YIELD

Category	LS Mean	SE	n
Treatment			
T1	–0.167	0.069	12
T2	–0.143	0.064	14
T3	–0.112	0.069	12
T4	–0.064	0.062	15
Herd			
1	–0.103	0.051	22
2	–0.140	0.043	31

SE = Standard Error; n = Number of observations

TABLE IV. ESTIMATED MEAN SALEABLE MILK PRODUCTION AND INCOME GENERATED BY SANGA COWS FED VARYING LEVELS OF CONCENTRATE SUPPLEMENT FOR 120 DAYS

Treatment	Estimated milk production (L) mean ± SE *	Cost of feed +	Net income from milk ++	n
T1	203.4 ± 12.5^{a}	0	162,720	12
T2	256.9 ± 11.6^{b}	42,000	163,520	14
T3	314.3 ± 12.5^{c}	63,000	188,440	12
T4	326.0 ± 11.2^{c}	84,000	176,800	15

Means with different superscripts are significantly different ($P < 0.05$); * SE = Standard Error; n = Number of observations; + 1 kg of feed cost Cedis 350.00 (US$ 0.15); ++ I L of milk was sold for Cedis 800.00 (US$ 0.35).

TABLE V. POSTPARTUM OVARIAN ACTIVITY OF COWS AND CALF WEIGHT GAIN WHEN FED VARYING LEVELS OF CONCENTRATE SUPPLEMENT FOR 120 DAYS

Treatment	Percentage showing ovarian activity	Percentage confirmed pregnant	Calf weight gain (kg)	n
T1	83.3	75.0	41.5	12
T2	92.9	78.6	44.9	14
T3	91.7	83.3	46.7	12
T4	86.7	73.3	45.4	15
Overall	88.7	77.4	44.7	53

4. DISCUSSION

The level of partial milk yield obtained in the present study is higher than that (1 L) reported by Ofori [15] for mix herds of local beef cattle in the same district. However, if one assumes that feed protein requirement is 1.25 times the milk protein [16], then one would expect, at least, the cows in T4 group to produce more milk than they did, assuming that the afternoon milk suckled by the calves equaled the morning milk extracted by the herdsmen. Looking at the good condition of the cows during the experiment, one cannot say that energy was limiting in their diet. The problem of the limited effect of the supplementation may be that the Sanga cow partitions less of its energy for milk production. The fact that supplemented cows produced significantly ($P < 0.05$) more milk than non-supplemented cows suggests the need for improved feeding of lactating cows in the area during the dry months. The significantly higher milk yield at the commencement of the dry season in November suggests that feed availability and/or quality may be better during the rainy season. Lactating Sanga cows may therefore need little or no concentrate feed in the rainy season.

The results suggest that 1.5 kg of concentrate per day (treatment T3) containing 18% CP may be the most economically viable level of supplementation for Sanga cows in the Kumasi district (Tables II and IV). The daily partial milk yield of 2.6 L produced by cows in treatment group T3 was not significantly different from the 2.7 L produced by cows in T4 group, but was significantly higher ($P < 0.05$) than the 1.7 L and 2.1 L produced by those in treatments T1, and T2, respectively. The T3 cows also produced the highest net income from milk sales (Table IV). T1 cows generated about Cedis 40 600/month (US$ 17.7) while T3 cows generated about Cedis 47 000/month (US$ 20.4). Each T3 cow, therefore, generated an additional Cedis 6,400 (US$ 2.8) per month compared to non-supplemented (T1) cows. The T3 cows produced 53% more milk and gained 16% more revenue from milk than their T1 counterparts. The importance of both milking and feed supplementation in the economics of cattle production in the Kumasi district can, therefore, not be over emphasised. One other factor worthy of note is the finding that feeding 2 kg/day of a concentrate containing 18% CP to Sanga cows may not be economical in the Kumasi area even though it may increase the quantity of milk for the market. The study has also shown that the present plane of nutrition is inadequate even for a low milk producing cow like the Sanga to realize its potential in the dry season. It would, therefore, seem unwise to import high yielding dairy cattle from Europe to the area if the feed situation cannot be markedly improved. The high producing, early maturing European breeds require a high plane of nutrition, which is very difficult to provide under tropical conditions, and in any case environmental conditions are likely to interfere with the conversion of feed even if adequate standards can be maintained.

The trend of the present results was expected as higher levels of nutrition allow for higher percentages of nutrients to be available for milk production. This is because maintenance requirements of a cow are roughly proportional to her body weight, but remain fairly constant regardless of the level of milk production. The raw materials from which milk constituents are derived, and the energy for the synthesis of some of these in the mammary glands, are supplied by the feed. The actual requirement for feed therefore depends upon the amount of milk being produced and upon its composition [16]. A cow fed at a higher plane would, therefore, be expected to produce more milk. It could be deduced from the present results that substantial amounts of money could be realized if the partial milking system is encouraged and a market found for the extracted milk.

From the study a Sanga cow supplemented with 1.5 kg/day of a concentrate containing 18% CP could generate about Cedis 320 000 (US$ 139) net income from milk every year, if a 200-day milking period is assumed. The effect of dairying on the local economy could, therefore, be enormous if all cows in the district were properly fed and milked. A greater part of the potential revenue from milk is lost to the economy because many local farmers are not interested in milk production. A campaign to bring to the fore the profitability of peru-urban dairying is therefore advocated. The fact that inadequate feeding could hamper profitable dairying also needs to be stressed. Table III confirms that cows are more persistent in milk production if feeding is improved. It is possible that apart from improving milk yield, the duration of milk production may also be prolonged by proper feeding of lactating cows under the partial milking system [17]. Even though supplemented cows did not show statistically significant reproductive performance ($P > 0.05$) in the present study, some earlier reports have shown that supplemented cows can have superior performance [3, 5, 7, 8].

The large variability in performance observed among individual cows suggests that selection of more productive cows or culling of less productive ones in conjunction with feed supplementation could be used to significantly enhance the productivity of Sanga cows in less endowed environments. It is suggested that to be able to develop the Sanga cow so as to be able to determine with any degree of accuracy its true productive potentiality, the primitive trait connected with the temperamental function of milk let down should be overcome. In this way milking would be less cumbersome in the Sanga cattle and more farmers could easily be convinced to participate in the emerging peri-urban dairying in Ghana.

5. CONCLUSIONS

It is concluded that with proper feeding of lactating cows and education of farmers, peri-urban dairying could be a significant component of the agricultural economy of the Kumasi area. A sustained means of information dissemination is considered vital for the growth of the emerging dairy industry in the area. It is therefore, suggested that farmers should be encouraged to form and sustain their own trade associations which could raise funds to ensure that member farmers receive vital information for their efficient operation. The associations could raise substantial amounts of money for their work by engaging in the supply of inputs like feed supplements, drugs and proven bulls or semen and artificial insemination (AI) services. They could retail the produce of member farmers in the form of a cooperative organization to help pay for the items and services offered to them.

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RESPONSES TO DRY SEASON SUPPLEMENTATION BY DAIRY COWS ON THE HIGHLAND ZONES OF MADAGASCAR

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Abstract

RESPONSES TO DRY SEASON SUPPLEMENTATION BY DAIRY COWS ON THE HIGHLAND ZONES OF MADAGASCAR.

Three feeding trials were conducted to evaluate the effect of different feed supplements on the productivity of dairy cows. The trials were conducted in 49 farms located in the Highland zones of Madagascar and comprised of 143 crossbred cows. Milk yield was recorded daily and live weight was measured at the beginning and end of each experiment. Progesterone concentration was measured in milk samples taken regularly for investigating post partum ovarian function. Milk production estimates were evaluated through regression analysis. The daily consumption of 0.6 kg urea-molasses minerals blocks (UMMB) resulted in an additional 30 to 55% milk production during the dry season. The nature of the supplemental feeds had no major effect on the onset of ovarian activity, which ranged from 28 to 95 days after calving. An economic analysis showed that the use of UMMB in addition to the usual concentrates was profitable to the dairy farmers.

1. INTRODUCTION

Dairy farming is a major agricultural activity providing additional income to farmers in the Malagasy highlands. There is also an increasing demand for milk as a result of urbanization and increasing population growth. Small scale rice-dairy farming is the predominant production system in the highlands of Madagascar [1].

Among the many problems faced by these dairy farms, scarcity of feed ingredients and their high prices are considered to be of major importance. In the conditions of the Highland Zones of Madagascar the increasing pressure on land to grow food crops and the ever expanding human population has resulted in a reduction in grazing land. Therefore, there is a need for smallholder farmers to be aware of the most efficient combination of roughages and concentrates for year round production.

This paper reports experiments in which dairy cows were given different feeds in order to increase milk performance, improve body condition score, evaluate the impact on postpartum cyclicity and evaluate the economic implications of supplementation.

2. MATERIALS AND METHODS

Three experiments were conducted on 49 farms during the dry seasons of 1997, 1998 and 2000. These farms are located in the peri urban zones of Antananarivo (latitude 18°55' S, longitude 47°3' E, altitude 1381 m) and Antsirabe (latitude 19°52' S, longitude 47°01' E, altitude l506 m). In these regions the climate alternates between a warm rainy season (November to May) and a cool dry season (June to October). Rainfall is unimodal, with a mean annual rainfall averaging 1360 mm and 1432 mm in Antananarivo and Antsirabe respectively.

Experiment I was carried out from July to November 1997 in the peri-urban zones of Antananarivo and Antsirabe. A total of 76 cows received one of the 3 supplement feeds already being used by the farmers: concentrates, groundnut seedcake, or fodder radish *(Rapharus sativa).* Cows were included in the experiment as soon as they had calved and the experiment continued for 10 weeks. The supplement level varied from 3–5 kg/cow per day for the concentrates, 1–4 kg groundnut seed cake and 10–15 kg of cultivated fresh fodder radish/cow per day. Most of the cows were stallfed and received a combination of hay and fresh forages as their basic diet.

Experiments 2 and 3 were conducted during dry seasons in 1998 and 2000 in the periurban zones of Antananarivo. Concentrates are mainly home made by participant farmers. Cows were supplemented with concentrates alone (2–6 kg/day) or a combination of concentrates (2–4 kg/day) and a compound of mixture of urea, molasses and minerals as a block (UMMB) [2, 3]. The latter was incorporated at the rate of 0.6 kg/cow per day. The UMMB consisted of 42% of molasses, 9% urea, 5% salt, 15% cement and 29% rice bran. Each block weighed approximately 1.2 kg. This was easy to transport and within the farmer's purchasing power.

Cows were milked by hand twice daily: in the early morning and in the evening. Milk yields were recorded daily by the farmers themselves and the data were collected every 1 or 2 weeks. The live weight (measured by using an electronic scale; True-Test, New-Zealand) and body condition score (BCS: 1–5 scale) were assessed before the distribution of the supplements and at the final visit to the experimental cows.

Milk samples were taken weekly from day 25 post partum until the animals were observed to be cycling or until day 120 postpartum. Progesterone concentrations were measured by radioimmunoassay (RIA) technique using a kit provided by the joint FAO/IAEA Division (Vienna, Austria). A cow was considered to be cycling when progesterone concentrations were equal or more than 1 ng/ml in two or three consecutive samplings.

Data were analysed by analysis of variance and regression equations (Microsoft Excel) were used to determine the rate of decline in milk production to modelize and predict the production in cases where the groups to be compared had the same initial level of production. (Jayasuriya 1999, personal communication). Benefit:cost ratio was calculated to assess the economical profitability of supplementation [4].

3. RESULTS

The crude protein (CP) and crude fibre (CF) content of feeds used in the experiments are shown in Table I. During the experimental period, no cows suffered of any major disease.

3.1. Milk production and live weight gain

3.1.1. Experiment 1

For each cow, experiment lasted from July to November 1997. The results presented in Table II show two different cow populations. Cows from Antsirabe have a higher production as they are a high-grade crossbred derived from the Norwegian Red breed, and those raised in Antananarivo are a mixture of different crosses from French Friesian and Normande breeds.

At Antananarivo, supplementation seemed to have no significant impact on milk production. At Antsirabe, the rate of decline in milk production was higher for cows fed the concentrates than for those on fodder radish. Assuming that the curves have the same origin the milk production from the radish group was 6% higher than for the cows receiving only concentrates.

3.1.2. Experiment 2

The experiment was conducted using two different production systems. An institutional farm was used as a control group where only concentrate (4–6 kg/cow per day) was used as the supplement. The UMMB was distributed in small farms and each cow received daily 0.6 kg of UMMB, in addition to 2–5 kg/cow per day of concentrate.

The two groups were different in term of production. But when comparing the rate of decline in milk production (Figure 1), the best-fit curves were polynomial (Table II). Assuming that the initial production is the same for the two populations, the results show that cows receiving concentrates and UMMB give 53.5% more milk than those fed on concentrate alone (Table III)

TABLE I. THE CHEMICAL COMPOSITION OF FEEDS GIVEN TO EXPERIMENTAL ANIMALS

Type of feed	DM	CP	CF
		(% DM)	
Natural pasture (dry season)	56.8	7.1	31.5
Oats	22.2	12.4	30.6
Fodder radish	7.7	20.1	15.1
Concentrates	90.7	12.8	6.3
Groundnut seedcake	90.1	44.8	7.4
Urea-Molasses-Block	85.2	40.8	5.2

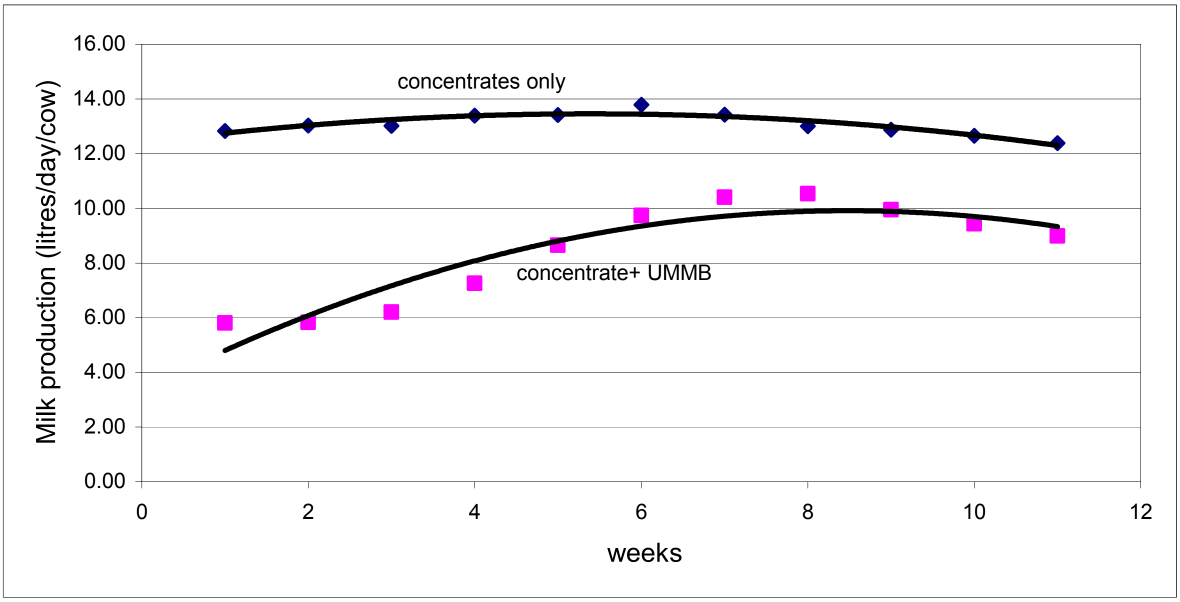

FIG. 1. Milk production of cows receiving only concentrates or a combination of concentrates and UMMB for 11 weeks during the dry season at Antananarivo (Experiment 2).

TABLE II. EFFECT OF SUPPLEMENTATION ON LIVE WEIGHT, LIVE WEIGHT GAIN AND MILK PRODUCTION

Experiment, Location, Supplement & Feed used	Number of cows	Mean body weight (kg)	Body weight gain (kg)	Mean daily milk production (litres)	Regression equations related to milk production	R^2
Experiment I (Antsirabe and Antananarivo)						
Antsirabe						
Fodder radish	10	469.0 ± 38.2	10.5 ± 7.9	20.3 ± 4.4	$Y = -0.0181X + 20.4$	0.33
Concentrate	22	432.2 ± 40.4	8.0 ± 8.4	14.6 ± 4.0	$Y = -0.2359X + 17.7$	0.85
Antananarivo						
Concentrate	20	429.0 ± 42.3	2.8 ± 3.8	9.7 ± 2.4	$Y = -0.1103X + 10.3$	0.72
Groundnut cake	24	406.5 ± 48.9	4.1 ± 5.3	7.2 ± 5.1	$Y = -0.1713X + 8.13$	0.94
Experiment II (Two production systems)						
Control Group (Concentrate only)	22	410	-	13 ± 5.3	$Y = -0.0351X^2 + 0.38X + 11.0.8$	0.85
Supplemented Group (Concentrate + UMMB)	22	387	-	8 ± 3.4	$Y = -0.0913X^2 + 1.54X + 3.34$	0.88
Experiment III (Peri-urban zones of Antananarivo)						
Concentrate	9	375	20.0	9.65 ± 2.79	$Y = -0.0235X^2 - 0.0476X + 12.55$	0.94
Concentrate + UMMB	14	396	23.0	10.82 ± 4.14	$Y = -0.0189X^2 + 0.2081X + 10.90$	0.90

Y = litres/day; X = weeks

TABLE III. MILK PRODUCTION ESTIMATED FROM REGRESSION CURVES, ASSUMING REGRESSION CURVES HAVE THE SAME ORIGIN

Supplement feed	Milk Prediction curves	Predicted milk production (litres)	Increase (%)
Experiment II (Experimental period of 11 weeks)			
Concentrate alone	$Y = -0.0351x^2 + 0.3783x + 11.8$	638.5	
Concentrate + UMMB	$Y = -0.0913x^2 + 1.5485x + 7.0$	980.0	53.5
Experiment III (Experimental period of 17 weeks)			
Concentrate alone	$Y = -0.0235x^2 + 0.0476x + 11$	1041	
Concentrates + UMMB	$Y = -0.0189x^2 + 0.208lx + 11$	1373	32

Y = litres/day; X = weeks

3.1.3. Experiment 3

This trial was also conducted in the peri-urban zones of Antananarivo. The main difference when compared to Experiment 2 was that both groups were from smallholder farms. Results presented in the Table II shows that the rate of decline in milk production (Figure 2) was higher with the group receiving concentrates only. Assuming that the daily initial production was 11 litres, the prediction curve estimates that total milk production during the 17 weeks would have been 1373 and 1041 litres for the cows given concentrate + UMMB and concentrate only, respectively (Table III). The UMMB supplementation resulted in a mean gain of 2.8 litres of extra milk per day.

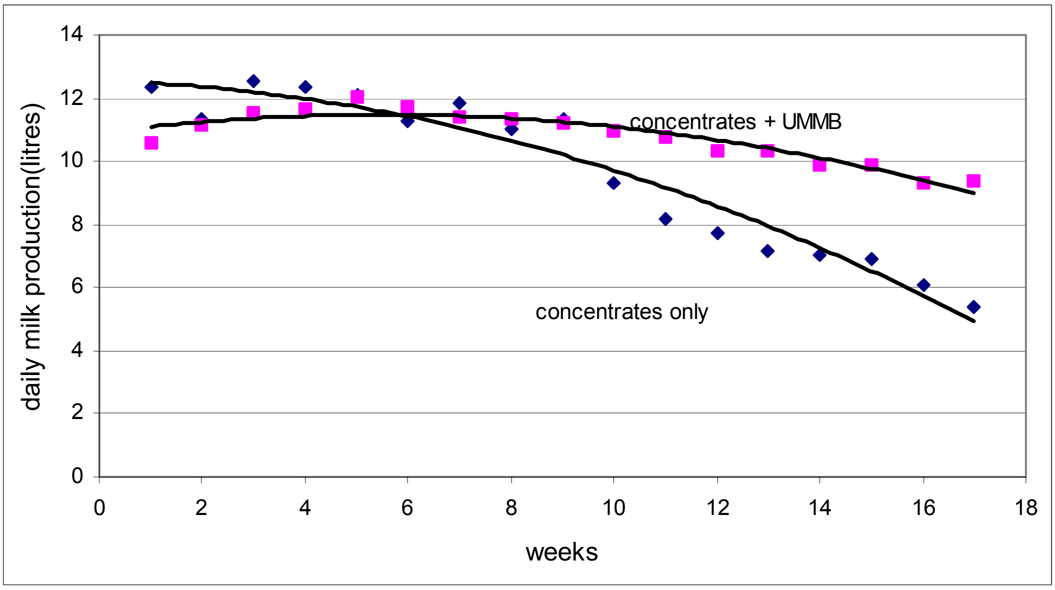

FIG. 2. Milk production of cows receiving only concentrates or a combination of concentrates and UMMB for 17 weeks during the dry season at Antananarivo (Experiment 3).

3.2. Post partum ovarian function

Both Experiment II and III results showed that there was no significant difference between the different types of supplements on the time taken for the manifestation of first oestrus from the time of calving. This interval ranged from 28 to 95 days.

3.3. Economical analysis

Benefit:cost analysis was used to evaluate the profitability of supplementing dairy cows in the smallholder farms. Considering the present cost of feed and the market price of milk, UMMB supplementation appears to be both economical and cost effective (Table IV).

TABLE IV. INFLUENCE OF TYPE OF SUPPLEMENT ON THE BENEFIT:COST RATIO AND THE BENEFIT (US $) PER LITRE OF MILK SOLD

	Concentrate alone		Concentrate + UMMB	
	Expt. 2	Expt. 3	Expt. 2	Expt. 3
Benefit:Cost ratio	2.07	2.20	5.00	4.4
Benefit/litre of milk sold (US$)	0.30	0.30	0.37	0.36

4. DISCUSSION

Constraints which limit the productivity of dairy cows under tropical conditions are multi-factorial [5, 6]. On-farm experiments presented in this paper show positive effects of supplementation on milk production.

In the first trial, there were more than 40 cows initially identified in the radish group. But 34 weeks later the radish supplement was no longer available. Cultivating and distributing fodder radish during the dry season may be a promising way of increasing the quality of dairy cow rations. The limiting factor is the availability of land for cultivating this forage in sufficient quantity for use during the dry season.

The other supplements are available all year round but they are more expensive. It is worth noting that feeding of concentrates, groundnut and cotton seed cakes are readily adopted by farmers who are principally limited either by their purchasing power, or by the availability of land for cultivating fodder radish.

In terms of production, supplementary feeding increases milk production by up to 55%. Regression analysis indicated that lower the initial milk production, the greater is the effect of supplementation. This study also showed that during the dry season, crude protein levels in pasture may fall below the 60 g/kg DM required for grazing animals, for meeting their maintenance requirement [7]. In this context, the supply of concentrates and particularly UMMB could be a very effective way of maintaining milk production especially during the dry season [8, 9].

The measurement of milk progesterone provides a better understanding of the onset of the ovarian activity. The observed mean calving to first ovulation interval showed a normal ovulatory oestrus within 60 days. However, most farmers prefer to wait for 90 days or more to carry out the first service, which is mostly by natural mating. This is a major reason why the mean calving interval of Madagasy cattle is around 418 days (n=200) [10], although the most economical inter-calving interval would be 12–13 months [12].

Strategic supplementation is already well proven and practiced by many farmers, but the extension services need to place more emphasis on the observation of post partum oestrus. These data and those which are continued to be recorded are important and they will be combined with the results of various surveys conducted in the Highland Zones of Madagascar within an integrated approach and for developing in the near future a decision support model that can be used by extension services and policy makers.

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POTENTIAL OF FODDER TREE/SHRUB LEGUMES AS A FEED RESOURCE FOR DRY SEASON SUPPLEMENTATION OF SMALLHOLDER RUMINANT ANIMALS

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Abstract

POTENTIAL OF FODDER TREE/SHRUB LEGUMES AS A FEED RESOURCE FOR DRY SEASON SUPPLEMENTATION OF SMALLHOLDER RUMINANT ANIMALS.

Fodder tree/shrub legumes have the potential for alleviating some of the feed shortages and nutritional deficiencies experienced in the dry season on smallholder farms. Zambia has a wide range of naturally occurring tree/shrub species that can be used as fodder for ruminants. Over the years a number of trees have been selected for their agronomic qualities and are currently being used in arable farming systems to promote soil fertility and erosion control. There is a need to evaluate them for use as fodder for ruminants in the dry season. Because of their high content of protein, minerals and vitamins and availability in the dry season, fodder tree/shrub legumes have the capacity to complement the feeding of crop-residues and natural pastures. Tree/shrub legumes also have other advantages in that they are available on-farm and can also be used as a source of food, timber and medicines at village level. Being deep rooted, fodder trees are rarely affected by seasonal climatic changes. The main limitation to their use as a feed resource for ruminants is the high tannin content which may have detrimental effects on the performance of animals. A number of techniques including, wilting, sun-drying, treatment with chemicals and ammoniation have been developed to minimize their adverse effects. Controlled intake through stall feeding or mixing of tree/shrub fodder with basal diets could also be used to mitigate their toxic effects. Research is currently under way to establish rumen microbes that have capacity to detoxify tannins. To promote increased use of fodder trees on smallholder farms, farmers must be provided with information on the good quality fodder trees and the approaches to effectively utilise them. They should also be encouraged to start planting fodder trees in their food crop farming systems or establishing fodder gardens on fallow lands.

1. INTRODUCTION

Nutrition has been documented to be one of the most important factors limiting ruminant production in the traditional smallholder sector of Zambia [1]. This is because ruminant animals in the smallholder sector depend on natural pastures and crop residues for the greater part of the year. During the dry season, the natural pastures and crop residues available for animals after crop harvest are usually fibrous and devoid of most essential nutrients including proteins, energy, minerals and vitamins which are required for increased rumen microbial fermentation and improved performance of the host animal [2]. Inadequate nutrition in ruminant animals has often been associated with heavy economic losses to the farmers because of animal weight and condition losses, reduced reproductive capacity and increased mortality rates. In order to improve the productive and reproductive capacity of smallholder ruminant animals, there is a need to look at ways of extending the availability and quality of feedstuffs produced on smallholder farms. One potential way for increasing the quality and availability of feeds for smallholder ruminant animals in the dry season may be through the use of fodder trees and shrub legumes. Towards the end of the dry season in Zambia, there is usually a substantial amount of green fodder from planted and naturally occurring trees which can be used as a source of feed for smallholder farm animals.

Unfortunately, whilst fodder trees have been used as a traditional supplement to fibrous crop residues in many countries, little has been done in Zambia to promote the use of tree and shrub foliage in overcoming nutritional deficiencies in the dry season. These forages have the potential in alleviating feed shortages experienced in the traditional smallholder sector. This needs to be exploited to re-enforce the achievements that have been made by crop and soil agronomists in establishing leguminous trees and shrubs in arable farming systems as a way of improving soil fertility and maintaining crop yields.

