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 project 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 ($CaSO_4.1/2H_2O$) 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) where slaked lime was not very effective binder, 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-con, 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, $CaCO_3$ 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 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 thewalls 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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Introduction to the First FAO Electronic Conference on Tropical Feeds and Feeding Systems

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Background
Livestock production constitutes a very important component of the agricultural economy of developing countries, playing, in particular, a key role in food security. In fact, the animal product part of the total food production is increasing at a much higher rate than that of cereals and other crops. Actually, the contribution of livestock goes far beyond direct food production (milk, meat and eggs) and includes multipurpose uses, such as: draught power (contributing to crop production, transportation...), skins, fibre, fertilizer and fuel, as well as capital accumulation. Furthermore, livestock production is closely linked to the social and cultural lives of several million resource-poor farmers for whom animal ownership ensures varying degrees of sustainable farming and economic stability.

The target group of FAO programmes is that of the small farmers. The main problems which presently limit the productivity of the small farmers' livestock are shortage and low quality of feed, and in some cases, high disease incidence and subsequent mortality of livestock. These problems are further aggravated by the lack of substantial capital investment, lower technological inputs and slow transfer of appropriate technologies. Despite the repeated efforts regarding animal health and genetics, during the past decades, the productivity has not increased due to the neglect of the feed component. This has particularly been the case in numerous developing tropical and sub-tropical countries where the main purpose of maintaining livestock is draught power and organic fertilizer, rather than for livestock products.

In order to feed the growing human population, it will be necessary to devote more land to food and cash crops and therefore the land available for pasture and fodder will be reduced as has already occurred in Asia. Wherever the rate of population growth is high, grain production will be more and more destined to satisfy the food needs of these populations and less or no grain will be made available for animal feeding. On the other hand, increased food and cash crops will produce more crop residues and agro-industrial by-products, many of which represent valuable animal feed resources.

Therefore, there is a need to promote new feeding systems taking advantage of sources of energy and protein which are not directly challenged by the food demand and which can be integrated in a sustainable agricultural production system. Several such systems are already known and have been tested under different tropical and sub-tropical conditions. Their aim is to utilize all available local resources, such as natural grasslands and high yielding crops (sugar-cane, palm oil, cassava tubers or sugar palm trees) as providers of energy and locally-grown soya or other legumes, multipurpose trees, animal and fish wastes, and aquatic plants as providers of protein.

There is a large number of different feeds available in the tropics (more than 600 are mentioned in the FAO publication "Tropical Feeds"). However, information on their nutritive value and their potential role as ingredients in local sustainable feeding systems is quite insufficient in most cases.

The major objective of the livestock development policies in developing countries is to ensure the optimum contribution of livestock to agriculture, in order to achieve food security, through an increase of the domestic production, and an improvement of income and welfare of the small farmers. The priorities of the developing countries favour production systems which are sustainable and environment-friendly, and which promote rural employment and reduce dependency upon imports. Livestock should be kept on feeding systems which do not require food demanded by people.

Why An Electronic Conference on "Tropical Feeds and Feeding Systems"?

On the occasion of the presentation of the document "Livestock and Improvement of Pasture, Feed and Forage", the FAO Committee on Agriculture (1993) recommended "the development of means for rapidly disseminating information on various feed resources by modern techniques (computer diskettes, CD-ROM, electronic mail)" and that "further efforts and research be devoted to this initiative". The need was also emphasized to disseminate the results coming from on-farm and on-station feed research on techniques suited to smallholder systems.

The Feed Resources Group (FRG) of the FAO Animal Production and Health Division has been very active in the production of publications in electronic format and supporting key database in recent years. It has been involved since the early eighties at the inception of the electronic journal LRRD "Livestock Research for Rural Development" published by CIPAV (a Colombian NGO) which focusses on the role of livestock technologies in rural development in the developing countries (Preston and Speedy, 1989). This journal is now distributed to about 1500 scientists in over 100 countries, (free of charge in developing countries). The FRG has continuously been involved in the editorial advisory board, the collection of contributions, the distribution, diffusion and FRG is also now cooperating with the editorial work. Moreover, LRRD has become the main vehicle of information for two FAO regional projects since it includes their news bulletins.

The first publication of the FAO book "Tropical Feeds" by Bo Gohl in 1975 has been much appreciated by scientists all over the world. A second edition was issued in 1981, and the book went out of print in 1990. For economic reasons, and also to take advantage of the tremendous progress made in electronic publications, the first computerized version of Tropical Feeds, revised by Andrew Speedy (Oxford University) was issued in 1991. This has greatly facilitated the updating of the information contained in this book. However much more information is still needed on tropical feeds, fodder plants, trees and shrubs. In order to better respond to the users' needs, more data should also be compiled on practical utilization aspects and feeding systems for the main domestic animal species.

