TOWARDS OPTIMAL FEEDING OF AGRICULTURAL BYPRODUCTS TO LIVESTOCK IN AFRICA

PROCEEDINGS OF A WORKSHOP
HELD AT THE UNIVERSITY OF ALEXANDRIA, EGYPT
OCTOBER 1985

By the

AFRICAN RESEARCH NETWORK FOR AGRICULTURAL BYPRODUCTS (ARNAB)

JULY 1986
INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA
P.O. BOX 5689, ADDIS ABABA, ETHIOPIA

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ARNAB NETWORK ASPIRATIONS

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SUMMARY

Research networks are desirable and can greatly enhance research progress and the application of results. Networks can be viable when they are formed by scientists who have a mutual desire and mutual trust and are working on a common problem. Within network activities, scientists must gain something, e.g., skills, knowledge, literature, or access to research and analytical facilities. These gains help to sustain interest. Network members must also share responsibilities and therefore contribute to the network. Through complementary research programmes and the exchange of information, research progress can be greatly enhanced. A true network of national scientists avoids the risk, inherent in more centralized forms of regional programmes, of the domination of national programmes by an international agency or coordinator.

INTRODUCTION

In this short paper, a few issues on organizational aspects of a network will be raised and reference will be made to ARNAB. As published literature on networks is very limited, the information contained in papers by Arnon (1968a) Plucknett and Smith (1984) and Toledo et al (1984) has been drawn upon. The review contains a definition of a network and research programme activities. A short account of the history of ARNAB has been included for the benefit of non-members.

DEFINITION OF NETWORK

To date, there is no specific definition of a research network. The word network implies a fabric with cross-linkages typified by a spider's web. Unlike a cobweb, there are no physical linkages in a research network and the linkages are flexible and voluntary. A description such as "cluster of scientists or institutions linked together by a common interest in working independently and inter-dependently on identified, shared, problems or potentials" is possible. The cluster of scientists may be within the same country or may be in different countries but they have certain problems or research programmes in common. In the case of ARNAB, a group of scientists based in different countries in various types of institutions are conducting research on crop residues and by-products as livestock feeds.

The above definition suggests that scientists, problems and research programmes are the main components of a network. Furthermore, a network must respond to the reactions of the users

of the results of the research programme. A schematic representation of a hypothetical network is given in Figure 1.

The components of a network deserve some discusion.

SCIENTISTS

Networks are composed of people; in a research network these are scientists working in a specified discipline or in interrelated disciplines. The nature of research is such that specialists are people who can contribute ideas to research programmes as well as execute them. On the other hand, one has to bear in mind that as the ultimate goal is to transfer technology to agents of change (extension workers) and users (farmers), the membership may include anybody who has an interest in receiving newsletters. ARNAB membership is open to any researcher in Africa. However, because networks set themselves certain tasks, a prerequisite is that the scientists should feel a need to cooperate. The need to cooperate arises from one or more of the following:

* A desire to overcome isolation and a need for cooperation;
* A desire to learn from others working in the same area;
* A desire to have access to literature, computer facilities, germplasm, etc., which are available in large laboratories;
* A desire among young scientists to acquire specific skills;
* A desire to contribute to other research programmes, within the country and outside;
* A desire for a forum through which scientists can communicate with policy makers and make an impact on policies on development activities;
* A likelihood of getting financial support.

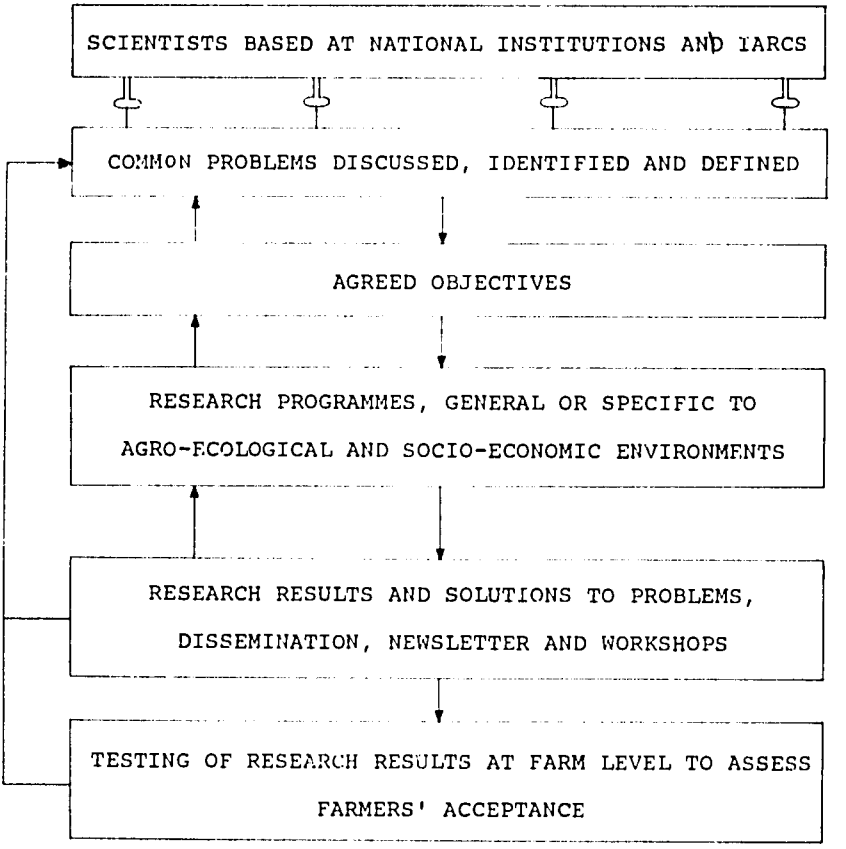
It is apparent that scientists need to see potential gains before forming or joining a network and during the operation of the network members must benefit if their interest is to be sustained.

NETWORK POTENTIALS AND COMMON PROBLEMS

Since it is not possible to examine all problems simultaneously, agricultural scientists must understand the agricultural industry, identify its problems and tackle the most limiting factors (problems) in order of priority. In the case of African livestock industries, the common problems are:

* The social and economic attitudes of farmers;
* The prevalence of disease: east coast fever, trypanosomiasis, blackleg, anthrax, foot-and-mouth;
* Inadequate feed supplies: seasonal availability of feeds and seasonal variation in feed quality;
* Poor marketing and distribution;
* Shortage of scientific and technical support;
* Inadequate mobilization of resources and sometimes misuse (e.g., overgrazing);
* External market restrictions: quarantine and political;
* Low genetic potential of livestock.

Figure 1. Schematic representation of network and how it functions.



The priority of these topics varies from country to country. The law of diminishing returns is cost effective; initially, relatively simple and empirical experimentation may give spectacular results. However, a stage is reached when further progress is dependent on a greater effort. One example of this is the improvement of milk production through cross-breeding and supplementary concentrate feeding.

Researchers identifying problems must accept the possibility of alternative solutions to the problems of the farming community and the needs of the country as a whole.

Typical national aspirations include:

* Self sufficiency in food supplies;
* Improvement of nutritional standards;
* Supply of raw materials for national industries;
* An ability to export crop/livestock products to earn foreign exchange for capital investment, sustain social services or sustain agricultural industry.

Scientists forming a network have to define the problem or potential which has been identified. In the case of ARNAB, it was recognized that crop residues and agro-industrial by-products contributed significantly to animal feed supplies. However, better exploitation of crop residues was limited by :

* Limited infrastructure for research/development;
* A scarcity of finance to support recurrent research expenses;
* Weak links between research and extension;
* Difficulty in forming multi-disciplinary research teams.

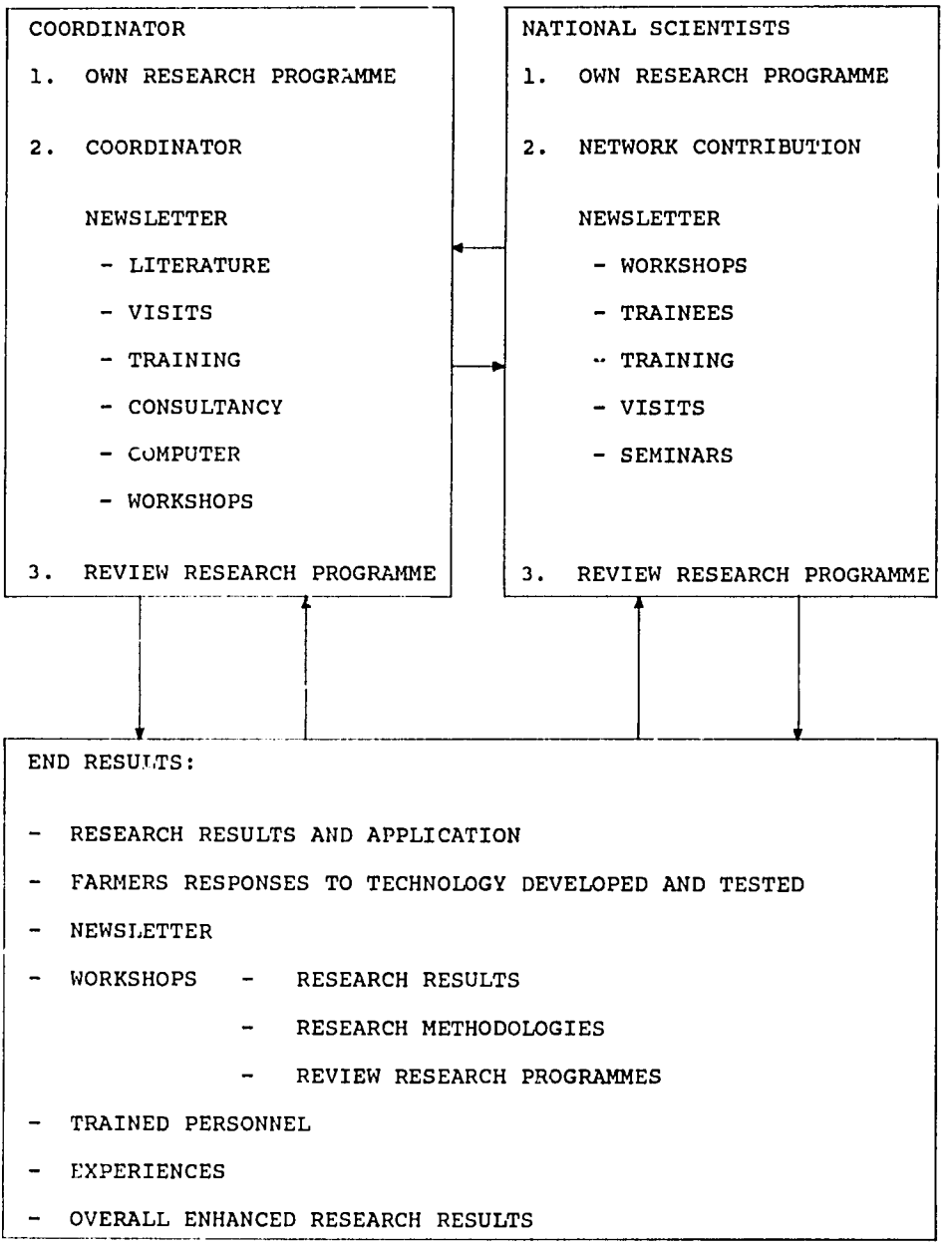
With these problems in mind, two workshops (ILCA/AAASA, 1980 and ILCA/FAO, 1981) recommended that ILCA should undertake the responsibility of coordinating a network. In this role, ILCA would alleviate some of the above constraints by:

* Training technical staff and young scientists;
* Making literature available through tables of contents of journals, reprints, books and literature search;
* Reducing isolation through distribution of a newsletter;
* Making consultants, e.g., socio-economists, available to biology-biased teams.

Other activities of ILCA as a coordinating institution were spelt out in the project document. To achieve these effectively, ILCA has to work with ARNAB members and this cooperation is pivotal in ensuring shared responsibilities and a flow of information through newsletters, which are important to the success of a network. Workshops are also important for fast dissemination of research results and offer opportunities for reviewing research methods and programmes. Figure 2 is a hypothetical model of shared responsibilities in a network and shows the flow of information and feedback.

IDRC has financially supported many ARNAB activities in the form of capital items, recurrent expenses and workshops. It is hoped that IDRC's financial support has been catalytic in getting ARNAB moving towards its objectives, which are to:

Figure 2. Shared responsibilities in a network and dynamism of network activities.



* Enhance rapid dissemination of research results through newsletters and annual workshops. Scientific journals take from one to several years to publish results;
* Provide forums for the exchange of information, experience, and feedback;
* Save time and funds by avoiding duplication and by running complementary national programmes, thereby greatly accelerating research progress;
* Make accessible facilities that are unavailable in national institutions;
* Enhance the development of research methods through testing and resolving methodological difficulties;
* Make it easier for scientists to extrapolate results through adoption of experimental and biometrical methods;
* Facilitate the exchange of potentially useful germplasm;
* Catalytically stimulate research activities;
* Offer training opportunities for scientists and technicians;
* Encourage small countries with limited capacities to participate in and benefit from broad-based research programmes;
* Provide a forum for influencing livestock production policies via the network;
* Provide a way for IDRC to develop contacts with national programmes and transfer promising technology.

While networks have the above benefits, they are also beset with basic problems. For example:

* There is the danger of domination by IARC, a funding agency or strong members of the network, resulting in a waning of interest by participating scientists;
* Networks may tend to isolate themselves from non-participants, and researchers not participating in a network may continue to be isolated;
* Networks formed without consultations with national scientists usually fail;
* National programmes may suffer if there are too many network programmes;
* Inflexible experimental designs encourage complaints;
* Some countries insist on goverment representation in networks;
* Changes in leadership are sometimes necessary but can be detrimental to networks because of the lack of continuity and the time needed to cultivate confidence;
* Many scientists may be unfamiliar with network activities and are slow to contribute to methods or to newsletters.

To avoid these risks, the prerequisite of perceived needs for cooperation must exist, or be cultivated, before the formation of a network; imposed networks should be avoided. Consultations must be held on the mode of operation of the network and the appointment of a coordinating agency. As networks are expected to promote participation, the coordinating institution should accept the responsibility as an equal partner. Built-in participation is important both technically and for the evaluation and review of the network.

Notwithstanding these difficulties, networks have produced proven benefits in many agricultural programmes, notably USDA research programmes, IRRI's rice programme and CIMMYT's cereal programme.

HISTORY OF ARNAB

The beginnings of ARNAB can be traced back to the workshop organized by ILCA and the Association for the Advancement of Agricultural Sciences in Africa (AAASA) in Douala, Cameroon in 1980. Fifty-two African scientists attended the meeting and unanimously recommended that ILCA should initiate the formation of an African Research Network for Agricultural By-products, consisting of scientists involved in research on crop residues for feeding to livestock. The recommendation was implemented by ILCA in 1981 with the launching of a newsletter and visits to national institutions. In 1981 (21-25 September) FAO and ILCA jointly organized a workshop in Dakar, Senegal, on crop residues and agro-industrial by-products in animal feeding. About 20 scientists from Africa attended the workshop and prepared initial recommendations for the ARNAB Network. Some of these showed clearly that African scientists have long been aware of the need for collaborative research programmes. Other workshops on the utilization of by-products within Africa were held in Tanzania in 1981, in Kenya in 1982 and in Egypt in 1983. In the 1981 and 1982 meetings the need for collaborative research was re-emphasized with the stated goal of enhancing research progress and the application of results.

Based on their 1981 workshop, FAO and ILCA organized an Expert Consultation in 1984. The major objective was to develop guidelines for research on the utilization of crop residues and agro-industrial by-products. The majority of the nucleus members of ARNAB attended this consultation and time was set aside for the ARNAB agenda. ILCA's proposal for funding by IDRC was discussed and the final project document was based on points raised by members. The current Alexandria meeting is essentially a follow-up of the one held last year.

In summary, ARNAB has evolved in the last 5 years and is mature enough to carry out collaborative research. This evolution has disclosed a few hitches but we shall try to resolve these in this workshop.

National research programmes are at different stages of development since a number of African scientists have been working in this area for more than a decade while others are just beginning.

EVALUATION

We have probably reached a stage when we should evaluate ARNAB's organization and activities and plan for future activities.

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THE USE OF DIAGNOSTIC SURVEYS IN DIRECTING ON-FARM RESEARCH: THE EXPERIENCE OF THE SMALLHOLDER DAIRY FEEDING SYSTEMS PROJECT IN TANZANIA

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SUMMARY

The survey was conducted in the Hai district of Kilimanjaro Region in February/March, 1984. The main objective of the survey was to identify those constraints related to livestock feeding that can be addressed by researcher designed innovations within the bounds defined by available resources and the institutional set-up.

The survey results indicate that natural grass, maize stover and bean haulms are the main feeds used. High transport costs are involved in moving the crop byproducts from the crop fields to the homesteads where livestock are kept. The shortage of concentrates and/or high costs involved limit their use. Molasses is available in large quantities but high transport costs have limited its use up to the time the survey was being conducted. A project is currently underway to construct storage tanks/selling centres in the villages and this should lead to a substantial reduction in costs. Research should focus on improving the nutritive value of the byproducts or the introduction of legumes. The economics of baling the byproducts and providing large volume transport to user centres should also be investigated.

INTRODUCTION

Technological packages recommended to farmers are, in general, a result of research efforts at research stations. It is true that testing of such packages takes place in localities where they are intended to be used, but the general practice has been to test these in researcher-controlled environments only. Involvement of the farmer is rare.

There is no doubt that the effectiveness of technological packages recommended to farmers will be dependent on the extent to which the following factors are taken into account during their formulation (Hardaker, et al 1985):

* The institutional setting and policy environment in which farming is conducted;
* The economic environment of farmers, including long term market prospects for inputs and outputs;
* Attitudes and personal constraints of farmers, including their desires or otherwise for change;
* The knowledge that the technological package is addressing already identified breakable constraints and exploitable opportunities within the existing systems.

The increasing interest in adaptive, on-farm research is a reflection of the failure of the more traditional approaches to solve the problems of low productivity in peasant agriculture. Under the umbrella of farming systems, methodologies have been proposed for conducting on-farm research (Zandstra, et al, 1981; Collinson, 1982).

Diagnostic surveys play a key role in identifying constraints that can be addressed by research and in providing base line information about the target farmers. The smallholder Dairy Feeding Systems Project in Tanzania has a large component of on-farm research and a diagnostic survey was used to identify constraints and tentative innovations for on-farm testing.

Choice of the study area

Kilimanjaro Region was chosen as the study area because its climate is well suited to dairy production. The region also has the largest and most advanced smallholder dairy production in the country. The land constraint and the production systems used in the region pose special problems for livestock feeding. The survey and the subsequent on-farm experiments were limited to the Hai district because of constraints on time and resources.

Description of the study area

Hai district is one of the six administrative districts of Kilimanjaro Region in the northern part of Tanzania. The district covers approximately 2308 km^2 and has a population of 172 317 and a population density of about 74.7 per km^2 (1978 census).

Two main zones can be identified; the highland zone and the lowland zone (Japan International Cooperation Agency, 1977). The highland zone enjoys milder temperatures and heavier, more reliable rainfall than the lowland zone. Most smallholder farmers in the district reside in the highland zone in permanent homesteads. Coffee and bananas are their main crops. Livestock raising in the highland zone is of the stall feeding type, with most animals being dairy cattle. Many parts of the lowland zone were developed only as recently as the 1960s. The main crops grown in this zone are maize, beans and finger millets. Livestock is mainly beef cattle. Most farmers residing in the highland zone also own farms in the lowlands and commute daily in the crop growing season to work on the farms.

Objectives of the survey

The main objective of the survey was to identify constraints related to livestock feeding that can be addressed by researcher designed innovations. To achieve the main objective, information was sought to describe a farmer in terms of livestock numbers and performance, crops grown and yields, purchased inputs and marketed output, use of home grown feeds and byproducts and constraints to increased production.

METHODOLOGY

Data were obtained from primary sources using two techniques. Informal interviews were conducted in December 1983 involving district and village officials and extension officers. In addition the managements of a sugar processing company and a livestock feeds company were interviewed. The objective of these informal interviews was to obtain information on:

* Institutional and policy settings that have a bearing on dairy production in the district;
* Inputs and output marketing arrangements;
* Livestock feed situation in the Kilimanjaro Region;
* Perceived constraints to smallholder dairy production in the district.

A formal survey was conducted in February/March 1984 using a structured questionnaire.

Survey design

A single household keeping cattle was used as the sampling unit in this study. A list of households keeping livestock was obtained from each village and these were used to construct a sampling frame. Thirty households were sampled from each of the five divisions of the district, forming a sample size of 150 households. A questionnaire was constructed to obtain the following information:

* Demographic characteristics of a household;
* Number of farm plots and distance from the homestead;
* Livestock types and numbers;
* Crops grown and their yields;
* Livestock feed sources and prices where applicable;
* Milk production and marketing;
* Perceived constraints to crop and livestock production;

Information was sought for the year 1983. The interviews were conducted by the researchers.

RESULTS AND DISCUSSION

Land constraint in the district precludes the use of technologies that make large demand for land. Table 1 presents results of farm size distribution across sampled households. All farmers sampled have farm plots in both the highland and lowland zones. The classification of farms by zone has been used because of the distinct differences in the crops grown in the two zones.

The results show that the majority of the sampled households have farms of less than a hectare in each of the two zones, but the farms on the lowland zone are on average larger than those in the highland zone. However, there is a large variation in farm size across sampled households as indicated by the standard deviation figures. There is a wide variation in distance from the homestead to the lowland farms. The survey results indicate an average distance of 18.8 km. This has serious implications for the cost of transport of farm products from these farms to the homesteads.

Table 1. Frequency distribution of farm size across households.

Range in hectares	Percent of households		
	Highland zone	Lowland zone	Total
1	41.0	33.8	5.2
1 - 2	32.6	32.5	22.1
2 - 3	15.8	12.5	33.8
3 - 4	3.2	3.8	11.7
4	7.4	17.4	27.2
Median	1.01	1.20	2.6
Standard deviation	2.07	5.17	5.17

N = 107
Source: Diagnostic survey.

Livestock production

Livestock production is an integral part of the farming system in the district. Land scarcity has contributed significantly to the high degree of dependence between the crop and the livestock subsystems. While the crop byproducts are extensively utilized as livestock feed, the manure from the livestock is in turn used on the banana/coffee and vegetable plots to maintain soil fertility.

Livestock numbers and herd size distribution

The 1978 census indicates that numerically, cattle are the most important livestock in the district, followed by sheep, goats and pigs respectively (Table 2). Traditionally, cattle have been kept to meet domestic milk needs and customary requirements such as payment of dowry. However, the rapidly growing demand for milk (as reflected by the high parallel market price of Tz shs 20.00 compared with the official price of Tz shs 10.00 per litre), coupled with the declining farm income from coffee resulting from falling real prices and persistent out-breaks of coffee diseases, has seen a rapid growth in commercial milk production by smallholder farmers in the district. The local Zebu is a low milk producer and is being replaced by improved breeds.

Table 2. Number of domestic animals in Hai district, 1975.

Type	Number	Average per household
Cattle	132,000	4.0
Sheep	28,200	0.9
Goats	9,000	0.3
Pigs	4,000	0.1

N = 107
Source: Adapated from Mlambiti, M.E., et al, 1982. Economic analysis of the Kilimanjaro Region - Tanzania. IAF No. 85. West Virginia University, p.13.

Table 3 presents cattle herd size distribution across sampled households. It is clear that among the sampled households the replacement of the local Zebu by improved breeds is almost complete. Farmers interviewed indicated that the herd .op size of cattle is constrained by feed availability and the associated high costs of acquisition.

Table 3. Cattle herd size distribution by type across households.

Number of animals	Percent of households with:					
	Local	Improved cows	Improved bulls	Improved growers	Improved calves	Total
0	92.6	9.3	73.1	57.4	37	0
1 - 2	6.5	45.4	25.0	38.9	51.8	12.2
3 - 4	0	37.0	1.8	2.8	7.4	36.7
5 - 6	0	4.6	0	0	1.9	29.3
>7	0.9	3.7	0	0.9	1.8	21.5
Mean	--	--	--	--	--	5.0
Median	0	2.6	0.18	0.37	0.89	4.6
Standard deviation	--	--	--	--	--	8.0

N = 107
Source: Diagnostic survey, 1983.

Cattle breeds and breeding practices

A wide variation of pure breeds and cross breeds was observed among sampled farmers. This variation is a reflection of what was available on the market when the farmer purchased his heifers, or the bull service/semen available at that moment for upgrading the local zebu. Often farmers keep more than one breed, as seen in Table 4.

Table 4. Distribution of improved breeds across households, 1983.

Breed	Percent of households
Friesian	10.8
Jersey	19.4
Ayrshire	3.2
Mpwapwa	1.1
Two pure breeds	31.3
Three pure breeds	8.6
Pure breeds and crosses	25.6

N = 107
Source: Diagnostic survey.

Most farmers indicated that, given a choice, the preferred breed is Jersey. The justification given is its relatively low feed requirement and the high butter fat content of the milk.

The survey results indicate that 63.1% of the farmers use natural breeding, 10.7% artificial insemination and 26.2% use both methods. Although natural breeding methods are commonly used, 92.6% of the sampled farmers do not own bulls (Table 3). Such a service is obtained either from neighbours or cooperative farms, at a cost. The low utilization of artificial insemination is due to the shortage of semen and equipment and the small number of veterinary extension staff who, in most cases, are not provided with transport. As a result the artificial insemination service has become very unreliable.

Information was also sought on the source of replacement stock. The survey results indicate that 58.4% of the sampled farmers raise their own replacement stock, 18.8% purchase replacement stock from government farms and other farmers and 22% utilize both sources. Scarcity of improved replacement stock on the market accounts for the large number of farmers raising their own replacement stock.

Feeds and feeding practices

Stall feeding of livestock is the most common practice in the highland zone of the district. Since agriculture is so intensive, there is hardly any land suitable for open grazing. The main sources of roughage are natural grass, maize stover, bean haulms, banana pseudo-stems and leaves, and established pasture plots. These are fed ad libitum when available. Minerals, in the form of naturally occuring sodium salts (magadi), are commonly sprinkled on roughage to improve palatability.

1. Natural grass

The reliability of natural grass as a source of roughage is restricted to wet seasons. Limited supplies are obtainable within the highland zone on unusual patches of land and along river banks. The lowland zone has a higher potential to supply grass but the poor condition of roads in the wet season limits its exploitation.

2. Crop residues

It is argued that the shortage of grass in the dry season is one of the major causes of drastic deterioration of livestock nutrition. Inevitably, crop residues, mainly maize stover and bean haulms become very important in the dry season. These are obtained mainly from the farms in the lowland zone.

The survey results indicate that 86% of the sampled farmers use both maize stover and bean haulms, while 9.7% use maize stover only and 4.3% use bean haulms only. While 67.7% of the sampled farmers depended entirely on crop residues from their own farms, 33.3% supplemented their crop residues with purchases from other farmers. The main constraint in obtaining these residues is transport. The shortage of transport, coupled with high hiring costs, has caused many farmers to rely on family and/or hired labour to head-carry the residues to their homesteads.

Due to the wide variation in the modes of transport used and

in the sizes of loads carried by head, it was not possible to estimate the amount of residues stocked per household per year. Estimates of costs associated with purchases and transport of crop residues for the year 1983 were obtained from only 47 farmers. These ranged from TZ shs 200.00 to TZ shs 5200.00 with a median of Tz shs 1755.00.

3. Established pasture

Farmers in the study area recognize that natural or established pasture is an economic input and are willing to, and do, pay for it. Despite the scarcity of land, an increasing number of farmers are growing their own pasture to supplement other sources. The majority of surveyed farmers had established pasture along footpaths and farm boundaries and in only a few cases had they set aside land for pasture establishment.

Many farmers indicated a willingness to replace part of their coffee plantations with grass if such an opportunity was provided. The grass species grown are Pennisetum purpureum (elephant grass), Tripscam laxum (Guatemala grass) and Setaria spp.

4. Standing hay

Use of standing hay is not a common practice in Hai district and only 13% of the sampled farmers used it in 1983.

5. Concentrates

The main, formal, retail sources of concentrate feeds are cooperative shops and the Tanzania Farmers Association. These sources supply maize bran, wheat pollards, cotton seed cake and dairy complete meal. Molasses is also available in large quantities from the Tanzania Sugar Company, located about 20 km south of Moshi. However, there is a critical shortage of concentrates which means that their use is below requirement. In 1983 only 59.8% of the sampled farmers fed concentrates to their livestock.

While molasses is available in large quantities, high transport costs have restricted its use. Work is in progress to construct storage tanks in selected village centres for stocking a molasses/urea mixture. The project is being supported by FAO/UNDP Dairy Development Services. To date, 19 centres have been established and are operational and this means that many farmers are now able to purchase the mixture in small quantities within walking distance of their homesteads.

Dairy Cattle Performance

The performance measures investigated in the survey include daily milk yield, lactation length and calving interval. For the purpose of this paper only milk yield performance is reported. As shown in Table 5, the majority of sampled farmers realized an average daily milk yield of between 5 and 10 litres. The mean daily milk yield was 7.3 litres. Farmers interviewed indicated that the lowest milk yield is in the dry season when grass is in short supply.

Table 5. Frequency distribution of average daily milk yield, 1983.

Range in litres per day	Percent of households
< 5	18.4
5 - 10	36.8
10 - 15	26.4
> 15	18.4
Mean	7.4
Standard deviation	7.6

N = 107
Source: Diagnostic survey.

CONCLUSIONS

Assuming that the survey results represent the true, overall picture, then the constraints related to feeds are:

* The high cost of transport of crop residues and grass from the lowlands to the homesteads;
* The low nutritive value of feeds used, particularly in the dry period.

With the re-introduction of cooperatives, there is a need to investigate the cost implications of baling and large-scale transportation of bales to the utilization areas. Research should be directed towards improving the nutritive value of crop residues since they form a very significant part of livestock feeds in the district. The results show that the established pastures do not include legumes and their establishment under the existing farming system should be studied.

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ON-FARM RESEARCH ON UTILIZATION OF CROP RESIDUES BY SMALLHOLDER DAIRY FARMERS IN HAI DISTRICT, TANZANIA

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SUMMARY

A diagnostic survey was carried out in Hai district in northern Tanzania with the objective of identifying the main constraints affecting smallholder dairy producers. Based on the results, on-farm experiments were initiated and included the feeding of baled maize stover and bean haulms to lactating dairy cattle on smallholder farms. A molasses/urea mixture was supplied as an additional feed resource. Although the primary data have not yet been statistically analyzed, general observation shows an increased milk yield for those farmers supplied with crop residues as opposed to those without.

BACKGROUND INFORMATION

Hai district is one of the six administrative districts of Kilimanjaro Region in the northern part of Tanzania. Export-oriented agriculture, particularly the production of Arabica coffee, has contributed significantly in making the economy of the region the most highly developed in Tanzania (Mlambiti et al, 1982). Land is, however, a major constraint in the agricultural development of the region. Most farmers in Hai district, as well as in most of the other districts, own two farms; a small farm (0.5 ha) on the mountain slopes and a second farm (1.5 ha) on the lowlands. Traditionally the farmers have their homesteads on the highlands or mountain slopes, where, in addition to growing coffee and bananas, they also keep a few livestock, particularly cattle. The lowland farms are used mainly for the production of food crops, normally maize, beans and finger-millet.

In recent years dairy farming has become an important agricultural activity, especially in Hai district - a drastic change from the situation reported by Beck (1961). The popularity of dairy farming results from the need to diversify agricultural production, which was mainly coffee, as well as from the traditional appreciation of milk as a quality food. The shortage of land available for fodder production is a major constraint on the ability of the smallholder diary farmer in Hai district to improve his production (Tibenda, 1977; Eldesten and Lijongwa, 1981). Traditionally, farmers have used unconventional feeds such as banana pseudostems, banana leaves and fodder cut from along roadsides and river banks as well as limited fodder from established plots of grass, mainly Setaria spp, Guatamala grass (Tripsacum laxum) and elephant grass (Pennisetum purpureum). In addition, farmers use crop residues from the lowland areas to feed their livestock. The significant role played by the residues

as an important feed resource has long been recognized in Tanzania (French, 1943), and yet farmers still face a number of constraints on their efficient utilization.

In 1983, the Sokoine University of Agriculture (through IDRC sponsorship) initiated a project which aimed, among other things, to identify the major production constraints facing the smallholder dairy producer in Hai district and similar areas, and to devise methods to overcome some of them. Project workers are currently studying ways to improve the efficiency with which these dairy farmers can utilize crop residues.

DIAGNOSTIC SURVEY RESULTS ON UTILIZATION OF CROP RESIDUES

A diagnostic survey carried out in Hai district in February/March 1984 confirmed the significance of crop residues as a feed resource for the smallholder dairy farmer. Most used both maize stover and bean haulms, although 10% of the sampled farmers used maize stover alone and 4% used bean haulms alone. All the farmers used at least one of the two types of crop residues. While 67% of the sampled farmers depended entirely on crop residues from their own farms, 33% supplemented these with purchases from other farmers. It was generally observed that the quantity of residues collected and transported was far below the farmers' requirements.

Shortage of transport coupled with the high cost of hiring transport has caused many farmers to depend on family and hired labour to head-carry the residues to their homesteads. Some farmers specifically singled out lack of transport as being the major cause for their failure to accumulate enough residues to meet their needs for the entire season.

A wide variation was observed in both the type of transport used and the sizes of the loads carried by head. In both cases the residues were transported loosely as there was no option for baling.

ON-FARM RESEARCH ACTIVITIES

In 1984, attempts were made to improve both procurement and feeding of crop residues. This was done through:

* Baling the crop residues to reduce their bulkiness and hence the transport costs;

* Feeding the baled crop residues with a molasses/urea mixture with the aim of improving voluntary feed intake as well as supplying energy and NPN.

Baling was carried out using a conventional John Deere hay baler model 342 A. Although this type of machine is not technically designed for baling such materials as maize stover or bean haulms, it was possible to bale these residues effectively by hand feeding them into the baler. On average, it was possible to bale 33 bales/h and 50 bales/h of maize stover and bean haulms respectively. Efficiency improved to 125 bales of bean haulms/h the following season. Materials for baling were obtained from

school farms, private farms and cooperative farms. The baled crop residues were transported and supplied to farmers and the costs were computed per bale and charged to farmers.

On average, baling reduced bulkiness by more than 300%. Bulkiness significantly affects transport costs as charges are normally based on truck loads or head-loads. The reduction in bulkiness is also important in allowing better use of storage space. The price charged per bale was Tz shs 7.00, which took into account baling and transport costs, and compared with the market price of Tz shs 20.00 to 25.00 per bale of maize stover and Tz shs 30.00 to 35.00 per bale of bean haulms.

Baling of maize stover using a standard baler, however, appears to be an inappropriate technology, especially for the smallholder dairy farmer. For this reason, the use of manually operated hay binders is being sought as an alternative technology. These will be tried under normal farming conditions and if effective, would appear to be more appropriate and could be more easily adopted by the small-holder dairy farmer. They could perhaps be used not only for baling crop residues but also for baling hay from the lowland areas which has hitherto been transported loosely and at high costs.

The molasses/urea mixture was obtained from a sugar cane processing factory about 20 km south of Moshi town. FAO (through UNDP dairy cattle development project URT/81/016) constructed a simple molasses/urea mixing plant at the sugar factory which became operational in 1984. The plant produces a mixture of molasses containing 3% urea. A distribution network has also been established and selected villages have become collection centres where tanks, each with a capacity of 10 000 litres, have been constructed. These molasses/urea centres became operational at the same time as baled crop residues were being introduced to farmers.

Two test villages in Hai district were selected for on-farm feeding trials. Ten farmers were selected in each village. Five of the selected farmers in each village were provided with baled crop residues and the molasses/urea mixture, while the remaining five formed the control group. As farmers had been using crop residues before, the only additional innovation was the provision of an adequate supply of baled residues, which could last a longer time, and the supply of the molasses/urea mixture. Farmers were given demonstrations on how to dilute and mix the molasses/urea mixture with the crop residues. Approximately 2 kg of molasses/urea mixture was used per cow per day. The crop residues were simply included in the farmers daily feeding pattern. A typical feeding pattern is shown in Table 1.

Under normal feeding management there is a wide variation in the quantity of forage offered per cow per day. This variation is caused by many factors, including availability of the forages and the availability of labour to cut and head-carry forages from the lowlands. The availability of a steady supply of roughages in the form of the baled crop residues was expected to increase milk yield. Previously the animals were underfed and the lack of sufficient forages has been reported to contribute significantly to the low milk production among smallholder dairy farmers in Hai district (Tibenda, 1977; Edelsten and Lijongwa, 1981).

Table 1. Typical feeding pattern of stall-fed dairy cattle among smallholder farmers in Hai district.

Types of roughages fed		
Morning	Noon	Evening
Banana leaves Banana pseudostems (chopped) Seteria spp or Guatamala grass (All mixed in a manger)	Maize stover Bean haulms Banana pseudostems (chopped) Banana leaves (All mixed in a manger)	Grass cut from lowlands, river banks and/or roadsides, Guatamala grass, Seteria spp or Elephant grass

The farmers' previous milk yield records, although in most cases scanty, together with the records from the control group, will be used as bench marks for assessing the impact of a steady supply of crop residues in the feed. Farmers were provided with data sheets for recording and monitoring milk yield in relation to the feeding regime. The monitoring and recording was carried out by the research team, livestock extension staff and the farmers. Although the data from these feeding trials have not yet been analyzed statistically, there appears to be a notable increase in milk yield on all the farms supplied with the crop residues. It must be pointed out, however, that the results of the on-farm trials require careful interpretation. Before any conclusions can be drawn, the data from the previous seasons must be compared in general terms with the data obtained from this season as well as those obtained from a research farm.

One additional crop residue which has been identified this season is bean haulm chaff. This consists of small broken particles of bean pods as well as broken and small bean seeds which pass through the sieving screens. In the diagnostic survey it was observed that a limited number of farmers use this product, which is mainly obtained free of charge from commercial farms in the West Kilimanjaro area. The major constraint to its use is transportation. The dusty product has to be filled in bags and transported by lorries. It is likely, however, to have a much higher nutritive value than bean haulms and may prove a very valuable feed resource, particularly when mixed with molasses. This crop residue is being included in the on-farm feeding trials this season, both at farmer level and on the research farm.

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PROSPECTS FOR EFFICIENT UTILIZATION OF AGRO-INDUSTRIAL BYPRODUCTS AND CROP RESIDUES FOR RUMINANT FEEDING IN THE SUDAN, WITH EMPHASIS ON QUANTIFICATION, NUTRITIONAL COMPOSITION, CONSTRAINTS AND RESEARCH RESULTS

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SUMMARY

Sudan possesses a huge animal wealth of about 23 million animal units. Pasture and range provide about 85% of the national feed resources; agro-industrial byproducts and crop residues contribute about 11% and cereal grains and forages about 4%.

Pasture and range resources have been seriously reduced by drought and desertification. Consequently, better use of residues and byproducts must be encouraged.