The objective of this presentation is to look at some of the advantages of using fodder trees and shrub legumes as a feed resource for smallholder ruminant animals in the dry season. Some of the factors that have restricted the use of fodder legumes in ruminant animal feeding are also presented. Lastly, an attempt has also been made to identify available technologies that have been developed to minimize the limiting factors and thus promote the use of fodder legumes as a feed supplement in the traditional smallholder sector of Zambia.

TABLE I. IMPORTANT FODDER TREES AND SHRUBS IN ZAMBIA

Local Name	Known Botanical Name
Leucaena	*Leucaena leucocephala*
Mutowa	*Diplorphynchus condylocarporn*
Mulombe	*Pterocarpus angolensis*
Caliandra	*Calliandra calothysursus*
Nyamundolo	*Cajanus cajan*
Kapululambuzi	--
Musamba	--
Mpondo	*Bauhinia petersiana*
Kankande	*Zyziphus Abyssinia*
Makechi	*Cassis siamea*
Chilalampili	*Clerodedrum uninatum*
Thuza	*Flacourtia indica*
Msekese	*Piliostigma thonnigii*
Msolo	*Pseudolachnostylis maproneifolia*
Kalumpangala	*Dichrostachys cinerea*
Kalama	*Combretumfrigrans*
Sesbania	*Sesbania sesban*
Mapoloyakalulu	*Canathium crassum*
Mpovya	*Annona senegalensis*
Mungonondo	*Terminelia sericea*
Mubanga	*Pericopsis angolensis*
Chipembela	*Xeromphis abovata*
Gliricidia	*Gliricidia sepium*

Source : Phiri, D.M. 1996 (personal communication).

2. IMPORTANT FODDER TREE AND SHRUB LEGUMES IN ZAMBIA

Table I shows some of the important trees that have been identified to be potential feed resources for ruminant animals in Zambia. Among these, probably the most familiar ones are *Leucaena leucocephala, Gliricidia sepium* and *Sesbania sesban* which have been established in nearly all parts of the country.

It should be noted that these trees have different agronomic requirements and can be found only in areas where climatic conditions favour their agronomic requirements. Thus, established trees on farm lands will also have different surviving capacities and some tree species may do very well in one part of the country and perhaps not so well in other areas depending on the prevailing climatic conditions and soil fertility. Most of the listed trees are still found in nature and can either be selected for establishment in arable farming systems or may be selectively maintained in natural grazing areas to be used as browse species. It should be noted that nearly all the fodder species currently grown in arable farming systems in Zambia were selected mostly to improve soil fertility or prevent environmental degradation through reduced soil erosion. Characteristics often considered for such purposes usually include factors such as establishment or growth rates, promotion of soil fertility, compatibility with food crops and promotion of soil stability. Feeding quality characteristics of generated fodder are given little attention. A very good example for this type of research is the one being conducted at Msekera Regional Research Station in Chipata. A number of farming system research programmes have addressed this problem through intercropping of legumes with cereal food crops to improve soil fertility and maintain crop yields without any use of chemical fertilizers. It is important that the trees that have been selected over years should be evaluated for feeding quality characteristics if they have to be used in feeding ruminant animals. The results from a number of studies have clearly demonstrated the potential of fodder trees and shrubs in meeting nutritional requirements of animals in the dry season. Some of the results are outlined below.

3. NUTRITIONAL CHARACTERISTICS OF FODDER LEGUMES

The composition of common fodder trees and shrubs is shown in Table II. The most important aspect of fodder trees as a source of feed for farm animals is the high protein content which ranges from 14–29%. Some studies have demonstrated a higher protein content of even up to 34% which, unlike in most grass species, does not seem to change with leaf maturity even when they dry and fall off to the ground [3]. The protein content in fodder legumes consist of both soluble and insoluble components and as such is used both as an important source of nitrogen for increased rumen microbial activity and by-pass protein for

TABLE II. CHEMICAL CONSTITUENTS (% IN DM) AND ENERGY (KCal/kg DM) OF SELECTED FODDER TREES AND SHRUB SPECIES

Source	Dry Matter (%)	Crude protein	Fibre	Ash	Calcium	Phosphorus	Energy
Acacia	29.0	15.1	22.6	8.2	1.21	0.06	8.4
Cassava	21.1	24.2	15.6	6.6	2.62	0.22	14.4
Calliandra	26.4	24.0	21.7	8.0	1.6	0.20	12.6
Erythrina	32.0	25.8	17.4	6.7	-	-	14.3
Ficus	17.0	14.0	22.4	5.8	1.31	0.17	12.0
Gliricidia	25.0	14.7	19.9	4.7	1.58	0.29	12.8
Jackfruit	36.6	14.0	22.1	11.5	1.46	0.15	14.2
Leucaena	30.0	22.2	19.6	4.4	0.27	0.12	12.1
Pigeon peas	25.2	22.8	20.1	5.8	0.37	0.17	13.4
Prosopis	23.4	14.0	17.8	6.8	2.73	0.15	11.2
Sebania	18.0	22.6	18.4	9.3	1.48	0.34	13.6
Tamarind	28.0	14.0	21.0	8.6	2.81	0.20	14.4

Source: [6].

supplying amino acids to the lower gut of the host animal [4]. In addition to being a good source of protein, fodder legumes are also an important source of minerals such as sulphur, calcium, copper and iron even though they have been shown to be a poor source of manganese, zinc and phosphorous. The other advantage of using fodder legumes as a source of feed for ruminant animals is that supplementation of forages up to about 35% does not seem to have any effect on the intake of fibrous feed materials. As such the intake of dry matter is often increased by the amount of green fodder given to the animal [2]. The increase in the intake of materials when animals are supplemented with fodder legumes may be due to increased microbial fermentation in the rumen and subsequent higher rate of passage of digesta through the gastro intestinal tract. The dry matter content of most fodder legumes is considerably low and tend to vary with leaf maturity. This has a detrimental effect on the use of fodder trees and shrubs as a source of metabolizable energy for animals especially when compared to grass species. The low metabolizable energy content of fodder legumes is also associated with the high fibre content of these materials which also tend to reduce protein digestibility in these materials [5].

A number of studies have been conducted to evaluate the potential of fodder legumes in promoting different aspects of productivity in animals. Table III shows the effect of fodder legumes *Gliricidia sepium* and *Leucaena leucocephala* in promoting dry matter digestibility of fibrous crop residues in beef animals. As mentioned earlier, both these fodder legumes produced a slight increase in dry mater intake of fibrous crop residues; increase being higher with *L. leucocephala*. The real gain in supplementing animals with fodder trees or shrubs was in the average daily weight gain, which increased with increased levels of green fodder in the diet. Thus, fodder legumes have the potential to increase intake of feed resources and to promote animal weight gain. This is further demonstrated in Table IV which presents comparison of diets supplemented with *G. sepium* foliage or urea-molasses blocks in promoting rumen ammonia production and live weight gains in animals. Again the results show that fodder legumes are comparable to urea-molasses blocks in promoting animal live weight gains in the dry season. Other studies have shown the importance of using fodder legumes in promoting milk production [4, 6]. Thus, it may suffice to say that fodder trees and shrubs have the capacity to promote all aspects of animal production when used as supplements.

TABLE III. DRY MATTER INTAKE (DMI IN kg), DRY MATTER DIGESTIBILITY (DMD IN g/kg) AND AVERAGE DAILY GAIN (ADG IN g/d) OF BEEF ANIMALS WHEN CROP RESIDUES ARE FED AT DIFFERENT LEVELS (g/kg FEED)

Source/levels	0.0	7.5	15	22.5	30
Gliricidia					
DMI	5.2	5.1	5.2	5.4	5.7
DMD	608	610	592	578	606
ADG	306	358	429	371	478
Leucaena					
DMI	5.2	5.8	6.2	6.6	6.7
DMD	598	611	616	616	590
ADG	538	711	719	789	850

Source: [7].

TABLE IV. RUMEN AMMONIA AND LIVE WEIGHT GAIN IN BEEF ANIMALS FED DIETS SUPPLEMENTED WITH GLIRICIDIA GREEN FODDER OR LIQUID UREA-MOLASSES

Supplement	Rumen NH_3 (mg N/L)	Initial weight (kg)	Final weight (kg)	Live weight gain (g/d)
No Supplement	50	194	244	580
Gliricidia	170	204	266	717
Urea-molasses	250	203	269	751

Each supplement was given at 10% of basal diet; source: [3].

4. ADVANTAGES OF PLANTING FODDER TREES/SHRUBS

Unlike other feed resources that may be used on smallholder farms, fodder legumes have a number of advantages in that they are readily available on the farm and can be used for other purposes. Being perennial plants, fodder trees are not susceptible to sudden climatic changes and continue to produce high quality fodder even during drought years when grasses and other annual forages are dry and long gone [8]. Their capacity to grow fast enables them to produce large quantities of biomass, which can be used not only for animal feeding but also as mulch in cropping systems. They are also used to control soil erosion [9]. When intercropped with food crops, fodder legumes do not compete with food crops for nutrients as their deep root system enables them to tap nutrients from the deeper soil layers, which are generally not available for shallow rooted food crops. They also improve soil fertility by fixing atmospheric nitrogen and have other symbiotic relationships, which enhances uptake of minerals such as phosphorus by plants [10]. In the dry season, fodder trees also provide shade to animals and protect them from the hot and dry weather conditions which are common at this time of the year. They are also used as a source of firewood, provide timber for construction and fencing, and function as a hedge around the fields. A number of these trees bare fruits, which are used as a source of food for humans. Others have pharmacological properties and have been used to treat a number of ailments at village level.

5. LIMITATIONS TO THE USE OF FODDER TREES AS A FEED RESOURCE FOR ANIMALS

The main limitation to effective utilisation of fodder legumes as feed for ruminants is the high content of tannins and other anti-nutrients such as saponins, cyanogens, mimosine, coumarins, etc which limit nutrient utilisation [4, 11]. These compounds are also known to have other detrimental effects, which may range from reduced animal performance to neurological effects and increased animal mortality rates [5]. The toxic effects of these compounds depend on their concentration in a fodder species and level of intake of the fodder. The most widely occurring anti-nutrient in plants is a group of polyphenolic compounds commonly called as tannins. Tannins limit animal performance by suppressing intake and digestibility of forages [12]. They bind feed proteins and enzymes to form feed protein-tannin complexes, which are resistant to both rumen microbial and enzymatic degradation. They also lower enzyme activity [13]. These compounds also enhance the loss of endogenous proteins, which affect overall nitrogen metabolism in the animal. It may also be noted that at lower levels (2–4%) of tannins, these could have beneficial effects on ruminant animals -- suppress bloat in ruminants and reduce excess degradation of high quality protein in the rumen. This helps in increasing the amount of rumen undegradable protein, which is finally made available to the host animal for supplying essential amino acids [14].

It must be emphasised that the purpose of pointing out the potential toxic effects of these compounds is to be aware of their presence rather than to discourage the use of fodder legumes by ruminant animals [4]. These compounds will be diluted in the main feed and will rarely exhibit their toxic effects since fodder legumes are generally not used as a sole feed for ruminant animals. It is also important to note that a number of ruminant animals, particularly sheep and goats have capability to adapt slowly to most anti-nutrients. Some possible mechanisms which make these anti-nutrients innocuous are their degradation by rumen microbes, inactivation by endogenous secretions and detoxification by liver [15, 16].

In order to minimise the detrimental effects of tannins and phenolic compounds in fodder legumes, several suggestions have been put forward, some of which can be applied in the traditional smallholder areas. Among these are the post-harvest processing techniques such as sun-drying and wilting of forages before they are fed to animals [17]. Conservation of fodder into bags or ensiling them in silo pits with other feed resources has also proved beneficial in minimising the detrimental effects of tree fodder legumes [18, 19]. Efforts to eliminate the effects of tannins and other anti-nutrients through heat processing have proved unsuccessful [20]. The use of tannin-complexing compounds like the polyethylene glycol has been proved beneficial in some countries [21, 22, 23]. Another approach for enhancing the use of fodder legumes is through mixing of fodder with other feed resources such as crop residues. This helps to dilute the overall concentration of tanniniferous compounds in the diets thereby minimising their effects. The other potential way may be to harvest the legumes and feed to animals in the stall in a controlled manner. Research conducted in Ethiopia and Australia has shown the presence of microbes in the rumen of some animals which have the capability to degrade mimosine to harmless products [24] and these can be successfully transferred to other livestock species [25]. There is a need for researchers to work on this approach so that more microbes may be identified to enhance the utilisation of fodder legumes in ruminant animals.

6. POTENTIAL TECHNOLOGIES FOR INCREASED USE OF FODDER LEGUMES ON SMALLHOLDER FARMS

In order for smallholder farmers to start using fodder legumes as a source of feed for ruminant animals in the dry season, they must be taught to identify important tree species that have the potential to be used as fodder in their localities. There is also a need to propagate selected fodder legumes in arable farming systems. Farmers must be trained to establish trees that have potential as animal feeds in their food crop fields. This may be done through alley planting of trees in cereal or legume fields. This is where lines of fodder trees are inter-spaced within the cropping area. The trees may also be established on farm boarders to form live fences which can be used to protect food crops from animal pests. The other alternative is to have fodder trees planted on contour lines or ridges in which case they will assist in protecting the soil against wind and water erosion. In some parts of Africa, fodder trees are planted in fallow or open lands as a way of reclaiming waste areas and at the same time to obtain fodder for farm animals. This may be done by establishing a three strata fodder production system where improved grass and legume species are planted on the ground with shrub and tree species forming the second and third strata. The aim should be to plant a mixture of grass and legumes species which can be used as a source of quality fodder for animals and of high protein legumes for human populations. The forages generated from such fodder gardens are not only of high nutritive value but also offer diversity to the diet provided to animals in the dry season. The other technique for increasing the use of fodder trees may be through selected removal of trees in the natural pasture and replacing them with fodder species. This will go a long way in promoting browsing in animals and hence the higher and better use of fodder legumes in the dry season. The fodder generated from planted trees may be grazed *in situ* by animals using controlled grazing techniques or may be cut and carried to animals in stalls. This will be determined by the local grazing system preferred by the farmer and also by the availability of labour on the farm. Other technologies that have been developed to enhance the use of fodder trees and shrubs include integrated tree cropping system, agro-forestry systems and food-feed intercropping systems.

7. CONCLUSION

Zambia has a great diversity of trees and shrubs, which can be used, as a source of feed for ruminant animals. A number of these trees and shrubs have been introduced in crop farming systems mostly to assist in maintaining soil fertility and crop yields. Many of these tree species can be used as a source of protein and minerals for ruminant animals, especially in the dry season when the natural pasture and crop residues used are devoid of such nutrients. Presence of anti-nutrients, in particular tannins in fodder trees and shrubs can limit animal performance, particularly when tree/shrub foliages are fed in large quantity. A number of technologies are available that can increase the use of foliage from trees and shrubs. These need to be introduced to smallholder farmers so that they may start using these valuable feed resources for increasing animal productivity.

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ENHANCING THE PERFORMANCE OF CUT-AND-CARRY BASED DAIRY PRODUCTION IN SELECTED PERI-URBAN AREAS OF THE UNITED REPUBLIC OF TANZANIA THROUGH STRATEGIC FEED SUPPLEMENTATION

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Abstract

ENHANCING THE PERFORMANCE OF CUT-AND-CARRY BASED DAIRY PRODUCTION IN SELECTED PERI-URBAN AREAS OF THE UNITED REPUBLIC OF TANZANIA THROUGH STRATEGIC FEED SUPPLEMENTATION.

A survey was conducted in 81 smallholder farms in the peri-urban areas of Morogoro (Site I: n=52) and Dar es Salaam (Site II: n=29). The results showed that food supply was insufficient and of poor quality resulting in the poor performance of cows. In order to investigate the effect of farm-formulated concentrate (FC) or urea-molasses multinutrient-blocks (UMMB) in improving the productive and reproductive performance of dairy cattle, two feeding trials were carried out in 56 farms, 48 at Site I and 8 at Site II. The cost:benefit analysis determined their suitability for incorporation in dry season feeding. The FC was given to 14 farms at Site I (n=37 cows) to be incorporated in the diet of cows at the rate of 0.8 kg per litre of milk produced. The UMMB was tested in 18 farms (14 at Site I and 4 at Site II), fed to 27 cows (18 in Site I and 9 in Site II) at approximately 0.7 –1.0 kg per cow per day. The Control group comprised of 14 farms (10 at Site I and 4 at Site II) with 28 cows (20 at Site I and 8 at Site II). The supplements were introduced to the farms after successful on-station trials for acceptability by dairy cows. Chemical composition and *in sacco* rumen degradability of the major feeds showed low CP content and degradability. Supplementation of forage with FC and UMMB was associated with increased milk production of 1.26 and 1.5 litres per cow/day and BCS and body weight changes of 0.2 and 4 kg and 0.25 and 8 kg, respectively. The improvement in milk yield, BCS and body weight change were significantly different in the UMMB supplemented cows ($P < 0.05$), but were similar in the FC supplemented cows ($P > 0.05$), and the control groups. Both supplementation strategies had no significant effect on reproductive performance. However, there was a slight reduction in the number of days postpartum (DPP) to first progesterone rise (65.3 vs 77.6), DPP to conception oestrus (120.2 vs 128.7), and calving interval (400 vs 414.5 days) in the UMMB supplemented cows compared to non-supplemented control animals. Conception rate improved from 48% in the control cows to 68% in the supplemented cows. Supplementation of dairy cows with FC and UMMB was cost effective when milk production increased by 0.93 and 0.66 litres/cow/day (break even increase) in the respective groups. The increase milk production gave a profit of US$ 0.11–0.29 per cow/day, which was a considerable increase in income in the case of small-holder farmers.

1. INTRODUCTION

Dairy production is an enterprise for smallholder farmers in many parts of the United Republic of Tanzania. Milk production in The United Republic of Tanzania relies partly upon the smallholder dairy sector, which comprises of rural and peri-urban farms. The peri-urban dairying, which is on the increase in recent years, is based on crosses of Zebu and exotic breeds of dairy cattle sustained on zero grazing, on local grasses with limited supplementation. The major forage for the animals during the dry season with all farmers is dry grass and/or maize stover or rice straw. The quality of the feed in dry season is insufficient to support satisfactory milk production and reproductive performance. The poor quality of the feeds render the dairy cows deficient in protein, and therefore do not meet maintenance and production requirements [1, 2].

Farm made concentrates (FC) have been shown to improve smallholder dairy cattle performance [3]. However, farmers rarely supplement their cows with protein concentrates because of the high cost of supplements. The use of UMMB as a supplement during the dry season has shown to increase milk production [4, 5] and improve growth rate in yearling heifers [6].

Milk progesterone determination by radio-immunoassay (RIA), in conjunction with rectal palpation and other relevant farm management records [7] has widespread application in monitoring of the reproduction function and disorders: identifying non-pregnant animals, silent heat, ovarian cyclicity, cystic follicles, retained corpora lutea (CL) and irregular cycles, in different species.

This paper discusses the effects of supplementation using FC and UMMB during the dry season on productivity and reproductive performance of dairy cows in Morogoro and Dar es Salaam municipalities. The cost:benefit analysis of the supplementation was carried out with the aim to determine their suitability for incorporation in dry season feeding of dairy cows.

2. MATERIALS AND METHODS

The study was conducted in two phases (survey and intervention) at two sites (Site I and Site II) during the dry seasons of years 1998 to 2000.

2.1. Survey

Before the beginning of the intervention phase, a brief survey was conducted in 52 farms in Site I and 29 farms in site II, with a major focus on farm management practices, using a structured questionnaire and interviews. At the end of the survey, willing farmers were selected randomly for the next phase.

2.2. Study sites

The two project sites I and II are municipal areas with high concentration of dairy cows managed at a smallholder level typical of peri-urban areas. Site I, Morogoro, is located 200 km west of Site II, Dar es Salaam. Both sites are located in the typically hot and humid semi-arid eastern United Republic of Tanzania with minimum and maximum temperatures ranging from 15–23°C and 32–34°C respectively, and relative humidity of 65–85%. Site I is situated at an altitude of 528 metres above mean sea level (msl) and Site II at 14 msl. The annual rainfall is between 800–1400 mm. Both sites have two seasons: a rainy season (March to May) and a dry season (June to February) interrupted by short rains in October to December.

2.3. Animals and Management

Smallholder farmers (48 at Site I and 8 at Site II), who were willing to participate in the study owned on average 4 milking cows and 1–2 ha of land for cultivation of food crops, with no land specifically allocated for pasture production. The animals, normally crosses of Zebu and exotic dairy breeds were in their second to fourth parity, with a daily milk production of 4–10 L and a BCS ranging from 2–4. The animals were kept indoors throughout and were zero grazed with the grasses, *Panicum maximum, Hyperrhenia rufa, Neonotonia, Wightii, Penisetum* and *Cynodon spp.* The major forage for animals during the dry season for almost all farmers was dry grass and/or maize stover.

Early weaning is the normal practice amongst the farmers. Cows are milked twice a day. Breeding is by artificial insemination (AI), natural service or both. Oestrus detection is done by the owner or herdsman at the time of milking, feeding or cleaning the barn.

2.4. Measurements and analyses

2.4.1. Milk production and body condition

Milk yields were recorded daily on data entry forms. The body weights of the cows were estimated by heart girth measurement using a measuring tape and that of calves using a spring balance. The body condition score was determined using the 1–5 scale with manual palpation of the lumbar spines.

2.4.2. Feeds

The amounts of forage and supplements given to cows were estimated and recorded and samples taken from representative farms for analysis for dry matter (DM), crude protein (CP) and ash content using methods described by AOAC [9]. Feed digestibility was estimated by the nylon bag technique on surgically rumen-cannulated steers [10].

2.4.3. Milk samples for progesterone RIA

Whole milk samples were collected by farmers or technicians during routine visits, processed according to the recommendations for collection and processing of samples and were analysed using the FAO/IAEA self-coating milk progesterone RIA kits supplied by the International Atomic Energy Agency [11].

2.4.4. Reproductive parameters

Dates of calving, occurrence of postpartum oestrus, inseminations and number of services per conception were recorded. Postpartum anoestrus intervals were determined from progesterone concentrations less than 1 nmol/L and the interval from calving to first oestrus when progesterone concentrations were above 1 nmol/L. The interval to first detected oestrus was determined from oestrus observations by the farmers and technicians/researchers during bi-weekly visits. Conception date was determined based on the elevated and sustained progesterone concentrations three weeks after insemination and was confirmed by rectal palpation. Calving interval was calculated from the actual dates of two successive calvings.

2.5. Supplementation trials

Two Trials were conducted to determine the effect of FC and UMMB as feed supplements on the performance of dairy cows during the dry season. Both supplements were taken to the smallholder farms after they were successfully tested on-station for acceptability by cows.

2.5.1 Supplementation with FC (Feeding trial I)

The FC, consisting of cotton seed cake, maize bran, mineral mix (brand Maclicke) and common salt (NaCl) (Table I), was fed to 37 cows at the rate of 0.8 kg per litre of milk produced. The components were mixed using shovels. This trial was carried out at Site I and a total of 24 farms participated; 14 farms (37 cows) being in the treatment group and 10 farms (28 cows) in the Control group. The animals in the Control group received 0.6 kg of maize bran per litre of milk produced.

2.5.2. Supplementation with UMMB (Feeding trial II)

The UMMB (see Table I for composition) was tested on 18 farms (14 at Site I and 4 at Site II), and was fed to a total of 27 cows (18 at Site I and 9 at Site II). The level of UMMB intake ranged from 0.7–1.0 kg per animal/day. The Control group of 28 cows (20 from Site 1 and 8 from Site II) were from 14 farms (10 at Site Site I and 4 at Site II). Each cow in the Control group received 0.6 kg of MB.

For the preparation of the UMMB, a modified cold process described by Sansoucy et al. [12] was used where the content of maize bran was increased and that of molasses decreased in order to obtain sufficient hardness of the blocks. Fertiliser grade urea, limestone, salt, and bone meal were also included. Cement was used as a binder to solidify the blocks. All solid components were mixed by hand. The salt was ground to a powder and mixed with water and added to the molasses. The liquid component was added to the solid component and mixed thoroughly by hand. The resulting mixture was transferred into wooden moulds (0.25 m × 0.2 m × 0.2 m) and pounded with wooden poles until satisfactory consistency was obtained. Following this, the blocks were removed from the moulds and air dried for at least two days.

In all trials farms were randomly assigned to treatment and control groups. The supplement FC was given postpartum and UMMB 1–2 months both pre- and postpartum. The trials lasted for 90–120 days.

TABLE I. COMPOSITION OF THE SUPPLEMENTS (% INCLUSION BY WEIGHT)

Component	FC	UMMB
Cotton seed cake	28	0
Mineral mix	1	0
Maize bran	70	33.5
Salt (NaCl)	1	2.3
Molasses	0	23.0
Urea	0	9.3
Limestone	0	4.6
Cement	0	13.0
Bone meal	0	2.3
Water	0	7.0
Total	100	100

2.6. Data analysis

Analysis of data was carried out using ANOVA to test differences in means using the linear model procedure with milk yield, BCS and reproductive parameters as dependent variables. The Student's t-test was used to compare differences in mean values of production and reproduction parameters, in treatment and control groups.

3. RESULTS

3.1. Survey phase

3.1.1. The availability and quality of feed

The survey conducted at the two Sites I and II showed that farmers rarely supplemented their animals with protein concentrates. At milking time, animals in all farms received a supplement of maize bran on very rare occasions the maize bran mixed with cotton seed cake, brewers waste or some mineral mix/lick. The supplement was given at an average rate of 0.6 kg/L of milk produced. Feed was scarce during the dry season and therefore animals received insufficient amounts of forage (<8.0 kg/day) most of the time. Feed analysis indicated low CP content and rumen degradability (Table II) in the dry season feeds as compared to the supplements (FC and UMMB).

TABLE II. CHEMICAL COMPOSITION AND *IN SACCO* DRY MATTER DEGRADABILITY OF DRY SEASON FEEDS AND SUPPLEMENTS (DATA ARE ON DRY MATTER BASIS)

Component (%)	Grass	Maize bran	UMMB	FC
DM	88.3	90.9	89.3	94.3
N	0.8	1.8	5.8	2.6
ADF	39.8	7.2	3.6	55.8
NDF	73.4	30.1	19.5	48.6
Ca	0.27	0.01	5.3	1.28
P	0.18	0.63	0.82	0.22
In sacco DM degradability (%)				
24 h	32.6	75.8	nd	nd
48 h	41.4	87.4	nd	nd

nd, not determined

3.2. Intervention phase

The mean values of each production and reproductive parameter for the UMMB supplemented cows at the two sites were pooled since no significant differences between the two sites were observed.