In 1994, a prototype of an electronic book (APH 102: Legume trees and other fodder trees as protein sources for livestock) was produced which constitutes the first step towards an electronic library to be made available through an Internet server. Six recent publications from the FRG should be transferred in the near future under the electronic format for inclusion in the electronic library. Savings gained through this new publishing policy could be devoted to the updating of previous publications and their transfer to this new format for distribution. This approach would greatly expand the potential readership throughout the world.

In developing countries, computers can now be found almost everywhere and electronic mail and INTERNET services are more and more available. This communication system is rapidly expanding since it has been recognized as the most cost-effective means of exchanging, circulating and updating information. It is the fastest way of getting inputs and distributing outputs from and to a huge audience. Since 1989, the FRG has been using Electronic mail to correspond on a regular basis with more than 50 countries (33 of them are developing countries) from the five continents. This network is currently enlarging very quickly, in particular with the help of trust fund network projects in Asia, Near-East and North Africa, and Latin America and the Caribbean.

Through electronic mail, the FRG has started to establish a small informal "Panel of Experts" (from Botswana, Colombia, Cuba, Denmark, France, India, Tunisia, UK, Vietnam...), which is regularly consulted for advising on identification of consultants, preparation of the programme of activities, technical matters, etc... This has proven to be a more efficient (prompt response) and cheaper way of receiving advice than the traditional FAO Panels of Experts.

From November 1992 to April 1993, the first electronic conference on Livestock Research and Development has been successfully organized by the Winrock International Institute for Agricultural

Development (USA), the International Forum on Sustainable Land-use Systems (INFORUM, USA) and the International Development Research Centre (Canada) with the participation of a few scientists from developing countries. At that time, however, this conference had difficulties in reaching scientists from the South. With the rapid progress of technology and the reduction of costs of equipment it has, at present, become much easier for developing countries to join the various electronic networks.

These developments are fully in line with the need for FAO to spare money on traditional publications and international meetings without jeopardizing its recognized leadership as a major repository of information, a major source of norms and a neutral international forum. In particular, the FRG could better comply with its responsibility for selective dissemination of feed information, related to the better use of available resources in new feeding systems, rather than just supporting the further collection of data and information *per se*.

Prospects

The objective of the FRG is to boost the exchanges of information and experience in the field of tropical feeds and feeding systems among developing countries. Many of them are currently suffering from the so-called `book famine', which is a major constraint to effective development. On the other hand, other developing countries are overflowed with often `non appropriate' information coming from industrialized countries. At the same time, due to the lack of an effective vehicle, very relevant information which is increasingly being generated in the developing countries is still not widely disseminated to other developing countries where this information would be most useful.

This unfortunate situation can now be improved in a cost-effective and sustainable manner thanks to the development of electronic publications, mail, and conferences. The latter are some of the fastest and most powerful tools for exchanging information and experiences. They will soon become essential instruments which will give access to a large range of information from which scientists and extensionists can choose options suitable for local conditions. Amongst other things, they will permit developing countries to spare the often scarce resources devoted to research, by sharing results and avoiding duplication.

One of FAO's primary functions is to collect, analyse, process and disseminate information. Another important role is also to act as a forum for its member countries. Electronic communications are a particularly appropriate tool for accomplishing these two functions.

This electronic conference on "Tropical Feeds and Feeding Systems" is the first of its kind organized by FAO. It should contribute to providing important material for updating its database and to facilitate the exchange of data among developing countries. For those interested who do not yet have access to electronic mail it is planned to distribute the proceedings on diskette, or possibly on paper.

The main object of this conference is that it should be the first step towards establishing a global network on "Tropical Feeds and Feeding Systems" which should allow for a continuous flow of information exchange and discussions among scientists all over the world. Although it appeared appropriate to start with tropical feeds as they concern most developing countries towards which FAO devotes the majority of its efforts, this network should eventually extend its scope to all feeds available throughout the world.

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 leguminous 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.

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 1993).

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

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).

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 $Y = X_1A + X_2B + X_3C$ was divided by X_1, so the value for A was 1. For the experiment referred to, X_2/X_1 was 0.4 and X_3/X_1 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.

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 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 amino-acids 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 NH_3, 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 NH_3 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 60°C, 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 10°C. Within the range of temperature of 20 to 45°C 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 10°C. 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 NH_3 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, NH_3 (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 et 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 NH_3 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).

Attemps 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 5°C 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 NH_3 released can bind the plant material, the remaining other 2/3 being in a labile form and lost, anyhow.