A survey indicated that more than 7 million t of residues and byproducts were produced annually over the last four years, consisting of cereal straws (sorghum and wheat), sugar-cane (molasses and bagasse), groundnut hulls and haulms, and the oilseed cakes of cotton, sesame and groundnuts. Field residues are mainly from sorghum and cotton.

Constraints on the use of residues and byproducts include: bulkiness, location in areas with lower animal population density, unsuitability for direct animal use and poor nutritive value.

Sorghum straw and groundnut hulls, each at 25% of the ration, supplemented with 20% molasses and 1.75% urea, gave excellent results for fattening beef cattle and sheep and appeared to be as good as conventional high grain rations. Cost of feeding was decreased. Both poultry manure (20% of the ration) and urea (1.5-1.75%) were effective in rectifying the nitrogen deficiency of the residues and byproducts used in this study. Physical treatment was more effective and economically feasible than treatment with sodium hydroxide.

INTRODUCTION

Agriculture is the major source of income in the Sudan. There are differences in agro-climatic zones, soil types and available water resources. Within arable farming, the major cash crops in Sudan are cotton, sesame, groundnuts, cereals (mainly sorghum, wheat and millets) and sugar-cane, which are raised under both irrigated and dry farming systems. A total of 7 million t of crop residues and agro-industrial byproducts (AIBP) are produced annually from these and other crops. Unfortunately, very little use has been made of these feed resources.

The more than 55 million head of cattle, sheep, goats and camels (over 23 million animal units) in the Sudan are raised mainly on pasture and range, which form the major livestock feed resource and provide about 85% of the total nutrient requirements of these animals. Of the remaining 15%, AIBP contribute about 11% and forages and concentrates about 4% (Kurdi, 1984).

However, in recent years drought and desertification have greatly reduced the potential DM yield of pasture and range. Full and efficient use of AIBP has to be promoted for feeding animals in the Sudan.

The objectives of this study were to:

* Quantify the different types of AIBP and assess their nutritive value;
* Identify constraints facing the use of AIBP for feeding ruminants in the Sudan;
* Enhance the nutritive value of AIBP by molasses and NPN (urea and poultry excreta) supplementation as well as by chemical and physical treatments.

RESULTS AND DISCUSSION

Types, amount and use of agro-industrial byproducts in the Sudan

Agro-industrial byproducts in the Sudan consist of cereal straws (sorghum, wheat, rice and millet), sugar-cane byproducts (molasses, bagasse and sugar-cane tops), oil seed cakes (sesame, cotton and groundnut), groundnut haulms and hulls, and fruit wastes (e.g., banana). The most important ones are cottonseed cake and sorghum straw (El Hag, 1984).

The estimated 7 million t of DM of AIBP produced annually in the Sudan provide approximately 3 million t of TDN (Table 1). The greater proportion of these byproducts is wasted (burnt or allowed to rot) rather than utilized as animal feeds. Partial use is made of AIBP, mainly during the critical summer period (March to July). Burning of AIBP (as the quickest way to clear land and control pests) poses a potentially serious environmental hazard.

Only a tiny proportion of the molasses available in the Sudan has been used for alcohol production and for feed manufacturing in the newly established feed mills in Khartoum. Until recently, the majority of molasses was disposed of in nearby rivers.

Problems limiting the use of agro-industrial byproducts as feeds in the Sudan

The major problems facing the use of agricultural byproducts for animal feeding in this country include:

* Bulkiness of byproducts and their availability in areas with lower animal population density;
* Poor infrastructure and the high cost of transport;
* Availability of byproducts in forms not suitable for direct animal use;

Table 1. Production of agro-industrial by-products in the Sudan (1980-84) and their TDN (in 1000 tonnes).

Item	Seasons				Ave. prod. in 4 yrs.	TDN*
	80/81	81/82	82/83	83/84		
Sorghum straw	2481.6	3932.4	2325.6	2182.8	2730.6	1447.2
Ground nut hulls	282.8	335.2	196.8	183.2	249.5	84.8
Ground nut residues	424.2	502.8	295.2	274.8	374.3	228.3
Cotton residues	229.6	372	466.4	500 4	399.6	195.8
Cotton gin trash	401.8	651	816.2	928.2	699.3	293
Millit stalks	392.8	407.2	272.8	251.2	331	140.7
Wheat straw	174.4	97.6	112.8	129.6	128.6	52.2
Wheat bran	32.7	18.3	21.2	24.3	24.1	14.9
Bagasse	1046.3	1184.8	1662.3	1836.6	1433	415.6
Molasses	86.1	119.5	141.3	164.2	128.5	82.2
Sugar-cane tops	189.6	139.9	219	254.1	200.7	80.3
Totals	6186.9	8244.7	6855.6	7167.4	7113.7	3200.8

* Values were calculated according to N.R.C. (1975).
Source: Ministry of Agriculture and Irrigation, Department of Statistics (1984).

* The general lack of understanding among livestock owners about the feeding value of byproducts;
* The relatively poor nutritive value of most AIBP.

Nutritive value and nutritional deficiencies of agro-industrial byproducts in the Sudan

Samples of the important and most abundant AIBP in the Sudan were collected from different locations and analysed for proximate composition (AOAC, 1965), cell wall constituents (Goering and Van Soest, 1970), and in vitro dry matter disappearance (IVDMD) (Tilley and Terry, 1963).

Chemical analyses show that AIBP were deficient in CP, high in CF and lignin and poor in IVDMD. Since most of the AIBP were poor in CP and readily fermentable carbohydrates, most of our research focussed on the following:

* Supplementation of AIBP with molasses and NPN (urea and poultry excreta) for sheep and beef cattle used in growth trials;

* Chemical (NaOH) and physical (grinding and pelleting) methods for improving the nutritive value of some selected AIBP.

It is well documented that utilization of NPN is enhanced by molasses supplementation. Molasses is one of the cheapest sources of energy and is available in relatively huge quantities (Table 1).

The usefulness of supplementing low quality AIBP (groundnut hulls, bagasse and sorghum straw) with both NPN (urea and dried poultry excreta) and molasses was demonstrated in studies with both sheep and cattle (Table 2).

The data show that AIBP, particularly sorghum straw and groundnut hulls, when used as basal diets and supplemented with urea and molasses, can give animal performances comparable to conventional (high grain) rations, and that molasses can be used effectively at up to 20% of the ration and urea at up to 1.75% (as fed basis). Bagasse seemed to be a rather poor byproduct and its level should probably not exceed 30% of the ration. At higher levels, such as 50%, bagasse was just adequate for maintenance purposes. The cost of feeding decreased by more than a third with the incorporation of byproducts and urea-molasses supplementation.

From these results it could be concluded that for fattening of both sheep and cattle in the Sudan, byproducts should not exceed 30% of the ration. Urea and molasses can be used effectively up to 1.75% and 20% of the ration respectively.

The results of another study (Table 3) showed that dried poultry excreta (DPE) was very effective as a source of NPN, was used successfully in replacing cotton seed cake (CSC) protein, and even improved animal performance compared to (CSC). The cost of feeding decreased by about 50% by using DPE. However the overall performance of sheep on both DPE and CSC-supplemented rations was relatively poor and was due to the low TDN content of

Table 2. Performance of Sudan desert sheep and beef cattle on rations containing variable levels of AIBP supplemented with urea and molasses.

Ingredients (%) (as fed)	Conventional high energy rations		Byproducts based rations			
			C	D3	E	F
Sorghum grains	50	50	15	15	20	20
Cotton seed cake	15	49	-	-	20	15
Wheat bran	19	-	30	30	20	5
Alfalfa hay	-	-	7.5	7.5	-	-
Sorghum straw	-	-	24.75	-	-	-
Groundnut hulls (GNH)	-	-	-	24.75	-	-
Bagasse	-	-	-	-	30	50
Molasses	-	-	20	20	8	8
Urea	-	-	1.75	1.75	1.5	1.5
Common salt	1.0	1.0	1.0	1.0	0.5	0.5
Total	100	100	100	100	100	100
Nutritive value (DM basis)						
% CP	15	16	14.8	12.7	13.7	9.5
% TDN	82	80	75	71.5	54	47.0
Animal performance (sheep)						
Days on test	75	-	-	75	75	75
Feed intake (DM) g	1280.8	-	-	1314.6	1175	948
Daily gain (g)	160.8	-	-	148.5	55	1.1
Feed/gain	7.97	-	-	8.85	21.0	862
Animal performance (beef)						
Days on test	-	67	67	67	-	-
Feed intake (DM) kg	-	9.83	8.74	8.58	-	-
Daily gain (kg)	-	1.22	1.12	0.66	-	-
Feed/gain	-	8.06	7.8	13.0	-	-
Cost/kg of the ration (LS)	0.16	0.21	0.12	0.12	0.13	0.10

Rations A and B are high energy rations based on 50% sorghum grains.
Ration C was based on 24.75% GNH.
Ration D was based on 24.75% sorghum straw.
Ration E was based on 30 % bagasse.
Ration F was based on 50 % bagasse.

Table 3. Performance of Sudan desert sheep on variable levels of AIBP supplemented with dried poultry excreta (DPE) and molasses.

Ingredients %	Cotton seed cake supplemented ration (% DM)	Dried poultry excreta supplemented ration (% DM)
Wheat bran	29.0	29.0
Dried poultry excreta	-	20.0
Cotton seed cake	20.0	-
Groundnut hulls	40.0	40.0
Molasses	10.0	10.0
Salt	1.0	1.0
Total	100	100
Nutritive value		
% CP	15.0	16.2
% DCP	9.5	10.6
% TDN	57.5	56.6
Sheep performance		
Feed intake (DM) g	1054.6	1295.6
Daily gain (g)	46.6	65.3
Feed/gain	24.2	19.8
Cost/kg gain (LS)	1.10	0.53

both rations. The poor TDN value was ascribed to the high level of groundnut hulls (GNH) in both rations. This again supports our belief that agricultural byproducts in fattening rations should not exceed 30%.

Research results with NPN and molasses-supplementation demonstrated the effectiveness of urea and DPE, and molasses in rectifying CP and energy deficiencies respectively. The cost of feeding decreased by more than a third.

Improvement of the feeding value of agricultural byproducts by chemical and physical methods

1. Chemical treatment (NaOH)

The effects of NaOH were studied using both wet (soaking) and spray methods with variable levels of the alkali. It was found that spray method at levels of 7-11% of the substrate (w/w) were the best. With the soaking method there was a very high DM loss (9-25%) in the treated byproduct.

Kurkedi (Hiscus sabdrifa) a local malvaceous plant, used as a beverage in the Sudan, was found to have a very acidic pH (2.4) at 1% conc (w/v). Owing to its low pH, kurkedi was evaluated as a neutralizing agent for the NaOH-treated byproducts for both laboratory and field trials. By-products were sprayed with a 1% solution of Kurkedi.

Feeding trials were carried out using NaOH-treated by-products.

a) Groundnut haulms

In this study, three rations based on 55% (DM basis) groundnut haulms (GNH) were compared with a standard high grain ration in a feeding trial using growing sheep. One of the GNH rations was treated with 11% NaOH; the second treated with 11% NaOH and then sprayed with kurkedi solution at 1% (w/v), and the third was fed without any treatment (control). There were five sheep per treatment and the trial lasted for 90 days.

The composition, nutritive value, digestibility and animal performance are summarized in Table 4. Animal performance was depressed due to NaOH and kurkedi treatments. Chemical treatment depressed the DM intake dramatically (36%) in relation to the control. However NaOH treatment slightly enhanced both DM and CF digestibilities. The NaOH treatment increased the total ash content of the ration and consequently decreased the OM content and this has been reflected in a low DM intake and poor animal performance on the NaOH-treated GNH. Therefore there was no benefit due to NaOH or NaOH-kurkedi treatment of the GNH.

Table 4. Effects of NaOH and kurkedi on feeding value of GNH-based rations.

Item	High grain ration	GNH treated with NaOH	GNH treated with NaOH + kurkedi	Control untreated GNH
GNH (% DM)	-	55	55	55
Sorghum grain	55	15	15	15
Wheat bran	15	-	-	-
Alfalfa hay	14	-	-	-
Cottonseed cake	15	12	12	12
Molasses	-	15	15	15
Urea	-	2	2	2
Salt (Nael)	1	1	1	1
Total	100	100	100	100
Proximate composition (DM basis, %)				
OM	91.0	85.4	85.4	92.2
CP	15.5	15.4	16.4	14.4
CF	11.4	23.6	25.8	25.3
Ash	9.1	14.7	14.6	7.85
TDN	75.5	44.8	45.1	47.4
Digestibility (%)				
OM	76.9	48.5	48.0	46.2
CP	79.5	74.0	79.4	79.8
CF*	50.3	33.4	35.4	22.0
Animal performance				
DM intake (g)	1212	860.6	859.0	1353
Daily gain (g)	137.0	-30.0	-35.3	28.5
Feed/gain	8.8	-	-	47.5
Price/kg (LS)	0.2	0.13	0.13	0.10

* Significant improvement in CF digestibility ($P<0.05$) due to NaOH and kurkedi treatments.

b) Sorghum straw

The poor performance of sheep on the NaOH-treated GNH was due to the high level of NaOH (11%) and the originally poor quality of the GNH (high content of lignin and crude fibre). Accordingly, sorghum straw was chosen as a substrate for NaOH treatment and the level of the alkali reduced to 7% from 11%.

In this trial three rations were based on 50% (DM basis) of sorghum straw. One ration was fed as a control without any treatment, the second was treated with 7% NaOH (w/w) and the third treated with 7% NaOH and then sprayed with kurkedi solution 1% (w/v). The three rations were fed to three groups of growing Sudan Desert sheep, with eight animals per treatment. The experiment lasted 75 days. Digestibility and animal performance data are summarized in Table 5.

Table 5. Effects of NaOH and kurkedi treatment of sorghum straw on nutrient digestibility and sheep performance.

Item	Control ration 50% sorghum straw	50% sorghum straw treated with 7% NaOH	50% sorghum straw treated with 7% NaOH + kurkedi
Composition of the rations (% DM basis)			
Sorghum straw	50	50	50
Molasses	15	15	15
Sorghum grains	20	20	20
Cotton seed cake	12	12	12
Urea	2	2	2
Common salt	1	1	1
Total	100	100	100
Proximate composition (% DM basis)			
OM	88.5	86.8	85
CP	11.2	11.1	11.0
CF	16.3	15.3	15.0
Ash	11.5	13.2	14.96
Digestibility (coefficients %)			
OM	65.5	69.5	66.9
CP	67.9	71.0	67.0
CF*	42.4	51.8	44.5
TDN %	59.2	61.7	59.4
Animal performance			
DM intake (g)	860.5	995.9	890.5
Daily gain (g)	7.2	36.75	20.5
Feed/gain (g)	119.5	27.0	43.4
Cost/kg (LS)	0.12	0.145	0.146

* Significant effect due to treatment ($P<0.05$).

There were no observed differences in the chemical composition of the rations due to the treatment. However, the ash contents of the treated rations were slightly higher than those of the control.

NaOH treatment significantly (<0.05) improved CF digestibility, unlike kurkedi which had no effect. However, in general, NaOH treatment tended to improve the digestibility of all the proximate components. This resulted in an increased TDN content of the NaOH-treated straw. Both NaOH and kurkedi rations increased feed intake, gain and efficiency of feed conversion. NaOH and kurkedi treatments had no effects on palatability of the rations. In conclusion, both NaOH and kurkedi improved animal performance beyond that obtained from untreated sorghum straw, which provided only sheep maintenance requirements.

2. Physical treatment (grinding and pelleting)

The grinding of fibrous materials increases the surface area exposed to microbial attack and accelerates the rate of flow of digesta through the gastro-intestinal tract. This results in a higher intake, up to 30% more (Kay, 1972). Pelleting increases feed intake and improves feed/gain, although the actual mode of action is not fully understood.

Due to the difficulties encountered in chemical treatment of byproducts (high cost of chemical, manual-labour and hazards), and the lack of pronounced animal response, grinding and pelleting (physical treatment) were tried as possible means of improving the feeding value of agricultural byproducts in the Sudan. Bagasse was selected for pelleting and was fed as the basal diet at three levels: 30%, 40% and 50% of the ration DM (rations also contained urea and molasses). Bagasse was fed either as pellets or in ground (unpelleted) form. The main objective was to study the effects of pelleting on digestibility and performance and assess the optimal level of bagasse for fattening sheep. Ration composition, digestibility and animal performance are summarized in Table 6. Pelleting improved palatability, DM intake and digestibility of all proximate components (except CF) at all levels of bagasse. Pelleting also remarkably improved daily gain and the efficiency of feed conversion. The daily gain in sheep fed pelleted bagasse at 50% was as good as the gain among those fed unpelleted bagasse at 30%. Without pelleting, bagasse at 50% provided only maintenance requirements. The overall improvement in feed efficiency at all levels of bagasse ranged from 45% to 100%. Pelleting improved feed intake by more than 20% at all levels of bagasse. Pelleting was more effective than NaOH (previous trial) in improving the nutritive value of agricultural byproducts.

CONCLUSION

Constraints on the use of AIBP as ruminant feeds in the Sudan include transportation, bulkiness and poor nutritive value. This research has clearly demonstrated that supplementation of AIBP by NPN (urea and poultry manure) and energy (molasses) may successfully rectify protein and energy deficiencies.

Table 6. Effects of variable levels of bagasse and pelleting on nutrient digestibility and animal performance.

Ingredient % DM basis	Bagasse 30%	Bagasse 40%	Bagasse 50%
Bagasse	30	40	50
Molasses	8	8	8
Sorghum grains	20	20	20
Cotton seed cake	20	15	15
Wheat bran	20	15	5
Urea	1.5	1.5	1.5
Common salt	0.5	0.5	0.5
Total	100	100	100

	Level of bagasse (% DM basis)					
	30		40		50	
Physical treatment:	Pelleted	Unpelleted	Pelleted	Unpelleted	Pelleted	Unpelleted
Proximate analysis (% DM)						
OM	91.5	91.9	91.0	90.0	90.0	88.5
CP	13.9	13.7	11.3	11.0	9.7	9.5
CF	19.0	21.1	21.2	21.8	21.8	25.3
Ash	8.55	8.02	9	9.59	10	11.5
Digestibility coefficients (%)						
OM	62.4	57	55.4	54.1	53.0	52.5
CP	69.5	66.6	73.6	59	61.7	67.4
CF*	31	43.7	26.8	40.9	27.5	41.6
% TDN	60.6	55.6	53.2	51.1	45.7	48.3
Animal performance						
DM intake (g/day)	1412.3	1175.1	1204.8	1012.8	1261.5	948.1
Daily gain (g)	122.68	54.8	78.22	46.54	71.23	1.1
Feed/gain	11.5	21.4	15.4	21.7	17.7	861.9
Cost/kg (LS)	0.22	0.17	0.2	0.15	0.19	0.14

* Significant reduction in CF-digestibility due to pelleting.

The optimum level of byproduct incorporation in fattening rations of sheep and beef in the Sudan should not exceed 30%. However, for maintenance purposes AIBP can form up to 50% of the ration.

Physical treatment of AIBP proved to be more useful in improving the nutritive value of AIBP and was economically more feasible than chemical treatment.

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PREDICTION OF NUTRITIVE VALUE OF SOME CROP RESIDUES AND AGRO-INDUSTRIAL BYPRODUCTS FROM THEIR CHEMICAL ANALYSIS

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INTRODUCTION

Natural pastures and crop residues, together with agro-industrial byproducts, constitute the principal feed resource in Senegal. An inventory of byproducts was prepared in 1979 by Mongodin and Tascher and various aspects of their use have been discussed by Sall (1985), Mbaye (1982) and Sansoucy and Emery (1982).

Some results obtained in Senegal are summarised in this paper, although they are limited to results concerning groundnut and cotton seed hulls offered alone or in association with more concentrated byproducts such as groundnut cake, cotton seed cake, wheat, rice or maize bran, brewers' dried grain and molasses.

OBJECTIVES

Studies have been concerned with the chemical analysis, voluntary intake by sheep, dry matter digestibility (DMD) organic matter digestibility (OMD) and nitrogen (crude protein) digestibility (CPD) of byproducts.

The results have allowed us to establish preliminary equations relating intake and nutritive value of various feeds to their chemical analysis.

MATERIAL AND METHODS

About 90 digestibility trials have been carried out of which 10 were on cattle. Standard methods were used: in vivo and in vitro (Tilley et Terry) digestibility; determination of crude fibre (Weende); total nitrogen and ash content.

The results were submitted to "step wise" regression analysis, permitting either simple linear or multiple equations to be derived.

RESULTS

Feed value of groundnut hulls and cotton seed hulls offered alone (Table 1)

Groundnut hulls and cotton seed hulls are characterized by a high fibre content, averaging 540-550 g/kg DM. Cotton seed hulls were however, more digestible; DMD was found to be 40% when fed alone and 44% when fed with a mineral supplement.

Table 1. Feed value of groundnut hulls and cotton seed hulls offered alone to sheep.

No. of trials	Description	Intake (g/kg DM)			%		g/kg		FU	$g/kgW^{0.75}$	
		DM	CF	CP	DMD	OMD	DOM	DCP	Energy	DMI	DOMI
3	Groundnut hulls	966	547	115*	26	27	912	41	0.05	47	13
2	Cottonseed hulls	963	547	60	40	41	400	-	0.29	42	17

* The high nitrogen content was caused by presence of kernel residues and skins.

Groundnut hulls had a DMD of only 26%. However dry matter intake of groundnut hulls was higher: 47 g DM/$W^{0.75}$ against 42 g DM/$W^{0.75}$ for cottonseed hulls which had a higher content of digestible crude protein (40 g per kg DM). This difference was due to the presence of kernel residues and skin debris in the groundnut hulls.

In energy terms, cotton seed hulls contained 0.29 FU per kg, and groundnut hulls only 0.05 FU per kg. The much higher protein content of groundnut hulls (115 g/kg) compared with cottonseed hulls (60 g/kg,) was due to the inclusion of kernel and skin debris in the former. DCP contents differed even more, 41 g/kg versus nil.

Nutritive value of supplemented groundnut hulls and cotton seed hulls

A series of trials was carried out with cattle and sheep using supplemented rations based on groundnut hulls or cotton seed hulls. The groundnut hull incorporation rate varied from 22 to 70%; for cotton seed hulls from 25 to 90%.

The ingestibility (DMI) of rations consisting essentially of groundnut hulls reached 125 g DM/kg $W^{0.75}$ at an incorporation rate of 38.5%. At the equivalent incorporation rate (37%), rations based on cotton seed hulls recorded DMI values of up to 94 g DM/kg $W^{0.75}$. This ingestibility varied with the content of crude fibre of which the optimum content for maximal ingestion was found to be 320 g per kg (Graph 1). This relationship has not been verified with groundnut hulls.

Compounded feeds based on cotton seed hulls were more digestible (59%) than those based on groundnut hulls (47%). Wheat bran and maize bran, mixed with groundnut hull rations were higher in digestibility (DMD between 46 and 55%) and energy content (0.46 to 0.61 FU/kg). Molasses and brewers' grains improved the voluntary intake (107 g DM/kg $W^{0.75}$).

Groundnut cake combined with molasses gave diets with the highest digestible crude protein content (121 g per kg DM) (Tables 2 and 3).

Cotton seed hull rations were lower in DCP content for a particular supplementation but were higher in digestible organic matter and energy content. However, voluntary dry matter intakes of groundnut hull rations were higher despite the relatively low dry matter digestibility.

In the case of intensive animal production systems, where the objective is high production, rations based on cotton seed hulls would be advisable, because of their rather higher DOM intake (46 compared with 44g/kg $W^{0.75}$).

Graph I. Intake evolution of cottonseed hull rations in terms of their crude fiber rates

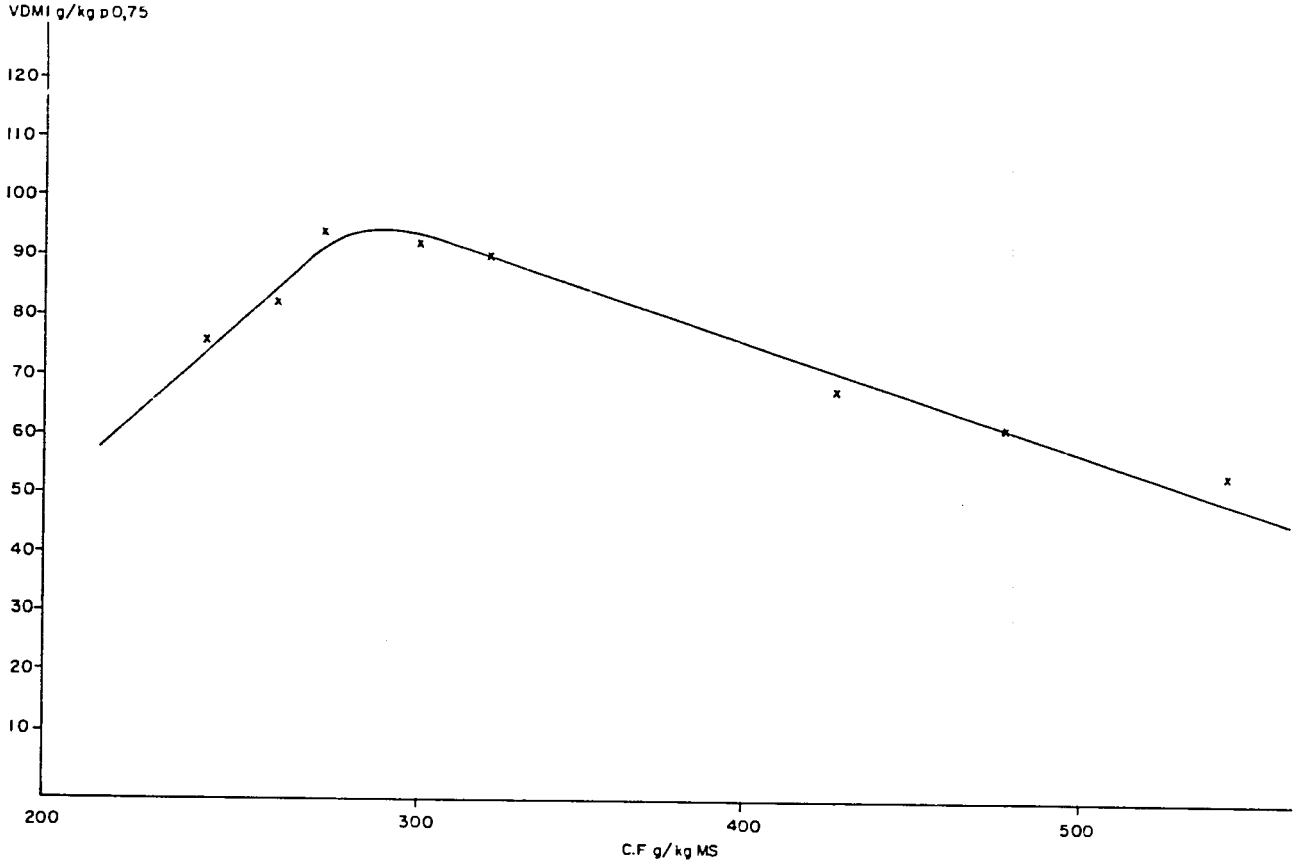

Table 2. Feed value of groundnut hull rations complemented by agro-industrial by-products.

No. of Trials	Principal concentrated feed in the ration	Intake (g/kg DM)			p.100		g/kg DM		UF	g/kgW$^{0.75}$	
		DM	CF	TNM	DMD	OMD	DOM	DNM	Energy	DMI	DOMI
4	Maize bran	955	3[illegible]5	104	55	56	543	52	0.60	93	93
11	Wheat bran	925	373	110	45	47	411	62	0.46	83	39
7	Brewers' dried grain + molasses	927	313	134	45	46	425	75	0.46	107	49
3	Groundnut cake + molasses	924	390	149	41	42	388	121	0.26	83	34

Table 3. Feed value of cottonseed hull rations complemented by agro-industrial by-products.

No. of trials	Rations description	Intake (g/kg DM)			p.100		g/kg DM		UF	g/kg W$^{0.75}$	
		DM	CF	TNM	DMD	OMD	DOM	DNM	Energy	DMI	DOMI
1	Cottonseed hulls 90 · cottonseed cake 10	965	475	123	54	55	532	61	0.53	93	37
1	Cottonseed hulls 82 · cottonseed cake 10 · molasses 8	936	547	84	63	62	580	34	0.63	61	38
2	Cottonseed hulls 37 · molasses 15 · wheat bran 30 cottonseed cake 6 · granicalcium 2 · salt 1	921	327	96	58	59	542	46	0.58	94	54
2	Cottonseed hull 25 · wheat bran 27.5 · ground sorghum 25 · groundnut cake 4 · carbonate of lime	947	282	118	61	63	528	21	0.66	83	52

Prediction of the nutritive value of rations of groundnut hulls complemented with agro-industrial byproducts from their chemical composition

Parameters used for deriving prediction equations from Dakar data are shown in Table 4. The established equations were simple (Table 5) or multiple (Table 6).

Simple equations, i.e., $y = ax + b$, were less precise, as shown in the correlation coefficients and standard errors, but they were easier to apply.

Dry matter and organic matter digestibilities and also the energy value of the rations were negatively influenced by crude fibre content. Food consumption was related similarly to the groundnut hull incorporation rate.

The most precise relationship was that between total crude protein content (x) and digestible crude protein content (y):

$$y = 0.91\ x - 45.39;\ r = 0.95;\ n = 30.$$

Clearly these results do not include all cases likely to be encountered. However, the results obtained can be used as a working basis for future applications, particularly for field workers who do not have adequate access to means of analysis or to bibliographic facilities to allow them to reach a quick decision.

CONCLUSION

Groundnut hulls and cotton seed hulls were included in a series of byproducts studied over several years in Senegal. Our interest in these two byproducts arose in the first place because they were produced near the cities and secondly because they constitute a good raw material to which to add concentrated feeds. They should find ready application in milk production and animal fattening enterprises, perhaps a more profitable use than burning them as industrial fuel in factories.

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Table 4. Equations variables for nutritive value prediction of combined groundnut hull rations.

Diges-tibility classi-fication	Independent variables												Dependent variables						
	GH %	Mol %	WB %	Ref %	Intake p.1000 of DM				Faeces p.1000 DM				DMD	OMD	DOM	DCP	FU (Leroy)	DMI	DOMI
					OM	CP	CF	NFE	OM	NM	CF	NFE							
63	100	0	0	53	964	119	459	354	954	84	625	229	26	27	259	57	0.02	47	12
64	100	0	0	38	974	84	626	223	936	75	642	200	25	28	276	28	0.07	55	15
66	100	0	0	33	970	73	561	172	970	78	561	171	38	39	383	27	-0.41	50	19
67	100	0	0	52	972	97	560	264	965	74	670	206	27	28	269	43	0.08	45	12
68	-	-	0	47	962	112	539	284	934	76	661	179	-	-	152	46	-0.21	51	8
69	-	-	0	37	975	99	538	297	943	76	672	187	21	23	226	36	-0.01	61	14
70	100	0	0	42	969	96	575	265	961	74	677	195	22	22	215	38	-0.06	54	12
80	100	0	0	47	964	135	625	148	948	124	754	131	-	-	109	23	-	43	3
81	100	0	0	28	953	117	650	148	954	112	699	122	34	34	327	43	0.16	63	21
82	100	0	0	34	955	124	653	131	953	122	661	125	-	-	111	37	-0.26	55	6
84	100	0	0	40	991	136	609	231	932	113	666	127	24	29	284	51	0.01	63	18
85	100	0	0	26	953	130	627	148	933	110	686	114	28	30	282	51	0.09	56	16
86	70	0	0	26	973	110	249	552	914	134	360	381	67	69	668	66	0.89	85	57
87	70	0	0	24	951	101	366	421	925	117	543	226	48	49	470	40	0.48	95	45
88	50	0	0	40	976	95	313	512	929	106	459	327	48	51	498	40	0.52	54	27
89	50	0	0	26	945	106	358	436	940	102	329	473	55	56	526	61	0.57	99	52
90	50	0	50	48	945	88	278	521	921	80	514	295	30	32	304	32	0.06	55	17
91	70	0	30	41	963	86	362	481	950	65	615	250	40	41	395	48	-0.06	68	27
130	73	0	25	38	934	101	457	340	933	58	654	201	28	28	261	59	0.03	64	17
131	73	0	25	29	829	100	448	261	687	73	564	234	30	42	348	49	0.16	68	24
120	38.5	0	30	35	924	127	297	472	924	127	297	472	43	44	408	69	0.29	92	38
121	38.5	0	30	26	926	97	316	489	889	112	489	273	52	54	502	43	0.48	125	63
143	60	0	38	35	945	148	459	311	909	114	381	387	41	43	409	81	0.29	57	23
235	40	12	45	11	915	139	341	405	892	99	502	264	43	44	408	82	0.21	97	40
292	30	0	49.5	23	940	114	317	480	911	104	586	207	50	52	489	62	0.47	105	51
220	30	0	47	7	926	122	273	498	905	96	431	349	52	54	496	77	0.48	113	56
228	30	0	47	12	916	129	251	499	886	98	488	278	53	55	504	83	0.42	73	37
285a	22.5	20	0	22	916	132	265	436	909	107	439	342	45	46	419	74	0.45	110	46
285b	22.5	20	0	25	915	131	264	440	909	107	439	342	46	47	428	74	0.46	107	46
291	22.5	20	0	19	938	139	364	361	911	116	439	323	46	47	442	76	0.46	102	45
308	28	10	0	16	908	228	367	286	895	95	607	181	36	37	336	168	0.17	85	28
314	35	12	0	10	940	133	359	364	940	133	359	364	44	45	424	76	0.46	71	30
319	58	10	0	22	919	207	390	296	919	207	390	296	44	44	409	155	0.31	84	34
320	68	10	0	25	929	143	486	272	904	91	614	187	38	40	368	87	0.21	79	29

Table 5. Simple prediction equations for nutritive value of groundnut hull rations complemented with agro-industrial byproducts.

Dependant variables (y)	Independant variables	Regression equations	Standard error of estimate	Correlation coefficient	Data number
DMD (p.100)	CF (g/kg DM)	y = - 0.06 x + 66.00	7.35	- 0.75	30
DMD (p.100)	CF (g/kg DM)	y = - 0.06 x + 67.21	7.60	- 0.74	30
FU (/kg DM	CF (g/kg DM)	y = - 0.001 x + 0.810	0.19	- 0.68	30
DCP (g/kg DM)	CP (g/kg DM)	y = 0.91 x - 45.39	10.19	0.95	30
DMI (g/kg DM)	Groundnut hull (p.100 of the ration)	y = 0.61 x + 113.88	15.13	- 0.75	30
		y = - 0.38 x + 65.86	10.81	- 0.71	30
DOMI (g/kg DM)	" "	y = - 0.38 x + 65.86	10.81	- 0.71	30

Table 6. Multiple regression equations for predicting nutritive value of groundnut hull rations complemented with agro-industrial byproducts.

Nutritive value (dependant variable)	Multiple regression equation	Standard error of estimate	Multiple correlation coefficient	Data number
DMD	1) 0.06 NFE - 0.07 NFEF - 0.08 CFF - 0.17 Ref + 68.13	4.72	0.92	30
	2) 0.04 FU - 0.03 CFF + 0.10 CP - 0.37 Ref - 17.06	5.68	0.88	30
	3) 0.06 CF - 0.11 OM - 0.41 Ref - 31.50	6.11	0.85	30
	4) 0.04 CF - 0.04 CFF + 75.29	6.82	0.80	30
DMD	1) 0.06 NFE - 0.06 NFEF - 0.09 CFF - 93.96	4.87	0.91	30
	2) 0.03 CF - 0.03 CFF - 0.45 mol - 0.35 Ref + 84.73	5.80	0.87	30
	3) 0.04 CF - 0.04 CFF + 76.32	6.83	0.79	30
DOM	1) 0.66 NFE - 0.79 NFEF - 0.91 CFF - 1.20 GH - 2.18 Ref + 83.99	44.92	0.81	30
	2) 0.31 CF - 0.36 CFF + 710.46	67.17	0.77	30
DCP	1) 0.88 NM - 0.44 CF - 24.49	8.50	0.97	30
FU	1) 0.0001 NFE + 0.38 NMF - 0.638	0.15	0.82	30
	2) 0.001 CF + 0.003 NMF + 0.400	0.17	0.76	30
DMI	1) 0.44 GH - 0.58 Ref + 121.25	15.13	0.79	30
DOMI	1) 0.06 NFE - 0.58 Ref + 20.16	7.70	0.87	30

USE OF INFIC NOMENCLATURE ON CROP RESIDUES AND BYPRODUCTS PRODUCED IN KENYA

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INTRODUCTION

The accelerated increase in human population in many developing countries and especially in Kenya (currently estimated at 3.9% per annum) has created a high pressure on agricultural land. In many cases land that is set aside for livestock production is getting smaller. For example, it is estimated that the per capita land availability in high and medium potential areas of Kenya is currently 0.51 hectares, in comparison with 0.64 hectares in 1979 (Said, 1980). Unfavourable land-to-human and land-to-animal ratios call for changes in livestock feeding systems. One such development has been the use of crop residues and byproducts for animal feeding - the mandate of the African Research Network for Agricultural Byproducts (ARNAB) and the theme of this workshop.

Agro-industrial byproducts have been used as livestock feeds since time immemorial. However, scientific studies on systematic utilization of such products started only at the turn of this century. Since then work has concentrated on the quantification and utilization by livestock of the available agricultural byproducts (Owen, 1976; Jackson, 1978; Kategile, 1981; Kategile et al, 1981; Said, 1982; Kayongo-Male and Kategile, 1984). One of the problems existing between various countries and researchers is the use of different local names in describing crop residues and agro-industrial byproducts. For example, maize bran and germ meal produced in rural areas by a pestle and mortar is called madeya in Malawi, pumba in Tanzania and wishwa on the Kenyan coast.

It is our contention that there is a need for the developing countries to describe feed crop residues and byproducts in such a manner that they will be understood internationally, in line with the International Systems for describing and naming feeds given by Harris et al (1980). In North America, such a need was realized and cooperating International Network of Feed Information Centers (INFIC) were established. The network assigns internationally acceptable names and numbers to some of the feedstuffs which are used for reference by research workers in different parts of the world. This paper discusses a study undertaken to identify and assign INFIC names and numbers to some of the common agro-industrial byproducts produced in Kenya.

METHODOLOGY

Materials

The crop residues and byproducts used were divided into two categories: farm crop residues and industrial byproducts. The main farm crop residues included were cereal straws of wheat, barley, oats, rice, the stovers of maize and sorghum and the haulms of beans, peas and groundnuts. Also included in this category were sweet potato vines, sugar-cane tops and banana stems, leaves and peelings.

The industrial byproducts included major groups such as the wastes of sisal, coffee, pineapple and sugar-cane, rice polishings, brans of cereal grains, cakes from oil seeds and nuts, brewers' wastes and pyrethrum marc. There were also some home extracted wastes such as chicha from coconut and wishwa (maize bran and germ meal).

