The African Palm: A strategic resource for integrated systems of tropical production

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The Cultivation of African Palm (*Elaeis guineensis* Jack)

For tropical countries, the African Palm represents an interesting and important alternative for the development of integrated, sustainable production systems which exploits the comparative advantages of the tropics. The climatic characteristics of the areas where the best yields of the african palm have been observed can be summarized as follows:

a. Rainfall equal to or higher than 2000 mm with good distribution throughout the year.

b. Maximum average temperature of 29'C and minimum average of 22-24'C.

c. Continual sunshine with a minimum of 5 hours/day throughout the year.

d. Flat or gently undulating deep soils, with good permeability and free drainage.

e. Loam or clay-loam soils.

f. Relative humidity higher than 75%.

The Palm System

This is not a single system. On the contrary, it is a system with various possibilities depending on the conditions and objectives of the producer, making it possible for the palm system to be used by small, medium and large producers. All the alternatives discussed here have some elements that are common to all cases: biological control for integral management of pests and diseases and the use of the animal traction for the harvesting. Legume crops are grown between the rows of the crop and these are used as covering for the soil and also to fix the nitrogen in the soil.

Six Alternatives

1. Commercial production

Current commercial cultivation of the oil palm is where 100% of the fruit produced is taken to the extraction plant to extract the raw oil, and later subjected to some processes of refinement and industrial use. Within the system, it is possible to integrate the growing and processing of the palm fruit with animal production.

Sheep (African hairsheep) have been used, the main purpose being to control the presence of weeds in between the crop, without affecting production.

The by-products obtained from the extraction process and refining (fibrous residue, palm kernels and palm-oil sludge) can be used for feeding animals. In exchange, animal manure is produced, which could be used in two ways: the production of biogas, or directly to fertilize the crop. Biogas can be used in the factory as an energy source, and also yields an effluent which is rich in minerals and can be applied to the palms or another crop in the farming system.

The rachis and the palm kernel, residues from the extraction process, go back into the system; the first one as a source of potash, as ash or after of a process of descomposition, and the second one as hard-core for the farm roads. In some cases the palm kernels are used as fuel in the boilers. The fibrous residues are also used as fuel for the boilers, being material of good calorific value. This system has permitted the location of extraction plants in places away from electricity supplies, allowing independence of the extraction process.

It is suggested that there should be a change in the management of the effluent or muds. Currently there is a policy of recovering the maximum oil present in this by-product by means of the florentino tanks, where the oil content will not be greater than 2 or 3% at the end of the process. For the implementation of this system it is proposed that the muds have a total content of oil near to the 8 or 10% at the end of the process. This means that the muds can be used as a source of animal feed, reducing the infrastructure needed to recover the oil after the clarification process, and instead being recovered by the animals and used for meat production.

Furthermore, in spite of recovering of the oil from the effluent, this is still the principal contaminant from the extraction plants that are emptied into the water sources, leading to pollution due to the high biochemical requirement for oxygen of these residues.

2. Alternative use of reject fruit

This is basically the same as the previous alternative, except that an additional element is introduced. 20 or 30% of the harvested fruit that enters the extraction plant is rejected on quality and used instead for animal feeding. This means that only fruits with better size, ripeness and oil quality will be processed, thereby improving the efficiency of the extraction process. The fruit that is destined for animal feeding will include the unripe fruit and also the fruit that is harvested from recent plantings.

By using some of the fruit for animal feeding, it is possible to increase the number of animals in the system, thereby increasing the production of manure and reducing dependence on fertilizers.

3. Intercropping

This involves the same activities as the previous alternative, but introduces a new element: the use of the inter-row area for the production of biomass for animal feeding, mainly sources of protein, which also contribute nitrogen to the soil.

The management system should involve minimum tillage to reduce labour demand and take account of the contribution of leaves, resulting from pruning, which will contribute to the crop.

Where a permanent crop is intended, the even rows may be planted, leaving the odd rows for harvesting operations.

4. Palm oil for livetsock feeding

This is similar to the previous alternative but the main difference is that 20 or 30% of the crude oil is used in the animal production programme, making feasible a radical increase in the number of animals, depending on the volume of processing of the extraction plant. This represents the integration of the agriculture and livestock components, which could lead to a major improvement in the efficiency of use of the available resources. It will result in a larger production of biogas, fertilizer and animal products and reduce the dependence of the system on bought-in fertilizer. This may be further enhanced by the introduction of green manuring.

It also provides an alternative to the producer for the use of oil when the market is saturated and prices are low. Meat, milk, eggs and other products could be produced at a lower cost compared to production systems based on grains.

5. Reduced crop density and additional crops

This involves further diversification and alternative crops, thus reducing dependence on the oil market.

It is possible to change the density of sowing and to employ a number of other alternative crops. It is a particular condition of the area where the palm plantations are established that the micro-climate is very favorable for crop production. The system will involve 20-30% of the crop for animal feeding and additional crops which do not compete significantly with the palm.

There is no single recipe for this type of integrated system and it could involve various trees of crops for harvesting or for animal feed. Some possibilities as they relate to the Colombian Orinoquia zone include growing palms with: fruits (lemon, mandarin, orange and others), cowpea (summer and winter varieties), *Arachis pintoi*, aromatic essences, cassava, sugar cane, chili pepper, cocoa, pringamosa, nacedero (*Trichantera*), maraton (*Gliricidia*), and bananas. Generally, it is important to use crops which do not interfere with the shallow roots of the palms.

There is also the possibility of association of the palm with epiphytes, of which there is a great diversity and demand in the national and international market. During its growth, the trunk of the palm favours the retention of water due to the position of the scales, which directly benefits the culture of epiphytes. Preferably the sowings must be done in alternate furrows, which will make the harvesting of fruits easier.

There are many alternatives that can be studied in the design of associations but it depends on the final objectives of the producer, always aiming to make more efficient use of the cultivated area.

6. Fully integrated system

The crop is not intended for oil extraction, but as a strategic base for the productive system, with the fruit intended for animal feeding. The initial focus is on pigs, the species of greatest capacity to realize an efficient extraction of the oil. The fibrous residues from the pigs are offered to cattle and horses; the nuts that are not broken by the pigs are recovered and then are cracked to be offered to hens. The resultant material could be used as fuel or for roads in the plantation.

The manure produced by the animals is used for the production of biogas, as a source of organic fertilizer for the crops, or for the manufacture of compost. The cultivation of palm is associated with production of biomass, preferably energy sources, such as soybean, cowpea, pringamosa or nacedero (*Trichantera gigantea*); likewise it is associated with crops like sugar cane, cassava and aromatic plants.

Free-range hens and the sheep are used as controllers of undesirables species, and rotation is also used for this purpose..

The pigs will stay at pasture during the fattening and gestation phases; paturition and the initial phase of lactation will be under cover and with restricted pasture, until the end of the lactation phase when the average pig weight is 20 kg. During their stay at pasture, the pigs will use the newly planted areas of palm or other crops. The system may be simplified so that the pigs could be grazed under the palms trees and it will not be necessary to transport the fruit from the place where it is located. Confined systems may be employed where the area is limited.

The palm could be associated with *Trichantera gigantea*, soybean, cowpea, sugar cane, pringamosa or cassava, in order to complete the animal diets, to increase the amount of biomass and to make the best use of soil resources. Likewise, it is possible to envisage association with cultures of bananas and epiphytes. Nevertheless, the main objective consists of crops established in association with the palm, to be used mainly for animal feeding. The density of sowing is modified depending on the design that is determined for the available area. It can involve keeping areas dedicated to the culture of palm with high densities, accompanied by areas of other complementary crops, or reduce the density to a total of 70 palms per hectare and with intercropping. The second alternative is likely to be more sustainable.

In this system the inputs are reduced to the minimum possible and it is intended to increase the products, by means of crop and animal integration. The soil management strategy involves the use of organic material by means of (worm) compost, green manure, application of biomass covering and recycling of nutrients from leaves and other residues after harvesting.

Other alternatives

There is a great number of possibilities for the design of palm systems, involving the native palms of Colombia. A interesting example of this is the moriche palm, which lives with its roots under the water and produces a fruit of a high energetic value. This local resource is important to the landscape and is at risk of disappearing. It is being eliminated by the farmers in the process of pasture improvement.

Animal Production Aspects

A series of consecutive trials, involving animal feeding on the oil and by-products from the extraction process, have been carried out by the author. This serves as the basis for the concept of crop-animal integration.

The animal species that is considered most appropriate for the palm system is the pig, due to its capacity for adaptation to the different components of the system and it demonstrates a high efficiency of use of the energy provided by the fatty acids of the oil palm. Ruminants use the fibrous by-products, provide animal traction, and generally help to ensure the maximum integration of crops and animal production.

The work is described in sequence, in relation to the alternative palm systems and the different products and byproducts used for animal feeding.

Oil-rich fibrous by-product:

This is the solid contents of the vibrating sieve that filters the raw oil after it has passed through the press. Itis yellow, fibrous, sweet-smelling and greasy to the touch. Its composition is as follows: dry matter 95.27%, protein 5.25%, ether extract 23.06%, crude fibre 15.05% and ash 1.99%.

Initially, it was evaluated as a substitute for the traditional energy sources like sorghum for pig feeding during the growing phase (20-35 kg), growing-fattening phase (35-60 kg) and fattening phase (60-90 kg). In equivalent energetic terms, levels of 25 (T0), 50 (T50), 75 (T75%) and 100% (T100) of the energy supplied by the sorghum were fed. The levels were set with reference the standares of NRC for the nutritional requirements of the pigs. The average results for each one of the treatments during the whole trial (20 kg to 90 kg) were as follows: daily weight gains were T0 0.525 (133 days); T25 0.592 kg (119 days); T50 0.632 kg (112 days); T75 0.629 kg (112 days) and T100 0.639 kg (112 days).

The results exceeded expectations. They demonstrated that it is possible to substitute 100% of the energy provided by the cereal, with good biological and economic results in the feeding of the fattening pigs.

In addition to substituting for cereals, Preston and Sarria (1990) demonstrated that a reduction of 30 to 35% of the protein was possible in the fattening phase of pigs when it is offered as a source rich in essential amino acids (based on Speer 1990)A second trial was therefore carried out to determine the optimum level of protein to use with this energy source on diets for fattening pigs.

Different levels of restriction of the protein were applied in relation to the recommended levels by NRC (1988) as follows:

T0 (Control): 256 g/day during the growing phase; 256 g/day during the growing-fattening phase; and 360 g/day during the fattening phase;

The other treatments received the same level throughout the fattening period;

Ta received 256 g/animal/day

Tm 228 g/animal/day, and

Tb 200 g/animal/day.

The treatment that took the least time to reach the final weight (22-90 kg) was T0 with 121 days; followed by Tm, Ta and Tb with 124, 126 and 135, respectively. The highest daily weight gain was obtained by the control treatment (T0) with 0.558 kg, followed by Tm, Ta and Tb with 0.545, 0.532 and 0.505, respectively. There was no significant difference between the protein treatments. The highest consumption of byproduct was presented in Tb with 2.56 k/day, followed by Ta, T0 and Tm with 2.45, 2.33 and 2.23 kg, respectively. The economic results were proportionally higher as the restriction of protein was increased, being of 11.5, 12.1, 17.3 and 17.0 USD for T0, Ta, Tm and Tb, respectively.

This trial demonstrated that it is possible to supply the fibrous byproduct with levels of protein lower than recommended.

Later, supplementation with methionine and B vitamins was evaluated, together with fibrous byproduct and restricted protein (200 g/day). The objective was to find if these supplements could improve the metabolism of the animal and consequently increase the animal response to the diet.

The treatments consisted of: TI without supplement; TII with Methionine; TIII with Methionine and B Complex and TIV with B Complex. The quantities used were based on NRC (1988). The average results in days to final weight (20 to 90 kg) were: 143 days for treatment I and 138, 133, 140 days for the treatments II, III and IV respectively; the daily weight gain was 0.48 kg, 0.50kg, and 0.466 for treatments I, II, III, and IV respectively; no significant differences were detected.

The consumption of oil-rich fibre residue for TI was 2.77kg, for T-II was 2.75kg, for T-III was 2.74kg, and for T-IV-I; no significant differences were detected. Consumption progressively increased with age and animal weight. The economic analysis was positive for all treatments. There appears to be no advantage of supplementing the byproduct-protein mixture with methionine or B vitamins.

Raw palm oil

The results obtained with the byproduct were mainly the result of the oil content. Raw palm oil is sometimes available in times of market surplus and when the extraction plant is in a remote place with high transport costs. In 1992, a study was conducted using raw palm oil in a pig-feeding programme. The experiment was designed to evaluate the benefits of raw palm oil as the basal diet to fattening pigs, and using Azolla filliculoides to replace part of the soya bean meal in the diet.

All groups received the same amount of raw palm oil, depending on whether the animals were in the growing-phase (20-60 kg) or fattening-phase (60-90 kg); the level of protein offered was 200 g/animal/day throughout. All the treatments were supplemented with 100and 150 g/d of rice bran in the growing, (20-60 kg)and feeding-phase (60-90 kg) respectively.

The consumption of Azolla during the growing-phase reached 51, 34, and 26% of the quantity expected during the 10, 20, and 30% of the replacement, which meant a total protein comsumption of 212, 202, 184, and 167 day/animal/day. During the fattening period, the total protein consumption was 100, 100, 97, and 69% of that initially expected for all four treatments.

The daily weight gain was 0.450, 482, 0.457, and 0.407 kg/day. (SE 0.13, P=0.80) for the growing phase; and 0.654, 0.692, 0.666 and 0.528 kg/day (SE 0.18; P=0.12) during the fattening phase. The average for all the fattening period was 0.526, 0.561, 0.535, and 0.452 kg/day for the 0, 10, 20, and 30% Azolla replacement levels. The dry matter feed conversion is clear evidence of the quality and potential benefits of this diet. For each level of substitution, from low to high, FCR was 2.1, 1.98, 2.0 and 2.2 respectively during the whole the period. These results are above the recommended ideal standards for the NRC (1988), and well above to the results obtained with commercial foodstuffs, or those obtained by growers using cereals.

A commercial demonstration (Penuela L and Ocampo A 1993; unpublished data) using 169 pigs, took place in San Nicolas swine farm located in the Department of Meta, Colombia. The animals were random-distributed in four groups using a daily ration per animal of 500 g of raw palmoil, 500 g of soya bean cake and 500 g of rice bran. The daily gain was 0.722, 0.628, 0.524, and 0.464 kg per day for each of the groups, and the dry matter conversion was 1.8, 2.0, 2.4, and 2.8 respectively. In economic terms, all groups showed an advantage, and the feed costs represented 46% for all production costs.

Whole palm fruit

The use of whole palm fruit was evaluated as an alternative energy source for fattening pigs, being intended as an alternative use for the crop and a further integration of crop and animal production.

This work was designed to evaluate the substitution in isocaloric terms of sorghum for 25, 50, 75, and 100% of whole African oil-palm fruit during the fattening phase. The animals received restricted protein level based on 200g soya bean cake , supplemented with vitamins and minerals. The daily weight gains for all the fattening phases were 0.625, 0.598, and 0.466 kg day respectively. The feed conversion based on dry matter was 3.2, 3.2, 3.3, and 3.4 .

The pigs demonstrated excellent ability to use the whole fruit, by eating all the way into the internal hard nut and it demonstrated the capacity to extract nutrients in a foodstuff without industrial processing. The utilization of whole fruits will allow the feeding system to be used by small, medium, and large farmers.

Based on previous experience, where strategic supplements of carbohydrates in oil-palm diets have favoured the animal response, an experiment was designed to determine the optimal level of rice bran in fattening diets based on whole fruits of African oil palm, and restricted protein 200 g/day (using soya bean cake fortified with vitamins and minerals). The treatments were 100, 200, 300, and 400 g. daily of rice bran during the growing phases, and 150, 250, 350 and 450 grams during the fattening phase; the fruit was given ad libitum. The daily weight gains, for all phases (growing and fattening), were 0.485, 0.515, 0.492, and 0.497 kg/day with feed conversion of dry matter of 3.2, 3.2, 3.3, and 3.3. The consumption of whole-fruits was 1.1, 1.1, 1.0, and 0.9 respectively. No significant differences were detected in any of the variables. The best economic response was found at 200 g of rice bran during the growing phase and 250 g during the fattening phase.

There appear to be excellent prospects for using oil-palm fruit and byproducts in pig nutrition. As an alternative to the industrial extraction process, intergrated production systems can offer a successful and sustainable alternative.

Indicators of Sustainability

Sustainability involves an equilibrium between production systems and the natural ecosystem. Production systems must take account of the natural ecology and biodiversity of the region.This is particularly important in the more fragile geomorphological zones.

We must also be concerned with the level of energy dependency, type of energy and quantity required for production. This implies the quantification of energy invested to obtain the final product, and an analysis of energy flow through the production processes. This is likely to be improved by integration of agricultural and animal systems. The potential to utilize the byproducts and the multi-purpose capacity of the species utilized are important. Recycling and exchange of nutrients are key elements to enable the system to function with a minimum inputs and the maximum outputs. The conservation, use and management of water resources are also essential to avoid the acceleration of the general ecosystem degradation. The elimination or diminution of contamination during production processes is an important indicator. Reducing the emission of carbon dioxide, methane gas, the release of clorofluorcarbon products, sulphur dioxide, and nitrate oxides are a priority for all.

In overall terms, sustainability may be measured as the ability to retain carbon over time. It is determined by the amount of biomass production and accumulation of organic matter through the use of multi-purpose crops with a high nutrient return. In turn, this depends on photosynthetic capacity and, in these terms, the perennial species has a predominant role in providing continuous biomass production.

In addition, the social function of production systems is to provide employment at a regional level.

Conclusions

The African oil-palm is a strategic resource for the development of integrated production systems in the tropics. It satisfies the principles of sustainability and has a high potential for small, medium and large farmers.

Azolla

Andrew Speedy

(Editor)

Extract from FAO Tropical Feeds Database

6 tropical and warm species (*A. filiculoides*, *A. pinnata*, etc.). The aquatic fern *Azolla* contains a symbiotic, heterocystous, blue-green alga, *Anabaena azollae* within cavities in its leaves. By the process of nitrogen-fixation the alga is capable of fulfilling the N requirements of the association.

An *Azolla* plant consists of a short, branched, floating stem, bearing roots which hang down in the water. Each leaf is bi-lobed, the upper lobe containing green chlorophyll while the lower lobe is colourless. Under certain conditions, an anthocyanin pigment, also occurs giving the fern a reddish-brown colour. This is particularly associated with over-fertilization of ponds, pollution and excess sunlight. Shaded conditions are preferred to full exposure to tropical sunlight.

The plant is highly productive with the ability to double its weight in 7 days. It can produce 9 tonnes of protein per hectare of pond per year. It is used as green manure (in rice paddies), stock feed and for controlling mosquitoes by blocking water-surface. Because the fern can form dense mats on water surfaces, it is classified as a water weed in many areas.

Azolla has reportedly been used as a feed for pigs and ducks in SE Asia; for cattle, fish and poultry in Vietnam; and for pigs in Singapore and Taiwan. It is described as an excellent substitute for green forage for cattle in Vietnam and may replace up to 50% of the rice bran used as feed for pigs in that country.

Although very low in DM, it contains a high level of protein (24% CP). The amino acid composition of *Azolla* compared well with reference protein sources. Methionine is low, as with many leaf proteins, but the value for lysine is more than twice that of corn.

As a supplement for growing pigs, performance was reduced compared to controls in the growing phase but the animals compensated and grew faster in the period from 24-89 kg. It has been used as a sole feed for lactating sows which have a higher intake to deal with the low DM content.

Ducks (650-1800g LW) consumed 350g Azolla when given free-choice with sugarcane juice and soya (about 5% of the diet). It is also used for grazing ducks and geese in paddy fields where the Azolla is used as a fertilizer.

As % of dry matter

	CP	ADF	NDF	Ash	EE	Ca	P	Ref
Azolla	23.4	26.6	39.2	15.5	5.1	0.10	0.05	634

Amino acid composition as % of crude protein

Azolla filiculoides Ref: 634

Arg	Cys	Gly	His	Ils	Leu	Lys	Met	Phe	Thr	Try	Tyr	Val
6.62	2.26	5.72	2.31	5.38	9.05	6.45	1.88	5.64	4.70	2.01	4.10	6.75

Research on Forage Trees

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Introduction

Socio-economic aspects

About 50% of the population of Central America consume less calories and proteins than the recommended levels established by many specialist institutions (FAO, 1984; INCAP, 1969; Von Hoegen, 1976). Despite a large increase in the population in Central America, total meat production decreased by 12% between 1980 and 1985, from 457,000 to 400,000 metric tons. Of this, beef production has decreased by 27%, from 303,000 to 221,000 metric tons (FAO, 1987 and 1990b). Between 1981 and 1988, per capita meat consumption decreased (FAO, 1991) and all Central American countries imported milk (FAO, 1990a).

Depending on country, between 45% and 78% of the farmers in the isthmus have farms between 3.5 and 10 ha in area, occupying between 0.4 and 10% of cultivated land (CATIE, 1985). In addition, land and capital restrictions, together with the location of many of these small farms in areas unsuitable for agriculture, make cattle exploitation difficult or impossible. Under these conditions, the energy contained in the food available on most of these farms is barely sufficient to satisfy the animals' maintenance requirements (McDowell and Bove, 1977 cited by Raun, 1982). All these considerations together with small and medium-sized producers' lack of access to appropriate technology, increased demographic growth and other aspects related to the social and economic situation in Central America, imply a need for novel solutions which will allow considerable changes in the currently used production methods. The development of technological alternatives that are more appropriate to the ecological and socioeconomic conditions of the region must play a decisive role in this process of change, so that consumer goods are produced using methods that are more sustainable and more in keeping with the rational use of natural resources.

Livestock production and natural resources

Many traditional land use practices (deforestation, extensive and extractive grazing, absence of erosion control, farming in unsuitable areas, etc.) bring about disturbances in the ecological balance and reduce the productive capacity of soils (Garríguez, 1983; Jiménez, 1983; Heuveldop and Chang, 1981). Moreover, the production and quality of tropical pastures is affected both by climatic factors (Minson and McLeod, 1970; Stobbs, 1975; Cubillos et al., 1975) and land and capital restrictions in most small farms (Avila et al., 1982).

As well as economic and social factors, the above also includes the type of agricultural technologies practiced in Central America since colonial times. The large herbivores of the Pleistocene period had already disappeared by pre-Columbian times (Janzen and Martin, 1982) and ruminants were not exploited as domestic animals. In those days the only native ruminants were deer which are more truly browsers (Sands, 1983; Morales, 1983). Moreover, the predominant vegetation type in all life zones was trees and shrubs. With the exception of corn, there were few grasses present and these were not an important food source for native herbivores (Janzen and Martin, 1982; UNESCO, 1979; National Geographic, 1992; Skerman and Riveros, 1992). This indicates that in most of the region, the natural vegetation of the land is quite different from that currently existing.

The settlement of Spanish colonists in Central America resulted in the introduction of land use technologies more appropriate to temperate climates, including the use of ploughing and livestock rearing along with the establishment of pasture for feed (Meza and Bonilla, 1990; Tosi Jr. and Voertman, 1977). These practices, which still continue, have contributed significantly to the deterioration and elimination of the natural cover with resultant negative effects on the soil and biodiversity. It has also prevented the possibility of rationally utilizing the forest in areas which have doubtful long and medium term production. With respect to traditional livestock rearing "...it is a very discouraging fact for grasslands experts to realize that animals feed more on shrubs and trees or on associations where woody species play an important role, than on true grass or legume species pastures." (Commonwealth Agricultural Bureau Publication, No 10, 1974, cited by Skerman et al., 1991).

The establishment of production areas on virgin lands has been part of a process which starts with the sowing of grain crops to take advantage of the fertility present after the forest has been felled. Once fertility starts to decline, the land is abandoned or dedicated to extensive agriculture or livestock rearing which is usually extensive and extractive in nature (Sands, 1983). Since the 1950's, over 50% of the natural forest has been converted to shifting agriculture or pasture (Collins, 1990; UNESCO, 1979; National Geographic, 1992). In the majority of cases these are over- grazed small farms or large areas with a small number of animals per unit area (Collins, 1990). In Central America, high productivity in pastures can only be maintained through the extensive use of inputs and labor due to, among other things, the rapid invasion by native woody species which struggle to establish themselves. "..whilst man persists in trying to maintain the pastures, nature struggles to develop forest." (Skerman and Rivero, 1992).

The questions therefore arise: What would have happened if, instead of introducing the plough and grass species, appropriate technologies had been developed to rationally utilize forest products? Apart from timber, can other forest resources be used to satisfy the demand for consumer goods in Central America's population? The results of research into forage trees and shrubs presented in this book contribute to a partial answer to these questions.

Trees and shrubs as feeds for ruminants.

Research into forage trees and shrubs began in CATIE in 1980. Later, the Science and Technology Institute (ICTA), the University of San Carlos in Guatemala and the National University of Costa Rica also became involved. CATIE's Animal Production Area concentrates its efforts on the appraisal of trees and shrubs as sources of forage and on their incorporation in ruminant production systems (Benavides, 1989). The work has an agroforestry focus and is carried out using the farming systems concept. It aims to develop technological alternatives that permit a greater sustainability in animal production systems and a more rational management of soil and forest resources.

The efforts of many professionals in Central America has led to the identification and appraisal of many tree and shrub species with excellent characteristics for foliage nutritional quality, biomass production and adaptability to different agricultural management practices (Benavides, 1991). Woody species with forage potential have been found on the Atlantic slope and Peten area of Guatemala, in the dry, Pacific zones and in the mountains of

Guatemala and Costa Rica (Pineda, 1988; Araya, 1991; Benavides, 1991; Mendizábal et al., 1993).

Research into forage trees

For a tree or shrub to qualify as a forage species, it must possess advantages in terms of nutritional quality, production and agronomic versatility over other traditionally used forage. The requisites for qualifying are: i) consumption by the animals must be sufficient to expect changes in the response parameters; ii) the nutrient content should be attractive for animal production; iii) the species should tolerate pruning and iv) significant levels of biomass production should be obtained. In addition, native species are recommended since these have the advantage of being adapted to their environment and can be established using cheap and simple agricultural practices.

More than ten years work has enabled the development of a methodology to rationalize and organize the research efforts on forage trees and shrubs. This methodology uses a process of successive elimination to leave only species that show the best forage characteristics.

Most of the work on animal response has been done on small ruminants due to their ability to transform these materials into products that are useful for man, the role they can play in farms where keeping cattle is restricted and the lower costs incurred by working on smaller animals. Nevertheless, the information produced can, in most cases, be extrapolated to larger ruminants in a qualitative sense and verified quantitatively as required.

Apart from a study of individual species using the aforementioned methodologies, studies have been carried out to appraise natural prairies and understories to generate alternatives that allow their rational exploitation and ensure the conservation of their biodiversity.

Identification and characterization of species

The first step consists of identifying and characterizing the species of trees and shrubs that have potential as forage species. This is done by one of three routes. The first uses surveys aimed at producers to find out which woody species are normally appetizing to the animals. The second route is direct observation of animals during grazing or browsing using frequency studies to establish the species that are most often taken. Finally, secondary information is used to work with species that have been mentioned in other studies.

Data obtained from producers and from the literature indicate the presence of species with forage potential in the humid tropics of the Atlantic coast of Costa Rica and the Peten of Guatemala, in semi-arid zones of the Dominican Republic and the Southern coast of Honduras, in mountainous zones of Costa Rica's Pacific coast that have prolonged dry seasons and serious erosion problems and in areas above 1000 masl on the high plains of Costa Rica and Guatemala that have a temperate climate (Table 1).

Direct observation of the animals has resulted in the identification of species that are particularly appetizing and have high in vitro dry matter digestibility (IVDMD) and high levels of crude protein (CP). These studies have allowed a preliminary appraisal of species which normally have no value and increase the usefulness of others which normally have other functions.

Observations of goats over a four month period in the humid tropical secondary forest of Turrialba showed that of 84 species that were consumed at least once, 9 species represented 54.2% of the total eaten. Furthermore it was found that the two species which were most sought were those with the highest IVDMD and CP. The results clearly showed that dry matter (DM) levels were lower for the more selected species, indicating that the animals select their food on the basis of "succulence" (Table 2).

During this study, information was also gathered on other uses these species have on the farm and on traditional agricultural management methods. In this way, the study benefits from the producers' knowledge by speeding up the research process.

Many of these species, as well as producing forage, are used for fuelwood, as ornamentals, in living fence-posts, for human consumption and as medicinal plants. A knowledge of these other uses can assist the adoption process when the species are included in feeding systems for ruminants.

Table 1. Some species of trees and shrubs with potential for forage identified in Central America.