3.2.1. Production parameters

Milk yield of cows supplemented with FC (Feeding trial I) and UMMB (Feeding trial II) increased from 6.75 L/d to 8.0 L/d and 5.5 L/d to 7.0 L/d, respectively, an increase of 1.25 and 1.5 L/cow/day for the two supplements. The increase in milk yield was non-significant in the FC group but was significantly different ($P < 0.05$) from the control in the UMMB supplemented cows. The respective changes in body weight and BCS in the treatment group as compared to the control group were 4 kg and 0.2 for FC and 8 kg and 0.25 for UMMB groups. The observed changes in body weight and BCS in the UMMB supplemented group were significantly different ($P < 0.05$) from the control group (Table III).

TABLE III. THE EFFECT OF SUPPLEMENTATION WITH FARM FORMULATED CONCENTRATE (FC) AND UREA MOLASSES MULTINUTRIENT BLOCKS (UMMB) ON MILK YIELD AND CHANGES IN BODY WEIGHT AND BODY CONDITION SCORE (MEAN ± SE)

	Feeding trial 1		Feeding trial II	
Parameter	FC	Control	UMMB	Control
Milk yield (L)	8.0 ± 0.3	6.7 ± 0.27	7.0 ± 0.3 ^{b}	5.5 ± 0.2 ^{a}
Body weight (kg)	319.0 ± 13	315.0 ± 11	369.0 ± 24 ^{b}	361.0 ± 17 ^{a}
Body condition score	2.7 ± 0.1	2.5 ± 0.1	2.9 ± 0.1 ^{b}	2.6 ± 0.1 ^{a}

^{ab} within rows, values with different superscripts are significantly different (P <0.05)

3.2.2. *Reproductive parameters*

The reproductive parameters measured included days post-partum (DPP) to first rise in milk progesterone concentration, DPP to first observed oestrus, DPP to conception oestrus, conception rate, inseminations/conception and calving interval, as shown in Table IV. These parameters in supplemented cows were not significantly different from those in the Control groups (P >0.05).

3.2.3. *Cost : benefit analysis*

The supplementation was cost effective if milk production in the respective treatments increased by 0.93 and 0.66 L/cow/day (break even increases). Supplementation of the dairy cow's diet with either FC or UMMB increased milk production by 1.26 or 1.5 L/cow/day, respectively (Table V). In terms of money this was equal to Tsh 346 and 413, giving a profit of 90 and 231 Tsh/cow/day (US$ 0.11 and 0.29), respectively.

4. DISCUSSION

Similar to the observations made by by Shem [1] and Msangi et al. [13], animals in the present study were unable to maintain a satisfactory level of milk production and reproductive performance, presumably due to inadequate intake coupled with the poor quality of the forages. These observations were also supported by the results of feed analysis, which showed low CP content in the feeds routinely used by farmers during the dry season. In a study conducted by Shem [1] in western United Republic of Tanzania it was shown that nitrogen content of grazing pasture and cut-and-carry grass differed significantly between wet and dry seasons (P <0.05). Similar findings of low nitrogen were reported by Kidunda [14] in a study of nutritive value of some tropical grasses and legumes at different stages of growth. The *in sacco* rumen degradability of the grass was very low (41.4%) which was lower than the potential degradability for Tanzanian forages reported by Shem et al. [15] and was in the range of rumen DM degradability reported for straws [16].

TABLE IV. EFFECTS OF SUPPLEMENTATION OF DAIRY COWS WITH FORMULATED CONCENTRATE (FC) OR UREA MOLASSES MULTINUTRIENT BLOCKS (UMMB) ON SOME REPRODUCTION PARAMETERS (MEAN ± SE)

	Feeding trial 1		Feeding trial II	
Parameter	FC	Control	UMMB	Control
Number of cows	37	28	27	28
DPP to:				
first progesterone rise	66.1 ± 4.8	81.3 ± 6.4	65.3 ± 7.9	77.6 ± 9
first oestrus	71.2 ± 5.3	86.3 ± 6.6	99.7 ± 12.0	111.9 ±11.0
conception oestrus	90.4 ± 5.0	102.4 ± 5.	120.2 ± 10	128.7 ± 13
Conception rate (%)	68	50.7	66.7	48.9
Inseminations/conception	1.3 ± 0.1	1.94 ± 0.2	1.5 ± 0.1	2.1 ± 0.2
Calving interval (days)	412 ± 13.0	417 ± 12	400 ± 13.7	414.5 ±15.6

The improvements recorded in all measured production and reproduction parameters between the animals supplemented with the FC and those in the control group were non significant and similar to reports by Jingura and Sibanda [3]. There was an increase of forage digestibility, feed intake and absorption of total nutrients but the improvement was not significant probably because farmers withdrew other routine supplements in favour of the experimental supplement in order to reduce costs, although they were urged to feed their animals at the established rate. This probably happened because the experimental supplement was distributed at no cost. Similarly, control farms were supplied with some maize bran at no cost, as an incentive for participating in the project.

TABLE V. COST: BENEFIT OF SUPPLEMENTATION WITH FORMULATED CONCENTRATE (FC) OR UREA MOLASSES MULTINUTRIENT BLOCKS

Source	FC	UMMB
Cost of supplement (Tsh/kg)	100	101
Cost of feeding (Tsh)	256	182
Price of milk (Tsh/L)	275	275
Break even milk increase (L/d)	0.93	0.66
Observed increase (L/d)	1.26	1.5
Profit margin (Tsh)	90	231

However, supplementation with the UMMB significantly improved milk production ($P < 0.05$) and body condition of dairy cows ($P < 0.05$). But it had no effect on reproduction parameters. The improvement in milk yield may be explained by the fact that the E:P ratio was balanced in the rations and lead to the subsequent maintenance of ammonia content in the rumen leading to an improved rumen environment for micro-organisms. Therefore, digestibility and dry matter intake of feed stuffs increased [17, 18]. In similar experiments in Tanga, Msangi [4] demonstrated an increase of 1.1 L in milk yield when the ration was supplemented with UMMB. The increase in milk production due to the provision of UMMB was much lower than that observed in the on-station study [19], but close to that reported by Habib et al. [20], Hendratno et al. [21] and Msangi [4].

The parameters used to indicate reproductive performance were DPP to first rise in milk progesterone concentration, DPP to first observed oestrus, DPP to conception oestrus, conception rate and calving interval. A more accurate way of measuring reproductive performance in dairy cows would be to record the number of open days, provided it is calculated from calving to conception [22]. In the UMMB supplemented group the interval from calving to resumption of ovarian cyclicity based on milk progesterone concentration was 65.3 days and DPP to first observed oestrus was 99.7 days, both of which were better than that of the control group. However, this improvement was not statistically significant ($P > 0.05$). These values were high probably due to the fact that the animals in the present study were stressed by under nutrition, poor management, high temperature and humidity. However these findings are close to those reported by Orellana et al. [23] for dairy herds in Chile.

The majority of the cows experienced cycles of short duration prior to cycles of normal duration. This observation is in agreement with that of Tegegne et al. [24]. The mean length of short cycles was 13 days. Short cycles arise due to weak corpora lutea and peak progesterone levels which create weak endocrine function. The progesterone amplitude of short oestrus cycles was low implying sub-functional corpora lutea. This phenomenon is considered beneficial in that the progesterone production act as a primer for resumption of normal cycles [25, 26].

The interval to first observed oestrus in both supplemented groups was greater than those reported by other researchers, and was most likely due to poor oestrus detection and ‘silent heats’. Heat was not properly detected as it was either too brief or sometimes not observed at all. The non-observation of heats lead to many animals remaining open for a long time, thus the prolonged calving interval of 400–412 days in the supplemented animals. Enough time should be given to heat detection in order to observe individual cows for at least 10–20 minutes and preferably three times a day; morning, afternoon and evening [22]. The interval to conception oestrus of 120 days is in agreement with findings of Msangi et al. [13] and Katyega [27].

The cost:benefit analysis indicated that supplementation with the FC and UM was cost effective since it allowed a marginal profit of Tsh 90 and 231 ($ 0.11 and 0.29), respectively. UMMB was more acceptable by farmers as it was less costly to feed and gave a better profit margin.

5. CONCLUSIONS

The widespread application of UMMB is only possible following large scale production of the blocks. Many farmers in Morogoro and few in Dar es Salaam have shown an interest in the use of the blocks during the dry period if the blocks could be made available in the animal feed markets. This could be undertaken either by the Ministry of Agriculture and Co-operatives, the Sokoine University of Agriculture (on cost recovery basis, as a productive venture) or by individual farmers/farmers' organizations on private business basis. To transfer this technology to other areas of the country, demonstrations of the possible benefits of the blocks under their own conditions would be necessary.

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EVALUATION OF THE COMPARATIVE GROWTH AND REPRODUCTIVE PERFORMANCE OF WEST AFRICAN DWARF GOATS IN THE WESTERN HIGHLANDS OF CAMEROON

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Abstract

EVALUATION OF THE COMPARATIVE GROWTH AND REPRODCUTIVE PERFORMANCE OF WEST AFRICAN DWARF GOATS IN THE WESTERN HIGHLANDS OF CAMEROON.

On-farm and on-station evaluations of the comparative growth performance of West African Dwarf Goats supplemented at an iso-nitrogenous level (6 g/animal/day) with leguminous browse *Calliandra calothyrsus, Leucaena leucocephala,* or *Gliricidia sepium,* or with cotton seed cake, were conducted around Dschang in the Western Highlands of Cameroon and at the University Experimental Farm. The animals were weighed every 21 days during the rainy season and every 14 days during the dry season for three months to evaluate their response to supplementation. Cotton seed cake, *L. leucocephala, C. calothyrsus* were the most accepted supplements. The weight gain of the animals fed with these supplements was significantly higher compared to that of the control animals. Mean weight of animals supplemented with *G.sepium* was not significantly different (P >0.05) from that of the control group during the rainy season. The average daily weight gains during the rainy period were 20.6, 19.1, 13.8, 4.5, and 3.1 g for *L. leucocephala*, cotton seed cake, *C. calothyrsus*, *G. sepium* and the control animals respectively, during the rainy season and 19.9, 16.1 and 1.7 g for cotton seed cake, *L. leucocephala* and the control animal respectively, during the dry season. Progesterone profiles were low and were unaffected by supplementation during the dry season.

1. INTRODUCTION

In many areas of Africa, ruminant livestock production has long been of major importance to the rural population. It has served many purposes: in the direct production of food, providing traction for transportation and land preparation, as a cash reserve for emergency investments and long term saving, and in the fulfillment of social obligations. However, ruminant production across most of these areas is constrained by the poor quality of the consumed feed.

The alternating relatively long-dry and short-rainy seasons, as one moves from the south to the north of tropical areas, has a major influence on the productivity and quality of rangeland [1]. During the rainy season, range plants grow rapidly and although their quality may be good early in the season, they mature rapidly with a resulting decline in quality. Their decline in quality impairs the productivity of ruminant livestock that depend mainly on grassland [1]. Often, the crude protein content of range vegetation particularly during the dry season is less than the critical level of 6–7% needed to maintain an efficient rumen function [2]. The growth rate and milk production of ruminants grazing tropical pastures or consuming crop residues alone are generally low and represent only about 10% of the animal's genetic potential [3]. This low productivity is due mainly to poor nutrition which lowers the resistance of animals to infectious and parasitic diseases, leading to high mortality rates among young (30–40% in calves and 50% in lambs and kids) and low fecundity in adult females (60–66%) [4].

Under the traditional system of management of small ruminants, animals are allowed to graze and scavenge on household waste in or around the village during the dry season. During the rainy season with most of the land under crop production, animals depend on grass found along the roadside, on fallow land or where they are usually tethered, and on household waste. While this system entails little or no cost to the producer, it has adverse implications on the nutritional status, growth rate, reproductive performance and disease resistance of these animals. As a result, feeding has frequently been cited as the most limiting factor in ruminant production in tropical Africa. This is particularly true in highly populated rural areas such as the western region of Cameroon (density 400–1000 inhabitants/km^2) where most of what was left as rangeland is actually being used either for crop production or construction of buildings. The general tendency is a decline in animal production and small ruminant production in particular, while it has been estimated that during the next twenty years, world wide demand for meat will increase 2.5 times faster than the supply [4].

Increasing the efficiency of livestock production is therefore imperative. There is a need to increase animal production through higher out put per unit area of land. In the light of this, a shift from a resource-based to a more science-based system of livestock production has to play an increasingly important role in achieving these objectives. Furthermore, in the tropics small ruminants are not seasonal breeders [5]. Reproduction should normally occur all the year round. Unfortunately, that is not the case and often long anoestrus periods are observed, poor nutrition being a major cause. Poor feeding leads to problems amongst which, a reduction in growth, late sexual maturity, abortions, long post-partum anoestrus, and temporary or total fecundity are predominant. In general, very little or no information exists on these parameters for West African Dwarf Goats (WADG) in Cameroon. As a result, production and reproductive management of this species has been difficult.

In view of the above problems, a research programme on the improvement of production and reproductive performance of WADG was undertaken at the University of Dschang. The objective of this study was to evaluate the comparative growth and reproduction performance of WADG supplemented at an iso-nitrogenous level with 3 species of leguminous browse *Calliandra calothyrsus, Leucaena leucocephala or Gliricidia sepium* or with cotton seed cake, during the rainy and the dry seasons.

2. MATERIALS AND METHODS

2.1. Experiment I

2.1.1. Study area

The study was carried out in Foto, a village around Dschang in the Western Highland zone of Cameroon, and at the University Experimental Farm, during the rainy season. This area is located at an altitude of 1400 metres, and receives an annual rainfall of 1700–2000 mm. The climate of the region is of Sudano-Guinean type influenced by the altitude. The mean annual temperature is between 20–22°C. The region has one rainy season, which lasts from mid March to mid November and one dry season from mid November to mid March. The original vegetation of the region was of a shrub savannah type. However, the region has been transformed by years of intense crops production and the natural vegetation can only be occasionally observed.

2.1.2. Animals

The animals used for this study were West African Dwarf Goats (*Capra reversa*). Four groups of 11 goats each (8 to 12 months of age) were used in the on-farm studies. A control group of 11 animals with similar characteristics was raised at the University Experimental Farm. The Study was conducted both on-farm and on-station concurrently, in order to speed up the adoption of the technique by the participating farmers. Furthermore, farmers were compensated if a feeding regime in the control group resulted in the death of any animals.

At the beginning of the trial all animals were vaccinated against goat plague (PPR). They received an antibiotic injection (long acting tetracycline) and underwent internal and external parasite control. In addition, all animals were regularly checked and treated for minor ailments as necessary.

2.1.3. Feeding

Animals were tethered every morning on fallow land or along the roadside where they stayed until night. They spent the night in the kitchen, the hangar, the veranda, or under the shade of the farmer's house. The major species of the pastures available to them during the day were: *Pennisetum purpureum, Pennisetum clandestinum, Brachiaria ruziziensis, Panicum maximum, Bidens spinosa, Titonia diversifolia, Chromolaena odorata, Sida spp., Setaria spp., Floribredum spp., Vernonia spp., Imperata cylindrica, Aspilia africa* and *Ageratum spp.*

Every morning 390, 513 or 380 g of fresh leaves of *L. leucocephala, G. sepium, or C. calothyrsus* respectively, corresponding to 6 g of nitrogen, were harvested from the University Experimental Farm and given to each animal of the corresponding treatment group. *G. sepium* just after harvesting or after keeping for one to two days, was distributed after soaking in a salt solution to improve its acceptability by the animal. Leaves of *C. calothyrsus* were offered just after harvesting. The fourth group, which was the cotton seed cake supplemented group, received 88.8 g of cotton seed cake per animal, corresponding to 6 g of nitrogen.

2.1.4. Data collection and statistical analysis

The entire study lasted for 84 days. After an adaptation period of 30 days, animals were weighed once every 3 weeks, early in the morning using a spring balance. Due to variation in initial weight, covariance analysis was carried out on the data and significant differences among adjusted treatment means were tested using the students '*t*' test [6].

2.2. Experiment II

2.2.1. Study area

This study was carried out during the dry season, between January and April 1999, at the University Experimental Farm. The station is located at an altitude of 1420 metres and receives an annual rainfall of 1700 to 2000 mm. The climate of the region is of Sudano-Guinean type influenced by the altitude. The mean annual temperature varied between a minimum of 10°C in July-August to a maximum of 25°C in February. The region has one rainy season, which lasts from mid March to mid November and one dry season from mid November to mid March.

2.2.2. Animals

Three groups of 6 goats each (1 to 2 years of age) and weighing between 7.7 kg and 14.3 kg, bought from different markets in the region, were divided into 3 groups. At the beginning of the trial all animals were vaccinated against goat plague (PPR). They received an antibiotic injection (long acting tetracycline) and underwent internal and external parasite control. All animals were regularly checked and treated for minor ailments as necessary.

2.2.3. Feeding

The study started with an adaptation period of two weeks during which the animals in the two supplemented groups were fed their supplement *ad libitum*. During the trial period, the animals were released into the pasture every morning at 10 a.m. and were brought back to their stalls between 5 and 6 p.m.

Every morning prior to releasing the animals to pasture, 390 g of fresh leaves of *L. leucocephala* or 88.8 g of cotton seed cake, corresponding to 6 g of nitrogen, were given to each animal of the respective supplemental groups. Leaves of *L. leucocephala* were distributed just after harvesting. The animals in the control group received an *ad libitum* quantity of pasture-forage mixture in their stalls before 10 a.m.

The major forage species in the pastures where animals grazed were: *Pennisetum purpureum, Panicum maximum, Brachiaria ruziziensis, Bidens spinosa, Titonia diversifolia, Sida spp., Setaria spp., Floribredum spp., Vernonia spp., Aspilia africa* and *Ageratum spp. Trypsacum laxum* was regularly cut and distributed to the animals.

2.2.4. Data collection and statistical analysis

Animals were weighed in the morning once every 2 weeks, using a spring balance. Blood was collected every three days by jugular venipuncture during the 51-day experimental period to obtain the progesterone profile. The blood samples were processed in the laboratory and the serum was conserved in a deep freezer at –20°C until RIA for progesterone was carried out. The analytical method used was that proposed by FAO/IAEA [7]. Analysis of variance was carried out on the weighted data and significant differences among treatments means were tested using the student's '*t*' test [6].

3. RESULTS

3.1. Experiment I

3.1.1. Voluntary intake

The average quantities of fresh and dry matter of supplements and the quantity of nitrogen ingested by each animal are presented in Table I. *G. sepium* was the least preferred legume with an average consumption of 2.9% of the 149 g of dry matter offered. Some animals did not eat the forage during the whole experimental period. The consumption of *C. calothyrsus* and *L. leucocephala* were respectively, 78.2 and 78.3% of the dry matter offered. While the voluntary intake of *C. calothyrsus* was relatively constant (128.1 g), that of *L. leucocephala* increased from 59.7 g at the beginning of the study to 126.5 g at the end. In general, the animals could not consume the total quantity of leaves offered because the leaves easily mixed with the dirt in the soil. The animals in the cotton seed cake treatment consumed the total amount of supplement offered to them.

3.1.2. Growth and average daily weight gains

Table II shows the average mean weight of animals at different periods and for the different treatments. From this table it can be observed that there was a consistent increase in body weight of various magnitudes, during the study period. The animals supplemented with *C.*

calothyrsus, Cotton seed cake and *L. leucocephala* had an average weight at 42, 63 and 84 days significantly different (P <0.05) from that of the control group. However, the average body weight at each of the above periods was not significantly different between the supplemented groups. The mean body weight of animals supplemented with *G. sepium* was not significantly different from that of the control group.

The logarithmic adjustment of the weight with time in weeks produced the following equations :

C. calothyrsus $Y_C = 0.6228Ln(x) + 11.728$ ($R^2 = 0.79$)

L. leucocephala $Y_L = 0.4784Ln(x) + 12.242$ ($R^2 = 0.69$)

G. sepium $Y_G = 0.0810Ln(x) + 11.657$ ($R^2 = 0.12$)

C. seed cake $Y_T = 1.1502Ln(x) + 11.649$ ($R^2 = 0.75$)

Control $Y_O = 0.1733Ln(x) + 11.157$ ($R^2 = 0.21$)

The coefficient of determination associated with each equation varied from 0.12 for the *G. sepium* group to 0.79 for the *C. calorthyrsus* group. The regression coefficient indicated the proportion of the variation of the weight that can be explained by the regression curve. The supplements had a relatively high influence on the growth of the WADG during this period of the year.

TABLE I. AVERAGE QUANTITIES OF SUPPLEMENTS AND NITROGEN CONSUMED DURING THE RAINY SEASON (g/ANIMAL/DAY)

Supplements		Weighing Period							
		21 days		42 days		63 days		84 days	
		Intake (g)	N (% of intake)	Intake (g)	N (% of intake)	Intake (g)	N (% of intake)	Intake (g)	N (% of intake)
Calliandra	FF	304.7		298.1		291.9		293.3	
Calothyrsus	DM	131.5		128.6		125.9		126.6	
	N	4.8	80.1	4.7	78.5	4.6	76.8	4.6	77.1
Leucaena	FF	180		287.1		373.3		381.4	
Leucocephala	DM	59.7		95.3		123.8		126.5	
	N	2.8	46.1	4.4	73.6	5.7	95.6	5.8	97.8
Cotton	FF	88.9		88.1		88.8		88.8	
Seed Cake	DM	78.0		77.4		78.0		78.0	
	N	6	100	5.9	99.1	6	100	6	100
Gliricidia	FF	6.3		11.5		22.7		15.8	
Sepium	DM	1.8		3.3		7.7		4.6	
	N	0.1	1.2	0.1	2.2	0.3	5.2	0.2	3

FF = Fresh forage; DM = Dry Matter; N = Nitrogen.

TABLE II. ADJUSTED MEAN WEIGHT (± SE) OF WADG AT DIFFERENT PERIODS DURING THE RAINY SEASON

Treatments	Adjusted mean weight (kg)			
	21 days	42 days	63 days	84 days
Calliandra calothyrsus	11.8 ± 0.84 a	11.9 ± 0.72 b	12.6 ± 0.70 b	12.5 ± 0.68 b
Cotton seed cake	11.7 ± 0.95 a	12.1 ± 0.92 b	13.4 ± 1.02 b	13.0 ± 0.97 b
Gliricidia sepium	11.7± 0.85 a	11.5 ± 0.95 ab	11.9 ± 1.02 ab	11.7 ± 1.00 ab
Leucaena leucocephala	12.3 ± 1.40 a	12.6 ± 1.21 b	12.5 ± 1.05 b	13.1 ± 0.92 b
Control	10.2 ± 0.48 a	10.1 ± 0.56 a	10.0 ± 0.51 a	10.8 ± 0.56 a

a,b: values in the same column with different following letters are significantly different (P <0.05).

The average daily weight gains are presented in Table III. The adjusted average daily weight gain varied from 3.1 g for the control to 20.6 g for the animals supplemented with *L. leucocephala*. In general there was a large fluctuation in the average daily weight gain during the trial.

3.2. Experiment II

3.2.1. Growth and average daily weight gain

Feed supplements distributed to the animals before their release on to the pasture during the dry season were totally consumed. Analysis of variance carried out on weighted data indicated a highly significant difference ($P < 0.01$) in body weight between the control and the treatment groups. However, there were no significant differences between the supplemented groups. A highly significant ($P < 0.01$) interaction was observed between the weight of animals and the weighing periods. On average the gain during the dry season were 0.17 kg for the control group, 1.6 kg for the group supplemented with *L. leucocephala* and 2.0 kg for the group supplemented with cotton seed cake. Given the high cost of the cotton seed cake it is evident that the small-scale farmer cannot use it as a regular feed supplement. Therefore, *L. leucocephala* represents the best alternative. In addition to its use as an animal feed, it can serve as a wind break, as fire wood and to reduce soil erosion and contribute to sustain crop production, particularly in this region where almost all land is under cultivation.
The logarithmic adjustment of the weight with time in weeks gave interesting results (Fig. 1). The coefficient of determination associated with these equations varied from 0.06 for the control group to 0.68 for the *L. leucocephala* group. This indicates that a high proportion of variation in weight can be explained by the regression curve and is related to supplementation. Table IV indicates the average daily gain for each treatment at different weighing periods. It appears from this table that during period four of the experiment, (i.e. 42–56 days) all animals lost weight. At this time all animals had an attack of coccidiosis. Animals supplemented with cotton seed cake showed an average daily weight gain of 19.9 g, the *L. leucocephala* supplemented group 16.1 g and the control group only 1.7 g.

3.2.2. Progesterone profile

Blood serum progesterone profile varied between 0–0.56 ng/ml for the control group, 0–0.72 ng/mL for the group supplemented with *L. leucocephala*, and 0–1.0 ng/mL for the group supplemented with cotton seed cake. The animals used in this trial had already reached puberty (5–7 months) and physiological maturity (11–12 months). However, no sign of cyclicity was observed.

TABLE III. ADJUSTED DAILY MEAN WEIGHT GAINS OF WADG DURING THE DIFFERENT STUDY PERIODS IN THE RAINY SEASON

Treatments	Adjusted daily mean weight gains (g) Period (days)				Whole experimental period (days)
	0–21	22–42	43–63	64–84	0–84
Calliandra calothyrsus	20.4	7.1	33.2	–5.7	13.8
Cotton seed cake	15.7	21.3	62.1	–22.9	19.1
Gliricidia sepium	16.6	–7.6	15.9	–7.0	4.5
Leucaena leucocephala	44.0	17.1	–5.9	28.0	20.6
Control	–4.1	–6.7	–2.8	37.1	3.1

TABLE IV. AVERAGE DAILY WEIGHT GAIN OF WADG DURING THE DIFFERENT PERIODS IN THE DRY SEASON

Treatments	Average daily weight gain (g) Period (days)							
	0–14	14–28	28–42	42–56	56–70	70–84	84–98	0–98
Control	–14.2	5	17.8	–22.8	7.1	5	14.2	1.7
L. leucocephala	3.5	12.8	30	–15.7	9.2	31.4	41.4	16.1
Cotton seed cake	25	–15	7.8	–20	53.5	37.8	50	19.9

4. DISCUSSION

4.1. Experiment I

From amongst the three fodder species, *G. sepium* was the least preferred during the rainy season. This low acceptability of *Gliricidia* was probably due to the taste and smell of the plant. This result is similar to that of Bennison and Paterson [8] who compared 8 indigenous browse species including *G. sepium* and *L. leucocephala* and found that *G. sepium* was the least preferred species by goats. Amongst different *G. sepium* ecotypes they also observed significant (P <0.05) differences in preference, Mexican ecotype being less preferred than that of Costa Rica. Jabbar et al. [9] also observed that in West Africa, *Gliricidia* was rarely used as a feed for ruminants because some farmers considered it as poisonous to sheep and goats.