Sampling and chemical analyses

Samples were collected from different parts of Kenya using the techniques for inventory as given by Kayongo-Male and Kategile (1984). For each sample, careful field notes were taken which included location, origin, physical description (part of the plant, stage of maturity, structure, texture, etc.) and processing technique. The samples were then analysed for moisture, ash, crude protein and fibre content according to AOAC (1980) to facilitate identification and assignment to the INFIC system.

Assignment of INFIC nomenclature

Assignment was based on the International Feed Description outlined by Harris et al (1980). The methodology stresses the importance of considering the six facets described in detail in the INFIC publication quoted. Briefly, the facets used are:

Facet 1 - Original material or origin (plant, animal, other basic material);

Facet 2 - Parts of the material used as feed as affected by processes;

Facet 3 - Processes or treatments to which the material has been subjected;

Facet 4 - Stage of maturity;

Facet 5 - Cutting or crop (for plants only);

Facet 6 - Grade (quality) for those feeds that do not fall within the descriptors describable in facets 1 to 5. For this facet descriptors used are expressed in terms of "more than" (minimum),"less than" (maximum) and "from to" of designated contents of crude fibre, protein, fat, etc.

Assignment of the INFIC international number was adopted from the INFIC tables which take into consideration the eight feed classes given by Harris et al (1980).

Results of the study

For some of the samples, the physical descriptors using facets 1 to 5 were sufficient to enable the assignment of the INFIC description and numbers. These samples are given in Tables 1a, 1b, and 1c.

Table 1a. Samples assigned INFIC descriptions and numbers using physical descriptors only (Facets 1-5).

Name and species	International feed number	International feed description	Local name
Banana			
Musa spp.	2-12-851	Stems, fresh	Banana stems
	2-09-902	Leaves, fresh	Banana leaves
	4-26-158	Peelings, fresh	Banana peelings
Barley			
Hordeum vulgare	1-00-492	Aerial part, sun-cured, mature	Barley straw
	4-00-521	Chaff and/or dust	Barley cleanings
	4-25-407	Brewer's solubles, wet	Brewer's yeast
Beans			
Phaseolus vulgaris	1-00-598	Straw	Bean haulms
Coffee			
Coffea arabica	1-13-456	Fruit without seeds, sun-dried	Coffee pulp
Cowpea			
Vigna unguiculata	1-01-646	Aerial part without seeds, sun-dried	Cowpea haulms
Cassava			
Manihot esculenta	2-29-060	Browse, fresh	Cassava top vines
	4-11-491	Peelings, fresh	Cassava peelings
Cashew nut			
Anacardium occidentale	4-26-857	Kernels with coats grade inferior	Cashew nut chips
Coconut			
Cocos nucifera	5-30-143	Kernels with coats oil residue, mechanical extracted, caked	Coconut cake/ copra

Table 1b. Samples assigned INFIC descriptions and numbers using physical descriptors only (Facets 1-5).

Name and species	International feed number	International feed description	Local name
Groundnut			
Arachis hypogaea	1-03-623	Aerial part, sun-cured, mature	Groundnut haulms
	5-03-648	Seeds without coats oil residue	
Maize			
Zea mays	4-02-841	Bran	Maize bran
	5-13-768	Bran with germs	Maize bran with germ (wishwa)
	1-08-390	Aerial part, sun-cured, weather damaged	Maize stover
	5-02-896	Germs	Maize germ meal
	1-02-780	Cobs, dehydrated, coarse ground	Maize cobs
	4-09-754	Chaff and/or dust	Maize waste
	5-14-649	Brewer's grain, dehydrated	Maize cleanings
Oats			
Avena sativa	1-03-305	Chaff	Oat cleanings
	1-03-285	Straw	Oat straw
Pigeon pea			
Cajanus cajan	2-13-914	Aerial part, fresh, mature	Pigeon pea vines
Pineapple			
Ananas comosus	3-26-968	Process residue, wet	Pineapple waste
Rape seed			
Brassica napus	5-15-410	Seeds, oil residues, solvent extracted	Rapeseed meal
Rice			
Oryza sativa	1-12-328	Aerial part, without heads, sun-cured, mature	Rice straw
Sorghum			
Sorghum bicolor	1-11-596	Bran	Sorghum bran
	1-0-302	Aerial part without heads and sun-cured	Sorghum stover

Table 1c. Samples assigned INFIC descriptions and numbers using physical descriptors only (Facets 1-5).

Name and species	International feed number	International feed description	Local name
Soybean			
Glycine max	5-04-600	Seeds oil residue, mechanical extracted, ground	Soybean meal
Sugar-cane			
Saccarum officinarum	2-04-692	Top aerial part with leaves, fresh	Sugar-cane tops
	4-14-454	Molasses, condensed	Molasses
	1-04-689	Bagasse, dehydrated or sun-cured	Bagasse
Sunflower			
Helianthus spp.	1-24-573	Seed heads without seeds, sun-cured	Sunflower heads
	5-30-146	Seeds without hulls, oil residue, mechanical extracted, caked	Sunflower cake
Sweet potato			
Ipomea batatas	2-10-522	Aerial part, fresh, mature	Potato vines
	4-10-515	Peelings, fresh	Potato peelings
Wheat			
Triticum aestivum	4-05-190	Bran, dry milled	Wheat bran
	1-20-823	Aerial part, sun-cured, dough stage	Wheat straw
	1-23-823	Chaff and/or dust	Wheat cleanings

Table 2 lists the samples whose assignment to INFIC nomenclature was based on both the physical descriptions (facets 1 to 5) and also chemical descriptions (facet 6) such as moisture, crude protein, crude fibre and ash content.

Table 3 lists those samples that do not exist in the INFIC data bank but were described using INFIC guidelines, style and country names. Descriptions of their physical forms have been included. If a byproduct is not exactly described in the INFIC data bank write to INFIC Type I member (see Appendix 1) providing the description and the descriptors of the feedstuffs and their chemical compositions.

DISCUSSION

The results given in Tables 1, 2 and 3 cover a small fraction of the number of crop residues and industrial byproducts that are available within the regions in which some of the ARNAB participants work. It is conceivable that in some cases

Table 2. Samples assigned INFIC descriptors and numbers using physical and chemical descriptors (Facets 1-6).

Name and species	International feed number	International feed description	Local name
Cotton Gossypium spp.	5-10-623	Seed oil residue, mechanical extracted, caked, 36% protein	Cottonseed cake
Rice Oryza sativa	4-26-201	Bran, more than 12% fibre	Rice bran
Wheat Triticum aestivum	4-05-205	Flour byproduct less than 9.5% fibre	Wheat middlings
	4-06-753	Flour byproduct less than 15% fibre	Wheat pollard

Table 3. Samples not in the INFIC data bank.

Name and species	Description	Local name
Coconut Cocos nucifera	Kernels without coats, oil residue, physical extracted, fresh	Coconut chicha
Finer millet Eleusine coracana	Aerial part without heads and sun-cured	Millet stover
	Bran	Millet bran
Lupine Lupinus spp.	Seeds without coats, oil residue, mechanical extracted, ground	Lupine seed meal
Pyrethrum Chrysanthemum cinerariae folium	Flowers, dry, ground, solvent extracted for pyrethrin	Pyrethrum marc
Sisal Agave cisalana	Leaves, mature sisal, fibre, mechanical extracted	Sisal waste
Sunflower Helianthus spp.	Chaff and/or dust	Sunflower waste

different scientists may be working on similar or very similar feeds but using different country names. An example has been given in this paper of a byproduct used in Malawi, Tanzania and Kenya under three different names. Harris et al (1980) advocates an international system for describing and naming feeds in order to describe and define them in concise, understandable terms for technical communication within and between various languages. There will also be the advantages of enhancing communication of information on feed composition and quality in national and international trade, and the adaptation of feed information to a coding system compatible with computer software.

It is apparent from Tables 1 and 2 that, in general, facets 1 to 5 were enough to describe the crop residues studied and that for processed agricultural byproducts facet 6 is necessary. There were, however, some "grey areas" in using the INFIC system which need some care. Situations where a percent figure given for a particular nutrient matches but other percent nutrients are different, pose a problem in adopting the INFIC system. Descriptions which are not absolutely specific may pose some problems, for example, when descriptors "green" or "brittle" are used it becomes difficult to describe the shades of "green" or the degree of "brittleness". However, in spite of these shortcomings, the INFIC system remains appealing for its many advantages and this paper advocates consideration for its adoptation by ARNAB workers and in ARNAB newsletters.

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APPENDIX I

INFIC Type 1 members

Australian Feeds Information Centre
Commonwealth Scientific & Industrial Research Organization (CSIRO)
P. O. Box 239
Sydney, N. S. W. 2148
Australia

Director: Dr T F Leche

Dokumentationsstelle der Universitaet Hohenheim
Paracelsusstrasse 2
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Director: Dr H Haendler

International Feedstuffs Institute (IFI)
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UREA VERSUS AMMONIA FOR UPGRADING GRAMINACEOUS MATERIALS

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SUMMARY

Urea is a safe and cheap chemical, frequently assumed to be the equal of anhydrous or aqueous ammonia for upgrading cereal straws in the warmer regions of the world.

This assumption was tested with moist grass hays, whole crop wheat and barley straws in the temperate climate of the United Kingdom, the chemicals being compared at equal nitrogen applications. In each study urea was found to be inferior to anhydrous or aqueous ammonia for improving dry matter digestibility and also, where examined, voluntary feed intake in sheep.

Laboratory studies showed that one possible reason for this was the formation of ammonium 'carbonate' (i.e., ammonium carbamate/bicarbonate) through the reaction of ammonia and carbon dioxide in a confined space at temperatures of about 20° C. This corroborated findings of ammonium 'carbonate' crystals in a silo of whole crop wheat ineffectively treated with ammonia.

It was concluded that at low ambient temperatures the carbon dioxide released by the hydrolysis of urea is detrimental to the efficiency of the upgrading process.

INTRODUCTION

There is considerable interest in the use of urea as a precursor of ammonia for the upgrading of cereal straw (Kiangi et al, 1981; Saadullah et al, 1981). Indeed, in this context, this safe and cheap chemical is frequently assumed to be the equal of anhydrous or aqueous ammonia when hydrolysis conditions are optimal.

Sheep studies

This assumption has been examined in three sheep digestibility trials at our institutes. In one, moist crops of mature perennial ryegrass (Lolium perenne) and tall fescue (Festuca arundinacea) hays were treated and stored for 2 months with 6% urea or 3.5% ammonia (DM basis) to elucidate their preservation and upgrading potentials, relative to those of field or barn-dried material (Tetlow et al, 1983/4). These hays were fed ad libitum to growing animals supplemented with a soybean

meal/commercial vitamin-mineral mixture at a rate of 0.15% of L.W. In the second study (Deschard, 1983) whole crops of winter wheat (Maris Huntsman) were ensiled untreated, or following treatment with respectively 6% urea, 3.5% anhydrous ammonia, 7% ammonium hydroxide or 5% sodium hydroxide. After storage for 60 days, they were fed with 20 g vitamin-mineral mixture to growing sheep, urea being hand-mixed with the NaOH-treated silage to correct a possible deficiency in rumen degradable nitrogen. The final trial (Sherwood, 1985) involved diets of barley straw (ad libitum) and concentrates (restricted), the straw being fed: (a) untreated (chopped); (b) following ensilage with 7% urea at ambient temperatures (-2 to 5° C) for 11 weeks (chopped); (c) following ensilage with 7% urea at 25° C for 11 weeks (chopped); (d) following immersion (bales dipped) in a solution containing 32 g urea per litre for 45 minutes, with subsequent aerobic storage at -2 to 5° C for 4 weeks (fed in long form); or, (e) following ammoniation (baled form) in a sealed polythene sheeted stack (80 g NH_4OH/kg straw DM) for 11 weeks at -2 to 5° C (fed in chopped form).

As shown in Table 1, our studies indicate that in the temperate climate of Great Britain the efficiency of upgrading urea is somewhat inferior to that achieved with ammonia, irrespective of the type of crop and the conditions employed. Other work has shown that treatment with anhydrous or aqueous ammonia may itself be sub-optimal when applied to moist crops stored under plastic sheeting on commercial farms (Ibbotson et al, 1984).

In vitro studies

The reasons for these variations in response are probably several, but at least in our studies the inferiority of urea relative to ammonia was not caused by inefficient hydrolysis, though the rate of ammonia release is still poorly defined.

A clue to one possible factor was provided by a recent experiment, designed to compare sodium hydroxide, urea and ammonia as additives for the conservation and upgrading of whole-crop winter wheat harvested at a dry matter content of 580-740 g/kg (Deschard et al, 1984). It was intended to apply the ammonia to the moist crop in a clamp silo via perforated plastic tubing placed in its base. In the event, the ammonia was trapped by moisture in the immediate proximity of the pipe and the untreated material proceeded to ferment in a conventional manner. When the silo was opened, the surface of the silage was found to be covered with crystals of ammonium 'carbonate' (ie carbamate/bicarbonate).

Since urea is hydrolysed to ammonia and carbon dioxide and since the latter gas accumulates in sealed stacks of moist straws these observations suggested that the inferiority of urea treatments and certain commercial ammonia treatments could be due to reaction of ammonia with carbon dioxide to form ammonium 'carbonate'. To test this theory, the following experiment was devised: samples (15g) of grass hay (860 g DM/kg) were placed in Kilner jars and treated with (A) 0, (B) 15, (C) 30 or (D) 45 g CO_2/kg hay DM followed by 35 g NH_3/kg DM at 20° C. For treatment (E), hay was exposed to 35 g NH_3/kg DM produced in situ by mixing

Table 1. Upgrading of mature crops for sheep.

Crop type	Moisture content %	Treatment	DMD* %	DDMI* g/kg LW	Author
Perennial ryegrass hay	15	Field-dried	54	8.4	Tetlow et al 1983/4
" " "	16	Barn-dried	56	9.4	
" " "	19	Field-dried (3.5% NH3)	62	14.1	
" " "	36	Ensiled (6% urea)	62	13.1	
" " "	36	Ensiled (3.5% NH3)	68	16.7	
Tall fescue hay	14	Field-dried	54	9.2	Tetlow et al 1983/4
" " "	15	Barn-dried	55	9.1	
" " "	19	Field-dried (3.5% NH3)	62	13.7	
" " "	34	Ensiled (6% urea)	60	12.2	
" " "	33	Ensiled (3.5% NH3)	65	17.2	
Whole crop wheat	62	Ensiled (untreated)	55	9.1	Deschard 1983
" " "	58	Ensiled (6% urea)	63	10.8	
" " "	55	Ensiled (3.5% NH3)	65	12.8	
" " "	63	Ensiled (7% NH4OH)	65	13.0	
" " "	60	Ensiled (5% NaOH)	68	15.0	
Barley straw-concs. (75:25)+	15	Untreated	54	10.8	Sherwood 1985
" " (72:28)	50	Ensiled (7% urea) 1.5oC	60	10.8	
" " (76:24)	50	Ensiled (7% urea) 25oC	63	13.2	
" " (76:24)	70	Dip (7% urea) 1.5oC	58	12.2	
" " (80:20)	50	Stack (8% NH4OH) 1.5oC	62	15.3	

* Data uncorrected for residues of added chemicals.
\+ Ratio of barley straw: concentrates (DM basis).

CaO (70 g/kg DM) and ammonium 'carbonate' ($NH_4HCO_3.NH_2COONH_4$, 31% NH_3; 110 g/kg DM) with water (120 g/kg DM) in a vial within the Kilner jar, the CO_2 being trapped as calcium 'carbonate'. Treatment (F) was untreated hay stored in a Kilner jar (Mason et al, 1985). All treatments were of 5 weeks duration.

The main results are given in Table 2. Hays (A) and (E) darkened within a few minutes of treatment, but with (B), (C) and (D) the colour change was progressively less intense. Ammonium 'carbonate' crystals appeared on the jars in treatments (C) and (D) after a few days, but started to disappear towards the end of the storage period. In vitro organic matter digestibility (OMD) and cell wall degradability by 'cellulase' (Wd) were assessed after 5 weeks. Relative to the untreated hay, treatments (A) to (E) improved OMD by 142, 112, 91, 74 and 156 g/kg and Wd by 207, 112, 76, 74 and 202 g/kg. These results suggest that carbon dioxide can reduce the efficiency of ammoniation through the formation of ammonium 'carbonate'.

Table 2. Effect of CO_2 on efficiency of upgrading hay by ammoniation.

	Treatment						
	(A)	(B)	(C)	(D)	(E)	(F)	SED
CO_2 (g/kg hay DM)	0	15	30	45	45*	0	
NH_3 (g/kg hay DM)	35	35	35	35	35*	0	
OMD (g/kg)	713	683	662	645	727	571	7.0
CWD (cellulase) (g/kg)	424	329	293	291	419	217	13.6

* $(NH_4)2CO_3$ - CO_2 absorbed by quicklime.
Source: Mason et al, 1985.

CONCLUSION

The stability of ammonium 'carbonate' is greatest at low ambient temperatures. Consequently, in the UK and other temperate zones one would expect the efficiency of upgrading with urea to be poorest with treatments applied during the damp, cool months of autumn and winter, when microbial activity is also minimal. In the tropics, however, where higher ambient temperatures stimulate microbial activity on the untreated crop, urea may be exploited for both its preservative properties (Pahlow, 1979) and its potential for upgrading (Sherwood, Table 1). Even so, wherever economic and technical conditions permit its effective use, best results are likely to be obtained with anhydrous or aqueous ammonia. Alternatively, hydrolysed urea may be exploited by treatment with quicklime to trap the carbon dioxide.

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THE NEW AGRI-AM PROCESS FOR AMMONIATION: STACK-AMMONIATION OF MATURE FORAGES USING AMMONIUM SALTS

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SUMMARY

In many regions of the world access to anhydrous or aqueous ammonia is limited and attempts to employ urea as a precursor for upgrading purposes have often produced disappointing results.

To alleviate this situation an attempt was made to exploit the ammonia in both volatile and stable ammonium salts, reacting these compounds with a stoichiometric excess of quicklime or slaked lime in the presence or absence of added water in laboratory studies. Because of their instability, ammonium 'carbonate' (ie. carbamate/bicarbonate) and ammonium bicarbonate effectively upgraded straws when heated with the straw in Kilner jars in the absence of lime, with or without added water, at 90°C for 15 h. Ammonium sulphate, in contrast, produced a similar response only when heated with quicklime or slaked lime in the presence of water. When these treatments were conducted at 20°C for 35 days the volatile salts and the ammonium sulphate were only effective when treated with lime and water.

The findings for mixtures of ammonium 'carbonate' or sulphate wih quicklime and water were then corroborated in sheep studies, using stack treatments of grass hay. Further work with cattle confirmed the effectivity of the ammonium sulphate-quicklime mixture in the stack technique.

It was concluded that these processes can provide a means of ammoniation for farm treatments, and it is suggested that the composition of the chemical residue can be manipulated through choice of salts and alkalis to provide a mineral supplement for animal feeds or a fertilizer for soil improvement.

INTRODUCTION

The process of ammoniation is widely used to increase the digestibility of organic matter and the nitrogen content of cereal and grass straws (Sundstol and Coxworth, 1984). Unfortunately, in many regions of the world access to anhydrous or aqueous ammonia is limited and attempts to employ urea as a precursor of ammonia for upgrading purposes have often produced disappointing results (Mason and Owen, 1985).

A potential source of ammonia, currently unexploited, is that available in ammonium fertilizers and other ammonium salts. Some of these chemicals are volatile, but ammonia can be released from the more stable compounds by reaction with a stoichiometric excess of such alkalis as quicklime, slaked lime or caustic soda. The objective of the present work was to examine the feasibility of exploiting this principle to upgrade mature forages by the oven and stack methods.

In vitro studies

In a preliminary study, a factorial experiment was designed to compare five sources of ammonia (aqueous ammonia, anhydrous ammonia, ammonium 'carbonate' (i.e., a mixture of carbamate and bicarbonate), ammonium bicarbonate and ammonium sulphate) under laboratory conditions. For this, samples of chopped barley straw (cv Sonja) were treated in Kilner jars with ammonia (35 g/kg straw DM) released from these chemicals by volatilization and/or by reaction with a stoichiometric excess of quicklime or slaked lime in the presence or absence of added water. In all cases the chemicals and added water were placed or mixed in a small glass vial within the Kilner jar, so that only gases or water vapour could come into direct contact with the straw. Half the jars for all treatments were then stored at 20°C for 5 weeks simulating a stack treatment, the remainder being held at 90°C for 15 h to simulate an oven treatment.

Tables 1 and 2 present estimates of in vitro organic matter digestibility for processes occurring in the absence or presence of added water, respectively. In the absence of water, heating the volatile salts to 90°C for 15 h gave improvements in digestibility which were similar or slightly inferior to those obtained with the positive ammonia controls, but under these conditions ammonium sulphate treatment gave little or no improvement. In contrast, at 20°C prolonged storage of straw in the presence of the potentially volatile salts gave responses which were no more effective than those achieved with ammonium sulphate. Furthermore, the results achieved with anhydrous ammonia (not reported in Table 1) tended to be inferior to those obtained with aqueous ammonia. The effect of lime was inconsistent.

Table 1. Upgrading barley straw using different ammonia sources* (no added water) (OMD in vitro: g/kg).

			NH_3 source			
		No NH_3	Aq.NH_3	$(NH_4)2CO_3$ a	NH_4HCO_3 b	$(NH_4)2SO_4$
90°C 15 h	-	329	432	376	411	303
	CaO	364	458	408	401	324
	$Ca(OH)_2$	319	432	435	420	349
20°C 35 d	-	315	433	339	338	322
	CaO	325	426	349	323	325
	$Ca(OH)_2$	301	455	379	362	350

* Rates: per kg straw DM: 0 g H_2O; 35 g NH_3; 0, 70 g CaO or 92.5 g $Ca(OH)_2$.
a. $(NH_4)2CO_3$ ≡ carbamate/bicarbonate mixture.
b. Lime and water rates doubled.
SED = 23.5.

Table 2. Upgrading barley straw (cv. Sonja) using different ammonia sources* (water added) (OMD in vitro: g/kg).

			NH_3 source			
		No NH_3	Aq.NH_3	$(NH_4)2CO_3$a	NH_4HCO_3b	$(NH_4)2SO_4$
90°C	-	283	442	467	418	327
15 h	CaO	294	427	450	453	438
	$Ca(OH)_2$	296	434	449	443	442
20°C	-	311	440	374	362	344
35 d	CaO	332	479	431	453	464
	$Ca(OH)_2$	324	466	406	478	473

* Rates: per kg straw DM: 120 g H_2O; 35 g NH_3; 0, 70 g CaO or 92.5 g $Ca(OH)_2$.
a. $(NH_4)2CO_3$ ≙ carbamate/bicarbonate mixture.
b. Lime anmd water rates doubled.
SED = 23.5.

In the presence of added water (Table 2), the situation changed, ammonium sulphate giving efficient upgrading when mixed with quicklime or slaked lime and kept under simulated stack or oven conditions. Moreover, at 20°C the 'carbonate' and bicarbonate treatments gave satisfactory improvements when lime was included in the process. Anhydrous ammonia and aqueous ammonia gave similar responses under these conditions. The results clearly indicate the potential use of both volatile and non-volatile ammonium salts for upgrading straw.

Sheep studies

These principles were also examined in in vivo digestibility studies with sheep and cattle. For the sheep trials (Table 3), baled perennial ryegrass hay (cv Cropper) of medium quality (1.5% N) was chopped and fed, untreated, or subsequent to ammoniation by one of four techniques. In the first, 440 kg hay DM were treated with anhydrous ammonia (35 g NH_3/kg hay DM : 90°C for 15 h) in a purpose-built, insulatd An-Stra-Verter oven, the ammonia being provided from an external pressure tank (conventional oven technique). The second approach used the same oven, but an attempt was made to produce the ammonia in situ by treating a mixture of 58.6 kg fertilizer grade ammonium sulphate and 33 kg quicklime with 60 kg water in a trough, placed in the bottom of the oven prior to heating (experimental oven technique). The third and fourth techniques were stack methods in which similar principles were applied to treat 465 kg hay DM with ammonia (35 g/kg DM). In these, dry mixtures of 63 kg ammonium sulphate fertilizer and 33 kg quicklime or 44 kg ammonium 'carbonate' (i.e., 310 g NH_3/kg DM) and 33 kg quicklime were treated with 60 and 50 kg water, respectively, in metal troughs placed close to the stack under the plastic sheeting. With both stack methods ammoniation proceeded at ambient temperature over 8 weeks during July and August, 1984. The hays were then fed ad libitum to sheep in a conventional digestibility-intake study.

As shown in Table 3, the two stack methods improved the

Table 3. Upgrading perennial ryegrass (cv Cropper) hay by ammoniation for sheep.*

Method:	Untreated	Oven-NH_3	Oven-NH_3	Stack-NH_3	Stack-NH_3	
N-Source:	-	Anh.NH_3	$(NH_4)2SO_4$	$(NH_4)2CO_3$+	$(NH_4)2SO_4$	SED
OMD, g/kg	636	690	619	671	680	10.0
OMI, g/kg LW	18.4	22.4	18.9	21.2	20.2	1.14
DOMI, g/kg LW	11.7	15.5	11.7	14.2	13.8	0.69
N retn. g/d	0.93	3.75	1.52	3.67	3.77	0.56

* All animals received supplement containing 1.4 g soybean meal, 0.5 g min/vit mix and 0.1 g Na2SO4 kg/LW.

+ Ammonium carbamate/bicarbonate mixture.

digestibility of organic matter almost as efficiently as did the conventional oven-ammonia method. However, intakes for these treatments by sheep were inferior to those for the conventional oven method though superior to those for the control. In contrast, the experimental oven technique gave poor results.

Cattle studies

For the cattle studies (Table 4), baled winter barley straw was fed untreated, or subsequent to upgrading by one of three techniques. In the first, 500 g straw DM were treated with anhydrous ammonia (35 g/kg DM) by the conventional An-Stra-Verter oven method, discussed above. The second was a stack method similar to those used in the sheep studies, but differing by treating a mixture of 66 kg ammonium sulphate fertilizer and 35 kg quicklime with 60 kg water to generate maximally 17 kg ammonia to upgrade 500 kg straw DM. In the third approach, straw was treated with sodium hydroxide (50 g/kg straw DM) using a J F Straw Processor, and then ensiled. The digestibility trial involved four British Friesian steers (c. 248 kg LW) tethered in individual standings. These were given each of the four straws (2.8 kg/d) according to a randomised latin square sequence, each fed together with rolled barley (1.8 kg/d) and fishmeal (0.2 kg/d) in diets designed to satisfy 1.3 times the maintenance energy requirement. The untreated and NaOH-treated straw diets were further supplemented with 40 g urea/d to equalize the nitrogen intake. Water was available at all times. Each trial consisted of a 21 day preliminary and a 5 day collection period.

Table 4 shows that in this experiment, where intakes were standardized, the stack method gave an improvement in digestibility which was very similar to that achieved with the conventional ammonia oven method. In the case of organic matter, this improvement was also close to that obtained with the J F ensilage system. In view of the high content of concentrate feeds in these diets, the improvements achieved were satisfactory.

Table 4. Upgrading winter barley straw (cv. Igri) for cattle.*

Method:	Untreated	Oven-NH_3	Stack-NH_3	Silo-JF	
Chemical:	-a	Anh.NH_3	$(NH_4)2SO_4$	NaOHa	SED
OMD, g/kg	668	725	722	730	7.4
DMD, g/kg	639	669	670	705	10.9

* Ration: 2.8 kg straw, 1.8 kg rolled barley, 0.2 kg fishmeal (1.3 x M).
a. Supplement: 40 g urea.

CONCLUSIONS

In general, these experiments demonstrate that ammonium salts, including fertilizers, can be used as a source of ammonia for upgrading. The troughs used as reaction vessels in the stack

treatments were rather inefficient since they provided no means for mixing the residues subsequent to the addition of water. This meant that ammonia produced in the base of each trough had difficulty in escaping to the surface of the residue. Clearly, the question of the structure of a simple reaction vessel which will permit the free movement of ammonia remains to be solved, as does the optimal ratio of chemical mixture to water.

A promising feature of this approach is that different ammonium salts (including urea hydrolysates) and alkalis may be used to generate ammonia and they may also be used in complex combinations. We have successfully tested a mixture of ammonium sulphate, di-ammonium hydrogen orthophosphate, quicklime and sodium hydroxide for this purpose in laboratory studies. Thus, the efficiency and rate of ammonia release can be altered, and the composition of the residue may be changed so that the latter can ultimately serve as a mineral supplement or lick for animals or as a fertilizer for soils. This may be used to reduce the effective cost of the ammonia treatment.

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BYPRODUCT UTILIZATION IN RUMINANT DIETS IN CYPRUS

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SUMMARY

Research work on crop residues and agro-industrial byproducts included surveys to evaluate and determine the quality and seasonality of production, quantity in relation to animal numbers and location, chemical composition of each byproduct, nutritive value, and the response of animals to diets containing various proportions of byproducts.

Experiments were carried out with dehydrated or ensiled citrus pulp, grape marc and poultry litter. Dehydration maintains the quality of byproducts high in moisture and sterilizes poultry litter. Ensiling was used as an alternative method because of the high cost of fossil fuel for dehydration. Ensiling killed pathogens present in poultry litter and silages made of citrus pulp and poultry litter or grape marc and poultry litter were used to replace part of the concentrate mixture of the basic diets of growing heifers and dairy cows.

Cereal straw is an important source of roughage but its nutritive value is very low. Straw intake and quality were improved when straw diets were supplemented with nitrogen and energy sources (soybean, or urea and barley grain). Alkali treatment using NaOH, $Ca(OH)_2$ in combination with urea also improved the quality of straw. However, the most promising method of improving the quality of straw seems to be ammoniation using a urea solution.

INTRODUCTION

In Cyprus, as in many other Middle East countries, low roughage production is the main constraint in ruminant production (Economides, 1985). As a result, large quantities of concentrate feeds are imported to meet the increasing demand of an expanding livestock industry. The use of locally produced feedstuffs, crop residues and agro-industrial byproducts (e.g., cereal straw, citrus pulp, grape marc and poultry litter) to replace these concentrate feeds is of great importance and was studied in our programme as a matter of high priority.

The objectives of this study were:

* To identify, quantify and describe the seasonal availability and alternative uses of all locally available ruminant feedstuffs;

* To determine the nutritive value and voluntary intake of these feedstuffs and to evaluate their use in ruminant

diets;

To identify where byproducts are produced and to relate this information to the numbers and types of animals.

MATERIALS AND METHODS

The following is a brief description of a series of experiments:

1. Experiments with dehydrated citrus pulp, grape marc and poultry litter

Dehydrated citrus pulp or grape marc were used in two separate trials to replace 20% of barley grain on an equal weight basis in dairy rations (Economides, 1974).

The use of poultry litter as a ruminant feedstuff has been studied extensively (Bhattacharya and Taylor, 1975). It can be used as a ruminant feedstuff provided it contains no pathogens, drugs or other medicants. Furthermore, high levels of minerals such as Cu should be withdrawn from poultry rations if the waste is to be used as ruminant feed. Early work in Cyprus on the use of dehydrated poultry litter in ruminant diets has been reviewed (Hadjipanayiotou, 1984). Poultry litter has been used in experiments with growing heifers, lactating goats and ewes, fattening kids and fattening calves to replace up to 30% of conventional concentrate mixtures.

2. Experiments with ensiled poultry litter, citrus pulp and grape marc

In view of the high cost of sterlizing poultry litter with the dry heat processing method, Harmon et al (1975) proposed the ensiling process in order to destroy existing pathogens.

Poultry litter was screened, using a 20 mm metal grid to remove caked material, and was ground in a hammer mill before being ensiled, alone, or in a mixture with straw, weeds and grapefruit peels, in small silos for laboratory investigations.

The effect of ensiled poultry litter with either grape marc (PLGM) or citrus pulp (PLCP) was studied in four experiments (Economides and Hadjipanayiotou, unpublished) with growing heifers and lactating cows (1 kg of a conventional concentrate mixture was replaced by 2 kg of PLGN or 4 kg of PLCP). The silages were prepared in earthen pits and the ingredients were added layer after layer.

One part of poultry litter (approx. 75% DM) was used for every four parts of citrus pulp (18.3% DM) or two parts of grape marc (50% DM). Some characteristics of the silages are presented in Table 1.

Table 1. Composition, acid content and pH of silages prepared from poultry litter mixed with either grape marc (PLGM) or citrus pulp (PLCP).

	PLGM	PLCP
Dry matter (%)	49.8	23.4
Crude protein (%)	18.9	14.2
Ash (%)	10.2	8.3
pH	5.04	3.73
Free acetic acid (%)	0.32	0.91
Bound acetic acid (%)	3.50	3.35
Lactic acid (%)	0.72	1.72
Butyric acid (%)	Nil	Nil

3. Experiments with cereal straw

The most important byproduct in Cyprus, cereal straw, constitues 75% of the presently utilized byproducts for ruminant feeding (Economides, 1984). Cereal straw in the long (baled) or chopped form is used extensively in all ruminant diets and all production systems in varying proportions with concentrates. The nutritive value of straw, however, is low, with low nitrogen content being the major factor limiting its intake (Elliot and Topps, 1963; Fick et al, 1973).

4. Supplementation of straw with nitrogen and energy

The importance of adaquate nitrogen intake in relation to energy intake on the performance of sheep has been extensively studied (Orskov, 1977; Kempton and Leng, 1980). Studies were carried out to determine the effect on the feed intake and performance of fattening lambs of a basal diet of oaten chaff, glucose and urea, supplemented with fishmeal and/or an infusion of glucose in the abomasum. Furthermore, the effect of supplementing straw with soybean meal (150 g/head/day) or a molasses-urea mixture (0.3-0.5 kg/head/day) was studied. Supplementing straw with nitrogen source and/or energy (Economides et al, 1981) significantly increased straw intake by mature Chios ewes (Table 2). Dry matter intake was increased by 19, 22 and 31% when straw was fed ad libitum in conjunction with barley grain alone (250 g/day), urea and barley grain (10 g urea and 240 g barley grain) and soybean meal (80 g) and barley grain (170 g), compared to the unsupplemented straw. Digestibility coefficients for DM, OM and CP of the total diet were significantly lower for the unsupplemented straw diet (Table 2). Barley grain alone, and urea and soybean supplementation increased the daily energy intake of the unsupplemented straw diet by 111, 144 and 152%, respectively.

Sheep fed the urea or soybean meal supplemented diets consumed adequate nitrogen to meet maintenance requirements whereas nitrogen intake was inadequate on the other two diets. Supplementing straw with barley grain only, increased straw intake and improved the energy balance of sheep, but nitrogen intake was very small.

Table 2. Effect of straw supplementation with nitrogen and energy on the performance of Chios sheep.

	Diets			
	Straw	Straw + soya + barley grain	Straw + urea + barley grain	Straw + barley grain
Intake (kg DM)	0.68	1.12	1.03	1.05
Digestibility (%)				
Organic matter	42	57	53	53
Gross energy	37	54	55	49
Crude protein	0	47	52	13
Energy intake (MJ/day)	3.75	9.45	9.20	7.90
Protein intake	0	51	53	7
Cost of supplementation US $/day	-	0.041	0.030	0.026

5. Experiments with urea treated straw

Treatment of low quality roughages with NH_3 has been recommended (Sundstol et al, 1979). The merit of NH_3 over NaOH is possibly that it is safer, although more unpleasant, to handle and also adds non-protein nitrogen to the straw. However, treatment of straw with urea to generate NH_3 has been proposed (Jackson 1978). Urea is more pleasant than NH_3, is less hazardous to handle and requires no pressure tanks for storage and transportation. The effect of ammoniation using urea on the intake and nutritive value of chopped barley straw was studied in two separate trials (Hadjipanayiotou, 1982). The straw was treated with a 10% urea solution at the rate of 400l/t straw and stored in sealed containers for 1, 15, 30, 45 and 60 days.

RESULTS AND DISCUSSION

As shown in Table 1, neither milk yield nor liveweight changes were affected by feeding 20% citrus pulp when the diets were isonitrogenous. However, cows fed grape marc produced less milk and gained less liveweight, indicating a lower energy value of grape marc compared with barley grain.

The in vitro digestible organic matter in the dry matter ("D" value) was 0.39, 0.43, 0.47 and 0.74 for poultry litter, straw, weeds and grapefruit peels respectively. The calculated digestible energy content of poultry litter, straw, weeds and grapefruit peel was 7.2, 7.9, 7.8 and 14.60 MJ/kg DM respectively. Addition of poultry litter at ensiling resulted in significant increases in nitrogen and ash content of the original material. All initial mixtures were positive for the pathogen Protaus but it was destroyed after ensiling.

The rate of growth of heifers fed PLCP silage was similar to that of heifers on the control diet (36 vs 33 kg). Dairy cows fed the PLCP silage (with calculated energy content of 11.6 MJ/kg DM) or the control diet produced similar milk yields, milk fat

content and liveweight changes.

Heifers fed PLGM silage (calculated energy content 7.1 MJ/kg DM) gained less liveweight (30 vs 39 kg) than heifers on the control diet. Dairy cows fed the PLGM silage or the control diet produced similar milk yields but cows fed PLGM produced milk with higher fat content (3.39 vs 2.52%) and lost 3 kg, while cows on the control diet gained 24 kg.

No pathogens were isolated in the poultry litter. Crude fibre content in both silages was high because poultry litter had been collected from a broiler house with sawdust bedding.

Voluntary intake, digestibility and intakes of energy and protein were considerably lower with straw compared with either barley or lucerne hays (Table 3). Intake of dry matter was respectively 12.9 and 31% higher for lucerne and barley hays than for straw. Crude protein content and the digestibilities of protein and organic matter were highest for lucerne hay and lowest for cereal straw (Economides et al, 1981). Its energy content was 5.5 MJ ME/kg DM and the intake of ME by sheep was 3.75 MJ/day, less than half the energy requirements of a 60 kg sheep (Economides, 1981) and zero protein intake.

Table 3. Protein content, intake and digestibility of straw, barley hay and lucerne hay.

	Barley straw	Barley hay	Lucerne hay
Crude protein (%)	3.6	11	24.3
Dry matter intake (kg/ewe/day)	0.68	0.89	1.55
Digestible protein intake (g/ewe/day)	0	45	320
Digestibility (%)			
Organic matter	42	60	67
Crude protein	0	46	35

In vitro digestibility reached maximum 45 days (Table 4) post-treatment, though the change in digestibility from 30 to 45 days was not significant. The overall increase in digestibility of treated straw over the untreated was 11 percentage units. Of the originally added N, 44% was retained in the straw and free NH3-N accounted for 31% of the retained N. NH3-N increased as the total N decreased with ensiling time.

Table 4. In vitro digestibility of DM, D- value, total N and NH_3-N concentration in the dry matter of treated and untreated straw.

	Untreated straw	Ensiling period (days)				
		1	15	30	45	60
DM digestibility	0.46	0.46	0.50	0.56	0.58	0.58
D- value	0.42	0.42	0.45	0.51	0.54	0.54
Total N (g/kg DM)	5.0	23.0	20.0	14.0	14.3	12.3
NH3-N (g/kg DM)	0.5	1.0	2.0	4.0	4.7	4.5

The voluntary intake and in vivo crude fibre and dry matter digestibilities of urea treated straw, fed alone, increased by 47, 40 and 20% respectively, compared with untreated straw (Table 5). The digestibility of the total diets was similar when either treated or untreated straw formed 20% of the diets. The digestible energy value of treated straw increased by 20%.