Trees	Scientific Name	Site
Aliso	*Alnus arguta*	HP/1
Amate, Higueron	*Ficus* sp.	HT/2, DT/3
Bilil	*Polimnia* sp	HP
Brasil	*Haematoxilum brasilleto*	DT
Chaperno	*Lonchocarpus guatemalensis*	HT
Copal	*Stemmadenia donnel-Smithii*	HP
Engorda ganado	(?)	HP
Guácimo	*Guazuma ulmifolia*	DT
Guanacaste	*Enterolobium cyclocarpum*	DT
Guarumo	*Cecropia peltata*	DT, HT
Jaul	*Alnus acuminata*	HP
Jicaro	*Crescentia alata*	DT
Jiote, Jinocuabe	*Bursera simaruba*	DT, HT
Jobo	*Spondias mombin*	DT, HT
Jocote, ciruela	*Spondias purpurea*	DT

Madero negro	*Gliricidia sepium*	HT, DT
Nacascolo	*Libidibia coriaria*	DT
Poro	*Erythrina cocleata*	HT
Poro enano	*Erythrina berteroana*	DT, HT
Poro gigante	*Erythrina poeppigiana*	HT
Sacumis	*Buddleia nitida*	HP
Sauco negro	*Sambucus mexicana*	HP
Tiguilote	*Cordia dentata*	DT
Zorrillo	*Roupala complicata*	DT
Shrubs	**Scientific name**	**Site**
Amapola	*Malvaviscus arboreus*	HT, DT
Carbon	*Mimosa* sp.	DT
Carbon blanco	*Mimosa platycarpa*	DT
Chaguay, Mongollano	*Pithecelobium dulce*	DT
Chicasquil, Chaya	*Cnidoscolus aconitifolius*	DT
do.	*Cnidoscolus chayamansa*	DT
Chichipince	*Hamelia patens*	DT
Chilca, Sacumis	*Senecio salignus*	HP
Chupamiel	*Combretum sufriticosum*	DT

Clavelon	*Hibiscus rosa-sinenesis*	HT, DT
Espino blanco	*Acacia farnesiana*	DT
Leucaena	*Leucaena leucocephala*	DT
Mano de leon	*Dendropanax arboreus*	HT
Moradillo, Chompipe	*Bomarea nirtella*	HP
Morera	*Morus* sp.	HT, DT
Pintadillo	*Caesalpinea eriostachis*	DT
Ramon blanco	*Brosimun alicastrum*	DT, HT
Ramon colorado	*Trophis racemosa*	DT, HT
Sauco amarillo	*Sambucus canadiensis*	HP
Tora blanca	*Verbesina turbacensis*	DT, HT
Tora Morada	*Verbesina myriocephala*	DT, HT
Zarza	*Mimosa albida*	DT

1/ Highland plains (HP) 2/ Humid Tropics (HT) 3/ Dry Tropics (DT). Adapted from: Benavides, 1983; ICTA, 1987; Pineda, 1988; McCammon-Feldman, 1980; Ammour and Benavides, 1987; Hernández and Benavides, 1993.

Table 2. Frequency of consumption and nutrient quality of plant species selected most often by goats in humid tropical secondary forest/1.

Species	Consumption frequency %	DM %	CP %	IVDMD %

Vernonia brachiata	10,1	22,6	29,6	68,4
Acalypha macrostachya	7,9	22,3	30,1	68,0
Heliconia sp.	7,6	23,4	20,0	38,1
Panicum maximum	6,7	22,6	16,9	54,1
Clibadium sp.	4,7	25,7	26,2	47,3
Helechos	4,6	30,7	20,1	26,3
Croton schiedeanus	4,4	32,7	27,1	23,4
Ovania polygama	4,4	40,5	20,8	40,8
Trofis sp.	3,8	37,0	15,8	65,2
Other species/2	45,8	-	-	-

1: Turrialba, Costa Rica. 2: 75 species.

Source: Rodriguez M., 1982, cited by Benavides, 1991.

In drier conditions, such as the south of Honduras, where precipitation is concentrated in 5 or 6 months of the year, the selection of species is influenced by the time of year, since rainfall affects the type of vegetation. A study carried out over six months was able to identify woody species that were particularly sought by goats and their variation over the time of study.

Information from the field has also helped in learning simple agricultural management techniques that are easy to carry out. In most cases, propagation is done through vegetative material (cuttings and stakes) which results in faster establishment and biomass production than sowing seed (Table 3). It was also found that producers showed a preference for the way the cuttings were taken, their size and the type of cut made (Table 4).

Table 3. Agricultural management of the woody species that are most used for ruminant feed in San Marcos, Guatemala.

	Propagation		Cuttings maturity		
Species	Cuttings	Seeds	Young	Mature	Time of planting
	% of farmers				
Miche/1	100	0	0	100	April-June
Sauco/2	100	0	75	25	April-June
Copal/3	86	14	90	10	April-June
Bilil/4	86	14	90	10	April-June
Engorda Ganado/5	100	0	0	100	April-June
Soloj/6	100	0	90	10	April-June
Moradillo/7	100	0	90	10	April-June
Canaque/8	0	100	-	-	-

1/ *Erythrina* sp. 2/ *Sambucus canadensis* 3/ *Stemmadenia donnel-Smithii* 4/ *Polimnia* sp. 5/ ? 6/ *Palia imperialis* 7/ *Bomarea nirtella* 8/ ?. Adapted from Ruiz, 1992.

Table 4.Management of tree and shrub species most commonly used as ruminant feed in San Marcos, Guatemala.

	Type of cut		Type of planting/1		Size, cm	
Species	Bicel	2 cuts	Vert.	Angled	Length	Diam
Miche	X	-	10	90	100	0,10
Sauco	X	-	8	92	100	0,10
Copal	X	-	8	92	100	0,15
Bilil	X	-	8	92	100	0,10
E. Ganado/2	X	X	14	86	150	0,15
Soloj	-	X	14	86	100	0,15
Moradillo	X	X	0	100	100	0,10

1/ Percentage of producers. 2/ Bicel = angle cut to avoid rot 3/ Engorda ganado

Adapted from Ruiz, 1992.

Preliminary information on the biomass production capacity should be obtained by pruning naturally growing trees. In this way, information can be obtained on survival after pruning and production capacity can be calculated over long periods of time, allowing the best to be pre-selected.

An example of this was observations made in the Western Highlands of Guatemala, at an altitude over 1500 masl, where acceptable yields had been obtained from Sauco Amarillo and Chilca species pruned every 180 days (Table 5). However, under these conditions, yields are determined not only by frequency of pruning but also by age of the plant and competition with other nearby plants for light and nutrients. In the southern zone of Honduras, almost at sea level and with only irregular rainfall for six months of the year, the best yields have been obtained from Guácimo and Tiguilote. The large yield difference from those obtained in Guatemala may be due, apart from climatic differences, to the fact that in Guatemala the species studied were shrubs whilst in Honduras they were older trees.

Evaluation of nutrient quality

In the second stage, samples of foliage from suitable species are taken to the laboratory for nutrient quality analysis. Initially, an analysis of CP content and IVDMD only are recommended, in order to concentrate efforts on species with the best characteristics. Those with least nutritional content should not be completely rejected, since they may have other interesting properties such as high rate of consumption or high biomass production during dry months, and so play a strategic role in feeding.

Most species show CP content two or three times that of tropical pastures and, in several cases, higher than commercial concentrates (Table 6). In addition, the IVDMD of some leaves may be very high, equal to or greater than concentrates. Two species of euphorbias stand out for their nutritional content: *Cnidoscolus acotinifolius* and *C. chayamansa*, the leaves of which are also used for human consumption (Araya, 1991).

Other species with CP levels over 20% and IVDMD over 70% include *Morus* sp. and a species of *Ficus* from the Peten, Guatemala, two Malvaceae (*Malvaviscus arboreus* and *Hibiscus rosa-sinensis*), two Caprifoliaceae (*Sambucus mexicana* and *S. canadensis*) and three Asteraceae (*Senecio* sp., *Verbesina turbacensis* and *V. myriocephala*).

Table 5. Total dry matter yield for Sauco amarillo, Engorda ganado and Chompipe by frequency of pruning.

Species	Pruning frequency months	Production/1 kg DM/tree/year
Total DM/2		
Sauco amarillo		
	3	1,61 +-0,69b

(*Sambucus canadensis*)	6	3,50 +-1,43a
Engorda ganado	3	0,06 +-0,04b
(?)	4	0,21 +-0,16ab
-	6	0,36 +-0,28a
Chompipe	4	0,17 +-0,10
(*Bomarea nirtella*)	6	0,17 +-0,11
Edible DM/3		
Sacumis	3	0,09 +-0,02b
Buddleia sp.	4	0,27 +-0,28a
-	6	0,29 +-0,13a
Chilca	3	0,44 +-0,33
(*Bacharis saliciofilia*)	4	0,56 +-0,34
-	6	0,56 +-0,37

1/ Values with the same letter do not differ statistically, $p<0.01$.

2/ Adapted from Mejicanos and Ziller, 1990

Nutrient content is affected by the age of the regrowth, the branch component and the position of the regrowth on it. In Erythrina leaves, under humid tropical conditions, wide variations in CP and IVDMD have been found for all biomass fractions according to their position on the branch (Table 7).

Differences have also been found in data taken by different authors from the same species. This may be due to differences already mentioned, to differences between laboratories or to climatic differences between sampling sites (Table 8).

Table 6. Dry matter, crude protein and digestibility/1 of foliage from woody species with forage potential identified in Central America.

Species	DM%	CP%	IVDMD%
Chicasquil fino (*C. aconitifolius*)/2	16,5	42,4	86,6
Morera (*Morus* sp)	28,7	23,0	79,9
Jicaro (*Crescentia alata*) (flores)	-	11,0	77,6
Chicasquil ancho (*C. chayamansa*)2	9,3	30,8	74,8
Tora morada (*Verbesina myriocephala*)	19,8	23,0	71,5
Chilca (*Senecio salignus*)	26,5	23,4	71,5
Amate (*Ficus* sp.)	-	14,4	71,3
Tora blanca (*Verbesina turbacensis*)	20,6	20,8	70,8
Clavelon (*Hibiscus rosa-sinenesis*)	24,8	21,0	70,0
Sauco negro (*Sambucus mexicana*)	17,9	25,0	69,8
Chaperno (*Lonchocarpus guatemalensis*)	-	19,5	69,4
Guachipelin	41,7	28,6	68,3
Cassia siamea	26,9	14,4	67,4

Ramon blanco (*Brosimum alicastrum*)	-	12,7	67,2
Zorrillo (*Roupala complicata*)	26,6	42,5	66,9
Amapola (*Malvaviscus arboreus*)	16,5	22,4	64,5
Sauco amarillo (*Sambucus canadensis*)	18,0	28,5	64,4
Copalchi	31,0	14,3	62,4
Chichipince (*Hamelia patens*)	-	17,5	61,6
Carbon blanco (*Mimosa platycarpa*)	-	16,0	60,0
Madero negro (*Gliricidia sepium*)	25,1	21,6	59,2
Nacascolo (*Libidibia coriaria*)	-	16,0	59,0
Chompipe, Moradillo (*Bomarea nirtella*)	19,0	18,7	58,4
Ramon colorado (*Trophis racemosa*)	-	12,9	56,5
Poro enano (*Erythrina berteroana*)	22,9	24,3	55,0
Espino blanco (*Acacia farnesiana*)	-	22,0	55,0
Guácimo (*Guazuma ulmifolia*)	37,6	15,6	54,3
Mano de leon (*Dendropanax arboreus*)	-	12,1	52,7
Guarumo (*Cecropia peltata*)	19,7	19,8	51,8
Poro gigante (*Erythrina poeppigiana*)	24,0	23,8	51,3
Poro de cerca (*Erythrina cocleata*)	24,3	21,6	51,2
Copal (*Stemmadenia donnel-Smithii*)	19,1	24,4	50,6

Jobo (*Spondias mombin*)	23,6	10,9	49,6
Bilil (*Polimnia* sp)	17,9	22,1	45,2
Tiguilote (*Cordia dentata*)	41,0	16,0	36,0

1/ In vitro dry matter digestibility. 2/ Cnidoscolus. Adaptado from Hernandez and Benavides, 1993; Araya et al., 1993; Mendizábal et al., 1993; Reyes and Medina, 1992; Godier et al., 1991; Medina, et al., 1991; Rodriguez et al., 1987.

Table 7. Dry matter, crude protein, in vitro digestibility and digestible energy of different foliage fractions from *Erythrina poeppigiana.*

Fraction	%DM	%CP	%IVDMD	DE/a
Apical leaf	17,5	38,4	74,1	3,27
Intermediate leaf	25,5	30,5	33,5	1,48
Basal leaf	26,2	27,1	37,4	1,65
Apical stem	17,0	12,2	54,4	2,40
Intermediate stem	20,1	10,6	47,4	2,09
Basal stem	21,5	9,2	34,1	1,50
Bark	17,0	14,1	78,3	3,45

a/ Mcal/kg DM. Benavides, 1983.

Table 8. Effect of age of regrowth on crude protein content and digestibility of leaves of some Central American woody species.

Species	Regrowth age in months		
	3	4	6
Crude protein, %			
Sauco Amarillo/1	25,5	23,0	15,6
Engorda ganado/1	-	24,8	21,9
Chompipe/1	-	18,3	15,6
Morera/2	23,1	6,9	16,7*
Morera/3	20,9	19,2	-
Amapola/4	21,6	20,8	-
IVDMD, %			
Sauco Amarillo/1	75,5	67,3	56,2
Engorda ganado/1	-	66,3	57,3
Chompipe/1	-	57,5	56,2
Morera/2	90,5	90,5	90,1*
Morera/3	77,2	76,9	-
Amapola/4	61,1	58,0	-

*/ Cut every 6, 9 and 12 weeks. 1/ Adapted from Mejicanos and Ziller, 1990. 2/ Adapted from Rodríguez et al., 1987. 3/ Adapted from Benavides et al., 1993. 4/ Adapted from López et al., 1993a.

A study of other chemical components such as lignin, tannins and toxins should also be made to detect any potential problems in acceptability, low growth response, milk production or poor animal health. Where there is evidence of negative nutritional factors, samples should be returned to the laboratory to evaluate the factor causing the problem and find possible solutions.

When *Gliricidia sepium* leaves were offered to goats stabled in Turrialba, consumption problems were noticed as the material was younger, with a higher IVDMD and lower DM content. The problem seems to be related to the place of origin of the material since, for the same trial, foliage from two different sites was used and there was a marked relationship between site and level of consumption.

As with other forage material, a strong correlation has been found in the foliage of shrubs and trees used between IVDMD and cell wall content, cellulose, tannins and lignins. Information from several species both from cold climates such as the Guatemalan Western Highlands and hot regions in Costa Rica may be useful to develop methods or formulate equations to predict the nutrient quality composition of foliage on the basis of the level of one chemical factor in the material.

Animal response

After testing nutrient quality values, large amounts of material, even plantations of the species, will be needed for the next phase: testing with animals. Tests are carried out to determine the animals' response parameters (acceptability and consumption, milk production, growth) when offered foliage from these species.

Erythrina poeppigiana is the species that has been studied most in the last decade in trials for consumption and production, showing ingestion levels greater then 3% LW in lactating goats (Table 9). Other studies have investigated the level of consumption of species which grow naturally in dryland grasslands, understories and natural forest regeneration sites and which have been selected after observing animals in pastures.

In the southern zone of Honduras, satisfactory consumption levels have been obtained for growing kids feeding on Guacimo and Tiguilote. With some species, a long period of familiarization is needed before the

consumption level is established. In the humid sub-tropics of the Peten in Guatemala, the foliage of species that are common on fallow lands and understories have been fed as a supplement to sheep in pasture and have been reported successfully consumed (Table 10). In this way, a normally under-utilized resource acquires a higher value, opening up a way of using non-timber forest products without destroying the forest.

Table 9. Consumption level of *E. poeppigiana* foliage by goats when administered alone or as a supplement to pasture or bananas and plantains.

Type of diet	Intake %LW	Authors
Alone	3,5	Benavides and Pezo, 1986
With green bananas	3,3	Esnaola and Benavides,1986
With plantain	3,3	Benavides and Pezo, 1986
With green bananas	2,8	Rodriguez *et al*., 1987
With green bananas and pasture	1,5	Esnaola and Rios, 1986

When there is little foliage, either because the plantation is small or because naturally growing plants are used for biomass production, certain observation procedures have been improvised to measure acceptability. In these cases, foliage from different species is offered at the same time and, as the trial proceeds, the most consumed species is eliminated to find out if the rest are also used. It has been observed that species with the highest IVDMD and greatest CP content are selected most initially, and as mentioned earlier, longer adaptation periods are needed than for traditional forage.

On hillsides of the Costa Rican Central Pacific zone, young stabled goats were simultaneously offered foliage from Chicasquil ancho, Chicasquil fino, Jocote and Guacimo. The most consumed species were

successively eliminated and it was observed that intake of the species that remained increased. Furthermore, with the exception of a period when only lesser quality foliage was used, it was found that the total consumption for all species increased between experimental periods.

Table 10. Dry matter consumption by penned sheep of foliage from woody species present in secondary forest, Peten, Guatemala.

Species	DM intake % Live weight	Typical deviation
Cecropia peltata	2,1/a	0,4
Brosimum alicastrum	2,0/ab	0,9
Lonchocarpus guatemalensis	1,4/bc	0,4
Hamelia patens	1,3/bc	0,3
Dendropanax arboreus	1,1/c	0,4
Trophis racemosa	1,1/c	0,7
	0,5/d	0,2

Ficus sp.	0,3/d	0,2
Spondias mombin	0,3/d	0,2

1/ Values with the same letter do not differ significantly, $p<0,05$.

Adapted from Hernandez y Benavides, 1993.

Two of the most common woody forage plants are Leguminosae in the genera *Erythrina* and *Gliricidia*. They have high CP contents but medium to low levels of IVDMD. Research results have shown that the energy complement of the feed increases the animals' response parameters noticeably and that the high starch content gives greater productivity than more simple sugars.

An evaluation of the effects of four energy sources on consumption and growth in lambs fed *Erythrina* foliage, in the humid tropics of Turrialba, showed that in all cases where an energy source supplement was given, consumption and weight gain were greater than in animals not receiving the supplement. The greatest responses were found with green bananas and yams (starches) and were greater than with molasses (simple carbohydrates) (Table 11).

Another study in Turrialba on goats fed pasture and green bananas showed significant increases in milk production in goats with mid-range milking potential in proportion to an increased level of supplementation with *Erythrina* foliage. An additive effect was also noticed on the total DM consumption as Erythrina consumption increased, whereas the effect on pasture consumption was not very significant.

Table 11. Weight gain and consumption for "Black belly" lambs fed Poro gigante (*Erythrina* sp.) foliage and supplemented with different energy sources.

Parameters	Nothing	Molasses	Green Banana	Green banana	Yam

			+ Molasses		
Mean wt. kg.	22,2	23,0	23,1	20,8	22,8
Gain,g/an/day/1	74,0/c	92,0/bc	91,0/c	112,0/ab	128,0/a
DM cons., % LW					
Erythrina	3,5	3,2	3,3	3,3	3,0
Supplement	0,0	0,8	0,9	1,1	1,3
Total	3,5	4,0	4,2	4,4	4,3

1/ Values with the same letter do not differ significantly, p<0,05.

Benavides and Pezo, 1986.

It is important to have an appropriate proportion of protein source (*Erythrina* foliage) to energy source (plantain) when these are used in the diet. This was found in a study carried out in Turrialba where goats in milk production were offered two levels of *Erythrina* and two of plantain supplements. Highest milk production occurred in treatments with a similar protein/energy ratio. (Table 12).

Table 12. Milk production and dietary protein/energy ratio in goats fed on pasture and different levels of *Erythrina* and green plantain.

Plantain level	High	Low	High	Low
Erythrina level	High	High	Low	Low
Milk, kg/an/day	1,27	1,09	1,09	1,13/1

CP/DE, (g/Mcal)2/	40,0	45,0	35,0	40,0

1/ Interaction between factors significant, $p<0,05$.

2/ Crude protein/Digestible energy (grammes/megacalorie).

Adapted from Castro, 1989.

Higher milk production levels have been obtained with species that have high CP and IVDMD and a very significant response has been observed when increasing amounts of foliage are administered to animals with diets based on pasture.

This is the case with Amapola and Morera foliage, where increased milk yields have been observed in goats in the humid tropics as the amount of foliage in the diet is increased. Milk production levels of 2.2 and 2.6 kg/animal/day have been achieved this way, normally only possible using commercial concentrates.

For both these species, dry matter consumption levels over 5% of live weight were reported. However, for animals with high production potential, there was a marked substitution effect on pasture consumption as well as an important additive effect on total DM consumption, for both species of supplements.

Yields approaching 800 kg milk/animal/300 day lactation have been observed for two goats fed for three years on solely Morera leaves and pasture in a module under humid tropical conditions. Mean production of over 4.0 kg/animal/day have been observed in the same module at peak lactation. In addition, an increased response in weight gain of over 100 g/animal/day has been found for lambs when the percentage of Morera foliage in the diet is increased (Table 13).

Agronomic evaluations

After selecting the species with the best characteristics, agronomic evaluations are carried out. The aim is to develop management techniques that provide high biomass yields in a way that is sustainable over time and involves the minimum use of external inputs. Research has included work on propagation techniques, the most appropriate spatial and temporal arrangements, the use of organic fertilizers (mulches and manures) and the possibilities of association with other crops or forages.

Table 13. Consumption level and weight gain in "Black belly" lambs fed on King grass supplemented with varying levels of Morera foliage

	Morera DM consumption, %LW			
Parameter	0	0,5	1,0	1,5
Starting weight, kg	15,7	15,8	15,8	15,1
Increase, g/animal/day/1	60/b	75/b	85/ab	101/a
DM consumption,kg/an/day				
King grass	0,7	0,6	0,6	0,6
Morera	0,0	0,1	0,2	0,3
Total	0,7	0,7	0,8	0,9
Consumption, % L.W.	3,5	3,7	4,0	4,3

1/ As a percentage of body weight.

2/ Values with the same letter do not differ significantly, p<0.01.

Adapted from Benavides, 1986.

Of all known methods, propagation by cuttings (stakes) is most used since the time taken to establish them is shorter, the technique is easy and well known by producers. The percentage of Amapola and Morera that successfully 'take' is about 90% in the humid tropics (Benavides *et al*., 1993; Lopez *et al*., 1993). In some species it is possible to plant the entire stake horizontally beneath the soil. This gives rise to several plants per stake and saves propagation material. However, there are variations between species that must be taken into consideration before a technique is chosen (Table 14).

The association of leguminous trees with grasses can be beneficial in two ways. Firstly, the association provides forage from the associated tree as well as the grass from the pasture. Cut grass production is not affected by the trees since the latter are frequently pruned (2 or 3 times a year) and do not compete for light.Table 15 shows the results of work done in the humid tropical conditions of Turrialba, where King grass (*Pennisetum purpureum* x *P. typhoides*) was grown intercropped with *Erythrina poeppigiana* planted as 2.5 m stakes at 1x3 and 2x3 m (1667 and 3333 trees/ha). No nutrient replacement was given to the soil and all the biomass produced was removed from the site. It was also found that nutrient yields per unit area were three times that of pasture grown in monocrop. Nevertheless, production falls in the short term, in the case of pasture and in the medium term, for *Erythrina*, if material is frequently removed without replacing nutrients.

Table 14. Effect of planting position on germination and number of shoots for Sauco, Amapola and Morera stakes.

	--- Planting position ---			
Species	Horizontal		Vertical	
	Germ.%	Shoots/stake	Germ.%	Shoots/stake
Amapola	58.0	1.0	87.5	4.3
Morera	90.4	2.1	100.0	3.1
Sauco	53.8	1.1	60.4	1.5

Esquivel y Benavides, 1993. Unpublished.

Table 15. Dry matter production (T/ha/yr) for King grass grown in association with *Erythrina* and in monocrop.

Year	Association mean	Check without trees
1	27,0/a	25,8/a
2	17,3/b	19,8/a
Mean	22,1/a	22,9/a

Values with the same letter horizontally do not differ significantly, p<0,05.

Benavides *et al*., 1989.

The other way of utilizing the benefits of the association is to use the *Erythrina* leaves as a green mulch for grasses. In humid tropical conditions with low soil fertility, pasture yields were found to increase when increasing amounts of *Erythrina* foliage (planted at 2x3 m and pruned every 4 months) were applied to the soil. Similarly, it was found that the mere presence of the trees, even without foliage application, stimulated greater pasture production than that for pasture without trees (Table 16).

Table 16. *Erythrina* and King grass dry matter deposited, exported and total (T/ha/yr.) according to amount of foliage added to the soil.

Parameters	Check without trees	Amount foliage added to soil			
		0%	33%	66%	100%
Produced/1					

Erythrina	-	9,0	8,6	8,2	9,2
Grass	12,42	21,0/c	20,6/c	26,6/b	30,3/a
Total	12,42	30,0/c	29,2/c	34,8/b	39,5/a
Exported/2					
Erythrina	-	9,0	6,3	2,2	0
Grass	12,42	21,0/c	20,6/c	26,6/b	30,3/a
Total	12,42	30,0	26,9	28,8	30,3
Erythrina deposited	-	0	2,3	6,0	9,2

1/ Values with the same letter horizontally do not differ significantly, p<0,01.

2/ Significant differences between check and treatment 0%, p<0,01.

Libreros *et al*., 1993

In livestock rearing, the relationship between animals and the plant component is traditionally one way, the animal benefitting from the plant but not participating in its production. In production systems where animals are managed in stables, a two way relationship can be established by using most of the manure the animals produce as fertilizer. In this way, the system is more balanced and the plant component benefits from nutrients contributed by the animals.

Moreover, those species that have the best forage characteristics are also those which extract most nutrients from the soil and, unlike members of the Leguminosae, cannot fix nitrogen. For this reason they

need applications of large amounts of chemical fertilizers. In order to find an ecologically rational solution, goat manure has been tested as a fertilizer in plantations of woody forage species. Sustainably high biomass yields have resulted and, in some cases, the yields have increased over time.

Biomass production in Morera increased significantly in an experiment carried out over three years in Turrialba, using Morera started from 30cm stakes planted at 22,700 plants/ha, with the addition of increasing amounts of goat manure. In fact, for equal levels of nitrogen fertilization, the goat manure produced yields higher than with chemical fertilizer (NH4NO3). An increase in biomass production between years was also observed.

With the same planting density and type of stake, positive responses have also been observed in Amapola plantations using the same amounts of manure. However, total yields were less and those with chemical fertilizers were higher (Table 17).

In areas with a bimodal rainfall distribution, it is important to evaluate the pruning techniques that will provide adequate biomass levels during the dry months. For this reason, work was done to evaluate the effect of prunings at the end of the rainy season on biomass production during the dry season. In the Dominican Republic, pruning living fence posts of *Gliricidia sepiu*m in October, November and December, not only delayed flowering, but also produced higher yields and edible biomass growth during the months of less rainfall (Table 18).

Table 17. Amapola dry matter production (T/ha/year) by biomass component, according to the amount of goat manure applied to the soil.

	Amount of manure/1				NH4-NO3/1
Component	0	240	360	480	480
Leaves/2	5,8/c	6,2/bc	6,9/b	7,1/b	8,1/a
Soft stem	1,9/b	2,1/b	2,1/b	2,4/ab	2,7/a
Woody stem	6,3/c	6,6/c	7,9/b	7,6/b	8,9/a

Total	14,0/c	14,9/bc	16,9/b	17,1/b	19,7/a
Edible	7,7/c	8,3/bc	9,0/bc	9,5/b	10,8/a

1/ Equivalent in kg N/ha/yr. 2/ Values with the same letter horizontally do not differ statistically, p<0,05.

Lopez *et al*., 1993.

Table 18. *Gliricidia sepium* dry matter production (g/tree) during months of dry season.

Component	Pruning month during dry season/1			
g/tree/pruning	February	March	April	May
Leaves/2	288/b	342/b	373/b	528a
Edible stems	66/b	60/c	69/b	96a
Woody stems	118/c	222/bc	315/b	569a
Total	457/c	617/bc	755/b	1192a
Total edible	355/b	402/b	442/b	624a

1/ Mean of initial prunings in October, November and December.

2/ Values with same letter horizontally do not differ significantly, p<0,02.

Adapted from Hernandez, 1988

Diet calibration

This stage attempts to generate information to produce diets based on the use of tree foliage. In vivo consumption and digestibility trials must be carried out using metabolic cages and in situ evaluations of breakdown in the rumen. Similarly, metabolic studies and nitrogen balances are done for lactating goats to define more precisely the efficiency with which the nutrients in each type of foliage are utilized. In this way, it has been found that Morera and Amapola foliage have high *in vivo* dry matter digestibility, the Morera showing particularly high digestibility for crude protein (Table 19).

Table 19. Consumption, milk production and in vivo dry matter and crude protein digestibility for Morera and Amapola foliage.

	Goat 1	Goat 2	Goat 3	Mean
Morera				
Intake, g DM/kg^0.75/day	101,0	109,0	101,0	103,7
Milk, kg/an/day	1,2	1,3	1,3	1,3
In vivo DM digestibility, %	78,4	78,7	80,8	79,3
In vivo CP digestibility, %	99,4	84,6	86,9	89,5
Live weight, kg	34,8	44,9	36,3	38,7
Amapola				
Intake, g DM/kg^0.75/day	108,0	117,0	102,0	109,0
Milk, kg/an/day	0,8	1,2	1,2	1,1
In vivo DM digestibility, %	64,0	63,9	64,9	64,3
In vivo CP digestibility, %	54,6	51,8	56,6	54,3

Live weight, kg	36,3	44,2	40,8	40,4

Adapted from Jegou, Waelput and Brunschwig, 1991

Exploitation of natural prairie and understory

Given that traditional production systems are based on browsing and grazing and the use of natural vegetation in prairies and understories, it is important to study the feeding behavior of herds to find possible ways of improving the system without drastic changes to the producer's methods of exploitation. With this in mind, the work aims to: i) characterize the ways of using vegetation cover and ii) determine the contribution of species taken during browsing on the animals' diets.