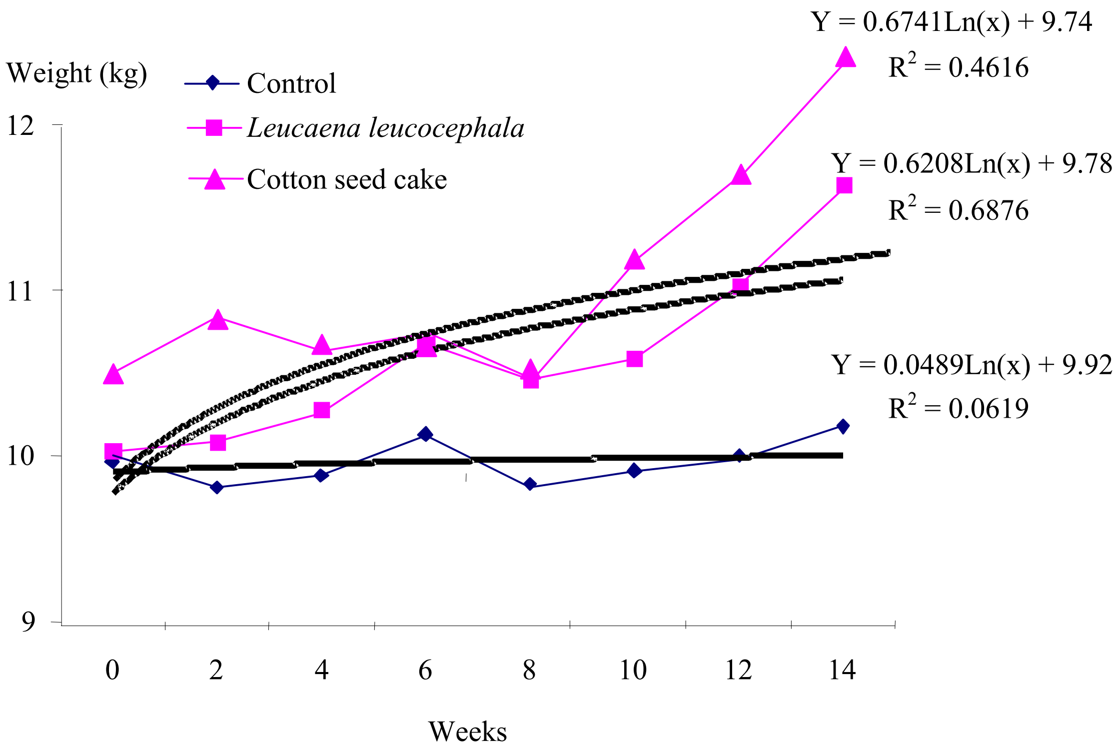

FIG. 1. Response of WADG to supplements of cotton seed cake and Leucaena lecucocephala

L. leucocephala intake was similar to that of *C. calothyrsus*. On the other hand, Paterson et al. [10] observed that *L. leucocephala* was more palatable and more acceptable than *C. calothyrsus, G. sepium* and *S. sesban* species by small ruminants. In the study by Paterson et al. [10], they concluded however that *C. calothyrsus* was the most promising plant species to replace or complement the cultivars of *L. leucocephala* that are presently in use.

During the whole experimental period, the mean live-weights and mean daily weight gains were not necessarily correlated with the supplement intake. This was probably related to the poor rangeland conditions. Most pastures were generally in very poor condition. It was thus very difficult for these animals to achieve adequate growth even when the acceptability of the supplement was good. This confirms the conclusions that the rate of growth and milk production by ruminants grazing tropical pastures or consuming crop residues alone is generally low [3].

G. sepium consumption was so low that the diet of animals supplemented with this forage was similar to that of the control group. This was exemplified by the mean live-weights and the mean body weight gains. The mean weight gain of animals of the control group was 3.1 g, which was higher compared to that observed by Paterson et al. [9] who reported a weight loss of 20 g/day for goats kept on hay alone in Zimbabwe and by Palmer and Tatang [11] who reported a weight loss of 35 g/day on sheep fed on hay alone *ad libitum*.

The average weight gain of animals supplemented with *L. leucocephala* was relatively higher than that of animals supplemented with *C. calothyrsus* or cotton seed cake. Animals from all groups showed a high fluctuation in mean daily weight gain during the whole experimental period. Most of this fluctuation can be related to a typical management problem in the region. Due to animal theft during the feeding trials some farmers decided to keep their animals indoors, and the only feed they received was the supplement or a small amount of forage collected while returning from the farms. Sometimes the quantities of supplements offered were higher compared to the quantity of the basic forage brought by the farmer.

The weight gain of animals supplemented with *C. calothyrsus* was 13.8 g/day. This is lower than the 24 g/day obtained by Paterson et al. [10] in Zimbabwe while supplementing local goats with a diet of 140 g/day of *C. calothyrsus* dry matter. In this situation however the energy source was adequate.

Despite the fact that these animals were raised on-farm in a tropical humid environment, where they are continually exposed to parasitic infestation which weakened the animals and caused growth reduction [12], the growth rate of these animals supplemented with limited amount of leguminous forage at one of the critical period of the year was relatively better.

4.2. Experiment II

This trial was carried out in the dry season. During this period, the nutritive value of forage was quite low. The difference in average daily weight gain observed between the treatment groups and the control can be related to the effect of the supplement. The average daily weight gain obtained in our experiment was low when compared to that of Zemmelink et al. [13] and Thys [14]. Zemmelink et al. [13] recorded a weight gain of 87 ± 21.8 g/day when goats were supplemented with cotton seed cake while Thys [14] obtained 122 ± 14.5 g/day when cotton seed cake and their shells were included in the diet of sheep. These results are however higher than those obtained by Manjeli et al. [15]; 12.65 g/day when they fed WADG on-station with *Pennisetum purpureum* and supplemented with 100 g of cotton seed cake per animal per day. The large difference in average daily weight gain observed between our experiment and those of Zemmelink et al. [13] and Thys [14] may be due to the fact that in their trial cotton seed cake was given *ad libitum*.

Jones [16] in a feeding trial with *L. leucocephala* recorded an increase in weight gain of 14%. Leng [17] observed that feeding goats with *P. purpureum* as a basal diet and supplementing with dry *L. leucocephala* mixed with ground soya gave an average daily weight gain of 45 g while *L. leucocephala* alone gave only 22 g/animal/day. These are in good agreement with the present results.

The progesterone profiles, which were low (ranged between 0–1.0 ng/mL) as compared to the values reported by Vaissaire [18] indicate that these animals were not cycling. Vaissaire [18] observed that in a cycling goat, serum progesterone levels varied between 5 to 16 ng/mL from the 7^{th} to 14^{th} day, then decreased to 0.8 ng/mL during anoestrus.

Theriez [19] observed that animals feed to ensure their maintenance first, then for milk production when there is a young one and only thereafter for reproduction. The same author showed that the ovulation rate increased significantly with the increase of body weight provided that feeding at breeding time is above that required for maintenance. Our experimental animals were bought from the market. We had no information on the manner they had been raised or on their nutritional condition during growth. It was therefore difficult to explain the cause of this anoestrus. Feeding during the first 12 months can affect reproductive performance in small ruminants [19]. Feeding, particularly between 0 and 2 months is critical for optimum reproductive performance at maturity [19]. Improved nutrition, during the production period, while ensuring some form of compensation cannot correct the negative effect of poor nutrition during the early growth. As a result a poorly fed females may not be able to express their genetic potential during the reproductive phase.

If the results of these preliminary investigations, particularly those related to reproduction are confirmed, they will indicate that the negative effect of poor nutrition is generally under estimated. Since in addition to weight loss during the critical period of the year, its effect is serious and insidious during reproduction at maturity. Therefore, the high prolificity which has often been attributed to this species of goats probably manifests itself to a lesser extent as compared to the real potential. It is therefore essential to expand and intensify such investigations on these animals as well as on all other ruminant species in the region.

5. CONCLUSIONS

It was evident from these feeding trials that *L. leucocephala* was the most consumed shrub legume yielding the highest live weight. Despite the high daily weight gain of animals fed on cotton seed cake, this by-product is relatively expensive (0.5 US$/kg) and given the economic status of local farmers, it is difficult for them to provide this feed as a supplement in a sustained manner to their animals. Thus, *L. leucocephala* and *C. calothyrsus* appear to be the most appropriate leguminous browse species for a sustained small ruminant production in this highly populated area of Cameroon.

The supplementation improves growth and body conformation of the animals. These animals are sold not only on the basis of their weight but also of their body conformation. With an increase of about 3 kg/animal in three months and a good body conformation, a farmer will be able to earn additional revenue of at least 4500 CFA without incurring any additional costs, besides labour costs. This represents a substantial gain for the farmers with almost no investment. In addition to body weight gain the use of leguminous browse improves soil fertility and structure, provides firewood to the household and acts as a windbreak when planted in a farm. The level of plasma progesterone was very low in all the experimental animals. Thus, at the levels studied supplementation had no effect on this parameter.

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MINERAL SUPPLEMENTATION IN TUNISIAN SMALLHOLDER DAIRY FARMS

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Abstract

MINERAL SUPPLEMENTATION IN TUNISIAN SMALLHOLDER DAIRY FARMS.

The aim of the experiment was to determine the effects of supplementation of di-calcium-phosphate in the form of blocks in late pregnancy (2 months before calving), on production and reproduction parameters of dairy cattle in smallholder farms. The experiment covered 63 animals in 20 smallholder farms, divided into control and supplemented groups. Results showed that mineral supplementation had a significant effect on calf weight, milk fat content and reproduction parameters. Calves born to cattle supplemented with di-calcium-phosphate were heavier by 1.67 kg than those in the control group. Similarly, the average milk fat content in the supplemented group was 5.6 g/L ($P < 0.01$) higher than in the control group. Inter-calving interval was lower by 38 days ($P < 0.05$) in the mineral supplemented cows compared to the control group. The body condition score of the cows and the milk quantity and quality (protein and density) were higher in the supplemented group than in the control group but the effect was not significant ($P > 0.05$).

1. INTRODUCTION

In many smallholder dairy farms in Tunisia, the ration is imbalanced and in many instances deficient in calcium and phosphorus. The poor reproductive performance such as inter-calving interval and the lower content and quality of fat in milk in these dairy herds are thought to be related to these mineral deficiencies.

To overcome these deficiencies in the organised and large farms, animals are supplemented with a local source of di-calcium phosphate in the form of a powder. This was initially added to the forage at the time of feeding. However, this source was unpalatable and some minerals were wasted. To overcome this non-palatability, it was later added to the concentrate feed, which was completely consumed. Although cattle were supplemented with the same quantity [1, 2] their production was different. Since the supplementation was calculated based on the most deficient animal, other cows were often over supplemented.

In the smallholder farms, di-calcium phosphate supplementation in the form of a block was a possible solution because it was more palatable (mixed with salt) and reduced wastage. The animals licked and regulated their mineral requirements as well.

2. MATERIALS AND METHODS

2.1. Animals

Sixty-three crossbred cows (80% Holstein × local breed) aged between 3–6 years and maintained under similar management conditions, and belonging to 20 farmers were used in this study. The average body weights were 588 and 563 kg for control (32 cows from 10 farmers) and supplemented animals (31 cows from 10 farmers), respectively. The supplemented group received di-calcium phosphate for one year, starting from late pregnancy (2 months before calving).

2.2. Feeding

The composition of the diet was different in the different farms and consisted of forages such as oat hay, wheat straw, alfalfa, berseem and sorghum and a concentrate such as barley, soybean or commercial concentrate available in the market. However, in all selected farms the diets were 10–15% deficient in both calcium and phosphorus.

The supplementation ration consisted of di-calcium phosphate mixed with salt in the form of a block (Table I) while the control ration consisted of 1% salt mixed with the concentrate.

The mineral blocks were prepared in a factory in the form of 5 kg cylindrical blocks. Salt was added to increase the palatability of the block. Blocks were distributed once every 2 months. The animals licked the blocks to satisfy their needs. The average daily block intake was 83 g/animal. The nutritive values of the feeds used in the farms are given in Table II.

TABLE I. QUANTITY OF CALCIUM AND PHOSPHORUS IN THE MINERAL BLOCK

	Calcium	Phosphorus	Salt	Ca:P ratio
As a percentage (%)	8.4	8.4	83.2	1: 1.003
g/5 kg block	420	421.5	4158.5	1: 1.003

TABLE II. NUTRITIONAL VALUE OF FEEDS (g/kg DM)

	NET ENERGY UFL	DIGESTIBLE PROTEIN		MINERALS	
		PDIN	PDIE	Ca	P
Berseem	0.88	150	125	1.28	0.39
Alfalfa	0.66	113	81	0.97	0.40
Sorghum	0.87	53	67	0.38	0.26
Hay oat	0.44	39	50	0.41	0.30
Straw wheat	0.40	18	34	0.30	0.31
Concentrate	0.89	111	91	1.95	0.58
Barley	0.97	88	98	0.22	0.41
Soya	1.02	303	213	0.63	0.76
Hulls wheat	0.71	111	100	0.30	1.01

1 UFL = 1700 kcal Net Energy Lactation.
PDIN = Intestinal digestible protein permitted by nitrogen.
PDIE = Intestinal digestible protein permitted by energy.

2.3. Measure of production and reproduction parameters

All cows were weighed every month using a weigh band. The calves were weighed using a spring balance. The body condition score (BCS) was estimated using the 1–9 scale. Milk production was measured daily in the farm but milk fat and protein were analysed in the laboratory [3].

Reproductive hormone progesterone was measured using the FAO/IAEA Self-coating RIA kits. Milk progesterone profiles constructed from twice weekly sampling were used to monitor ovarian activity in post partum cattle. The milk samples were taken and stored at 4°C in the farm and later, analysed in the laboratory. Cows were examined for uterine involution one month after calving. Forty-five days after insemination, a pregnancy diagnosis was carried out by rectal palpation of the uterus to confirm pregnancy.

2.4. Economics of feeding the mineral block

Block intake was determined every 60 days. Cost of production was calculated as:

$$B = Y - X,$$

where

B = benefit

Y = improvement in production and reproduction

X = cost of daily intake of minerals.

2.5. Statistical analysis

The statistical analysis was carried out using SAS procedure. Comparison of paired groups was tested with paired difference test, performed using the non-parametric test. The GLM procedure was used to analyse the data.

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3. RESULTS

The supplementation of lactating dairy cattle with di-calcium phosphate in the form of a mineral block improved calf weight gain by 1.67 kg, which was significantly different from the weight gain of calves in the control group. Calcium and phosphorus supplementation significantly increased the milk fat content of milk although there was no effect on the quantity of milk produced.

Mineral supplementation improved all reproduction parameters. Conception by first AI was significantly higher in the supplemented group as compared to the non-supplemented group (36.8 vs 25%, respectively). Similarly, supplemented group required less number of services/conception, had a lower calving to conception AI period and a lower inter-calving interval.

4. DISCUSSION

The mineral supplementation had a significant effect on dairy cattle production and reproduction. Ca and P are required for the utilisation of energy and protein, without which protein and energy would not be properly used. When given a nutritionally balanced diet, calves developed a large muscle mass, grew well and increased the mineral content of the bones [4 –9].

The availability of calcium and phosphorus improved the fat content in milk. This was achieved by the better utilisation of forages, due to the adequate presence of calcium improving the buffering capacity of the rumen. The increase in fat content in milk could have been due to the production of a higher ruminal molar percentage of acetic and butyric acids due to the fermentation of fibre [10].

The reproductive performance was considerably improved by mineral supplementation. It is known that a deficiency in phosphorus decreases the energy production and is associated with poor fertility, apparent dysfunction of the ovaries causing inhibition and depression or irregularity of oestrus [11–13]. Supplementation with di-calcium phosphate improved the reproduction potential and reduced the inter-calving interval [14].

The cost of 5 kg mineral block was US$ 2.00. The average block intake was 117 g/day, amounting to US$ 0.017/day. The benefit from the increased fat content was US$ 0.010/L. Since the average milk production was 14 litres per day, the benefit due to mineral supplementation was US$ 0.14. It has been estimated that for each day of delay in the pregnancy of a cow a farmer loser US$ 2.00. Thus, the reduction in inter-calving interval due to mineral supplementation benefited the farmer by an estimated US$ 38. The average daily gain by the farmer was calculated as:

0.140 + 38/365–0.017 = US$ 0.331. This amounted to the price of 1.5 L of milk.

TABLE III. MEAN (± SE) PRODUCTION AND REPRODUCTION PARAMETERS FOR CONTROL AND SUPPLEMENTED GROUPS

Parameters	Control group	Supplemented group
Production parameters		
BCS	3.15 ± 0.22 (n=243)	3.27 ± 0.37 (n=280)
Calf weight (kg)	37.1 ± 1.6^{a} (n=243)	38.7 ± 1.8^{b} (n=30)
Milk production (L)	13.6 ± 1.0 (n=243)	14.5 ± 0.8 (n=280)
Milk density (g/L)	1029.1 ± 0.6 (n=186)	1029.3 ± 0.5 (n=171)
Milk fat (g/L)	33.0 ± 2.0^{a} (n=243)	38.6 ± 2.5^{b} (n=280)
Milk protein (g/L)	28.9 ± 1.1 (n=243)	29.4 ± 1.3 (n=280)
Reproduction parameters		
1st AI success (%)	25.0 ± 2.1^{a} (n=8)	36.8 ± 3.1^{b} (n=11)
> 3rd AI success (%)	26.6 ± 3.1^{a} (n=8)	15.7 ± 1.0^{b} (n=5)
Services/conception	2.25 ± 0.11^{a} (n=31)	1.84 ± 0.12^{b} (n=30)
Calving to conception AI (d)	166 ± 4.5^{a} (n=31)	126 ± 6.2^{b} (n=30)
Calving interval (d)	436 ± 5.6^{a} (n=31)	398 ± 7.1^{b} (n=30)

AI: Artificial Insemination; SE: Standard Error; BCS: Body Condition Score; $^{a,\ b}$: different superscripts denote a significant difference at $P < 0.05$.

5. CONCLUSION

Supplementation with di-calcium phosphate improved milk production and reproductive performance in dairy cattle. The mineral should be incorporated along with common salt (NaCl) in order to increase palatability.

It is recommended that industrial scale production of the block should be undertaken and blocks distributed to smallholder farmers in areas where calcium and phosphorus deficiency is prevalent.

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EVALUATION OF FORAGE LEGUME *LABLAB PURPUREUS* AS A SUPPLEMENT FOR LACTATING BUNAJI COWS

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Abstract

EVALUATION OF FORAGE LEGUME *LABLAB PURPUREUS* AS A SUPPLEMENT FOR LACTATING BUNAJI COWS.

The effects of forage legume lablab (*Lablab purpureus)* as a supplement for Bunaji cows was investigated both on-station and on-farm. The results of the on-farm trial involving five herds in each of two villages (control and supplemented) showed that supplementation with 3 kg of lablab increased milk off-take significantly (P <0.001) (1.27 ± 0.09 vs. 0.71 ± 0.1 kg per cow/day for supplemented and non-supplemented cows, respectively). Cows in the supplemented group showed a higher gain in body weight compared to non-supplemented animals (411 ± 1.4 vs. 127 ± 1.8 g/day respectively). They also showed a higher (P <0.001) body condition score than those in the non-supplemented group (3.5–4.5 vs. 2.0–3.5). Overall mean weight gain for calves was however, similar for both supplemented and non-supplemented groups (428 ± 5.3 vs. 428 ± 1.5 g/day). Supplementation of suckling Bunaji cows with lablab improved the performance of the animals and the income of the farmers.

1. INTRODUCTION

Domestic milk production is largely dependent on smallholder agro-pastoralists settled in and around large towns and villages, taking advantage of the increasing demand for dairy products from the rapidly urbanizing populations. This group of producers faces various constraints relating to inadequate and poor quality feed especially in the dry season and high incidence of diseases such as gastrointestinal parasites, which limit milk production [1]. The smallholder dairy producers depend largely on range vegetation and cereal crop residues as the major feed resources for their cattle. The availability and quality of these feeds fluctuate due to the seasonal pattern of forage growth. For cattle dependent on such feed resources, supplementary feeding is essential especially during the dry season. However, agro-pastoral cattle farmers seldom practice supplementary feeding in the dry season because of scarcity and high cost of conventional concentrate feeds.

High quality sown forages such as leguminous fodder have been found to provide adequate dry season supplementation and improve the productivity of grazing cattle [2]. It has not been widely adopted mainly because of competition for land and labour resources. This and other factors prompted the introduction of multipurpose legumes into the farming systems to provide feed for animals and food for the farmers. One such legume is lablab (*Lablab purpureus*).

This study was therefore designed to evaluate the effectiveness of lablab as a supplement feed for Bunaji cows under the smallholder agro-pastoral production system.

2. MATERIALS AND METHODS

2.1. Study sites

Two trials, one on-station and the other on-farm, were conducted. The on-station trial was conducted at the National Animal Production Research Institute (NAPRI), Zaria, while the on-farm trial was in smallholder agro-pastoral farms in two villages around Zaria. Zaria lies between latitudes 10 and 11° north and longitude 7 and 8° east, in the northern boundary of the sub-humid zone. Mean annual rainfall for the area is 1100 mm, lasting from May to October, with about 70% falling between July and September. Mean daily temperature during the wet season is 25°C and range from 14 to 36°C during the dry season. Relative humidity during the raining season averages 72% and range between 20 and 37% during the dry season. The dry season commences with a period of cool weather known as "harmattan" which lasts from November to January.

2.2. On-station trial

Fifteen lactating Bunaji cows (5 per treatment) weighing between 240–300 kg and 4–6 years of age were randomly assigned to three treatments. The treatments involved feeding whole cottonseed, lablab or a mixture of 50% lablab and 50% maize offal, as a supplement to cows grazing natural pastures. The animals were fed 2 kg of the respective supplement individually during milking in the morning before going out for grazing. The calves were separated from the dams on return from grazing in the evening and allowed to join the cows after milking the following morning. The daily milk yield from partial milking of the cows and weight changes of both the dams and the calves were recorded. The trial lasted for a period of 18 weeks.

2.3. On-farm trial

Based on the finding on-station, an on-farm trial was designed to evaluate the effectiveness of lablab as a supplement for lactating Bunaji cows under the smallholder agro-pastoral production system. Two villages (Basawa and Hanwa) about 30 km from NAPRI were selected. Five herds were in turn selected from each village. The herds in Basawa received the supplement feed while those in Hanwa served as the control.

2.3.1. Cattle management practices in the study areas

Milk production in the study areas was largely by indigenous Bunaji cattle kept mainly by the Fulani ethnic group who grow cereal crops in addition to their primary cattle herding activities. The food crops commonly grown include sorghum, millet, maize, cowpea, groundnut, rice, pepper and tomatoes. Residues from these crops especially the cereal crops are important animal feed resources especially during the dry season. Cattle are herded in the fields in the morning after milking to graze natural vegetation in the land after the crop harvest. They are returned in the evening and corralled at night. Supplementation with protein rich feed is not a routine management practice by most of the farmers because of the high cost of these feeds.

Milking is done once a day in the morning. Milking often starts between 1–2 months after calving, depending on the farmer. This delayed commencement of milking is to allow the calves to take enough milk from the dams for their sustenance during the first few months of life. Once milking has started, the calves and dams are kept separated overnight. The calves are allowed to suckle the dam in the morning for about 5 minutes before milking by the farmer. The farmers then partially milk the cows, the remainder of the milk is left for the calves to suckle during the day.

It is only when they observe symptoms of disease that the farmers buy drugs to treat animals. The farmers engage the services of veterinarians to attend to serious medical problems.

2.3.2. Experimental animals

From each herd, a minimum of 6 lactating cows weighing between 220–260 kg and aged between 4–8 years were used. The animals came into the experiment as they calved. At the beginning of the study, all the animals in selected experimental herds were screened to ascertain their general health, nutrition and reproductive status. Where a case of ill health was observed such animal was treated accordingly. All the experimental animals were de-wormed at the beginning and end of the supplementary period, and 1 month after the supplementation.

2.3.3. Supplementation

The experimental animals from the herds in Basawa were fed lablab (*Lablab purpureus*) forage as the supplement. Lablab is a forage legume recommended for the Nigerian savanna. It is a fast growing plant with high foliage and seed production potential, and is capable of maintaining its nutritive value far into the dry season (up to February) [4]. The lablab forage was grown and processed on-station at NAPRI. Each animal was fed 3 kg of lablab forage/day after milking in the morning before going out for grazing. The supplementation lasted for only 45 days beginning from the first day of milking since the feed produced could only last for this time period.

2.3.4. Feed analysis

Samples of the feed were analysed for DM [5], CP and Ash [6], and NDF and ADF [7].

2.3.5. Data collection

The weights of the animals were estimated one month before supplementation, at the beginning of supplementation and a month after the feeding trial using a Dalton weigh-band. Body condition scoring of the dams was done using a 1 to 5 scale.

The milk off-take (quantity of milk available to the farmers) was measured using plastic measuring cylinders starting from 1–2 months after calving. This was carried out weekly up to 30 days after the trial.

2.3.6. Cost-benefit analysis

A cost-benefit analysis was carried out to determine the profitability of the supplementation. Inputs used in the partial budget were costs of feed and de-worming drugs, while the outputs (products) were milk off-take for human consumption and live weight changes in both dams and calves. Both inputs and products were costed at prevailing producers' market prices of the commodities. The cost:benefit ratio was determined by dividing the total cost of inputs (TC) by that of outputs or revenue (TR).

2.3.7 Data management and analysis

All records were stored in Dbase [8]. Analyses of milk and growth performance was carried out using GLM methodology [9]. The model used considered herd, parity, treatment, weekly milk off-take, monthly weight of dam, calf weight and body condition score of dam. The results are presented as a mean ± SE.

3. RESULTS

3.1. On-station trial

Table I shows the chemical composition of the supplements and Table II shows the results of the feeding trial.

The three feeds had similar dry matter content while whole cottonseed and maize offal had slightly higher crude protein but lower neutral detergent fibre and acid detergent fibre than lablab.

Partial milk off-take of Bunaji cows fed whole cottonseed, lablab forage or lablab + maize offal were not significantly (P >0.05) different (Table II) although the yield was slightly higher for cows fed lablab. The cows fed lablab showed higher but non-significant weight gains than those on whole cottonseed or lablab + maize offal. However, live weight gain in calves of dams fed whole cottonseed was higher than those on lablab or lablab+maize offal. The cost of supplement/litre of milk was significantly lower (P <0.05) for cows fed lablab and lablab+maize offal compared to those fed whole cottonseed.