Table 5. Voluntary intake, digestibility, digestible energy concentration, crude protein retention and absorption, ruminal NH_3-N concentration and pH of the four straw diets.

	Diets			
	US	TS	US+C	TS+C
Voluntary straw intake (kg DM)	0.45	0.80	-	-
Digestibility (%)				
Dry matter	42	53	73	74
Organic matter	44	55	74	76
Crude fibre	52	73	49	59
Crude protein	0	34	73	73
Gross energy	40	48	74	76
Digestible energy (MJ/kg DM)	7.34	8.80	14.76	15.08
Crude protein (g/day)				
absorbed	negative	20.3	106.0	115.0
retained	negative	negative	47.0	44.0

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REQUIRED MINERALS FOR THE IMPROVEMENT OF POOR QUALITY ROUGHAGES

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SUMMARY

There are two main adjustments usually practised during the manufacturing of feeds for ruminants. The first one is the addition of 2% calcium carbonate to bring the Ca/P ratio within its proper range (2:1). The second is the addition of 1% sodium chloride to compensate for the Na deficiency in most ingredients.

Analysis of roughages and mineral balance trials conducted using these ingredients showed some interesting phenomena: (a) roughages (contrary to cereal grains and protein meals) are richer in Ca and relatively poor in P (on average the ratio is 7.5:1). Thus roughage-based diets must be supplemented with P rather than Ca; (b) roughages need less supplementation with sodium chloride as the Na/K ratio in roughages is 1:3 compared with 1:10 in cereal grains/protein meals; (c) there are considerable differences in mineral patterns and in availability of roughages brought from different localities.

INTRODUCTION

Improvement of the nutritive value of crop residues and by-products could be approached through:

* Getting rid of the barrier coating the plant cells which prevents the utilization of its digestible nutrients (e.g., by alkali or acid treatments);

* Supplementing the residue/byproduct with the deficient nutrient(s). This may be done by introducing a legume or supplements rich in protein, non-protein nitrogen, vitamin A and/or minerals.

This paper discusses the mineral mixtures which are appropriate for the supplementation of fibrous residues and by-products when these are processed in a feed mill. Application of these mineral mixtures are designed to be within the molasses portion along with urea and vitamin A.

DIFFERENCES IN MINERAL CONTENT BETWEEN LOW AND HIGH FIBRE FEEDS

Rice straw, maize stalks and horsebean straw contain more Ca and less P than cereal grains and protein meals. A similar trend was observed, but to a lesser extent, in Na and K (Table 1).

Table 1. Comparison between some mineral contents (%) of concentrates and roughages.

Concentrates			Roughages		
Ca	P	Ratio	Ca	P	Ratio
0.16	0.63	1:4	2.24	0.30	7.5:1
Na	K	Ratio	Na	K	Ratio
0.14	1.44	1:10	0.39	1.17	1:2.9
Ingredients			Ingredients		
Cottonseed cake Linseed cake Peanut cake Corn Wheat bran Maize bran			Corn stalks Rice straw Horsebean straw		

This draws attention to the fact that the traditional inclusion of 2% Ca-carbonate should not be applied to roughage-based diets which need, rather, the addition of a phosphorus source. Also, the normal allowance of 1% sodium chloride may be reduced by 50% for roughage diets.

RECOGNITION OF MINERAL DEFICIENCIES

The mineral content of the same ingredient was found to vary considerably over the country (Table 2).

Balance trials showed that roughages may contain high percentages of a certain mineral yet the animal is in negative balance when fed such a diet. It is speculated that this reflects the unavailability of the mineral irrespective of its high concentration in the feed.

The availability of minerals in roughages was tested *in vitro*. The ground sample was incubated for 12 hours in water (simulating the neutral pH in the rumen) and then, after centrifugation, the mineral fraction was estimated in the supernatent. The sediment was then incubated at pH 2 (simulating the conditions in the abomasum). The acid soluble mineral fraction was also estimated in the supernatent. Finally, the sediment was incubated for 12 hours at alkaline pH (8.2) simulating conditions in the small intestine. The sum of water, acid and alkaline soluble mineral fractions, expressed as a percentage of the initial mineral content, was considered to be an indicator of availability (Table 2).

A comparison between the available amounts of mineral consumed voluntarily in the roughage feed, and the standard requirements of the animal, indicates the gap which needs to be filled by the supplement (Table 3).

Table 2. Average percentages of differences in the content and availability of roughage ingredients from six governorates.

Mineral	Ingredient	Average difference (%) between governorates	
		Content	Availability
Ca	Rice straw	334	63
	Corn stalks	182	78
	Horsebean straw	286	55
P	Rice straw	1850	38
	Corn stalks	138	21
	Horsebean straw	185	8
Fe	Rice straw	398	42
	Corn stalks	744	60
	Horsebean straw	1517	28
Na	Rice straw	218	87
	Corn stalks	819	67
	Horsebean straw	519	33
K	Rice straw	281	31
	Corn stalks	152	45
	Horsebean straw	721	9

Table 3. Suggested formula of mineral mixture to supplement poor quality byproducts.

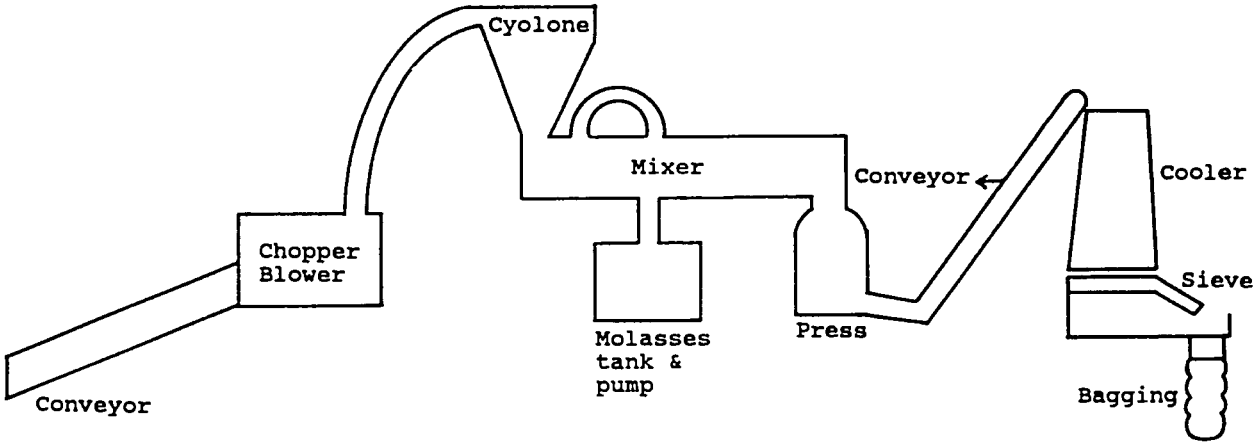
Mineral	Kg to be added per tonne (DM basis)
P	3.0
Na	0.5
Fe	0.5
Mg	0.6
Zn	0.1
Mn	0.1
Cu	0.1
Co	0.01

The homogeneous distribution of the supplement in the roughage requires some form of mechanical mixing. The chopped roughage can be sprayed with heated molasses (to 35-40°C) in which urea, vitamin A and minerals are dissolved, or mixed with a stirrer, and pumped from the molasses tank to the mixer (Figure 1).

The final product should be offered to lactating animals as a meal; the pelleted form is more suited for fattening animals.

There are indications that a specific mineral mixture should be formulated for each location and for different physiological functions (e.g., pregnant, lactating, dry, fattening, growing and young animals).

Figure 1. Components of the roughage manufacturing plant.



UTILIZATION OF RICE STRAW ON SMALL FARMS IN EGYPT

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SUMMARY

This study was undertaken to improve the feeding value and quality of rice straw by adding molasses or molasses and urea, or ensiling with urea or sodium hydroxide (5% NaOH) with or without supplementation using a concentrate mixture. Four rams were used in the digestibility trials.

The results show that the feed intake of rice straw when fed alone was very poor but it increased significantly with the addition of 5% molasses. Addition of urea and molasses enhanced feed intake more than the addition of molasses alone. The values were 2.17, 1.43 and 1.13% of the bodyweight of the animals respectively.

The digestion coefficients of DM, OM, CP, EE and NFE were also significantly increased by addition of molasses and urea. An even better improvement in the digestion coefficients was achieved by ensiling rice straw with either urea (5%) or NaOH (5%).

The feeding values (on DM basis) in terms of TDN % were respectively 38.7, 39.7, 44.3, 56.3, 60.2, 49.0 and 55.9 for straw (untreated), treated with molasses, treated with molasses and urea, ensiled with urea, ensiled with urea and mixed with concentrate mixture, ensiled with NaOH, or ensiled with NaOH and mixed with concentrate mixture. DCP was very low with rice straw, with or without molasses (0.07%), and was improved by the addition of 2% to 3.77% urea and greatly improved if ensiled with or without supplementation with a concentrate mixture. The percentage improvements in the TDN % over the control (rice straw alone) were 2.6, 14.5, 45.5, 55.7, 26.7, 44.6% for straw (untreated) with molasses, molasses and urea, ensiled with urea, ensiled with urea and supplemented with concentrates, ensiled with NaOH and ensiled with NaOH and supplemented with concentrates respectively. The cost of one tonne of TDN from rice straw alone was about LE 97.25 and for the different treatments costs were LE 96.65, 92.32, 79.36, 85.29, 107.96 and 102.43 LE, respectively. This indicates that ensiling rice straw with urea greatly increases its feeding value and decreases the cost of one tonne of TDN, even compared with rice straw alone.

Ensiling rice straw with urea can be recommended as a suitable method for the treatment of rice straw on small-scale farms in Egypt.

INTRODUCTION

Millions of tonnes of lignocellosic material are going to waste every year in Egypt. Most of it collects as unavoidable by-products around industrial sites (sugar mills, wineries, canning factories, etc) or comes from cereal production and foliage residues. These materials are of low digestibility to ruminants and have a low nitrogen content. Consequently, they have a low animal production potential. Straws are a poor livestock feed. Rice straw is no exception. It contains about 80% potentially digestible substances and is therefore a source of energy. However, its actual digestibility by ruminants is only 45 to 50%. Furthermore, the amount the animal can eat is limited to less than 2% of bodyweight because of the slow rate at which it is fermented in the rumen (Jackson, 1978). Methods for chemically treating straw have been known for a long time (Jackson, 1978). Of the chemicals used, sodium hydroxide is neither cheap nor easy to obtain in Egypt at the present time. Known methods of ammonia application are technically not feasible under small farm conditions owing to poor roads and the difficulty of obtaining polyethylene.

Oji and Mowat (1979, personal communication) have found that urea can be broken down to ammonia in maize stover containing 55 to 65% dry matter. Gadre (1979) showed a 71% increase in the intake of digestible dry matter in wheat straw treated with 4% urea for 1 month in a small cement silo when fed to growing crossbred heifers. In Egypt, urea is available to all farmers and is used as a fertilizer. It is cheaper than sodium hydroxide (126 and 250 LE/t respectively).

The present work was carried out to study the effect that rice straw ensiled with urea or sodim hydroxide would have on the feeding value of straw-containing diets for sheep.

MATERIALS AND METHODS

Preparation of the ensiled rice straw

Rice straw was chopped with a J.F. machine to a length of 5-10 cm and then divided into three equal portions. The first was kept in dry form and the second ensiled, after the addition of 5% urea in water, with the moisture content being raised to 65%. The third portion was sprayed with 5% caustic soda and ensiled after adding water to raise the moisture content of the silage to 65%. Plastic sheets were used to cover the bottom and the top of the trench cement silos. After one month the silage was mixed with 5% molasses if the rice straw had been ensiled with urea, or with 5% molasses and 2% urea if the rice straw had been ensiled with NaOH or left without treatment.

Digestibility trials

Four mature cross-bred Rahmany rams of c. 60 kg liveweight were used in the digestibility trials. The animals were fed the following diets:

1. Rice straw alone;

2. Rice straw plus 5% molasses;
3. Rice straw plus 5% molasses and 2% urea;
4. Rice straw ensiled with 5% urea and supplemented with 5% molasses before feeding;
5. Rice straw ensiled with 5% urea and supplemented with 5% molasses plus a limited amount of concentrate mixture (0.380 kg/head/day) before feeding;
6. Rice straw ensiled with 5% sodium hydroxide and supplemented with 5% molasses and 2% urea before feeding;
7. Rice straw ensiled with 5% sodium hydroxide and supplemented with 5% molasses and 2% urea plus a limited amount of concentrate mixture (0.380 kg/head/day) before feeding.

All the feeds were mixed with 1% calcium carbonate, 1% common salt, 0.1% trace elements and 0.1% vitamin mixture before feeding. The animals were kept in individual pens and were fed the treated or untreated rice straw ad libitum. Water was available at all times. Each digestibility trial consisted of a 21-day preliminary period followed by a 7-day collection of total faeces and urine. Samples of feeds and faeces were analysed for the proximate composition using the AOAC (1970) method. Statistical analysis was made according to Snedecor (1956).

RESULTS AND DISCUSSION

The chemical analysis of the food ingredients used in the present experiment is shown in Table 1. Rice straw alone contained 3.98% crude protein and the addition of molasses did not increase the protein content. However, the addition of 2% urea increased the protein content to more than 8%. Ensiling rice straw with either urea or sodium hydroxide decreased the crude fibre content relative to that in the untreated rice straw.

Table 1. Chemical analysis of feed ingredients used in the digestibility trials.

	Dry matter %	% of DM				
		CP	EE	Ash	CF	NFE
Rice straw	91.08	3.98	1.36	16.42	34.89	43.35
Rice straw treated with 5% molasses	90.77	3.84	1.09	16.71	32.42	45.94
Rice straw treated with 5% molasses and 2% urea	90	8.62	1.23	16.57	36.37	36.63
Rice straw ensiled with 5% urea plus 5% molasses	68	9.05	1.52	17.73	29.08	42.62
Rice straw ensiled with 5% NaOH plus 5% molasses and 2% urea	72	8.82	0.88	21.60	28.85	39.85
Concentrate mixture	91.40	17.40	3.72	6.95	16.58	55.35

Table 2 shows the effect of the different additives (molasses and/or urea) and treatments (ensiling with urea or NaOH) and supplementation with concentrate mixture on the feed intake, digestibility coefficient and nutritive value of the rice straw. The results show that the intake of rice straw when fed alone was very poor but the addition of 5% molasses significantly increased the feed intake. Addition of urea and molasses enhanced feed intake more than the addition of molasses alone.

The addition of molasses to the rice straw slightly increased the digestibility coefficients for DM, OM, EE and NFE, though the differences were not significant (Table 2). The content of TDN was not improved by the addition of molasses. On the other hand, urea addition significantly increased the digestibility of DM, OM, CP and EE and also improved the nutritive value (DCP % and TDN %). A diet of unsupplemented rice straw is not adequate to maintain animals. They lose weight if no supplementary protein is given (Jackson, 1978) because this material contains less than 4% crude protein and a level of approximately 6% is needed to prevent weight losses. It has been reported that urea treatment of straw increased its digestibility and nitrogen balance (Dolberg et al, 1981). Ensiling the rice straw with either urea or sodium hydroxide in the present study slightly decreased the intake of straw relative to the intake of unensiled supplemented material. However, the differences were not significant. On the other hand, it was found that ensiling the straw significantly increased the digestibility of DM, OM, CP, CF and NFE relative to untreated straw. The nutritive value was greatly improved by ensiling, and ensiling with urea significantly increased the TDN relative to that for straw ensiled with NaOH. Addition of the concentrate mixture to diets containing ensiled rice straw increased the values for DCP % and TDN %.

In Eastern Europe, urea was used in industrial plants for the production of straw pellets about 10 years ago (Bergner et al, 1974). In Bangladesh, Dolberg et al (1981) treated rice straw with 5% urea and ensiled the material for 10-20 days. They found an increase of 8-12 percentage units in organic matter digestibility in vitro. In the present work, the urea treatment increased organic matter digestibility by about 13 percentage units in vivo. These results show a highly significant difference in feed intake of more than 79% between ensiled and untreated rice straw. Gadre (1979) showed a 71% increase in digestible dry matter intake in wheat straw, when the straw was treated with 4% urea for 1 month in a small cement silo and fed to growing crossbred heifers.

The results show that the addition of a limited amount of concentrates (0.380kg/head/day) improved digestibility coefficients and the nutritive value of the diets. However, the differences were not significant. Rice straw ensiled either with urea or NaOH showed significant improvement in nutritive value relative to the untreated rice straw, but there were no significant differences between rice straw ensiled with urea or with NaOH for this parameter.

Oji and Mowat (1979, personal communication) reported that urea can be broken down to ammonia in maize stover containing 55 to 65% dry matter. Abou-Raya et al (1983) reported that boiling

Table 2. Effect of different additions and treatments on the intake, coefficients of digestibility and nutritive value of rice straw.

	Feed No.*						
	1	2	3	4	5	6	7
Feed intake (kg DM/day)							
Rice straw	0.68+.03c	0.86+.05b	1.30+.15a	1.22+.16a	1.07+.13a	1.16+.14a	1.30+.18a
Concentrate mixture	-	-	-	-	0.38+.00	-	0.38+0.0
Digestibility coefficients (%)							
Dry matter	40.88+8.71c	43.52+6.52c	56.81+2.5b	69.17+3.93a	71.64+4.93a	69.97+6.68a	72.55+5.6a
Organic matter	45.05+7.93c	47.63+6.0c	63.44+2.21b	71.80+3.86a	74.72+4.88a	71.43+6.11a	73.99+5.3a
Crude protein	0.29+.12c	0.22+.05d	33.60+7.55b	70.94+6.60a	66.51+6.96a	65.39+6.9a	64.86+4.5a
Ether extract	13.26+3.45d	32.32+3.60c	75.84+5.82b	75.52+3.31b	80.18+3.49ab	84.15+3.0a	80.02+8.87ab
Crude fibre	48.07+3.82c	42.38+2.41d	48.93+9.4c	63.34+4.24b	70.36+5.04a	49.64+7.3c	61.34+8.4b
Nitrogen free extract	49.53+5.1c	54.75+7.0bc	58.63+4.2b	69.58+4.28a	73.30+5.34a	68.31+8.0a	70.20+5.77a
Nutritive value (%)							
Digestible crude protein	.07+.08d	.07+.05d	3.77+.69c	7.83+.59b	10.84+.78a	6.70+.62b	11.56+.56a
Total digestible nutrients	38.66+5.3c	39.68+4.85c	44.28+2.64bc	56.25+2.98a	60.18+4.61a	48.98+4.90b	55.91+4.55ab
% improvement in TDN	-	2.6	14.53	45.50	55.66	26.69	44.62

* See text.

rice straw in water or in 0.1, 0.2 or 1% $Ca(OH)_2$, or spraying the straw with 16% NaOH, significantly increased its nutritive va .

Ensiling straw with 5% urea was not very successful under Norwegian conditions, but when a small amount of soybean meal was added to the treatment as a source of urease, the digestibility of urea treated straw increased. Low temperature (10-15°C) was found to be a limiting factor (Sundstol, 1983). In Egypt, it has been found that the coefficients of digestibility for rice straw treated either by ensiling or with alkali were rather higher than those of untreated material. Furthermore, ensiling rice straw, treated or untreated, caused a clear improvement in its nutritive value (Nabawia et al, 1983). The present results also show that ensiling rice straw greatly improves its nutritive value.

Table 3 shows the cost of the test treatment for rice straw and the governmental concentrate mixture. The results show that ensiling rice straw with urea greatly decreases the cost of one tonne of TDN even when some 25% of the diet was provided in a concentrate mixture (diets 4 and 5).

Finally, the ensilage of rice straw with urea (5%) can be recommended as a suitable method for improving the nutritive value of this material on small scale farms in Egypt. The suggested method uses urea, which is available on all farms, is cheaper and safer to apply than NaOH and increases the N and TDN content of the straw.

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Table 3. Cost of the tested treatments of rice straw.

Diet No.	Cost of feed ingredients (LE)*						Total cost LE/tonne	TDN %	Cost of 1 t TDN
	Rice straw	Concentrate mixture	Molasses	Urea	NaOH	Minerals & vitamins			
1	35	-	-	-	-	2.6	37.60	38.66	97.25
2	35	-	0.75	-	-	2.6	38.35	39.68	96.65
3	35	-	0.75	2.53	-	2.6	40.88	44.28	92.32
4	35	-	0.75	6.30	-	2.6	44.65	56.26	79.36
5	25.90	17.42	0.75	4.66	-	2.6	51.33	60.18	85.29
6	35.0	-	0.75	2.53	12.0	2.6	52.88	48.98	107.96
7	26.95	15.41	0.75	1.94	9.62	2.6	57.27	55.91	102.43

Concentrate mixture

Calculated on the basis of the following prices (LE/ton):

1. Rice straw 35 (including 5 LE/t for chopping)
2. Concentrate mixture 67
3. Molasses 15
4. Urea 126
5. Sodium hydroxide 250
6. Minerals and vitamins (limestone 15; common salt 15; vitamins 2000; minerals 30.)

RICE STRAW IN COMPLETE PELLETED DIETS FOR SHEEP

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SUMMARY

Shortages of feed and increasing feed costs at a time of increasing demand for more animal products have stimulated interest in ways of making effective use of agro-industrial by-products in the diets of ruminants in Egypt.

Chopped rice straw was mixed with the governmental concentrate mixture in a ratio of c. 1:1 and pelleted with or without the addition of 3% urea, 3% urea and 6% molasses, and 2% mineral mixture, with or without previous treatment with 5% NaOH or 4% NaOH plus 2% $Ca(OH)_2$. The sodium hydroxide or sodium hydroxide and calcium hydroxide were sprayed on to the chopped rice straw before grinding and pelleting.

The experimental complete pelleted diets were fed to four mature Rahmany sheep in several digestibility trials and compared with the governmental concentrate mixture alone. The results showed that the voluntary feed intake was significantly increased by including rice straw in the pellets. The values were 1.44 kg/day and 1.73-2.18 kg/day for the concentrate mixture alone and the pelleted diets respectively.

The digestibility coefficients (%) of DM and OM and the feed value (TDN %) were similar when the concentrate mixture was fed alone (diet I) or mixed (1:1) with rice straw (diet II) without any addition. The addition of urea (diet III) compared with no addition (mix II) had no significant effect on OM, EE and NFE digestibilities or the feed value (61.5 and 60.6% TDN respectively); however, the digestible crude protein was significantly increased (12.2 and 9% respectively). The addition of 6% molasses and 2% minerals and vitamins (diet IV) significantly increased the digestibilities of DM, OM, CP, CF and NFE, and also raised the feed value (TDN %) related to diets I, II and III respectively. NaOH (5%) treated straw in mix V did not increase the digestibilities or the feed value relative to the untreated rice straw (diet IV). Treatment of rice straw with 4% NaOH and 2% $Ca(OH)_2$ (diet VI) had a negative response on the digestibilities and feed value compared to diet II.

The cost of one tonne of TDN was calculated as LE 104.2, 109.0, 111.7, 103.6, 114.4 and 129.7 for diets I, II, III, IV, V and VI respectively.

The present results suggest that the pelleting of untreated rice straw with the governmental concentrate mixture and additions of molasses, urea and minerals (diet IV) provides a suitable complete diet for use on large farms in Egypt.

INTRODUCTION

In Egypt, serious shortages of feed hinder improvements in animal production. However, there is an increasing demand for more animal products brought about by increased population growth and improved living standards.

The annual feed requirement of animals in Egypt is estimated to be about 7.56 million t of SV (starch value). There are two distinct feeding periods during the year - winter and summer. During the winter period, which covers 165 days from December to May, berseem is fed and this supplies 4.81 million t of SV (69.1% of that supplied by all feedstuffs). In this period, animals do not require more than 3.47 million t of SV. Consequently, there is a surplus of 1.34 million t from green berseem. During the summer period, which lasts 200 days, animals and poultry require 4.07 million t of SV. The summer feeding stuffs (green forages, straws and concentrates) provide 2.1 million t of SV (Gabra, 1984). Therefore, there is a deficiency of about 1.91 million t of SV. The above data show that there is an unbalanced distribution of nutrients over the year. The animals are overfed in winter and underfed in summer.

More effort should be made to increase the availability of feed in Egypt through the utilization of agro-industrial by-products in ruminant diets. Cereal straw (about 11 million t, El-Saify et al, 1983) is the most widely available of all crop residues, but its value is limited by its inherently low digestibility (35-45%), its limited consumption by animals (less than 2% of the bodyweight) and its slow rate of passage (Jackson, 1978). The net result is a low intake with little or no surplus energy for growth, work or production. Protein supplements increase intake while alkali treatment of straw increases digestibility, and usually voluntary intake as well (Jackson, 1977). On small-scale farms, ensiling rice straw with urea (5%) is the best method of using rice straw (Nour, unpublished data). However, on large-scale farms (feedlots), grinding and pelleting of straw could be the best method of utilization. It is not yet known whether the separate effects of alkali treatment and grinding and pelleting are additive. It seems likely that the high temperature and pressure combination to which treated straw is subjected in the pelleting process enhances the effectiveness of alkali treatment. The industrial processing of straw into pelleted complete diets, containing 60-80% straw, appears to have good prospects in Asia, where large numbers of milk animals are kept in or near cities and feed is transported from the surrounding countryside. Factories for this purpose have already been designed (Rexen and Vestergaard Thomsen, 1976).

The main objective of this research was to study the effect of different treatments of rice straw (with 5% NaOH or with 4% NaOH and 2% $Ca(OH)_2$) together with additions (urea-molasses and mineral mixture) on the feeding value and cost of a complete diet, containing 40-50% rice straw, for sheep.

MATERIALS AND METHODS

Rice straw bales were chopped through a J F machine (straw processor SP 2000). A portion of the chopped straw was sprayed with 5% NaOH (20% solution) as described by Jackson (1977). Another portion of the straw was sprayed with 4% NaOH and 2% $Ca(OH)_2$ in concentrated solution. The treated portions of rice straw were kept for 1 week.

Six pelleted diets were then prepared in the feed mill from components described in Table 1. Four mature Rahmany rams of about 45 kg liveweight were used to estimate coefficients of digestibility, nutritive value and nitrogen balance of these pelleted diets. The animals were kept in individual pens and fed ad libitum. Each trial consisted of a 21-day preliminary period followed by a 7-day collection of total faeces and urine.

Samples of feeds and faeces were analysed for proximate composition using the AOAC (1970) methods. Statistical analyses were made according to Snedecor (1956).

RESULTS AND DISCUSSION

The chemical composition of the tested diets is presented in Table 2. The diets (except the concentrated mixture, diet I) contained between 12 and 14% ash, 3.92 and 5.11% ether extract, 12.4 and 17.6% crude protein, 19.9 and 25.7% crude fibre and 41.5 and 45.8% nitrogen-free extract. The differences in crude protein between the tested diets are due to the effect of urea addition, while the differences in crude fibre are due to alkali treatments in diets V and VI.

Results for dry matter intake, digestibility coefficient and the feeding value of the diets are shown in Table 3. Diets I and II show the differences between the governmental concentrate mixture and the complete ration containing concentrate and rice straw in the ratio of 1:1. Rice straw increased the feed intake of animals from 1.44 to 2.31 kg/head/day respectively. A similar result was reported by White et al (1971). Addition of urea (diet III) or urea/molasses and minerals (diet IV) did not increase the feed intake to the level of diet II. On the other hand, the treatment of rice straw with alkali (diets V and VI) decreased the feed intake relative to the control diet (diet II).

The digestibility coefficients for DM, OM and NFE and the feeding value (DCP % and TDN %) were slightly decreased by substituting rice straw for 50% of the concentrate mixture but the digestibilities of crude protein, ether extract and crude fibre were significantly increased in the complete diet containing 50% rice straw (Table 3). The complete diet contained about 12% crude protein, which is about optimum for maximum protein utilization in ruminants. The concentrate mixture contained more than 17% protein. Consequently, one could expect a higher digestibility of crude protein in the concentrate mixture than in the complete diet. On the other hand, the source of crude fibre in the concentrate mixture was mainly from cotton seed hulls in cottonseed cake. In previous work, Fahmy and El-Shazly (1979) found that the digestibility coefficients for cotton seed hulls were respectively 34.5, 41.8, 40.6, 44.4 and

Table 1. Composition of the complete pelleted diets containing rice straw.

	Diet No.					
	I	II	III	IV	V	VI
Concentrate mixture*	100.0	50.0	50.0	50.0	50.0	50.0
Rice straw+	-	50.0	47.0	40.0	40.0	40.0
Urea	-	-	3.0	3.0	3.0	3.0
Molasses	-	-	-	6.0	6.0	6.0
Minerals and vitamins	-	-	-	2.0	2.0	2.0

* The concentrate mixture contained 42% undecorticated cotton seed meal, 25.5% wheat bran, 5% rice bran, 22% maize, 2% molasses, 2% limestone, 1% sodium chloride, 0.1% Vit. A & D and 0.4% mineral mixture.
+ Rice straw in diet V was previously treated with 5% NaOH and in diet VI with 4.0% NaOH and 2.0% $Ca(OH)_2$.

Table 2. Chemical composition of the experimental pelleted diets.*

Diet No.	Dry matter (%)	% on DM basis				
		CP	EE	Ash	CF	NFE
I Concentrate mixture	91.4	17.4	3.72	6.4	6.6	55.4
II Complete diets	92.3	12.4	4.99	14.0	25.7	42.9
III " "	92.6	15.7	5.09	12.1	21.6	45.6
IV " "	92.0	15.6	5.11	12.5	25.3	41.5
V " "	91.4	15.8	3.92	13.6	20.9	45.8
VI " "	86.9	17.6	4.83	14.8	19.9	43.0

* The chemical analysis of untreated rice straw was 93.0% DM and on % of DM basis the following: 3.93% crude protein, 2.04% ether extract, 16.5% ash, 43.4% crude fibre and 34.1% nitrogen free extract.

Table 3. Coefficients of digestibility and nutritive value of the pelleted diets.

	Complete diets*					
	I	II	III	IV	V	VI
Feed intake (kg/day)	1.44	2.31	2.07	2.18	1.73	1.96
Digestibility coefficient %						
Dry matter	62.4+1.2	60.7+4.7	58.4+1.5	68.9+1.6	69.4+2.5	57.7+1.2
Organic matter	65.1+1.0	63.6+4.1	63.2+1.4	71.8+1.5	71.9+2.4	61.8+1.4
Crude protein	67.5+1.1	72.7+2.8	77.6+0.8	80.5+1.0	79.1+1.9	75.1+0.4
Ether extract	79.9+1.6	94.1+1.8	94.1+1.4	94.6+1.9	93.2+1.4	88.7+3.1
Crude fibre	41.1+2.3	54.2+2.7	49.2+3.1	66.5+2.6	61.0+2.9	42.9+3.1
Nitrogen free extract	70.3+1.0	63.0+5.9	61.4+2.4	69.0+2.0	72.7+2.5	62.1+2.1
Nutritive value %						
Digestible crude protein	11.8+0.1	9.0+0.4	12.2+0.1	12.5+0.2	12.5+0.2	13.4+0.2
Total digestible nutrients	64.3+0.9	60.6+3.4	61.5+1.1	68.7+1.5	66.6+2.1	58.1+1.0

*See table 1 for diet composition.

38.8% for OM, CP, EE, NFE and crude fibre. On the other hand, Fahmy (1985) showed that the digestibility coefficients for rice straw were 63.5, 5.8, 59.3 and 75.2% for OM, EE, NFE and CF respectively. From these results it can be concluded that the digestibility of CF in rice straw is double that in cotton seed hulls and this may explain the higher CF digestibility in the complete diet containing rice straw. The addition of urea to the diet (diet III) did not improve digestibility or feed value expressed as TDN %. However, the addition of urea significantly increased the digestibility of crude protein relative to the unsupplemented diet (diet II). The addition of urea/molasses and minerals and vitamins to the complete diet (diet IV) significantly increased the digestibility of DM, OM, CP, CF and NFE and also the feed value of this diet.

The TDN value of rice straw (40%) was found to be much lower than that of the governmental concentrate mixture (64.3%). However, feed consumption, digestibility and feed value of the diets containing rice straw were not significantly different (Table 3). This means that the presence of rice straw in the diet improved the utilization of feed constituents. A similar result was obtained by Fahmy et al (1968) and Nour and El-Shazly (1980) with rice hulls. The addition of sand to a diet high in concentrates stimulated better utilization of the ration (Gooley and Burroughs, 1962). The relatively high silica in rice straw (in the present experiment) and rice hulls (Fahmy et al, 1968; Nour and El-Shazly, 1980) may have produced a similar effect.

Replacing 50% of the governmental concentrate mixture with rice straw, molasses, urea and minerals produced no significant differences in digestibility and nutritive value, though mean TDN % was higher in the concentrate mixture (diet I) than in the complete diets without molasses, urea, minerals and vitamins (diets II and III).

On the other hand, it was found that previous NaOH-treatment of rice straw (diet V) did not improve the digestibility or feed value relative to the complete diet containing untreated rice straw. Treatment of rice straw with 4% NaOH and 2% $Ca(OH)_2$ greatly decreased the digestibility of DM, OM, CF and NFE and the TDN % relative to the diets containing untreated rice straw alone or treated with NaOH (Table 3).

From the present results the cost of TDN % was calculated for each diet (Table 4). The cost of one tonne of TDN in the governmental concentrate mixture was about 104.2 LE. This cost was increased by substituting rice straw (diet II), rice straw and urea (diet III) or rice straw treated with alkali, urea and molasses (diets V and VI) for the concentrate. However, the cost decreased with diet IV. This clearly indicates the great potential of complete diets to help overcome the problem of feed shortage in Egypt by increasing the quantity of feeds without seriously affecting the quality. By applying these results, the amount of pelleted material could be increased from c. 1.5 million t to 3 million t.

Table 4. Cost (LE) of one tonne of pelleted feeds.

	Complete diets*					
	I	II	III	IV	V	VI
Concentrate mixture	67	33.5	33.5	33.5	33.5	33.5
Rice straw	-	17.5	16.5	14.0	14.0	14.0
Urea	-	-	3.8	3.8	3.8	3.8
Molasses	-	-	-	0.9	0.9	0.9
Minerals and vitamins	-	-	-	4.0	4.0	4.0
Sodium hydroxide	-	-	-	-	5.0	4.0
Calcium hydroxide	-	-	-	-	-	0.1
Diet manufacture	-	15.0	15.0	15.0	15.0	15.0
Total cost (LE/t)	67.0	66.0	68.0	71.2	76.2	75.3
Feeding value (TDN %)	64.3	60.6	61.5	68.7	66.6	58.1
Cost of one t TDN	104.2	109.0	111.7	103.6	114.4	129.7

*See Table 1 for diet composition.

The cost was calculated on the following basis (LE/t):

1. Concentrate mixture	67.0
2. Rice straw (chopped)	45.0
3. Urea	126.5
4. Molasses	15.0
5. Minerals & vitamins	200.0
6. Sodium hydroxide	250.0
7. Calcium hydroxide	15.0

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BYPRODUCT UTILIZATION IN EGYPT: A PROPOSED STRATEGY FOR THE DEVELOPMENT OF ANIMAL FEED RESOURCES

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SUMMARY

The shortage of animal feed resources and increasing cost of traditional animal feeds have stimulated the utilization of agro-industrial byproducts as feeds for ruminants. This paper sets out a strategy for the development of animal feed resources in Egypt for the year 2000 and discusses utilization of the available byproducts in improving the feed balance.

FEED AND ANIMAL RESOURCES IN EGYPT

Recent studies on the development of the livestock population in Egypt (Table 1) indicate that the rate of annual growth of the national herds of buffaloes and cattle is about 1.7 and 1.4% respectively. During the period 1980-2000, the annual growth rate of sheep and goat and camel herds is expected to be 0.7 and 0.5% respectively. However, the number of non-ruminant herbivores is expected to decrease at a rate of 0.5% in accordance with Ministry of Agriculture plans calling for an increase in farm mechanization. The relative importance of livestock in Egypt is indicated in Table 2. The annual feed requirements are estimated in terms of total digestible nutrients (TDN) and total digestible protein (DCP) according to the National Research Council (NRC, 1970) standards which suggest 1500 kg of TDN and 140 kg of DCP for each animal unit. The annual feed requirements amount to 9.9 and 0.93 million t of TDN and DCP respectively (Table 3). The feed requirements of cattle and buffaloes account for 29% and 38% respectively of the total livestock feed budget in Egypt. It is also noted that 17% of the total requirements are consumed by non-ruminant herbivores. The modern approach of utilizing farm machinery in agricultural operations will certainly reduce the stress of non-ruminants upon the nutritional requirements of livestock. Table 3 shows the present and the projected nutritional requirements of the livestock population in Egypt by the year 2000. The requirements will increase from 9.9 million t of TDN and 927 000 t of DCP in 1984, to 12.2 million t of TDN and 1.1 million t of DCP by the year 2000.

ANIMAL FEED RESOURCES IN EGYPT

The domestic sources of raw materials in Egypt are shown in Table 4. Roughages contribute the major portion of all available feed resources and represent 78% of the TDN. Green fodder represents 70% of the TDN in the total roughages. Berseem contributes more than 56% TDN and 87% DCP of the total roughages.

Table 1. The development of livestock population in Egypt during 1976-1984.

Animal type	1976	1978	1980	1984
	Animal population ('000 head)			
Cattle	2079	2587	2423	2782
Buffaloes	2226	2542	2009	2531
Sheep	1878	2554	2488	2479
Goats	1349	1440	2409	2387
Camels	101	93	126	146
Non-ruminants	1528	1685	1719	2239

Source: Central Department of Agricultural Statistics, Ministry of Agriculture and Food Security, Cairo (1984).

Table 2. Relative importance of livestock types in Egypt and the projected populations in the year 2000.

Animal types	Year 1984		Year 2000	
	Total animal units ('000)	% of total population	Projected populations ('000 units)	Relative importance %
Cattle	1947.77	29.41	2500.87	30.85
Buffaloes	2531.13	38.22	3427.15	42.28
Sheep	495.85	7.49	561.80	6.93
Goats	381.94	5.77	432.74	5.34
Camels	146.21	2.21	159.81	1.97
Non-ruminants	1119.42	16.90	1024.17	12.63
Total	7081.32	100	8106.55	100

Source: Central Department of Agricultural Statistics, Ministry of Agriculture and Food Security, Cairo (1984).

Table 3. Annual nutritional requirements of livestock in Egypt and the projected demand for animal feeds by the year 2000.

Livestock	Requirements ('000 tons)	
	TDN	DCP
Cattle	[illegible]921.65	292.69
Buffaloes	[illegible]96.70	345.36
Sheep	[illegible]43.77	69.42
Goats	572.91	53.47
Camels	219.33	20.47
Non-ruminants	1679.13	156.72
Total (for 1984)	9933.49	927.13
Demand by the year 2000	12159.82	1134.92

Table 4. Amounts and nutritive value of feeds for livestock in Egypt.