Observation of a herd of goats feeding on degraded prairie shows that there is an important variation in the type of vegetation preferred. Whilst in the dry season (March and April) the animals preferred woody species, as soon as the rainy season started, the consumption of herbaceous plants increased markedly.

This type of study has provided an understanding of grazing animals' behavior and not only identified woody species that are most preferred but also which parts of the biomass are used by the animals. It has been found that not only green leaves but also fruits, flowers and dry leaves form important parts of the diet and that each component is taken according to the seasonal variation in availability.

Technology validation and economic evaluation.

The validation of technologies generated by the research process is essential to guarantee their future adoption and to adapt them to real conditions in the production process. The validation process is done in two ways: i) on-farm research in places where much of the work is done, which encourages the chances of adoption and ii) implementing the most promising technologies developed on experimental stations on farms, allowing adjustments to be made according to real-life production conditions.

To date, most of the technologies have been implemented at the level of small farms, for goat production systems designed for family consumption.

Apart from the technology aspect, it is essential to know the economic yield of the alternatives generated, both at the experimental level and at the site of production.

For the economic evaluation, the following have been carried out: a partial budget analysis of the experiments done at field station level, a profitability analysis (cash flow and income) *ex post* of the technologies implemented on the demonstration module and an analysis of family benefit and cash flow and income at farm level.

The analyses carried out to date indicate that applying the technologies with forage trees in farms is profitable and that their presence contributes to an improvement in the economic situation of the family.

In lactating goats fed on a basic pasture diet, the use of *Erythrina* foliage and other agricultural sub-products (rejected bananas) as a supplement gives a better return than using concentrate feed, even though the latter gives greater production (Table 20).

Table 20. Milk production, dry matter consumption and economic benefit obtained from two diets fed to stabled lactating goats.

Parameters	Pasture +*Erythrina* + banana	Pasture +concentrate
Milk, kg/animal/day	1,1	1,3/1
Intake		

King grass	0,5	0,5
Ripe banana	0,6	-
Erythrina	0,4	-
Concentrate	-	0,7
Total	1,5	1,2
Partial benefit, US$/animal/day	0,6	0,5

1/ $p<0,05$.

Gutierrez, 1985.

The cost of foliage (from planting to administering as feed) that is nutritionally similar to commercial feeds is much lower than these. This accounts for the greater profitability found in the agroforestry demonstration model run by CATIE, where the goats are fed exclusively on pasture and Morera foliage (Table 21).

Environmental impact evaluation for the technologies.

An attempt has been made to identify and, where possible, quantify the effects of the new and traditional technologies on the soil and vegetation. The aim is to produce recommendations designed to ensure

sustainability of production and optimize the use of natural resources. In the case of soil, it is important to find out the effects on chemical and physical characteristics and, although this information is normally detected in the long term, it is useful to monitor changes.

Table 21. Cash flow (US$) for the financial analysis of the agro-forestry demonstration model for goats in Turrialba, Costa Rica.

Description	1991/92	1992/93	1993
A. Costs			
A.1 Investment			
Morera and Erythrina	4,61	4,61	2,88
Pasture and Erythrina	1,66	1,66	1,04
Installations	16,07	16,07	9,37
Breeding stock	50,00	50,00	31,25
Subtotal	72,34	72,34	45,21
A.2 Fixed			
Opportunity cost for land	21,17	21,17	13,23
A.3 Variables, labor			
Pruning, weeding, cutting, transport	182,65	176,19	109,77
Leaf stripping, chopping and feeding	138,45	133,55	83,20
Milking	89,05	85,90	53,52
Goat shed cleaning	54,60	52,67	32,81
Manure fertilization	26,00	25,08	15,63

Salt	30,66	30,66	19,16
Deparasitization	1,40	1,40	1,40
Maintenance	6,50	6,27	3,90
Subtotal	455,31	511,72	319,39
Total cost	527,65	584,06	377,83
Discounted cost stream	610,82	643,92	396,72
B. Income			
B.1 Milk production	672,66	813,99	549,03
Discounted income stream	778,68	897,42	576,48
C. B - A discounted	167,86	253,50	179,76
B/C 1,36	1,27	1,39	1,45
NPV/1 601,12	-	-	-

1/ NPV = Net Present Value

Oviedo *et al*., 1993

Part of the research into forage trees is to develop techniques for plantations which provide soil conservation in areas suffering problems with erosion. Thus, shrub species can be used to control soil loss since they can be planted at high density, are perennial and can be grown in association with other crops.

Over a three year period, two types of Amapola plantation were established on a hillside site with serious erosion problems. The two plantations were:Amapola sown in high density along the contours, associated with grass and Amapola sown along the contour with a greater separation between rows and associated with corn. Soil loss was compared with a plot of corn grown in the traditional way (bare soil). A measurement of the amount of soil eroded per year showed that the

loss was less in the Amapola plantations.

Impacts of research on agroforestry with goats

One good example of the effect that the technologies developed have had is the changes made in exploiting goats in Costa Rica over the last decade. In this country, at the same time as the use of woody forage species has increased and the use of grasses has decreased there has been an increase in the size of herds and the levels of milk production per animal.

In summary, research into forage trees and shrubs carried out by CATIE has:

i) Demonstrated the feasibility of introducing an agroforestry focus as a non-traditional livestock research alternative.

ii) Developed silvopastoral production technologies which considerably increase sustainability and productivity per unit area and can be transferred to small and medium sized farms and adapted to the conditions of large producers.

iii) Favored the definition and organization of institutional policy and the creation of infrastructure for research and promotion of silvopastoral and forage tree systems in the countries of the region.

iv) For the first time in Central America, trained highly qualified professional personnel on forage trees by means of postgraduate studies, intensive courses and in-service training.

v) Generated knowledge on the alternative uses of natural resources and tropical biodiversity, which can be used for the promotion, formulation and execution of research and promotional projects in Central America.

Conclusions

The research conducted to date in CATIE on forage trees shows that:

i) The foliage of many species of trees and shrubs can improve the quality of diets traditionally used for feeding animals. The crude protein content of this foliage is usually double or triple that of grasses and, in several cases, the energy content is also higher, even when compared to commercial concentrates. Their presence in the diets significantly increases milk production and weight gain in the animals.

ii) Many species of trees produce abundant quantities of edible biomass per unit area, can tolerate pruning and are easily managed, from an agricultural point of view. In associations of pasture with woody forage species, the production of crude protein per unit area can be significantly increased over that obtained from grass in monocrop.

iii) In association with pastures, some tree species have no effect on or even significantly increase the production of the grasses.

iv) During the dry season, trees can produce larger quantities of forage than can be produced by pasture, and in a more sustainable form, where chemical fertilizers are not used.

v) Since forage species can be found in most of the life zones of Central America, silvopastoral systems can be developed in many ecological conditions. Moreover, because of their agricultural versatility, they can utilize places with area limitations without competing with other agricultural activities.

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Caesalpinia paraguariensis

Abstract

Caesalpinia paraguariensis (Fabaceae): forage tree for all seasons. Aronson, J and Toledo, CS. 1992. *Economic Botany*. 1992, 46: 2, 121-132.

Guayacan (*Caesalpinia paraguariensis*) is an under- exploited multipurpose tree legume of the semi-arid Chaco region of southern South America. Aspects of the tree's botany, ecology, biogeographical distribution and past and present uses are presented, and its importance as a source of fodder for domestic livestock including cattle is emphasized; other economic uses include wood, tannin production, bee forage, ink and dye, medicine and amenity planting. A typical phenogram of the tree is presented, showing that the abundant, and annually reliable, fruit crop lasts nearly year-round. Nutrition data on pods, seeds and leaves are given, as are characteristics of the wood. Merits of *C. paraguariensis* are discussed in comparison with various tree legumes frequently used in dryland reforestation and agroforestry programmes.

Table 1. Protein and lipid content of pods (without seeds), seeds (incl. testa) and leaflets of *Caesalpinia paraguariensis, Faidherbia albida, Prosopis chilensis, Tamarindus indica* and *Ceratonia sislqua*.

	Pods		Seeds		Leaves	
	CP %	EE %	CP %	EE %	CP %	EE %
Guayacan	**10.1**	**-**	**-**	**-**	**17.8**	**-**

F.albida	27.4	4.0	20.5	16.4	20.2	3.1
P.chilensis	11.0	2.0	35.2	5.3	23.5	2.9
T.indica	10.1	1.0	18.3	7.4	15.8	9.6
C.siliqua	6.9	1.2	18.5	2.0	-	-

The most important use of the Guayacan has not been previously described, let alone developed through purposeful management and germplasm selection. We refer to the usefulness of this tree as a source of valuable forage for livestock. Four traits are worth noting here.

1. The nutritional characteristics of Guayacan pods, seeds and leaves compare favorably with those of several widely-planted legume trees considered important sources of forage (Table 1).

2. The fruit production of mature Guayacan trees is also equal to or greater than that of most forage trees found in semiarid and arid regions. Preliminary data on 20 marked trees indicate an average yearly yield of 5.0 + 3.0 kg pods per tree per year (Saravia Toledo, unpublished data). If 40 trees were preserved per hectare, this would represent approximately 200-240 kg of pods/ha/yr of high quality forage.

3. Only about 10% of pod fresh weight consists of seeds, the hard coats of which render them indigestible to livestock. The rest of the pod is all useful cattle food, similar in consistency to dry carob pods (Aronson and Ovalle, unpublished data).

4. Mature Guayacan trees (10-20 years) bear their fruits over an extended period each year, despite inter-annual variations in rainfall or temperature extremes. This productivity stands in sharp contrast to that of many leguminous taxa and other trees (e.g., beech (*Fagus*), oak (*Quercus*) and *Pistachia*), that tend to have heavy yields in "mast" years, and very little fruit in intervening years. In many Prosopis and Acacia species , good fruit crops are typically pro-duced only every 2nd or 3rd year, at least in theChaco region, in Chile and in the SW USA . Guayacan,

by contrast, offer reliable and plentiful forage in the Chaco, even in years ofsevere drought (e.g., 1988-1989). Although tannin content is high (15-23%) in some pods, this apparently does not affect palatability or digestibility for livestock. Cyanogenesis has not been found in this species). Most forage trees in the Chaco (e.g., Acacia and Prosopis spp. and Ziziphus mistol) drop nearly all their fruits within a brief period at the beginning of the rainy season (Nov.-Dec.). By contrast, Guayacan pods ripen over 7 to 9months, including the critical drought period when little else is available for livestock in the Chaco.

In summary, the high nutritional value of Guayacan leaves, seeds and, especially, pods (Table 1), combined with the exceptionally long period of fruit drop (7-9 months), and regular annual production of pods makes this species as promising as an important forage tree as any of the more than 80 other indigenous tree and large shrub species in the semiarid to subhumid Chaco regions.

Optimizing the use of poor quality roughages through treatments and supplementation in warm climate countries with particular emphasis on urea treatment

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Introduction

There is no doubt that the main basal feeds for ruminants in warm climate developing countries are essentially crop residues and poor quality grasses from rangelands either grazed or, even manually collected at a very advanced vegetation stage, when mature, during the dry season.

What is less obvious are the ways and means for optimal use of these feed resources at both the nutritional and economical levels.

The objective of this paper is, after rapidly reminding the basic principles for optimizing the digestive use of poor quality roughages, to quickly review the main technologies available for optimizing these roughages and, in the mean time, to try highligting assets and drawbacks of transferring them at the practical level.

Basic Principles for Optimizing Poor Quality Roughages Digestion

We will not embark here in a detailed course on ruminant nutrition physiology, this has been done quite clearly in previous papers out of which Leng's one. The purpose is more to recall the key basic points related to the digestive utilisation of poor quality roughages that every one should bear in mind when facing a situation involving the use of such feed resources. The aim is in fact to understand those basic principles so that the solution sorted out be adapted to the practical situation in the best nutritional way as possible.

These key principles are as follows:

(a) To feed the micoorganisms of the rumen in such a way that the cellulolytic strains be favoured. Poor quality roughages are fairly and slowly digested in the rumen. The energy required for the synthesis and the fermentation activity of the micro-organisms is that contained in the roughages cell-walls. It is slowly released. But poor quality roughages are low in N, minerals and vitamins. The N requirement for microbial synthesis (roughly 145 g CP per kg Organic Matter Fermented -energy- in the rumen, figure still subject to more precision) is not met by the N intake from the basal diet. N, in the form of degradable protein (or, better, NPN) for NH3 supply to the microbes, is therefore the main supplementation component. Also vital for the microorganisms synthesis and activity are the minerals (out of which S, Mg; Cu and Zn).

(b) To feed the host animal the necessary nutrients (namely aminoacids and glucogenic precursors) that would ensure a satisfactory nutritional and reproductive status for his production. Such supplementation implies feeds

that are as rich as possible in by-pass N (protein of alimentary origin) and in digestible cell-walls so that the rumen fermentation of cellulolytic type is not negatively affected (avoid rapid drops of pH consequently to soluble carbohydrates fermentation).

There exist two ways for improving the feed value of poor quality roughages (PQR). One is of nutritionnal nature, it is the supplementation. The other one is of technological nature, it is the treatments. Since the treated roughages will have often to be supplemented and since the final and same objective will be optimizing the cellulolysis in both cases of untreated and treated roughages, we propose first to consider the treatments and, secondly, the supplementation.

The various treatments

We will not undergo a comprehensive description of all the treatments utilized in the past and available at present time. Let us say, in order to summarize, that the "urea treatment" (which shortens the right expression "urea-generated ammonia treatment") is the treatment best adapted to the small farmer's conditions, both at the individual small scale treatment and at the collective large scale treatment.

As a matter of fact the classical anhydrous ammonia treatment requires, (a) industrial ammonia, either locally produced or imported, (b) a distribution network: roads, lorries and tanks of this ammonia and (c) trained staff for ammonia manipulation from the the master tank down to the stack of straw to be treated. All these conditions are seldom met in developing countries.

Urea treatment: principles and factors of success

The "urea treatment" is the result of two processes which occur simultaneously within the mass of forage to be treated: ureolysis which turns urea into ammonia, and the subsequently generated effect of the ammonia on the cell walls of the forage. As they have already been described and discussed in many review articles out of which Chenost and Besle (1993) we will briefly recall them in order to concentrate more on their practical implications.

Ureolysis

Need for a ureolytic medium

Ureolysis is an enzymatic reaction that requires the presence of the urease enzyme in the treatment medium. Urease is practically absent in straw which is a dead graminaceous material. According to research work (Williams et al., 1984; Hassoun, 1987; Yameogo-Bougouma et al., 1993; ...) and the numerous field experience acquired during the last decade, urease produced by the telluric ureolytic bacteria during the treatment of residues such as straw or maize stalks, is sufficient, at least under conditions where humidity imposes no limits. Only in the specific case of intentional reduction of water (20 to 25 l added to 100kg straw) for mechanization purpose (Besle et al, 1990) will addition of urease be necessary.

The physico-chemical conditions of treatment, namely humidity and temperature, and their interactions, must therefore favour the activity of these bacteria and that of their enzyme.

Humidity

The ideal humidity of ureolysis is 100% (water solution), of course impossible to reach in a complex (heterogenous) medium composed of plant material and water.

This is why, nevertheless, water content of the medium is one key factor of success of the "urea treatment". This also why there are so many contradictory statements amongst people practising this treatment.

More than the amount of water to add (which will depend on the water content of the material to be treated), the humidity percentage of the treatment medium to reach will be the best informative criteria. Results of both experimental and practical works achieved untill now show that this percentage, should never be less than 30%, and not greater than 60%. Below 30%, ureolysis may be severely reduced and, even, not take place. On top of that it will be more difficult to compress the mass of forage and expell the air when the former is in the loose form (of

course less problems with bales since the plant is already pressed). As a result, not enough NH3, too much oxygen in, still, a somehow moistened medium, will lead to a bad alcali treatment and to mould development.

Beyond the (arbitrary) upper limit (50 to 60%) the problems encountered will be,

- **inadequate compaction of the forage mass,**
- **leaching of the urea solution downward the bottom layers (urea/ammonia overdosage with its associated toxicity risks),**
- **insufficient diffusion of the generated NH3 within the forage mass, in view of its hygroscopic characteristic (ammonia would bind on the water instead of the plant cell-walls),**
- **development of moulds, because of the moisture and an inadequate ammonia environment (trapped by the excessive water).**

Within this recommanded range, there are no fixed rules and the amount of water to add will be left to one's own jugement according to the prevailing local conditions, eg, availability and cost of water, hygrometry of the ambiant air, watertightness of the enclosure, type of forage to treat (structure/easiness to compact it), etc.

50kg water to add is an easy figure to remind and is generally applied at the practical level. Added to 100 kg of a 90% DM straw it leads to a final moisture content of 30%.

Temperature x duration

The optimal temperature of ureolysis would lie between 30 and 60C, according to the type of urease. The speed of the reaction is multiplied (or divided) by 2 for any increase (or decrease) in temperature of 10C. Within the range of temperature of 20 to 45C the ureolysis can be completed after one week or even 24 hours. The temperature is therefore not a concern in tropical climates. However the activity of urease is either severely reduced or even cancelled out for temperatures below 5 to 10C. One must therefore be very careful in tropical highlands (eg Tanzania, Madagascar plateaux) where night frosts can take place during the dry season when it is time to treat.

Alkali treatment of the generated ammonia:

The factors ensuring a good alcali treatment are of course the same as with NH3 treatment. Without going back into the detailed study of the alcali treatment factors (Sundstol and Owen, 1984) we will say that regarding humidity and temperature, and their interaction, the parameters supposed to be already met for a good ureolysis are also favouring the alkali treatment. However, duration, type of forage and, overall, NH3 (therefore urea) dose and their interactions will have to be taken into consideration with much more attention.

Urea dose (alkali dose) x type of forage x duration

The quantity of alkali to be used is the first factor responsible for the efficiency of the alkali treatment. It is unfortunately still a subject of much controversy. The majority of anhydrous ammonia treatments involve quantities of ammonia of 3 kg per 100kg of DM of treated straw (Sundstol and Owen, 1984). This figure would correspond, if ureolysis is total, to 5.3 kg of urea per 100 kg DM of straw.

Now many authors, e.g. Williams et al. (1984), Ibrahim and Schiere (1986), do not observe the increase in digestibility of the treated matter that could have been expected with an increased dosage of applied urea. Some even go so far as to recommend the use, in practise, of threshold dosages of urea of 4kg for 100kg of straw (rice straw), for lack of evidence that higher dosages would improve the treatment.

This point deserves some examination in order to avoid any false interpretation, as several phenomena are obviously involved and it is very difficult to dissociate them from one another:

a-Ammonia treatment via alkaline resulting from ureolysis takes place in a more humid environment than anhydrous ammonia treatment. Therefore at a given NH3 dose, the urea treatment is most probably more efficient and the tendency is to reduce the quantity of urea.

b-If it is more efficient than ammonia treatment, the urea treatment is slower. As a matter of fact and as suggested by Sahnoune (1990), ureolysis generates intermediary products (ammonium carbamate and

bicarbonate) which make the fixation of nitrogen and, above all, the alkaline hydrolysis of the plant cell walls, slower than in the case of anhydrous ammonia treatment. It is therefore possible that some authors, working on treatments of a very short duration, as often happens in tropical areas, do not observe the expected reaction to an increase in urea dosage. However the duration parameter has a significant effect on the effectiveness of alkaline treatment (Chenost and Besle, 1993).

c-Finally, and above all, the capacity of the forage to react to alkaline treatment depends upon the botanical family, the species and the variety to which it belongs. This capacity can essentially be linked to the nature of the phenolic acid/lignin linkages: more or less ether or ester-linked forms, therefore more or less potentially broken down. The fact that legumes contain fewer phenolic acids and that their lignins are less alkali soluble may explain, for instance, their weaker susceptibility to alkali treatment than grasses. There are great variabilities within grasses, little known and therefore difficult to quantify, in the nature and the structure of the lignins from one species and one variety to another. This question still needs more fundamental research work in order to improve our understanding of the degradability of plant cell walls.

As a result of the latter point (c) there would therefore be not one but several optimal dosages of alkali, differing according to the species and the variety to which the straw or forage belong. It is for instance quite probable that dosages which are sufficient for certain rice straws, would not be for others, or even more probably, would not be sufficient for wheat straws.

Unfortunately, we are still grossly lacking necessary information to predict these differences.

Dias da Silva and Guedes (1990) link the capacity of a straw to respond to alkaline treatment to its buffering capacity (phosphate), to the optical density at 280 nm of buffering extract (Besle et al., 1990), and to the saponifiable ester linkages of this extract (24 straws comprising 6 cultivars of wheat, rye and triticale were cultivated in 4 different agro-ecologic environments. Colucci et al. (1992), in agreement with Tuah et al. (1986) and Givens et al. (1988), observe that this capacity is as large as the initial digestibility of the straw is low, and that the links between initial digestibility and response to treatment are specific to the botanic species.

In practice, the majority of both experimental and field work has led to recommend the dose of 5kg urea per 100kg (as such) of straw. This dose ensured good results in many field Projects developed in Africa, Madagascar and Asia (Chenost and Kayouli, 1996).

Attempts are being made, essentially in China and Vietnam, to reduce the amount of urea without loosing alcali treatment efficient through association of lime (Ca(OH)2) with urea. A recent trial in Vietnam indicates that treating with 2.5% urea plus 0.5% lime and 0.5% salt gives the same increase of the rice straw feeding value compared to a 5% urea treatment (Bui Van Chinh *et al.*, 1993)..

Duration x ambiant temperature

The duration of the alkali treatment *per se* is longer than the ureolysis process. The recommended treatment time ranges from more than 8 weeks for temperatures around 5C to less than 1 week for temperatures above 30 C (Sundstol and Owen, 1984).

In classical tropical climates the alkali treatment can thus be achieved after 1 week. However, in view of what has been said earlier, the duration to be recommended in practice should never be below one week. As treatment efficiency improves with time it is any how better to wait two weeks before opening the treatment provided the forage and farmer's time availabilities allow such a time table. In tropical highlands (eg Tanzania, Madagascar plateaux, ...) where night frosts can take place during the dry season it is better to recommand at least 3 weeks. We were even compelled to advise 5 weeks at the practical level in the case of the Madagascar Merina Highlands (Chenost, 1993) in view of the very cold nights (periodical slowing down of the ureolytic activity from day to night time).

Air and water-tight

Ammonia is released much more slowly from the ureolysis process than from an anhydrous ammonia tank injection. The risks of losses of ammonia in the atmosphere is thus reduced since ammonia can bind on the forage cell walls and on the water medium almost simultaneously to its release. However only around 1/3 of the NH3

released can bind the plant material, the remaining other 2/3 being in a labile form and lost, anyhow.

This point will as important as the duration of storage is long and the volume of treated material small. The target indeed is to maintain the more anaerobic and ammoniacal atmosphere as possible within the mass of forage in order to achieve not only the best treatment but also the less development of moulds as possible.

Other "urea" treatments

A rather old but not yet really adopted procedure is to utilise urine as the source of urea. The first trials took place in Sri Lanka and Bangladesh in the early 80s. Dias da Silva (1993) 's review on this subject concluded that,

- **the treatment efficiency is very variable in view of the urine variability itself (urea dilution, type of animals or, better, of the diet they are fed),**
- **because of the very high urine/straw ratios imposed to get an increase in digestibility values the acceptability of the treated material is somehow reduced or not really improved,**
- **the urine collection, storage and handling still remain a constraint at the practical level**

However, this process still deserves attention.

Practice of urea treatment

The purpose of this chapter is, once the factors controlling the urea treatment have been described, to consider the various practical problems that arise when implementing the urea treatment technique at the practical level. Indeed there is no fixed model technique but rather one which is adapted for the particular local environmental conditions in question.

Strategy and type of treatment depend essentially on,

- **the straw or forage conditionning : loose form, either long or chopped; bales, either manually or mechanically**

(pressed) made;

- **the quantity of forage or straw to treat, depending on the number of animals and the time during which they have to be fed;**
- **the farmer's technical skill and facilities and his financial situation.**

Once treated and if well covered to be maintained in anaerobical conditions, the forage can be stored for several months. It is therefore theoritically possible to treat at one time the quantities required for the whole feeding period. These quantities may however sometimes be too large and necessitate too much labour and space for storage. It is then necessary to treat smaller quantities in successive treatment operations repeated during the feding period.

Depending on the strategy choosen (optimum compromize between frequency and size) will result various types of treatment implying different constraints.

These are essentially fixing up the compromize between the lower cost as possible for the better treatment quality as possible. The former will depend on the use of locally, instead of purchased, materials; the latter will essentially depend on the air/water tightness of the treatment medium.

Various types of treatments have been described here and there (out of which Schiere and Ibrahim, 1989 and, more recently, Chenost and Kayouli, 1996).

They range from the the small pit digged in the soil (only in firm clay and not draining soils) to the classical pressed bales stack covered with plastic sheets as in the anhydrous ammonia treatment, with all the intermediary solutions such as baskets or any other containers, various types of clamps (3 walls-system), existing construction eg storehouse, unused pens, etc...

One of the subjects of controversy is the air and water-tightness of the treatment medium. Quite often now it is said that the urea treatment doesn't call for any covering : such an advice is dangerous and should not be stated like that. When the treated roughage is to be stored for a long time, "do not dream" it is necessary to cover in

order to avoid moulds development and bad ammonia fixation. Some practical field observations allow such statements: this only relates to the case of large stacks, covered with untreated packs or bales of straw that provide a "self covering"; the outer straw which is of course somewhat damaged does represent only a small proportion of the whole bulk of the inner treated straw.

This can, no way, be satisfactory in the case of small quantities treated where covering remains necessary. In these latter cases however the use of local material can solve the problem without resorting to the conventionnal plastic sheets. These have been experienced successfully with banana leaves, seko mats, banco, mud, old plastic bags (sewed with one another), etc... Tunisia and Morocco are presently experiencing the cover of urea-treated large stacks with mud (mud is already beeing used for decades by farmers to protect their stacks of straw in the field against rain).

Assessment of the treatment efficacy

The best assessment of the treatment efficacy is of course the animal response in terms of intake and performances. However, in field conditions, the question is often raised by the extension agents as to how can they be sure, prior to feed it to the animals, that their treatment was successful when opening the silo they prepared with the farmers.

Without going, here also, in the detailed controversy linked with the prediction aspects of the feeding value of treated (and moreover untreated, see earlier) straws and poor quality roughages, we would simplify by saying that,

(a)the first and simplest criteria of a good treatment is the physical aspect of the treated roughage:

- marked change of colour from clear yellow to brown or dark brown (dark yellow is not enough),

- strong but good ammonia smell, without any trace of bad fermentation smell,

- smooth texture of the straw or the stalks which become easy to twist and to fold,

- absence of any mould.

(b) the second stage, if any doubt, is to resort to the Kjeldalh N assay. A poor alcali treatment is generally associated with a bad N fixation and therefore a low CP content. The increment of the CP content of DM should at least be of 5-6 percentage points (CP/DM going from 3-4 up to 9-10 %, taking into account the systematic 2/3 loss in the form of labile ammonia that cannot bind). One important point, generally misinterpreted, is that a greater increment is not necessarily synonymous of a good treatment : on the contrary, it should ring the bell of residual urea not totally turned into NH3 because of partial ureolysis (and, therefore, small ammonia production). As a matter of fact a 4 % CP straw "treated" with 5 kg urea / 100 kg ends up with a CP content of 18.6 % when no ureolysis took place.

(c) the third step, only justified when dealing with relatively high producing animals that must not be fed under their requirements, is to resort to the prediction of digestibility / intake in view of the need of more precision.

- the classical feed analysis will by no way be able to predict any feeding value. Neither CF nor NDF, ADF and ADL will help. It is therefore absolutely useless to loose time and money in recommanding them.

- the only, but costly, resorts are the *in sacco* technique or gas test for degradability measurement for feed value prediction, or cellulase or *in vitro* digestibility techniques for digestibility prediction.

All these points have already been discussed in the literature (summarized in Chenost and Reiniger, 1989) and earlier in the Conference but it was worth mentionning them in the particular case of poor quality roughages.

Conclusion

As a conclusion it is now possible to say that provided some key rules are observed the "urea treatment" is technically perfectly adapted to the small farmer conditions, at both the individual and the cooperative level. A lot

of practical field experience has been acquired now in an extremely wide range of agro-ecological and sociological conditions with success.

Hermeticity is less a concern than with anhydrous ammonia treatment and is not necessarily important when large quantities of plant material is treated (self covering).

What remains to be further analyzed is its actual rate of adoption in practice.