This point will be 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 NH_3 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 constituting 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.

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,

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 LW (kg)		Straw intake (kg DM/d)	
Cattle (130-140)[1]	1.7	1.7	1.9
Cattle[2]	2.1	2.3	2.9-3.0
Cattle (75-78)[3]		2.2	2.4
Cattle (166-178)[4]			3.9-4.8
Cattle[5]		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 LW (kg)		Liveweight gain (g/d)	
Cattle (130-140)[1]	35	75	110
Cattle[2]	103	213	238-30
Cattle (75-78)[3]		207	297
Cattle (166-178)[4]	141		207-336
Cattle[5]		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

- 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.

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.

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

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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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 practice in general use 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 analysed 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 analysed 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/cm². 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	166.4±55.0	
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 therefore 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 1990).

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 15-20°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 1996: these proceedings).

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 1995b), 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 (Ørskov, 1985) and details of procedures are as described previously (Liu et al 1995b). 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 Ørskov (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 1996: these proceedings).

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
N D F	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
Grams per day									
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
Percent 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 92 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 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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Strategy for sustainable use of natural renewable resources: constraints and opportunities

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The role of livestock in rural development

Livestock production (i.e., all aspects of production systems, their products and by-products) in tropical countries of the less-developed World, has been and must continue to be one of the most important economic and social activities of human culture. In these regions of the world, hundreds of millions of people depend directly or indirectly on livestock-based activities, the analysis of which is complex and multi-sectorial.

Many technical and economic endeavours, at national and international levels, have attempted to increase animal production and animal productivity in the tropics but results in general have been meagre. Of the many explanations of this phenomenon, perhaps the most pertinent is the lack of understanding of the ecological, socio-economic and cultural limitations inherent in these countries and which constrain severely the application of conventional development models.

Paradoxically, there are also incredible opportunities for sustainable development, thanks to the enormous cultural and biological riches of the tropics, the rational exploitation of which could support sustainable production in the medium and long term, but which have not been considered seriously in previous attempts to develop the livestock sector in these regions.

The role of livestock in developing countries is quite complex and extends beyond their traditional uses to supply meat and milk as is invariably the case in the industrialized countries (Sansoucy, 1995).

They are certainly multi-purpose. They are valued for one or several (sometimes all) of the following traits: capital, credit, traction, milk, meat, hides, fuel and fertilizer. Thus, for families without land, livestock are primarily a means of increasing the family income. For the crop farmer especially in Asia, but increasingly in Africa and Latinamerica, the large livestock - cattle and buffaloes - are primarily sources of traction and power. In many societies the dung is used for fuel and to a lesser extent as fertilizer. For the transhumant grazier livestock may be most valuable as a capital resource and a source of credit. Production systems must take into account these varied roles, and must be adapted to specific local situations.

If, as expected, fossil fuel prices increase in the long term at rates exceeding average inflation in the industrialized countries, then one increasing role will be the use of livestock as sources of power in agriculture. This is already the case for many countries in Asia with low GNP and low international purchasing power (eg: Bangladesh and Vietnam).

The other issue, which perhaps relates more specifically to Latinamerica, and parts of Africa, is that the principal livestock production system is extensive grazing by large ruminants, the establishment of which has mostly been through the destruction of the natural ecosystems of the tropical rain and cloud forests. These systems have consolidated the position of the medium to large landowner/cattle rancher and, by so doing, minimized opportunities for the small scale farmer.

Despite the privileged role accorded to extensive cattle ranching - witness the supporting research and development efforts over more than three decades by both international and national institutions - these production systems have become increasingly less profitable, due to increased prices of animals, feeds and other inputs, as well as increasing land prices due to competition with other end use patterns. The result has been their conversion into secondary activities kept in place by support (subsidies!!) from industry and commerce.

Livestock are enormously important to the economies of the less-developed countries as a whole. According to Brumby (1987) when, to the direct economic value of animal products, the value of livestock in providing rural transportation, draught power for cultivation, manure for crop production and their ability to utilize non-arable land and the agricultural residues is added, livestock accounts for about half the total agricultural production. Livestock also play a critical role in maintaining a cash flow for poor farmers who grow their crops essentially to provide food for their own household. Milk, meat and hides will always be sought after by those segments of society that have the necessary purchasing power to acquire these products. To the farmer-producer these products represent opportunities for generating income.

Economic growth and renewable natural resources

It is becoming a matter of increasing concern (Daly, 1993) that the present rate of economic growth is already outstripping the capacity of the earth's ecosystems: (i) to produce the required resources; and (ii) to absorb the pollution caused by present levels of economic activities. The impact of the expected doubling of the human population by the mid-term of the next century, most of which will take place in developing countries, coupled with the aspirations of the present and future under-privileged majority, poses a threat that can in no way be described or predicted.