	Annual amounts ('000 t)	Nutritive value ('000 t)	
		TDN	DCP
Roughages:			
Green	58998.33	5027.10	1125.82
Dry	5133.30	2155.46	34.78
Total	64131.63	7182.57	1160.10
Concentrates:			
Grains and seeds	1315.37	1063.31	74.07
Byproducts	1635.00	1016.35	202.40
Total	1950.37	2079.66	276.47
Total roughages and concentrates	-	9262.23	1436.58

All other green fodders play a limited role in animal feeding and contribute only 1.5% of the roughage energy. The total annual amount of straw produced in Egypt is about 5.5 million t. The annual concentrate production is in the order of 3 million t and represents only 22% of the TDN in Egypt. By-products from vegetable oil, cereal milling and rice polishing industries, together with sugar-cane molasses, represent the bulk of concentrates (50 and 7% of TDN and DCP respectively). About 14 million tonnes of non-traditional feeds (Table 5) could be used annually in Egypt.

Table 5. Potential non-conventional feeds in Egypt.

Crops	Annual production of field crops ('000 t)	Potential crop byproducts ('000 t)
Corn (stalks)	3450.98	3321.69
Corn (cob)	3450.98	576.00
Sorghum	647.32	867.19
Sugar-cane	10953.00	2000.00
Sugar beets	425.00	446.25
Rice (hulls)	2716.00	500.00
Cotton (stalks)	-	2285.00
Vegetables	7695.00	2308.50
Fruits	2712.00	1084.80
Total	-	13389.43

The projected supply of animal feeds during the period 1984-2000 is based on the following assumptions, which are included in the five year agricultural development plan:

* A 10% improvement in berseem production to be achieved through better management. Berseem production is expected to reach 55.7 million t in the year 2000;

* An increase in the area cultivated with summer green fodder in the valley from 90 000 feddans in 1981/82 to 135 000 feddans in 1986/87 and 250 000 feddans in the year 2000;
* An increase in the area cultivated with green fodder in newly reclaimed land from 110 000 feddans in 1981/82 to 478 000 feddans in 1986/87 and 600 000 feddans in the year 2000;
* An intensification of production of the main field crops such as wheat, corn, rice and cotton;
* An expansion in the production of soybean crops;
* Maximum utilization of non-conventional feeds in the formulation of balanced livestock rations.

Based on these assumptions, it is expected that roughages will provide livestock with 11.1 and 1.5 million t of TDN and DCP respectively by the year 2000 (Table 6) and 0.430 million t of TDN and DCP.

Table 6. Projected supply of feeds for livestock by the year 2000.

	Projected amounts ('000 t)	Nutritive value ('000 t)	
		TDN	DCP
Roughages:			
Green	94733.03	8265.14	1477.72
Dry	6104.00	2278.47	22.19
Total	100837.01	11043.61	1499.19
Concentrates:			
Grains	3013.00	2446.98	170.88
By-products	2184.45	1359.53	259.02
Total	5197.45	3806.51	429.90
Total projected feed supply	-	14850.12	1929.09

Roughages are expected to account for 74.4% of the total projected supply of energy (TDN) in the year 2000. Green fodder is also expected to represent 79.9% and 59% of the projected supply of energy in the roughages and the total feed resources respectively. Summer green fodders will account for 28.2% of the energy supply in the total green fodders. The locally produced concentrates are expected to provide about 26% of the projected supply of energy in the feed resources of Egypt.

Due to expected improvements in the production of the main field crops, vegetables and fruit, the unconventional feeds are expected to increase to about 16 million t. Assuming that the availability of these non-traditional feeds will be in the order of 40%, the expected available energy will amount to 3.3 million t in the year 2000 (Table 7).

Table 8 shows a comparison between projected demand and supply of animal feeds. The supply is expected to cover only 84.4% and 88.8% of the demand for TDN and DCP respectively in the

Table 7. Projected supply of non-conventional feeds.

Feed	Projected annual production ('000 t)	Projected amount available for feeding ('000 t)	Nutritive value ('000 t)	
			DCP	TDN
Corn stalks	4135.68	2067.84	20.68	827.14
Sorghum stalks	1145.30	572.65	5.73	229.06
Corn cobs	732.36	439.42	4.39	197.74
Bagasse	3874.50	1356.07	13.56	476.63
Sugar beet residues	1224.00	1224.00	48.96	550.80
Rice hulls	571.86	457.49	4.57	114.37
Vegetable residues	3204.00	1281.60	64.08	576.72
Fruit residues	1500.40	600.16	24.01	270.07
Cotton stalks	2514.00	502.80	2.51	75.42
Total	16390.61	8502.03	188.49	3315.94

year 2000. It seems that the use of non-traditional feeds in the formulation of livestock rations will be the major solution to the deficit of the feed balance in the future.

A national programme for 1984-1988, sponsored by the National Academy of Science, is being carried out by the University of Alexandria, Ain Shams, Mansoura, Cairo and the Ministry of Agriculture in order to study the following aspects of the utilization of non-conventional feeds in the formulation of balanced livestock rations:

* A survey of unconventional feeds of economic importance;
* Methods of improving the nutritive value and palatability of non-traditional feeds;
* Formulation of balanced, integrated livestock rations based on the use of non-conventional feeds. Some balanced rations are now being used in a pilot test conducted jointly at village level by the extension service of the Ministry of Agriculture, Alexandria University;
* Additives and supplements required to make up for deficiencies in rations based on non-conventional feeds;
* Economics of the use of various non-traditional feeds in the formation of balanced livestock rations.

Table 8. Projected feed balance without or with non-conventional feeds by the year 2000 in Egypt.

	Animal requirements ('000 t)			Feed resources ('000 t)	
	DCP	TDN		DCP	TDN
			A. Without non-conventional feeds		
Livestock	1134.92	1215.82	Roughages	1499.92	11499.30
Poultry	1038.06	5972.36	Concentrates	429.90	3806.51
Total	2172.97	18132.18	Total	1929.82	15305.82
Balance				-243.16	-2826.26
Self-sufficiency %				88.8	84.4
			B. With non-conventional feeds		
			Roughages	1499.42	11499.30
			Concentrates	429.90	3806.51
			Non-conventional	188.49	3979.13
			Total	2118.32	19284.95
Balance				-54.6	1152.77
Self sufficiency %				97.5	106.4

EFFECTS OF WATERING FREQUENCY ON THE RESPONSE OF SHEEP TO SUPPLEMENTATION WITH MOLASSES/UREA AND NOUG CAKE (Guizotia abyssinica)

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SUMMARY

A 102-day growth and digestion balance experiment was conducted to study the effects of noug (*Guizotia abyssinica*) cake and various watering frequencies on the growth rate, and feed intake and utilization of teff (*Eragrostis tef*) straw (TS) and molasses-urea (MU, 2.5% urea) by male castrated highland sheep. Four of 12 sheep (average initial weight: 16.9 ± 0.17 kg) were subjected to one of three watering frequencies (WFs); once every 3 days for 30 minutes, once/day for 30 minutes and *ad libitum*.

Noug cake, which constituted 13.7% of the total DM intake of half of the sheep, had a substitution effect on the intake of TS. Sheep offered NC consumed 36% less straw than those without noug. However, sheep fed NC had significantly ($P<0.05$) higher apparent dry matter (73%) and nitrogen (70%) digestibilities and growth rate (23 g/day) than those without the meal (65, 63% and -6 g/day respectively).

Sheep on the *ad libitum* regime consumed more MU, total feed and water, digested DM, N and fibre better, and gained more weight than those on the other WFs. In general, sheep on the once/day WF performed the poorest, while the performance of those watered once/3 days was intermediate.

Rumen ammonia concentrations increased as the interval of watering increased. Rumen ammonia in sheep fed NC was eight percentage units higher than in those not fed NC, but fibre digestibility was lower in the sheep given noug. This suggested that the fibre in NC is fairly indigestible, probably because NC contained 61% more lignin than TS. Molasses-urea intake was negatively correlated with that of straw ($r = -0.67$, $P<0.017$). Intake of MU depressed fibre digestion.

There were no apparent digestive or metabolic disturbances in sheep on any WF, eventhough MU constituted 59 to 66% of total DM intake. Thus, watering once/3 days instead of once/day or ad libitum, restricted feeding of an oilseed cake and free feeding of MU could be important components of a strategy for enhancing survival of sheep during drought.

INTRODUCTION

Ethiopia has the largest livestock population in Africa. About 80% of these animals are raised in the intensely cultivated highlands (Bisrat, 1985). Livestock productivity in the Ethiopian highlands is suppressed by inadequate feed and water supplies,

disease and poor utilization of agro-industrial byproducts such as noug (Guizotia abyssinica) cake (NC) and molasses (Bisrat, 1985).

Another constraint to livestock productivity in the Ethiopian highlands is the inadequacy of data on livestock resources and livestock performance. The objective of this study was to determine the effect of three watering frequencies, and the feeding of teff (Eragrostis tef) straw and molasses-urea with and without NC on sheep growth rate, rumen ammonia levels, feed intake and nutrient utilization.

MATERIALS AND METHODS

General procedures

The experiment was arranged as a 2 (0 and 100 g noug cake (NC)/sheep/day) x 3 (watering frequency) factorial. There were four male castrated sheep on each watering interval (average initial weight: 16.9 + 0.17 kg) two with and two without NC. All sheep were drenched with a broad spectrum anthelminthic 2 weeks before initiating the trial. Sheep were housed in metabolism crates.

Molasses-urea (2.5% urea w/w) was fed ad libitum in a small can placed securely in a compartment within each metabolism crate. Each sheep's NC, served as one meal each morning, was placed in the other compartment. Teff straw (TS) was fed ad libitum (i.e., 125% of the realized intake during a 10-day preliminary period) and was divided into two equal portions given in the morning and afternoon.

Water was served in plastic buckets tied securely on to the crates and was weighed before and after being offered. Water for sheep on the restricted watering frequencies (WFs) was offered after straw, NC and molasses-urea (MU) had been given.

The trial consisted of three periods: feeding and growth (days 1-84, including a 10-day adaptation period), digestion balance (days 86-100) and rumen fluid collection (days 101 and 102).

Feeding and growth period

Samples of TS, NC and MU offered were taken weekly, bulked at the end of the period, subsampled and dried in a forced draft oven for 24 hours at 60° C. The samples were then ground through a 1 mm screen and analysed for dry matter (DM), ash, nitrogen (N), acid-detergent fibre (ADF), neutral-detergent fibre (NDF) and lignin.

Samples were dried, in duplicate, in a forced air oven overnight at 100° C and subsequently placed in a muffle furnace overnight at 550° C, for DM and ash determinations respectively (AOAC, 1975). Nitrogen was analysed using a Kjeldahl digestion and distillation procedure (AOAC, 1975). Samples were digested at ca. 400° C in digestion tubes containing concentrated sulphuric acid (specific gravity, 1.84) and a Se-based catalyst tablet.

Aliquots of digests were steam-distilled after reduction with 40% NaOH (w/v). The distillate was collected in 2% boric acid solution and titrated against standard HCl (0.10 N). Neutral-detergent fibre, ADF and lignin were determined according to van Soest and Robertson (1979).

Sheep were weighed weekly, without prior fasting. All sheep were weighed on the same day, which was the day before sheep on the once/3 days WF were to receive water. The chemical composition of feeds offered is presented in Table 1.

Table 1. Chemical composition of feed ingredients offered.

Feed ingredient	Crude protein	Acid-detergent fibre	Neutral-detergent fibre	Lignin	Ash
	%		DM basis		
Teff straw	3.0	41.8	70.5	5.2	8.0
Noug cake	32.3	32.7	34.0	13.3	11.5
Molasses/ urea	12.7	-	-	-	17.3

Digestion balance period

This consisted of two digestion periods of 7 days each, during which urine and faeces were collected over 24 hour periods. For sheep on the once/3 day WF, urine and faecal collections began on the day before water was to be given.

Daily faecal excretions were collected quantitatively in canvas bags lined with plastic bags. Urine collected passed between the wooden slats of the crates and drained on to zinc urinary trays (required frequent cleaning) and into plastic buckets. This method of urine collection made it difficult to determine N retention with certainty.

Five ml of concentrated sulphuric acid was placed in each bucket to acidify and preserve each sheep's urine output. Each sheep's daily urine output was agitated vigorously to ensure a good blend and measured volumetrically. At least a 30% aliquot of the well-mixed urine was added to the sample of the previous day(s) which was then refrigerated and subsampled at the end of each period for N analysis. Fifty percent of each sheep's faecal output was dried daily at 105° C for 24 hours for DM determinations and the remaining 50% was bulked and refrigerated. At the end of each period, the composited faecal samples were mixed well, subsampled, dried at 60° C for 24 hours, ground and used for chemical analyses as specified above.

Samples of feeds offered were collected daily and composited weekly. Feeds refused were recorded daily and composited weekly on an individual sheep basis. The weekly composites were divided into two portions - one dried at 60° C and the other at 105° C, for chemical analyses and DM determinations respectively. Digestion coefficients were calculated according to standard procedures (Schneider and Flatt, 1975).

Rumen fluid collection period

Rumen fluid samples were taken using a suction pump and stomach tube. A stainless steel strainer, used for excluding large particulate matter from the rumen fluid samples, was attached to the end of the tube that was inserted through the mouth into the rumen of each sheep. Rumen fluid samples were collected before feeding (0 h) and again at 1/2, 1, 2, 3, 4 and 5 h post-feeding, placed in plastic bottles each containing 3 ml of concentrated sulphuric acid, and analysed for ammonia after Kjedahl digestion and distillation methods (AOAC, 1975).

All data were subjected to analysis of variance and differences among treatments were detected using t-tests (Snedecor and Cochrane, 1967).

RESULTS AND DISCUSSION

Growth period

Interaction between level of NC and WF was not significant ($P<0.05$) for any of the parameters measured (Tables 2 and 3). Sheep given NC ate less TS, consumed more MU and more total feed DM, drank more water and gained more weight than those without access to the meal.

Straw consumption was significantly depressed by the availability of noug cake (equivalent to about 13.7% of the diet DM intake) and intake of molasses ($r = -0.67$, $P<0.017$). The reduction in straw intake by MU and NC may have been due to a substitution effect.

Sheep on the ad libitum WF ate more MU and total feed, drank more water and gained faster than those on the other WFs. However, sheep given free access to water consumed less TS than those watered once/3 days. For all parameters, except water intake, sheep on the once/day WF performed the poorest. Performance of sheep watered once/3 days exceeded that of those watered once/day, probably because of the sharp increase in total feed and water intake in the former group on the day that water was provided. On average, the increase in feed intake by sheep watered once/3 days, on the day that water was given, was 60-90% more than the average feed intake during the following 2 days of water deprivation.

Total DM intake was lower in sheep on the two restricted WFs than in those given free access to water, in agreement with Balch et al (1953) and Asplund and Pfander (1972). Asplund and Pfander (1972) stated that reduced feed intake under restricted watering occurs because a certain amount of water is necessary to allow normal passage of DM through the digestive tract.

Water intake in sheep on the once/3 day, once/day and ad libitum WFs were 1.10, 1.18 and 1.83 litres/sheep/day respectively, similar to results obtained by Taneja (1965). In that study, grazing sheep were watered once/day, once/2 days, once/3 days and once/4 days. Those receiving water once/3 days drank 1.32 litres/sheep/day.

Table 2. Feed and water consumption and liveweight change.

Measurements	Watering frequencies			SEx
	Once/3 days	Once/day	Ad libitum	
Feed intake (g/day)				
1. Straw (as-fed)				
Without noug	302	200	239	44
With noug	160	141	175	
2. Molasses/urea (as-fed)				
Without noug	449	542	600	60
With noug	700	593	813	
3. Noug (as-fed)				
Without noug	-	-	-	-
With noug	100	100	100	
4. Total DM*				
Without noug	564	532	605	30
With noug	694	607	780	
Water intake (litres/day)				
Without noug	0.90	1.00	1.45	
With noug	1.30	1.35	2.20	0.07
Liveweight change (g/day)				
Without noug	-13	-17	13	
With noug	33	-6	43	8.0

* Includes straw, molasses/urea and noug cake at DM contents of 90, 65 and 95% respectively.

Table 3. Nutrient digestibilities, rumen ammonia concentration and urine excretion.

Measurements	Watering frequencies			SEx
	Once/3 days	Once/day	Ad libitum	
Digestibilities (%)				
1. Dry matter				
Without noug	60.7	60.1	73.2	
With noug	71.8	70.3	78.0	3.40
2. Nitrogen				
Without noug	61.8	57.5	69.3	
With noug	70.7	65.4	74.3	1.97
3. Acid-detergent fibre				
Without noug	48.9	43.5	53.7	
With noug	44.8	30.8	35.9	1.34
Rumen ammonia concentration (mg %)*				
Without noug	7.6	14.5	19.9	
With noug	22.3	21.9	21.2	3.03
Urine excretion (ml/day)				
Without noug	100	197	279	
With noug	233	420	442	11.9

* Mean ammonia concentration in rumen fluid samples taken before feeding, and at 0.5, 1, 2, 3, 4 and 5 hours post-feeding.

Under drought conditions, there is a cyclical weight loss between watering. This is caused by high water consumption on the day of watering. For example, camels may drink up to 140 litres of water on the day water is given and this may increase the dehydrated weight by 25% (Field, 1985). A precaution against this increase in liveweight was taken during the current study by weighing all sheep on the day before sheep on the once/3 days watering regime were to receive water.

Digestion balance and rumen fluid collection periods

Dry-matter and N digestibilities were higher in sheep fed NC than in those deprived of the meal. These results may have been a reflection of the increased N status of sheep fed noug. Because N deficiency is the primary nutritional limitation in cereal crop residues (Butterworth and Mosi, 1985; Mosi and Butterworth, 1985), strong positive relationships have been found between increasing N intakes and cellulose digestibility, intake of low quality roughages and bodyweight gains in young animals. These effects of N intake in ruminants may be mediated through the rumen microbial population, as indicated by the highly significant relationship found between direct counts of rumen bacteria and N intake (Moir and Harris, 1962).

Although the concentration of rumen ammonia in the rumens of sheep given noug was 8 percentage units higher than in those without the meal (Table 3), fibre digestion was lower in the former group, possibly because of the depressing effects of sugars on fibre digestion (i.e., sheep fed noug ate more molasses/urea than those without noug) and because of the increase in indigestible fibre from noug cake. Noug cake is obtained through expeller or solvent extraction. The cake remaining after oil has been removed has a very high percentage of seed hulls which account for the high fibre and lignin contents of noug (Table 1).

The concentration of rumen ammonia increased as WF increased (Table 3), possibly because the intake of MU increased as the watering interval was increased. Asplung and Pfander (1972) reported that the rumens of sheep on very restricted watering ("high feed, low water") were more acidic and contained higher levels of volatile fatty acids than those of sheep on "low feed, low water" and "high feed, high water".

Dry-matter, N and fibre digestibilities tended to be higher in sheep watered once/3 days than in those watered once/day (Table 2), in agreement with the findings of Balch et al (1953), Thornton and Yates (1968) and Asplund and Pfander (1972). Asplund and Pfander (1972) suggested that drastic curtailment of defecation (not observed in the current study) and exaggerated accumulations of DM in sheep under water restriction caused elevated digestibilities of DM and N. Inadequate water causes DM accumulation in the digestive tract (probably the rumen) by slowing down the rate of passage of feed residues (Balch et al, 1953). A progressive slowing down of the rate of passage would result in higher apparent digestibilities without any alteration in digestive function or rumen kinetics (Asplund and Pfander, 1972). These data infer that high digestibilities in ruminants undergoing severe water restriction may be an artifact.

The phenomenon of exaggerated digestibilities has often been observed in short-term studies on water restriction. For example, in the study of Asplund and Pfander (1972), digestion data were collected after a 14-day adaptation period. Digestion data in such trials are perhaps collected before animals have adapted physiologically to water restriction (Asplund and Pfander, 1972). The current experiment is one of the most long-lasting experiments on water restriction. The phenomenon of high digestibilities under water restriction appeared to have occurred in this trial, despite the fact that digestion data were taken after sheep had been on their watering regimes for nearly 3 months.

The main daily urine output of sheep on the once/3 days, once/day and ad libitum WFs were 167, 309 and 361 ml respectively. This means that sheep on the ad libitum WF excreted 14 and 54% more urine than those watered once/day and once/3 days respectively. Water intake in sheep watered ad libitum was 36 and 40% greater than in those allowed to drink once/day and once/3 days respectively (Table 2). Because the percentage difference in urine excretion between sheep on the ad libitum WF and those watered once/3 days was much greater than the difference in their water intake, it can be said that water conservation was highest in sheep watered once/3 days and lowest in those on the free choice watering regime.

Asplund and Pfander (1972) reported reduced faecal and urinary water excretion under severe water restriction and concluded that this water-conserving mechanism is more efficient in sheep than in cattle.

CONCLUSION

Ethiopia has the largest livestock population in Africa; 80% of these animals are found in the Ethiopian highlands. Livestock deaths caused by drought are a perpetual problem in this and some other African countries. However, no data from work done in the Ethiopian highlands have been reported on the long-term effects of water restriction and noug cake feeding on growth rate, rumen parameters, and feed intake and utilization in sheep given molasses/urea free choice.

Data from this experiment, one of the most long-lasting studies on water restriction for domestic ruminants, suggest that after a long period of water restriction, sheep adapted physiologically to infrequent watering. These adaptations were manifested through reduced urinary water excretion and increased feed consumption on the day of watering, and were demonstrated most vividly in sheep watered once/3 days. Sheep given noug cake digested dry matter better and grew faster than those without the protein cake. In light of the continuing drought problems facing Ethiopia, it is concluded that watering highland sheep once every 3 days for 30 minutes, instead of ad libitum or once/day for 30 minutes, is an economical and labour-saving "drought response" watering frequency, and that providing at least 14% of the diet DM as noug cake may enhance the survival of sheep during drought.

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EFFECTS OF ENSILAGE, ADDED NITROGEN AND ENERGY ON THE UTILIZATION OF GRAIN SORGHUM STOVER BY BEEF CATTLE

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SUMMARY

Different combinations of urea, molasses and groundnut meal were individually fed to 60 Bunaji x Friesian crossbred heifers as a supplement to diets based on either dry sorghum stover or untreated/treated sorghum stover silages. Intake was increased by ensiling and by groundnut meal, and depressed by urea and molasses.

INTRODUCTION

More than 80% of the ruminant animals in Nigeria are located in the Guinea Savanna and Sahel zones in the north of the country where they are managed by the pastoral Fulani and agro-pastoralists. Cattle, sheep and goats increase their bodyweights during the wet season, but they lose a considerable amount of the gained weight during the subsequent dry season. Fodder conservation is not undertaken by the herdsmen while the excessively large numbers of livestock per family preclude the economic feasibility of supplementary feeding without government subsidy.

The Savanna and Sahelian zones are the major cereal (sorghum, Sorghum vulgare; millet, Pennisetum typhoides; maize, Zea mays) growing region of Nigeria. The grain is normally harvested by November leaving over 60% of the total dry matter in the field as crop residues. Traditionally, sorghum stovers are grazed as well as being used for fencing materials for dry season farm plots, and as part of the roofing structure for thatched houses. However, for several months, cereal crop residues, mainly sorghum stovers, constitute the principal source of fodder. They are so intensively grazed that by the end of March there is little or nothing left on the field (Van Raay et al, 1971).

Ways must be found to reduce considerably both livestock losses and the time taken to attain maturity or slaughter weight, even when only the cheapest feed resources, such as poor native pastures, crop residues and other roughages, are available. This might be achieved by utilizing the crop residues more efficiently so as to at least maintain animal body weight, and possibly obtain liveweight gains during the annual dry periods.

Animal performance on crop residues can be improved by chemical treatment and by supplementation (Sundstol and Owen, 1984). The objective of this study was to compare the effectiveness of different ways of ensiling dry sorghum stover,

fed with and without nitrogen and energy supplementation, in increasing feed intake and cattle performance. Results from the investigation might pave the way for making recommendations for future use of sorghum residues in maintaining ruminants.

MATERIALS AND METHODS

The study was carried out at the headquarters of the National Animal Production Research Institute, Shika, Zaria, which is located at latitude 11° 11' N and longitude 7° 38' E at an altitude of 640 metres. It is within the northern Guinea Savanna zone with a 50 year annual rainfall mean of 1050 mm.

Sixty Bunaji (zebu) x Friesian/Holstein crossbred heifers and steers whose average age was 22 months, with a mean liveweight of 190 kg, were treated for both external and internal parasites. They were divided into six groups of 10 animals based on liveweight and age. Groups were randomly allocated to one of six diets. The diets were based on dry grain sorghum stover, untreated and treated grain sorghum stover silages, as listed below, and fed ad libitum, supplemented with or without different combinations of urea, molasses and groundnut meal, as follows:

1. Dry grain sorghum stover (93.4% dry matter) chopped with silage harvester;

2. Dry grain sorghum stover chopped as in treatment 1 and treated with calculated amounts of clean water to reduce the dry matter to about 62% before it was ensiled in a trench silo;

3. Dry grain sorghum stover was chopped as in treatment 1 and treated with calculated amounts of aqueous solution of 0.25% urea and 0.5% blackstrap molasses before it was ensiled as in treatment 2.

From the three sorghum stover-based diets, six rations were formulated and one group of animals was assigned to each of the following six treatments:

I. Control - ad libitum dry grain sorghum stover + mineral salts;

II. Ad libitum dry grain sorghum stover + groundnut meal + mineral salts;

III. Ad libitum dry grain sorghum stover + molasses + urea + mineral salts;

IV. Ad libitum untreated grain sorghum stover silage + mineral salts;

V. Ad libitum treated grain sorghum stover silage + urea + groundnut meal + minerals;

VI. Ad libitum treated grain sorghum stover silage + urea + molasses + mineral salts.

The animals were assigned to individual feeding pens in a latin square arrangement. Chemical composition of feed components is given in Table 1. Urea/molasses solution was administered by sprinkling the calculated amount on top of the dry sorghum stover and treated sorghum stover silage (treatments III and VI respectively) before feeding time. Groundnut meal (454 g) was given as a separate meal which was completely consumed before stover was offered ad libitum (about 120% of intake). Fresh water and a complete mineral lick (Table 2) were always available. Feeds offered and refused were recorded daily and samples taken for analysis according to the methods of AOAC (1970). There was a standardization period of 14 days followed by an experimental period of 60 days. Animals were weighed every 7 days.

RESULTS AND DISCUSSION

The chemical composition of the various rations used is given in Table 1. Ensilage significantly ($P<0.05$) improved dry matter intake (Table 3). This is attributable partly to texture, odour and palatability of the resultant silage from the stover and partly to the faster rate of digestion and passage of the silage digests compared with dry stover (Koes et al, 1974; Holmes, 1962). Addition of urea and molasses had a depressive effect on the intake of dry sorghum stover but this was not significant. On the other hand, urea and molasses had an associated non-significant effect on the intake of stover silage (Table 3). Pooled data for feed intake showed a highly significant ($P<0.001$) superiority for treatments containing groundnut meals over other diets, regardless of the form in which the stover was fed.

Although ensilage significantly improved dry matter intake, there was no corresponding benefit in animal productivity. This might indicate that the silage-based rations were used less efficiently than the dry stover. Similarly, dry stover supplemented with groundnut meal supported a higher average daily gain than the corresponding stover silage-based diet (80 vs 10 gm).

Analysis of variance showed that these small differences in weight gain were not significant and there were no significant interactions between added nitrogen and energy.

These results indicate that there is no economic merit in ensiling sorghum stover before it is fed. The addition of urea, however, may have a relative advantage over dry sorghum in maintaining liveweight while supplementing the stover with a protein source, such as groundnut meal, may increase daily gain. The effects of oilseed meal could be attributable to a contribution of by-pass or escape protein which would increase the yield of rumen microbial protein (Van Soest, 1982).

CONCLUSIONS

It may be concluded that crossbred cattle can, at the very least, be maintained, and possibly even obtain liveweight gains, during the annual dry periods by feeding cereal crop residues, such as sorghum stover, with limited additional protein and a complete mineral lick. These means are within the reach of the

Table 1. Composition of rations on dry matter basis.

Items	Treatments					
	1	2	3	4	5	6
Dry matter	92.81	9.00	76.00	56.90	67.22	54.10
Crude protein (N x 6.25)%	4.75	8.20	6.75	4.43	7.50	6.57
NDF%	82.82	62.57	65.99	82.63	74.68	63.94
Non-CWC %	17.18	37.48	34.01	17.32	25.32	36.06
Hemicellulose %	28.75	24.43	24.22	28.68	27.22	22.00
ADF %	54.07	38.07	41.77	54.00	47.46	41.94
Cellulose %	46.36	32.16	35.81	45.98	40.29	35.83
Lignin %	7.72	5.91	5.96	8.01	7.17	6.11
Ash %	6.11	13.12	7.01	6.22	10.77	7.71

1 = Dry sorghum stover
2 = Dry sorghum stover + groundnut cake
3 = Dry sorghum stover + urea + molasses
4 = Untreated stover silage
5 = Untreated stover silage + groundnut cake
6 = Treated stover silage + urea + molasses

Table 2. Mineral composition of ration fed.

Treatments	Concentration (ppm)									
	Na	Ca	K	Mg	Mn	Cu	Co	Zn	Fe	P
1	127.5	4100	11000	2100	59.58	4.0	4.0	120	300	140
2	137.5	5650	10600	3050	34.83	11.5	2.5	140	720	2875
3	187.7	6950	14000	2400	45.83	4.0	3.0	135	465	260
4	140.0	6400	10000	2150	96.25	5.0	2.0	115	740	300
5	132.5	4200	10400	3050	82.50	12.5	2.5	145	1165	2525
6	177.5	5950	13600	2350	73.33	4.5	3.0	140	525	1315

1 = Dry sorghum stover
2 = Dry stover + groundnut cake
3 = Dry stover + urea + molasses
4 = Untreated stover silage
5 = Untreated stover silage + groundnut cake
6 = Treated stover silage + urea + molasses

Table 3. Performance of cattle fed sorghum stover based diets.

Item	Treatments						
	1	2	3	4	5	6	S.E.
Number of animals	10	10	10	10	10	10	10
Total DM intake/ animal/day (kg)	2.50a	3.40b	2.27a	3.45b	4.65c	3.12b	0.51
Mean initial liveweight (kg)	187.13	186.25	190.75	191.75	188.62	188.25	7.64 n.s.
Mean final liveweight (kg)	184.25	191.00	188.00	185.62	189.00	184.75	7.94 n.s.
Average liveweight gain or loss/ animal/day (g)	50.0a	80.0c	-50.0a	-111.0a	10.0b	-60.0a	26.96

Means within the same column with different superscripts are significantly different ($P<0.05$).
1. = Dry sorghum stover
2. = Dry sorghum stover + groundnut cake
3. = Dry sorghum stover + urea + molasses
4. = Untreated stover silage
5. = Untreated stover silage + groundnut cake
6. = Treated stover silage + urea + molasses

average livestock farmer in this part of Africa. However, it is desirable that if such a feeding system is adopted, the animals should be kept under either intensive or semi-intensive management, otherwise the levels of energy and protein available in the feed intake would not meet the animals' requirements for extensive grazing, with resultant losses in liveweight and even livestock.

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PREPARATION OF CASSAVA PEELS FOR USE IN SMALL RUMINANT PRODUCTION IN WESTERN NIGERIA

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INTRODUCTION

In the towns and villages of Western Nigeria, small ruminants (sheep and goats), are traditionally kept in backyard production systems. These animals are important sources of meat as they are cheaper to rear than cattle and require less space and shelter. Further, production requires little equipment and only small quantities of feed. They are often seen scavenging on rubbish heaps, village greens and freshly abandoned farms where they graze crop residues. The small carcass is convenient for the rural economy since the meat can easily be consumed in one day without the need for cold storage or any other form of preservation.

In this traditional management system, it is not unusual for sheep and goats to be given supplements of fresh cassava chips in the morning or evening. Cassava peels, from the processing of the roots for starch, cassava flour or tapioca and gari, are also fed. Cassava peels have not, however, been used as a basis for ration formulation in an organized fattening scheme.

Cassava meal is an important cereal substitute in Europe with Thailand, China, Indonesia and Brazil as major exporters. It was once thought that cassava chips could become an export crop from West Africa and a possible source of foreign exchange. However, given its importance in human nutrition in this zone, and the many industrial uses to which the crop is now being put, or for which it has potential, it is quite clear that cassava chips or meal will not be an economical livestock feed in West Africa. The lack of adequate technology for the production of cassava chips, the labour costs and the need for synthetic amino acids in its utilization by non-ruminants are other major constraints. By contrast, cassava peel is becoming an important byproduct and is available from the local processing of cassava root for gari as well as from the newly introduced, large-scale plants producing gari and starch. Indeed, villages with substantial numbers of small ruminants, situated near gari processing plants, have experienced a boom in sheep and goat production, especially where adequate browse is available.

The project

The purpose of this project is to see to what extent a balanced diet, based on cassava peels, can be formulated using supplements available to the livestock owner at village level or which can be easily obtained at minimal cost.

During its first year the project will:

* Develop drying and ensiling methods for cassava peels;

* Determine optimal feeding levels of cassava peels for sheep and goats;

* Determine optimum combinations of cassava peels and cocoa pods in sheep and goat diets;

* Identify important byproducts in the humid forest belt and estimate quantities available for livestock feeding.

Pending receipt of materials and equipment for the project, some preliminary work was carried out. This report presents the results of preliminary observations on the chemical composition of cassava peels, and the effects of drying and ensiling.

REVIEW OF LITERATURE

Krauss (1921) concluded that the feeding value of cassava peel was equal to that of maize. Walker (1951) fed cassava peelings to sheep and goats in Equatorial West Africa. Since then, there have been no reports in the literature on the value of cassava peels for ruminant animals from this region of the world. However, Devendra (1977) reported studies on the effects of dietary cassava chips from a sweet variety using 20-80% levels in isonitrogenous rice straw or molasses-urea diets fed to sheep. The results showed that the digestibility of dry matter in the rice straw-based diets increased significantly with the inclusion of dietary cassava. However, for all the molasses-urea based diets, dry matter digestibility decreased significantly with increasing levels of cassava inclusion. In the rice straw diets, the addition of cassava significantly increased nitrogen retention; the reverse was true for molasses-urea diets. A similar trend was observed for organic matter, crude protein, ash, ether extract, nitrogen free extract and energy digestibilities.

Since the work of Devendra, there has been additional evidence in the literature of animal responses to cassava based diets fed to ruminants (Tudor and Norton, 1982; Cockburn and Williams, 1984). Some work has been reported on the value of cassava peel as a dietary source for non-ruminant stock. Sonaiya and Omole (1977) fed cassava peel to finishing pigs and Adeyanju and Pido (1978) fed the fermented cassava peel to broiler chicks. These researchers recorded significant economic benefits in reduced feed cost and increased revenue/feed costs derived from increased levels of fermented cassava peel in the diets. They could not, however, feed the peel beyond the 20% level.

Cassava skin, which is removed on peeling, is known to contain higher levels of cyanogenetic glucosides than the root meal. In order to prevent goitrogenic and other neuropathological effects in animals, it will be necessary to process the peel if the intention is to use it as the main source of energy. Not much is known about the ability of the ruminant to digest cyanogenetic glucosides without deleterious effects. Generally, supplementation of cassava diets with high levels of sulphur

amino acids, particularly cystine and methionine, and iodine, largely eliminates the goitrogenic activity due to thiocyanate production. However, amino acid supplementation is considered impractical in terms of developing an adaptable village level technology. Processing of cassava by drying or ensiling is known to reduce the content of glucosides in the product (Charavanapavan, 1944; Akinrele, 1964).

These simple processes were considered adequate for processing cassava peel as livestock feed.

CHEMICAL COMPOSITION OF CASSAVA PEEL AND THE EFFECT OF SUN-DRYING

Results of studies in our laboratories so far indicate that cassava peel represents about 8-10% of the root dry matter. The peeling is high in the soluble carbohydrates (62%) and low in fibre (16%) with a moderate level of nitrogen (1%) (Table 1). The data of Devendra (1977) show lower N levels, higher fibre and higher soluble carbohydrates; they were using a sweeter variety than the one used at Ile-Ife. Recent work with the new, bitter varieties indicates that fresh cassava peel has a pH of 5.7 and that drying substantially increases the percent dry matter content, as well as the ash content, with little effect on the crude protein and ether extract (Table 2). Dry matter of the fresh, air-dried cassava peels was determined at 105° C for 24 hours.

Table 1. Chemical composition of cassava peel (% of dry matter).

	Devendra (1977)	Adegbola (1980
Dry matter	n.d.	13.5
Crude protein	4.8	6.5
Crude fibre	21.1	10.0
Ether extract	1.2	1.0
NFE	68.6	62.5
Ash	4.2	6.5
Ca	0.312	n.d.
	0.127	n.d.
Mg	0.215	n.d.
Gross energy (MJ/kg)	2.96	1.65
Digestible energy (M/kg)	n.d.	1.03

Table 2. Preliminary data on the chemical composition of fresh and dried cassava peels (% of dry matter).

	Fresh peel	Air-dried peel
Dry matter	28.5	66.25
Crude protein	5.74	5.43
Ash	7.0	15.5
Ether extract	3.25	3.5
pH	5.70	

It can be assumed that drying would substantially reduce the amount of HCN liberated, as has been observed for the sliced roots by Charavanapavan (1944) and Razafimahery (1953). This reduction in HCN level will probably only take place with slow drying, since drying at higher temperatures has been proved to be less efficient. Drying took place on a concrete floor for 4 to 5 days by which time the material was beginning to darken. In addition, the lower N content of the drier material probably reflects the loss through volatilization of the released HCN.

CASSAVA PEEL SILAGE

Small laboratory silos, in the form of plastic containers 16 cm high and 11 cm diameter, were used to study the effect of the period of ensiling and the degree of chopping and compaction of fresh cassava peels. The objective was to find out if good silage could be made by simply encouraging the villager to throw the waste peels into a container and compact them.

Observations were made on the pH, dry matter content, colour, odour, texture and the presence or absence of mould in the ensuing silage mass. These observations were made at 14, 21, 28 and 35 days after ensiling. While the tightly packed containers had 1 kg matter put into them, the moderately packed containers were filled with 0.8 kg fresh cassava peel. The dry matter content of the silages was determined by placing them in the oven for 6 hours. For the first 2 hours the oven was set at 80° C but was reduced to 70° C for the remaining 4 hours. The result from this method of dry matter determination for silage has been shown to agree with the toluene distillation method, which compensates for the loss in the volatile organic acid (Perch and Tracey, 1956).

Determination of pH was carried out by mashing the cassava peel in distilled water using five times the weight of the sample. It was allowed to stand for 2 hours, then filtered to determine the pH using the EIL pH meter model 38B.