Supplementation of Untreated and Treated Poor Quality Roughages (PQR)

Principles

The principles of a good digestive utilisation of PQR have already been enumerated and discussed earlier. As a consequence let us recall and summarize in saying that any PQR supplementation should, in the following hierarchical order,

- **favour the rumen cellulolysis,**
- **enhance rumen microbial synthesis,**
- **supply the animal with the required nutrients for maintenance and, when necessary, for production, bearing in mind that the latter cannot be compared with the one expected with good forages.**

The first step is to feed the "rumen" we are talking of "catalytic" supplementation, which can ensure more or less to maintenance level. This supplementation is typically ensured by NPN (namely urea) and minerals supply.

The second step is to feed the "host animal", when the first step is inadequate to sustain more production than the maintenance, we are then talking of "extra supplementation".

This supplementation should,

(a) be as "cellulolytic" (digestible cell-walls) as possible so as to avoid any negative digestive interactions and too high subtitution of the roughage for the supplement,

(b) be brought in such quantities that the basal PQR keeps constituing the major part (2/3 when supplementation is rich in starch, 1/2 when supplements is rich in digestible cell-walls) of the diet.

These two points are of particular importance in the case of treated PQR if one does not want to loose the benefit of the treatment because of negative digestive interactions,

(c) bring a maximum amount of digestible nutrients to the intestine (having escaped ruminal fermentation) to satisfy the animals productive needs,

For socio-economical reasons it should be ensured by as much local feed resources as possible and avoid the use of classical concentrates (or their components, ie cereals earmarked for human nutrition and high quality oil cakes earmarked for non ruminant production but unfortunately quite often exported).

The catalytic supplementation for subsistance or moderate production

The strategic supplements are urea and minerals. Various ways exist of bringing them to the animal. The older one is utilizing liquid molasses as a carrier. Molasses-urea mixtures are still being used and commercialized in certain countries such as Egypt.

A more convenient practice, developed through FAO projects, which becomes popular all over developing countries is the multinutritionnal block (Sansoucy, 1986). The carrying medium is solid and therefore easier to transport. The block is licked, which ensures a small progressive and regular intake of urea. These blocks provide the opportunity of utilizing any type of locally available agro-industrial by-products eg brans, pulps, poultry litters, etc..., which provide the animal with other nutrient sources than urea and mineral, the strategical ones.

Average daily intakes are 400 to 800 g for large ruminants, 300 to 500 g for camels and 100 to 150 g for small

ruminants. With a urea incorporation rate of 5 to 10 %, these intakes allow a N ingestion that covers the N microbial requirement to ferment the potentialy degradable Organic Matter contained in the straw or roughage fed or grazed (otherwise impossible). As this degradation is accelerated the actual intake of roughages is increased. As a result of expressing the potential digestibility of the roughage and improving its intake, the physiological status of the animals, its liveweight gain or working efficiency or milk production, are improved in a substantial way but, at the same dose of urea, not to the same extent as with urea treatment (table 1).

Such blocks can be manually manufactured by the small farmer himself with the minimum investment.

Table 1. Comparison of the effect of the same quantity of urea, used either as a supplement of for treating rice straw on intake and growth rate of cattle.

Straw	NT	CU	TU
Animals		Straw intake	
LW (kg)		(kg DM/d)	
Cattle (130-140)1	1.7	1.7	1.9
Cattle2	2.1	2.3	2.9-3.0
Cattle (75-78)3	-	2.2	2.4
Cattle (166-178)4	-	-	3.9-4.8
Cattle5	-	2.8	4.0
Cattle (177-196)6	4.3	-	3.6

NT = untreated; CU = supplemented with urea; TU = urea treated

Straw	NT	CU	TU
Animals		Liveweight gain	
LW (kg)		(g/d)	
Cattle (130-140)1	35	75	110
Cattle2	103	213	238-30
Cattle (75-78)3	-	207	297
Cattle (166-178)4	141	-	207-336
Cattle5	-	111	246
Cattle (177-196)6	304	-	598

1 Saadullah *et al.*, 1981 and 1982

2 Perdok *et al.*, 1984

3 Saadullah *et al.*, 1983

4 Kumarasuntharam *et al.*, 1984

5 Jaiswal *et al.*, 1983

6 Promma *et al.*, 1985

Supplementation for a higher production level (untreated and treated PQR)

The most common "strategic" supplements, as opposed to the conventional ones, consist in,

- farm residues such as haulms and leaves of pulse crops and vegetables, etc. They provide green or digestible matter of plant origin (and of course vitamins) and their N concentration is interesting,

- by-products of locally processed food and, to a lesser extent, cash crops (the latters are processed in cities and their co-products seldom come back to the farmers village); these are essentially brans and broken cereals (rice,etc.), cotton seed (lintless) and cakes, palm oil kernels, etc.: they provide both proteins of relatively low degradability and energy,

- tree (mainly legumes) foliages: they provide digestible cell-walls and, overall, naturally protected nitrogen (tannin content). However, tannin content should not be too high (counteracting proteolysis). Attention should also be paid to the possible presence of other antinutritional factors,

- by-products of animal origin (fishing, slaughter house) and animal excreta (poultry litter): they provide high quality proteins.

Apart from the importance and the nature of the energetic fraction of the supplement, one point may have generally been under appreciated, particularly in the case of treated roughages : it is the quality and the quantity of the supplementary protein. Research and practical work show clearly the interest of protein supplementation of treated PQR. This is illustrated by the very interesting responses of intake, digestibility and growth-rate of growing Yellow Cattle to increasing levels of supplementary cottonseed cake (table 2) in commercial operations in China. (Dolberg and Finlayson, 1995)

This "synergetic" supplementation is, in the practice, unfortunately quite often not respecting the rules considered above. In systems where cereals may in certain parts of the year be cheaper than straw (Maghreb, Near East, ...) the synergic properties of local resources are neglected in favour of commercial concentrates inefficiently utilized in too high proportions.

When lower animal performances levels are acceptable (for animals kept at maintenance level) the simple treatment without supplementation will be enough. However it will be very important to make sure that the minerals be not a limiting factor to fully express the treatment effect.

Table 2. Response of "Yellow Cattle" intake and growth rate to increasing levels of cotton seed cake as supplements of urea treated rice straw.

1. Fan *et al.*, 1993

Cotton seed cake offered (kg/d)	0	0.25	0.5	1.5	2	2.5	3
Straw intake (kg DM/d)	-	-	-	-	-	-	-
Initial weight (kg)	175	170	183	193	175	194	215
Final weight (kg)	184	204	231	263	249	269	294
ADG (g/d)	99	370	529	781	819	841	880

2. Zhang Wei Xian *et al.*, 1993

Cotton seed cake offered (kg/d)	0	1	2	3
Straw intake (kg DM/d)	5.0	5.1	4.5	4.2
Initial weight (kg)	182	183	183	183

Final weight (kg)	205	237	246	258
ADG (g/d)	250	602	704	836

Conclusion

Urea treatment as such and multinutritional blocks are now widely divulged in practice since they represent the simplest and easiest way of optimizing PQRuse by ruminants.

Urea treatment, superior to urea supplementation, improves the nutritional status of animals and their performances. An average improvement of 200 g/d of the ADG of growing cattle, an increase of 1.0 to 2.5 kg of milk produced per day and a better efficiency of draught animals are observed.

One important feature to bear in mind is that the lower the production level of animals, the better response to feeding treated PQR. As a matter of fact treated PQR are all the more valuable as their proportion in the diet is important.

Recommendations given relative to urea treatment should not be followed rigidly but, to the contrary, should be reasoned and adapted to the agro-ecologic conditions under which the treatment is carried out.

Improved knowledge of the capacity of straws to respond to alkaline treatment should allow the modulation of the urea dosages to be used with a view to economically improving the efficiency of the treatment. This capacity remains, unfortunately, difficult to predict, through a lack of simple or reliable criteria.

More attention should be paid to the use of locally available feed resources as "synergetic" supplementation of either untreated or treated PQR. As an example, the relatively fair quality of the nitrogen generated via treatment justifies the importance of correct reasoning of the quantity and, above all, the nature of the nitrogen supplement in treated forages.

Development measures, to be followed along with the extension programmes of such techniques, and agro-economical and sociological considerations regarding rate of adoption and impact of such techniques have voluntarily not been considered in this paper. However they deserve the uppermost attention when launching poor quality roughages-based development programmes.

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Conference Discussion

The conference opened with a *Welcome* from Dr T Fujita, Director Animal Production and Health Division, FAO Rome and Instructions on *How to Participate* from AW Speedy, Oxford. There was also an *Introduction* by R Sansoucy and C Dalibard (FAO) and a description of *The Development of the FAO Tropical Feeds Information System* by AW Speedy.

The first paper was on Evaluation of Tropical Feeds by RA Leng in which he discussed the differences between forage from tropical and temperate regions and the evaluation of forages, with particular reference to the problem of rumen microbial nitrogen status and its effects. This was extended to supplements, including by-pass protein, but also more digestible carbohydrates, minerals and vitamins. He stressed the very limited significance of chemical analysis, especially of ADF and NDF fibre analysis, and of the limitations of rumen degradability coefficients, given the error attached to the intercept estimate, as well as the more practical question of the basal diet mixture. He also noted the interaction between climate and nutrition which was relevant in tropical countries. He concluded that feeding trials, involving supplementation with molasses-urea blocks to optimize rumen fermentation, were most appropriate. Supplementation could then be carried out with small amounts of more digestible feeds and by-pass protein to determine responses.

There was considerable discussion of this paper with support for the tenet of reduced emphasis on feed chemistry from M Hadjipanayiotou (Cyprus), P Colucci (Canada) and a group of postgraduates from Armidale University,

Australia. M Sanchez (FAO) noted the problem of limited resources for laboratory establishment in developing countries. P Thorne (NRI, UK) added the dimension of selectivity, e.g. in goats, as a further problem of feed characterization.

Margaret Gill (NRI, UK) criticized the generalizations in R A Leng's paper and noted the joint role of chemical analysis and animal experiments, and the relative importance of pasture and browse. She further advocated the consideration of feeding systems and strategies (as opposed to the short-term approach) and requested the conference to consider where information was really lacking. Bo Göhl (FAO, Botswana) also supported a more holistic approach.

S Sundstøl (Norway) also expressed surprise concerning the criticism of chemical analysis but supported the attention to molasses-urea blocks and considered that optimization of the rumen environment was indeed possible in the field. Later in the conference, a paper was received from M Chenost (France) on Optimizing the use of poor quality roughages through treatments and supplementation in warm climate countries with particular emphasis on urea treatment and two papers by J-X Liu *et al*. on The effects of urea-mineral lick blocks on the live weight gain of local yellow cattle and goats in grazing conditions and The kinetics of fibre digestion, nutrient digestibility and nitrogen utilization of low quality roughages as influenced by supplementation with urea- mineral lick blocks.

ER Ørskov (Rowett Institute, UK) presented an alternative view to Professor Leng based on the estimation of feed potential and provided a complete paper on the Plant factors limiting roughage intake by ruminants, with equations for the estimation of degradability and intake. This received criticism from L Kahn (Australia) on the basis of the problem of basal feeds and the inaccuracy of the constant in the equation and a more detailed response from Professor Leng who reiterated his points. He also replied to M Gill and stressed the difficulty of dealing effectively with pasture and grazing. R Sansoucy supported the importance of pasture and stressed the effectiveness of molasses-urea blocks in this context.

Generally, the conclusions of this part of the conference support Professor Leng's contention that evaluation of

roughages must be carried out with attention to rumen nitrogen supply and the testing of supplements as by-pass nutrients. Chemical analysis, including degradability coefficients, may be included but its limitations must be accepted and greater emphasis should be placed on animal feeding trials, with attention to the wider principles of ruminant nutrition.

Still other contributors noted the special attention needed for legume trees and their evaluation, including the evaluation of anti-nutritional factors, tannins, etc. from M Wanapat (Thailand) and C Lascano (CIAT, Colombia). A Finzi (Italy) contributed some useful description and data on Cordyla africana from Somalia, a shrub with 27% protein in leaves, and used for poultry. Other materials had been tested in this area. A Gupta (India) emphasized the importance of drought feeds and the use of indigenous knowledge in this area.

There followed a paper by TR Preston (Vietnam) on Strategy for sustainable use of natural renewable resources: constraints and opportunities. This attracted surprising little comment except from RL Meirer on the problems of urban livestock and energetic efficiency. AW Speedy commented on the need to consider natural ecosystems and their modification as the basis for sustainable feeding systems in the future. R A Leng commented again that attention should be paid mainly to available byproducts and the limited feeds available, separating basal forages from roughages, and regarded the proposal of the modification of natural ecosystems as �back to nature'. However, Speedy commented again that the conference had concentrated on very few feeds (straw, forages, molasses-urea blocks and a limited range of supplements such as cottonseed cake) whereas there was a multitude of alternative feeds available in the tropics and information was seriously lacking. Preston also noted the lack of attention to monogastric animals and this was supported by F Dolberg (Denmark) who noted the absence of interest in this field by the CGIAR Centers. It was a serious criticism of the conference so far that it had been almost entirely concerned with ruminants. There was, however, a paper on Aquaculture feeds and feeding by AGJ Tacon.

To encourage further contributions on feeds, recent articles on *Azolla*, Molasses, Blocks, *Gliricidia* and *Prosopis juliflora* were circulated. As further examples, a list of Useful plants from Colombia by Zoraida Calle was circulated and a paper by Komwihanglio, Goromela and Bwire (Tanzania) on Tanzanian forage species was included. A

substantial paper was also provided by JE Benavides (Costa Rica) on Research on forage trees, including details of a large number of species and methods of testing including animal responses.

Turning attention to palms, a paper was contributed by A Ocampo (Colombia) entitled: The African palm, strategic resources on integrated systems of tropical production in which he considered novel ways of incorporating palm fruits and oil in rations for pigs within different systems of production from small- to large-scale. Additional information on palms was provided by the coordinator from published literature by AA Atchley (1984), Nutritional value of palms, JF Morton (1988) on Borassus flabellifer (Palmyra or Toddy Palm) and MJ Balick and SN Gershoff (1981) on Jessenia batana, as well as further papers on Caesalpinia paraguarensis by J Aronson and CS Toledo (1992) and Opuntia spp. by CE Russell and P Feller (1987).

However, the conclusion must be reached that there was rather little information on the large range of alternative species and systems applicable in the tropics. The conference had concentrated mainly on the use of low quality roughages for ruminants, supplementation with molasses-urea blocks and other treatments, and a very small range of supplementary feeds. Despite this, there are indications of a considerable number of candidate species and an important need to increase the scope of Tropical Feeds to include new feeding systems, especially those applicable to the ruminant AND to the monogastric species, taking advantage of their complementarity.

Critical assessment

The Electronic Conference operated for 5 months and reached a very large number of people, compared to a conventional Expert Consultation. There were some technical difficulties, most notable that the original list was devised by the Coordinators and the e-mail addresses set up by them. This led to some errors and a problem with certain systems not recognizing the 'errors to' command in the message headers. This led to error messages being circulated to all participants and duplication of material, with a consequent cost, especially to participants in developing countries with high communication charges. This is regretted but was difficult to predict as it was a fault at the remote computer and not at the server. This will be solved in future by sending a single message to

participants asking them to register personally with their correct e-mail address.

It was also difficult to encourage regular and widespread participation, probably because of the remote nature of the conference and the fact that participants were involved in other work or travelling at certain times. The Coordinators could have done more to encourage participation and perhaps provided more regular summaries to assist participants.

At a technical level, it has already been stated that the conference was mainly limited to the question of forage evaluation for ruminants and stimulated less interest in the wider range of species and in systems for monogastric animals. This reflects real deficiencies in the international research and development strategy in animal nutrition and feeds. There should be a serious reconsideration of the balance of effort and Tropical Feeds should be expanded to include a much wider range of alternatives, particularly where these relate to more sustainable technologies and higher overall biomass production.

However, despite these technical issues and limitations, the Electronic Conference did much to demonstrate the possibilities of this medium and, in the degree of participation, was far more effective than a single Expert Consultation. Furthermore, it was achieved at a small fraction of the cost. It should serve as the basis for on-going communication and information dissemination on feed resources and feeding systems and there is good case to continue to maintain the list in the future. There is also good evidence of the need to continue the Tropical Feeds and Feeding Information System project and to further expand the database of information.

Appendix 1. List of Participants' Countries

Developing Countries (37)	Developed Countries (12)
Barbados	Australia
Bangladesh	Belgium

Burkina-Faso

Bolivia

Botswana

Brazil

Chile

China

Colombia

Costa Rica

Cyprus

Dominican Republic

Egypt

Ethiopia

Guatemala

Honduras

India

Indonesia

Kenya

Laos

Malaysia

Canada

Denmark

France

(+Guadeloupe)

Italy

Japan

Netherlands

Spain

Sweden

UK

USA

Mali

Mexico

Morocco

Niger

Nigeria

Peru

Philippines

Senegal

Sri Lanka

Thailand

Turkey

Tunisia

Uruguay

Venezuela

Vietnam

Zimbabwe

Appendix 2. List of Participants' E-mail Addresses

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Plant factors limiting roughage intake in ruminants

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Introduction

A debate on plant and other factors limiting roughage intake in ruminants is both relevant and timely. It is relevant because in the last decade we have learned a great deal more about it. It is timely because in the last decade or two it has been recognized, at least in countries in which environmental constraints (e.g. dry seasons and winters) cannot be buffered by high level of concentrate feeding, that static feed evaluation systems whether based on starch equivalents, total digestible nutrients, metabolizable energy or grain units have a limited relevance since none of them can predict voluntary feed intake. As a result these systems are of limited use for farmers who want to predict the production capacity of pastures or roughages and to assess their exchange rates to other forages. They are of limited value also for the planners of livestock production who need to know the potential feed intake of farm animals in order to predict if only approximately, the potential livestock production in a region from the available feed resources.

The problem of intake is of course not a new realization, many researchers have paid attention to this. Crampton (1957) attempted to predict intake from digestibility and chemical composition and found no good relationships

and he suspected that degradation rate was an important factor though had no means of measuring it. Van Soest (1982) made a great contribution by attempting to divide the plants chemically in order to determine intake. While this was perfect within plants i.e. predicting intake at different stages of maturity, it was not accurate when divergent plants like legumes and grasses were involved. Balch (1969) attempted to predict intake by the number of chews required per unit of feed. Teller *et al*. (1993) advanced the hypothesis that the animals had a finite capacity to chew whether it be eating or rumination and that the total would not exceed about 16 h/day. Minson (1990) lists a whole range of factors plant and animal including grinding resistance to predict forage intake. Lechner Doll *et al*. (1991) described the importance of particle density in the rumen and its effect on rumen retention time which in turn could affect intake.

There are no doubt differences in the capacity of different ruminants to digest roughages. Ruminants that are most selective usually have the smallest rumen volume (Hoffman, 1989). Mould *et al*. (1982) demonstrated large differences between breeds of cattle in Bangladesh and Britain. Even within the same animals the gut volume is affected by pregnancy and lactation as discussed by Kay (1990). Hoffman (1989) discussed the seasonal variation in gut volume as response to quality of diets. Animal factors relating to intake will be discussed in more detail in another paper but here we must conclude that it is unlikely that description of plant factors can predict intake under all circumstances. One could hope that it would accurately predict ranking as there will be additional effects of season, breed, physiological state etc.

In this article I will review briefly the plant factors and plant dependent animal factors, which determine the intake and digestibility of roughages by ruminants and so the value of roughages in terms of animal production. This has been our main objective at the International Feed Resources Unit at the Rowett Research Institute. I will trace the stages by which, making full use of roughage degradability studies *in vitro* and *in vivo*, we have been able to define a feed potential index which provides a simple integrated measure of the value of roughage for animal production.

Rumen Environment

Definition of conditions

In order to pursue these lines of thoughts we have found it most rational to assume that the rumen environment for cellulolysis was as far as possible optimal i.e. adequate N, S, minerals etc. and optimal pH conditions. In other words intake would be limited by the plant factors which affected fill and subsequent removal. While in practise it may not always be possible to achieve optimal rumen conditions we found it most convenient to express the value of a feed under optimal conditions. The feeds may also contain antinutritive factors which may not only inhibit degradation of the feeds themselves but also affect degradation of accompanying feeds. Some of these factors will be referred to later. Antinutritive factors can both inhibit rumen microbes or affect the host animal.

In the following some of the characteristics of roughages that influence fill and removal are discussed below. They are solubility (A) the insoluble but fermentable fraction (B), the rate constant (C) the rate at which long particles are reduced to small particles (D), the rate of removal of small particles (E), and the rumen volume (F). It will be immediately apparent that A + B are the potential digestibility and by definition:

100-(A + B) will be totally indigestible.

***Solubility* (A)**

The best hay is made during dry weather because with rain a proportion of soluble material contained inside plant cells will be washed off and both intake and digestibility will be decreased. The soluble material consisting largely of soluble carbohydrate and protein occupies little space in the rumen and is also rapidly fermented in the rumen. For both reasons it is a very important factor relating to roughages.

The soluble content can be determined in several ways. The simplest is to wash the roughages with water for a given period and measure the loss of dry matter. It can also be determined as that which is soluble in neutral detergent solution i.e. 100-NDF. It is also possible to measure the soluble organic matter which may be desirable in samples with high content of soluble ash. In our laboratory we often use the loss of dry matter or organic matter from samples contained in nylon bags that have been exposed to the washing procedure but not incubated

in the rumen.

***Insoluble but potentially fermentable fraction* (B)**

This is determined by extrapolating the exponential curve describing degradation of insoluble material to its asymptote. This potential or asymptote is seldom achieved in practice due to rumen retention time and the degradation rate (see later). It is clear that the fraction which is totally indigestible, 100-asymptote, will require space in the gut until it is eliminated in the faeces.

***The rate at which the insoluble fraction B is digested* (C)**

It is clear that the importance to the animals of the B fraction is determined not only by its size but also by its potential rate of fermentation, as this will determine the amount of the B fraction that will be released within the time span limited by the rumen retention time. It follows that the B fraction and the C value should not be considered in isolation from each other.

***The rate at which large particles are reduced to small particles* (D)**

This factor, depends on chewing rumination and microbial disintegration in the animal and is a very elusive parameter. Yet it is undoubtedly important for some feeds. If the rate at which the large particles are reduced to particles small enough to enter the liquid phase and be exposed to outflow is greater than the rate at which small particles flow out then it will be no constraint to feed intake. In our laboratory we measured this parameter by measuring outflow or rumen retention time of mordanted long or small hay particles. This is of course not totally realistic as the mordanted particles are completely undegradable and therefore not exposed to microbial disintegration. Some feeds, such as palm pressed fibre or sisal pulp, contain very tough fibre which is reduced to small particles at a rate much slower than the outflow of small particles.

***Outflow of small particles* (E)**

This parameter depends in part on rumen motility and, differs substantially between roughages. There are very large differences in the outflow of small particles from ground fibrous roughages and of protein supplements. Ørskov *et al*. (1988) showed that in circumstances in which the outflow of protein supplements was 0.06, the outflow of roughage was only 0.03. These differences reflect the length of time it takes for particles to traverse the solid mass of rumen contents and become suspended in the liquid phase from which outflow occurs. Outflow therefore depends on the shape and specific gravity of the small particles and on the hairiness which makes then cling and adhere to large particles in the solid phase. The specific gravity, is an elusive parameter as fermentation gases can be entrapped inside cell walls and make them less buoyant. There is still a great deal to learn about the factors affecting outflow of small particles. The question which we must address is whether the variation between fibrous roughages is sufficiently large to warrant a specific value to improve prediction of feed intake. There is no doubt variability in specific gravity between roughages and type of roughages and between small particles from seeds and roughages.

***Rumen volume* (F)**

This factor is also extremely important but not a plant factor as such. The volume of the rumen, determines how much fermenting material can be accommodated at any one time. It is a factor which has been neglected in selection procedures for animals. Indeed in some countries it has probably been selected against as a high killing out percentage, i.e. carcass weight as a percentage of live weight, has been taken to be advantageous. It is undoubtedly genetic in origin (Ørskov *et al.* 1988). Animals selected on the basis of high or low outflow rate consistently showed differences in flow rates regardless of level and type of feed offered. Cattle in Bangladesh also have a much higher gut content (33%) (Mould *et al*., 1982) than normally reported for Friesian Cattle (Campling *et al*. (1961)).

Antinutritive factors

The identification of the above range of factors governing forage intake supposes that the animals will actually eat the diet. However, throughout evolution plants have developed survival strategies to prevent them being eaten by

voracious herbivores or in some instances also making use of them to spread their roots or seeds. During some growth stages the animals are discouraged from eating them while in others they may be encouraged. Different herbivores have also developed survival strategies, like the ability to select certain parts of the plants or to develop microbial populations capable of minimising antinutritive factors such as the microbial destruction of mimosine (Jones 1981) and some tannins from tanniferous plants (Brooker *et al* 1993).

Antinutritive factors are often associated with legumenous herbage shrubs or trees rather than gramineae. The recent interest in multipurpose trees has also stimulated research into simple techniques for the identification of antinutritive factors. Thus Khazaal and Ørskov (1993) used the simple yet effective gas evaluation technique of Menke and Steingass (1988) to identify microbial antinutritive factors. The difference in gas evolution with and without a compound which complexed antinutritive tannins provided a measure of the extent to which fermentation was inhibited.

It is clear from the above description of factors affecting intake of roughages that only the A, B and C values are strictly speaking plant factors. Although affected by plants, D and E are also affected by animals in so far that the actions of chewing and rumination are involved. In the following I would like to examine the extent to which feed intake and feed utilization can be predicted from a description of feed characteristics. Here the nylon bag technique has been extremely useful, with degradation characteristics supplemented by the exponential equation p = a + b(l-e-ct) developed by Ørskov and McDonald (1979). This equation was originally developed for protein supplements in which the intercept was also an approximate expression of solubility. However this is not necessarily the case for roughages due to the occurence of a lag phase or a period in which there is no net disappearance of the insoluble but fermentable substrate B. Accordingly A was defined as the laboratory determination of solubility and B as the insoluble but fermentable substrate, defined here as (a + b)-A, i.e. the asymptote less the solubility. The rate constant C is as in the original equation. The major plant factors affecting intake can now be derived from this relatively simple description in the absence of antinutritive factors.

The ability of these plant factors to predict intake and animal performance has been tested in four separate trials in different parts of the world with different feed resources. The first trial was reported from our group using

different types and varieties of straws with and without ammonia treatments. A total of ten straws with A values of 12-24, B values of 26-48 and C values of 0.0304-0.0481 were tested. The results are given in Table 1 below.

Table 1. Accuracy of Estimating Digestibility, Dry matter Intake, Digestible Dry Matter Intake and Growth Rate of Steers from Feed Degradation Characteristics, as Indicated by the Multiple Correlation Coefficients (r) between Factors of the Degradation Equation and these Parameters. (Ørskov and Ryle 1990).

Factors Used in Multiple Regression Analysis	Digestibility	Dry Matter Intake	Digestible Dry Matter Intake	Growth Rate
(A + B)	0.70	0.83	0.86	0.84
(A + B) + c	0.85	0.89	0.96	0.91
A + B + c	0.90	0.93	0.96	0.95
Index value	0.74	0.95	0.94	0.96

The use of the asymptote (A + B) was superior to the use of metabolizable energy concentration to predict intake. Adding to the rate constant (C) significantly improved the prediction which again was further improved by separately using A, B and C as defined earlier.

The same principle was used in a trial by Kibon and Ørskov (1993) in which six browse species from the North of Nigeria were fed to goats. Table 2 shows very similar results to those shown in Table 1 except that the prediction from asymptote (A + B) was not so good.

Khazaal *et al*. (1993) obtained almost similar accuracy for determining feed potential when ten leguminous herbages from Portugal, were fed to sheep (see Table 3). As in the previous work the addition of the rate constant significantly improved the accuracy of prediction.

Finally similar results were obtained in a large trial reported by Shem and Ørskov (1993) in which 17 different feeds, including several types of maize stover, banana leaves, bean straws and Napier grass, grown on the slopes of Mount Kilimanjaro were given *ad libitum* to steers (Table 4).

Table 2. Accuracy of Prediction of Digestibility, Dry Matter Intake, Digestible Dry Matter Intake and Growth Rate from the Factors of the Exponential Equation and the Index Value as Indicated by the Multiple Correlation Coefficients (Kibon and Ørskov, 1993)

Factors Used in Multiple Regression Analysis	Digestibility	Dry Matter Intake	Digestible Dry Matter Intake	Growth rate
(A + B)	0.65	0.57	0.15	0.41
A + B + c	0.88	0.99	0.92	0.99
Index value	0.75	0.90	0.88	0.81

Table 3. Accuracy of Estimation of Digestibility and Intake of Hay by Sheep from Degradation Characteristics of Leguminous Forages as Indicated by the Multiple Correlation Coefficients. (Khazaal *et al*., 1993)

Factors	Digestibility	Dry Matter Intake
(A + B)	0.82	0.77
(A + B) + c	0.86	0.88
A + B + c	0.95	0.88

Table 4. The Estimation of Digestibility Dry matter Intake, Digestible Dry Matter Intake and Growth Rate of Steers from the Feed Degradation Characteristics as Indicated by Multiple Correction Coefficients (r) (Shem and Ørskov

1994).