It is quite clear that future scenarios of resource utilization must be predicated on:

- Optimizing the capacity of the earth's ecosystems to produce biomass, as the only renewable source of energy, chemicals, and food, without compromising the biological diversity on which the survival of all ecosystems depends.
- Minimizing waste through recycling, which reduces the need for raw materials and helps to protect the environment.

For livestock to play a symbiotic role in such a scenario, it will be necessary to give priority to species that combine efficiency of conversion and productivity, produce low emissions of methane (a major "greenhouse" gas), and have the capacity to use by-products and residues from other primary industries.

Pigs and scavenging poultry undoubtedly are the preferred animal species in this scenario, but there will be an increasing role for the small, as opposed to large, ruminants and for the small non-ruminant herbivores (Cardozo, 1993). High reproductive rate is what gives the competitive edge to these species. Aquatic systems with multiple production of fish, ducks, geese, water plants and other animal and plant species, will also find an increasingly important niche in the new livestock development model. The large herbivores will have a primary role as sources of power and fertilizer for agriculture, which they will achieve by recycling the residues from the crops they help to produce. Increasingly they will be expected to combine these activities with milk production and reproduction. The use of castrated males for work is a luxury which future pressures on resources will make increasingly less attractive. As with the plant kingdom, the need for biodiversity per se will justify the domestic use of the widest possible range of livestock species.

Among the largely unexplored possibilities of the diverse animal species present in tropical ecosystems, the natural wildlife - mammals, birds, reptiles, fish and crustaceans - can also make a contribution to sustainable livestock production systems, especially because of their adaptation to the ecologically fragile zones and their contribution to biodiversity (Cardozo, 1993).

Sustainable use of natural renewable resources

The World Commission on Environment and Development (Brundtland Report, 1987) defined sustainability as "ensuring that development meets the needs of the present without compromising the ability of future generations to meet their own needs". To this can be added the need to respond to the pressures increasingly coming to bear in both industrialized and developing countries to safeguard natural resources (see Brown *et al.,* 1991). In livestock-based agriculture, production systems must take into account these issues. In practical terms this means measuring the "sustainability" of the system according to its effects on:

- The economy
- The environment
- The need for energy (especially from fossil reserves)
- Animal welfare
- Food quality and security

Economic constraints:
The prerequisite of any livestock system is that it should be profitable to the producer. In all industrialized countries, the costs of livestock production have escalated mainly because of the increase in the cost of labour caused by rising expectations (standard of living) and competition from other industries. The situation is exacerbated in those countries where farm size is small and therefore unit costs of mechanization are high. Faced with such situations, governments have resorted to subsidizing agriculture through guaranteed support prices and other forms of financial assistance. The total cost of this support amounts to a staggering 75% of the total value of agricultural production in Japan, 40-50% in the European Economic Community and up to 25% in the USA.

Producers are supported in industrialized countries through subsidies and protected markets. These supports have two important consequences: (i) they increase the price of food to the domestic consumer; and (ii) they reduce the economic growth of many developing countries unable to export primary and secondary commodities against the barriers of tariffs and quotas.

Such policies in the long term are not sustainable. They are inefficient in resource utilization since they direct expensive resources (often produced with cheap fossil fuel) into products which could be produced elsewhere with fewer resources. The production of wheat and milk in some oil-rich countries, which is only made feasible with massive inputs derived from fossil fuel (in fertilizers, irrigation and machinery) is an example of this misguided policy.

For the world economy to grow at an optimum and more equitable rate, it is essential that there is free trade in basic commodities. The objective of GATT (General Agreement on Trade and Tariffs) is precisely to promote the concept of "comparative advantage", whereby commodities are produced in the areas/countries which use least resources for that purpose. Unfortunately, the free movement of capital means that the principal beneficiaries from the exploitation of "comparative advantage" are likely to be the large multi-national companies. An even more worrying issue is that comparative advantage can also mean advantage gained by not paying the environmental cost of a given production activity.

Another world trend likely to have considerable economic impact is a likely cutback in the availability of cereal grains for livestock feed. Two factors will contribute to this trend. On the one hand, the rising human population in low income countries will increase the demand for cereal grain which usually is the cheapest staple either to produce locally or to import from world markets. On the other, state subsidies and protection, although still at high levels in the industrialized countries, will gradually be reduced as a result of the GATT agreement. Grain prices will rise as a consequence. Increasing cost of agro-chemicals and fossil fuel through environmental pressures will lead to cutbacks in the use of these inputs which in turn will lead to lower crop yields and increased costs of production.