TABLE I. CHEMICAL COMPOSITION OF SUPPLEMENTARY FEEDS

Component	Whole cottonseed	Lablab	Maize offal
Dry matter	94.1	93.0	92.9
Crude protein	19.9	13.5	16.6
Neutral Detergent fibre	53.3	57.0	55.1
Acid detergent fibre	36.9	38.7	30.2

TABLE II. MILK OFF-TAKE (KG/DAY) AND BODY WEIGHT GAIN (G/DAY) OF BUNAJI COWS AND CALVES SUPPLEMENTED WITH WHOLE COTTONSEED, LABLAB OR LABLAB+MAIZE OFFAL

Treatment	Whole cottonseed	Lablab	Maize offal
Partial milk off-take	1.14 ± 0.40[a]	1.43 ± 0.64[a]	1.29 ± 0.3[a]
Live weight gains			
Dams	81.4 ± 40.1	83.6 ± 25.7	74.1 ± 15.3
Calves	245.9 ± 90.6[a]	215.5 ± 71.1[a]	197.6 ± 17.8[b]
*Cost of feed/L of milk	12.1 ± 1.1[a]	7.3 ± 1.1[b]	7.8 ± 1.2[b]

[ab] Means (± SE) with different superscripts are statistically different (P <0.001); *Cost in Nira.

3.1. On-farm trial

The mean daily milk off-take in the different herds from the on-farm trial is shown in Table III. The results show that supplementation of grazing agro-pastoral cows with lablab forage resulted in a significant ($P < 0.001$) increase in milk off-take.

The body weight gains of cows and calves are shown in Table IV. The cows supplemented with lablab forage had significantly ($P < 0.001$) higher body weight gains than the non-supplemented cows. However, there was no significant ($P > 0.05$) difference in body weight gain of calves between the supplemented and non-supplemented groups. Body condition score of animals in the supplemented group varied from 1.2–2.5 before supplementation and changed to 3.5–4.5 at the end of the experiment compared to 1.5–2.0 and 2.0–2.5 in the control group.

3.3. Cost-benefit analysis

At the prevailing market prices, the gross benefit of supplementation over non-supplementation was Nira 3457.62 per cow and the cost:benefit ratio was 1:1.5.

TABLE III. MEAN MILK OFFTAKE (kg/COW/DAY) OF LACTATING BUNAJI COWS IN AGRO-PASTORAL HERDS SUPPLEMENTED WITH LABLAB

Treatment		
	Supplemented	Non-supplemented
Day1 (Initial)	0.81 ± 0.12^{a}	0.61 ± 0.10^{b}
End of trial	1.45 ± 0.12^{a}	0.78 ± 0.12^{b}
30 days after the trial	1.55 ± 0.16^{a}	0.75 ± 0.14^{b}

^{abc}: means±SE with different superscripts are statistically different ($P < 0.001$).

TABLE IV. MEAN BODY WEIGHT GAIN (g/DAY) OF LACTATING COWS IN AGRO-PASTORAL HERDS SUPPLEMENTED WITH LABLAB

	Treatment	
Animal	Supplemented	Non-supplemented
Cows	411.0 ± 1.4^{a}	127.1 ± 1.8^{b}
Calf	427.8 ± 5.3^{a}	427.8 ± 1.5^{a}

^{abcd} overall means ± SE within columns with different superscripts are statistically different ($P < 0.001$).

4. DISCUSSION

The partial milk off-take in Bunaji cows fed lablab forage as a supplement in the on-station trial is similar to that reported for the same breed of cows that grazed natural range and received cottonseed cake supplement [10]. Given the fact that cottonseed cake is a more expensive supplement than lablab forage, the results of this trial indicate that lablab has a good potential as a cheap and alternative source of protein for dairy cattle.

The results of the on-farm trial also show that supplementary feeding of lablab to grazing agro-pastoral cattle during the dry season resulted in significant increases in milk off-take for human consumption and live weight changes in cows. Ehoche et. al. [11] reported similar increases in body weight in cows supplemented with legume forages. The similarity in the performance of calves in the supplemented and non-supplemented groups could be attributed to strategic management practices adopted by the farmers. The farmers delayed the commencement of milking their cows for almost 2 months after parturition. Even when the milking started, a reasonable quantity of milk was left for the calf. Nicholson [12] estimated the quantity of milk left for the calves by the traditional herdsmen during milking to be about 60%.

The high milk production trend observed during the trial in the supplemented herds compared to the non-supplemented herds was maintained for 30 days after the feeding had ended. This is an indication that the residual effect of supplementation is carried over for a period of time, at least up to 30 days after the end of supplementation.

5. CONCLUSIONS

From the results it could be concluded that supplementation of lactating Bunaji cows with lablab forage improved the milk off-take, body weight and body condition of the animals and resulted in economic benefit to the farmer. The estimated cost:benefit ratio (1:1.5) indicates that the farmer can benefit by supplementation.

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DEVELOPMENT AND FIELD EVALUATION OF ANIMAL FEED SUPPLEMENTATION PACKAGES FOR IMPROVING MEAT AND MILK PRODUCTION IN RUMINANT LIVESTOCK USING LOCALLY AVAILABLE FEED RESOURCES

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Abstract

DEVELOPMENT AND FIELD EVALUATION OF ANIMAL FEED SUPPLEMENTATION PACKAGES FOR IMPROVING MEAT AND MILK PRODUCTION IN RUMINANT LIVESTOCK USING LOCALLY AVAILABLE FEED RESOURCES.

Molasses is a major by-product of the sugar industry in Mauritius and is still under-utilized for livestock production because of legislation and handling problems. A combination of urea, molasses and other feed ingredients can be used to produce urea-molasses multinutrient blocks (UMMB) that can be fed to livestock as a supplement. The main objective of UMMB supplementation is to provide a constant source of degradable nitrogen throughout the day, to promote growth of rumen microbes in ruminants fed poor quality forage. In Mauritius, studies were undertaken to evaluate the effect of UMMB supplementation on milk production, reproduction parameters and live weight change. Sixty cows were initially involved, 30 receiving UMMB over and above their normal ration and 30 constituting the control group. These studies have shown that UMMB improved milk yield of cows although the animals were already fed a dairy concentrate. Cows that calved resumed ovarian activity slightly earlier in the treatment group (67 ± 32 days) than those in the control group (73 ± 36 days). Body condition was not affected by UMMB supplementation.

1. INTRODUCTION

Natural fodder and crop residues such as sugar cane tops and leaves are important forage feeds in the livestock production systems in Mauritius. However, they are often of poor quality, usually deficient in protein and minerals. To improve production, the farmer should optimise the efficiency of utilisation of the available feed resources. This is done by the use of supplements that provide the deficient nutrients, especially protein. Some of these supplements can sometimes be produced using locally available ingredients and agro-industrial by-products such as sugarcane molasses and bagasse.

Molasses is a major by-product of the sugar industry in Mauritius. It is a good, palatable and cheap source of energy for ruminants. Use of liquid molasses by small farmers, however, is very limited due to problems related to transport, storage and legislation. One strategy to get over this obstacle and increase the use of molasses in the animal industry is through the manufacture of urea-molasses multinutrient blocks (UMMB). The technique consists of mixing the required feed ingredients in a container and pouring the mixture into moulds and leaving to solidify into blocks. This strategy of producing UMMB has been proposed in many countries by the FAO and the International Atomic Energy Agency (IAEA) in order to develop affordable and sustainable supplementation packages for improving the productivity of smallholder farms. UMMB can be fed through out year but are more beneficially utilised during the dry season or when the animals are grazing low quality pastures. Major advantages of using the blocks are their convenience in terms of packaging, storage, transport and ease of feeding.

This project comprised of two phases. Phase I consisted of formulating and testing a feed supplementation package using locally available feed resources. Phase II dealt with field evaluation of UMMB as a supplement for lactating cows.

2. MATERIALS AND METHODS

2.1. Phase I. Development of Urea Molasses Multinutrient Blocks (UMMB) as a feed supplement for livestock production

The objectives were to produce a supplementary feed, convenient and easy to use, for improving milk and meat production, and to maximise the use of locally available feed materials to reduce high cost of concentrate feeds.

2.1.1. Development of UMMB

The ingredients and their respective amounts required to prepare UMMB can vary depending on their availability and cost, and also according to the objectives for which the blocks are to be utilised, i.e. for maintenance or production. Ingredients available locally are sugarcane molasses, urea, common salt and wheat bran. Other ingredients such as minerals, vitamins and a source of good quality protein like cottonseed cake are imported and are readily available on the local market. Cement is used as a binding agent.

Studies conducted in Canada and USA on the utilisation of cement and its by-products as minerals for animals have not revealed any negative effects when fed up to a maximum of 3% of the total daily dry matter intake [1]. Studies conducted at AREU using manufacturing procedures as described by Aarts et al. [1] resulted in several formulations that produced blocks of appreciable hardness. These formulations were later reviewed to optimise the utilisation of sugarcane molasses and decrease the proportion of cement thereby reducing the cost of production of the blocks.

2.2. Phase II. The effect of supplementing dairy cattle with urea-molasses multinutrient blocks (UMMB) on reproductive performance and milk yield and quality

Phase II of the project consisted of on-farm testing of UMMB blocks, as a feed supplement for dairy cows. The study was implemented at Bon Accueil/Lallmatie area where fodder quality and availability is a major constraint to production. The project commenced on 5th March 1998 and ended in October 1999.

The studies undertaken aimed at determining the effects of feeding UMMB to 7-month pregnant cows up to 4 months post-partum, on milk yield, milk quality, resumption of ovarian activity and body condition score.

2.2.1. Experimental animals

From a total population of around 1400 cows, 60 cows were randomly selected and gradually introduced to the study as and when they reached 7-month stage of pregnancy. These animals were then randomly allocated to 2 groups of 30 head each. One group constituted the treatment group (with UMMB) while the other was the control (without UMMB). Cows kept as control received mixed forages and a dairy concentrate. Those in the treatment group received in addition, a regular supply of UMMB as a supplement.

2.2.2. *Feeds and feeding*

All animals were stall-fed. The average smallholder unit consisted of 2–5 cows; only 4 farmers had 6–12 cows. The selected animals were given the basal diet as per the farmer’s routine practice, which consisted of cut and carry forage, plus a small amount of dairy concentrate varying from 2.0 to 5.0 kg/animal per day. The forages consisted of mixed species, grasses, vines and leaves, and sugarcane tops during the harvest period. This diet was the control. The treatment group received, in addition to mixed fodder and the concentrate, a regular supply of UMMB as a lick, during the whole period of study, without interruption. The UMMB was placed on racks, which were fixed in front of the cow at a height of 30 cm above the floor to prevent contamination with urine and faeces. Blocks weighing 10–15 kg were used for convenience and their consumption was monitored weekly. All the animals got used to licking the blocks within an adaptation period of 2 weeks.

2.2.3. *Monitoring of milk yield*

Field visits were carried out once a week to monitor the intake of UMMB and the daily milk production. Milk production was recorded by the farmers on pre-designed sheets. These were checked on each visit for accuracy and consistency.

2.2.4. *Parameters observed*

The following parameters were observed and records maintained.

- UMMB intake of individual cows
- Milk production
- Assessment of cows for body condition score
- Estimation of live weights.
-

Samples of milk were collected monthly for the analysis of quality. Proximate analysis was carried out on feed and UMMB samples collected regularly.

3. RESULTS

3.1. **Phase I**

The composition of a few formulations of UMMB are presented in Table I. Costs of production (in November 1999) include transport and labour for each formulation.

Table II shows the chemical composition of the block selected for on-farm trial (RF2) as against the original formulation. The mean calculated metabolizable energy (ME) value varied between 10.9 and 11.0 MJ/kg dry matter (DM) respectively, for the two blocks.

3.2. **Trials for UMMB intake**

Initially, 8 kg blocks were manufactured according to formulation B1. Intake trials were conducted with 2 groups of 8 adult Friesian heifers. UMMB was given together with a basal diet consisting of about 25 kg of fresh fodder and 2 kg of a dairy concentrate/head per day. Intake of UMMB ranged from 400 to 1300 g per head/day. There was no incidence of urea toxicity. No other adverse symptoms were observed.

TABLE I. SUMMARY OF FORMULATIONS AND THEIR COSTS OF PRODUCTION

	Original formulation	Revised formulations (RF)		
Ingredients	Block B1%	RF1%	RF2%	RF3%
Molasses	40	40	45	50
Urea	10	9	8	8
Mineral mixture	5	4	3	2
Salt	3	3	2	1
Cottonseed cake	5	6	6	5
Cement	17	12	12	12
Wheat Bran	20	26	24	22
Cost of production (MR/tonne)	3630	3514	3175	2900

MR: Mauritian Rupee (US $ 1.00 = MR 25.00)

TABLE II. CHEMICAL COMPOSITION OF UMMB (% ± SD) ON FRESH WEIGHT BASIS

Component	Block B1	RF 2
Dry Matter (DM)	77.7 ± 4.2	83.2 ± 0.4
Crude protein (CP)	27.5 ± 2.3	30.3 ± 0.7
Crude fibre (CF)	2.2 ± 0.5	2.1 ± 1.3
Ether Extract (EE)	1.4 ± 1.5	0.3 ± 0.2
Calcium (as Ca)	5.5 ± 0.5	4.8 ± 0.5
Phosphorus (as P_2O_5)	1.4 ± 0.2	2.1 ± 0.1
Ash (other than Ca and P_2O_5)	17.6 ± 1.8	16.9 ± 1.8

3.3. Phase II

In this experiment, 60 cows were initially involved but some were dropped due to unreliability of milk production records, deaths and sale to other regions.

3.4. Intake of UMMB

Intake of UMMB ranged from 200 to 2200g and the average intake observed was 706 ± 495 g/head/day (n = 28). No adverse symptoms were recorded.

3.5. Milk Yield

The peak milk yields were attained as early as 2 weeks in some instances. However, all cows in both groups reached their peak milk production at 4 weeks post-calving. The mean peak milk yield at 4 weeks was 12.0 ± 4.0 and 13.2 ± 3.4 litres per head per day for UMMB-supplemented and non-supplemented groups, respectively. The average daily milk yield per head computed over 120 days of lactation was 10.9 ± 3.0 (n = 20) and 11.7 ± 2.7 (n = 23) litres respectively ($P < 0.05$), for the two groups.

3.6. Milk quality

Milk samples were collected on a monthly basis and analysed for solids, fat, protein and lactose. Figures were compared with standards as quoted by Schmidt [4] and the Ministry of Agriculture, Mauritius.

3.7. Resumption of ovarian activity

The interval from calving to resumption of ovarian activity was found to be 67 ± 32 days (n = 22) for animals in the treatment group and 73 ± 36 days (n = 27) for those in the control group. These differences were not significant. The longest interval was in the treatment group with 150 days while for the control it was 132 days.

3.8. Body condition score (BCS) and liveweight of animals under study

The condition scoring system was based on handling two areas of the cow to assess the level of fat cover, namely, the loin area and around the tail head. A condition score of 1.0 to 5.0 was adopted with a BCS of 1.0 indicating absence of fatty tissue in the pelvic and loin areas and a BCS of 5.0 indicating excessive fat.

Most cows in the study had fairly good body condition scores ranging from 2.5 to 3.5. During the first two months in milk the cows lost more than 0.5 points in the BCS, stabilising at a score >2.5 by 120 days. At around 200 days in milk, the BCS was close to 3.0 in both the treatment and the control groups of animals, indicating that body reserves that were lost in early lactation were being replenished.

Since it was not practical to use any form of weighing scale to weigh the stall-fed animals body weight was estimated visually.

3.9. Nutritive value of feeds

Feeds that were utilised were sampled regularly once a month for the analysis of dry matter (DM), crude protein (CP), crude fibre (CF), crude fat (EE), ash and nitrogen-free extract (NFE) by standard methods (Table III).

TABLE III. THE CHEMICAL COMPOSITION (% DM ± SD) OF SOME FEEDS USED IN THE FEEDING TRIALS (ON DRY MATTER BASIS)

Feed	DM (%)	CP	CF	EE	Ash	NFE
		(% IN DM)				
UMMB	77.7 ± 4.2	35.4 ± 2.3	2.8 ± 0.5	1.8 ± 1.5	31.5 ± 4.1	28.5
Cowfeed concentrate	83.7 ± 2.7	16.2 ± 1.1	6.2 ± 0.8	2.2 ± 1.4	9.7 ± 0.5	65.7
Cottonseed cake	88.5 ± 4.9	44.9 ± 2.7	13.0 ± 1.7	9.6 ± 1.0	6.0 ± 0.3	26.5
Sugarcane tops	28.0 ± 5.3	6.4 ± 1.3	30.4 ± 2.9	3.2 ± 0.4	5.4 ± 0.9	54.6
Mixed fodder	29.0 ± 7.1	7.6 ± 3.1	34.1 ± 5.3	2.1 ± 0.7	6.6 ± 1.8	49.6

4. ECONOMIC ANALYSIS

Only the cost of UMMB supplementation has been considered since all other variable costs are the same for both groups. Following assumptions were made in the calculation of cost of production.

- ♦ Basal diet consisting of cut and carry forage at no cost to the farmer.
- ♦ The daily concentrate allocation to lactating cows is 3.0 kg/head although the recommended practice is to feed 0.5 kg concentrate per litre of milk produced. This item has not been computed as it is common to both groups.
- ♦ Labour cost is not included since it is predominantly family labour.
- ♦ Selling price of milk is Rs 9.00/litre.

4.1. Data used in analysis

Total milk production was estimated for the complete lactation period of 305 days (43 weeks) and was found to be 2892 and 2739 litres for UMMB-supplemented and non-supplemented cows, respectively. Assuming the total milk consumed by a calf to be 375 litres, amount of saleable milk for the two groups of animals were 2517 and 2364 litres, respectively. The mean daily intake of UMMB was 700 g/cow fed during a period of 365 days and the cost of production of UMMB (Block B1-Table 1) was Rs 3.63/kg.

Results show that the profitability per cow increased by Rs. 45000 with UMMB supplementation in the regions selected for the experiment (Table IV).

TABLE IV. ADDITIONAL REVENUE THROUGH SALE OF MILK IN A WHOLE LACTATION

	UMMB-supplemented cows Cost (Rs/cow)	Non-supplemented cows Cost (Rs/cow)
Purchases (UMMB)	927	-
Returns (Sale of milk)	22653	21276
Net Revenue/cow (Rs)	21726	21276
Additional revenue/cow (Rs)	450	-

5. DISCUSSION

The cows under study were of mixed breeds, mostly Friesian and Creole crosses. Most of the cows were in good condition as reflected by their body condition scores. The productivity of these animals is usually greatly constrained by the lack of good quality fodder, especially during the dry season. To improve production, most smallholder dairy farmers have adopted the practice of supplementing their animals with a dairy concentrate, locally referred to as “cowfeed”. The major components of this dairy concentrate are sugarcane molasses, cotton seed cake, maize and wheat bran. Its high crude protein content (16.2% DM) and energy value (10.0 MJ ME/kg DM) make it an excellent supplement for dairy cattle. Over and above this supplement some farmers also feed cottonseed cake

In relation to milking, the farmers involved in the study adopted one of the following three systems:

- Partial milking: milking 3 teats and leaving 1 teat for the calf
- Partial milking: milking partially all 4 teats
- Complete milking and bucket-feeding the calf

As a consequence of these different practices, a correction factor was applied to the recorded daily milk production of each individual cow. An average quantity of 3 litres was added to the daily production of partially milked cows, disregarding any residual milk. Unlike temperate breeds of cattle which attain peak milk yields at about 6 weeks after calving, dairy cattle in the tropics tend to attain this peak as early as 2 to 4 weeks as found in the study. Moreover, this peak was not highly pronounced, and was close to the average daily milk yield per head as computed over 120 days of lactation. Although the weekly milk production during the first week of lactation was higher in the control group (82 litres) as compared to the treatment group (72 litres), the production was the same in the thirteenth week (Figure 1).

Using regression analysis of the weekly milk yields, a linear relationship was generated for each group of animals. The rate of decline in milk production over time was different for the two groups of animals. The treatment group showed a lower rate of decline (–0.695 litres/week) as compared to the control group (–1.5386 litres/week), an effect which could be attributed to the beneficial contribution of the UMMB supplement (Jayasuriya, Personal communication).

Treatment Group $Y = -0.695\ X \pm 82.18$ $(R = 0.4)$

Control Group $Y = -1.5386\ X \pm 96.78$ $(R = 0.7)$

Where,

Y = weekly milk yield (litres)

X = lactation period (week)

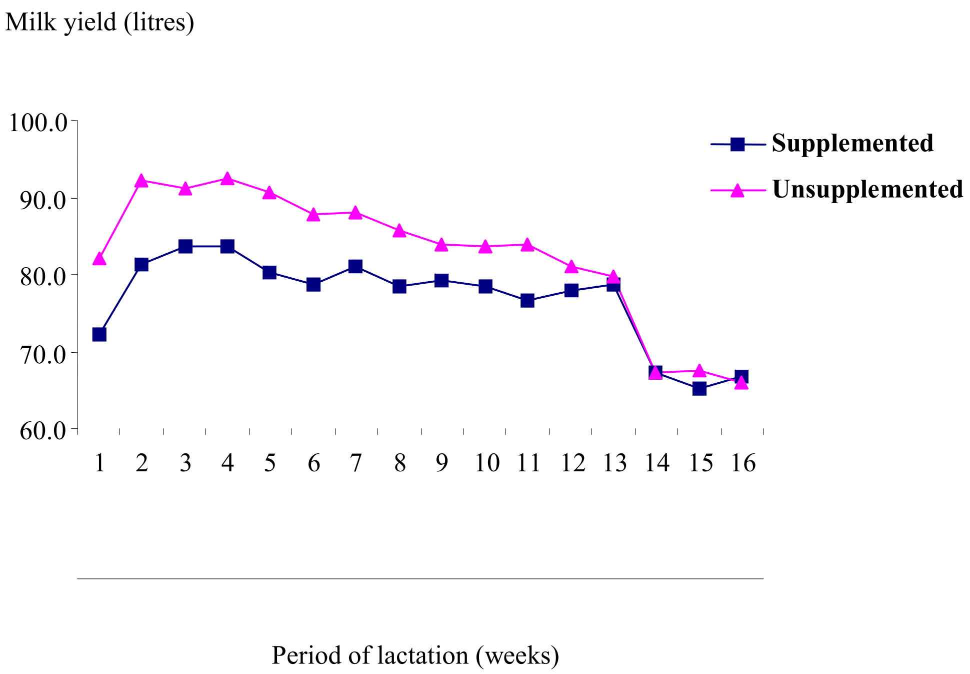

Figure 1: Milk yield of supplemented and un-supplemented group of cows.

The linear relationships generated by the regression analysis indicate a better fit in the control group as opposed to the treatment group. However, these relationships were useful in estimating the total milk produced by each group of animals over a whole lactation of 43 weeks. Accordingly, the average milk yield of UMMB-supplemented animals was estimated at 2892 litres and it exceeded that of non-supplemented ones (2739 litres) by 153 litres, ensuring a net financial benefit of Rs. 450.00 per cow, after taking into consideration additional expenses incurred for feeding UMMB.

Moreover, regarding basal feeds supplied to animals, forages and cane tops were of medium quality (6.0–7.6% CP and 30–35% CF on DM basis). Most animals were in good body condition at calving. They had enough energy available for the synthesis of milk in early lactation, a time when the animal has a difficult time consuming enough forage to meet her maintenance and milk production requirements. Results obtained in Indonesia with UMMB supplementation showed that responses depend on the quality of the basal diet. Quick response to UMMB supplements is obtained when animals are fed rice straw. In a ration with high by-pass nutrients, the responses are negligible or even negative [2].

The fat content of milk in the treatment group during the first month (2.7%) and that of milk in control group in the first two months of lactation (3.2%) were quite low. Otherwise, all figures were comparable or higher than data quoted by Schmidt [4].

The UMMB supplementation appears to have a positive effect on the resumption of ovarian activity. Cows that calved resumed ovarian activity slightly earlier in the treatment group (67 ± 32 days) than those in the control group (73 ± 36 days). This compared favourably with findings by Hendratno [2] in Indonesia where UMMB supplemented cows showed resumption of ovarian activity at 85.3 ± 52 days against 88.5 ± 21 days for control animals. In Mauritius dairy cows resumed ovarian activity much earlier with or without UMMB supplementation compared to animals in West Java where animals were raised on straw-based diets.

6. CONCLUSION

Livestock is an important source of cash income at the smallholder level. The productivity of dairy cows is greatly constrained by the lack of good quality feed, especially during the dry season. Supplementation with the locally manufactured dairy concentrate is a common practice among smallholder farmers, with some even feeding cottonseed cake as an additional supplement to cows in lactation. Supplementation of cows already receiving some concentrates with UMMB marginally improved milk yield with a much slower rate of decline in the milk production than in the non-supplemented group. Also, there appeared to be an improvement in the reproductive performance of the animals, as observed from the resumption of ovarian activity. Feeding of UMMB to animals raised on low quality fodder may be an alternative to other forms of supplementation especially when these become unavailable or too expensive. UMMB may perhaps constitute an innovative feeding strategy for other species of livestock as well where concentrates feeding is not a common feature, namely in goat rearing and deer ranching.

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THE EFFECT OF SUPPLEMENTATION STRATEGIES ON REPRODUCTIVE AND PRODUCTIVE PERFORMANCE OF COWS KEPT UNDER DIFFERENT HUSBANDRY SYSTEMS IN SUDAN

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Abstract

THE EFFECT OF SUPPLEMENTATION STRATEGIES ON REPRODUCTIVE AND PRODUCTIVE PERFORMANCE OF COWS KEPT UNDER DIFFERENT HUSBANDRY SYSTEMS IN SUDAN.

Three extensive systems of husbandry practices were chosen in the semi-arid rainfed area of Western Sudan (Latitude 11°15' and 16°30' N, Longitude 27° and 32° E). Cattle production in sedentary, transhumance and migratory systems were closely monitored through a period of 365 days (June 1999–June 2000). Cattle herders were randomly selected from those who were willing to participate in the project and implementation of supplementary feeding with poultry manure/molasses or molasses alone. Selection was based on different geographical sites around El Obeid city (600 km west to Khartoum capital). In the sedentary system seven groups of cattle herders were selected and were designated as farms SA, SB, SC, SD, SE, SF, and SG. In the transhumance system the cattle herders were desinated as TA, TB, and TC and in the migratory system, MA, MB, MC, MD, and ME.