Factors Used in Multiple Regression Analysis	Digestibility	Dry Matter Intake	Digestible Dry Matter Intake	Growth rate
(A + B)	0.85	0.83	0.84	0.80
(A + B) + c	0.95	0.84	0.88	0.90
A + B + c	0.98	0.90	0.93	0.93
Index value	0.95	0.90	0.92	0.89

One feed (banana pseudostems) was excluded because the intake was far less than expected, possibly because it contained 95% of water; intake could therefore have been limited by the rate at which the water was excluded or by other unidentified factors.

The results summarized in Table 1 to 4 are promising and indicate that for many roughages a reasonably precise estimate of feed potential can be obtained from simple studies using nylon bags incubated in the rumen of sheep or cattle. A similar, though not quite as precise, estimation based on the dynamic gas evolution technique has been reported by Blummel and Ørskov (1993). No doubt there will be exceptions, as with banana pseudostem and possibly with feeds containing extremely tough fibre such as palm pressed fibre and sisal pulp.

From both a practical and conceptual point of view of feed potential, it would be desirable to create one value, as was attempted from the work described in Ørskov and Ryle's book of 1990. The multiple regression equation intake Y = X1A + X2B + X3C was divided by X1, so the value for A was 1. For the experiment referred to, X2/X1 was 0.4 and X3/X1 was 200. In other words a straw having an A value of 15, a B value of 30, and a C value of 0.04 would have an index or feed potential value of 15 + 12 + 8 = 35. This value has of course no biological meaning but can indicate the potential consumption and therefore the potential performance of the animals. In this work a potential value of 33 enabled the animals to consume sufficient for their maintenance need. The above results

also illustrate that the value of a feed can be improved by improving A, B or C. An improvement in the A value relative to B may have no effect on overall digestibility yet still enable the animals to consume more. The accuracy is quite surprising, probably because the degradation rate constant may be positively correlated with for instance D and E, thus making it less important to know the values for these parameters.

The concept appears to be correct and the future feed evaluation table may well take the form of Table 5. The concept of feed potential also needs to be developed for pasture evaluations so that the expected performance of grazing animals in different seasons can be predicted.

Table 5. Description of Feeds in Terms of the Factors of the Exponential Equation and the Index Value

Type of Feed	A	B	c	L	Index Value
Spring barley straw (Celt)	10.3	33.8	0.0466	4.8	33.1
Spring barley straw (Corgi)	12.8	37.1	0.0580	6.7	39.2
Spring barley straw (Doublet)	10.9	39.9	0.0495	5.8	36.8
Winter barley straw (Gerbel)	6.6	39.1	0.0247	3.3	27.2
Oat straw (Ballad)	11.4	38.2	0.0240	2.7	31.5
Rice straw (Sasanisiki)	17.1	36.0	0.0399	4.2	39.5
Maize stover	15.6	46.7	0.0356	12.8	41.4
Barley leaf blade	15.6	70.2	0.0672	5.0	57.1
Barley stems	13.5	36.4	0.0406	7.3	26.2
Oat leaf	11.3	49.4	0.0352	3.9	38.1

Oat stems	12.4	29.8	0.0152	1.5	27.1
Rice leaf	15.1	37.2	0.0340	5.2	36.8
Rice stems	30.0	33.5	0.0484	4.7	53.1
Maize cob	12.5	41.5	0.024	16.1	33.9
Maize leaf	19.7	38.0	0.041	14.2	41.5
Maize stem	14.1	36.9	0.032	11.2	35.5
Hay	21.5	49.6	0.037	3.2	59.0

E.R. Ørskov and W. J. Shand (unpublished). L = lag phase

These new concepts have already given rise to new perspectives.

1. The concept of feed potential in different regions can be of value for planning the most appropriate type of animal production commensurate with the feed resource. Thus reproduction, milk production and fattening can be allocated to separate areas. It also helps to avoid the problems for both humans and animals when exotic high-producing animals are imported into areas in which there is a total mismatch between animal and feed potential. I have seen appalling malnutrition in thousands of European and American Holstein cows in South America, Asia and Africa. Application of the concept of feed potential could prevent such mistakes happening again.

As mentioned in the introduction, the expression of feed potential refers to feeds that are consumed under conditions in which the rumen environment is optimal. Less than optimal conditions will prevent the feed potential from being expressed as both intake and nutrient extraction may be limited. Some of these deficiencies can be overcome by addition of urea or the specific limiting factor. Problems of pH can be largely overcome by limiting processing of concentrate and by feed management. Some problems cannot be rectified economically and sometimes less than the feed potential has to be accepted in practice.

2 . The concept also clearly illustrates that roughages can be upgraded by chemical, biological or physical means or by genetic selection by concentrating on any of the three factors A, B and C. For instance chemical treatment has the greatest effect on the B value. Enzymic treatment affects mainly the A value. Genetic selection can be aimed at any of them; it does not need to enhance digestibility as long as feed intake is the limiting factor.

3. The index or feed potential can help planners predict potential livestock production in different regions and, last but not least can provide farmers for the first time with an exchange rate for their roughage feeds.

Are feed potentials additive? To my knowledge, this has not been adequately tested but there appears to be no reason why they should not be. Basically, I think they are, if the utilization is expressed as work or as energy deposited or retained. However it is most likely that the daily work involved in chewing and rumination is similar whether the index value is 20 or 60. This would mean in effect that if the work in chewing activity is reasonably constant then the energy available for other purposes should increase with increasing index value; this perhaps brings us back to the general observation that concentrates are more efficiently utilized than roughages. In other words, while intake of digestible energy will be linearly related to feed potential, the animal's performance will show a small but consistent non-linear effect, whereby energy available for maintenance, protein and fat deposition will increase per unit increase in absorbed energy. This needs now to be investigated.

I would finally like to pay tribute to the great Canadian scientist E.W. Crampton. He had great visions of events and depth of understanding. He wrote in 1957 that the extent of voluntary consumption of a forage is limited primarily by rate of digestion of its cellulose and hemicellulose rather than by contained nutrients or the completeness of their utilization. He continued to say "Rate of digestion may be retarded by any one of numerous circumstances which interfere with the numbers or activity of rumen microflora. These include excessive lignification from advanced maturity, practical starvation of flora from nitrogen or specific mineral deficiency or the presence of excess of bacteriostatic agents". Had he continued on that line and been able to determine rate of digestion as we now can, he would surely have been well ahead of us now. He must surely be considered as one of the giants of ruminant nutrition.

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Postscript

The concepts need further elaboration but it would appear that simple measurements such as the A, B and C value provide a much better description of feed value than digestibility and metabolizability and considerably cheaper.

There will be exception or feeds which are consumed in lesser quantities than predicted. One feed isolated here was banana pseudostem which was consumed in much less amounts than predicted probably due to its higher moisture content (95%). Other feeds contain antinutritive factors which reduce feed intake.

Finally the concept emphasises that feed potential or feed value can be improved both by A, B and C values. Generally in the old systems improvements in feed value is taken to be improvement only in digestibility. Feeds which have similar digestibility can have substantial differences in feed potential. This means that genetic selection for improved crop residues can be aimed at improving any of the three characteristics and likewise upgrading procedures.

Breeds and types of animals will no doubt be different. Indigenous animals can probably consume more roughage than exotic animals but this is not a great problem. It could perhaps be used to describe differences between breeds and types of animals.

The best laboratory measurements which come close to predicting feed potential is the dynamic gas evaluation technique which has the further advantage that it can detect phenolic related antinutritive factors. Chemical analysis are very poor and I think we all agree that we need to be very critical about spending time and resources on that. NIR where it is available and can be calibrated to predict the feed characteristics hold some promise for rapid determination.

Comments on optimising rumen environment

Several authors have commented on the importance of optimising rumen environment for maximal rate and extent of degradation of cellulosic roughages. I would like to draw attention to some interesting work carried out by ILRI. Niger and ILRI IBADAN (Nigeria) where fistulated animals were grazing or offered the seasonally available feeds. About every two weeks a standard cellulosic material was incubated in their rumen and the degradability determined. Using this approach it is possible to identify periods in which the basal feeds are underutilized and the limiting factors can be identified and if possible rectified by appropriate supplements. This approach ensures also that scare supplements e.g. brans, tree leaves etc. are utilized most efficiently as they support utilization of basal feeds as well as being utilized as a source of energy or protein in their own right. I would finally add that while the feed characteristics can be determined in any rumen in which cellulolysis is optimal trials aimed at optimising rumen environment can only be done in the area and with the feeds to which it applies.

Evaluation of tropical feed resources for ruminant livestock

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Introduction

The primary concern of this expert consultation is the assessment of the potential levels of animal production that can be achieved on feeds for ruminants that are available in the tropics.

The title suggests that there may be basic differences in evaluation methods for tropical feeds as compared to those available in the temperate countries. However, many feeds and feed ingredients are exported from their country of origin and the definition of tropical or temperate has little significance. For example a majority of poultry meats and eggs produced intensively and marketed in the tropics are produced from grains imported from temperate countries. Prices of surplus grain on world markets are likely to be subsidised to remain low despite the often high cost of pollution and loss of soil fertility accompanying mechanised production in the temperate countries.

Until recent times there has been a massive trade of protein meals from tropical developing countries to the temperate developed countries to support high levels of animal production in the latter areas (Borgstrom 1980).

The other contrast is that in ruminant production systems in temperate countries only or mainly high quality ingredients are used in compounding feeds. In turn this supports high production rates close to the genetic potential. Temperate countries in general must maximise production and therefore feed conversion efficiency through feeding and breeding in order to minimise the costs of feed, labour and capital depreciation which together are the largest proportion of their variable costs. Because of the high nutrient densities of the feeds used to feed livestock in temperate countries the diets are rarely significantly deficient in any nutrients. This is not the case when agro-industrial byproducts, crop residues or tropical pastures are fed.

Differences between temperate and tropical countries

Developing countries are mostly located in the tropical areas of the world, animals are often managed in small numbers, utilising the byproducts of agriculture, agro-industries or grazing pasture on land not easily farmed or

too infertile for cropping. The cost of agricultural labour in these countries is relatively low or is not an issue such as the cost of family labour.

The basic differences are as follows:

- **In the developed (temperate) countries in order to be profitable animal productivity needs to be maximised by meeting the animals' requirements for nutrients. To achieve this farmers generally use high quality energy dense feeds which are also high in protein. The nutritional research required in the temperate countries therefore is largely fine tuning of the nutrient balances arising for digestion and absorption from a diet.**
- **In the developing countries (tropical), land for ruminant feed such as pasture or crops specifically grown for forage is not generally available and the animal must depend on locally available byproducts of agriculture and industry which are often deficient in certain nutrients. In these countries there is a need to optimise production from the available resources by providing minimum amounts of the deficient nutrients. The level of production is even then often well below the animals genetic potential.**

The major exception to these generalisations are in developed countries with low population densities and large tracts of land where labour costs are high and extensive grazing systems with low nutritional inputs persist because they best suit the short-term economic situation but perhaps are eventually non-sustainable as without inputs fertility of these rangelands decline.

These fundamental differences pose different criteria for feed evaluation and indicate different sources of feeds for ruminants. For example straw is regarded as a major feed resource for ruminants in many developing countries whereas it is regarded as of little value in temperate developed countries and its disposal is now a major pollution problem. In those countries that have extensive grasslands the major resource is pasture usually from relatively infertile land and which rarely supports more than medium levels of production. Evaluation of pastures by chemical analysis is rarely relevant, as the intake of pasture and its composition is unknown and changes progressively with seasonal conditions.

In the following discussions feed evaluation is discussed in relation to optimising animal production from local resources rather than maximising animal production from high quality feed resources.

Local/imported feeds for livestock

A presumption made here is that there are only a few basal feeds and options for feedstuffs in any single locality and therefore there are few feeds to evaluate. This then lends itself to evaluation of feeds in feeding trials with the target animals.

With limited chemical knowledge of the feeds and a few principles of ruminant nutrition the compilation of diets to optimise production from the least cost basal feed resource can be accomplished and local feeding trials can be used to determine the response to graded levels of supplement inputs. The data from these trials then becomes the basis for "rule of thumb" recommendation for widespread development of feeding systems. A response curve to any input then allows economic level of supplementation to be used.

This assertion often disappoints scientists who have mastered complex computer models or computerised least cost diet formulation. It also angers others from the temperate countries, presumably because they feel that perhaps the applicability of their science is being challenged. However, if the feed evaluation systems, as applied to temperate countries (e.g. the ARC system or Cornell Metabolisable Protein System) were applied literally in developing countries most of the present ruminant feeds of the developing world would be rejected as being too low in digestible nutrient densities to be useful.

The standards of developed countries for feed quality based on any energy measurements for ruminant are clearly misleading when they are applied to poor quality forage or non- conventional feedstuffs (see Leng 1990). In at least two major developments in Asia involving millions of animals in each, high growth rates of cattle (Guo Tinshuang and Yang Zhenhai, 1994: Dolberg & Finlayson 1995) and high milk production in cows (NDDB - see Leng 1989) have been achieved on feeds that are rejected in developing countries as being of too poor quality, yet these systems have production outputs that come close to those of many developed country systems based on high

quality pastures.

Primary consideration of feed resources

The first approach to feeding must be to identify:

- **the feed resources in ample supply and that are therefore available to provide the bulk of a ration for the local herd or flock.**
- **the supplements (usually high in minerals and/or non protein nitrogen and/or protein) needed to balance the animal's nutrition on the biomass resource.**

The former resources are comprised largely of fibrous carbohydrates that require microbial fermentative activity for digestion and include:-

- **biomass from grasslands, waste land, roadsides and bunds between crops,**
- **crop residues,**
- **agro-industrial byproducts high in cellulose,**
- **crops grown specially for feeding to ruminants (grasses, sugar cane and silages).**

These are generally all bulky feeds that are not economically transportable any distance and must be fed to ruminants within a few kilometres of where they are harvested.

Molasses and sugar cane juice which contains sugar that can be digested intestinally appears to be the only dense carbohydrate resources sufficiently available in the developing countries to be considered as a basal feed resource for ruminants. However, export to developed countries, industrial processing and the demand for other uses (e.g. alcohol production) makes it unlikely that they will be used extensively as a basal feed for ruminants in the future. Molasses remains an important resource as a concentrated multi mineral source particularly for ruminants.

The other group of feed resources are the supplements. These provide essential nutrients in high concentrations and therefore blend with, complement and balance basal feed resources. These resources include concentrated sources of minerals (e.g. residue after fermentation of molasses); bypass proteins, (e.g. cottonseed meal); non protein nitrogen sources (e.g. urea and poultry manure) or their precursors in the rumen (e.g. fresh forage plant proteins); fat (e.g. from oilseed cakes) and vitamins (e.g. vitamin A - from green grass). Because these resources are to be used as a small proportion of a diet relative to the basal feed, they can often be transported economically. Where these supplements cannot be delivered economically then resources have to be produced and/or processed locally to provide the critical nutrients needed to balance low protein forage based diets, particularly with respect to the provision of a protein meals that escapes rumen degradation (see Leng *et al.*, 1977; Preston & Leng 1987; Leng, 1990; Leng, Choo and Arreaza, 1992).

Evaluation of basal feed resources

In relation to tropical feeds for ruminant livestock the major resources that fall into this category are straws and stovers, pasture grasses and agro-industrial byproducts of sugar cane industry, that is bagasse and sugar cane tops. These are all categorised as poor quality forages which in general means that they are of low digestibility i.e. generally lower than 50% digestible and are low in protein and non protein nitrogen (NPN) (often less than 6% CP) and variably deficient in a number of minerals. Mineral components of such biomass obviously depends on growing conditions including soil fertility, climate and stage of maturity of the plant at harvest. These forages will need to be supplemented to correct their nutrient deficiencies e.g. fermentable N, bypass protein and minerals. There appears to be therefore little point in measuring chemical entities on the forages per se without supplements, although they are often fed in developing countries alone. Knowledge of the potential deficiencies for the microbial system in the rumen is most important since this is often the limitation that determines the nutritional value of the feed. The first criteria in a feed evaluating system is to understand the likely order of deficient nutrients firstly for microbial growth in the rumen which determines the potential extraction of nutrients by the rumen microbiota (see later) and then for the animal.

Assessment of degradability of a feed in the rumen

The balance of nutrients potentially made available from and the digestibility of the dry matter in the rumen are the most important criteria of the potential of a basal feed. Digestibility primarily establishes the intake of the basal feed once nutrient deficiencies for the rumen microbes have been corrected (Minson, 1982), however, intake is effected by climate and a range of other factors.

There are only a few methods available to assess digestibility these include in vivo, in sacco or in vitro methods. A number of chemical analysis can be used to predict digestibility but except for rapid screening processes these seem to be of little value against the more direct measures of digestibility determined in vivo or in sacco. Digestibility values are only valuable if they are determined with some accuracy in a well designed digestibility trial. In vitro digestibility is highly correlated with the in vivo potential digestibility but standardisation is necessary. The nylon bag technique (in sacco digestibility) provides valuable data on digestibility provided the technique is standardised and the curve of disappearance of dry matter from the dacron bag in the rumen is well defined using replicate samples taken over a time period. It is however, apparent that in most laboratories the nylon bag technique is rather crudely applied.

The disappearance curve for dry matter may be analysed to provide data on fractional digestibility rate and the potential dry matter digestibility. Orskov *et al.* (1988) have argued that the coefficients of the disappearance curve of dry matter loss with time from nylon bags in the rumen can be used as a primary measure of nutritional value of a forage and allow prediction of growth rate (see later).

A major point to be stressed here, however, is that the nutritional value of a forage alone is not always the important issue. The nutritional value of the diet containing the forage as a major component and balanced to achieve efficient microbial growth in the rumen and efficient partitioning of nutrients into tissue or milk synthesis is the most important issue and therefore knowledge is needed of:

- **the level of production on the forage which is supplemented to ensure the diet meets the microbial growth**

requirements in the rumen.

- **the response of relationships of production to level of the appropriate supplements.**

It is thus relevant now to discuss methods for assessing the efficiency of the rumen and the composition (quality) of the appropriate supplements.

Defining the status of microbial growth on the rumen

An approach to estimating the net efficiency of microbial growth in the rumen depends upon knowledge of rumen biochemistry - mainly the factors that are involved in the production of VFA in the fermentative processes relative to microbial growth in the rumen. Microbial protein synthesis relative to VFA production determines the protein to energy ratio (P/E ratio) in the nutrients absorbed. Maximisation of microbial growth on any carbohydrate resource requires all necessary microbial nutrients to be present and at optimum levels, this then leads to a maximisation of the P/E rates in the nutrients absorbed from the rumen (Leng 1982). The best estimate of rumen efficiency is microbial cells available. The main in vivo method to measure microbial cells produced in or leaving the rumen appears to be in the quantity of purine excreted in the urine (Smith and McAllen 1971) purine excretion in g/d relative to digestible feed intake is an index of the efficiency of the rumen microbial ecosystem (Chen and Gomes 1992).

Other approaches to assessing the relative microbial growth include an in sacco method. In this method the digestibility and a,b, and c of the disappearance curve of a standard forage has been measured in an animal with an efficient rumen and then these same measurements are made in the rumen of an animal fed the basal feed resource (see later). This indicates whether microbial growth is sufficiently high to maximise digestibility but not necessarily microbial growth yield per unit of feed digested.

A further approach measures the relative rate of incorporation of a marker (usually 35S) into microbes in rumen fluid from an animal on a diet and compares this with rumen fluid from another animal known to have a highly efficient rumen microbial ecosystem (Hendrickx & Martin 1963).

Evaluation of supplements

- Supplements needed to maximise production from the basal feed resource are obviously variable and at times include:-
- minerals - calcium, phosphorus, sulphur, magnesium, sodium and trace minerals etc. required by both the microbial ecosystem in the rumen and by the animal.
- calcium requirement in particular, as a deficiency of calcium in solution in the rumen specifically inhibits cellulase activity, Ca^{++} is a co-enzyme for the microbial cellulolytic enzymes (Walker & Leng, 1994).
- non-protein-nitrogen (mainly ammonia) and sulphur source for rumen microbial growth.
- a source of bypass protein to enhance the essential amino acid supply to the animal.
- supplements that improve the overall digestible energy density of a low digestible basal feed. Included in this group are high digestibility forages, molasses, sugar cane or its juice and fats.

Assay of mineral supplements

It must be stated at the outset that many potential supplements have multiple roles. For example, most protein meals are high in phosphorus and minerals, molasses and distillers slops because of their origin as a plant juice contain a fairly complete array of minerals including trace elements. Urea molasses multinutrient blocks (UMMB) are designed to provide urea, a complete mixtures of minerals and some slowly degradable protein (see Sansoucy, Arts and Leng 1988).

Mineral components of standard materials can generally be assumed from literature values and local knowledge. However, mineral components of unknown but potential sources may need to be measured in laboratories specialising in such analysis to pick up the most likely limiting minerals. The mineral content of some recently recognised potential sources depend very much on the growing conditions of the plants. For example duckweed is a variable source of N, P, S and K depending on the water concentration on which the duckweed is grown (Leng *et al.,*1995). However, the level and number of minerals needed in a supplement are extremely difficult to asses and

again only a 'rule of thumb' approach can be applied. Usually a "shot gun" mixture is the best option, particularly where molasses, poultry manure or distillers slops are available to provide such a mixture.

Local knowledge of supplements is often essential, for example, with molasses, the sulphur and calcium content depends on the method of clarification of the sugar-cane juice in the manufacture of sugar. The process may use sulphur dioxide (e.g. parts of China), bentonite (e.g. in Australia) or calcium hydroxide (e.g. in Cuba).

The most valuable sources of minerals include:

- **Concentrated plant juices, which besides the minerals required by the plant to grow are often fortified in their processing or lend themselves to ease of fortification with minerals**
- **Dried faeces of chickens and pigs fed high quality diets.**
- **Aquatic plants that concentrate minerals (e.g. duckweed and azolla).**
- **Distillers slops that arise from molasses fermentation to alcohol and are often discarded into the nearest water resource.**
- **Tree foliages and forage legumes can also be a very useful source of minerals. For example the response of small ruminants on poor quality forages to supplements of leucaena leaf meal has been shown to be due mainly to its mineral content (Goodchild and McMeniman 1994).**

Fermentable N

Urea or ammonia can be used directly in feed supplements. As most unprocessed proteins also provide fermentable N or ammonia in the rumen, an assessment of solubility of a protein source, or extent and rate of production of ammonia when incubated in rumen fluid are strong indicator of the fermentable N in a protein meal. The best option for assessing the availability of fermentable N is to measure the level of rumen ammonia in animals given the feed. The ammonia level should be at a minimum 100mg N/l but levels up to 200mg N/l are more efficiently used (Perdok and Leng 1990; Kanjanapruthipong & Leng, 1995). In order to be sure the technique above can be used to assess microbial growth efficiency, it is necessary that an efficient rumen is achieved when

sources of rumen ammonia are fed.

It is usually more economically important to protect such proteins from rumen degradation and in this way provide the animal with amino acids, augmenting those from the rumen microbes digested in the intestine and replace the low availability of ammonia from the protein by using urea.

Although there is some indication that amino acids are required by some rumen microbes for growth, particularly on starch and sugar based diets recent research indications are to the contrary for forage based diets (Maeng et al 1976; Leng, 1990; Kanjanapruthipong & Leng, 1995).

Bypass protein

Productivity of ruminants under a wide variety of feeding systems is improved by supplementation with a protein meal that, because of its physical and chemical characteristics, is not quickly degraded in the rumen and significant quantities escape to the intestines to be absorbed as amino acid (see Preston & Leng, 1987). This has been recognised widely since the early 1970's but the end effect was recognised much earlier (Marston, 1932). The need for both a source of NPN and protein in roughage diets fed to ruminants was first extensively promoted by Leng *et al.*, 1978 and Preston & Leng ,1987). Many feed evaluation systems now attempt to incorporate the need for fermentable N and bypass protein into their calculations. However, quite clearly, from applied research results supplementation of ruminants on poor quality forages with protein meals containing a high level of escape or bypass protein has shown up quite alarming discrepancies when productivity levels are compared with those calculated from the energy density of a feed (see Leng, 1990). Whereas standards based on the metabolisable energy density of a poor quality forage suggest negligible production on such feeds it is now demonstrated, on a massive scale, that growth and milk production of cattle can be promoted with bypass protein from a few grams per day to levels that would be highly applauded for cows fed on high quality fertilised and irrigated grasslands. Recently, McClennan et al (1994) claimed that bypass proteins have a major effect on productivity of cattle fed a medium quality hay but they suggested it could be accounted for by using the feeding standards based on metabolisable energy density of the feed. However, as will be demonstrated when their data is combined with

experiments from the world literature a different interpretation is required.

The requirements of cattle for minerals, NPN and bypass protein are well exemplified by data from around the world on supplementation of cattle given straws and hays supplemented with cottonseed meal. Solvent extracted cotton seed meal protein appears to be about 75% protected from rumen degradation (Leng et al 1984). When fed to ruminants it increases the protein nutrition of the animal per se.

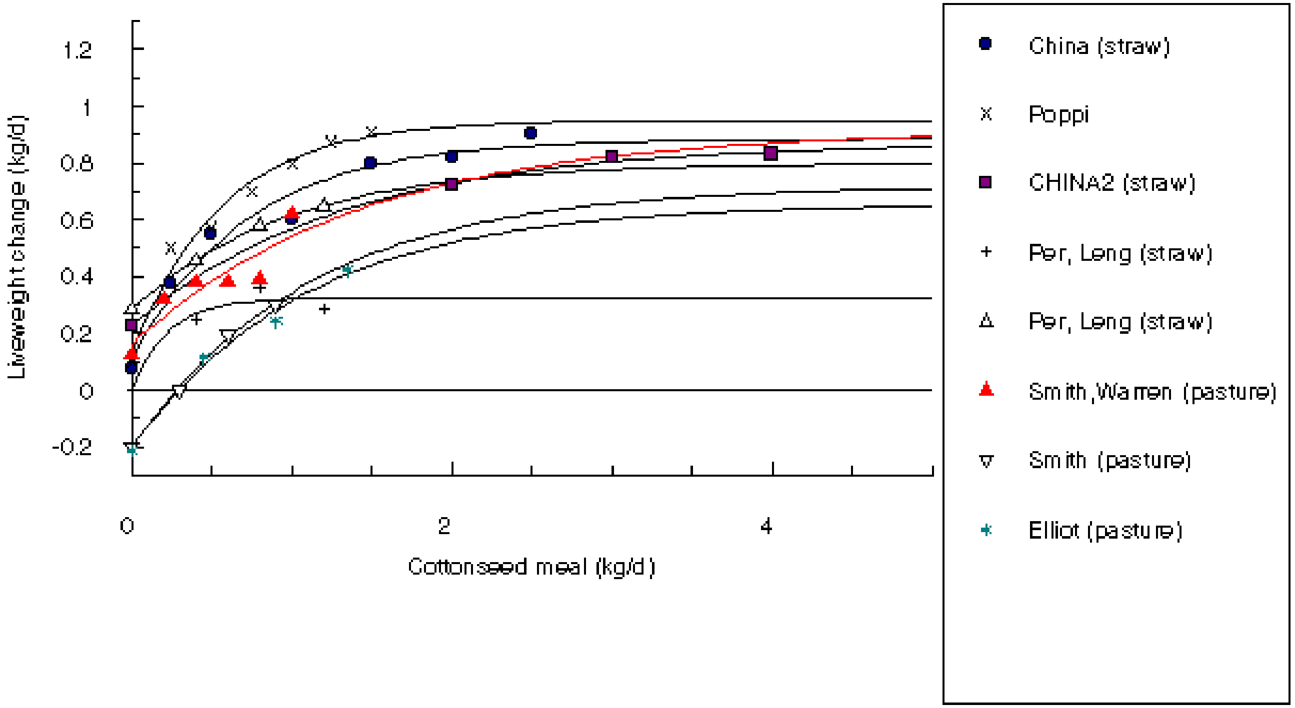
The response in growth rate of young cattle to incremental increases in cottonseed meal is shown in Figure 1 for eight studies from various countries. The response relationships has been fitted to the equation

$$\Delta GR = x + y\,(1-e^{-zq}) \qquad (1)$$

where GR = growth rate in kg/d; x is growth rate without cottonseed meal supplementation; y is the potential growth rate on such a diet and z is the fractional growth response to cottonseed meal supplement level (q).

Whilst the shape of the response relationships appear to be similar, between experiments the potential growth rate without supplements and at optimum supplementation rate are quite variable between forages of different digestibilities. For example there is a large difference in cattle fed straws that are untreated or have been treated with ammonia to improve digestibility (see figure 1). Thus digestibility units. Thus digestibility of forage or some description of the progress of digestion of straw are important in feed evaluation and determine both the growth rate when only the rumen is balanced to support efficient microbial growth or when both rumen and the animal is balanced for nutrients.

Figure 1. *Results from 8 studies of the effect of supplementing cottonseed meal to cattle (140-200kg LWt) fed poor quality forages. Basal forages including straw, ammoniate insiled straw and pasture.* ● from Dolberg and Finlayson 1995, × McClennan *et al* (1994), ■ Dolberg and Finlayson 1995, + Perdok & Leng (1990), Δ Perdok & Leng (1990), σ Smith and Warren (1986), ∇ Smith and Warren (1986), ⌶ Elliot and O'Donovan (1971)



Prediction of potential productivity of cattle on a basal forage. Towards a measure of forage quality for feeding to ruminants.