It was observed that good silage can be made after 14 days in tightly packed containers, without loss in dry matter, with a pH of 4.35, a pleasant sweet odour (possibly from lactic acid) and no fungal growth or dark coloration. Results are best when the ensiled material is chopped into smaller pieces and not left as whole, regular peels (Table 3). Under ideal conditions, good silage is made in 2 weeks but the quality of such silage may remain uniform for only a few days (Table 4).

However, when left for 4 and 5 weeks (Table 5), the silage tends to become darker and the odour less pleasant. Softness increases and there is more fungal growth, even when chopped into smaller particles and tightly compacted. Unchopped, moderately packed peels turned to rotten masses in 4 to 5 weeks.

These observations are only indicative of the qualities of silage obtainable using simple technology which can be adapted to the village level. Following the observations, an attempt was made to ensile a large quantity of chopped, tightly packed, cassava peels. A 200 litre drum was filled with cassava peels, covered with thin plastic sheeting and weighed down with heavy

Table 3. Preliminary observations on ensiled fresh cassava peels (after 14 days).

	Chopped		Not chopped	
	Tightly packed	Moderately packed	Tightly packed	Moderately packed
pH	4.35	4.7	4.4	4.8
Dry matter	34.10	20.42	33.02	23.50
Colour	Uniform light brown	Light to dark brown	Light brown	Fairly dark brown
Odour	Pleasant	Almost	Pleasant	Near vinegary
Texture	Uniformly firm	Fairly soft	Firm	Fairly firm
Other observation	No fungal growth	Some fungal growth	Slight fungal growth	Noticeable fungal growth throughout the entire mass

Table 4. Preliminary observations on ensiled fresh cassava peel (after 21 days).

	Chopped		Not chopped	
	Tightly packed	Moderately packed	Tightly packed	Moderately packed
pH	4.35	4.75	4.45	4.9
Dry matter	33.70	20.9	32.65	18.5
Colour	Light brown	Dark brown	Fairly light brown	Dark brown
Odour	Pleasant	Vinegary	Fairly pleasant	Vinegary
Texture	Firm	Soft	Fairly firm	Soft
Other observation	No fungal growth	Noticeable fungal growth	Pockets of fungal growth + top spoilage	Noticeable fungal growth

Table 5. Preliminary observations on ensiled fresh cassava peels, tightly packed.

	Chopped		Not chopped	
	28 days	35 days	28 days	35 days
pH	4.40	4.35	4.45	4.5
Dry matter	33.50	33.60	32.43	32.2
Colour	Light brown	Medium brown	Medium brown	Dark brown
Odour	Fairly pleasant	Less pleasant	Near vinegary	Vinegary
Texture	Fairly firm	Fairly soft	Fairly soft	Soft
Other	Slight fungal growth	More fungal growth	Top spoilage	Larger pockets of fungal growth

stones to ensure compaction. After 2 weeks the silage was opened. It was light brown in colour, sweet smelling and free from fungal growth. However, the ensiled silage darkened within an hour of opening and after about 2 hours it had turned very dark. This browning effect may be due to oxidation of some of the organic acids produced during ensiling. Ohochuku and Ballantine (1983) have indicated that the compounds responsible for the objectionable (vinegary) odour in the fermented cassava mass include butanoic, propanoic and acetic acid, butanoic acid being the most offensive.

When the ensiled material was offered ad libitum to four sheep in a preliminary feed trial, it was largely rejected, perhaps due to lack of familiarity. We have previously observed sheep and goats relishing sweet-smelling cassava peel silage on a disposal dump near a gari processing factory. On the other hand, the rejection may be due to the presence of hydrolysed HCN as the silage was not drained. Charavanapavan (1944) has indicated that "stale" cassava can be more toxic than the fresh and there may be a need to allow the hydrolysed HCN to drain away.

From these observations it appears that in order to make good silage from cassava peels, care must be taken to ensure good compaction and adequate drainage, and to prevent rapid oxidation or the formation of organic acids after ensiling.

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THE UTILIZATION OF SUGAR-CANE TOPS IN COMBINATION WITH LEUCAENA LEUCOCEPHALA AS A FEED FOR GOATS

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INTRODUCTION

Mauritius imports a substantial amount of its requirement for animal products thus negatively affecting its already strained balance of payment situation. This heavy dependence on imports is, no doubt, a phenomenon common to many developing countries. In recent years, the government has been promoting the animal production sector in order to rectify this situation and to create employment.

However, one of the major factors limiting increased animal production in Mauritius is the unavailability of land for feed production, due to the small size of the country and the high population density. There are, on the other hand, huge quantities of certain agro-industrial byproducts which, to date, have been little utilised as animal feed. Some 40% of the island's total area is devoted to sugar-cane production.

In non-disaster years, the average production of sugar-cane tops is estimated at 1.3 million t (UNDP, 1981). Of this, only 5-10% is utilised as feed during the crop season. Other byproducts include maize stover and cobs, obtained primarily from the interline growing of maize in the sugar-cane fields, and poultry litter/manure. Neither of these are used as animal feeds, despite their vast potential.

It is evident that in the future, agricultural waste products will play an increasing role in meeting the feed requirements of ruminants.

No doubt one of the reasons for the low level of utilisation of ligno-cellulosic wastes is their low protein content. This can, however, be overcome by supplementing the basal diet with locally produced, cheap leguminous forage. The forage which has been investigated so far, and which has proved to be a valuable protein supplement in ruminant diets, is Leucaena leucocephala.

The objectives of this investigation were to assess the nutritive value of Leucaena, to examine the effects of the mode of presentation of Leucaena with sugar-cane tops on animal performance, and to evaluate the effects of the various dietary treatments on carcass yield and composition.

MATERIALS AND METHODS

Eighteen bucklings, each approximately 6-7 months old and similar in size and weight, were divided into three groups of six each.

The animals were dewormed with Thibenzole and given 14 days to adjust to their new surroundings and feed before the experiment started. All animals were properly identified and weighed. During the experimental stage of 100 days, animals were weighed weekly after overnight fasting. After 60 days, half the animals from each treatment were slaughtered after overnight fasting and the carcass characteristics determined according to the procedure described by Owen and Norman (1977). The remaining animals were fed for a further 40 days and then slaughtered for carcass analysis. The experiment was replicated 6 months later with female goats of the same age but no carcass evaluation was carried out.

Diets

Three diets were formulated and one group of goats was assigned randomly to each diet. The diets were:

Diet A - Elephant grass (Pennisetum purpureum) + concentrate (control);

Diet B - Sugar-cane tops and Leucaena (1:1 w/w, fresh basis; offered separately);

Diet C - Sugar-cane tops and Leucaena (offered as a mixture).

All the fibrous feed components were chopped and offered ad libitum to the group-fed animals. The concentrate was a feed formulated for growing sheep and was given at the rate of 25 g/kg metabolic weight. A standard mineral-vitamin mixture and water were freely available. Daily feed intakes were recorded and weekly samples of fresh feed were processed for subsequent determination of dry matter intake and chemical composition.

Statistical analysis

An analysis of variance was carried out to determine the effect of the treatments. When the differences among the means were significant ($P<0.05$), the Duncan multiple range test (Steel and Torrie, 1960) was used to compare the means.

RESULTS

General observations

During the first experiment, two animals died, one on diet A and the other on diet C. In the second experiment, two animals on diet A and one on diet B, died. In some cases pneumonia caused the death but in other cases no proper cause could be established. Intoxication by mimosine did not apparently play a role. No clinical symptoms, such as profuse salivation or alopecia goitre, were observed. Examination of the tongue and oesophagus of the slaughtered bucklings did not reveal any ulceration, a common feature of Leucaena poisoning. The chemical composition of the various feed components used in the experiments is shown in Table 1. Table 2 presents the data on the

dry matter intake, daily weight gain and efficiency of feed utilization for the various dietary treatment.

Table 1. Chemical composition (%) of feed components used.

Feed component	Dry matter	Expressed as % of dry matter				
		Crude protein	Crude fibre	Nitrogen-free extract	Ether extract	Ash
Elephant grass	20.8	8.5	35.4	45.1	1.4	9.5
Concentrate	88.7	20.5	7.3	44.6	19.4	8.2
Sugar-cane tops	31.3	4.6	36.8	49.2	1.4	8.1
Leucaena	28.2	23.2	27.8	39.8	2.8	6.4

Table 2. Dry matter intake, daily weight gain and feed utilization.

	Experiment I			Experiment II		
	Diet			Diet		
	A	B	C	A	B	C
No. of animals	6	6	6	6	6	6
Initial weight (kg)	10.0	11.1	14.0	13.7	11.6	12.6
Duration of experiment (days)	100	100	100	100	100	100
Total dry matter intake ($kgW^{0.75}$/day)	75±32a	77±29a	58±20b	40±25a	61±25b	60±10b
Dry matter intake kg feed/kg gain	12.6	12.2	11.0	11.9	14.0	12.4

Treatment means with common superscripts are not statistically different at $P<0.05$.

Buckling feeding experiment

The effects of dietary treatment on daily weight gain and dry matter intake per kg metabolic bodyweight were very highly significant ($P<0.001$). Average daily gains of 38, 43 and 43 g were recorded for animals fed on diets A, B and C respectively. The difference in weight gain was not statistically significant ($P>0.05$), indicating that a diet of sugar-cane tops in combination with Leucaena was at least comparable to the control diet.

Animals fed diet C had the lowest dry-matter intake (kg $W^{0.75}$), which was significantly lower ($P<0.05$) than the values of diets A and B. However, the best efficiency of feed utilization (kg feed dry matter per kg mass gain) was observed for diet C, implying that this diet, despite the low level of dry matter intake (g/kg $W^{0.75}$), was more efficient. This could possibly be attributed to the more balanced nutrient intake in this treatment

in which selection for the individual feed components was minimal. Selection of feed components in favour of Leucaena was more pronounced in diet B.

Female goat feeding experiment

Dietary treatment exerted a highly significant effect on dry matter intake/kg $W^{0.75}$. Animals fed diets B and C consumed significantly ($P<0.05$) more dry matter than animals fed the control diet. However, the daily weight gain recorded indicated only a negligible difference among the various treatments. The poorest efficiency of feed utilization was noted for animals on diet B, while the values for animals on diets A and C were similar.

Carcass characteristics

The slaughter and dissection data are presented in Table 3. Dietary treatments exerted a significant influence ($P<0.05$) on most of the parameters investigated. On the other hand, the duration of feeding (60 or 100 day period) influenced only the dressing rate ($P<0.01$) and the weight of the loin ($P<0.05$) significantly. It must be noted that animals fed diet B yielded consistently higher values for all the parameters, which were, however, not significantly different. Significantly higher values ($P<0.05$) for all parameters were recorded for animals reared on diet C. This can be attributed not only to the dietary treatment but also the higher slaughter weight. The fact that few differences exist among the three dietary treatments is shown in Table 4.

Table 3. The effect of dietary treatments on carcass characteristics.

	Dietary treatment		
	A(n=5)	B(n=6)	(Cn=5)
Liveweight at slaughter (kg)	11.6	12.7	15.9
Cold carcass weight (kg)	4.6a	4.8a	6.6b
Dressing rate (%)	36.5a	38.8a	43.2b
Neck (kg)	0.4a	0.5a	0.7b
Shoulder (kg)	0.8a	1.0a	1.4b
Thorax (kg)	0.9a	1.1a	1.4b
Loin (kg)	1.0a	1.2a	1.7b
Hind leg (kg)	0.4a	1.1a	1.5b
Meat (kg)	2.7a	3.1a	4.5b
Bone (kg)	1.1a	1.4ab	1.7b
Fat (kg)	0.1a	0.1a	0.3b
Meat:bone ratio:1	2.3	2.3	2.8

Treatment means with common superscripts are not statistically significant at $P<0.05$.

Table 4. Relative proportion of the carcass joints and tissues (% of cold carcass weight).

Cold carcass weight (kg)	Dietary treatment		
	A 4.05+0.3	B 4.76=1.09	C 6.63+1.2
Carcass joint			
Neck	10.7	10.1	10.3
Shoulder	19.3	20.4	20.4
Thorax	22.0	22.3	21.0
Loin	24.2	22.4	25.0
Hondles	23.2	23.1	22.9
Carcass tissues (%)			
Meat	65.7	65.3	68.3
Bone	28.2	28.8	25.0
Fat	3.2	2.7	3.9

DISCUSSION

The results of this study indicate that sugar-cane tops, a waste product of sugar-cane production, available in considerable quantities, could be used to formulate rations that sustain reasonable levels of growth in fattening goats. Sugar-cane tops are deficient in protein but can be successfully supplemented with the locally available legume, Leucaena leucocephala, to provide a balanced diet at a cost reasonable for economic production.

The dry-matter intake/kg $W^{0.75}$ of the bucklings is in agreement with the data compiled by Devendra (1980) for tropical breeds, and other breeds introduced in the tropics, and those of Rekib (1979) for certain Indian breeds. The dry-matter intake was generally lower in comparison with other published values for temperature breeds and lactating animals. However, it is known that temperate breeds and lactating animals are capable of consuming higher levels of dry matter.

Average liveweight gains recorded are comparable to some data on tropical breeds (Singh and Senghor, 1970; Devendra and Chenost, 1973; Darbadaho et al, 1976; Fielding, 1977), but well below other published figures (Campbell, 1977; Naude and Hofmeyer, 1981). These depressed growth rates may be attributed partly to the inherent, relatively low, genetic growth potential, to some degree of inbreeding and to unfavourable climatic conditions prevailing during part of the experimental periods. The commonly observed depression in growth rate after weaning (from the fourth to the eighth month) as reported by McDowell and Bone (1977) could also have played a role.

The generally poorer efficiency of feed utilization of the female goats fed sugar-cane tops and Leucaena diets may, to some extent, be explained by the relatively lower levels of dry matter intake and/or growth rates. That high feed intake and high growth rate positively affect feed utilization efficiency is adequately

supported by Fehr et al (1976) and Naude and Hofmeyer (1981). The feed conversion efficiency obtained in this study partly agrees with the findings of Devendra (1967) who recorded feed conversion ratios of 9.0, 10.5 and 16.7 for the Kambing Katjang breed fed a high, medium and low plane of nutrition.

Comparable efficiency of feed utilization was obtained by Wilson (1985) and more favourable data were reported by Ueckermann (1969) and Naude and Hofmeyer (1981) using improved breeds and better planes of nutrition.

The absence of any symptoms of Leucaena poisoning may be an indication that the animals possess certain micro-organisms in the rumen capable of degrading the toxic principle of the Leucaena, as reported by Jones (1981).

The results of the dressing rate are generally similar to the values obtained for tropical breeds by several authors (Ghanekar et al, 1973; Owen and Norman, 1977; Laor, 1978; Fielding, 1980). These results also agree with the fact that, to a certain extent, the dressing rate increases with increasing slaughter weight and age.

Jointing procedure, no doubt, has an effect on the percentage of the various joints in the cold carcass. The adoption of jointing procedures recommended by Owen and Norman (1977) yielded proportions of the various joints comparable with those of the authors. The percentage of meat in the cold carcass was found to be more favourable in animals fed sugar-cane tops and Leucaena as a mixture. This is possibly due to a better energy/protein ratio, whereas the percentage of fat was slightly higher than the values for diets A and B. The published data (Owen, 1975; Fehr et al, 1976; Gall, 1982) on the percentage of carcass tissue in the cold carcass are in agreement with the results obtained in this study. However, the meat to bone ratio tended to be lower, probably due to the relatively poor body conformation of the animals.

CONCLUSIONS

It may be concluded that the use of sugar-cane tops, adequately supplemented with Leucaena, appears to be technically feasible as a feed for fattening goats, However, further investigations are required to assess its economic feasibility and to determine the most appropriate mode of presentation of the feed components to goats, given the particular feeding habits of these animals. Further research is required on processing methods, on the possibility of upgrading sugar-cane tops by micro-biological treatment, and on developing proper methods of preserving sugar-cane tops for the inter-crop season.

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LEUCAENA LEAF HAY LEUCAENA (LEUCAENA LEUCOCEPHALA CV PERU) AS PROTEIN SUPPLEMENT FOR MALAWIAN GOATS FED CHOPPED MAIZE STOVER

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SUMMARY

Four male Malawian local goats weighing about 16 kg each were used in a 4 x 4 latin square design experiment to investigate the effect of Leucaena leaf hay (91.9% DM, 25.8% CP) supplementation on the voluntary intake and digestibility of maize stover (93.1% DM, 4.4% CP). The treatments were: (A) ad libitum maize stover (AS); (B) A + 100 g Leucaena hay/goat/day; (C) A + 200 g Leucaena hay/goat/day (LS 200); (D) A + 300 g Leucaena hay/goat/day (LS 300).

With increasing levels of Leucaena hay supplementation, daily water intake increased significantly ($P<0.05$), total dry matter increased ($P<0.01$) from 176.4 g/day to 393.0 g/day, daily crude protein intake increased ($P<0.01$) from 7.5 g/day to 66.2 g/day and daily maize stover dry matter intake decreased ($P>0.05$) from 176.4 g/day to 163.0 g/day.

The apparent digestibility coefficients for organic matter and crude protein were significantly ($P<0.05$) higher from treatments LS 200 and LS 300 compared with treatment AS.

INTRODUCTION

Supplementation with high protein forages has been shown to increase the efficiency of utilization of crop residues by ruminants (Mosi and Butterworth, 1983; Kang et al, 1982). Leucaena leucocephala is a tropical forage legume which is rich in protein and which has consequently become important in the world of research as a protein supplement for ruminants fed poor quality roughages such as maize stover (Jones, 1979; Devendra, 1983, 1984). The objective of this study was to investigate the effect of Leucaena leaf hay on the intake and digestibility of maize stover by Malawian local goats.

MATERIALS AND METHODS

Four male Malawian local goats (about 16 kg each) were used in a 4 x 4 latin square design experiment lasting 56 days. At the beginning of the experiment, the animals were drenched with Ranide (Merke, Sharpe & Dohme) to ensure freedom from endoparasites and were then confined in individual metal crates throughout the experimental period. The treatments were: (A) ad libitum chopped maize stover (AS); (B) A + 100 g Leucaena

hay/goat/day (LS 100); (C) A + 200 g Leucaena leaf hay/goat/day (LS 200); (D) A + 300 g Leucaena leaf hay/goat/day (LS 300). The experiment was divided into four 14-day periods, each consisting of a 9-day preliminary period followed by a 5-day measurement period. The Leucaena leaf hay was given to the animals at 08.00 h daily and the maize stover was offered 3 hours later. No mineral supplements were given and clean drinking water was made available daily. Feeds (both offered and refused) and faecal samples were analysed for dry matter, ash and crude protein using AOAC 1970 procedures. Data were compared using the Duncan's multiple range test.

RESULTS AND DISCUSSION

Proximate analyses of the maize stover and Leucaena leaf hay used are shown in Table 1. The data on voluntary intakes of goats fed chopped maize stover as affected by Leucaena leaf hay supplementation are presented in Table 2.

Table 1. Proximate analysis of feeds used in the experiment (on dry matter basis).

	Maize stover	Leucaena leaf hay
Dry matter (%)	93.13	91.95
Organic matter (%)	94.71	89.30
Crude protein (%)	4.38	25.38

There were significant differences ($P<0.05$) between treatments in daily water intake. The range was from 3.37 to 6.05% of bodyweight per day. Treatment A was significantly ($P<0.05$) lower than the other treatments, but there were no significant ($P>0.05$) differences between treatments B, C and D. Increasing Leucaena leaf hay supplementation decreased ($P>0.05$) the daily stover dry matter intake expressed as g/day or g/kg W 0.75/day or kg/100 kg bodyweight. This could have been due to substitution effects. However, increased Leucaena leaf hay supplementation significantly ($P<0.01$) raised the total daily dry-matter intake by goats fed maize stover. This is similar to the findings of Hulman and Preston (1981) who reported a significant increase in daily total dry matter intake in ruminants when sugar-cane was supplemented with Leucaena forage. Treatment C seemed to be the level of Leucaena supplement (200 g Leucaena hay/goat/day) that resulted in optimal total dry-matter intake (41.74 g/kg W 0.75/day) (Table 2). The results reported in Table 2 indicate significant ($P<0.01$) increases in the daily crude protein intakes (7.51-66.19 g/day or 0.89-8.36 g/kg W 0.75/day). The optimum Leucaena leaf hay supplementation (treatment C) constitutes approximately 33.3% of the total diet. Cochran et al (1984) reported that Leucaena forage can be used successfully at levels of 30-40% of the total diet of goats consuming poor quality roughage.

Leucaena leaf hay supplements had no significant ($P>0.05$) effect on dry matter digestibility; however, the values increased from 45.77% to 54.27% with Leucaena leaf hay supplementation.

Table 2. Voluntary intakes of goats fed chopped maize stover as affected by leucaena leaf hay supplementation.

	Level of leucaena leaf hay supplementation			
	0g	100g	200g	300g
Daily free water intake				
kg	*0.57b	*0.75ab	*1.00ab	*1.02a
kg/100 kg body weight	*3.37b	*4.88ab	*6.05a	*5.65a
Daily dry matter intake (stover)				
g	176.35	171.54	171.83	163.12
kg/100 kg body weight	1.03	1.03	1.02	0.89
g/kg $BW^{0.75}$	20.81	20.69	20.54	18.34
Daily dry matter intake (total)				
g	176.35b	260.26b	348.15a	393.01a
kg/100 kg body weight	1.03c	1.58b	2.08a	2.15a
g/kg $BW^{0.75}$	20.81c	31.65b	41.74a	44.13a
Daily crude protein intake				
g	7.50c	30.72b	53.11a	66.18a
g/kg $BW^{0.75}$	0.88d	3.77c	6.48b	8.36a

Means followed by different letters in the same row differ significantly ($P<0.01$) or *($P<0.05$).

Organic matter digestibility was significantly (P<0.05) increased from 59.23% to 75.95%, and crude protein digestibility (P<0.05) increased from -50.58% to 55.4% with Leucaena leaf hay supplementation. However, there were no significant (P>0.05) differences among treatments B, C and D (Table 3). The increased organic matter and crude protein digestibilities with Leucaena leaf hay supplementation obtained in the present study agrees with the findings of Devendra (1984) who reported a significant increase in organic matter and crude protein digestibilities by replacing rice straw with 30% Leucaena leaf hay in goats fed rice straw alone.

Table 3. Nutrient digestibilities of chopped maize stover by goats as affected by Leucaena leaf hay supplementation.

	Level of supplementation			
	0g	100g	200g	300g
Dry matter (%)	45.77a	50.86a	47.97a	54.26a
Organic matter (%)	59.23b	71.82b	66.52b	75.94a
Crude protein (%)	50.58b	36.91a	42.02a	55.40a

Means followed by different letters in the same row differ significantly (P<0.05).

The results of the study reported here indicate that Leucaena leaf hay can be successfully used as a protein supplement for Malawian local goats commonly fed low quality forages/roughages such as maize stover, bean pods and rice straw during the dry season.

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PERFORMANCE OF BEEF CATTLE FATTENED ON CROP RESIDUES AND CROP BYPRODUCTS IN MALAWI

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INTRODUCTION

The Republic of Malawi is a landlocked country. It lies between 9 and 17° latitude and 33 and 36° longitude. It is approximately 900 km long and 200 km across at its widest point. Total area is about 118,000 km^2. The country shares common boundaries with Tanzania, Mozambique and Zambia and has a population estimated at 6.12 million in 1981. The annual population growth rate is approximately 2.6%.

More than 90% of the population live in rural areas and depend on small-scale agricultural production. Size of holdings varies from region to region (1.72, 1.81 and 1.96 ha in the south, central and north respectively). The population is concentrated in the southern (50%) and central (36%) regions where pressure on land is becoming increasingly severe. This has prompted the intensification of both crop and livestock production.

The beef industry in the country is partly constrained by the small size of the national herd which is estimated at 930,000 head of cattle. This is owned by about 10% of the population which means there is a heavy, localised concentration of cattle which has resulted in the rapid degradation of grazing areas. This situation, in addition to traditional systems of management, makes improvements very costly and not readily acceptable to the cattle owners.

OBJECTIVE OF THE SCHEME

A stall-feeding scheme started in one of the districts in southern Malawi in 1957. Until 1963 it remained fairly static. The prime objective in those days was the production, not of high grade beef, but of farmyard manure in order to increase crop yields on the very small holdings in the highly populated areas. In 1963, however, Malawi had to start importing beef which meant a drain on foreign exchange. It was therefore decided to expand the scheme throughout the highlands of the southern part of Malawi and then to the central part where more crop residues were available.

Other objectives included:

* Intensification of rural animal production through the utilization of crop residues and byproducts;
* Promotion of the integration of crop and livestock production;
* Reduction of land pressure by finishing steers in pens.

OPERATION OF THE SCHEME

Briefly, the scheme is run as follows. A livestock marketing officer, on behalf of the Ministry of Agriculture, buys cattle at the local markets organised by the Department of Animal Health and Industry. Under normal conditions, steers qualifying for stall-feeding are those which have attained minimum liveweights of 227 and 300 kg for Malawi zebu and exotics respectively, and have two to four permanent teeth. The steers are taken to government holding stations where they are checked for diseases and dosed for internal parasites.

The Department of Animal Health and Industry maintains livestock breeding units and also supplies steers to the stall-feeding scheme. Lists of available steers are sent to the animal husbandry officers who allocate them to farmers. At all times the steers belong to the Ministry of Agriculture. The animal husbandry staff advise on proper feeding. Farmers each receive a pair of steers to fatten for a minimum period of 150-180 days, before selling them to the cold storage company.

Feeding standards

During the early years of the scheme, Bvumbwe Agricultural Experimental Station recommended the following ration (%):

Maize bran	59
Maize meal	20
Pigeon pea	17
Meat and bone meal	3
Salt	1

Use of this ration did not spread far and was very soon discontinued because of the escalating prices of the ingredients and competition with human food requirements. In the later years of the scheme, work concentrated on determining the nutritive values of crop residues and testing these on stall-fed steers to assess their performance and to evaluate the economic feasibility of feeding crop residues and crop byproducts. These have remained the main feeds until now. Table 1 indicates the approximate percentages of crude protein and crude fibre in the common feeds in the stall-feeding scheme.

Table 1. Crude protein and crude fibre percentages for the feeds used in fattening steers.

Feed	Crude protein %	Crude fibre %
Maize bran	10.7	5.5
Maize stover	3.2	30.6
Groundnuts haulms	11.2	39.9

Source: Empel, van G and Frank P J (1979) FAO working paper no. 25, UNDP: Government of Malawi (unpublished).

The crop residues and byproducts are fed ad libitum. In the southern part, green forages (e.g., a local species of Napier grass) are fed in addition. In principle, each steer should receive 4 kg of maize bran daily up to finishing time. This feed is at present in short supply, especially since a smallholder dairy programme also uses maize bran as a major feed ingredient.

Data on stall-feeding in Malawi are presented in Tables 2, 3 and 4 (Agyemang et al, 1984).

Table 2. Mean values and standard deviations (SD) for various parameters of animal performance.

Measure	Blantyre area		Lilongwe area	
	Mean	SD	Mean	SD
No. of steers	2498		2985	
Initial weight (kg)	298	20.2	271	22.5
Final weight (kg)	401	48.2	370	44.2
Carcass weight (kg)	210	27.6	194	23.3
Dressing percentage	52.3	2.2	52.3	1.4
Daily weight gain (kg)	0.59	0.48	0.50	0.22
Total days on feed	188	52.8	213	54.4

Table 3. Least square means for initial and final weights (Blantyre).

		Liveweight (kg)	
	No.	Initial	Final
Overall	2498	298	399
Breed group:			
Local zebu	749	235	339
Crossbred exotics	1021	292	392
Exotics	728	369	467
No. of teeth:			
0	291	293	396
2	1195	302	401
4	852	292	399
6	160	300	402
Month at start of feeding:			
January	190	301	414
February	123	300	402
March	445	303	413
April	230	305	412
May	297	291	399
June	380	300	406
July	125	300	389
August	153	395	382
September	107	298	393
October	261	292	392
November	111	298	370
December	76	297	411

Table 4. Least square means for liveweight gain, days on feed and carcass grade.

	No.	Liveweight gain (kg)	Days	Grade
Overall	2498	0.56	193	1.5
Breed group:				
Local zebu	749	0.54	201	1.8
Crossbred exotics	1021	0.55	194	1.5
Exotics	728	0.60	182	1.2
No. of teeth:				
0	291	0.57	204	1.5
2	1195	0.58	191	1.4
4	852	0.54	197	1.4
6	160	0.56	178	1.5
Month at start of feeding:				
January	190	0.57	214	1.4
February	123	0.59	173	1.4
March	445	0.60	184	1.3
April	230	0.77	183	1.6
May	297	0.64	177	1.3
June	383	0.63	175	1.6
July	125	0.55	179	1.7
August	153	0.51	202	1.6
September	107	0.53	186	1.4
October	261	0.45	234	1.5
November	111	0.36	220	1.7
December	76	0.56	184	1.1

Initial weight

Initial weights depend on breed type, age of steer (as shown by the number of permanent teeth) and the month and year the steers are put in stalls.

Three types of breeds are issued to farmers: exotic (Brahman, Sussex and Friesian steers), mixtures of the exotics (crossbreds) and Malawi Zebu. The first two are issued to farmers at minimum weights of about 300 kg. Malawi zebu steers with six or more teeth are fully grown and are very likely to be issued at weights greater than the 227 kg for Malawi zebu steers with four teeth or less. During adverse weather conditions feed resources are inadequate and most steers lose weight and go into the stalls in rather poor condition.

Final weight

The breed of steer and time of year it is put in the stall affects the final weight. Bigger breeds normally end up with higher weights than the Malawi Zebu. Feeding levels are controlled by the feed resources available and the attitude farmers have to the breed. In times of adequate resources, soon after harvest, steers receive more feed. Some farmers prefer the

bigger breeds claiming they give a higher economic return. Considering the size of these steers, this claim is doubtful when it comes to the feed input and the gross margins, which are normally low.

Daily weight gain

Feed resources seem to influence weight gain. A difference is clear between the south, where variations according to time of year are conspicuous, and the central region, where feeding seems to be uniform throughout the year. Weight gain is greater in the south where steers have frequent access to green forages. Differences between breeds are negligible.

Total days in stall

Malawi zebu steers tend to stay longer in stalls and nearly all those in the south come from the rural herd which is under a communal grazing system characterized by low quality grasses. These steers are normally first to recover from grazing stress. Steers with two or no teeth are still in their high growth wave and take longer to finish regardless of the high initial weights. Underfeeding and grazing effects are probably the cause of this long stay in stalls.

Carcass grades

Exotic steers have grades of "choice" and "prime". Steers with four or more teeth normally have their carcasses down-graded due to too much fat deposition. Steers that do not finish completely, due to inadequate feeding, have low grades.

CONCLUSION

The Malawi zebu could be considered the most profitable breed to use in the stall-feeding programme given the existing feed resources. The breed is adapted to make use of the limited crop residues and natural grasses available in the country. The country is self-sufficient in high-grade meat and therefore no imports of beef are needed. The abattoirs in the country obtain their slaughter cattle from cattle markets, stall-feeding and dairy steers. Stall-feeding contributes about 20% of the total slaughter in these abattoirs.

Integration of livestock production and cropping is becoming more accepted because the manure produced by the steers in stalls, once applied to the soil, sometimes raises yields more than the use of chemical fertilizers. Pressure on land is eased because the scheme allows steers to be removed early from the communal grazing land and be finished in pens. The scheme provides an income for the small-holder farmers who use it to buy more inputs to increase crop yields.

The average total meat consumption per year is about 5500 tonnes. Some 10% of this meat comes from the stall-feeding scheme.

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MAIZE STOVER IN MAINTENANCE DIETS FOR SHEEP AND GOATS IN CAMEROON

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SUMMARY

Maize stover/oilseed cake diets fed to sheep and goats showed that maize stover/cottonseed cake diet was consumed more than ($P<0.01$) maize stover/groundnut cake diets. Sheep ($P<0.01$) consumed significantly more feed than goats. Mortalities were higher in goats than sheep. In vivo percent digestibility coefficients showed that maize stover/brewers wet grain silage was comparable to alkali-treated low quality roughages.

INTRODUCTION

The northwest and western provinces of Cameroon produce about 800 t of maize and about 600 t of rice annually. Thus about 3080 t of farm residues (maize stover, maize cobs, rice straw, rice bran, etc) are available (Fomunyam 1984). In these regions two million sheep and goats are tethered during the cropping season (mid-March to mid-October) and, during the months after harvests, are extensively grazed in crop fields while the daily diet is supplemented with household refuse such as cocoyam, plantain, banana and cassava peels, maize or rice bran, brewers grains, oilseed cakes, etc.

This management system is self-limiting in that herd sizes are small. Reproduction is not controlled and is frequently affected by poor nutrition. Females are randomly bred and young are born small and weak. Mortalities are high for adults and young alike. Bush fires in the dry season reduce available feed to almost nothing and weight losses increase.

Moreover, there is an increased trend towards two-season cropping (i.e., producing food in both the rainy and dry seasons) in order to increase production to meet the demand of a population growing at an annual rate of 2.4%. Also, more and more of the grazing land will inevitably be needed to ensure extensive cultivation of food crops. In the final analysis, then, sheep and goats must be confined.

The consequence of these constraints is that sheep and goat farmers are tending to reduce their already small herd sizes from a range of 5-10 to about 1-2, or are completely replacing small ruminant production with non-ruminant production.

In order to establish feeding packages for sheep and goats in the dry season, a series of studies have been initiated in an attempt to quantify village sheep and goat feeding patterns.

MATERIALS AND METHODS

In the first of two trials, 12 grassland dwarf sheep and goats, 6 months old, with an initial average weight of 14-16 kg, were fed field-dried maize stover supplemented with either cottonseed cake or groundnut cake in a 2 x 2 factorial. The maize stover was hand-chopped in 3 cm pieces and fed free choice in an 80:20 maize stover/oilseed cake ratio for 12 weeks (Table 1). Salt and water were provided ad libitum.

Table 1. Composition of maize stover/oilseed cake diets fed sheep and goats (%).

Components	Diet I	Diet II		
	Maize stover groundnut cake	Maize stover cottonseed cake	Maize stover at harvest	Maize stover field-dried
Moisture	7.5	6.6	20.9	5.9
Crude protein	15.2	13.7	6.8	5.6
Crude fibre	30.3	47.4	30.2	36.2
Ether extract	3.3	2.2	2.7	1.7
Organic matter	83.2	92.8	92.2	96.8

In a second trial, 3 cm maize stover pieces and brewers wet grains (60% DM) mixture were ensiled in a pit 90 cm x 150 cm x 90 cm. The pit was lined with plastic sheets. Each layer was packed by four men trampling on the material and the final layer was covered with plastic sheets, banana/plantain leaves and earth 30 cm high. The chemical composition of the mixture was: dry matter, 59.1%; crude protein, 7.8%; crude fibre, 26.2%; ether extract, 3.2%.

Digestibilty trials, using six adult grassland dwarf rams full-fed, were carried out. An 8-day collection period followed a 10-day feeding period. Faeces and feedstuffs were separately dried in a forced draught oven and pooled for analysis.

RESULTS AND DISCUSSION

Table 2 shows that the maize stover/oilseed cake diets were poorly consumed by sheep and goats and at maintenance levels only, although the ruminants consumed significantly ($P<0.01$) more of Diet I than Diet II. Sheep ate significantly ($P<0.01$) more of the diets than goats. Weight gains and percent mortalities of animals followed the same pattern as for feed intake.

The low intakes and subsequent weight gains show that the diets were not very palatable, as has already been shown by several authors feeding low quality forages (Orskov, 1977; Theander, 1981).

The increased intake of cottonseed cake-based diet rather than groundnut cake-based diet, might be because cottonseed cake

Table 2. Feed intake, weight gain and percent mortalities of sheep and goats fed maize stover/oilseed cake diets.

Diet	Species	Daily feed intake (g DM/ animal)	Daily weight gain (g/animal)	Percent Mortality
I	Sheep	201.0y	0.4y	16.7y
	Goat	129.5x	0.04x	67.3z
II	Sheep	225.5y	2.5z	0.0x
	Goat	147.6x	0.6y	16.7y
	S.E.M.	15.24*	0.25*	5.7*
Dietary means				
I		164.7x	0.2x	42.0x
II		201.6y	1.6y	8.4y
S.E.M.		7.12*	0.6*	3.2*
Animal species means				
	Sheep	228.3y	1.5y	8.4x
	Goat	137.5x	0.3x	42.0y
	S.E.M.	7.12*	0.6*	3.2*

x, y, z: Means within columns followed by the same letters are not significantly different at P<0.01.
* Significant.

is less oily (3.9% ether extract) than groundnut cake (11.6% ether extract) and thus more palatable. The general low intakes of both diets may be due to the bulkiness and dryness of the maize stover, although the ruminants have been observed nibbling at the stover in maize fields and in this experiment.

Devendra and Burns (1970) observed that the feeding habits of goats were unlike those of other ruminants; goats often prefer browse plants and low quality herbage. It could be expected from this that goats would consume more of the present diets than sheep but the reverse was observed. Bell and Lawn (1957), Chaudhary and Majinndar (1962) and Devendra (1967) have shown that digestion in goats is similar to the digestion of sheep and other ruminants. It is not clear why the daily feed intake by goats has been so poor but the mortalities must have been due to this low intake.

Table 3 shows that the digestibility of maize stover/brewers wet grains silage was similar to results obtained by other workers from alkali-treated maize stover. Mehrez et al (1981) showed that dry matter digestibilities of 61.0% and 60.3% for alkali sprayed or soaked maize stalks were comparable to results observed in this study. However, crude fibre values of 74.7% and 75.1% from their study were higher than values of 62.3% observed in this study, but crude protein values were 45.5% and 26.5% in their study - much lower than values of 63.8% in the present study. The observation of Guggolz et al (1971) showed that dry matter digestibillty of 60% for 5% ammonia-treated maize stover was similar to the present results.

Table 3. In vivo digestibility coefficients (%) of maize stover/brewers wet grain silage.

Digestibility coefficients	Percent
Dry matter	57.2
Crude protein	63.8
Crude fibre	62.3
Ether extract	77.5

In the above studies, the diets were supplemented with protein sources as well as mineral supplements, whereas in this study, salt was the only added nutrient. In related studies, digestibility values of sodium hydroxide-treated Hyparrhenia (Katagile, 1981) and ensiled treated alkali straw (Garmo, 1981) were similar to values obtained from these studies.

It should be noted that although the above diets are not fed for a considerable time by farmers, several combinations of diets are fed interchangeably and probably the nutrient requirements, at least for maintenance, are met by these diets.

Considering that Cameroon does not produce chemicals, it is suggested that the improvement of these diets, as outlined above, would be economically feasible because there would be a reduced loss of foreign exchange from importing chemicals and reduced pollution of the land via chemicals in wash water from treated roughages. The technology of these improved feeding patterns can be easily adopted by farmers, in contrast to transferred technologies of sophisticated roughage treatment methods.