In each system the recently calved cows were monitored for post-partum ovarian activity using milk progesterone radioimmunoassy. Days to conception were taken as non-return to oestrus. Regression analyses were done for fertility parameters against body weight (BW) and body condition score (BCS) at calving, 30, 60, and 90 days from calving, as well as milk yield (MY) at 30, 60, and 90 days from calving. Poultry manure/molasses mixture was used to replace farmer's concentrate diet in farm SB (supplementation) of the sedentary system while in others the concentrate ration usually used by the farmer was partially susbstituted by molasses. In the migratory system the poultry manure/molasses mixture partially supplemented the farmer's concentrate diet (substitution) of all animals. In the farms belonging to transhiumance system molasses alone was used as a substitution diet. The results revealed that there was a wide variation in both days to first ovulation and days to conception in all systems of production. The majority of cows showed delayed post-partum activity and days to conception, especially in the transhumance system. Cows in both sedentary and migratory systems showed gradual increase in BW and MY from calving up to 90 days, while those of the transhumance showed a steady decrease in both these parameters. BCS was found to decrease from calving to 60 days in all systems. Regression analyses showed significant negative correlation between BW and BCS (at calving, 30, 60, and 90 days from calving) and days to ovulation and conception. Dry season showed an adverse effect on fertility compared with the rainy season. Poultry manure/molasses diet as supplementation showed the best increase in milk yield in the sedentary system, but when used as a substituted diet in the migratory system milk yield increased only slightly. Diets substituted with molasses alone increased milk yield remarkably in both sedentary and transhumance systems. Also recently calved cows that received any of the above diets in the sedentary system were found to resume post-partum activity earlier than before supplementation. Cross breds, had shorter days to ovulation and conception than the local ones, but showed lower pregnancy rates. It could be concluded that, poor reproductive performance in cows kept under extensive traditional system was due to poor management practices, which ignored high-energy supplementation during late pregnancy and early lactation, especially during the dry season when rangeland pastures deteriorate drastically. Suckling further exacerbated the effect of poor nutrition resulting in extended post-partum anoestrus and low conception rates. Controlled mating and suckling together with good feeding strategies may greatly enhance reproductive performance of cows kept under extensive systems of management.

1. INTRODUCTION

Sudan has a livestock population of 103 million; approximately 33 million are cattle. The bulk of the cattle population is of the local beef type, living under the pastoral system of management. Sudan has the largest extent of permanent pasture and the largest number of pastoralists compared to any other African country. Three main categories of pastoralists can be recognized.

The migratory pastoralists are those that are on constant move with their animals in pursuance of forage and water. During the rainy season (July to August) they settle in camps near a city and graze their animals in the nearby fields. With the advancement of the season they move out in search of pasture and water, covering long distances. As the dry season approaches the herders settle around sorghum fields to make use of sorghum residues as the main diet of the animals. Once the grain has been harvested cattle graze the standing stover and ungrazed stover is stored in sacks for feeding during the winter. Cows produce 2–3 litres of milk/day during the wet season. However, by the end of the dry season, there is no surplus milk over and above the needs of calves. Dry season feeding is mainly dependent on stored pasture and sorghum stovers. Concentrates are given only to milking cows at the rate of 2 kg/cow/day.

Migratory people as well as their animals, suffer from heat stress, lack of water and food. By the time next rains arrive, adult animals may have lost over 30% of their body weight and young animals would be weak and vulnerable to diseases [1]. Many tribes rare cattle, sheep, camels and goats together in their herds as a means of harnessing the marginal and constantly changing resources to support their existence [2].

In the transhumance system, pastoralists with their animals move from a home-base located at the centre of the migratory route, between wet and dry season camping areas. It is an adaptive system whereby rangeland use is inseparable from the livelihood of the people. Movement is across several ecological zones [3]. The transhumance are conservative to their environment and provide meat, milk and milk products to the sedentary people. It is the demand for these products that has kept the pastoral system expanding [4].

In the sedentary system of cattle management, there are two production systems, the traditional and the improved. The traditional system is subsistence-oriented and is characterized by low inputs with a resultant low productivity. The improved system consists of intensive crop-livestock smallholders, peri-urban production and semi-intensive management. Output from this system is generally several times more compared to the traditional system. Production from all systems has remained comparatively lower than those from other areas of the world due to inadequate feed, both in quality and quantity, poor management of the available feed resources and the reproductive wastage due to low conception and calving rates, delayed age at puberty and first calving, high mortality due to diseases and inadequate health care.

The general constraints to all pastoralist systems include (a) an erratic rainy season from July to October, (b) the domination of rangelands by annual grass species offering neither an optimum carrying capacity nor adequate nutrition around the year, (c) scarcity of water towards the middle and end of dry season (d) expanding cultivation, (e) unperscribed burning of rangelands, and (f) restriction of mobility due to the closing of many migration corridors by farmers and ranchers [5]. Due to such pressures, transhumance have become more dependent on farming to avoid purchase of grain [5]. Sorghum and groundnut are cultivated when the opportunity arises; however, crop residue utilization is not strictly adopted.

The present study was undertaken to investigate the influence of various supplementation strategies on production and reproductive performance of cattle under the three management systems.

2. MATERIALS AND METHODS

2.1. Study area

The present investigation focused around the cattle herders of El Obeid city, about 600 km from the capital Khartoum. This is the semi-arid rainfed area in Western Sudan (Latitude 11^{o} 15’ and 16^{o} 30’N, Longitude 27^{o} and 32^{o}E) with temperatures ranging between 30–35^{o}C during most of the year and over 40^{o}C during the dry season (April to June). The rainy season extends from July to October. The dominant vegetation is a varying mixture of grasses and shrubs. [6]. The cattle farms comprising of 15–50 animals are concentrated around urban centers and are the main suppliers of milk to the inhabitants. Millet is the main food grown for human consumption with sorghum, watermelon, groundnut, sesame and roselle (kerkade) grown as cash crops.

2.2. Husbandry practices

2.2.1. Sedentary pastoralists

Seven cattle owners were randomly selected from different geographical sites around El Obeid city for studies on the sedentary system of production. They were designated as farms SA, SB, SC, SD, SE, SF, and SG. Each farm had an area of 10–15 ha, which was being cultivated with sorghum for local consumption. During the rainy season farmers settle in drier areas avoiding the flooded areas, which are usually uninhabitable because of unpleasant smell and biting flies. Cattle spend around 6–9 h grazing during the day, moving over small (3–4 km) distances. Surface water from natural ponds and catchment areas is their source of drinking water. During the dry season, more time is spent grazing (8–10 h) moving over longer distances (7–8 km) in search of good quality forage. They come back to the farms and then move another 1–2 km to find drinking water from deep wells in the city. Crop residues and concentrates are offered before the afternoon milking. Approximate 1–2 kg of a concentrate ration is offered to each milking cow. Mature animals are kept in open enclosures made from local materials or barbed wires. Calves are kept in separate sheds with a roof for protection against the sun.

2.2.2. Migratory pastoralists

Five farmers MA, MB, MC, MD and ME, from the migratory system of production, each having between 5–20 cows were selected. In this system cattle owners were on constant move with their animals in pursuance of forage and water. They have homelands in which they settle during certain times of the year. During the rainy season (July to August), cattle herders settle in camps. Mature animals are kept lose; calves are kept in sheds. With the advancement of the rainy season and as the pasture becomes dry, cattle herders move in an eastward direction away from the city in search of pasture and water. They cover long distances before settling around the sorghum fields. During the dry season the herders return to the villages moving in a southward direction and covering a distance of about 20 km. Animals are allowed to drink from deep-water wells located about 2 km from their settlements. Dry summer feeding depends mainly on stored pasture and sorghum stover. Concentrates are given only to milking cows at a rate of 2 kg/cow/day.

2.2.3. Transhumance pastoralists

The transhumance system was represented by three cattle herders who were willing to participate in molasses supplementation. They were chosen during their settlement around El Obeid city in the summer of July 1999. They were designated as TA, TB, and TC herds. Due to controlled breeding, all cows calved during the rainy season. Recently calved cows in each herd were of the same number and parity. Concentrate feed (2 kg/animal/day) was given to milking cows during the dry season. Milking cows generally do not move with the rest of the herd in the southward migratory route in the dry season, but those that become dry during this period are allowed to join the migratory herd.

The transhumance cattle herders move from north to south and backwards along rainfed rangelands located in western Sudan. Mobility is a principle defense against the fluctuating climate, the periodic droughts and the uneven rainfall. During the rainy season they settle in the north. The trek back south is undertaken once the rain stops. The scarcity of water dictates their fast return. Pre-weaned calves of less than one year are kept indoors within the camp and sometimes tied to a common rope. One year old calves are allowed to graze nearby and around the homestead. Calves and bull calves are kept in thorn-fenced kraals all year round. They are allowed to suckle their dams twice a day, during milking time in the morning and in the evening. Rarely are cows kept in confinement; only when they are sick or to avoid the risk of grazing the surrounding crop farms.

Breeding season is regulated so as to coincide the birth of calves with a period of better nutrition, which is the wet season. This is done by allowing the calves to suckle for a short period or preventing suckling altogether. To prevent suckling, thorns attached in two rows to a rope are tied around the calf's muzzle. A major problem of this technique is that the cow becomes dry soon after conception and the calf gets little milk for nourishment.

In all systems, weaning was done gradually and mating was natural with bulls running with the herd. All farms depended on hired animal attendants to look after their herds and on their experience for health care and disease treatment. Vaccination against rinderpest and anthrax were carried out only when outbreaks were expected. Prevailing diseases were pneumonia, internal and external parasites. The supplementary feeds used in each farm are shown in Table I.

TABLE I. CONCENTRATE FEED INGREDIENTS USED IN THE FARMS

Husbandry System	Farm ID	Sorghum (%)	Wheat bran (%)	GNC (%)	GNH (%)	Salt (%)	Others (%)
Sedentary	SA	55	20	29	-	1	-
	SB	50	-	18 –19	30	1–2	-
	SC	60	9	30	-	1	-
	SD	43	-	16	42	1	-
	SE	40	-	-	-	-	BR (60)
	SF	50	20	19	10	1	-
	SG	60	10	29	-	1	-
Migratory	MA	48	23	28	-	1	-
	MB	47	22	30	-	1	GM
	MC	45	20	-	-	1	SC (34)
	MD	50	17	32	-	1	-
	ME	49	20	30	-	1	-
Transhumance	TA	50	20	29	-	1	-
	TB	79	20	-	-	1	-
	TC	-	20	-	-	1	BR

GNC, groundnut cake; GNH, groundnut hulls; SC, sesame cake; GM, guar meal (crude protein 16%, 4.4% ether extract); BR, brewery residue (22% crude protein, 1.1% ether extract).

2.3. Supplementation trial

For all three systems the period of study consisted of two phases, a survey phase of 10 months during which the husbandry practices were closely monitored and an intervention phase where the appropriate supplement was given over a period of 9 weeks.

In the case of the sedentary system poultry manure-molasses was given as a complete diet to farm SB (2 kg) during the intervention phase. As for the other farms, the concentrate ration usually used by farms was partially substituted by molasses i.e. for every 1 kg concentrate ration removed, 1kg of molasses was added. Farm SA was used as a control.

For farms in the migratory system, poultry manure/molasses was given as a substitute. Of the 2 kg of concentrate fed 1 kg was substituted with poultry manure/molasses mixture.

In the transhumance system molasses alone was given as a substitute mixed with farmers’ concentrate diet.

2.4. Measurements

2.4.1. Milk Sampling

Milk samples (10 mL) were collected into tubes containing sodium azide at weekly intervals beginning at 10 days from parturition and every week thereafter until the animal was confirmed pregnant by non-return to oestrus. Milk samples were centrifuged for 10 minutes at 2500 *g* to remove fat and then stored in a sealed plastic container at –20°C until assayed for progesterone. Concentrations of progesterone in the defated milk were measured using the solid-phase RIA system supplied by the Joint FAO/IAEA Division [7]. Progesterone concentrations greater than 1 nmol/L were considered to indicate cyclic ovaries.

2.4.2. Body weight and body condition score

Body weight was determined by measuring the heart girth using a weigh band. Body codition score was carried out according to one-to-nine scale (1 emaciated, 9 obese) [8]. The above parameters were measured at calving and at 30, 60 and 90 days after calving. Faecal samples were regularly collected for determining the gastrointestinal parasite burden.

In addition to measuring the milk progesterone profile, body weight, body condition score and milk yield were also recorded, when ever possible.

2.4.3. Statistical analysis

Regression analyses were carried out using Statistical Analytical System (SAS). Least significant difference (LSD) was used to detect statistical significance between means.

3. RESULTS

3.1. Resumption of ovarian activity and conception

Few cows resumed ovarian activity within 45 days after calving under all three-production systems. However, by 90 days the percentage of cows resuming ovarian activity was over 60% and this reached 100% by 120 days. Conception followed a similar trend (Table II).

TABLE II. NUMBER AND CUMULATIVE PERCENTAGE (WITHIN PARENTHESIS) OF COWS RESUMING OVARIAN ACTIVITY AFTER CALVING

Husbandry system	Total number of cows	Resumption of ovarian activity (days)			
		<45	46–60	61–90	90–120
Sedentary	73	15 (21)	15 (42)	14 (62)	27 (99)
Migratory	62	3 (5)	18 (35)	21 (69)	19 (100)
Transhumance	36	12 (33)	6 (50)	11 (80)	7 (100)
		Conception (days)			
Sedentary	73	5 (7)	11 (22)	18 (47)	39 (100)
Migratory	62	12 (19)	23 (56)	12 (75)	15 (99)
Transhumance	36	7 (19)	9 (44)	12 (77)	8 (99)

The mean interval from calving to first ovulation was lowest in the transhumance system compared to the other two systems (68 vs 89 and 94). There was a wide variation in the resumption of ovarian activity between farms in the other two systems. A similar trend was observed in the interval from calving to conception (Table III).

3.2. Effect of season

The season appeared to have an effect on the interval from calving to first ovulation and the number of days to conception. There was early resumption of ovarian activity ($P < 0.05$) in both sedentary and migratory systems during the wet season (July to October) compared to dry months (April to June). Animals reared under the sedentary husbandry system showed early resumption of ovarian activity and early conception during the wet season compared to those reared under the migratory system. In the case of transhumance system of management all cows tended to calve in the wet season.

TABLE III. INTERVAL (MEAN ± SD) FROM CALVING TO FIRST PROGESTERONE RISE AND CONCEPTION IN ALL HUSBANDRY SYSTEMS

Husbandry System	Farms	Interval from calving to first progesterone rise	Interval from calving to conception
Sedentary	SA	71.3 ± 45.1^{c}	126.0 ± 46.0^{b}
	SB	92.1 ± 54.3^{b}	226.0 ± 52.6^{a}
	SC	61.7 ± 14.9^{d}	102.6 ± 48.9^{b}
	SD	85.5 ± 39.1^{b}	174.1 ± 81.6^{b}
	SE	71.2 ± 35.8^{c}	103.2 ± 16.2^{b}
	SF	74.5 ± 48.7^{c}	112.2 ± 21.8^{b}
	SG	167 ± 59.6^{a}	165.7 ± 57.1^{b}
	Mean	89	144
Migratory	MA	87.5 ± 31.6^{b}	108.2 ± 20.0^{b}
	MB	91.2 ± 14.7^{b}	99.1 ± 14.2^{c}
	MC	105.6 ± 29.4^{a}	123.4 ± 21.3^{b}
	MD	93.7 ± 21.2^{b}	102.1 ± 13.9^{b}
	ME	94.2 ± 25.7^{b}	120.4 ± 28.7^{b}
	Mean	94	110
Transhumance	TA	57.1 ± 38.2^{d}	100.0 ± 35.6^{b}
	TB	73.3 ± 31.2^{c}	105.3 ± 31.1^{b}
	TC	74.5 ± 43.9^{c}	139.2 ± 24.5^{b}
	Mean	68	114

[abcd] Values within the same column bearing different superscripts differ significantly at $P < 0.05$.

Under the sedentary system of management the interval from calving to first progesterone rise and calving to conception were significantly ($P < 0.05$) longer during the dry season compared to the wet season. Conception rate was better in the wet season. However, in the migratory system although cows that calved during the summer showed a significatnly ($P < 0.05$) longer interval from calving to first progesterone rise, interval from calving to conception were not significantly different between the two seasons (Table IV).

In the transhumance system all cows claved during the wet season and had realatively shorter calving to first ovulation and calving to conception.

3.3. Effect of breed

When the effect of breed was tested for post-potrum ovarian cyclicity or days to conception in the sedentary system of management, the cross breds took significantly ($P < 0.05$) more time to return to cyclicity compared to the local animals. The migratory system showed the opposite. Days to conception was also longer ($P <0.05$) in the cross breds in the sedentary system. For both systems, conception rate was higher ($P <0.05$) with the local breed. The transhumance local showed the lowest ($P <0.05$) interval to first progesterone rise and the highest ($P <0.05$) conception rate (Table V).

3.4. Body weights, body condition score and milk yield

At the time of calving the mean body condition score was 5.2, 6.7 and 4.6 respectively for sedentary, migratory and transhumance systems of production. The body condition score declined progressively up to 60 days under all three management systems and thereafter tended to improve.

Milk yield from cows of the transhumance was highest ($P <0.05$) at both 30 and 60 days from parturition. The sedentary cows showed the lowest ($P <0.05$) yield at 60 days. At 90 days differences in milk yield between the three systems appeared to be non-significant.

TABLE IV. EFFECT OF SEASON ON DAYS TO OVULATION AND CONCEPTION FOR COWS KEPT UNDER DIFFERENT HUSBANDRY SYSTEMS

Husbandry systems	Season	Calving to ovulation (Mean ± SD)	Calving to conception (Mean ± SD)	Pregnancy rate
Sedentary	Dry summer	87.0 ± 52.7^{b}	136.4 ± 67.2^{a}	90.4
	Wet summer	69.4 ± 42.3^{c}	107.7 ± 71.0^{b}	96.1
Migratory	Dry summer	106.2 ± 24.4^{a}	118.0 ± 22.0^{b}	93.5
	Wet summer	85.1 ± 22.1^{b}	101.9 ± 16.2^{b}	96.8
*Transhumance	*Dry summer	-	-	-
	Wet summer	68.3 ± 37.7^{b}	114.8 ± 32.1^{b}	100

[abc]Values in the same column within a system bearing different superscripts differ significantly at $P <0.05$.
* all cows calved in the wet summer

TABLE V. EFFECT OF BREED ON DAYS TO OVULATION AND CONCEPTION FOR COWS KEPT UNDER DIFFERENT HUSBANDRY SYSTEM

Husbandry systems	Breed	Days to ovulation (Mean ± SD)	Days to conception (Mean ± SD)	Pregnancy rate (%)
Sedentary	Local	79.9 ± 48.8^{c}	133.1 ± 59.4^{b}	87.7^{a}
	Cross	122.0 ± 52.2^{a}	267.0 ± 25.5^{a}	6.8^{c}
Migratory	Local	97.5 ± 25.0^{b}	110.5 ± 21.2^{b}	98.2^{a}
	Cross	73.6 ± 19.7^{c}	101.6 ± 14.1^{b}	71.4^{b}
*Transhumance	Local	68.3 ± 37.7^{c}	114.8 ± 32.1^{b}	100^{a}

[abc]Values in the same column within a system bearing different superscripts differ significantly at $P <0.05$.
* All cows consisted of local breed.

3.5. The Intervention phase

The chemical analyses of the farm rations and introduced rations are shown in Table VI. When poultry manure/molasses was used as sole ration the crude protein (CP) and metabolizable energy (ME) were slightly decreased while ash content increased. Farms SC, SD, and SE shared the same diet; therefore, the chemical composition of the rations were similar. SF and SG used the same ration; the only change was shown in nitrogen free extract (NFE) content, which was increased due to the addition of molasses.

In the migratory system (Farms MA, MB, MC, MD and ME), where poultry manure/molasses mixture was added to the cattle owners' ration in the ratio of 50:50, the chemical analyses showed that the CP content changed only marginally while, CF, EE, NFE and ME changed substantially.

The addition of molasses to the diet of transhumance animals produced little or no change in the chemical composition.

3.6. Effect of supplementation on milk yield

Table VII gives a summary of the effect of intervention diets on milk production under the different husbandry systems. In the sedentary system, except for farm SA (control) all animals showed significant ($P < 0.05$) increases in milk production. The change in milk production ranged from 18–23% due to supplementation. A relatively small and insignificant change was seen in the migratory farms.

3.7. Cost:benefit analysis of milk production

An estimate of cost of feed, milk yield, gross revenue, and the ratio between revenue and cost for the different production systems are shown in (Table VIII). The net revenue under all production systems increased with supplementation, more in the case of sedentary and transhumance systems compared to the migratory system. The net increase in revenue was both because of increased milk production as well as reduced cost of feed.

4. DISCUSSION

Fertility of cows kept under traditional extensive systems was shown to be low as indicated by long post-partum anoestrus period and long days to conception in the majority of cows investigated. This was largely correlated with nutritional and other environmental stress. Similarly, other studies revealed the low fertility of zebu cattle in tropical and subtropical areas [9]. Other factors, which might have influenced fertility, included, body condition score (BCS), body weight (BWT) and health disorders [10, 11]. In the sedentary system, farm SC showed the shortest days to ovulation and conception as this farm used controlled suckling. Similarly, it has been shown that calf creep feeding strategies improved conception through reduced suckling [12]. In the migratory system cows in herd MB showed better fertility parameters and were in a better nutritional status since they were frequently supplemented with guar meal. The effect of BWT on fertility was clearly demonstrated by farm SG and cows in herds TB and TC of the transhumance system as these had significantly low BWT, which was reflected on extended post-partum anoestrus and long days to conception. Similarly, the studies of Singh [13] on the combination effect of age and BWT revealed that conception rate depended largely on BWT than age. Low BWT at birth and slow growth rate during pre-pubertal period may have been responsible for the poor fertility of these cows.

TABLE VI. CHEMICAL COMPOSITION (DM BASIS) OF RATIONS USED BY FARMERS AND THOSE OF SUPPLEMENTED OR SUBSTITUTED RATIONS

Composition of rations used by sedentary farmers (survey phase)							
Farm ID	DM (%)	CP (%)	CF (%)	EE (%)	NFE (%)	Ash (%)	ME (MJ/kg)
SA	93.5	34.8	8.2	4.5	45.9	6.5	12.4
SB	93.9	16.7	17.4	6.6	47.5	11.8	11.5
SC	93.4	33.1	4.8	6.2	50.2	5.7	13.1
SD	93.4	30.1	4.5	6.2	53.5	5.7	13.1
SE	92.9	32.2	4.3	6.4	42.9	7.2	11.8
SF	93.3	21.2	6.4	6.8	58	6.7	13.0
SG	93.2	20.4	10.3	4.5	58	6.8	12.2

Composition of supplemented rations used by sedentary farmers (intervention phase) *							
1 (SB)	97.3	20.0	9.2	1.5	46.6	22.6	19.8
2 (SC, SD, SE)	93.9	24.8	5.3	4.3	51.8	9.8	12.9
3 (SF, SG)	96.8	19.7	3.4	4.1	75.4	9.4	12.5

* poultry manure/molasses mixture was given as a complete diet to farm SB. For other farms except farm SA (Control farm) molasses alone partly (50%) replaced the farmer's ration. Also see note below.

Composition of rations used by migratory farmers (survey phase)							
MA	94.5	21.1	7.8	4.4	61.1	5.6	12.8
MB	94.6	22.7	7.7	4.5	59.4	5.7	12.8
MC	94.3	23.7	7.7	6.3	59.9	5.4	13.8
MD	94.6	23.0	7.5	5.6	58.0	5.9	12.9
ME	94.4	22.6	7.5	5.6	59.8	5.6	12.9

Composition of substituted rations used by migratory farmers (intervention phase) **							
MA	95.9	20.6	3.9	2.9	41.6	6.1	9.3
MB	95.9	21.4	3.9	3.0	40.2	6.1	9.3
MC	96.0	21.6	3.7	3.8	34.9	6.0	8.0
MD	95.7	21.5	3.9	3.6	41.0	6.3	9.1
ME	95.9	21.5	3.9	3.6	40.9	6.1	8.1

** poultry manure/molasses mixture partly (50%) replaced the farmer's ration.

Composition of rations used by transhumance farmers (survey phase)							
TA	95.5	9.9	10.3	3.7	67.0	4.5	14.1
TB	95.9	7.8	12.3	2.9	68.7	4.6	12.1
TC	95.1	5.1	22.1	1.1	62.0	4.8	10.7

Composition of substituted rations used by transhumance farmers (intervention phase) ***							
TA	95.5	9.3	14.9	2.7	64.0	4.5	14.1
TB	96.4	7.4	10.7	2.9	69.7	5.6	12.3
TC	97.2	6.1	23.1	0.1	63.0	4.8	10.7

*** molasses alone partly (50%) replaced the farmer's ration.

Note:

1: poultry manure/molasses given to farm SB as complete diet (supplementation)

2: molasses given to farms SC, SD, and SE as substituted ration which constituted at the time of the study of sorghum grain and groundnut cake in the ratio of 1:1.

3: molasses given to farm SF and SG as substituted ration constituted at the time of the study of wheat bran alone.

TABLE VII. WEEKLY MILK YIELD (kg) AS AFFECTED BY SUPPLEMENTATION AND WITHDRAWAL IN DIFFERENT HUSBANDRY SYSTEMS

Farms	Before supplementation	Supplementation	Change (%)	Withdrawal	Drop in milk yield (%)
SA	^{A}25.8 ± 2.3^{a}	^{A}25.0 ± 2.8^{c}	–3.0^{d}	^{A}18.2 ± 1.9^{c}	27.0^{d}
SB	^{B}28.4 ± 8.4^{a}	^{A}47.3 ± 7.3^{a}	39.7^{b}	^{C}18.0 ± 4.3^{c}	61.8^{a}
SC	^{B}26.4 ± 3.2^{a}	^{A}25.9 ± 4.1^{c}	26.4^{c}	^{C}19.6 ± 4.1^{c}	45.3^{b}
SD	^{B}23.1 ± 3.9^{a}	^{A}31.4 ± 6.8^{b}	26.3^{c}	^{C}20.1 ± 3.9^{c}	31.6^{c}
SE	^{B}23.7 ± 1.8^{a}	^{A}35.0 ± 10.6^{b}	32.3^{b}	^{C}23.6 ± 3.0^{b}	32.5^{c}
SF	^{B}25.7 ± 4.3^{a}	^{A}29.5 ± 9.3^{c}	13.1^{d}	^{C}22.2 ± 1.7^{b}	24.9^{d}
SG	^{B}19.2 ± 3.2^{b}	^{A}30.6 ± 6.2^{c}	37.1^{b}	^{C}22.2 ± 1.9^{b}	27.4^{d}
MA	^{A}25.7 ± 3.8^{a}	^{A}25.8 ±2.4^{c}	0.62^{e}	^{A}25.9 ± 2.5^{a}	0.15^{e}
MB	^{A}28.1 ± 2.6^{a}	^{A}28.3 ±2.4^{c}	0.07^{e}	^{A}27.9 ± 2.5^{a}	1.14^{e}
MC	^{A}28.1 ± 2.8^{a}	^{A}28.3 ±2.7^{c}	0.67^{e}	^{A}28.5 ± 2.7^{a}	1.3^{e}
MD	^{A}24.7 ± 4.8^{a}	^{A}25.0 ±4.8^{c}	1.01^{e}	^{A}24.8 ± 5.0^{b}	0.64
ME	^{A}23.4 ± 7.6^{a}	^{A}24.5 ±6.0^{c}	4.72^{e}	^{A}23.5 ± 0.6^{b}	0.47
TA	^{B}25.3^{a}	^{A}27.6^{c}	41.9^{b}	ND	ND
TB	^{B}24.2^{a}	^{A}25.5^{c}	31.2^{b}	ND	ND
TC	^{B}22.9^{a}	^{A}24.9^{c}	66.6^{a}	ND	ND

$^{A, B, C, a, b, c, d}$ values with different superscript differ significantly at $P < 0.05$. Upper case letters for comparing means within the row, lower case letters for comparing means within columns.
*ND = not determined

TABLE VIII. AVERAGE FEED COST AND REVENUE FROM MILK SALES, BEFORE AND AFTER SUPPLEMENTATION (RANGE WITHIN PARENTHESIS)

	Production system					
Item	Sedentary		Migratory		Transhumance	
	Before	After	Before	After	Before	After
Cost of concentrate (Ls/kg)	144 (108–186)	106 (96–136)	222 (212–228)	136 (131–139)	180 (87–272)	104 59–138)
Milk yield per kg feed (L)	1.84 (1.8–2.1)	2.3 (1.8–3.4)	1.88 (1.7–2.0)	1.93 (1.6–2.1)	2.10 (1.5–2.7)	3.02 (2.4–3.8)
Gross revenue *	1842 (1650–2025)	2300 (1800–3350)	1882 (1755–2030)	1931 (1670–2025)	2105 (1495–2695)	3022 (2450–3825)
Net revenue	1702 (1664–1922)	2193 (1664–3242)	1750 (1638–1801)	1795 (1532–1960)	1925 (1407–2514)	2917 (2450–3825)
Benefit:cost ratio	11.8:1	20.6:1	7.9:1	13.2:1	10.7:1	28.0:1

Ls, Sudanese Lira; *, Sale price of milk = Ls. 1000/litre.