All nutritional evaluation standards are or were predicated on the premise that there are no nutrient deficiencies for optimum digestion of the feed substrate in the rumen. This alone makes them unusable in most feeding systems discussed in this presentation. However, deficiencies of specific nutrients are the primary cause of low productivity of cattle in the tropics and it is rather misleading to quote a standard feed evaluation for instance

based on prediction of digestibility without knowing the need to correct the nutrient deficiencies.

When the rumen is made efficient with NPN and minerals the most important supplements to forage based diets are protein meals. Identifying the reasons for a response to any particular supplement, however, is not simple. For example, many vegetable protein meals contain a full complement of trace minerals and are rich in phosphorus. Thus protein meals could provide additional ammonia in the rumen and the limiting minerals in addition to intestinal amino acids for absorption.

Supplementation of cattle on low true protein forage based diets with protein meals has shown that levels of production from a feed under these conditions are considerably higher than predicted from the apparent digestible or metabolisable energy contents of the basal feed (see Webster 1989). For example the production responses of cattle fed poor quality roughage and supplemented with deficient nutrients for rumen microbes (e.g. molasses urea blocks) and cottonseed meal are some times ten times more efficient in converting metabolisable energy to liveweight gain than predicted by the ARC-metabolisable energy system (see Leng, 1990).

The level of production in ruminants on a basal forage diet without supplements and the maximum response to supplementation appears to be controlled by the digestibility characteristics of the basal feed. The nutritional value of a forage is therefore highly dependant on the kind and level of supplementation.

In search of a formula to describe nutritional quality of a forage based diet.

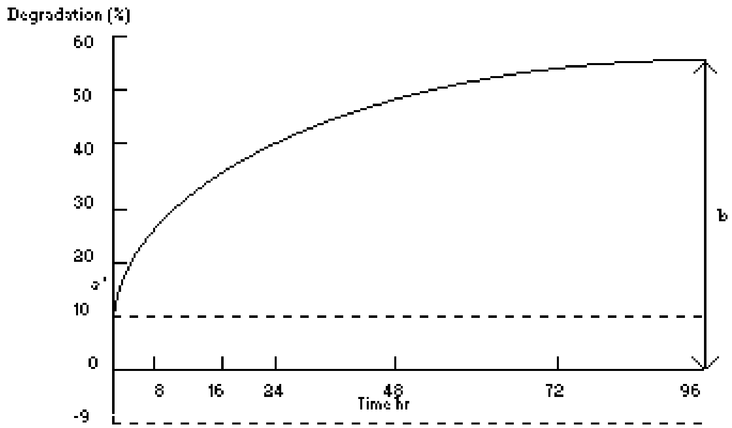
Orskov (1989) asserts that most analytical approaches to estimating the feeding value of forages are of little value. He has recently suggested an approach to estimating the feeding value of forages by using the characteristics of the time course of solubilisation of forage dry matter from nylon bags held in a functional rumen of an animal. Using feed ground to a standard size and incubated in the rumen in standardised nylon bags, the disappearance of dry matter with time is established. A typical curve is shown in Figure 2. The best description of the curve is given

by the equation

$$p=a+b(1-e^{-ct}) \qquad (2)$$

Where a is the solubility in water or dry matter disappearance at zero time, b the upper quantity that will potentially disappear (or maximum potential digestibility) and c is the fraction of non- soluble dry matter that disappears per hour (t) (Orskov & Mc Donald 1979).

Figure 2. *Description of degradation characteristics of a typical fibrous residue using the expression* $p = a + b(1-e^{-ct})$. (Ørskov & Mc Donald 1979).



Orskov and his colleagues have developed a number of such curves for different forages held in nylon bags in the rumen of sheep fed roughage diets balanced to give an efficient rumen. The intakes of straw and growth rates of cattle (200kg LWt) fed that straw ad lib fortified with minerals and with an additional supplementation of 1«kg concentrate per day was measured. These were then related to a,b and c generated using nylon bags of each forages/dry matter. Growth rate (GR) was best describe by the equation

$$\Delta\ GR=0.0571a+0.126b+17.02c+K \qquad (3)$$

where K is a constant equivalent to -1.261kg/day. This is the rate of weight loss when a,b and c are each zero and therefore is synonymous with weight loss in starvation. Unfortunately K is large relative to the low growth rates of cattle on straw based diets. The accuracy of the prediction of growth then depends heavily on the error around K. The latter constant has not yet been determined in vivo by starving animals for a period.

The data used by Orskov (1989) to generate Equation 2 is shown in Table 1. The percentage contribution of K to the predicted growth rate from equation 3 when the animal is fed straw plus 1.5 kg 16% crude protein concentrate (and nutrients to optimise rumen fermentation) is shown in the same Table. Although the prediction of growth rate depends on the accuracy of a,b or c and the error around K this may still be a useful guide we have to the value of a feed in supporting growth in an animal.

The accuracy of the estimation of K is an important consideration in estimating GR at zero supplementation since an error of +/-150% (0.064 +/-0.108kg/d) change in the predicted growth rate at the lowest growth rate reported in the data set used by Orskov (1989). On the other hand at the highest growth rate similar errors in K give an error +/-16% (i.e. 0.783 +/-0.127 kg/d).

If prediction of growth rate at zero protein supplement intake by cattle on forage based diets could be predicted with some accuracy it should be possible to superimpose a response curve to a bypass protein starting with the former value as the initial growth rate without supplementation. It may, however, be more appropriate to carry out growth studies to determine the growth rate without protein meal supplementation in order to establish GR at zero supplement and then predict the response to proteins. This should be a major discussion point for by the expert panel. The response curve then has the equation.

$\Delta GR=0.051a+0.126b+17.02c-1.261+y(1-e^{-qz})$	6

Predicting responses to a bypass protein

In Figure 1 the response of young cattle consuming a low quality forage to increasing quantities of cottonseed

meal (a good bypass protein) are shown for various investigations in a number of countries. These response relationships were fitted to equation 1.

Predicting the extent of bypass protein in a protein meal

The best option here would be to examine growth response curves to protein meals on the same feed, comparing in particular y and z in Equation 1.

Leng et al (1984) used in increased wool growth for sheep fed a low protein basal diet. Almost all the major protein meals available in any locality in Australia were assayed in two trials. In the research it is assumed that formaldehyde treated casein was 100% protected so a bypass protein index compared all other protein meals to the response to this supplement.

A further easier approach is to grade protein meals according to the rate and extent of degradation to ammonia in rumen fluid, again standardised against one protein meal of known bypass characteristics. Where proteins are shown to be highly degraded or degradable in the rumen, some form of protection of the protein needs to be carried out.

A comparison of the nutritional value of a concentrate mixture and cottonseed meal

As an exercise to further examine the usefulness of an approach to basal feed evaluation and supplement quality, the growth response in cattle given ammoniated or untreated straw with 0.7kg molasses and 6 levels of a 16% concentrate mixture (1 to 6kg/d) (Creek et al 1983) are shown in Figure 4. The growth rate at zero concentrate intake was again calculated by fitting a curve.

$$\Delta GR = x + y\,(1 - e^{zc}) \qquad 5$$

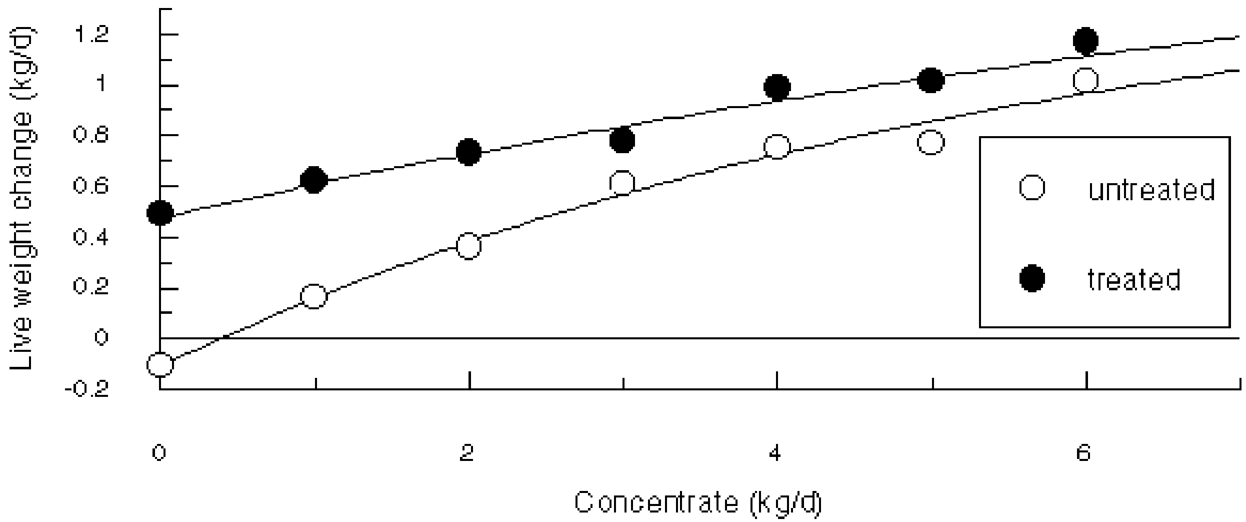
where c in this case is the quantity of concentrate fed.

Table 1 Relationships of fermentative digestion characteristics a (g/100g), b (g/100g), c (fraction/h) for straws (± ammonia) in dacron bags in the rumen and growth rate of cattle (from Ørskov 1989)

Forage + ammoniation				Contribution to calculated growth rate (kg/d)					Growth rate (kg/d)*	
	a	b	c	a	b	c	k	k / a+b+c	predicted	actual
1. Winter Barley -	6.0	32.9	0.0337	0.342	0.415	0.574	1.267	0.95	.064	.106
+	7.9	54.4	0.0258	0.450	0.685	0.440	"	0.80	.208	.359
2. Winter Barley -	5.1	38.2	0.0391	0.291	0.481	0.665	"	0.88	.170	.126
+	7.9	45.2	0.0351	0.451	0.570	0.597	"	0.82	.351	.332
1. Spring Barley -	3.4	48.7	0.0483	0.200	0.614	0.822	"	0.77	.369	.400
+	0.4	60.4	0.0457	0.365	0.761	0.778	"	0.67	.637	.608
2 Spring Barley -	7.5	48.0	0.0303	0.428	0.605	0.516	"	0.81	.182	.198
+	9.3	52.1	0.0376	0.531	0.656	0.640	"	0.69	.560	.602
Winter Wheat -	7.7	40.9	0.0343	0.440	0.515	0.445	"	0.91	.233	.273
+	9.0	51.9	0.0364	0.513	0.654	0.883	"	0.61	.783	.516

* Actual growth rate here is growth on the basal feed with urea plus 1.5kg/day concentrate

Figure 4 *Growth response to cattle fed untreated (❍) and ammoniated straw (λ) and supplemented with 0.7 kg/d molasses and graded amounts of a concentrate (16%CP) (Creek et al 1983).*

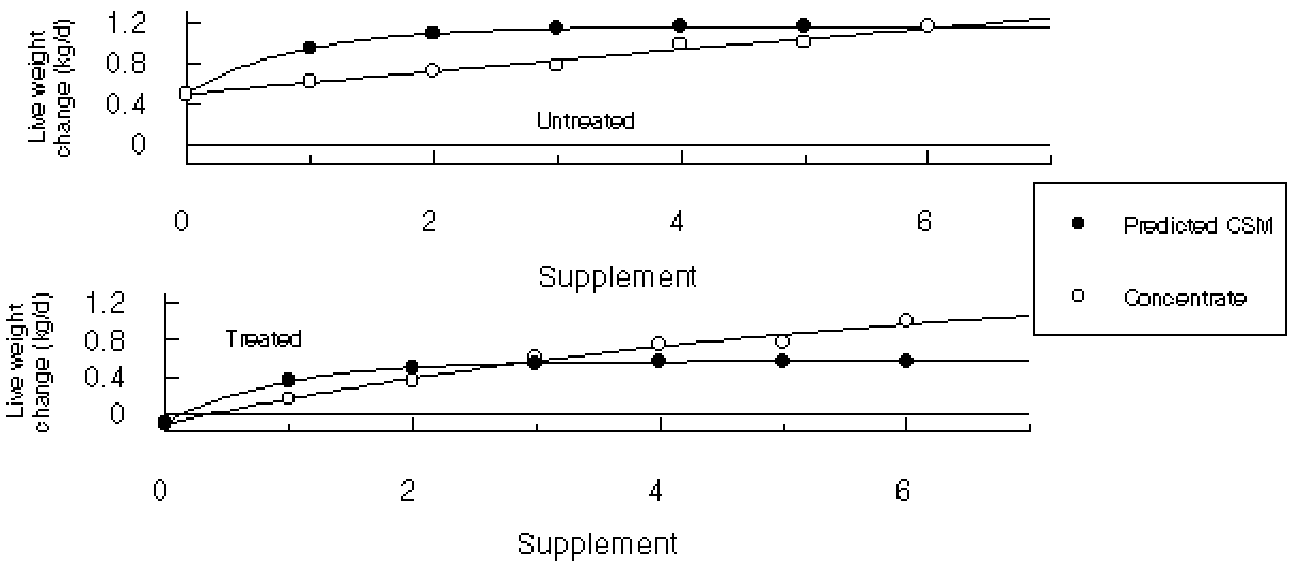


The growth rate at zero concentrate intake was predicted.

Taking this as growth rate at zero supplementation the theoretical response to increasing increments of cottonseed meal to these straws were fitted to illustrate the dissimilarity in response relationships to a "balanced concentrate with 16% CP" and a bypass protein of 40-45% protein in cattle fed treated and untreated straws (Figure 5).

The predicted pattern of responses to supplements of cottonseed meal fed to cattle on a rice straw diet shown are completely different to that from more conventional concentrates presumably because the cottonseed meal improves efficiency of feed utilisation and a grain based concentrate generally substitutes more for the basal diet.

Figure 5 *The relationship of growth rate and supplement intake (concentrate (○); cottonseed meal (●)) of cattle fed untreated straw and straw treated with ammonia to improve digestibility.(Creek et al 1983)*



It should be clearly noted that forage substitution by concentrate occurs, whereas a bypass protein tends to maintain or increase intake of the basal forage (see Leng 1990)

Supplements to increase productivity once the utilisation of the basal feed resources has been optimised.

High digestibility forage

Figure 1 shows that supplements to basal feeds to optimise productivity at a final level set by the initial growth rate where only the rumen is efficient. At the upper level of response to supplement the only methods for increasing productivity further is to replace the basal feed resource with a more digestible feed that does not

exhibit negative associative effects on the digestibility of the basal feed. The addition of a high digestibility forage to a low digestibility forage often stimulates digestibility of the basal feed as well as increasing the digestibility of the total feed (Ndlovu & Buchanan 1985). The response curve should be the same shape but starting at a higher growth rate at zero supplementation.

Sugars and Grains

Grain generally interacts with forages depressing the forage utilisation. This may be due to limited ammonia availability but also by other influences. On the other hand, at times addition of sugars can stimulate the overall total energy intake without depressing digestibility of forage so long as the amounts and availability of ammonia (and in all probability minerals) are increased commensurately.

Complex interactions occur within the rumen when sugars/starches are mixed with fibre with quite marked changes in the microbial ecosystem particularly with respect to protozoa and fungal densities. An increase in protozoa often lowers P/E ratio from the rumen because protozoa predate bacteria (Bird & Leng 1978). The response to feeding sugars (molasses) which stimulate at times protozoal densities in the rumen can often be unpredictable, at least with the level of knowledge we presently have. The alteration in P/E may change efficiency of feed utilisation by ruminants and production improves without increases in feed intake. In general, however, these feeds should be used sparingly if at all in increase digestibility of a feed.

Fat

Fats have been regarded as both beneficial and detrimental feed ingredients for ruminants depending on the level of inclusion (see Palmquist, 1988). Fat analysis is relatively easily undertaken by using an ether extract but this does not recognise the presence of insoluble soaps. In general fats are regarded as nutritionally beneficial up to 4-5% of a diet. Fats are absorbed extremely efficiently after hydrolysis to long chain fatty acids in the rumen (Thornton and Tume 1987) and deposited extremely efficiently in adipose tissue provided they are also given a bypass protein supplement (Van Houtert & Leng 1993). Above 5% or so the fats become detrimental because of a

depressing effect on digestibility of the forage component of a diet. Recent studies have demonstrated that it is the concentration of long chain fatty acids in the rumen that effect digestibility. The mechanism of action on cellulolysis appear to be through reduction of free calcium ions in solution (Ca ++), through the formation of calcium soaps of fatty acids. It is the low Ca++ that apparently suppresses microbial cellulase activity (Walker and Leng, 1994 unpublished). Increasing calcium intake progressively, results in elevated free calcium ions, and the effects of long chain fatty acids on forage digestibility are removed. Thus the level of calcium (in available form) in the diet is extremely important in deciding the nutritional value of high fat diets. The research that has shown that calcium can remove the detrimental effects of fat now paves the way for strategic supplementation with high fat diets that can be used to increase the energy density of low digestibility roughage.

Vitamin

The most likely deficiency of a vitamin in a roughage diet fed to ruminants is Vitamin A. Often the supplementary feeding value of a green forage source far exceeds the potential value on the basis of its protein and energy and at these times it is possibly a result of the additional Vitamin A which can be deficient when crop residues are fed over a prolonged period.

Climate influence on predicability of the nutritional value of a feed

Ruminants are extremely well adapted to cool environments but appear to have poor adaptation to hot conditions (Blaxter, 1962). A number of studies have demonstrated that animals selected for short shiny hair-coats consistently out-produce similar breeds with rough-hairy coats. This may be related to a low density of sweat glands. Buffaloes have no sweat glands.

As animals progress from cold to hot conditions their needs for protein relative to fat or fatty acid precursors change as follows:-

- **under cold conditions the requirements for oxidisable substrate such as fat and short chain volatile fatty acids**

is increased totally and relative to the requirements for amino acids for tissue synthesis i.e. the P/E ratio in the nutrients required by the animal is decreased.

- **under hot humid conditions the need for oxidisable substrate for heat production may be close to zero and the P/E ratio in the nutrients required by the animal is increased although total nutrient requirements may be decreased.**
- **Animals at the upper level of their ability to control their body temperature in a hot environment, may be heat stressed by the extra heat produced in an inefficient rumen microbial ecosystem or where acetate burn-off is required because of the imbalanced nature of the nutrients absorbed (see Leng et al 1993).**

Heat stress in ruminants, which is indicated by excessive respiration rates in general reduce feed intake. This in turn would reduce the heat increment associated with fermentative digestion and also the heat released in fertile cycles of metabolism or in synthesis (of milk or tissue).

Sources of heat for inducement of heat stress in ruminants

Heat is absorbed directly from the environment e.g:

- **air surrounding the animal**
- **contact of the animal with hotter bodies**
- **irradiation heat from the sun.**

Heat is also produced in:-

- **microbial digestion of feed in the rumen (the more efficient the rumen the lower the heat)**
- **maintenance of the tissues dynamic state**
- **essential function - maintenance of cell homeostatic, conversion of absorbed products into tissue synthesis or reserve energy sources (largely fat and glycogen).**
- **oxidation of compounds that are constrained from synthetic processes because of imbalanced availability of**

nutrients and must be oxidised in futile metabolic cycles.

The animal may control to some extent its environmental heat load by changes in their behaviour e.g. seeking shade, standing in water and varying their feeding periods. All these may reduce feeding time and therefore overall feed intake.

The animal may control to some extent its metabolic heat load by reducing its workload in movement, changing its selection of feed components with lowest heat increment. For example at high environmental temperatures and humidities cows in India reduce their forage intake but consumed a bypass protein supplement extensively (Kurup,1994).

Heat production in fermentative digestion in the rumen is variable and dependant on the efficiency of microbial growth in the rumen. Heat increment in the animal is largely a function of the balance of nutrients absorbed in particular there is evidence that the amino acids absorbed from microbial cells plus bypass protein controls relative metabolic heat production (see Leng *et al.*, 1993).

Thus an animal unsupplemented and fed on a poor quality forage could have considerable metabolic heat generation, which if the animal was cold could be put to good use in keeping the animal warm. On the contrary the heat production might exacerbate a heat stress in an animal in a hot/humid environment which would largely result in reduced overall feed intake.

Interactions of climate/diet

Animals that are in a hot climate can therefore be expected to have a lower intake of an unbalanced diet than animals in cool/cold climate. In general on a poor quality roughage diet if the rumen of an animal in a hot/humid environment is deficient, in say fermentable N and/or sulphur and/or phosphorus then this will:-

- **reduce digestibility - by as much as 5 to 10 units**

- **reduce efficiency of microbial cell growth per unit of organic matter digested and therefore lower P/E ratio in the nutrients absorbed.**
- **reduce feed intake both because of the lower digestibility and also because the extra heat from the rumen and the animal.**

Correcting the rumen deficiencies will:

- **increase digestibility**
- **increase P/E ratio in nutrients from microbial digestion in the rumen, this in turn will decrease overall heat load from heat of fermentation and metabolic heat**
- **the increased digestibility together with the decreased heat production will allow an increased feed intake that will vary according to the environment of the animal and its ability to lose heat.**

If the extra metabolic heat resulting from imbalanced nutrients has a major control over appetite then large responses in feed intake will occur when bypass protein are introduced into the diet.

Overview

The nutritional value of a forage therefore depends on the environment of the animal and the access the animal has to supplements. A clear demonstration of the responses is shown in data by Lindsay and Loxton 1981. Their research was carried out with cattle supplemented in mid summer in the dry tropics of Australia. Feed intake in cattle given poor quality hay was improved by feeding urea/sulphur but further improved when bypass protein was also given. This same discussion has been used to rationalise the results from different research institutions where results of supplementation of cattle on poor pasture or poor quality forages have given different effects (see Leng, 1990).

The research in this area is still limited by the endless discussions about whether the differences, observed between researchers at different sites are real. If the explanation for the differences is in the differences in

climate, then a poor quality forage can be considered to have a different nutritional value depending on the climate and the supplements used. The responses to supplementation of cattle aimed at balancing the nutrients available to nutrient requirements will have greater effects on production rates in the tropics as compared to cool or cold regions. Not only the climate of the tropics will be implicated but the animals insulation (hair, coat), its ability to dissipate heat or to modify its behaviour to minimise heat stress will also change the nutritional value of the feed.

Conclusion

There can be no confidence in using digestibility or chemical analysis of feeds to predict the likely productivity of ruminants from the feed resources that are generally available in tropical countries. The only realistic approach appears to be based on feeding trials with ruminants on basal feed resources with access to multinutrient blocks and then to categorise response curves to bypass protein inputs. Improving nutritive value then requires progressive supplementation of the basal feed with small quantities of a higher digestibility feeds to determine the responses to these inputs at optimum supplementation levels.

There appears to be little chemical analysis needed. The major approach is to gain experience with the few feeds that have to be assessed and measure responses to the two categories of supplements discussed in the body of this document.

The bottom line - the challenge

It may surprise the reader that no references are made in this document to NDF, ADF or lignin or any other methods of chemical analysis. It is this writer's personal opinion that these are useful techniques for investigating feed utilisation but have little to offer feed evaluation. A common problem with research methodology is that quite often applied research in which the main approach is the feeding trial, often quote the detergent analysis, seldom do these receive more then a passing reference in the discussion and it is seldom that they (chemical analysis) contribute anything to explaining the applied production responses but nevertheless they seem to be

mandatory for acceptance for publication. The present writer has had a paper turned down because the feed given to cattle, which was straw, was not analysed. It is now time to challenge the chemical approaches to describing feed since it often ties up competent technical staff, delays publication and therefore knowledge transfer to the end user and emphasises the evaluation of the feed and not the response of the animal to that feed. The expert consultation should consider recommending a cessation of the use of such chemical analysis.

Publications are now starting to appear in which a,b,c of nylon bag degradation pattern of a forage are reported again without using them to predict growth rate and without discussion.

It is suggested that few feeds are available in quantity in any one locality and therefore the best options may be to do the necessary feeding trials to assess their value.

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FOREWORD

T.Fujita

Director, Animal Production and Health Division, FAO, Rome.

We are very pleased to invite you to participate in this first electronic conference on "Tropical feeds and feeding systems" organized by the FAO Animal Production and Health Division.

With the wide extension of electronic communication over the world, this new technology is no longer a privilege of industrialized countries. Many scientists in developing countries now have access to it and the network is expanding very rapidly. It will soon become the most common means of exchange between scientists.

The role of animal nutrition and feeding systems has often been underestimated in livestock development programmes. However, feeds constitute the most expensive component of all animal production systems and any improvement in their use has an important and immediate effect on production level and cost.

During the last 20 years FAO has devoted a lot of efforts to improving knowledge on Tropical Feeds and Feeding Systems, starting with the publication of the book "Tropical Feeds" by Bo Gohl in 1975. Along the same lines, the research conducted by some pioneers has led to a better understanding of nutritional constraints and mechanisms involved in feeding animals in the tropics.

New technologies have been developed which are now applied in many countries. I would just like to mention amongst others:

- ammoniation of cereal straw with urea

- manufacture of multinutrient blocks

- sugarcane fractionation for feeding monogastric (on juice) and ruminants (on fibre)

- greater integration of multipurpose trees in feeding systems

- molasses-fish waste silages

- etc ….

The FAO Animal Production and Health Division is proud to have had a role in contributing to these achievements. However we are aware that much remains to be done in this field and that it is necessary to involve all scientists in working towards new developments. This is why we have great expectations from this electronic conference to which we invite you to contribute. Scientists such as yourselves have over the years accumulated a wealth of knowledge and we would like to help you in sharing your experience through this conference.

I have given the responsibility of organizing this conference to Rene Sansoucy, Senior Officer (Feed Resources) and Christophe Dalibard (Animal Production Officer)

As the Oxford Forestry Institute has a lot of experience in electronic communications and is already collaborating with FAO in various fields, they have accepted to cooperate in the management of the conference: Andrew Speedy who is a Lecturer from this Institute will act as conference coordinator.

Various well-known scientists have already accepted to contribute some "main papers" for discussion, and we look forward to your full participation in these discussions. Full details will be soon sent providing you with all necessary practical instructions on how to join the conference.

I thank you in advance for your contribution and wish you every success in this new venture.

Gliricidia sepium

Andrew Speedy

(Editor)

Extract from FAO Tropical Feeds Database

***Gliricidia sepium* (Jacq.) Steud. (Syn. *Gliricidia maculata* H.B.K.) is a fast-growing, tropical, leguminous tree up to 10-15 m. high. It is one of the commonest and best-known multipurpose trees in many parts of Central America, where it probably originated, but it has also spread to West Africa, the West Indies, southern Asia and the tropical Americas. (28 provenances have been collected from Central America by the Oxford Forestry Institute and are being tested world-wide.)**

Used for timber, firewood, medicinal purposes, charcoal, living fences, plantation shade and green manure, it has good potential as fodder for livestock.

The plant grows best in warm, wet conditions with optimal temperatures of 22-30C and rainfall 800-2300mm. It flourishes on fertile soils but has also been observed to grow well on acidic soils and those with a high clay content. It is easily established from cuttings or seed, although seed-establishment is recommended when used in situ because of deeper rooting.

***Gliricidia* may be harvested at 3 month intervals to maximize foliage yield. Reported yields are 14.9 tonnes green foliage/ha/yr (6.6 tonnes DM) over 5 years (30.2 tonnes fresh/ 11.9t DM in the first year) but in a trial of different provenances in Colombia (562), 53-98 tonnes/ha/yr of biomass was obtained, corresponding to 15-25 tonnes DM/ha/yr. Leaf represented 53-63% of edible biomass. Total yield of crude protein was up to 4.7 tonnes/ha/yr.**

Available data indicate that *Gliricidia* is rich in protein (23% CP) and calcium (1.2%), two nutrients found at only low levels in non- leguminous tropical forages. Its high fibre content (45% NDF) makes it a good roughage source for ruminants. The plant contains sufficiently high levels of most minerals (except phosphorus and copper) to meet

tropical livestock requirements and it would therefore make an excellent feed during the dry season.

Nutrient content varies with age, season and physiological state (before and after flowering). In leaves of older plants (after flowering), protein and calcium decline whereas fibre, phosphorus and other minerals increase.

Digestibility of DM is moderately high (c. 60%) and it should improve the digestibility of poor quality feeds when used as a supplement. Rumen (nylon-bag) degradability of *Gliricidia* is high (62% DM and 19% N in 24 hours cp. to 49% and 7% for *Leucaena*).

Antinutritional Factors

Some potentially toxic substances have been found in *Gliricidia*. HCN content has been reported up to 4mg/kg and cyanogens may be present. High levels of nitrates (during the rainy season) are suspected of causing `cattle fall syndrome' in Colombia but levels declined to negligible in winter. *Gliricidia* may be a `nitrate accumulator'. Un-identified alkaloids and tannins have also been reported.

However, evidence of toxicity under practical feeding conditions has been rare. The balance of evidence suggests that the plant could be toxic to non-ruminants but conclusive evidence of toxicity to ruminants under normal feeding is lacking.