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THE USE OF CROP RESIDUES IN LIVESTOCK PRODUCTION SYSTEMS IN THE COMMUNAL AREAS OF ZIMBABWE

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SUMMARY

The basis of animal production in Zimbabwe is natural grazing from the range. The quantity and quality of grazing fluctuate with the rainy season which is from November to March. For the remainder of the year, grazing is very poor and in communal areas the situation is further aggravated by very high overstocking rates, with a national overstocking rate of 64%. Communal areas are located in regions IV and V where rainfall is low (less than 510 mm) and soils are poor. Crop residues assume great importance in decreasing the level of feed deficit, but the quantities vary and depend mainly on rainfall. The main crop residues used are maize and sorghum stover and legume haulms, mainly groundnut. Most stovers are fed to animals in situ, but some farmers harvest and store these residues to feed to their animals later in the year. Generally, these residues are fed without any attempt to improve their nutritive value, save for a salt lick in some cases. There is potential for improving the feeding of these residues by use of such simple measures as supplementation with poultry litter, legume haulms and physical processing.

INTRODUCTION

The basis of cattle production in Zimbabwe is natural grazing from the veld (range). The seasonal fluctuations in the quality and quantity of natural grazing follow the seasonal rainfall distribution. With the advent of the warm, rainy season in November there is regrowth of highly nutritive grass but its quality declines progressively as the season advances to the dry winter in April. The decline in quality of grazing is due to a drop in the crude protein content of veld herbage from about 15% early in the Zimbabwe summer to about 3% by the end of May (Elliott, 1964). The situation in the communal areas is further aggravated by very high overstocking rates. Without the use of crop residues, especially maize stover, during the dry winter months the level of animal production would be far lower than it is.

AGRO-ECOLOGICAL REGIONS AND CATTLE DISTRIBUTION

Zimbabwe is divided into five agro-ecological regions based mainly on the quantity of rainfall and the type of agricultural production they can support. Details of these regions may be found in the publication by Vincent and Thomas (1960). The distribution of rainfall ranges from more than 710 mm in region I to less than 410 mm in region V. Most communal areas are in

regions IV and V with annual rainfall figures of 510 mm and below. The total livestock numbers correspond to the land mass distribution, and the recommended livestock carrying capacities decrease from 4 ha per livestock unit (LU) in region I, to 12 ha per LU in region V.

With 25% of overall communal land area under cultivation, there is a national overstocking rate of 64% (Sandford, 1982). This varies with the province, being highest in Masvingo (170%) and lowest in Mashonaland (6% understocked). In some areas, stocking rates may be as high as 15 times the recommended levels (Agritex, 1983).

QUANTITIES OF CROP RESIDUES PRODUCED IN COMMUNAL AREAS

The quantities of the different crop residues produced depend on the total area cultivated and the quality of the season, as well as other inputs such as fertilizers. It is very difficult to give an accurate estimate of the quantities. The main crop residues are from maize, sorghum, bulrush millet, finger millet and legume crops such as groundnuts and bambara nuts.

The annual economic review issued by the Agricultural Marketing Authority (1983) gave figures for grain production from maize, sorghum, soybean and groundnuts for 1980/81 and/or 1981/82.

Assuming that the grain yields are equivalent to the stover or crop residues, it follows that maize stover ranges from about 665 000 t to just over 2 000 000 t, sorghum 40 000 t, soybean 677 000 t and groundnuts 71 100 t at least. The allocation of cultivated land to the different crops is not constant every year but maize occupies the bulk of it. In one survey carried out in Mashonaland East, maize occupied 68% and groundnuts 12% of the cultivated area, the rest being cultivated with bulrush and finger millet (PTA, 1982).

USE OF CROP RESIDUES AND IMPACT ON PRODUCTIVITY

According to Mombeshora et al (1985), crop residues constitute a major source of feed for livestock in communal areas. Some farmers leave the crop residues in the field while others harvest the stover and store it for feeding in the dry season. The residue used most frequently is maize stover. The proportion of farmers harvesting stover before feeding varies from one area to another. In a survey carried out in two communal areas, Mombeshora et al (1985) found that in Mangwende only 17% of cattle owners harvested or stored crop residues compared with 96% in Chibi. The picture is therefore far from uniform throughout the country.

Differences are also found in the importance of harvested crop residues as a source of livestock feed or as manure or bedding, depending on whether the stover is from grain or legume crops. In Chibi, more farmers prefer grain stover as feed rather than bedding and vice versa in Mangwende. Legume stover, despite its higher nutritive value, is preferred primarily for bedding in both areas.

It is possible that farmers who do not collect their stover, but leave it in the field, lose half its value through trampling by the animals.

Pen fattening of cull cows and old oxen is practised sporadically by individual farmers using crop residues, homegrown grain and a purchased protein supplement.

There is very little evidence of differential feeding of crop residues to the more productive animals, such as draught oxen and milking cows. This area may be worth investigating. Similarly, no attempt has been made to improve the nutritive value of crop residues.

The impact of feeding crop residues on the productivity of communal area livestock is difficult to quantify. With an estimated average calving rate of 41%, and an offtake of 2%, (Sandford, 1982) productivity is very low. As most areas are severely overgrazed, the crop residues made available to cattle during winter play a major role in keeping animals alive. In some areas, nutritional stress may be more acute in summer since in winter cattle have access to cropping areas. It is possible that crop residues provide the main source of nutrients for half the year from about May to October. It is quite likely that without these residues cropping would be jeopardised since the condition of the draught animals at ploughing and planting would be far worse.

The potential value of unimproved crop residues, especially maize stover, may be shown from the results of a trial carried out at Grasslands Research Station. A herd of 60 cows, which was grazed on planted dryland star grass-legume pastures during the summer months (November to May), obtained all its feed from unharvested stover for the remainder of the year. Allowing a hectare of stover per cow these animals achieved a mean calving rate of about 85% over 5 calving seasons (Grant et al, 1985). The average calving rate in the absence of crop residues was 41% (Sandford, 1982).

SUGGESTED WAYS OF IMPROVING NUTRITIVE VALUE OF CROP RESIDUES

Very little research effort has been directed to improving animal production by feeding crop residues in communal areas. This work has been achieved by extension workers who advise the farmers to harvest and store their stover. A survey was made by the Farming Systems Research Unit in two communal areas mentioned already (Mombeshora et al, 1985). This survey and several others have shown several possible areas of intervention to improve the value and contribution of crop residues to animal production in communal areas.

Harvesting methods

It is known that the nutritive value of stover depends, among other factors, on the stage at which it is harvested. Early harvesting followed by grain drying may be beneficial. This needs investigating.

Supplementation of grain stovers with other residues

Legume stovers such as groundnut and soybean haulms have a higher nutritive value than grain stovers. It is worth determining what levels may be fed to improve animal gains on grain stovers, while the practice of intercropping grain legumes with maize to improve the nutritive value of stover may be worth studying.

The use of urea in drinking water, or sprayed on to stover, has been suggested as a possible means of improving the nutritive value of crop residues.

Strategic feeding of crop residues

This includes selectively feeding productive animals, such as draught oxen and milking cows, on harvested and stored stover. It is necessary to investigate the effect of feeding oxen, either throughout the winter season until the stover runs out, or just before and during the planting period.

CONCLUSION

The use of crop residues on their own is unlikely to provide sufficient forage for large numbers of animals. Methods aimed at improving nutritive quality will go a long way towards reducing the magnitude of the feed deficit. When the potential contribution of crop residues is taken into account, the level of overstocking in the communal areas is not as high as is normally depicted. However, the position gets worse every year as more and more grazing land is converted into arable land.

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STRATEGIES FOR OPTIMISING THE UTILIZATION OF CROP RESIDUES AND AGRO-INDUSTRIAL BYPRODUCTS FOR LIVESTOCK FEEDING IN THE TROPICS

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INTRODUCTION

In order to develop feeding systems it is necessary to relate information on the nutritional characteristics of feed resources to the requirements for nutrients according to the purpose and rate of productivity of the animals in question. In the industrialized countries, this information has been incorporated in tables of "feeding standards" which interpret chemical analyses of feed resources in terms of their capacity to supply the energy, amino acids, vitamins and minerals required for the particular productive purpose.

The relevance of feeding standards for developing countries, particularly those in the tropics, has been questioned from the socio-economic (Jackson 1980) and technical (Graham 1983; Preston 1983) viewpoints. It has been apparent for many years that feeding standards based on assigned nutritive values (e.g. net energy) are misleading when unconventional feed resources are used (e.g. Preston 1972; Leng and Preston 1976; Preston and Leng 1980), since the rates of production achieved may be considerably less than what was predicted. More importantly, this often led to the rejection of many available feed resources which were considered to be too low in digestible energy to support productive functions such as growth and milk production. It also encouraged researchers to copy feeding systems used in temperate countries which are relatively "predictable", but which require feed resources that are unavailable, and/or inappropriate on socio-economic grounds, in most developing countries.

ALTERNATIVE APPROACHES TO THE DEVELOPMENT OF FEEDING SYSTEMS

The justification for a new approach to the development of feeding systems for ruminants, not based on conventional "feeding standards", is that:

* The efficiency of the rumen ecosystem cannot be characterised by any form of feed analysis

* Feed intake on some diets bears no relationship to digestibility and is much more influenced by supplementation

* Availability of amino acids cannot be inferred from the crude protein content of the diet

* The energy value of a diet, and the efficiency of its

utilization, are largely determined by the relative balances of glucogenic energy, long-chain fatty acids and essential amino acids absorbed by the animal

The misconceptions inherent in any system based primarily on feed analysis are that it is almost impossible to predict:

* Whether the feed can support efficient rumen function

* The nature, amounts and the proportions of the end-products of fermentative digestion

* The potential for rumen escape of nutrients and their digestibility in the small intestine.

For these technical reasons, and also because of differing socio-economic circumstances, it has been proposed that a more appropriate objective, especially for developing countries, is to "match livestock production systems with the resources available" (Preston and Leng 1986).

This paper sets out the guidelines for applying these concepts to the development of feeding systems which aim to optimize the utilization of locally available feed resources and to build on traditional practices. Farming systems in developing countries are notoriously difficult to change and innovation must be introduced gradually without inducing excessive risk which may, in the poor conditions of small farmers, directly affect the well-being of the family.

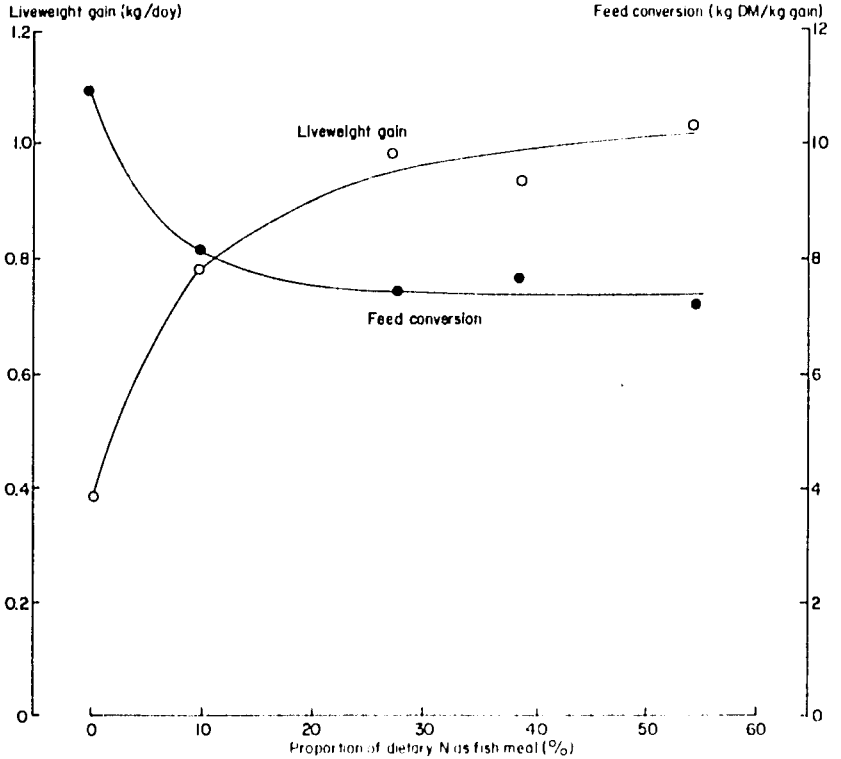
ANIMAL RESPONSE TO NON-CONVENTIONAL FEED RESOURCES

Doubts concerning the usefulness of conventional feeding standards for ruminants in tropical countries surfaced during development work in Cuba (Preston and Willis 1974) in the 1970s when livestock production systems were being established on non-conventional feed resources (i.e. molasses-based diets). In these cases, although nutrient requirements were satisfied, according to traditional feeding stanndards, the responses of the animals did not correspond to the predicted levels of performance.

This research demonstrated that small inputs of bypass protein (e.g. Peruvian fishmeal) increased dramatically growth rate and feed efficiency of fattening cattle (Figure 1). In contrast, this feeding system was not able to support hign levels of milk production (Figure 2), because of the greater demands of lactation for glucogenic compounds and the relative deficiencies of these in the digestion end-products on molasses-based diets because of the low-propionate, high-butyrate fermentation (Marty and Preston 1970).

The high potential yield of animal products per unit of land devoted to sugar-cane stimulated the subsequent research in Barbados, Mexico, Mauritius and the Dominican Republic aimed at establishing livestock production systems applying the principles which had been developed for feeding molasses (both feed resources have similar concentrations of soluble sugars) (see Preston and Leng 1978a,b).

Figure 1. *Addition of fish meal to a basal diet of molasses/urea and restricted forage improved growth rate and feed conversion. The response was curvilinear. (from Preston and Willis (1974).*



Research on the feeding value of derinded (Donefer E and James L, cited by Pigden 1972) and chopped (Preston et al 1976) sugar-cane demonstrated that:

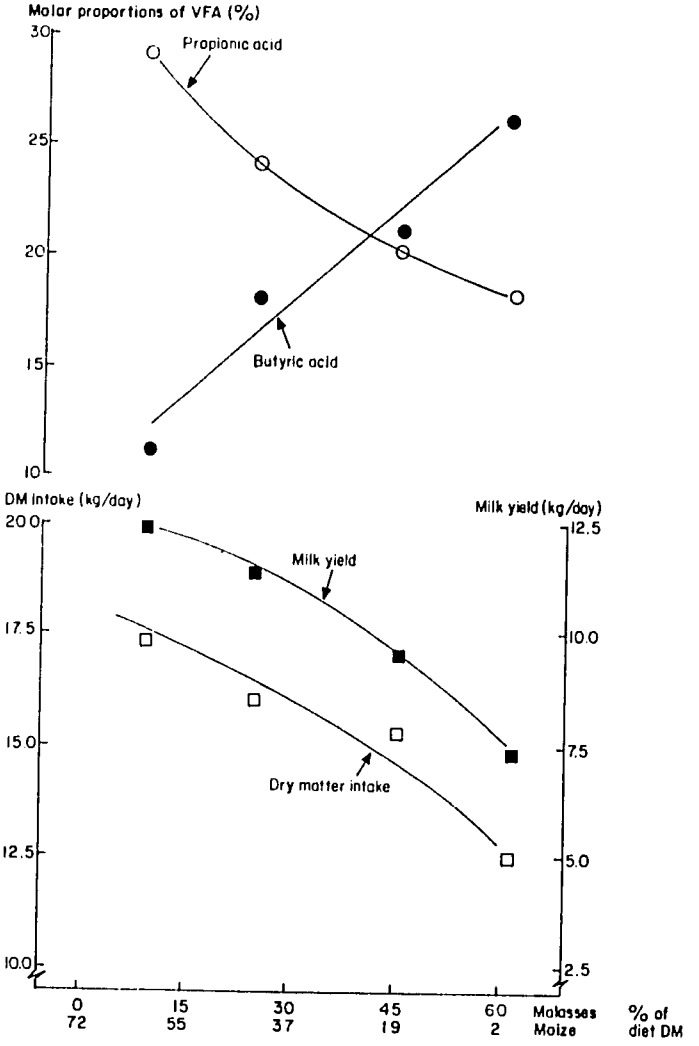
* Feed intake was often low even though digestibility was high (60-70%)

* The animals on this feed apparently needed glucose or glucose precursors because all the sugars are fermented, rumen propionate levels are no higher than observed on high-fibre diets, and the presence of a dense population of ciliate protozoa reduces the availability of microbial protein to the animal (Bird and Leng 1985).

The implication of these two findings is that rumen function did not provide the required balance of nutrients for productive purposes (see Leng and Preston 1976).

Recognition of the role of fermentable N and bypass protein in low-N diets led to research aimed at increasing productivity of cattle and sheep on a range of fibre- and sugar-rich low-N feeds (Leng et al 1977; Preston and Leng 1984). Prior to this work, these feed resources were considered to have little value other than to support maintenance and were universally referred to as 'low quality' fibrous feeds.

Figure 2. *Effect of replacing maize grain with molasses on the pattern of rumen fermentation, feed intake and milk yield in Holstein cows in Cuba. As dietary molasses increased, propionic acid decreased and there was a concomitant fall in dry matter intake and milk yield (from Clark et al 1972).*



This led to attempts to improve the digestibility of fibrous feeds by, in particular, alkali treatment (Jackson 1977, 1978). However, the value of alkali treatment was partly obscured by the failure to recognize that the first limitation was not digestibility but the imbalance of nutrients at the level of both the rumen and the whole animal (Leng 1982; Preston and Leng 1984).

Combining alkali treatment and appropriate supplementation has led to practical rice-straw-based feeding systems being applied on farms in Bangladesh (Dolberg et al 1981; Davis et al 1983) and Sri Lanka (Perdok et al 1982; Jayasuriya 1984).

The significance of these developments is not so much the use of molasses nor of straw in animal feeding, since both these feeds have been incorporated into diets of ruminants in industrialized countries for many years. The issue is the magnitude of the contribution of molasses and straw to the total dietary dry matter. In industrialized countries their contribution rarely exceeds 10-15% of the diet in the case of molasses, and 20 to 40% for straw, the rest of the ration being cereal grains, highly-fertilized grasses and legumes and oil seed cakes. In contrast, in developing countries the feeding regimes aim to use crop residues and agro-industrial byproducts as the principal component of the diet because these are the locally available resources; and there are restrictions on the use of grain for livestock feeding for financial, political and socio-economic reasons.

There are many reasons why crop residues, mature pastures and sugar-rich byproducts perform differently when fed as the main component of a diet than when fed as relatively minor components. Some of these differences can be explained on the basis of interactions and associated effects among nutrients, and between nutrients and the site of digestion.

NUTRITIVE VALUE

In order that responses in animal productivity to supplements can be predicted accurately on a particular diet, it is necessary to take account of the constraints to metabolism. These are the relative amounts of amino acids, glucogenic energy, VFA energy and long-chain fatty acid energy in the end-products of fermentative and intestinal digestion, since this is what determines the animal's productivity.

Productivity of ruminants is influenced primarily by feed intake which in turn is determined by feed digestibility and the capacity of the diet to supply the correct balance of nutrients required by animals in different productive states. The two major variables that need to be considered are:

* The amounts and balance of nutrients required

* The quantitative availability of nutrients from the diet

The balance of nutrients required depends upon:

* The amounts of dietary components unchanged by rumen fermentation that are absorbed (amino acids, glucose and long-chain fatty acids)

* The rates of production of the end-products of fermentative digestion (which can be highly variable)

* Productive functions (pregnancy, lactation, growth, work, maintenance, depletion or repletion of bodyweight)

* Environmental factors (disease, parasitism, temperature and humidity, and other sources of stress)

The availability of nutrients from a diet is highly dependent on:

* The microbial ecosystem in the rumen which influences the availability of microbial protein, VFA energy and glucogenic energy

* The chemical composition and physical form of the diet which influences the amounts of protein, starch and long-chain fatty acids which escape the rumen fermentation.

At the present time, it is not possible to match requirements of nutrients for production with the nutrients which become available from digestion, because of the many interactions among the animal, its rumen microbial ecosystem and the diet.

The most widely available low-cost feeds for ruminants in the majority of developing countries are usually native pastures, crop residues and to a lesser extent agroindustrial by- products. Fermentable nitrogen, as urea, is also relatively easy to obtain as it is usually the main source of fertilizer nitrogen. The expensive, and often unavailable (or exported), feeds are the protein meals, derived from oilseed residues and the processing of animals, fish and cereal grains.

The available feed resources are thus primarily sources of potentially fermentable carbohydrates and fermentable nitrogen. This emphasizes the fundamental role played by rumen function in feeding systems in developing countries, especially those in the tropics. The contrast with the industrialized countries is noteworthy since the utilization of their feed resources (dominated by starch-rich cereal grains and protein oilseed meals) depends to a much lesser extent on efficient rumen function. In fact, it is usually advantageous to promote escape of starches and proteins from the rumen so they can be digested in the intestine.

The first step in the strategy to promote efficient utilization of tropical feed resources is to maximize rumen function. This usually means maximizing the rate of degradation of cell wall carbohydrates (the exception is when sugar-rich molasses-based diets are used). Having derived the maximum benefit from rumen fermentation, in terms of the amounts of

volatile fatty acids and microbial protein, the next step is to balance these end products of digestion with the amino acids, glucose (and/or its precursors) and long-chain fatty acids which are needed, in varying amounts, for all productive functions such as work, growth, reproduction and lactation.

The potential of the diet to supply these needs will be governed by:

* The pattern of rumen fermentation, since this will determine the relative amounts of microbial protein to VFA that are produced and the proportion of propionic acid which is the main source of glucose;

* The amounts of protein, starch and fat in the diet (more usually in the supplement), and the extent to which these nutrients escape the rumen fermentation

The extent to which the protein in a supplement escapes the rumen is partly a function of its rate of degradation (solubility) in the rumen. It is likely to be influenced greatly by the rate of flow of fluid and small particles out of the rumen. This latter characteristic will be influenced by processing of the feed (by physical or chemical means), the presence of some green forage, the amount of protein reaching the duodenum and external factors such as temperature and exercise/work.

The same factors will influence the supply of glucose and glucogenic precursors in terms of the likely bypass of starch to the duodenum. However, the nature of rumen fermentation will have a major influence in terms of the supply of propionic acid.

RELATING NUTRIENT SUPPLY TO PRODUCTIVE STATE

There is insufficient information available to permit the precise quantification of the proportions of the different nutrients required for different productive states. Nevertheless, an approximation of the needs of animals can be attempted. The suggested scheme attaches relative priorities to the groups of nutrients according to the physiological and biochemical processes underlying the expression of the particular productive state (see Table 1).

The groups of nutrients to be varied for different productive states are:

* VFA energy

* Glucogenic energy

* Amino acids

* Long-chain fatty acids (LCFA)

VFA energy arises from the rumen fermentation of all types of organic matter principally carbohydrates. The principal way of increasing VFA energy in a particular feed is to increase

intake and/or the rumen degradability by supplementing with bypass protein and/or alkali treatment (mainly ammoniation).

Table 1. The first limiting nutrients for different physiological functions. These nutrients must be supplied in sufficient quantities and proportions to meet the needs for different functions. When the balance of nutrients is optimum feed intake is increased and feed utilization efficiency is improved.

Physiological function	Limiting nutrients
Growth (lean tissue)	Amino acids
Growth (fattening)	Glucose, LCFA*, amino acids
Puberty	Glucose, amino acids
Conception	Glucose, amino acids
Pregnancy	Glucose, amino acids
Lactation	Glucose, amino acids, LCFA
Work	Glucose, LCFA

* Long-chain fatty acids.
Source: Preston and Leng (1986).

Manipulation of the rumen to provide extra protein and glucogenic precursors is still at the experimental stage. Dietary supplementation is the most obvious way of manipulating the supply of absorbed amino acids, glucose and glucose precursors.

Most supplements are expensive and their use in ruminant nutrition competes with monogastric animal and human nutrition. If the primary feed resource is a product of low nutritive value, which would have been wasted if it were not fed to ruminants, it can be argued that the ruminant uses these concentrate supplements more efficiently than monogastric animals. For this reason the term "catalytic" supplement has been used to describe these effects (Preston and Leng 1980). Suckled milk, given in small amounts (<2 litres daily) as a supplement for calves given a straw or molasses-based diet, is a good example of a "catalytic" supplement.

It is mandatory that research should produce response relationships to distinguish economic from biological optima. As a rule of thumb, the role of the supplement ceases to be "catalytic" when it exceeds about 30% of the diet dry matter. Beyond this point it assumes a major role and substitution occurs.

The productive functions of ruminants and the need for supplementary nutrients are discussed in detail by Preston and Leng (1986). The conclusions from their review are outlined below.

Work

Work requires ATP (adenosine triphosphate) generated from the oxidation of long-chain fatty acids, with obligatory requirements for glucogenic compounds and for amino acids (to repair the wear

and tear of tissues and replace protein secretions) (see Leng 1985). Since body reserves are a major source of LCFA, it becomes important to allow working animals to fatten in the non-working season.

Maintenance

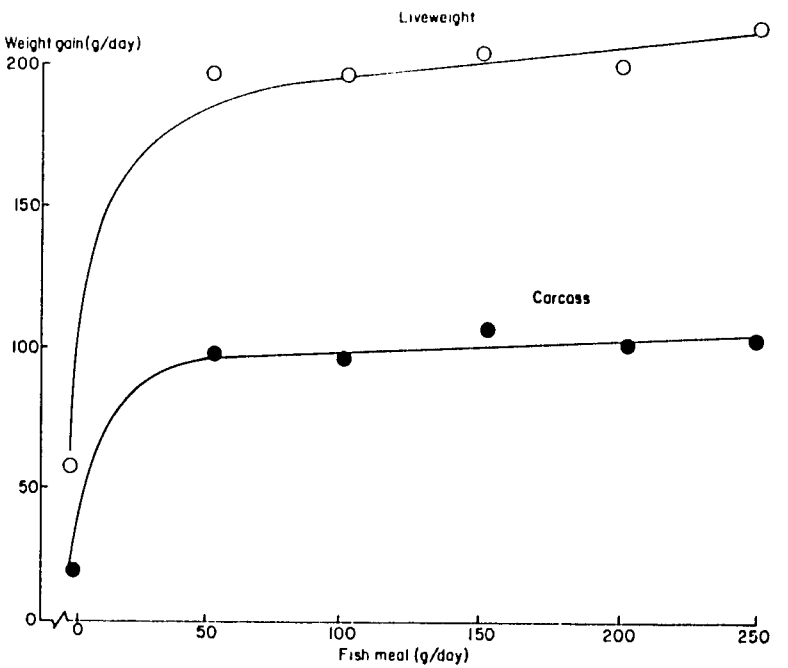
Maintenance alone obviously requires less energy expenditure than work so there is a proportionately higher demand for amino acids (relative to energy) than in the working animal. This will always be provided by a rumen system which is adequate in fermentable nitrogen.

Growth

Growing animals have a very high requirement for amino acids for tissue synthesis and glucose for oxidation in specific tissues (e.g. brain). In addition considerable amounts of glucose must be oxidized to provide the NADPH required to synthesize fat from acetate. A dietary source of LCFA which can be incorporated directly into fat will spare glucose oxidation.

High growth rates cannot be supported on the products of fermentative digestion and bypass protein supplements are essential to take advantage of the VFA energy absorbed. Data taken from Bangladesh and Cuba demonstrate this rationale. Cattle on ammoniated (urea-ensiled) rice straw, when supplemented with only 50 g/d fish meal, increased their liveweight gain threefold (Figure 3). On a molasses-based diet of higher

Figure 3. *A small supplement of fish meal dramatically increased growth in live and carcass weight in young Zebu cattle fed a basal diet of ammoniated (urea-ensiled) rice straw in Bangladesh (from Saadullah 1984).*



energetic potential, 450 g/d of fishmeal were needed to raise liveweight gain from 300 to 900 g/day (Figure 1).

Reproduction

The supply of glucogenic precursors relative to total energy is an important feature of the improved energy status which results in increased fertility. Recent studies have demonstrated that even when the protein supply is adequate, improvement in the "quality" of the energy (by increasing the glucogenic precursors in the end-products of digestion) accelerated puberty in both males and females (Table 2).

Table 2. Increasing the glucogenic status in the end-products of rumen fermentation (by feeding monensin/lasalocid) of growing bulls and heifers improved their fertility.

	Bulls		Heifers	
	Control	Lasalocid	Control	Monensin
Rumen VFA (% molar)				
Acetate	65	60	74	69
Propionate	21	32	19	26
Butyrate	15	7	6	3
Testicular volume (cm)	57	91		
Increase in scrotal circumference (cm)	3.1	5.3		
Fertility (% cycling)			58	92

Sources: Neuendorff et al (1982); Moseley et al (1982).

Conception rates of cows grazing sub-tropical pasture during the dry season were improved by giving bypass protein (Table 3). A supplement providing fermentable energy (molasses) was much less effective confirming the report of Moseley et al (1982) that it is the "quality " of the energy (i.e. energy in the form of glucogenic compounds) which is the critical issue.

The growth of the conceptus has little effect on the protein and energy demand of ruminants until the last third of gestation when most of the foetal tissues are deposited. It appears that rumen function even on diets of low digestibility can support the birth of a viable offspring of normal weight. This was shown in studies in which urea was included in the drinking water of ewes on nitrogen-deficient pasture (Table 4).

Calf birth weight was increased when pregnant cattle, given a basal diet of hay of low digestibility (45%), were supplemented with urea. However, to prevent bodyweight loss and/or promote

weight gain of the dam through pregnancy, it was necessary to provide additional bypass protein (Table 5).

Table 3. Liveweights and conception rates of lactating beef cows grazing native pasture and either a rumen-fermentable carbohydrate (1.86 kg/d of: 85% molasses, 12% cottonseed meal, 17% urea and 1% diammonium phosphate) or a bypass protein meal (1.5 kg/d of cottonseed meal).

Supplement	Liveweight (kg)	Pregnancy (%)
Nil	302	10
Rumen-fermentable CHO	332	20
Bypass protein	343	60

Source: Hennessy (1986).

Table 4. Birth weight and growth rate of lambs, and feed and nitrogen intake, wool yield and liveweight loss of ewes grazing low-protein dry pasture.

Attribute	Flinders grass	Flinders grass + urea (2.2 g urea/ litre)	Flinders grass + urea (1% w/w of grass)
Ewes lambed	20	20	20
Feed intake (g/d)	900	1190	1250
Nitrogen intake (g/d)	8	15	18
Ewe liveweight loss (kg)	12	8	9
Ewes milked	11	-	10
Milk yield (ml/4 hr)*	60	ND**	94
Lamb survivors	12	16	16
Lamb birth weight (kg)	2.9	3.2	3.2
Lamb growth rate (g/d)	35	81	84

* Mean yields measured on days 1, 11 and 21
** Not determined
Source: Stephenson et al (1981).

It appears that urea supplementation enhances milk production to a level that ensures survival of the offspring by the strategy of giving urea. But to allow the young animal to grow, milk yield must be further stimulated by feeding a bypass protein meal.

Milk production

The major constraint to milk production on diets based on crop residues and agro-industrial byproducts appears to be the availability of glucogenic compounds to provide the glucose for lactose synthesis and for oxidation to provide the NADPH for synthesis of fatty acids.

Table 5. Mean liveweight change and dry-matter intake of pregnant cows (415 kg liveweight) fed spear-grass hay supplemented with urea/sulphur (US) and a bypass protein meal (PP). The experiment was carried out over the last 60 days of pregnancy; the hay was of low digestibility and contained 0.4% N.

Diet	Hay intake (kg DM/d)	Liveweight change (kg/d)	Calf birth weight (kg)
Spear grass	4.2	-0.81	22
Spear grass + US*	6.2	-0.31	31
Spear grass + US + PP**	8.1	+0.75	32

* US supplied 55 g/d N.
** PP supplied 1 kg/d of a protein pellet containing 80% cottonseed meal, 10% fish meal and 10% meat meal (protected with formaldehyde).
Source: Lindsay et al (1982).

There is good evidence that in large ruminants about 50% of the fatty acids of milk arise from dietary fat. A dietary source of lipid can thus reduce considerably any imbalance caused by relative deficiencies of glucogenic energy and amino acids in the end products of rumen digestion. For many feeding systems in the tropics the level of fat in the diet could be a primary constraint to milk production.

The points to be stressed are that:

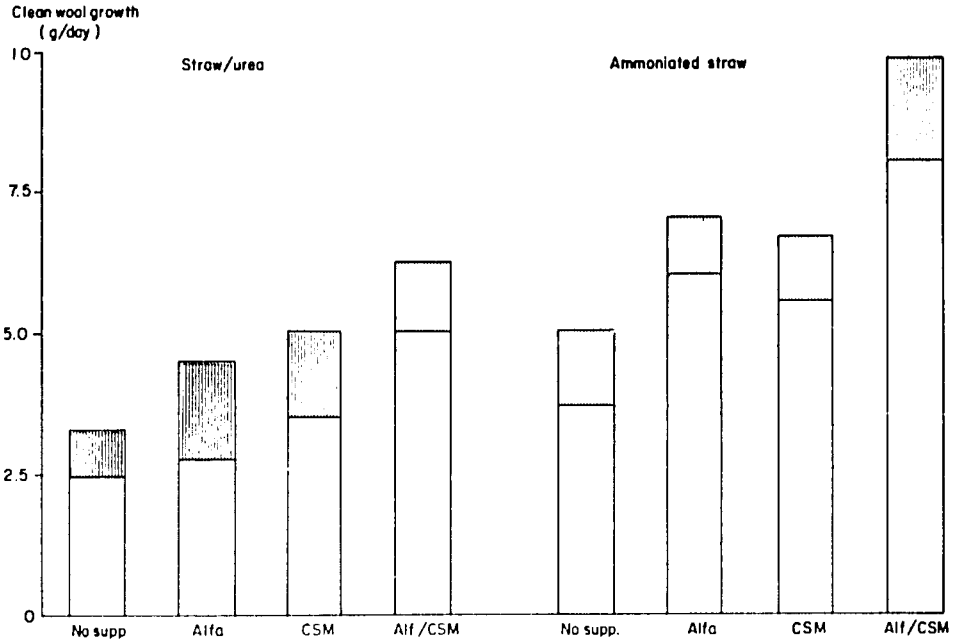
* Bypass protein, because of its effects on feed intake, almost always stimulates milk production and depending on the imbalance in nutrients (fermentation pattern) may cause animals to mobilize body reserves. This may be prevented by the use of high-fat, high-protein meals that supply both protein and long-chain fatty acids for digestion post ruminally.

* Bypass starch or manipulation of the rumen to give higher propionate production (e.g. by supplementation with monensin), because it balances nutrients for milk production, may prevent mobilization of body reserves without large effects on feed intake and therefore on milk production. But because it balances the nutrients for milk production, efficiency of energy utilization is increased and bodyweight is often increased.

Wool or hair production

The effect of nutrition on wool production appears to be dependent almost entirely on the quantity, and balance, of the amino acids absorbed. Therefore, feed intake is the primary limitation to wool or fibre growth. Improving the balance of protein relative to energy in the products of digestion (e.g. removing protozoa from the rumen, supplying a rumen "activator" and/or giving bypass protein) will increase wool and fibre growth (Figure 4).

Figure 4. *Supplements providing rumen "activators" (alfalfa hay) and or bypass protein (cottonseed meal: CSM) increased the wool growth of sheep fed a basal diet of wheat straw that had been sprayed with urea or ammoniated (Ammonia gas). There were additional benefits (shaded upper part of columns) when the sheep were defaunated (Bird S H, Romulo B and Leng R A, unpublished data).*



PRINCIPLES OF SUPPLEMENTATION

The proposed scheme (Table 6) is empirical but is considered to be appropriate for the conditions of most developing countries.

Select the basal carbohydrate-rich resource

The first step is to select the basal carbohydrate resource according to availability, potential fermentability and price. Supplementary nutrients should then be provided in accordance with their relative priorities and costs.

Fermentable N

The first supplement to be considered should be a source of fermentable nitrogen (usually urea or ammonia) to ensure the level of rumen ammonia is above 150 mg/litre of rumen fluid. The generally recommended minimum level of rumen ammonia to support efficient use of fermentable carbohydrate for microbial growth is 50 mg/litre. However, this appears to be too low to optimize the rate of degradation of fibrous substrate, since the disappearance rate of cellulose and fibre from nylon bags in the rumen was increased when the concentration of ammonia was raised to 200 mg/litre (see Figure 5).

Table 6. Priorities for nutritional supplements to optimize the utilization of diets based on crop residues, sugar-rich agro-industrial byproducts or high-biomass producing tropical crops.

1: Select the carbohydrate-rich resource which will be the basis of the diet.

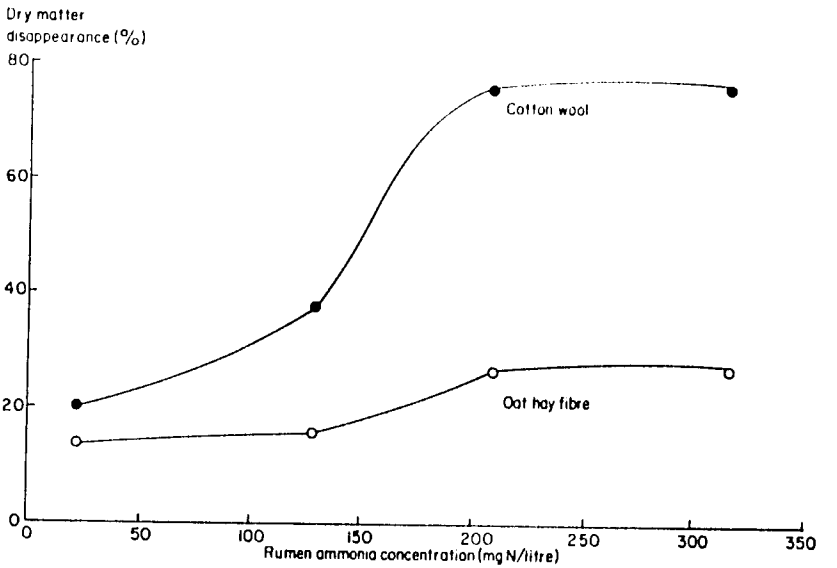
2: Ensure the rumen ecosystem is optimum by:
   (i) Providing fermentable N (a total of about 3 g N/100 g fermentable carbohydrate) to raise rumen amonia levels to at least 15 mg/100 ml rumen fluid.
   (ii) Supplying a highly digestible (preferably green) forage

3: Balance the end-products of digestion by:
   (i) Manipulating the rumen (increase propionate, accelerate flow rate out of the rumen, reduce or eliminate protozoa)
   (ii) Supplementing with sources of bypass nutrients to improve protein:energy ratio and raise the glucogenic status of the diet in accordance with animal needs:

   * Protein
   * Starch
   * Long-chain fatty acids (LCFA)

Source: Preston and Leng (1986).

Figure 5. *Effects of rumen ammonia concentration on degradability of cotton wool and oat hay fibre as measured by the nylon bag technique. The sheep were fed a basal diet of oat hay and had access to urea/molasses blocks containing 10, 15 or 20% urea (from Krebs and Leng (1985).*



When the substrate was alkali-treated maize cobs (Alvarez et al 1983), rate of dry matter loss from nylon bags in the rumen increased linearly as rumen ammonia concentration was raised from 30 to 120 mg/litre of rumen fluid.