Numerous studies have shown that the inhibitory effect of suckling is mediated by inhibition of luetinizing hormone (LH) secretion [14–16] through a reduction of pulsatile secretion of hypothlamic gonadotrophin releasing hormone (GnRH) [17]. On the other hand weaning was shown to hasten oestrus [17–19].

During the rainy season animals were allowed to graze the native pasture without additional supplemental feeding, which failed to fulfill the requirement for meat and milk production. Milking cows were supplemented with concentrate diets during the dry season only. Cows in their pre-partum period received no supplementation and hence were likely to calve in poor condition. Also it has been shown that cows, which calve in poor body condition, have only a small pool of recruitable (2–5 mm) follicles and few if any growing (6–9 mm) follicles for a prolonged period post-partum [9].

Prolonged post-partum anoestrus in lactating cows under extensive systems may reflect an adaptive mechanism, which prevents reconception until nutritional, or other environmental conditions become favorable for reproduction. Furthermore, it has been shown that responses to pre-partum BWT change may depend on BCS at parturition, since pregnancy rate of cows in good body condition at calving is affected little by minimal BWT changes either before or after parturition [20, 21] whereas dramatic BWT losses after calving can reduce pregnancy rate [21].

Days to conception were significantly longer and conception rates were significantly lower in the dry season compared to the wet season where ambient temperatures exceeded 40^{o}C. Similar findings were reported by other workers [22] which could be related to the inhibitory effect of thermal stress resulting in reduced hypothlamic GnRH secretion, lack of LH secretion and consequently affecting ovarian follicle development [23]. This condition might also be exacerbated by poor nutritive value of the pasture. Although concentrates offered by farmers were of good quality, they were not offered in adequate quantities as they were sometimes given every other day due to their high cost. This could place cows in negative energy balance and thereby affecting the calving to conception interval and conception rates. Farms SA and SB in the sedentary system did not seem to benefit from extra night grazing during the dry season. Most of the cows in both farms showed long days to conception which could be attributed to poor quality of the pasture and extra energy expenditure during grazing. Heat stress seemed to impose an adverse effects on the cross breeds as reflected on longer days to conception and lower conception rates.

Poultry/manure molasses used as a complete diet showed the highest increase in milk yield in the sedentary system. However, when used to replace 50% of the migratory diet, milk yield increased only slightly. In the transhumance system molasses was used alone as substituted diet and showed significant increase in milk yield. Similarly, it has been shown that supplements fed during the post-partum period are more likely to be diverted towards milk production, thus benefiting calf growth [9].

5. CONCLUSION

Nearly all farmers under extensive systems used sorghum grains in the diet of their animals. This is not a wise strategy since sorghum constitutes the major diet of Sudanese in many parts of the country. Using alternative diets, which are cost-effective and increase both milk yield and fertility should be encouraged. This will reduce competition with human food, increase farmers' income and allow surplus to be exported.

Management of post-partum anoestrus under extensive tropical environments should focus on the conservation of body weight and body condition score by strategic and adequate supplementation during late pregnancy and early lactation.

Restricted suckling would reduce stimulus of cow-calf interaction and hence reduce days to conception.

There was no benefit of keeping crossbreds since neither milk yield nor conception rates were improved. Selection could be done among indigenous breeds where adaptation and milk yield were optimum. These were the ones which came into estrus within reasonable time and could produce a calf every year.

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MIXED CROP-LIVESTOCK PRODUCTION SYSTEMS OF SMALLHOLDER FARMERS IN SUB-HUMID AND SEMI-ARID AREAS OF ZAMBIA

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Abstract

MIXED CROP-LIVESTOCK PRODUCTION SYSTEMS OF SMALLHOLDER FARMERS IN SUB-HUMID AND SEMI-ARID AREAS OF ZAMBIA.

Livestock production activities among small-scale farmers of semi-arid (Agro-ecological zone 1) and sub-humid (Agro-ecological zone 2) areas of Zambia are integrated with crop production activities in what is termed as crop/livestock farming system. This is a closed system in which production of one enterprise depends on the other. In Zambia, crop production depends on draught animals for tillage of cropping area, animal manure for fertilisation of crops while livestock depend on crop residues for dry season feeding. Good quality grass is generally available in adequate amounts to support reasonable level of livestock productivity during the rainy season. But livestock rely on low quantity and poor quality, highly fibrous perennial grass from veld and fibrous crop residues during the dry season. These resources are inadequate to support optimum livestock productivity activities. Poor nutrition results in low rates of reproduction and production as well as increased susceptibility to diseases. With the increasing human population cropping land is expanding, leading to increased production of crop residues. This has however, reduced the grazing land available for ruminant production. In Zambia large quantities of crop residues (stovers, husks and straws, legume tops and hulls, sugar cane tops, cassava leaves, potato vines, etc.) are left in the field where they are wasted each year because small-scale farmers lack the knowledge on how best to use them. There is a need to find ways to reverse this situation by adapting known and workable technologies to local conditions and by introducing new approaches for improving the use of crop residues and poor quality fibrous feeds. Efforts should also be made to enlarge feed resource base. The technologies should be simple and effective. In the presence of a dynamic market system, livestock production in a crop/livestock system could be intensified and made profitable for small-scale farmers.

1. INTRODUCTION

A mixed crop-livestock farming system consists of integrated crop and livestock activities. Field crop production depends on the supply of draught animals and animal manure. Draught animals play a key role in tillage of land while animal manure fertilises field crops. Livestock in this system depend on extensive grazing of natural veld and crop residues during the dry season. This is a closed system in which waste products of crops are used by livestock, which in turn return its own waste (manure) back to the crop field.

2. DISTRIBUTION OF MIXED SYSTEMS

Mixed farming is the largest animal production system in the world (Table I). It produces 92% of world's milk supply, 70% of sheep and goat meat and 100% of buffalo meat. Half of this meat and milk comes from developing countries [1]. About 40–80% of livestock in the tropics are associated with mixed crop-livestock farming systems. In Zambia, over 97% of goats and more than 70% of cattle are reared on smallholder traditional mixed farming systems.

TABLE I. LIVESTOCK INVENTORY OF MIXED FARMING SYSTEMS*

Species	Number (millions)	Percent of global population	Percent in developing countries
Cattle	860.6	66.9	78.8
Buffalo	148.0	100.0	99.9
Sheep and goats	1096.8	63.9	87.8
Dairy cattle	192.2	85.0	78.7

*Data have been taken from [2]

3. CROP RESIDUES FOUND IN ZAMBIA

Crop residues found in Zambia include stovers of cereals such as sorghum, maize and millet and haulms of leguminous crops such as beans and groundnut, straws from rice and other crops, sugar cane tops, cassava leaves, sweat potato vines and planted agro-forestry species. Maize stover is the most abundant of all crop residues in Zambia.

Many of these crop residues are left in the field after harvest. Livestock are allowed to graze them in the field. The crop residues are trampled by livestock, and termites and forest fires quickly destroy them. Farmers do not have the know-how on how best to utilise these residues which could form a major source of livestock feed. Some programmes in Zambia (e.g. Southern Province Household Food Security Programme) have started to sensitise farmers to collect crop residues from the field and store them in homesteads. They are trained on how and when to give crop residues to animals and also how to treat crop residues to make them more palatable [3].

4. ADVANTAGES OF MIXED FARMING SYSTEMS

Mixed farming systems are found to be more efficient compared to specialised crop or livestock production systems [4]. Land is more intensively utilised as population density increases, and crop-livestock interactions intensify. An example is the predominantly cassava-livestock interaction in densely populated areas of Nigeria where 77–100% of animals are fed on farm-grown cassava, whereas in the sparsely populated areas of Zaire and The United Republic of Tanzania, only 8–50% of animals are fed on cassava [5]. Thus population increase has led to intensification of the system in Nigeria.

Mixed farming is beneficial in that it improves soil fertility. Adding manure to soil, increases nutrients and soil water holding capacity and improves soil structure [2]. In addition, if rotations of various crops and forage legumes are used, they replenish soil nutrients and reduce soil erosion.

The crop-livestock system has the advantages of allowing diversification of risks, using labour more efficiently, recycling wastes thus preventing nutrient losses, adding value to crops and crop products while providing cash for purchasing farm inputs. This system is responsive to market development. When there is access to dynamic urban markets, there is positive intensification and diversification of production. Farmers become integrated into the market economy, specialising and allowing them to take advantage of economies of scale. An example is the semi-arid Machakos District of Kenya where because a dynamic market was available, horticulture and smallholder dairy production activities became very profitable. The extra income from these profitable ventures has been put back on the land for soil improvement programmes thus making the system sustainable.

5. FAILURE OF MIXED SYSTEMS

Crop-livestock systems can fail and more rapidly so in semi-arid areas which cannot support intensive cropping. When human population grows, more and more grazing land is converted to cropland thus reducing grazing land. This reduces nutrient flow into cropland. Crop production is pushed to marginal areas causing soil erosion; consequently, farm size becomes small and forage for livestock reduces. With deteriorating crop/grazing land ratio and without adequate substitution of soil fertility by other sources, fertility gaps arise. Losses of 15 kg N/ha per year in Mali and 100 kg N/ha per year in Ethiopian highlands have been reported [2]. Declining soil fertility, overgrazing, increased soil erosion and loss in soil microflora result in loss of agricultural productivity.

6. USES OF LIVESTOCK IN CROP-LIVESTOCK SYSTEMS

For rural people on mixed farming systems, livestock is the important link to the money economy and an essential element in their survival strategies [6]. A survey carried out in 1995, of 211 smallholder farms in medium-rainfall crop-livestock system in Zambia, identified draught power (33.3%) followed by the need for cash (30.5%) as major reasons for rearing cattle. For goats, the main reason was the need for cash (37.5%) followed by consumption (35%) (Table II). This cash was mainly used for buying seeds, fertiliser and chemicals (39.6%) and for purchasing food (25.2%). Seventeen and 14.4% of the cash was used for buying farm equipment and paying school fees, respectively. Manure was used for vegetable growing. Although manure use in this study was low, it is essential in the Zambezi flood plain of Western Province. In this area, crop production is only possible after application of manure to the cropping area by weekly corralling of the animals in the field. Thus smallholder farmers who do not own livestock are the most food-insecure.

7. CONSTRAINTS TO LIVESTOCK PRODUCTION IN MIXED FARMING SYSTEMS

7.1 Negative soil nutrient balance

The major constraint in most crop-livestock mixed systems on smallholder farms in developing countries, including Zambia, is the negative soil nutrient balance. Deficits are often covered by flow of nutrients from communal grazing areas to cropland but this is not adequate. Recycling of nutrients and control of soil erosion in these areas is a big challenge to researchers and development workers.

7.2. Scarcity and poor quality of feeds

Ruminant animals on smallholder farms of mixed system depend on fibrous crop residues and native pastures for the bulk of their feed requirements. These feeds are inadequate in quantity and are of poor quality with low digestibility especially in the dry season.

TABLE II. REASONS FOR REARING CATTLE AND GOATS

Parameter	Percent of total smallholder farms surveyed	
	Cattle[a]	Goats[b]
Income	30.5	37.5
Consumption	2.8	35.1
Draft power	33.3	0.2
Manure	5.5	8.5
Milk	12.9	2.0
Lobola	10.8	1.3
Social occasions	3.5	14.8
Social status	0.8	0.7

Total farms surveyed: a= 211; b= 459.

8. SOLUTIONS TO MIXED FARMING SYSTEMS

There is a need to generate environmental friendly technologies and policies for accelerated production. Many technologies having the potential to improve the condition of smallholder farmers are known, but the major challenge is for extension workers to convince farmers to adopt these technologies. Methods already known need to be applied at the farm level to test their adaptability and to demonstrate their profitability to farmers. Other methods of treating residues and evaluating supplements should continue to be researched. New dry season feed resources that can be integrated into the production system should be identified.

There are a number of technologies that can be introduced to smallholder farmers to improve quantity and quality of feeds and to increase animal productivity. These are:

- Improving soil by mulching, conservation tillage (which is being promoted by Zambia National Farmers Union, ZNFU), contour farming, terracing and strip cropping [7]
- Introducing multipurpose fodder shrubs, grasses and legumes to reduce soil erosion and as animal feed [8]
- Improving feed quality through treatments of crop residues [9]
- Reducing nutrient losses from manure by stall feeding
- Strategically supplementing specific classes of animals (e.g. lactating animals) to improve efficient use of limited feed
- Using multi-nutrient feed blocks.

Soil improvement studies with shrubs and legumes have been carried out in Zambia [8] and programmes emanating from such studies are now being implemented at the farm level (e.g. Sustainable Development Programme in Southern Province). However, these programmes have excluded the utilization of trees and shrubs for livestock feeding. Moreover, research efforts on treating crop residues by research institutions in Zambia have not been followed by adaptation of the technology at the farm level. Future research should address these aspects.

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LIVESTOCK SECTOR IN ZAMBIA: OPPORTUNITIES AND LIMITATIONS

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Abstract

LIVESTOCK SECTOR IN ZAMBIA: OPPORTUNITIES AND LIMITATIONS.

Zambia is endowed with a vast feed resource base for animal production purposes. However, the feed resource base is not fully utilised and this is manifested by low livestock productivity. The quality and production levels of animal products depend largely on the quality and quantity of feed, which is fed to the livestock. Among the constraints limiting livestock productivity in Zambia, insufficient and low quality of veld grass, particularly during the long dry season (March-November) is responsible for low production levels and poor reproductive performance in ruminants. The problem of inadequate veld grass can be overcome by feeding crop residues which are in abundance during the dry season. Zambia produces large quantities of sugarcane tops, bagasse and straws from maize, sorghum, wheat, millet and rice. These could sustain livestock productivity if supplemented with protein sources or treated with urea. Despite the production of large quantities of crop residues, these are wasted by burning or get destroyed by termites. There is a need, therefore, to develop feeding systems based on crop residues which are compatible with the farming systems in Zambia and to promote such feeding systems.

1. INTRODUCTION

The Livestock Sector in Zambia is increasingly becoming an important component of Zambia's economy. For example, its contribution to the National Gross Product in 1996 and 1997 was estimated at 6.4 and 6.5% respectively. This accounts for about 35% of the total agricultural production. In 1997, the livestock sector accounted for 33% of agricultural exports.

In Zambia, about 23% of the per capita supply of protein comes from animal products. However, with regard to meat consumption, beef is the most preferred, followed by pork, chicken, rabbit, mutton/lamb and goat meat. Cattle contribute at least 61% of the meat and milk consumed in the country. In view of the above, the livestock sector has tremendous potential and capacity in contributing to poverty alleviation, increasing the socio-economic status of most people and, consequently, contributing significantly to the economic growth of the country. However, the potential of the sector is under-estimated and hence minimal.

This paper will attempt to discuss the production ratios and major limitations to increased productivity. For the purpose of this workshop the discussion will be confined to ruminants.

2. PRODUCTION RATIOS AND MAJOR CONSTRAINTS TO INCREASING PRODUCTIVITY OF RUMINANTS

Ruminant livestock numbers in the traditional sector comprise 2.7 million cattle, 700 000 goats and 70 000 sheep. These figures represent 82, 97 and 64% of the national cattle, goats and sheep respectively. Most of these animals are concentrated in Eastern, Western and Southern Provinces. Despite these large numbers, their productivity is very low and hence the livestock production sub-sector is not expanding at a sufficient rate to meet the needs of each household and increasing population. The demand for animal products is constantly out stripping the production and supply. The increased output of animal products observed in the traditional sector, has largely been due to increased animal population rather than increased productivity. For example cattle numbers in the traditional sector are increasing by 3.5% per annum. Sheep and goats numbers have been estimated to increase at 5 to 7% respectively, per annum. The increase in cattle and goat numbers is justified by the increasing number of traditional farmers who are going into livestock farming.

In Zambia, constraints to increased ruminant production include inadequate marketing infrastructure such as low price incentives; disease (tick borne diseases, helminthiasis, trypanosomosis); inappropriate livestock research; inadequate extension services and poor animal husbandry practices. However, there is concrete evidence that nutritional stress, in terms of quantity and quality of available grazing, particularly during the dry season (April-November), limits ruminant productivity. For instance, in cattle, low productivity is manifested by high calf and adult mortality rates (20 and 9% respectively) and overall low reproductive efficiency [1]. The low reproductive efficiency is characterised by low conception and calving rates (45–50%) coupled with periods of anoestrous and long calving intervals (≥450 days).

Nutritional stress, due to crude protein deficiency in mature natural veld grass, has also been responsible for slow growth rates (five-to-seven years to reach mature market weight, low birth and weaning weights; [2]); low milk production and inefficient performance of draught animals, due to their poor physical condition resulting from underfeeding during the long dry season.

Mature poor quality roughages are deficient in rumen degradable nitrogen, RDN [3]. The consequences are reduced dry matter intake of such poor quality roughage, largely due to a limited supply of RDN for rumen microbial activity [4]. Ruminants that depend entirely on poor quality roughage are, therefore, unable to meet their nutrient requirements (amino acids) for reproduction, growth rate and milk production during the long dry season. Most ruminants fed on poor quality roughage, especially during the long dry season, are always in negative nitrogen balance [5], an indication that these roughages are unable to meet the nutrient demand for maintenance and production [6].

The low feeding value of roughages may ultimately give rise to a poor response to veterinary treatments and inadequate exploitation of the genetic potential of both indigenous and, to a greater extent of exotic breeds. The net effect is low output of milk, meat, wool, hides and skins, with corresponding increased costs of production [7]. Where nutrition is inadequate, as is the situation in most parts of Zambia, parasites have major effect on ruminant productivity, emphasising the greater necessity for the control of diseases and parasitism.

Other than a limited supply of RDN in poor quality roughage, poor performance of ruminants in the traditional sector is further complicated by a critical shortage of veld grass due to severe overgrazing, especially in most parts of the Eastern and Southern provinces of Zambia, where cattle and goat numbers have soared. The scarcity of grazing is enhanced by uneven distribution of rainfall and persistent droughts, resulting in reduced biomass availability; the Southern, Eastern and Western Provinces being the most affected.

The scarcity of grazeable veld grass is further complicated by the distribution of tsetse fly. Livestock numbers are negatively correlated to the severity of tsetse infestation. It is estimated that about one third (120 000 km^2) of Zambia's natural grazing resource is infested and unusable [1], thus confining the livestock to the remaining two thirds. Consequently this causes a negative impact on the environment and productivity of both the uninfected areas and livestock.

The problem of shortage of grass in most parts of Zambia is exacerbated by the ever increasing importance of arable production of cash crops (maize, sorghum, millet, wheat, rice, groundnuts, soybeans, sunflower, cotton and sugarcane) at the expense of grazing land. However, the residues arising from these crops, particularly maize, sorghum, millet, wheat and sugar cane can be utilised by ruminants when veld grass is scarce. Unfortunately, as with mature veld grass, crop residues have a low feeding value due to their low protein content [8].

In Zambia, approximately 2.06 million, 59 600, 95 777, 13 653 and 53 278 metric tons respectively of maize, sorghum, millet, rice and wheat straws are produced annually. Nakambala Sugar Estate grows sugarcane and hence produces substantial quantities of cane tops, bagasse and molasses as sugarcane by-products. This suggests that crop residues and molasses are more important as a source of feed for ruminants in the dry season, particularly in the traditional sector. However, crop residues are grossly under utilised, much being burnt or destroyed by winter fires. Therefore, there is a need for specific research to develop appropriate technologies which will encourage the use of this local feed resource base, particularly sugarcane tops, bagasse, maize and sorghum stovers, agro-industrial by-products (oil cakes) and forage legumes. It is important to note that technologies that are aimed at improving the feeding value of roughages should be socially acceptable to the subsistence farmers, technically feasible, economically viable and environmentally friendly.

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SOME TOOLS TO COMBAT DRY SEASON NUTRITIONAL STRESS IN RUMINANTS UNDER AFRICAN CONDITIONS

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Abstract

SOME TOOLS TO COMBAT DRY SEASON NUTRITIONAL STRESS IN RUMINANTS UNDER AFRICAN CONDITIONS.

Dry season nutritional stress is a major constraint to ruminant livestock production in semi-arid areas. After the rains finish, quantity and quality of grazing fall rapidly, leaving cereal crop residues as the major feed resource. These residues are low in N and high in crude fibre, characteristics which restrict intake and digestibility, so that underfeeding results. Improved handling and storage procedures as well as chemical and physical treatments can all improve their quality. Other strategies include: rate of offer of stover; compensatory growth; conservation of fodder. Farmer-selection should also consider multiple use of the options available.

1. INTRODUCTION

Zambia, typical of the Central Southern African region, usually receives rain from November to April (hot season), followed by a long dry period (winter and spring). These defined seasons are characterised by the live-weight gain/live-weight loss patterns, typical in tropical livestock production systems.

In the traditional farming sector cattle and goats are the major species of domestic livestock. They rely on natural pasture during the wet and early dry seasons and crop residues for the remainder of the dry season (goats should benefit from the browse flush before the arrival of the rains).

When the rains cease the quantity and quality of grazing falls rapidly [1], so that winter grazing is fibrous and low in crude protein (CP.; around two per cent). As the grazing fails, accepted practice is to redress the deficit with crop residues. However, whilst the ruminant can digest fibrous feeds (this is the characteristic which ensures its place in the crop/livestock farming system), efficient use of these resources demands supplementation and, or, modification of them. This is especially true where production targets (growth; reproduction; lactation; draught) have to be met. Under-supply of nutrients is often a combination of lack of feed coupled with an imbalanced diet.

Efficient rumen function depends on supplying sufficient N to act as a substrate for the growth of cellulolytic bacteria. Maximisation of microbial protein production requires protein and energy sources with similar breakdown rates. Dry season feeds generally require supplementary N, and this is often supplied as non-protein-nitrogen (NPN, urea). It is rapidly broken down in the rumen and, therefore, requires a source of readily available energy (e.g. molasses or green forage) if it is not to be lost from the system as ammonia [2]. True proteins, for example legume stovers and oilseed cakes, also contain some energy but can be costly if not home produced.

Total nutrient supply is a summation of intake and digestion, both dependent on adequate dietary N. The requirement for protein is twofold: firstly the rumen needs a source of N to ensure a maximum supply of digestible nutrients; secondly, when microbial protein is insufficient to meet the production requirements of the animal a supply of bypass protein will be needed. Preston and Leng [2] considered that between 10 and 20% of digestible nutrients should ideally bypass breakdown in the rumen.

Before discussing crop residue utilization two general points need discussing. The first is choice of breed of animal. An animal must be adapted to its environment, both in its ability to tolerate the stresses of that environment and its nutritive requirements relative to the amount of feed on offer. Introducing large exotic breeds with a high production potential will not succeed unless management, including nutrition, can also be changed, not often possible for resource poor farmers. Moyo [3] found that the small indigenous Mashona cattle produced the highest weight of weaners, per cow per year, compared to larger breeds and their crosses.

Water intake is related to dry matter intake [4]. In a dry hot climate there are differences between breeds in their water requirements, in that *Bos indicus* cattle have a lower intake than *B. taurus*, the difference increasing as ambient temperature increases [5].

2. CROP RESIDUES

With the dominant role of crop residues in dry season feeding, especially towards the end of the season, the farmer needs to know the options for: storage; supplementation; modification of the residues; and management of his animals. He needs a 'tool box' from which he can select appropriate options.

2.1. Harvesting and storage

Rapid removal of stover from the field after grain harvest reduces leaf loss and senescence ([6]; S. Ncube personal communication). Storage under cover, with some movement of air will allow completion of the drying process and reduce the absorption of moisture during damp weather (not unusual during the dry season), thus preventing, or reducing, the formation of mycotoxins [7].

Where residues have to be moved over relatively long distances, the cost of transport becomes an issue. Separation of leaf and stem, the stems being left *in situ* and the leaves being compressed in a box baler, has been carried out in The United Republic of Tanzania [8, 9]. Another advantage of this technique was a reduction in the amount of storage space required.

2.2. Supplementation

The extent and rate of digestion of fibrous feeds are increased by a nitrogen supplement, resulting in a greater dry matter intake [2]. This will be reflected in the extent of live-weight change.

The amount of CP required is usually expressed as a percentage of the dry matter and varies according to the production target: beef finishing diets 12–14 percent [10]; more for high yielding dairy cows [4]. However, maximum intake of poor quality roughage is probably achieved with six to eight percent CP. True protein, especially that with a low solubility, such as fishmeal or cottonseed meal, will give a larger response than those with a high solubility [11], which will include NPN [2]. However, the choice will depend on availability and cost, the largest differences being between no supplementation and some N, rather than source of N (iso-nitrogenous supplements of cottonseed meal or combinations of cottonseed meal and urea fed to steers grazing natural range land in the dry season) [12].

Locally available protein sources, such as legume residues, pods, green fodder, poultry manure and oilseed residues (e.g. from the extraction of sunflower oil for household use) all have a part to play [2, 13–16].

In semi-arid areas green fodder is often not available in the dry season. However, fodder from multi-purpose trees can be ensiled and their value as protein supplements for milking cows has been demonstrated [17]. Many species are leguminous, thereby contributing both to soil fertility and the supply of fuel wood [2].

As in Zambia, where there is an established sugar industry and, therefore, a supply of molasses, the molasses/urea multi-nutrient block can be a cheap and effective supplement, formulated to meet a range of circumstances. Its manufacture and use will be dealt with elsewhere in this proceedings [18].