Uses

***Gliricidia* is most likely to be used as a green fodder/protein supplement to low-quality tropical forages and by-products for cattle, sheep and goats. It may be used as the sole feed in the dry season. There is some localised evidence of poor palatability and reduced intake of basal diet (there is some suggestion that a period of adjustment may be required) but substitution of *Gliricidia* for grass, rice straw/rice polishings, cocoa-pods and bagasse/molasses/ rice-polishing/poultry manure diets to weaner lambs, goats, growing heifers and growing bulls have produced the same or improved growth performance. Normal feeding levels have been 1-3% of body weight**

(i.e. 3-9kg/day fresh to 300kg cattle) although goats have been fed solely on *Gliricidia*.

In one trial, ewes have produced a higher lamb crop, better lamb weights and had reduced ewe weight loss. In another, lambing results were poorer - attributable to lower feed intake.

The few results with milk cows and buffaloes showed similar or slightly increased milk yield and milk fat yield.

Laying chickens have been fed 4.5% sun-cured *Gliricidia* in diets and gave good egg production, egg weight and yolk colour. It has been found that diets containing up to 10% *Gliricidia* can be fed to growing chicks without affecting performance and survival. At 15%, intake, f.c.e. and growth were reduced and haemoconcentration, fatty liver and coagulation necrosis lesions were observed.

As % of dry matter

	DM	CP	CF	EE	Ash	NFE	Ca	P	Ref
Average	21.9	23.0	20.7	3.1	9.7	42.8	1.3	.18	558
Leaves	19.5	26.8	16.8	6.7	9.8	39.9	-	-	559
Stem	19.8	13.9	50.4	1.7	6.9	27.0	-	-	"
Whole plant	19.6	21.2	28.8	5.1	8.2	36.8	-	-	"
Leaves	25.4	30.0	14.4	4.3	8.0	43.6	-	-	117
Stem	14.1	20.5	30.2	1.5	10.2	37.6	-	-	"
Whole plant	24.1	23.1	13.4	4.2	9.6	49.7	-	-	"

Digestibility %

	Animal	CP	CF	EE	NFE	Ref
Leaves/stems	Cattle	55.3	-	-	-	560
Leaves/stems	Sheep	53.5	-	-	-	"

Nylon bag degradability

	a (%)	b (%)	c (/hour)	12hr (%)	48hr (%)	Ref
Gliricidia leaves						
DM	19.1	48.6	0.105	53.9	67.4	633
N (CP 18.3)	28.9	44.9	0.074	55.3	72.5	"
Gliricidia (freeze dried)						
DM	-	-	-	73.7	79.1	630
N	-	-	-	84.1	-	"
Gliricidia, 6 weeks						
DM	-	-	-	-	75.7	632
Gliricidia, 12 weeks						
DM	-	-	-	-	70.4	"

[P (rumen degradability at time t) = a+b*(1-exp(-c*t))]

Urea Block Manufacturing and Feeding: Middle East Experience

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Introduction

Poor quality roughages comprise the only part of the diet for ruminant animals in most Middle East countries for a considerable part of the year. Animals on such diets are on negative energy balance and supplementary feeding with energy and nitrogen has been used for improving the nutritional status of animals (Capper *et al.*., 1989; Hadjipanayiotou *et al.*., 1975).

Molasses-urea blocks (MUB) have been used as supplements for animals kept under extensive systems of production (Sansoucy 1986). Despite of promising results from MUB feeding their wider application is restricted due to lack of molasses in certain countries and/or areas within countries. As a result, urea block manufacturing without any molasses was promoted by the Food and Agricultural Organization of the United Nations in different parts of the world (Hassoun 1989; Hadjipanayiotou *et al.*., 1993a,b). The present paper reviews studies carried out in Cyprus, Iraq, Jordan and Syria aiming at Urea block (UB) manufacturing and feeding with or without molasses and the performance of animals on poor quality basal diet offered along with UB made of a variety of by-products and of binders.

Syria

The work on UB manufacturing and feeding in Syria started in March 1991 with the commencement of the

FAO/UNDP/SYR/89/003. A large number of UB formulae with or without molasses and using a variety of binders were made (Hadjipanayiotou *et al.*., 1993a).

The binders used were cement, plaster of paris (CaSO4.1/2H2O) and slaked lime (Ca(OH)2. Slaked lime was a better binder than plaster of paris. Although slaked lime was a better binder compared to cement, the choice between the latter two should depend on relative availability and price.

Ingredients used in MUB manufacturing were urea, salt, broiler litter, dried cage layer excreta, wheat bran, solvent extracted olive cake, fresh sugar beet pulp and sugar-beet molasses.

The Syrian studies in line with those of Hassoun (1989) showed that UB can be made without any molasses; the amount of binder required, however, was relatively higher (>10% <15%) especially when poultry excreta was incorporated in the mix. On the other hand, even with a low level (5%) of molasses a 6% slaked lime gave good UB. The amount of water required was increased with decreasing molasses level in the mix; with mixtures without any molasses, up to 50 l of water per 100 kg mix were required.

Aarts *et al.*. (1990) reported that when using a concrete mixer, the wheat bran must be introduced in successive small quantities at a time in order to get a homogenous mix. In the Syrian studies, introducing the ingredients in the order water, urea, salt, binder, molasses, poultry excreta and wheat bran showed that the order of mixing is not as critical as has been reported by Aarts *et al.*. (1990), and that introduction of wheat bran can be made in large portions. It seems therefore, that mixing procedure can be altered in order to find the easiest and quickest way to produce the blocks.

Details on UB manufacturing, including preparation of ingredients, mixing, moulding, demoulding, UB assessment and curing applied in Syria were reported by Hadjipanayiotou *et al.*. (1993a).

Animal Studies

Studies carried on research stations and/or using animals belonging to farmers showed that animals on UB

perform better than those on the non-supplemented diets (Tables 1,2 and 3).

Cyprus

Studies in Cyprus followed those in Syria and continued studying further aspects of UB manufacturing. In seven tests carried out from June to November 1993. UB were made using a variety of ingredients (chopped straw, poultry litter, ground barley, fresh brewers grain, fresh tomato pulp, crude olive cake (COLC), urea, salt and wheat bran), binders (cement, slaked lime alone or in combination) and amounts of water.

Table 1. Effect of urea-block feeding on the performance of Awassi ewe-lambs offered chopped cereal straw *ad libitum*, Hama Research Centre (Test period: 22/12/90-21/2/91)

	No block	Block	SD
No of animals	35	35	-
Initial weight (kg)	40.1	40.7	5.26
Final weight (kg)	34.9	37.5	1.97***
Weight loss (g/day)	88	53	38.7***
Feed intake (g/day)			
Straw	744	770	-
Block intake	-	90	-

Table 2. Performance of Awassi Sheep grazing stubble (29/9- 24/10/90) without (control) or with blocks.

	No block	Block	SD

No. of animals	86	83	-
Daily weight loss (g)	56	6	71.7*
Block intake (g/day)	-	47	-

Table 3. The effect of urea-block feeding on the performance of Awassi sheep grazing cereal stubble in the Salamieh area, Hama (Test period 12/9-24/10/91)

	No block	Block	SD
No. of animals	99	100	-
Initial weight (kg)	45.8	44.8	5.52NS
Final weight (kg)	41.5	43.0	0.73***
Weight loss (g/day)	101	41	44.3***
Block intake (g/day)	-	97.3	-

Details on individual formulae and other characteristics have been reported by Hadjipanayiotou (1995). In line with Syrian studies (Hadjipanayiotou *et al.* 1993a), but at variance with tests in other FAO projects (Rene Sansoucy and Michael Allen personal communication), slaked lime was an effective binder. Combination of two binders improved hardness (H) and compactness (C) of UB; five percent cement and 5% lime gave better UB than when 10% lime or 10% cement were used. Lime gave harder UB than cement. In the Cyprus studies there was no need for more than 10% binder. Incorporation of olive cake and brewers grain improved UB quality; incorporation of tomato pulp and chopped straw gave UB that could be easily transported but were of low density and spongy. Incorporation of high moisture by-products in UB reduced the amount of water required, but increased storing/curing area required.

Animal studies

In a trial with mature, dry Chios ewes the value of UB as supplement to straw (US) offered *ad libitum* was compared with other supplements (concentrate, lucerne hay (LH) and urea-treated straw (UTS) offered *ad libitum*). The present study showed that UB made of by-products can be used for replacing conventional supplements such as top quality roughage and scarce and expensive concentrate feeds. Furthermore, UB feeding gave better results than UTS (Table 4).

Table 4: Performance of Dry Chios ewes offered straw *ad libitum* alone (US) or with a supplement of urea block (US+UB), concentrate (US+C) and lucerne hay (US+LH) and/or urea-treated straw (UTS) alone.

	US	UTS	US+ UB	US+ Con	US+ LH	SD
No. of animals	7	7	7	7	7	-
Initial weight,kg	64.1	64.2	63.2	64.5	62.7	10.0
Final weight,kg	57.2	59.7	59.6	60.6	59.9	9.4
Weight loss,kg	6.9b	4.5ab	3.6a	3.9a	2.8a	2.3
Intake, g/kg.75/d						
Straw	35ab	41a	35ab	33ab	29b	6.8
Supplement	-	-	14a	10b	14a	3.7

Iraq

Work in Iraq and Jordan was initiated under the auspices of the Mashreq project RAB/89/026, Increased Productivity of Barley, Pasture and Sheep. The author worked as a consultant for the project and with national

scientists in the two countries formulated a work plan that included on state and private farm studies. Ingredients used for UB manufacturing were wheat bran, rice bran, poultry litter, date pulp, beet pulp, corn cobs, reed, urea, salt, CaO, CaCO3 and whey.

Different type of mixer was/is used in Iraq. This type of mixer beats and compresses the material against the walls of the container. This smearing action results in better mixing of the ingredients, blocks of higher density, compactness and hardness. There are now two plants of UB manufacturing in Iraq, a state one (Baghdad area) with an output of 3.5 t daily and a private (Mosul area) with an output of 2.5 t per day. Both plants sell their UB to farmers (Annual Report,1993/94 Mashreq Project RAB/89/026).

Animal studies

In a number of studies carried out on state and private farms the beneficial effect of UB feeding on the performance of ewes grazing cereal stubble was obvious (Table 5).

Table 5. Effect of feeding UB on the performance of Awassi ewes grazing cereal stubble (Annual Report 1993/94, Mashreq Project)

Experimental site	Mosul, Al-Muside		Mosul, Al-Irbeed	
Treatment	No UB	UB	No UB	UB
No. of ewes	30	30	30	30
Days on test	36	36	36	36
Initial weight,kg	48.4	49.4	46.6	46.0
Final weight,kg	50.8	53.6	48.5	48.8
Weight gain,g/d	50	115	51	75

Jordan

Ingredients used in Jordan for UB manufacturing were urea, salt, sun-dried olive cake, poultry litter, wheat bran, fresh brewers grain, fresh tomato pulp , cement and slaked lime. Most formulae, like in Cyprus, Iraq and Syria were of very good H and C.

Animal studies

In line with other Mashreq countries UB feeding resulted in an improved growth rates, and the use of UB gave better results than UTS (Table 6).

Table 6. Effect of feeding supplements of UB and UTS to Awassi sheep grazing cereal stubble (Annual Report, 1993/94, Mashreq Project)

	UB	UTS	Control
No. of ewelambs	12	12	11
Initial weight,kg	28.8	31.8	29.7
Final weight,kg	31.3	33.9	31.5
Days on test	30	30	30
Weight gain,g/d	83	70	61
Extra cost, JD	0.05	0.08	0.0
Net return,JD/head	6.1	5.17	4.6

Conclusions

It is concluded that it is possible to make UB of good hardness and compactness without any molasses. Brewers grain and COLC when available, not only can be used for UB but they can also improve UB qualities. Furthermore, tomato pulp can be used in UB, and incorporation of high moisture by-products in UB will reduce the amount of water, but will increase storage/curing area required. COLC seems to have binding qualities, and at high levels of inclusion (15%) may facilitate the use of less quantities of binders. The fact that COLC is available during the rainy season, make its use for UB manufacturing problematic, since dehydration of UB is longer. Surpluses of COLC, however, can be easily preserved by ensiling in heaps next to oil mills (Hadjipanayiotou 1995), and utilized in UB after February.

It seems that when making UB without any molasses/COLC and/or other ingredients having binding qualities, the type of mixer used is of greater significance for making good quality UB. The concrete mixer is just turning and mixing the material, whereas other mixers, beat and compress the material against the walls of the container. This smearing action produces UB of higher density and results in better contact between the binder(s) and the other ingredients. It is my opinion that mixers that beat and compress the material against the walls of the container might have to be used for making good quality UB without molasses.

Hardening of UB increased with advancing storage period. Sansoucy (1986) reported that resistance of 5-6 kg/cm2 to penetration would seem appropriate to ensure the desirable level of production. Long storage of at least some formulae results in an extremely hard blocks that could reduce block intake seriously. It is preferred that UB are made at a time prior to their use so that they would reach the desired degree of hardness at the time required. However, when long storage period is inevitable, wrapping and/or storing the blocks in polyethylene sheets/bags will maintain the desired hardness.

Slaked lime can replace a great part of cement; the selection of the binder therefore, should depend upon price and availability. For certain UB formulae, combination of the two binders may improve UB qualities (Hadjipanayiotou, 1995).

Preston and Leng (1987) concluded that UB feeding is a technology that can be applied by small farmer whereas

preparation of a urea solution and spraying it onto straw is a demanding and often arduous task making its wider application problematic. Since the present findings showed a greater response to UB than UTS straw feeding lend further support the conclusions of Preston and Leng (1987). Finally, It is concluded that UB made of by-products can be used for replacing conventional supplements such as good quality roughage and concentrate feeds fed to ruminant animals.

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Indigenous Knowledge in Utilization of Local Trees and Shrubs for Sustainable Livestock Production in Central Tanzania

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Introduction

Trees and shrubs are of value in agriculture as they directly or indirectly contribute to crop and livestock production. They provide fodder to animals and replenish soil fertility. Similarly, they are useful to people when

they provide wood for various purposes, when used in human and veterinary medicine and also for environmental conservation. Appreciable work has been done on Leucaena species (Skerman 1977). Similarly, a lot of work has been done on Sesbania species (Kategile and Adoutan 1993). Attempts to increase knowledge on exploitation of these two species and many of the trees and shrubs locally found in tropical Africa have also been discussed by Atta-Krah (1989) and Lamprey et al (1980).

The aim of this paper is to highlight the current state of knowledge on utilization of different local trees and shrubs among agro-pastoralists in the Dodoma and Singida regions, in the semi-arid zone of Central Tanzania.

Study Methodology

Formal surveys were conducted in Singida and Dodoma regions in 1991 and 1993 dry seasons, respectively as part of the diagnostic phase for the implementation of the project "The potential of crop residues and natural vegetation as ruminant feeds during the dry season in Central Tanzania". These surveys followed the informal surveys done in both regions in 1991 and 1992 respectively. After the informal surveys, the regions were divided into clusters based on climate and other aspects of the farming system (Goromela et al 1993). The regions are in the semi-arid zone.

A total of 153 structured questionnaires were developed and used. Only the crop/livestock farmers from the selected villages were interviewed. The respondent was the household head. Information from the questionnaire, related to utilization of trees and shrubs and other natural vegetation, were coded and summarised using a pocket calculator. Only 121 questionnaires were used in the analysis after data scrutiny.

Results and Discussion

Utilization of trees/shrubs for livestock feeding

The interviewed farmers (agro-pastoralists) were able to identify which tree/shrubs species and which vegetative part was favoured by which class of livestock (Table 1). The farmers, however, named these trees and shrubs in their vernacular language (Appendix 1).

***Acacia tortilis* was the most known tree species as indicated by 73 percent of respondents (n = 121). Some farmers collect pods of this tree species (including those of *Acacia albida*) and keep them at their homes for the purpose of feeding calves and sick animals which can not walk long distances in search of feed and water during the dry season. Unfortunately, no grinding or any other physical treatment was reported to be practised for the purpose of improving the nutritive value of the pods. Reasons given to the question as to why they do not grind the pods varied. Some indicated that the work is laborious especially for those with large herds of cattle. However, the majority did not know if this could be of value in feeding practices. Apart from *Acacia tortilis*, *Dichrostachys cinerea* was reported to be known and used by 40% of respondents (n = 121). Its fruits and leaves were reported to be favoured particularly by small ruminants. Other high ranking species were *Ecborium* species and *Boscia indica* whereby 20 and 17 percent respectively of all the respondents knew and utilized the species in livestock feeding.**

TABLE 1: Knowledge on utilization of some tree/shrubs species for livestock feeding in Central Tanzania

Tree/shrub species	Respondents	Animal species	Favoured plant parts
Acacia tortilis	73	Cattle, sheep, goats	Pods, leaves
Acacia mizera	7	Sheep, goats	Leaves
Acacia albida	7	Cattle, sheep, goats	Pods, Leaves
Adansonia digitata	2	Goats	Fruits
Brachystegia sp	7	Cattle, goats	Leaves
Commiphora sp	2	Cattle, goats	Leaves

Boscia indica	17	Cattle, goats	Leaves
Delonix elata	5	Cattle, goats	Leaves
Dichrostachys cinerea	40	Goats, cattle	Leaves, Fruits
Ecborium sp	20	Cattle	Leaves
Ficus sp	3	Goats	Leaves
Grewia bicolor	3	Goats, cattle	Leaves
L. leucocephala	10	Cattle, sheep/goats	Leaves
Markhamia zanzibarica	3	Cattle, goats	Leaves
Solanum sp	5	Goats	Flowers
Watheria sp	2	Cattle, goats	Leaves
Ziziphus mucronata	2	Cattle, goats	Leaves

Note: Total is > 100% due to multiple responses.

The response given by the interviewed farmers on their experiences on utilization of various trees and shrubs were comparable to observations made by Backlund and Bellskong (1991) who closely followed the herds of livestock grazing in selected farms in Mpwapwa district, Dodoma region.

Veterinary Use of Trees and Shrubs

Some trees and shrubs are utilized by agro-pastoralists in treatment of animal diseases and disorders (Table 2). For example, the stem of a climbing plant "Mtakalang'onyo" (Euphorbia sp) is pounded and mixed with water. The

material is squeezed out into the reproductive tract of a cow leaving the mother liquor to induce the expulsion of the retained placenta. On the other hand, *Maerua edulis* and *Boscia grandiflora* leaves are used in treatment of some poultry diseases.

Table 2. Veterinary use of some trees and shrubs

Tree species	**Animal**	**Comments**
Euphorbia sp	Cow	Stem pound and mother liquor used (Mtakalang'onyo) to expel retained placenta.
Stegnotaenia araliacea	Cattle, Goats	Leaves mixed with water to treat diseases characterised by difficulties in breathing.
Maerua edulis	Poultry	The roots of *M. edulis* are mixed with leaves of *B. grandiflora* to treat poultry diseases.
Boscia grandiflora	Poultry	-

Treatment of Livestock Products

Some farmers use trees and shrubs to preserve livestock products such as milk. Wood from some of the trees/shrubs (Table 3) is burned and produces smoke that is forced into gourds used to store the milk. This smoke is believed to increase the shelf life of milk and to impart desirable flavours to the "clotted" and concentrated product. Studies conducted at Sokoine University of Agriculture (SUA) on traditional smoking of milk practised by different tribes in Tanzania show that smoke treatment inhibits growth and activity of mesophyllic and thermophilic lactic acid bacteria, although the treated product might not be favoured by everybody tasting the milk (Chenyambuga *et al*. 1993).

Table 3. Trees used for smoking of milk in Central Tanzania

Boscia angustifolia	*Boscia grandiflora*
Capparis fascicularis	*Euphorbia candelabrium*
Maerua angolensis	*Maerua parvifolia*
Mundulea sericea	

Establishment of Trees and Shrubs

Very few farmers in the surveyed areas established local trees for animal feeding and/or for any other purposes, for example for fuel. Some farmers, however, kept a few stands of trees near their homes or in their fields (especially *Acacia tortilis*) although they did not plant them. These people kept the trees purposely for shade. *Ficus* species (Mirumba), *Morus* species (Mulberry trees) and *Leucaena* leucocephala were established near homesteads according to 12% of the respondents (Table 4).

Table 4. Establishment of some trees and shrubs for fodder in smallholder farms in Central Tanzania

Tree species	Respondents	
	n	%
Acacia sp	0	0
Dichrostachys cinerea	0	0
Ficus sp (Mirumba)	2	2
Leucaena leucocephala	7	6

Morus sp (Mulberry trees)	5	4
Total	14	12

Total number of respondents was 121.

The main reason given for giving little or no effort to establishment of the local tree and shrub species was the slow rate of growth of these trees/shrubs. Similar comments were made by Atta-Krah (1989). Unfortunately, the faster growing shrubs such as *Morus* species (Mulberry trees) were not widely grown for unspecified reasons.

On the other hand, in areas where social development and research institutions have introduced zero-grazing technology, farmers are encouraged to establish some browse species for livestock feeding and for other multiple uses. In Mvumi Division, Dodoma Rural District (Dodoma region) the Diocese of Central Tanganyika (D.C.T-Anglican Church) in collaboration with the Soil Conservation Project in Dodoma (HADO) has encouraged farmers to establish Leucaena species that are currently used as fodder. Some other trees such as Senna siamea and Azadirachta indica were introduced mainly for soil conservation purposes, for wood and for shade. Similarly, the Livestock Production Research Institute (LPRI-Mpwapwa) in collaboration with the Swedish Agency for Research and Cooperation with Developing Countries (SAREC) and HADO, has enhanced planting of fodder trees in Kondoa District, Dodoma Region where zero grazing technology has been introduced. On top of this, LPRI is doing agronomic and nutritive value studies of some of the local and potential browses that have been identified (Table 5).

Table 5. Mean values of agronomic characteristics of local trees and shrubs evaluated at LPRI Mpwapwa

Tree/shrub	Leafiness (0-10)	Leaf-drop (0-10)	Greenness (0-10)	Plot cover (0-10)	Vigour (0-10)
Albizia harveyii	7.37	2.87	7.37	9.12	7.50

Crotalaria spp	7.75	2.00	7.00	7.00	7.50
Combretum guanzee	8.12	1.87	7.62	9.87	8.37
Delonix elata	5.75	1.37	6.50	3.75	5.25
Grewia similis	7.37	0.75	6.12	6.75	7.25
Helinus spp	8.12	1.25	8.00	8.62	8.25
Jasminum spp	5.25	1.25	5.62	3.00	3.50

Preliminary results on agronomic evaluation of the seven tree/shrub species evaluated at LPRI evaluation plots show that *Combretum guanzee, Helinus species, Albizia harveyii* and *Crotalaria* species are better in most of the parameters studied including germination, vigour, leafiness and greenness.

Conclusion

The multiple use of the local tree and shrub species in different farming systems has led to negative and positive effects. The negative one is related to wiping out, for example, of the species that are more palatable to grazing and browsing ungulates as well as those with very good wood for fuel and tool making. As a result many areas are bare and are susceptible to wind and water erosion. The positive effect involves exploiting of this knowledge from users (farmers) and incorporating it in research and development systems for the benefit of the present and future generations. It is therefore important for all parties (research- extension-farmers) to work collectively for the purpose of building a sustainable livestock production system through efficient utilization of multipurpose trees and shrubs.

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Appendix 1: Some Trees/Shrubs used as fodder in Central Tanzania

Local Name (Kigogo)	Botanical Name	Family
Mbilimisi	*Erythrina obyssinica*	Papilionideae
Mbukwe	*Terminalia stuhlmanni*	Combretaceae
Mbanhumbwahu	*Canthium* sp.	Rubiaceae
Mdejedeje	*Acacia seyal*	Mimosoideae
Mdonho	*Commiphora stuhlmanni*	Bursecaceae
Mfuku	Acacia nilotica	Mimosoideae
Mgombwe	Brachystegia sp	Caesalpiniaceae
Mgonandela	Acacia rovumae	Mimosoideae
Mguji	*Brachystegia* sp	Caesalpiniaceae
Mguwoguwo	*Markhamia obtusifolia*	Bignoniaceae
Mkakatika	*Cassia orbbreviata*	Caesalpiniaceae
Mkambala	*Acacia meuifera*	Mimosoideae
Mkata kivimbi	Vepris glomerata	Rutaceae

Mkola	*Afzelia quanzinsis*	Caesalpiniaceae
Mkore	*Grewia bicolor*	Tiliaceae
Mkuliza	*Maerua angolensis*	Capparidaceae
Mkunguni	*Salvadora persica*	Salvadoraceae
Mkungugu	*Acacia tortilis*	Mimosoideae
Mkutani	*Albizia anthelmintica*	Mimosoideae
Mmemenhamene	*Allophyllus africana*	Sapindaceae
Mnyangwe	Zizziphus mucronata	Rhamnaceae
Mpela	*Adansonia digitata*	Bombaceae
Mperemehe	*Grewia platyclada*	Tiliaceae
Mrumba	*Ficus* sp	Moraceae
Msanze	*Premna* sp	Verbenaceae
Msasi	*Dombeya shumpangae*	Stalculiaceae
Msingisa	*Boscia angustifolia*	Capparidaceae
Msusuna	*Grewia burtii*	Tiliaceae
Mtafuta	*Grewia* sp	Tiliaceae
Mtalawanda	*Markhamia zanzibarica*	Bignoniaceae
Mtindilihala	*Maerua* sp	Capparidaceae
Mtumba	*Boscia grandiflora*	Capparidaceae

Mtumba	*Boscia indica*	Capparidaceae
Mtundulu	*Dichrostachys cinerea*	Mimosoideae
Mturatura	*Solanum* sp	Solanaceae
Mube	*Cassiopourea mollis*	Rhizophoraceae
Mvugala	*Acacia* sp	Mimosoideae
Mvumvu	*Cadaba farinosa*	Capparidaceae
Mwiliganza	*Acacia albida*	Mimosoideae
Mwima chigula	*Maerua angolensis*	Capparidaceae
Mwolowolo	*Calyptrothea taiensis*	Portulaceae
Mzaza	*Acacia senegal*	Mimosoideae
Mzejezeje	*Sapium bussei*	Euphorbiaceae

The Effects of Urea-mineral Lick Blocks on the Liveweight Gain of Local Yellow Cattle and Goats in Grazing Conditions

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Introduction

Natural grasses and cereal straws are the main sources of roughage for cattle and goats in the subtropical regions of China. The general practice is to graze the animals on unimproved hill pasture during the spring and autumn seasons, and to feed them on crop residues during winter. Supplements such as protein, cereal grains and minerals are rarely offered to cattle and goats, and the animals are usually unable to maintain their body weight. Weight losses may and often do occur during the winter season when they are solely fed on untreated straw.

The primary limiting factors of cereal straw are their low contents of nitrogen (N), their low intake and poor digestibility. Hill pasture in our region are mainly grasses which have established and grown naturally. Despite the differences which exist from place to place, they are low in nutritive value. Liu *et al* (1995) observed that hay prepared from natural pasture had a similar content of N and digestibility of dry matter comparable to that rice straw (RS). Heifers however fed on a hay-based diet had daily gain significantly lower than those on an improved ammoniated RS diet (578 vs 780 g/d) (Liu et al. 1990).

When wild grasses and cereal straws are given to ruminants alone or form a high proportion of their diet, the primary consideration should be to overcome the resulting nutrient limitations by dietary supplementation. One of the most critical nutrients is considered to be fermentable N used by the rumen microbes. Urea is probably the most common source of supplementing fermentable N, and can be sprayed on to cereal straws or may be mixed with available energy supplements. The use of urea/molasses blocks (UMB) is a convenient way of avoiding the excessive intake of urea (Leng and Preston 1983).

Despite the differences in formulation from place to place, UMB feeding has given positive results in many parts of the world (Kunju 1986; Hadjipanayiotou *et al* 1993b). In China, Chen et al (1993) observed that the use of supplementary UMB increased the milk yield of dairy cows by 6.7 %, and the daily gains of heifers by 15.5 %.

However molasses is not freely available in many regions of China nor in many other countries, and attempts have therefore been made to produce blocks with low content of molasses (Hadjipanayiotou *et al* 1993a).

Molasses in our region is in short supply and if available is expensive. A urea-mineral lick block without molasses (ULB) has recently been manufactured for local cattle and goats to eliminate some dietary deficiencies and to improve their rates of growth. The objective of the present paper was to investigate the performance of cattle and goats in grazing conditions with or without ULB.

Materials and Methods

Description of the Lick Blocks

Urea, salt and minerals are the main ingredients of ULB. Its formulation was derived on the basis of the composition of traditional feedstuffs (Xu 1989, Zhejiang Academy of Agriculture 1983). The ingredients and composition of ULB are shown in Table 1.

Salt and urea, and cement as a binder were used as purchased, while the remainders of the minerals were purchased as a mixture already prepared in a feed additive plant. The ingredients were then mixed by a shovel on a concrete floor. Approximately 200 kg of mineral mixture were prepared every time. The mineral premix and cement were mixed first, and they were then well mixed with the rest of ingredients. The mixture was then compressed in a mould measuring 15 cm x 15 cm x 10 cm, and the resulting blocks weighing 2 kg each were wrapped immediately.