Rate of degradation of cell wall carbohydrate is of paramount importance when the diet is based on crop residues; because it is the rate of degradation of fibre which eventually limits feed intake and therefore animal productivity.

When rumen ammonia levels are lower than 150 mg/litre it is recommended that the effects of adding urea should be monitored under the prevailing field/farm situation. As a general rule, if a deficiency is suspected, urea should be added at the rate of about 1-2% of the organic matter in the diet. It is desirable that supplementation ensures an almost continous supply of ammonia-nitrogen in the rumen and the use of molasses/urea blocks or high-urea (10%) liquid mixtures with molasses is a convenient way of ensuring this. Ammoniation using ammonia gas, or through ensiling with urea, are other ways of proving a continuous supply of rumen ammonia with the associated advantage of upgrading the carbohydrate component. A recent development is the generation of ammonia from mixtures of dry chemicals (e.g. ammoniate sulphate and quicklime) when these are mixed with water (Mason et al 1985).

Highly digestible forage

The second supplement should be a source of highly digestible forage, preferably legume (or a byproduct such as beet pulp) given at about 10-20% of the diet. The exact action of this type of supplement on rumen function is not fully understood. In some way it helps to ensure a more efficient rumen environment for the digestion of cell wall carbohydrate (Table 7) perhaps by providing micro-nutrients (e.g. peptides, amino acids, minerals, vitamins) which increase fungal biomass and/or the rate of bacterial colonization of the fibre.

Table 7. Dry matter disappearance from nylon bags of straw incubated in the rumens of sheep fed on untreated straw or straw supplemented with sugar beet pulp.

	Diet of host sheep	
	Untreated straw	Straw plus 150g beet pulp/kg staw
Rumen pH	7.0	6.9
Rumen NH_3 (mg/litre)	151	129
Dry matter loss (%)		
In 24 hr	39	41
In 48 hr	46	50
In 72 hr	51	55

Source: Silva and Ørskov (1985).

Bypass protein

The third supplement should be an oilseed meal, cereal bran or an animal byproduct meal (supplying protein and fat) and should be given in amounts not to exceed 30% of the total diet dry matter. The 30% limit is to prevent depression/substitution of the digestible energy of the basal diet. Lesser amounts may be more economical, and it is imperative that feeding trials be carried out to define response relationships. In this way the amount of supplement can be related to the rate of animal productivity. The optimum level (in economic rather than biological terms) and the degree of response to the supplement, will depend upon the fermentability of the basal diet.

Long-chain fatty acids (LCFA)?

Supplementation with a source of long-chain fatty acids (LCFA) is a strategy that promises to be of considerable benefit, especially on diets with a low content of lipids (e.g. crop residues and molasses). However, more research is needed before making recommendations.

ALTERNATIVE SOURCES OF SUPPLEMENTS

The limiting nutrients for production on most tropical feed resources are fermentable nitrogen, glucogenic precursors and bypass protein and dietary long-chain fatty acids. Urea, oilseed cakes, cereal milling byproducts and animal byproduct meals are the logical supplements when available. However, there are many situations where farmers do not have access to these supplements either because they are not locally available or are too expensive. In addition, there is often a reluctance to use urea because of the fear of toxicity.

Livestock excreta

Excreta from all types of livestock have been used in livestock rations. It is obvious that excreta in general must be a poor source of fermentable carbohydrate and protein. However, long-chain fatty acids may build up in litter as small amounts will be present in faeces and they are only slowly degraded by micro-organisms in the litter. Microbial growth in the litter will therefore tend to concentrate these fatty acids.

Excreta from ruminant animals are high in refractory cell-wall carbohydrate with smaller amounts of microbial cells (from the caecum) and some urea if the urine is incorporated with the faeces. The monogastric species produce the most valuable excreta; and especially in the case of poultry, there may be considerable contamination with wasted feed grains. Excreta from poultry is rich in nitrogen mostly as uric acid which is hydrolysed to ammonia by rumen micro-organisms.

Excreta (often depathogenized with formalin or by ensiling) have been used widely in the developed countries as a component of cereal-grain-based diets in which their main contribution is as a source of non-protein nitrogen and minerals.

In developing countries, only poultry litter has found ready acceptance as a component of livestock feeds. It appears to play a particularly appropriate role in high-molasses diets, where it complements the readily fermentable sugars and the low levels of fermentable N and of phosphorus. There appears to be a particularly beneficial effect of poultry litter on rumen propionate production in cattle fed a molasses-based diet (Fernandez and Hughes-Jones 1981; Marrufo 1984). It is well documented that this is reflected in higher levels of animal performance (Meyreles and Preston 1982; Meyreles et al 1982).

The data in Table 8 show that poultry litter is less effective than fishmeal or an oil cake meal for supplementing cattle given a molasses- or a pasture-based diet, from which it can be inferred that it provides little or no bypass protein. This is to be expected in view of its chemical characteristics.

Table 8. Poultry litter is a less effective supplement than fish meal (in a molasses diet) or sunflower cake (on pasture), indicating that it supplies little or no bypass protein.

On pangola pasture (plus 1.5 kg/d of molasses-urea):

	Amount of supplement (kg/d)			
Poultry litter	1.3	1.0	0.64	0.0
Sunflower cake	0.0	0.12	0.31	0.6
Liveweight gain (g/d)	480	580	680	740

Diet of molasses-urea ad libitum and restricted forage:

	N-supplement	
	Poultry litter	Fish meal
Liveweight gain (g/d)	575	825

Sources: Delgado et al (1977); Preston et al (1970).

Legume forages and foliages from food crops

An alternative resource which can serve as a source of fermentable N and of bypass protein is a forage crop grown on the farm, or produced as a byproduct or residue from a food crop. A legume crop has a further advantage because of its capacity to fix atmospheric nitrogen and thus spare the need for fertilizer N. Based on the premise of using protein economically, then the intake of these forages should be restricted and therefore it is preferable to grow the legume as a pure sward.

The amount of bypass protein in a legume (green or dry and used as a supplement) has not been estimated. It may be beneficial to grow tannin-rich legumes when these are to be used as supplements to crop residues.

The tree legumes such as gliricidia, erythrina and leucaena have very great potential because they are high yielding and perennial. They are also deep-rooted and may have access to water and nutrients (e.g. phosphorus) unavailable to smaller plants. In the tropics, tree legumes have a special role, since they can also be used for shade (e.g. in coffee plantations), as "live" fences and as sources of fuel. Some of them (e.g. glyricidia and erythrina) can be established easily from cuttings hence their use as "live" posts.

The other valuable forages are from cassava and sweet potatoes and, to a lesser extent, bananas. Some results from using these materials as supplements in molasses-based diets are described by Ffoulkes and Preston (1978).

Attributes of legumes as supplements

In developing countries where competition for land to grow crops or grazing is high, the area likely to be sown to fodder legumes will be almost always a small proportion of the total. It follows therefore that the role of a legume must be to increase the efficiency of utilization of the basal diet (i.e. a low-N pasture or a crop residue) at low levels of supplementation (usually less than 20%) and used "catalytically".

As a priority, the legume should have a high protein content to supply both fermentable and bypass protein; there will be additional benefits if the legume contains other critical nutrients (e.g. lipids, minerals, vitamins and other plant compounds) which enhance the rumen ecosystem so as to increase microbial growth, rate of fibre digestion, propionate production and escape of dietary protein.

It is likely that legume forages rich in tannins will be superior as sources of bypass protein since tannins link with proteins during mastication, and appear to reduce microbial degradation of plant proteins (Reid et al 1974). The high levels of tannins in Lotus pedunculatus, whilst protecting protein from degradation, reduce digestibility of fibre by inhibiting the activity of bacteria (Chesson et al 1982) and fungi (Akin and Rigsby 1985). Barry (1985) considered that the ideal concentration of condensed tannins was 20-40 g/kg diet dry matter; and that higher levels (76-90 g/kg) were detrimental. He also found that sheep could adapt to high tannin levels. Provided that tannin-rich plants are only used as supplements (e.g. less than 25% of the diet dry matter), there is unlikely to be a serious problem and their presence in the diet may well be beneficial (Barry and Manley 1984). Examples of tropical legumes which are known to contain tannins are: leucaena, glyricidia and sesbania.

In situations where the fermentable N requirement can be met from other sources (e.g. urea or animal excreta) the need is to reduce the degradability of the legume protein so as to increase its bypass characteristics. This has been shown to occur when a forage is artificially dried and more so when pelleted (see Table 9). Rarely will it be economic to dehydrate or pellet legume forages and sun-drying is the only feasible alternative.

Table 9. The bypass properties of clovers are increased when the herbage is frozen or dried and pelleted.

	Fresh	Frozen	Artificially dried/pelleted
Amino acid intake (g/d)	127	127	124
Amino acids entering small intestine (g/d)	80	133	175

Source: Preston and Leng (1986).

As discussed earlier, secondary plant compounds such as tannins are known to protect dietary proteins against rumen microbial attack. Thus if a freshly harvested or grazed legume is to be used as a bypass protein supplement then it should be selected for a relatively high content of tannins.

This point is illustrated by the data in Table 10 which show that although the tannin-containing legumes (trefoil and sanfoin) were less palatable than lucern, nevertheless they supported faster growth rates in heifers. The authors concluded that this was because more of the protein in the legumes containing tannins escaped degradation in the rumen.

Table 10. Relative palatability of three legumes, and heifer growth performance when grazing them.

	Alfalfa	Trefoil	Sainfoin
Relative palatability*	34	46	45
Liveweight gain (g/d)	670	810	800

* Percentage rejection of forage on offer.
Source: Marten and Ehle (1984).

Tropical legumes generally are richer in tannins than are temperate legumes and therefore should function better as sources of bypass protein. Evidence for this is provided by the results of feeding trials with tropical tree legumes discussed earlier. It must be emphasized that when legumes contain a high proportion of protected protein, then some other source of rumen fermentable nitrogen will be required, usually urea.

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STRATEGIC SUPPLEMENTATION TO OPTIMISE RUMEN FUNCTION AND THE BALANCE OF ABSORBED NUTRIENTS IN RUMINANTS FED LARGELY ON CROP RESIDUES

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INTRODUCTION

ILCA's strategy for improving the utilisation of fibrous crop residues and byproducts in livestock feeding (see Preston and Leng 1986) is based on an appreciation that:

* These feed resources yield nutrients to the animal mainly through the processes of fermentative digestion in the rumen.

* Because of their generally low contents of nitrogen and lipids and the low digestibility of fibrous crop residues, the end products of digestion are imbalanced in terms of the amounts of amino acids, glucose precursors and long-chain fatty acids relative to the total energy supply, mainly as short-chain fatty acids.

Feeding strategies should therefore aim to maximise fibre degradability in the rumen, optimise microbial protein synthesis and promote escape of dietary protein and lipid supplements from the rumen fermentation.

Fibre digestion in the rumen is enhanced by: (i) supplying a readily fermentable source of nitrogen so that rumen ammonia levels are maintained in the range of 15 to 25 mg/100 ml rumen fluid (Krebs and Leng 1984); and (ii) giving small quantities of readily digestible forage (Gutierrez and Elliott 1984; Silva and Ørskov 1985). Escape of protein from the rumen is facilitated by supplemention, either with oilseed or animal byproduct meals (Preston and Leng 1984), or with legumes with moderate contents of tannins (Marten and Ehle 1984).

Evidence that an inefficient rumen ecosystem is probably the first constraint on the productivity of much of Africa's ruminant population is given in Figure 1 which shows rumen ammonia levels in cattle and sheep on communal grazing in the Ethiopian highlands during the dry season. Rumen ammonia was much lower in cattle than in sheep on the same grazing and considerably less than is required to maximise cellulose digestion. The results given in Table 1 show that the situation in housed dairy heifers fed mainly meadow hay can be even worse, some animals having barely detectable amounts of ammonia in the rumen fluid.

These low levels of rumen ammonia indicate that substantial benefits in livestock productivity could be expected by providing a supplement which would elevate rumen ammonia to 15-20 mg/100 ml, considered to be optimum for cellulose digestion.

Table 1. Ammonia levels in rumen fluid of growing heifers and dry cows fed meadow hay and molasses on the Debre Zeit State farm in Ethiopia.

Growing heifers (n=5)	Dry cows (n=4)
----- Rumen ammonia (mg/litre) -----	
22 ± 3	28 ± 5

Note: The recommended level of rumen ammonia is at least 100 mg/litre of rumen fluid for maximum rate of degradation of fibre.
Source: T R Preston and R A Leng (unpublished data).

In natural feeds, rumen ammonia arises from the degradation of dietary proteins. However, in situations where protein is in short supply, and this is the case in much of Africa, it will be more economical to use true protein in a way that will escape the rumen fermentation; and to supply rumen ammonia from some non-protein source such as urea, ammonium salts or livestock excreta.

Four methods have been used to supplement ruminant diets with urea. The urea can be sprayed on the feed as an aqueous solution; it can be mixed in liquid molasses at various concentrations up to 15%; it can be incorporated in a molasses-based block with a gelling agent to make the block solidify; or it can be added as as an aqueous solution to the crop residue or byproduct followed by ensiling to convert the urea into ammonia.

In selecting one of the above methods it is desirable that the system used is simple, carries no major risks and maintains rumen ammonia levels as constant as possible throughout the day and night. One way of satisfying most of the above constraints is by incorporating the urea in a solid block which the animals must lick or chew.

UREA-MOLASSES BLOCKS

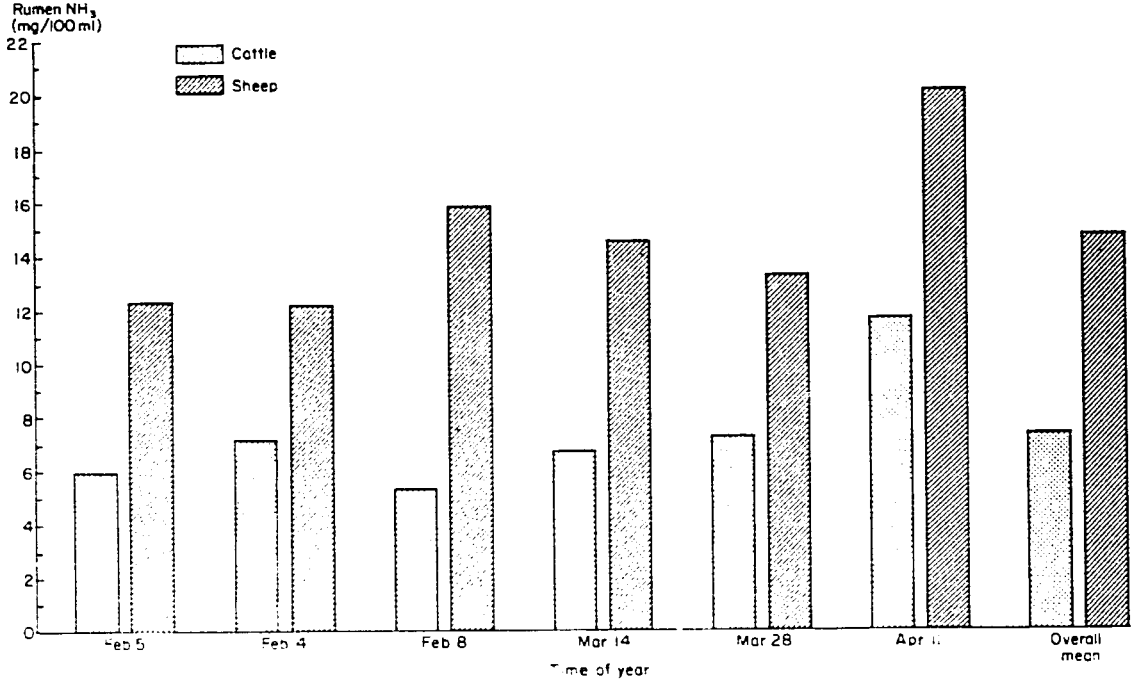
The National Dairy Board of India (NDDB 1984) has given considerable impetus to this scheme by manufacturing blocks in their feed mills and supplying them to smallholder farmers participating in their village milk cooperatives.

The following series of trials, built on the Indian experience, was aimed especially at examining the apparent synergism which exists when urea-molasses blocks are given together with sources of bypass (escape) protein.

Molasses-urea blocks for fattening oxen

Sixteen mature highland oxen were tied in individual stalls and fed a basal diet of wheat straw and one of the following supplements:

Figure 1. *Ammonia level in rumen fluid of cattle and sheep grazing on communal pastures in the Debre Berhan area of Ethiopia.*



Source. A Negussie (unpublished data).

* Urea sprayed on the straw (44 g/d in aqueous solution);

* Noug cake (Guizotia abyssinica)(2 kg/d);

* Free access to a block containing (% by weight) urea 10, wheat bran 15, calcium oxide 12, salt 5, triple-superphosphate 3, molasses 55;

* The urea-molasses block plus 2 kg/d of noug cake.

The results are summarised in Table 2. The group receiving both block and noug cake gained 570 g/d, which was more than double the gain (220 g/d) of those that received only the noug cake (220 g/d); the groups which received only aqueous urea on the straw, or had only the block, lost 190 and 68 g/d, respectively. The synergistic effect of combining the urea-molasses block with the noug cake is particularly evident in these results.

Table 2. Mean values for liveweight change, feed intake and feed conversion in oxen fattened on a basal diet of wheat straw and supplements of urea, or urea-molasses block and/or noug cake (55 day trial).

	Urea	Block	Noug	Noug/block
Liveweight (kg)				
Initial	294	294	294	295
Daily change*	-0.19	-0.068	0.22	0.57
Feed intake** (kg/d)				
Straw	4.88	4.26	4.81	4.69
Urea	0.04	0.041	-	0.046
Block		0.41	-	0.41
Noug			1.78	1.95
Total	4.92	4.67	6.59	7.10
Feed Conversion**	?	?	32	12

* SE of mean = ± 0.065.
** Feed intakes and conversion are on basis of 90% dry matter.
Source: H Soller (unpublished data).

Urea-molasses blocks for lactating crossbred cows

This trial aimed at examining combined supplementation with a urea-molasses block and noug cake on the milk yield of crossbred cows (Holstein x Zebu) fed a basal diet of low-N (1.2% N in DM), low-digestibility (43%) meadow hay. As in vitro studies indicated that the protein in the noug cake was highly soluble, a comparison was made of heated (105° C for 1.5 hours) and unheated cake. Subsequently, two levels of noug cake (1 or 2 kg/d) were compared. In both trials, the protein treatment was given with or without the urea-molasses block.

The cattle were given the experimental diets during consecutive 28-day periods (trials 1 and 2 respectively), following a period of standard feeding (hay ad libitum and 2 kg/d of noug cake). The milk yield during the period of standard feeding was used as a covariate to adjust the yields recorded during the experimental periods.

The results are given in Tables 3 and 4. In both trials, milk yields and total dry matter intake were significantly increased, and hay intake tended to be increased, by allowing the cows access to urea-molasses blocks. Heating the noug cake had no effect on milk yield or feed intake. The most important finding was that while milk yield was increased by feeding 2 rather than 1 kg/d noug cake in the absence of the block, there was no difference due to level of noug cake when the cows had access to the block.

Samples of rumen fluid taken during both experiments showed that the urea-molasses block increased rumen ammonia concentrations in both trials (12±1.2 vs 9.8±1.2 and 18.4±4.0 vs 11±0.6 mg ammonia/100 ml rumen fluid for trials 1 and 2 respectively.

Milk yield was significantly related with rumen ammonia level in trial 1 (r = 0.65 and 0.64 for samples taken before and 3 hr after feeding)(see also Figure 2); and in trial 2 for the 1 kg/d noug cake level (r = 0.63 and 0.39 before and after feeding) but not for the 2 kg/d noug cake level.

It can be concluded from these trials that urea-molasses blocks are an effective method of raising rumen ammonia levels when the basal diet is a low-N forage. A urea-molasses block plus a limited (1 kg/d) quantity of an oilseed cake appears to be an adequate supplementary feeding regime for crossbred cows fed low-N, low-digestibility forages as their basal diet.

MILK PRODUCTION ON CROP RESIDUES

Sugar-cane tops are produced in large quantities in many countries in Africa and are usually burned (to facilitate harvesting of the current crop and subsequent fertilizing and soil preparation). When they are collected (e.g. by farmers living close to the estate) they are used inefficiently for livestock production, mainly because of their nutrient imbalance (low content of N and of lipids) as discussed earlier.

The following experiment was set up to incorporate sugar-cane tops in a practical feeding system for lactating cattle, and to examine the use of fresh alfalfa forage as a supplement expected to provide both rumen "activators" and bypass protein.

Supplementation of sugar-cane tops for milk production

The experiment was carried out on one of the dairy farms managed by the Ministry of State Farms of the Ethiopian Government. Sixteen Friesian cows in early to mid-lactation were assigned at random to the control group (fed ad libitum meadow hay and 2 kg/d of 50/50 wheat bran and solvent-extracted noug cake for

Table 3. Effect of supplements of urea (as a urea-molasses block containing 10% urea) and untreated or heated (105° C for 1.5 h) oilseed cake (*Guizotia abyssinica*) on milk yield, liveweight change and feed intake of crossbred cows (Friesian X Zebu) given a basal diet of low-N (1.2%) and low-digestibility (43%) meadow hay.

	Noug Cake		Heated noug			
	-B	+B	-B	+B	SE	Sig
Milk yield (kg/d)						
Pre-expt(1)	5.32	5.80	5.61	4.83		
Experimental(2)	5.23	5.88	5.12	5.98	0.18	0.02
Liveweight (kg)						
Mean	401	340	399	379		
Change/d	-0.21	0.04	0.14	-0.39	0.17	0.20
Feed intake (kg/d)						
Hay (3)	8.92	9.19	8.29	9.88	0.50	0.27
Block		0.71± 0.39		0.80± 0.37		
Noug cake	1.98	1.92	1.81	1.92		
Total DM (3)	9.74	10.6	9.0	11.2	0.50	0.07

1) During the 3 weeks prior to starting the experiment.
2) Adjusted by covariance for milk yield prior to the experiment and for mean liveweight during the experiment.
3) Adjusted by covariance for mean liveweight during the experiment.

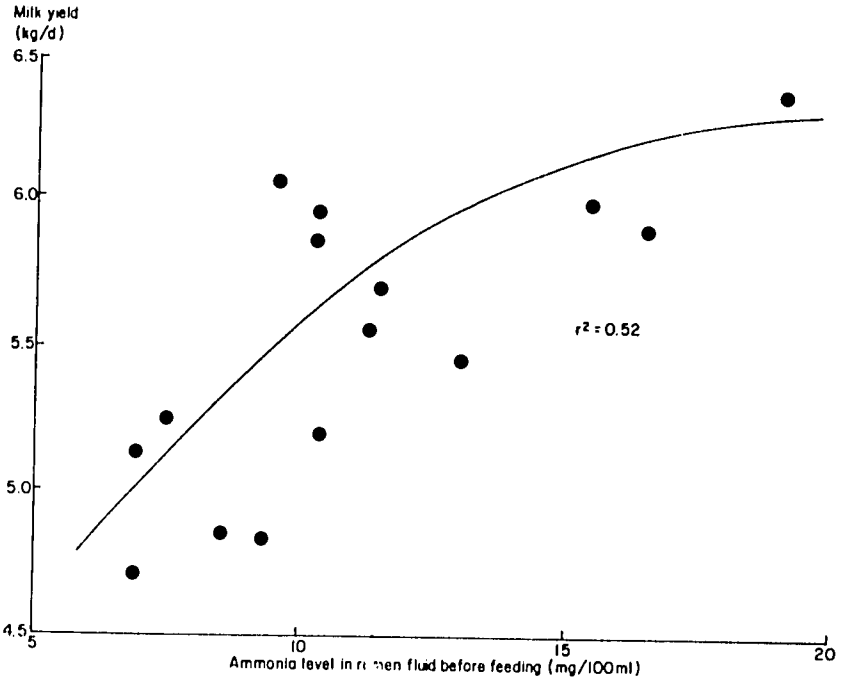
Source: T R Preston, R A Leng, P J Brumby and M Nuwanyakpa (unpublished data).

Table 4. Effect of supplements of urea (as a urea-molasses block containing 10% urea) and either 1 or 2 kg/d of noug oilseed cake (Guizotia abyssinica) on milk yield, liveweight change, and feed intake of crossbred cows (Friesian X Zebu) given a basal diet of low-N (1.2%) and low-digestibility (43%) meadow hay.

	1 kg/d noug		2 kg/d noug			
	-B	+B	-B	+B	SE	Sig
Milk yield (kg/d)						
Pre-expt (1)	5.32	5.80	5.61	4.83		
Experimental(2)	4.20	5.37	5.18	5.42	0.20	0.01
Liveweight (kg)						
Mean	395	396	336	371		
Change/d	-0.64	-0.39	-0.27	-0.27	0.23	NS
Feed intake (kg/d)						
Hay(3)	8.72	9.60	8.80	9.26	0.41	0.48
Block		0.68±0.11		0.68±0.16		
Noug Cake	1	1	2	2		
Total DM (3)	8.76	10.1	9.72	10.7	0.39	0.05

1) During the 3 weeks prior to starting the experiment. (During this time the cattle were fed hay and 2 kg/day of cereal-based concentrate).
2) Adjusted by covariance for milk yield prior to the experiment and for mean livewight during the experiment.
3) Adjusted by covariance for mean liveweight during the experiment.
Source: T R Preston, R A Leng, P J Brumby and M Nuwanyakpa (unpublished data).

Figure 2. *Relationship between rumen ammonia (before feeding) and milk yield in crossbred (Friesian x Zebu) cattle receiving a bazal diet of low-N (1.2%) and low-digestii ility (43%) meadow hay supplemented (or not) with a urea(10%)-molasses and with 2 kg/d of oilseed cake (T R Preston, R A Leng, P J Brumby and M Nuwanyaka, unpublished data; cited by Preston 1986).*



maintenance plus 500 g of the same mixture for each litre of milk) or to three experimental groups which were fed a basal diet of ad libitum "burnt" chopped sugar-cane tops, 2 kg/d of a mixture of molasses/urea (10% urea), and 1 kg/d of noug cake and either 0, 6 or 12 kg/d of freshly harvested alfalfa forage (mid-bloom stage). The experimental period was 42 days during which milk yields were recorded and adjusted (by covariance) according to the yield during a 28 day pre-experimental period when all the cows were fed the control diet.

Total dry matter intake and milk yield increased linearly as the level of alfalfa was increased and did not differ significantly from that on the control diet at the highest level of alfalfa (Table 5). Supplementation with alfalfa did not depress intake of the sugar-cane tops.

Rumen ammonia concentrations 3 hours after feeding were in the range 20-30 mg/100 ml of rumen fluid and did not differ among treatments.

The on-farm cost of cane tops is only one tenth of that of hay and supplementation with farm-grown alfalfa, 2 kg/d of molasses/urea and only 1 kg/d of noug cake is obviously more economical, and more in the national interest, than the feeding of 7 kg/d of a mixture of bran and noug cake.

Table 5. Effect on feed intake and milk yield of Friesian cows of supplementing a basal diet of chopped sugar-cane tops (harvested after burning of the standing crop), molasses/urea and noug cake, with alfalfa forage.

		Alfalfa forage (kg/d)				
	Control	0	6	12	SE$\bar{X}$	Sig
Milk yield (kg/d)[1]	9.58	7.42	8.01	9.01	±0.29	0.001
Feed intake (kg/d)						
Hay	6.2					
Cane tops		18.4	19.1	17.4		
Alfalfa forage		-	6.0	12.0		
Molasses		1.6	1.6	1.6		
Urea		0.2	0.2	0.2		
Noug Cake		1.0	1.0	1.0		
Concentrates	7.1					
Total DM	11.6	9.74	11.2	11.8	±0.35	0.005

1) Adjusted by covariance for average milk yield during two 4-week periods pre- and post-experiment when the control diet was given.
Source: A Belete and T R Preston (unpublished data).

The need now is to test the system with other crop residues (e.g. cereal straws) and to examine alternative sources of legume forages better adapted than alfalfa for tropical conditions.

FATTENING OF CATTLE AND SHEEP ON STATE FARMS

EXPERIMENTS IN BEEF PRODUCTION ON STATE FARMS

Background

Innovations were introduced into three programmes:

* The ranches used to quarantine cattle purchased from pastoralists, prior to fattening or slaughter for export.
* The feedlots at Kuriftu and Wonji where cattle are intensively fattened prior to export.
* The quarantine ranches used to hold sheep and goats purchased from pastoralists prior to export

Quarantine ranches for cattle

The innovations consisted of:

* Supplementary feeding of molasses/urea (2.5%) (given ad libitum) and restricted quantities (500 g/d) of poultry litter and noug cake.

* Building of large thorn bush enclosures (minimum of 10 m^2/head) for holding the cattle at night (previously the space allowance in the night corral was only 2 m^2/head); this allowed feed troughs (half oil drums) to be placed in the corrals with sufficient space for the animals to eat freely.

Results for one of the ranches where these recommendations were put into effect are particularly succesful; the cattle are now fattening when previously they were losing weight. The "thorn fence" feedlot is very much cheaper than a conventional structure and the running costs are also reduced.

Feedlots

In the feedlots, it was recommended that the existing system of restricted (3 kg/d) molasses and liberal concentrate feeding (4 kg/d of a 50/50 mixture of wheat bran and noug cake) be changed to ad libitum molasses (with 2.5% urea) and restricted supplementation with noug cake (1 kg/d) and poultry litter (500 g/d).

Several pens in one feedlot were put on this regime but after a trial period of 2-3 weeks the programme was stopped because of an unexpectedly high incidence (some 5% of animals were affected) of molasses toxicity (cerebro-cortical necrosis caused by interference with energy supply to the brain due to insufficiency of thiamine and/or glucose; see Losada et al, 1971).

It was suspected that the high toxicity incidence was related to the feeding of sugar-cane tops and not to the ad libitum molasses, since toxicity was also observed in a second feedlot where molasses was restricted to only 3 kg/d.

Nevertheless, it appeared to be necessary to demonstrate on an experimental basis that ad libitum molasses could be fed safely to fattening cattle and that the proposed minimum supplementation would support high rates of liveweight gain.

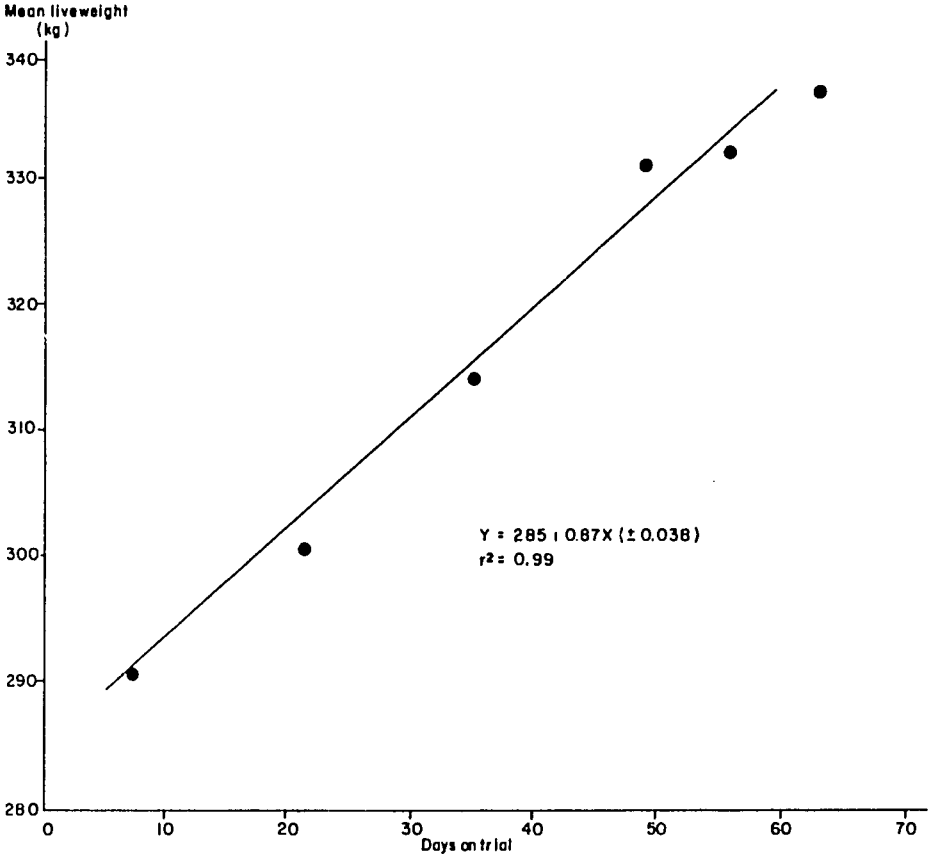
Stategic supplementation of straw- and molasses-based diets for growing/fattening bulls

Thirty mature bulls were brought from one of the holding ranches to the ILCA Highlands research farm at Debre Zeit. They were in very poor body condition and it was decided to put them on a growing ration based on teff straw (with 1% urea) and 500 g/d of noug cake and 500 g/d poultry litter for a period of 63 days.

Mean liveweight gain (Figure 3) during this recovery period was surprisingly high (870 g/d), reflecting rapid compensatory growth.

At the end of the 63-day period the basal diet of 50% of the animals was changed to molasses (with 2.5% urea) fed ad libitum; the straw was restricted to 0.8% of liveweight (DM basis). The remainder of the cattle stayed on the same straw/urea diet as they had received previously.

Figure 3. *Average liveweights of 24 Zebu bulls (and estimated rate of liveweight gain) during a 63-day period when they were fed tef straw supplemented with urea (1.5% by weight of the straw), 500 g/d of poultry litter and 500 g/d of noug cake (M Hiwot, T Tadesse and T R Preston, unpublished data).*



The following experimental treatments were applied to the cattle on both basal diets:

* No supplement;

* 500 g/d noug cake (increased to 1 000 g/d after 63 days);

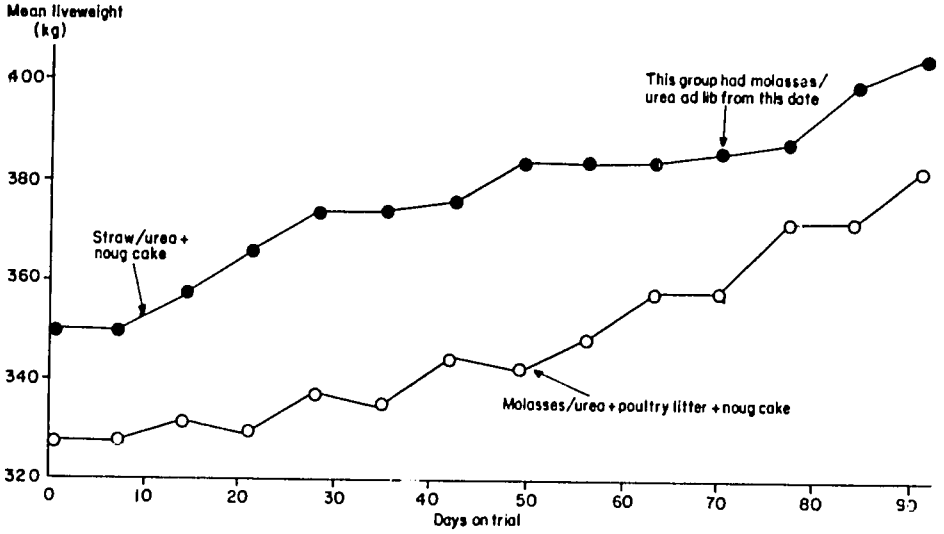
* 500 g/d poultry litter; and

* 500 g/d of noug and 500 g/d of poultry litter.

After 70 days on these regimes, two animals from each replicate (originally three animals per replicate) on the straw diets were offered free choice molasses which contained 10% urea for one week, then 6% urea for one week and finally 2.5% urea.

Liveweights are plotted in Figure 4 for two groups of animals: four cattle that were fed the straw and noug cake diets (no differences due to poultry litter therefore the results for

Figure 4. *Mean liveweights of Zebu bulls during a 98-day period when they were fed either: ad libitum molasses/urea (2.5%), 500 g/d of noug cake and 500 g/d of poultry litter; or ad libitum straw (with 1.5% urea) and 500 g/d noug cake (with or without 500 g/d of poultry litter). For the latter group, a liquid mixture of molasses containing urea was offered ad libitum from day 70 to 77 (10% urea), from 77 to 84 with 6% urea and from 84 to 91 days with 2.5% urea (M Hiwot, T Tadesse and T R Preston, unpublished data).*



the two treatments were combined); and three animals fed the molasses/noug cake/poultry litter diet. Mean values for effects of poultry litter on liveweight gain on straw- and on molasses-based diets are given in Table 6.

Table 6. Effect of poultry litter on liveweight gain of Zebu bulls given basal diets of molasses/urea or straw/urea (gain estimated by linear regression of weight against time)

Basal diet	Poultry litter -	Poultry litter +	SEx	Signif.
Molasses(i)	385	717	89	0.06
Straw(ii)	488	488	90	NS
	Noug cake -	**Noug cake +**		
Molasses	503	507	146	NS
Straw	407	609	126	.20

(i) From day 21 to 91; (ii) from day 7 to 70 (before the introduction of molasses)

Points to note are:

* It took 21 days for the cattle to adapt to the molasses diet, when the urea concentration was 2.5% (period 0-21 days on Figure 4) whereas when the molasses was offered at 10% urea, adaptation was immediate (days 70-91 in Figure 4). The results are confounded with time, and therefore must be interpreted cautiously, but the suggestion is that the high urea concentration aided the adaptation from straw to molasses. Possibly the sudden introduction of fermentable sugars in the diet, due to the animals eating large quantities of molasses, led to temporary rumen ammonia deficiency (when urea was only 2.5% of the molasses) and a consequent disturbance of the rumen microflora, and that this was corrected by giving 10% urea (on this treatment the animals ate 6-7 kg/d of molasses containing 600-700 g urea!!).

* On the molasses/urea basal diet (ignoring the first 3 weeks) there was a significant improvement ($P = 0.06$) in liveweight gain due to the poultry litter (683±96 g/d with and 371±90 g/d without poultry litter).

* Poultry litter did not influence performance on the straw diet (488±125 and 488±36 g/d with and without poultry litter).

* Performance tended to be better with noug cake in the diet for both the straw and the molasses diets.

These findings are in general agreement with those in the literature (Meyreles et al 1982; Meyreles and Preston 1982) namely that the stimulatory effect (as opposed to simple substitution) of poultry litter is only observed on molasses diets. The hypothesis that this is due to the poultry litter increasing rumen propionate (Fernandez and Hughes-Jones 1981; Marrufo 1984) is currently being evaluated in ongoing trials at ILCA.

The above observations suggest that the most economical fattening system is likely to be:

Ad libitum straw (or other fibrous crop residue or byproduct) supplemented with urea (2% of straw DM) and 500 g/d oilcake meal for first 56-84 days. The exact time will depend on the condition of the cattle at the start (thin animals will continue to grow on a straw-based diet for a longer period). Molasses should then be introduced, initially with 10% urea, then, in successive weeks, 6% and finally 2.5% urea, and the feeding system continued until the animals achieve the necessary finish (i.e. degree of fatness).

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