2.3. Physical treatment

In smallholder livestock systems most physical treatments of residues are either too expensive, the equipment is not available or too labour intensive. However, there are benefits in reducing particle size (not necessarily fine grinding), for ensiling (see below) and in stall-feeding. The level of CP required in the diet will depend on a number of factors: nature of the diet; form of protein; age of animal; physiological status of animal [4]. Reduction in particle size can be achieved by using a power driven chopper, a hand operated chaff cutter, a panga or a guillotine blade.

There are other advantages, in that the surface area of non-lignin material exposed to microbial attack in the rumen is increased, thus increasing the rate of digestion, thereby reducing a possible limitation to intake [19]. The smaller the particle size the less scope there is for selection. Fine grinding (expensive and not common in practice) can reduce intake by increasing dustiness). Osafo et al. [20] found that chopping increased intake in sheep but not in cattle.

2.4. Chemical treatment

The potential for increasing digestibility and intake of fibrous residues through treatment with alkali has been widely researched and comprehensively reviewed [21]. Urea treatment is of most practical significance in the tropics, acting both as an alkali and a source of supplementary N to materials inherently low in crude protein.

Treatment procedure will vary according to circumstances. In Zimbabwe, Smith et al. [22] found that 5% urea, in solution, added at a rate of at least 20%, weight for weight, solution to dry stover, followed by an incubation period of five weeks gave the greatest improvement. The stover had been rotor slashed before treatment. Although successful upgrading of whole stover is possible, reduction of particle size aids ensilage as well as the other advantages listed above.

Urea treatment is relatively easy to apply and is effective. However, its uptake at farm level has been slow. Cost is often cited as a reason for this. To overcome this the following should be considered:

(a) Offer large quantity of the stover, to allow selection of the most nutritious material (leaf) and then treat the refusals, thus reducing the volume of material to be treated. Intake of treated refusals has been found equal to that of the original material [23]. The stems resulting from leaf stripping [9] could also be chopped and treated.

(b) When ammonia treated straw (20% of straw intake) was fed as a supplement, the intake of untreated straw was increased [15]. In China, some farmers claimed that treating 25% of the wheat straw offered increased total straw intake.

(c) The use of urine as a substitute for urea [24]. Urine is a freely available resource which, if acceptable, is effective as an upgrading agent.

(d) Consideration of locally occurring alkalis. Magadi, which occurs naturally in parts of East Africa, improved the digestibility of straws and stover, albeit to a lesser extent than NaOH [25]. The efficacy of such local products must be set against their cost for a true evaluation to be made.

(e) Enzyme (cellulase and hemicellulase complexes) treatments to breakdown fibre are currently being tested. There have been mixed responses so far but Phipps et al. [26] have stressed that the potential for unlocking nutrients in fibrous tropical feeds is enormous.

2.5. Amount of roughage offered

The components of stovers and straws are leaf, sheaf and stem material. Owen and Aboud [6] suggested feeding excess straw to selective feeders, such as goats and sheep, the rejected material then being offered to comparative non-selectors including cattle. Smith et al. [22] offered increasing amounts of coarsely ground (14 mm screen) maize stover to lambs and steers. At the higher levels of offer, intake was increased more in lambs than steers, supporting the hypothesis [6] that sheep are more selective than cattle. This would result in a high stem: leaf ratio being a bigger constraint to intake with sheep and goats than with cattle. These two species also retain digesta in the rumen for less time than cattle, thus resulting in less efficient digestion than in cattle [27].

However, with milking cows intake increased when more stover was offered, to the extent that a small increase in milk yield was detected [28]. A similar pattern of responses has been observed with sorghum stover [20].

2.6. Other dry season feeding strategies

What else can the farmer do to ensure that his livestock survive the dry season in a condition appropriate to meet the production targets.

(a) Grazing stovers versus carrying and storing. The non-livestock owner will leave stovers *in situ,* to be grazed, by arrangement with neighbours, etc. In this way he ensures some manure on his field and can probably negotiate favourable terms for contract ploughing. Whilst removal increases the efficiency of use of a feed resource, its effects on the nutrient cycling within the crop/livestock system are not fully understood. As farmers become 'commercial', with an increased amount of produce being sold off the farm, the potential loss of nutrients from the system can be balanced by the purchase of animal feed and fertilizer [29]. This area of farming systems/nutrient cycling warrants investigation, especially where the cost of fertilizers prohibits adequate usage.

(b) The cycle of weight loss in the dry season followed by accelerated growth in the wet season is common in the tropics. However, the long term effects of dry season weight loss are not always appreciated. Smith and Manyuchi [30] found that, with indigenous cattle, no supplementation in two successive dry seasons reduced carcass weight by 27 kg after the final wet season and a 90 day pen feeding period immediately before slaughter. The supplemented groups received a cottonseed meal/maize meal/urea mix (10:9:1). As the onset of puberty is related to live weight, it is reasonable to assume that age at first calving will also be affected by prolonged periods of underfeeding, as is reconception. Prolonged calving intervals are often nutrition related [31, 32].

(c) Although supplements are often fed on a daily basis, they can be fed as infrequently as once per week. However, if adopting this strategy care must be taken with urea containing compounds, especially with group-fed animals [33].

(d) Stover quality is not a constant, but varies between cultivars. Smallholder livestock farmers often select dual purpose varieties, because of cost, availability and characteristics of the crop (e.g.: feeding quality of stover; brewing quality of grain; resistance to attack by birds). Research is addressing these issues [34, 35].

(e) Dry season feeding need not be restricted to grazing and crop residues. There is increasing interest in conservation of forage, by making silage from planted forage [36]. The silage is made in plastic bags. Because of the use of arable land and the cost of bags, the silage must be a component of a productive enterprise such as dairying.

3. CONCLUSIONS

- The effects of underfeeding in the dry season can affect both immediate production and lifetime performance of livestock.
- There are large quantities of crop residues available in Zambia (Simbaya, this proceedings) for livestock feeding.
- The nutritive value of residues can be improved by correct harvesting and storage, supplementation with N and physical and chemical treatment. Locally occurring sources of protein, such as tree pods should be fully investigated (J. Sikosana. Personal communication). Conservation of fodder, as silage, for milk production should also be investigated.
- Of the tools suggested here, a combination will probably be most effective. It is for the extension worker and farmer to decide on the options most appropriate for a given set of circumstances. Availability and costs of off-farm inputs, together with the perceived value (sales and outputs used within the household) will be the determining factors.
- The options presented here should not be seen as definitive. Further research is needed, particularly at the farm level. Closer collaboration between those in development within the Central/Southern Africa region is called for. A group of projects, funded by the Department for International Development (DFID, UK, managed by the livestock production programme of Natural Resources International, Ltd.) in Zimbabwe is addressing the potential to alleviate the dry season feed shortage [33]. However, because of the pivotal role of low protein/fibrous materials (crop residues and natural grazing) in dry season feeding, a modest improvement (5–10%) would substantially reduce the effects of underfeeding on both survivability and production.

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AVAILABILITY AND FEEDING QUALITY CHARACTERISTICS OF ON-FARM PRODUCED FEED RESOURCES IN THE TRADITIONAL SMALL-HOLDER SECTOR IN ZAMBIA

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Abstract

AVAILABILITY AND FEEDING QUALITY CHARACTERISTICS OF ON-FARM PRODUCED FEED RESOURCES IN THE TRADITIONAL SMALL-HOLDER SECTOR IN ZAMBIA..

More than 85% of ruminants in Zambia are found in the traditional smallholder sector and their production is limited by inadequate nutrition during the dry-season. This is because these animals depend on fibrous crop-residues and natural pasture which are usually in short supply and of low nutritive value. Inadequate nutrition in the dry season often results in reduced productive and reproductive performance of livestock which culminate in substantial economic losses to the farmers. The approach to improved nutrition of smallholder owned animals in the dry-season may be through increased utilisation of on-farm feed resources. The first approach would be to teach farmers to conserve wet-season fodder for dry-season supplementation of animals. The next step would be to improve the feeding quality of available fodder. This may be done through treatment of crop residues with urea or poultry manure and supplementation of animals with urea/molasses blocks. The quality of dry-season feed materials may also be enhanced through intercropping of cereals with fodder legumes or establishment of fodder gardens. Farmers must also be taught new methods for improving their natural grazing areas through establishment of fodder legumes, selected thinning of browse species, introduction of rotational grazing and reduction of animal stocking rates. These strategies may be successfully implemented after changes to communal ownership of land are made where the farmers are given title to their land.

1. INTRODUCTION

Zambia is endowed with a ruminant population of approximately 2.6 million cattle, 580 000 goats and 65 000 sheep [1]. More than 85% of these animals are in the traditional smallholder sector. Despite the apparently high concentration of ruminant animals in rural areas, there is still a potential to increase livestock production in the traditional smallholder sector. Unfortunately, current government efforts to improve the productivity of animals in this sector are being hampered by a number of constraints, of which inadequate nutrition has been documented as the most important [2]. This is because ruminant animals in the smallholder sector of Zambia are maintained with minimum inputs, and dependent on natural pastures and crop residues for the greater part of the year. In the dry-season, the available pastures and crop-residues are usually in short supply and often poor, and are characterised by low concentrations of energy, protein and other nutrients (minerals and vitamins), which are required to maximise rumen microbial activity [3]. Feeds available in the dry season also have a high content of dietary fibre ranging from 35 to 48%, which has a limiting effect on intake and digestibility of feeds [4]. Associated with dietary fibre are the anti-nutritive factors such as lignin and silica, which are known to inhibit microbial fermentation in the rumen [5].

Inadequate nutrition in the dry-season usually results in reduced body weight and condition scores in adult animals, poor milk yields and long calving intervals in nursing cows, retarded growth and increased mortality rates in calves. Also associated with poor nutrition is the increased susceptibility of animals to stress and disease challenges, which result in these animals performing below their expected genetic potential [6]. All these factors result in heavy economic losses to the farmer. To improve the productive and reproductive capacity of smallholder-owned ruminant animals, there is a need to develop feeding strategies that will enhance the quality and sustained availability of feed resources produced on-farm.

The objective of this presentation is to give an outline of farm produced feeds that have a potential to be used as dry-season supplements for smallholder ruminant animals in Zambia. An attempt will also be made to point out some of the strategies that may be used to enhance quality and extend availability of feed materials so that they can be used to improve productivity of smallholder ruminant animals in the dry season.

2. CURRENT AGRICULTURAL SITUATION IN ZAMBIA

Zambia has a total land area of about 75.26 million ha of which only 5.27 million ha are currently being utilised for arable and permanent crops [1]. This leaves more than 69 million ha for other activities including tourism and development of ruminant grazing areas. Thus, there is still a lot of potential for increasing ruminant productivity in rural areas, as most of the land is undeveloped. In terms of water availability, Zambia has reserves of ground and surface water compared to other countries within Southern Africa. Thus, most potentially available grazing areas will have access to water.

The potential for increasing animal production may be deduced from the profile of Zambia's population. The majority of Zambian people depend on agriculture for their subsistence (Table I), emphasising the importance of agriculture to this country's economy. It is saddening, however, to note that the agricultural sector which employs more than 70% of the economically active people (Table I) only contributes between 11 and 16% to the country's gross domestic product (GDP). This may be explained by the fact that the agricultural sector in Zambia only uses about 20% of the country's potential arable land and that most small-scale farmers only produce enough for their own consumption, with very little, if anything, left for sale. This again demonstrates that the key to improving the country's economy is by increasing the productivity of small-scale farmers in rural areas. This is a challenge to all working in the agricultural sector and also to the government as a policy making body. The livestock sector already contributes more than 35% of the total agricultural output in the country, but the smallholder contribution should be increased.

TABLE I. DISTRIBUTION OF THE ZAMBIAN POPULATION (MILLIONS) IN RECENT YEARS

	General Population		Economically Active Population		
Year	Total	Agriculture	Total	Agriculture	% of Total
1990	7.2	5.4	2.9	2.2	75
1995	8.1	5.8	3.4	2.4	72
1997	8.5	6.0	3.6	2.5	71

Generated from [1].

3. MAJOR FEED RESOURCES FOR RUMINANT ANIMALS IN ZAMBIA

3.1. Natural Pastures

In Zambia, as in many other parts of sub-Saharan Africa, natural pastures or veld form the basis of ruminant production in terms of nutrition. Natural pastures include annual and perennial species of grasses, forbes and trees [7]. The type and quality of natural pastures found in a given area will depend on local ecological and climatic conditions. Notable among the natural grazing areas of Zambia are the Kafue and Zambezi flood plains of Southern and Western provinces, respectively, which have capacity to support large herds of cattle even in the dry season [8]. Generally, natural pastures are able to support animal productivity in the rainy season without any problems. However, in the dry season these pastures can hardly maintain the animals as most of the feed resources at this time of the year are of very low nutritive quality. This is because the quality of natural pastures, particularly grass species tend to vary with the season (Table II).

TABLE II. NUTRITIONAL QUALITY CHARACTERISTICS (%) OF THE NATURAL VELD AS INFLUENCED BY SEASONAL CLIMATIC CHANGES

Season	Dry Matter	Protein [1] (% DM)	Fibre (% DM)	TDN[2]	Energy[3]
Nov.–Jan.	24.8	8.0	32.6	54	980
Feb.–Apr.	38.7	4.2	38.0	49	865
May–Jun.	51.2	2.1	44.0	26.3	464
Aug.–Sept.	73.3	1.5	47.6	20.0	351

[1]Digestible Crude Protein, [2]Total Digestible Nutrients, [3] in Kcal/kg.

At the beginning of the rainy season, the young succulent grasses have a very high concentration of essential nutrients and have the capacity to support animal growth. But as the rainy season advances, there is a drastic reduction in the content of proteins and other nutrients which is also accompanied with a rapid increase in fibre content. As the quality of natural pastures deteriorates, animals are forced to eat more, in an effort to meet their nutritional requirements. Normally, intake at this time of the year is limited by the rumen capacity of the animal. Levels of vitamins and minerals, which are high at the beginning of the rainy season, are almost non-existent towards the end of the dry season. This again tends to limit animal performance and unless the animals are adequately supplemented they can not perform as may be expected. Other problems, which may be associated with natural pastures as a source of feed for ruminant animals, include:

- Seasonal and low productivity of natural grasslands which may be influenced by prevailing soil conditions. The quality of natural pastures is also influenced by the absence of legume species in communal grasslands. This tends to limit the nutritional quality of available fodder and the animals are thus, unable to meet their protein, energy and mineral requirements.
- In rural areas there are no sustainable range management techniques for smallholder farmers to use in order to improve their communal grazing areas. As a result most of the natural pastures are over grazed and at times degraded due to uncontrolled grazing.

- The communal land tenure system which is practiced in most rural areas, hampers the development or maintenance of communal grazing areas. This has often resulted in over-use of grazing areas resulting in all the problems outlined above. There is also no control of animal numbers, as all the villagers want to compete for available pasture in the communal grazing areas.
- Communal grazing and lack of fencing have also made it impossible for villagers to practice rotational grazing in natural pastures to allow for the regrowth and regeneration of preferred fodder species. This has often resulted in the disappearance of some species, particularly legumes, from these areas.
- Since there is often no supplementation of minerals in the smallholder sector, the mineral content of natural pastures depends on soil fertility. Animals may be adversely affected unless efforts are made to correct these deficiencies.

3.2. Crop Residues

In addition to natural pastures, crop-residues are another major source of feed for ruminant animals in the dry season. Crop-residues are materials generated after the crop has been harvested [4]. Thus, the value of crop-residues produced in a particular area will depend on the amount and type of crops grown in that area. Smallholder farmers usually practice mixed agriculture and, therefore, have crop-residues. Maize is the most important crop grown in Zambia (Table III) and accounts for more than 60% of the total crop-residues produced in the smallholder sector [9]. However, not all the crop-residues produced in the country are used for animal feeding. After harvest, the majority of residues are considered as a nuisance and are simply burnt to clear the fields for the next cropping season. Some of the residues are ploughed under as a way of recycling nutrients into the soil while some are simply left to rot in the fields. Where crop-residues are used for feeding animals, most are grazed *in situ,* often with a lot of wastage from trampling and soiling with animal manure and urine [10].

TABLE III. THE AMOUNT AND TYPE OF MAJOR CROPS CULTIVATED AND PRODUCED ('000 METRIC TONS) IN ZAMBIA TOGETHER WITH THE AMOUNT OF CROP RESIDUES ('000 METRIC TONS) GENERATED FROM EACH CROP

Crop	Cultivated Area ('000 ha)	Amount produced (‘000 m tonnes)	Residues generated* (‘000 m tonnes)
Cereals and Tubers			
Maize	600	963	1926
Sorghum	45	31	62
Millets	80	61	61
Wheat	18	60	60
Rice	12	13	13
Cassava	106	540	1080
Sugar Cane	13	1420	2840
Legumes and Pulses			
Legumes	30	13	13
Soy Beans	76	29	29
Ground nuts	100	50	50
Cotton seed	66	35	22
Sunflower	48	8	16

Generated from [1]
* Amount calculated from crop yields according to ratios reported by Devendra [3]

The major constraint to using crop-residues as a feed resource, is their high fibre content (Table IV), which tends to limit intake and digestibility in animals. Crop-residues are also associated with low protein and mineral contents, which cannot support adequate microbial growth or meet the host animal's nutrient requirement for increased performance. It should be noted that there are ways for enhancing the feeding value of crop-residues, although most of the techniques developed to date have not yet been adopted in the traditional smallholder sector. Technologies available include the treatment of crop residues with alkaline chemicals such as sodium and ammonium hydroxides. Even though chemical treatment has proved beneficial in increasing the intake and digestibility of residues, its applicability in rural areas is limited due to the cost and availability of these chemicals. There is also the danger of toxicity. The most promising techniques are urea treatment of crop residues or the use of urea/molasses mineral blocks.

Another reason for restricted use of crop-residues in the smallholder sector is the lack of storage facilities for residues for use in the dry season. There is also a lack of knowledge in the traditional sector on methods of improved utilization of crop residues. There is also a shortage of labour for handling and storage of crop-residues on the farm. The distribution of crop-residue production does not often correspond with animal distribution, thereby causing a short fall in some areas and a surplus in others (Table V). Due to their high bulk density, transportation of these materials to needy areas may not be economical.

TABLE IV. NUTRIENT COMPOSITION (%) OF CROP-RESIDUES FROM VARIOUS PLANTS PRODUCED IN ZAMBIA

Residues	Dry Matter	Protein	Fibre	DCP[1]	TDN[2]	Energy[3]
Maize stover	90.6	4.9	35.8	2.3	45	827
Millet straw	88.9	3.7	37.1	0.3	44	1091
Rice straw	91.5	3.8	32.1	1.2	37	639
Sorghum stover	85.1	4.5	27.7	1.5	48	865
Ground nut straw	90.5	10.8	28.0	7.6	60	1053
Beans straw	86.0	4.0	42.8	1.4	40	715
Cassava leaves	90.4	1.2	3.5	0.5	75	2670

[1]Digestible Crude Protein, [2]Total Digestible Nutrients and [3] in Kcal/kg.
Modified from Chimwano [11].

TABLE V. DISTRIBUTION OF RUMINANT LIVESTOCK ('000) AND CROP-RESIDUES ('000 METRIC TONNES) IN DIFFERENT PROVINCES OF ZAMBIA

Province	Cattle	Sheep	Goats	Crop-residues
Central	363	3	195	613
Copperbelt	57	3	6	94
Eastern	251	6	125	670
Luapula	11	8	19	25
Lusaka	75	1	16	138
Northern	11	10	15	202
NorthWestern	5	10	10	34
Southern	1100	11	224	574
Western	500	----	4	73

Adopted from Aregheore [9].

3.3. Agro-Industrial by-products

The agro-industrial by-products are derived from the processing of a crop or animal product, usually by an industrial concern. Included in this category are materials such as molasses, bagasse, oilseed cakes, maize milling products, citrus pulp, and animal by-products including meat and bone meal, fish meal and others. These materials are usually of very high nutritive value and often expensive for the traditional smallholder farmers. The main limitation to increased use of such materials in rural areas is that they are usually produced in urban or peri-urban industrial areas. Thus, if these products are to be utilised by smallholder farmers, they have to be transported back to rural areas. These products are also in high demand by the commercial farmers, who are mostly located in peri-urban areas, thus having an advantage over small-scale farmers, not only in terms of purchasing power but also in transport costs. Due to the nature of these by-products, they often require special transportation and storage facilities (e.g. molasses). It should be noted that, there has been an increase in on-farm processing of agricultural products in recent years. The most notable among these is the processing of oilseeds into cooking oil using the Yenga Press Machine. There is usually a considerable amount of oilseed cake resulting from such processing, which can be used as a source of protein for ruminants. On-farming maize milling has also increased dramatically in recent years and all the by-products including bran and a number of meals can be used as supplements for ruminant animals. Home brewing is another widespread practice in the traditional smallholder sector and by-products of this activity are very high in nutrient content and can be used to supplement animals in the dry season.

3.4. Non-Conventional Feed Resources

Grouped in this category are resources not normally considered as feed by traditional smallholder farmers and yet have potential to be utilised as feed for ruminants. There is no clear demarcation between these materials and the ones outlined above apart from the very fact that these have not yet been accepted as feeds by the majority of smallholder farmers. Included in this category are poultry manure, waste products of animal processing, such as offals from fish or monogastric animals, and feather meal. Most of these have a very high nutrient composition and can be used as a major source of protein, energy and/or minerals [12]. It is important to note that using these materials as feed does not only contribute nutrients and off set feed costs, but also utilises waste materials as these materials are usually considered as a potential environmental hazard. Consumer and cultural considerations may prevent the use of some of the materials available to farmers. To prevent the spread of animal diseases, all animal waste products meant for use as feed must be heat processed before feeding and this can be done by direct sun drying or fermentation in ammonia-silo pits. Fermentation has advantages in that it will de-activate some of the veterinary drug residues and also destroy all pathogenic organisms that may be present in the manure. Fermentation will also eliminate odours, which are often associated with unprocessed manure. Current studies at the Livestock and Pest Research Centre on the use of ammoniated crop-residues with poultry manure have shown that animals respond with better weight gains and condition scores than when fed fertilizer grade urea treated stovers or when supplemented with urea/molasses mineral blocks (Table VI; [13]).

Multi-purpose fodder trees may also be included in this category of non-conventional feed resources as they are not yet widely accepted as a feed resource for ruminant animals in Zambia. More information on their use is needed. Fodder legumes have a very high protein content which can be used to meet both microbial requirements for increased fermentation of the basal diet and amino acids for the host animal [14]. Fodder legumes have advantages over other feed resources in that they are available on the farm and can also be used for other purposes such as fire wood, food, medicines and construction or fencing materials [5].

TABLE VI. WEIGHT GAIN (WG) AND BODY CONDITION SCORE (BCS) OF COWS, HEIFERS AND STEERS ON STOVER SUPPLEMENTED WITH UREA-MOLASSES MULTI-NUTRIENT BLOCKS (UMMB) AND STOVER AMMONIATED WITH POULTRY MANURE OR UREA

	Control		UMMB		Stover ammoniated with urea		Stover ammoniated with poultry litter	
	WG (g)	BCS	WG (g)	BCS	WG (g)	BCS	WG (g)	BCS
Cows								
April	320	5.8	269	5.5	291	5.3	297	5.3
November	244	4.8	224	5.0	230	4.9	250	5.3
Heifers								
April	230	6.0	134	6.0	135	5.5	156	5.8
November	192	5.1	142	5.8	143	5.6	158	5.6
Steers								
April	182	5.8	167	5.3	190	5.8	143	5.5
November	155	5.0	174	5.4	178	5.1	151	5.8

4. STRATEGIES FOR INCREASED UTILIZATION OF FEED RESOURCES PRODUCED ON-FARM

- In order to improve utilisation of natural pastures in rural areas, there is a need to train farmers to embark on fodder conservation techniques so that excess herbage production in the wet season is made available in the dry season.
- Farmers must be encouraged to collect and stack all crop residues after the grain harvest instead of allowing animals to graze them *in situ*. The conserved residues should be used as animal fodder during the latter part of the dry season when there is virtually nothing for animals apart from browse. This will also minimise the problem of trampling and soiling of residues with manure. Farmers need instruction in methods of improving the feeding value of crop residues.
- There is also a need to integrate the production of crops with that of animals. Intercropping of cereal crops with food legumes will not only help in improving soil fertility, but also the quality and quantity of crop residues generated after crop harvest. Intercropping of legumes with cereals will also have the advantage of producing high quality protein foods (often used as vegetables) for the resource poor rural communities.
- Farmers need encouragement to start establishing fodder gardens or legumes, so that they can either graze their animals directly or use the cut and carry system to feed their animals. These may be established in open fallow lands or lands which have not been utilised in the past. Permanent fodder sites may also be established on contour lines or farm boundaries, where they also contribute in controlling soil erosion and protecting arable crops from animals. The fodder legumes established in this manner can be used to provide a valuable feed resource when most needed in the dry season.
- There is a need to introduce rotational grazing in communal grazing areas which will assist in reducing pressure on preferred grass and tree species, thereby reducing the effects of overgrazing and the ultimate effects of water and wind erosion. This may be done through changes to the present land tenure system where individual farmers would be given title to their land, which they can then choose to use more effectively. Improved grazing systems may also be done through chiefs or community participation, where a particular community may come up with a programme, meeting the government's objectives, to maintain or improve their communal grazing areas. Another alternative is for the farmers to start improving their grazing areas through planting of legume species in the natural pastures. This will assist in improving the productivity and quality of feed materials from these pastures.

- Farmers should be encouraged to select suitable stock for production and to match animal numbers to the feed resources, particularly remembering the shortages that will occur in the dry season. The economic benefit of this practice to the farmer will be the sale of excess animals at the end of the rainy season when they are still in good shape and are likely to fetch a better price on the market. The sale of animals at this time of the year will also provide the farmer with cash to purchase feed supplements for his remaining animals.

The other strategy which may be used in rural areas would be through thinning of non-fodder trees and replacing them with browse species. Selected thinning of trees has often resulted in an increase in grass yields.

5. CONCLUSION

Poor nutrition is considered as the main factor limiting animal production in the traditional smallholder sector. The most important sources of feed for smallholder ruminant animals are the natural pastures and the fibrous crop residues. These materials are of low nutritive value in the dry season and do not have the capacity to meet the nutritional requirements of livestock at this time of the year. In order to improve the productive capacity of smallholder animals in the dry season, there is a need to embark on fodder conservation techniques which should not only allow for year-round availability of feed resources but also improve the quality of feedstuffs available to the farmer. A number of technologies have been developed and tried on-station which need to be evaluated on-farm so that they may be adopted by smallholder farmers. In addition to increased processing of crop-residues, the farmers should be trained to improve natural pastures through rotational grazing, planting of legume species, thinning of non-browse species and reducing stocking rates in their communal grazing areas.

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