TABLE 1: Ingredients and composition of urea-mineral lick block

Ingredients	%	Composition #	g/kg
Urea	10	N*6.25	250

Salt	65	Ca	>9
Cement	15	P	>5
Mineral premix	10		mg/kg
Total	100	Fe	1300
		Cu	140
		Zn	520
		Mn	450
		I	10
		Co	5
		Se	3

 # Moisture content was less than 15 %.

Cattle Trial

A cattle trial was conducted in the village of Suichang County in southern Zhejiang. Thirty-two local breed yellow cattle were selected from different farms and divided into two groups of sixteen based on their sex, age and liveweight. They were then randomly allocated to control (no block) or ULB treatments (Table 2). All animals were treated with anthelminthic (methyl- thio-imidazole) prior to trial. The cattle grazed on hill pasture during the day and were offered RS ad libitum in stalls at night, at which time the animals on treatment had free access to the ULB. The trial lasted for sixty days and all animals were weighed at the beginning and at the end of trial. The results were analyzed using a Student "t" test.

TABLE 2: Animals used in cattle trial

	Control	ULB group
No. of animals (head)	16	16
Male/Female	8/8	8/8
Age (year)	2.7+/- 1.4	2.7+/-1.3
Live weight (kg)	169.1+/-54.4	166.4+/-55.0

Goat Trial

The goat trial was conducted on two private farms (Farms A and B) in Fuyang County. Sixteen and twelve growing goats were selected from Farms A and B respectively. All animals were treated with anthelminthic (methyl-thio-imidazole) prior to trial. On each farm, the goats were divided into two equal groups and were randomly allocated to treatment either with or without blocks. All goats grazed together on hill pasture during the day and were offered RS ad libitum in stalls at night. The animals with block treatment had free access to the ULB along with their RS at night. The trial lasted for three months and all animals were weighed at the beginning and at the end of the trial.

The results were analyzed as a two-way factorial design in which farm was considered as one of factors. Because initial liveweight and liveweight gain were not significantly different between farms, the results were compared using a Student "t" test.

Results and Discussion

The ULB used was of a good hardness and the breaking strength was 40 kg/cm^2. Furthermore, the ULB was easily transported and offered to the animals. Even in situations of high humidity there were no losses from mould

growth or from the slake of blocks when they were offered to the animals over a long period of time.

The ULB was palatable to both cattle and goats and in the initial period of both trials we had to limit time of access to avoid an excessive intake of ULB. The consumption of ULB became stable after about ten days from the commencement of the trial. On average, the intake of ULB was 50 g/head/d for cattle and 10 g/head/d for goats. Thus a ULB block weighing 2 kg is sufficient per head of cattle for forty days or for 10 goats for twenty days.

The results of the two feeding trials are presented in Tables 3 and 4. Both cattle and goats with access to ULB performed better than those on the control diet. Liveweight gains were significantly higher in animals with access to block than in those with no block; 370 vs 203 g/d for cattle and 95 vs 73 g/d for goats.

TABLE 3: Economics of using a urea-mineral lick block as a dietary supplement for local yellow cattle

	ULB group	Control	Prob
Number of animals	16	16	
Initial liveweight (kg)	169.1+/-54.4	169.1+/-54.4	
NS weight gain (g/d)	370	203	<0.05
Comparison	182	100	
Daily cost of supplements (RMB yuan #)	0.10	0	
Net Daily income (RMB yuan #)	1.75	1.02	

 # 1 US$ = 8.3 Yuan

The animals offered blocks had better body condition and looked healthier than did control groups. Although intakes were not determined because of the difficulty of "on farm" conditions, the improvement in productive

performance of the animals on treatment was encouraging. Hadjipanayiotou et al (1993b) observed that effects of urea-containing blocks on liveweight gains in cattle and sheep were more pronounced than the effects on feed intake. In other words, there appears to be a marked improvement in diet digestibility.

In both trials the grazing available to the animals was natural pasture only with no concentrate supplements. It is considered that the available energy ingested does not provide the nutrients required by animals for a high level of productivity and thereforet a large response in animal performance to the mineral contents of the blocks cannot be expected. With growing lambs on ensiled sisal pulp, Rodriguez et al (1985) observed that there was no response in animal performance to providing an appropriate mineral mixture. However limited amounts of either a good quality green forage or rumen undegradable protein apparently improved the liveweight gain in lambs. Further study is therefore needed to investigate the effects of ULB feeding on the productive performance of animals when supplemented with a combination of locally available carbohydrate and protein sources.

TABLE 4: Effect of urea-mineral block feeding on the live weight gain of local goats

	ULB group	Control	Prob
Number of animals	14	14	
Initial liveweight (kg)	10.4+/-1.6	11.7+/-2.0	NS
weight gain (g/d)	95	73	<0.05
Comparison	130	100	
Daily cost of supplements (RMB yuan #)	0.03	0	
Net daily income (Yuan #)	0.55	0.44	

 # 1 US$ = 8.3 Yuan

Conclusion

Urea mineral blocks without molasses are palatable to local yellow cattle and goats grazing on natural hill pasture. Mineral available can result in growth rates in cattle and goats significantly higher than in those without access to blocks. It is concluded that lick-blocks containing urea and minerals can be widely used to improve the productive performance of animals with access to only low quality roughages.

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The Kinetics of Fibre Digestion, Nutrient Digestibility and Nitrogen Utilization of Low Quality Roughages As Influenced By Supplementation with Urea-mineral Lick

Blocks

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Introduction

It has been recognized that when animals are offered a low-nitrogen, high fibre roughage such as rice straw (RS), one of the critical nutrients is fermentable nitrogen (N) available to rumen microbes (ARC, 1984). The use of urea/molasses blocks is a convenient way of avoiding an excessive intake of urea, and will ensure an almost continuous supply of ammonia-N (Preston, 1986).

Urea/molasses block feeding has given positive results in many parts of the world (Kunju 1986; Hadjipanayiotou *et al.* 1993b, Chen *et al.* 1993). The blocks which contain molasses are highly palatable, but are unlikely to be widely applied in many countries because of unavailability of molasses. Therefore some workers have attempted to manufacture blocks with reduced quantities of molasses (Hadjipanayiotou *et al*.1993a, Liu *et al.* 1995a).

The objective of this study was to evaluate the effect of a urea-mineral lick block (ULB) without molasses on rumen fibre digestion kinetics and on the nutrient digestion and nitrogen utilization of rice straw (RS), ammonia bicarbonate treated RS (ABRS) and hay prepared from natural pasture.

Materials and Methods

Animals and their management

Three yearling lambs each equipped with a rumen cannula and weighing about 30 kg were dosed with

anthelminthic and housed individually in metabolism crates. Feeds were offered in two equal meals per day at 0900 and 1800 h, and the daily amounts were calculated to exceed that eaten on the previous day by about 10 % to avoid selective feed intake. All animals had free access to drinking water.

EXPERIMENTAL FEEDS

The RS (Japonica, cv. 'Zhenongda 40') was obtained from the Experimental Farm, Zhejiang Agricultural University. The ABRS was prepared by the stack method: one ton of RS was treated with 100 kg ammonia bicarbonate and 250 kg water for 30 days at an ambient temperature of 15-2 deg. C (Liu *et al.* 1991). Hay was prepared from natural pasture which is the main roughage source for ruminants in our region. The composition of the experimental feeds are presented in Table 1.

TABLE 1: Chemical composition of the experimental feeds

Feed	DM (%)	OM (%DM)	CP (%DM)	NDF (%DM)
Rice straw (RS)	81.8	86.0	8.8	69.9
AB-treated RS	80.7	85.2	12.5	61.8
Hay	83.1	78.0	10.6	60.0

The ULB was prepared without molasses, and contained 4 % N with all minerals. The composition of the ULB used were the same as described in previous study (Liu et al 199?).

Experimental design and procedures

The experimental design was two 3x3 Latin square designs, one for roughage with ULB and one without ULB. Each period consisted of 21 days, the first 10 days of which were for adaptation followed by 11 days of measurements. A digestibility and N balance trial was conducted over 5 days (from day 11 to day 15), while the rate of passage of digesta through the rumen (kp) was determined. The degradation of crude protein (CP) and dry matter (DM), and digestion of neutral detergent fibre (NDF) in the rumen were measured from day 16 to day 21.

The digestibility of nutrients and N balance were determined by total collection of faeces and urine. Feed and faeces were analyzed for DM, organic matter (OM), CP (Association of Official Agricultural Chemists, 1990) and NDF (Goering and Van Soest, 1970). The N content in urine was analyzed by the Kjeldahl method.

The procedures determining the kp were the same as described previously (Liu et al 1995), where the model of Grovum and Williams (1973) was used.

Rumen digestion of NDF and ruminal degradation of CP and DM were determined in sacco (Orskov, 1985) and details of procedures are as described previously (Liu *et al.* 1995). The parameters of digestion kinetics of NDF in the rumen were estimated using the model of Mertens and Loften (1980). The nonlinear iterative least square procedure was used to fit the equation:

$$R=PED*\exp(-kd(t-LT))+U$$

where R is the percentage of NDF recovered at time t (h), PED is the potential extent of digestion at fractional rate kd (kd>0), LT is the discrete lag time of digestion, and U is the indigestible fraction (U=100-PED).

Ruminal degradation of CP and DM was calculated from the disappearance rate from dacron bags incubated in the rumen. The data were fitted to the model of Ørskov (1985):

$$p=a+b(1-\exp(-ct))$$

where p is disappearance rate at time (t), a is the rapidly digestible fraction in the rumen, and b is the fraction

slowly digested at rate c (c>0).

The effective degradability (dg) of CP and DM was calculated using the equation presented by Orskov (1985): dg=a+bc(c+kp)

Statistical analyses

The results were analyzed as a two-way factorial design (Steel and Torrie, 1960), in which square was considered as a factor.

Results and Discussion

The results of the digestion trial are presented in Table 2. The dry matter intake of all three roughages slightly decreased with ULB supplementation but the differences were not significant. Intake of ULB was estimated to be about 10 grams per day, which was similar to that obtained for goats (Liu et al 199?).

The digestibility of DM and OM of RS was increased by 13.1 and 12.7 % (P<0.05) and approached to that of ABRS, indicating that the effect of ULB on digestibility of RS is similar to that of treatment with AB. The hay used in this study was of low quality as shown by its digestibility, which was the same as that of RS. The digestibility of hay was significantly increased by ULB supplementation (P<0.05). When ABRS was supplemented with ULB, the digestibility of all nutrients was improved.

TABLE 2 The effects of using a urea-mineral block lick on the intake and digestibility of experimental diets offered to lambs.

Roughage	Rice Straw		ABRS		Hay		Significance		
Block supplement	-	+	-	+	-	+	R	B	RxB

Intake (gDM/d)	576	534	683	591	735	705	*	NS	NS
Digestibility (%)									
Dry matter	48.9	55.3	54.4	57.1	49.1	55.0	*	**	NS
Organic matter	51.8	58.4	57.6	60.2	53.0	58.5	*	*	NS
N*6.25	39.5	45.7	60.1	61.0	35.2	48.8	**	*	NS
NDF	62.6	66.8	65.6	68.5	66.2	69.4	*	*	NS

 # R, roughage effect; B, block effect; RxB, interaction effect between roughage and block; *, different significantly P<0.05; **, P<0.01; NS, not significant.

The results of N balance are shown in Table 3. Nitrogen intake was lower in lambs given the RS (P<0.05) even with ULB. When RS or hay was given alone the faecal N loss was above 60 %. Ammonia treatment and ULB supplementation were able to decrease the faecal N loss on RS diets. The lambs fed on ABRS with or without ULB had the highest urinary N loss, while the lowest urine N losses were from those animals on hay. The ULB increased the N losses from urine on all roughages, regardless of the amount and the proportion to N intake. Without the ULB, N retention (NR) was highest in lambs on ABRS, followed that on hay, with the lowest in animals on RS. While the feeding of ULB increased the NR in lambs on hay, the NR in animals on ABRS decreased due to the ULB supplementation. No difference was found in the NR from animals on RS with or without ULB.

TABLE 3 The nitrogen utilization of lambs fed on experimental diets with or without a urea mineral lick block

Roughage	Rice Straw		ABRS		Hay		Significance		
Block supplement	-	+	-	+	-	+	R	B	RxB
Gramsperday									

Nitrogen intake	8.1	8.1	13.2	12.3	12.5	12.5	**	NS	NS
Faecal loss	4.9	4.4	5.4	4.8	8.1	6.4	**	*	NS
Urine loss	1.6	2.2	2.3	3.1	1.2	1.6	*	*	NS
Retention	1.6	1.5	5.5	4.4	3.2	4.5	**	NS	NS
Per cent of intake									
Faecal loss	60.5	54.3	40.9	39.0	64.8	51.2	**	*	NS
Urine loss	19.8	27.2	17.4	25.2	9.6	12.8	*	*	NS
Retention	19.7	18.5	41.7	35.8	25.6	36.0	*	*	NS
N Retained/N									
Digested (%)	50.0	40.5	70.5	58.7	72.7	73.8	* *	*	NS

 # See footnote in Table 2.

The proportion of N retained to N digested decreased with ULB supplementation in lambs on RS or ABRS, but there was little change in animals on hay. This may be associated with an unbalanced supply of N and energy to the rumen microbes when straw diet was supplemented only with ULB, resulting in the inefficient use of N.

The results obtained for DM and CP degradation in the rumen are shown in Table 4. Without ULB, the degradability of DM and CP was significantly higher for ABRS than that for RS and hay, with little difference between RS and hay. The ULB had little effect on the rumen degradation of DM and CP in any of the three feeds.

TABLE 4 Constants of the equation p=a+b(1-exp(-ct)) for the degradation of dry matter and crude protein of experimental feeds in the rumen of lambs with or without a urea mineral lick block

Roughage	Rice Straw		ABRS		Hay		Significance		
Block supplement	-	+	-	+	-	+	R	B	RxB
DM degradation									
a (%)	16.0	12.4	15.9	16.1	19.5	20.0	**	NS	*
b (%)	52.8	58.0	55.1	53.8	49.2	56.1	NS	NS	*
c (%/h)	3.07	3.45	4.08	5.53	3.25	2.66	**	NS	*
kp (%/h)	2.96	2.88	3.14	2.71	3.54	3.00			
dg (%)	42.9	44.0	52.0	52.2	43.7	46.3	*	NS	NS
a+b (%)	68.8	70.4	71.0	69.9	68.7	76.1			
DM degradation									
a (%)	36.1	32.1	35.2	30.0	29.3	28.0	NS	NS	NS
b (%)	50.7	50.4	53.1	45.0	46.0	44.6	NS	NS	NS
c (%/h)	0.98	1.72	3.95	5.68	2.06	1.85	*	NS	NS
dg (%)	48.7	50.9	64.4	60.5	46.2	45.0	*	NS	NS

 # See footnote in Table 2.

The parameters of NDF digestion in the rumen are presented in Table 5. When given alone, the RS had a similar value for the potential extent of digestion (PED) and its digestion rate to hay, but the discrete lag time (LT) for RS was lower than that for hay. The AB treatment increased the PED (P<0.05) and kd (P.0.05). Neither the PED nor kd for RS and ABRS was influenced by the feeding of ULB, but the kd for hay was significantly increased. The product

of PED*kd (NDF digested per hour) was, however, increased by 9.2 and 30.3 % for RS and hay respectively, though little effect was observed for ABRS. The LT for hay was shortened by ULB feeding.

TABLE 5 Parameters of the ruminal digestion kinetics of dietary fibre in lambs with or without a urea mineral lick block

Roughage	Rice Straw		ABRS		Hay		Significance		
Block supplement	-	+	-	+	-	+	R	B	RxB
PED (%)	59.2	59.6	62.3	63.1	59.6	55.2	*	NS	NS
kd (%/h)	3.29	3.58	5.68	5.19	3.32	4.67	*	NS	*
PED*kd (%)	1.95	2.13	3.54	3.27	1.98	2.58			
LT (h)	5.4	5.4	5.6	5.1	6.3	5.0	NS	NS	NS
kp (%/h)	2.96	2.88	3.14	2.71	3.54	3.00			
EED (%)	26.6	28.2	33.6	36.1	23.1	28.9	**	*	NS

 # See footnote in Table 2.

EED is calculated as: PED*kd/(kd+kp)*exp(-kp*LT).

The effective extent of ruminal fibre digestion (EED) was estimated according to Huang and Xiong (1990) and is shown in Table 5. The RS had an EED value similar to that of hay and treatment with AB improved the rumen fibre digestion and increased the EED of RS by 26 %. The ULB improved the EED for all roughages, suggesting that ULB can improve the integrated digestion of low quality roughage fibre in the rumen.

Conclusion

The ULB significantly increased the nutrient digestibility of RS and hay, and slightly improved the digestibility of ABRS, possibly as a result of an improved digestion of fibre in the rumen. Both the amount, and the proportion of N retention to intake were increased by ULB supplementation in lambs fed on hay. The proportion of N retained to N digested decreased with the feeding of ULB in animals on RS or ABRS, indicating that the effect of ULB on the efficiency of N utilization varied between different roughages. It was concluded that when low quality roughages high in fibre and low in N are supplemented with ULB containing urea and minerals, a synchronized supply of N and energy to rumen microbes should be considered to improve the utilization efficiency of N.

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Molasses

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Extract from FAO Tropical Feeds Database

Molasses can be produced from citrus, wood sugar, sugar beet and sugarcane. Here will be described the different types of molasses that can be produced from clarifying, concentrating and/or extracting sucrose from sugarcane juice in a raw sugar factory and from refining raw sugar in a sugar refinery, as well as their primary use in animal feeds. They are: integral or unclarified molasses, high-test molasses, A molasses, B molasses, C (final) molasses and syrup-off.

Integral high-test molasses is produced from unclarified sugarcane juice which has been partially inverted to prevent crystallization, then concentrated by evaporation until approximately 80% of DM content. Because it is concentrated from unclarified sugarcane juice, heavy incrustations and scum deposits lead to frequent mill interruptions and therefore to increased factory maintenance costs.

High-test molasses is basically the same as integral high-test molasses; however, since the sugarcane juice has been clarified before evaporation and therefore the impurities removed, the negative factors associated with integral high-test molasses are not present.

"A" molasses is an intermediate product obtained upon centrifuging the A masecuite in a raw sugar factory. Approximately 77% of the total, available, raw sugar in clarified/concentrated sugarcane juice is extracted during this first centifugation process. The "A" molasses, which is produced simultaneously with the "first" or "A" sugar, contains 80-85% of DM. If used immediately there is no need for partial inversion; however, if it is to be stored it must be partially inverted, otherwise it could crystallize spontaneously in the storage tanks.

"B" molasses is also known as "second" molasses. It, too, is an intermediate product, obtained from boiling together "seed-sugar" and A molasses to obtain a B masecuite, which is then centrifuged to extract an additional 12% of raw sugar. At this point, approximately 89% of the total recoverable raw sugar in the processed cane has been extracted. B molasses contains 80-85% of DM and generally does not crystallize spontaneously; however, this depends on the purity of the original sugarcane juice and the temperature at which it is stored.

The last molasses is known as "C", "final" or "blackstrap" molasses and in some countries as "treacle". It is the end product obtained upon combining "virgin" sugar crystals obtained from syrup crystallization and B molasses to form a C masecuite, which after boiling and centrifuging produces C sugar and C molasses. Even though C molasses is considered the end or final product in a raw sugar factory, it still contains considerable amounts of sucrose (approximately 32 to 42%) which to date has not been recovered by an economically viable method.

Syrup-off, known also as "liquor-off" or "jett", is the end product obtained from the centrifugation of the final

refined masecuite in a raw sugar refinery. Normally, syrup-off is sent to the raw sugar (front) section of the refinery where it is reprocessed in order to recover more sucrose. Due to its high content of sucrose, 90-92% of DM, it is an excellent energy source for monogastrics; however, it can be an expensive option. The decision would necessarily be of an economic nature, including the overall thermal balance of the refinery; it might pay to sacrifice sucrose to save bagasse, or another refinery energy source. Finally, in the process of refining raw sugar, another type of "final" molasses is obtained, called "refinery final molasses" representing less than 1% of processed raw sugar. Since it has a very similar composition to that of final molasses produced in a raw sugar factory, it is usually deposited in the C molasses tanks.

In some countries the juice is extracted in a simple animal or mechanical driven press, then boiled in open vats. In this rudimentary process no sucrose crystallization occurs, but rather as the undiluted juice is boiled, the impurities, the coagulated proteins and minerals, surface and are removed to produce a type of molasses called "melote" of 50% DM. The further boiling, and finally, incorporation of air into the masecuite produces "pan" sugar. In addition to the different types of liquid, cane molasses, dried C (final) molasses with 91% DM is a commercial feed ingredient.

There are approximately 60 countries that produce sucrose from sugarcane. Due to cane varieties, climate and different process technologies, the composition of the above described products can vary substantially. For example, in Cuba, the purity, ie, the relation of sucrose to the total DM of the cane juice, can be as high as 88%; in other countries this figure varies from 76 to 80 percent. An example of the importance of this factor could be the following: B molasses obtained from an initial juice of high purity has a very high probability of crystallizing during storage, whereas A or B molasses obtained from a juice of low purity (78-80%) will not crystallize during storage. These differences can be important when related to animal feeding systems.

Molasses is used basically as source of energy; it is free of fat and fibre with a low nitrogen content. The nitrogen free extract (NFE), the main fraction representing between 85-95% of the DM, is composed of a mixture of simple sugars and a non-sugar fraction. The non-sugar fraction is poorly digested and fermented in the gastrointestinal tract. It is the increasing amount of the non-sugar fraction in each successive type of molasses, from A to C, that

determines the nutritional value of molasses for animal feeding. The amount of the non-sugar fraction as a percent of the total nitrogen free extract DM is: high-test, 9; A molasses, 18; Bmolasses, 23; and C molasses, 33 percent. The amino acids in molasses have not been considered due to their low content in the order of 0.5% of AD product. One gallon of syrup-off or A molasses weighs 5.3 Kg; the same amount of B and C molasses weighs 5.4 and 5.5 Kg, respectively.

Use: 1) low level

Final molasses is used to improve the palatability of dry feeds where it is often incorporated at levels of between 5 and 15% (AD) in the final mix. It is used between 5 and 8% as a binder in pellets and in pre-digested bagasse pith at a level of 15 percent. A solution of three parts of water to one of molasses can be sprayed by plane over parched grass or standing hay to improve palatability and/or leaf loss. This same technique, but hand-sprayed, and with the possible addition of non-protein-nitrogen (NPN), is used to improve the palatability of sugarcane trash when used as a dry season, maintenance ration. Because molasses ferments quickly, it is sometimes added to a silo at a level of 5% to enhance the fermentative process, as well as to increase palatability. It can also be used at the rate of 50 Kg/m^2 as a sealant for horizontal silos.

The economics related to the commercial use of molasses, together with restricted by-pass protein for intensive beef production has been re-evaluated to the point where molasses, in either liquid or solid form, is currently promoted as a "carrier" for non-protein-nitrogen and other additives. Molasses is generally "more available and cheaper" when cattle and sheep are hungriest, ie, when grass is less green; however, when fed alone or mixed with only 3% of urea, its palatability is not affected and therefore it should be restricted to 2-3 Kg/head/day. If used as a carrier for higher concentrations of NPN, the bitterness of the urea in the molasses serves as an auto-regulator causing the cattle to consume about one kg/head/day. This formula is (AD): C molasses,

80-85%; urea, 10-15%; salt 2.5% and dicalcium phosphate, 5.5 percent.

Molasses can also be used as a supplement during the rainy season,

where it serves to increase carrying capacity rather than improve performance; in this case, the energy obtained from forage is replaced by the more readily fermentable energy from the molasses. Caution must be taken when the spring rains begin; if the molasses is diluted it will rapidly ferment into alcohol and may fatally poison the cattle. As molasses/urea is deficient in phosphorus, it is necessary to add phosphoric acid to the mixture or provide the cattle with mineral supplementation. Drinking water must be available, constantly.

A multi-nutritional or molasses/urea block can be made by mixing together, and in the following order: final molasses, 50%; urea, 10%; salt, 5%; dicalcium phosphate, 5%; calcium hydroxide, 10% and lastly, 20% of a fibre source such as wheat middlings or dried, bagasse pith. Cement may be used instead of hydrated lime but it first must be mixed with 40% of its weight in water before adding it to the other ingredients. If possible, the NPN components should be 8% of urea and 2% of ammonium sulphate in order to include a source of sulphur for the rumen organisms. Sheep will consume between 150-180 grams/day and cattle approximately 500 g/day. The block should be with the animals a minimum of 16 hours daily, and preferably 24 hours.

Mixed in drinking water it is used to hydrate baby chicks during the first hours upon arrival from the hatchery. Finally, fresh fish or fish-offal, and snails can be preserved by mixing 50:50 with final molasses, then fed with B molasses to pigs, ducks and geese.

Use: 2) high level

A commercial beef fattening system, developed in Cuba and still used with modifications after more than 25 years, it is based on free-choice final molasses mixed with 3% of urea, restricted fish meal or another protein source, restricted forage (3 Kg /100 Kg LW) and free-choice mineral mix of 50% dicalcium phosphate and salt. The molasses/urea mixture, which represents some 70% of total diet DM, contains 91% final molasses and 6.5% water. The urea and salt are first dissolved in water before being mixed with the molasses; this mix is top-dressed, once daily, generally with 70g of bypass-protein (fishmeal) per 100 Kg of liveweight.

In a large, feedlot operation, the daily ration/head is calculated in terms of: 90g mineral mix, 250g fishmeal, 6 Kg

molasses/urea and 10 Kg of forage. The ADG can be between 0.8 and 1.0 Kg with a DM conversion of between 10 and 12; however, under average feedlot conditions the gains are between 0.7 and 0.8 Kg/day.

Although molasses can completely replace cereals in a beef feedlot operation, such is not the case with milk production, particularly with high producing dairy cows. In this case, the molasses/milk system does not perform adequately. It has been postulated that the problem could be one of insufficient glucose precursors related to the digestion of the molasses, particularly since the demand for this nutrient is greater in milk than in beef.

When fed in large amounts, and incorrectly, molasses may be toxic. The symptoms of molasses toxicity are reduced body temperatures, weakness and rapid breathing. The animals usually have difficulty standing and try to lean against some support with their forelegs crossed. The remedy is to immediately give them a solution that is rich in phosphorus and sodium, and to take the animals off molasses feeding for a few days. The causes of molasses toxicity are most often a scarcity of drinking water in close proximity to where they are being fed or a too rapid switch-over to high molasses diets. A modification to this feeding system is to use restricted grazing, usually one and a half hours, twice daily.

After decades of intense research to improve the performance of swine fed high levels of final molasses, a solution promoted in the early 80's by the Cuban sugar industry, was to simply change from C molasses to B molasses; presently, that country uses more than 400 thousand tons of B molasses for animal feeds, annually. Gestating sows are fed a protein supplement and B molasses to represent 64% of the DM of the daily diet. The three basic fattening rations, in % DM, are: 1) treated organic wastes (33), dry ration (33) and B molasses (33); 2) protein supplement (53) and B molasses (47); and 3) "protein molasses": B molasses (70) and Torula yeast cream (30), which as an integral diet of 36% DM contains 14% CP in DM.

Poultry, particularly geese and ducks, can be fattened on liquid diets containing up to 60% DM of molasses, preferably high-test, A or B molasses. Theoretically, the same system, level and types of molasses work for broilers and layers, however the management factor is crucial. An on-farm, immediate-use, mixing system to include 18 to 24% DM of high-test, A or B molasses in dry feeds for poultry is possible.

Two unconventional feeding systems for rabbits using more than 35% molasses in DM are: 1) "protein molasses" mixed with wheat bran or sun-dried, ground, sugarcane to soak up moisture and 2) "macro- pellets", that use the basic idea of the molasses/urea block but without urea. The air-dry formula for the one kilogram "macro- pellet" is: B molasses or syrup-off, 45-50%; whole, toasted soybeans, 25%; mineral mix, 5%; hydrated lime, 8-10% and a source of fibre, 10-15 percent. Both feeding systems require an additional 50% DM of forage.

As % of dry matter

Type of molasses:	DM	CP	CF	Ash	EE	NFE	Ca	P	Ref
High-test, Cuba	85	1.3	0.0	2.8	0.0	95.7	0.5	0.03	383
A molasses, Cuba	77	1.9	0.0	4.6	0.0	93.6	0.62	0.03	"
B molasses, Cuba	78	2.5	0.0	7.2	0.0	90.4	0.80	0.04	"
C molasses, Cuba	83	2.9	0.0	9.8	0.0	87.4	1.21	0.06	"
C molasses, Uganda	74	4.2	0.0	8.6	0.0	87.2	0.71	0.07	69
Syrup-off, Cuba(a)	75	0.8	0.0	1.3	0.0	98.0	1.15	0.07	602
Melote, Colombia(b)	50	-	-	-	-	88.0	-	-	603

(a) from refinery; (b) from "pan" sugar ("panela")

Digestibility, %

	Animal	ME	DM	NFE	Ref
C molasses	sheep	10.9	-	83	263

"	cattle	8.8	-	-	604
"	pig	11.8	81	89	602
"	poultry	8.4	-	-	605
High-test	pig	13.6	96	98	602
A molasses	pig	12.8	94	96	"
B molasses	pig	12.3	90	92	"