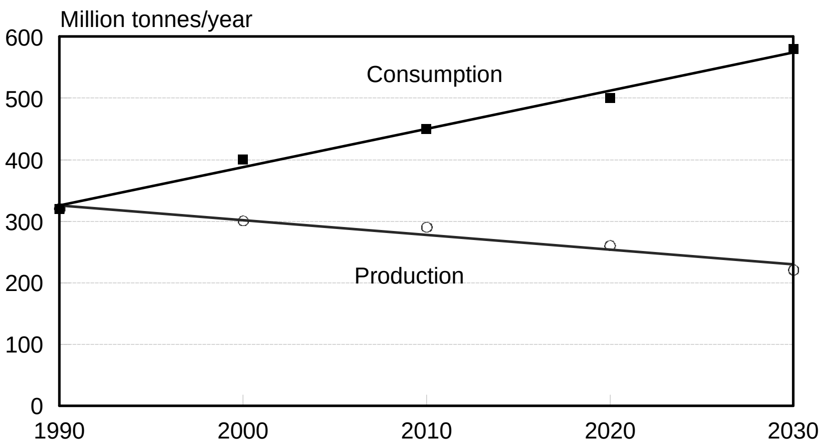

Figure 1: Predicted trends in production and consumption of cereal grain in China (1990-2030)(Source: Brown 1994)

The case of China puts this in perspective. Presently there is a balance between production and consumption of feed grains at about 300 million tonnes annually. However, consumption for animal feed, now approximately 20% of the total, is increasing fast in pace with the increasing aspirations of the people for more animal products in their diet. At the same time the arable area is steadily decreasing due to the inroads of economic development through construction of roads, factories and houses. It has been predicted that, with present trends, by the the year 2030 China could face an annual cereal grain deficit equal to the present rate of production of 300 million tonnes.

For the poor small scale farmer, in a less-developed country where subsidies on the scale presently employed by the industrialized countries are out of the question, the priorities are food security and to maintain their life style (eg: as with pastoralists and indigenous peoples). The essential steps to achieve this are to produce first for family consumption, using an integrated production system involving crops, forestry and livestock, and which ensures self-reliance by making maximum use of renewable natural resources with minimal dependence on inputs from outside.

This is a more economical and ecological way of improving their standard of living, as compared with the developed country models which have used fossil fuel to achieve this end.

Environmental issues

The productivity and efficiency of livestock production per animal unit in the least-developed countries is considerably less than in the more-developed world. But 'productivity' and 'efficiency' are references that relate specifically to temperate agricultural practices. In the tropics, livestock activities are different -- how does one measure the efficiency of survival, or as a credit institution? These and other productive traits are achieved with minimum inputs of fossil fuel. The biomass availability and the potential to produce more biomass in those countries which are in the tropics is many times higher than in the major industrialized countries which are exclusively situated in temperate zones. But we have only just begun to recognize the potential of tropical feed resources, let alone devise ways of exploiting them in a way which will be sustainable.

Another factor likely to become increasingly important in the future is the potential for tropical soil-based ecosystems, derived from decaying biomass, to foster atmospheric nitrogen fixation (Patriquin and Moncado, 1991), sequester carbon (Hall *et al,*. 1991) and oxidize methane (Keller *et al.,* 1990; Mosier *et al.,* 1991). Threats to the environment come from:

- Atmospheric contamination (global warming)
- Deforestation
- Accelerated erosion
- Soil and water pollution
- Loss of biodiversity
- Excessive human aspirations and lack of awareness of the finite nature of renewable resources

Global warming

Livestock production is intimately linked with build-up of atmospheric carbon dioxide and methane since: (i) emissions of carbon dioxide are caused mostly by burning fossil fuel and tropical deforestation; (ii) some 20% of methane emissions arise from digestive fermentation in the gut of herbivores, the methane itself contributing to some 15% of total greenhouse gases.

Forests and high biomass producing crops are important sinks for carbon dioxide (one ha of sugar cane is a permanent sink on average for some 80 tonnes of this greenhouse gas). Decaying biomass in contact with soil appears to be an important ecosystem where anaerobic micro-organisms oxidize methane (Keller *et al.,* 1990; Mosier *et al.*, 1991). Use of animal traction reduces the burning of fossil fuel; and permanent (as opposed to slash and burn practices, which provide for natural regeneration of the forest) tropical deforestation is mostly caused by activities leading to establishment of pastures for extensive ruminant livestock production.

Alternative methods of livestock production using high biomass-producing crops, fed mainly to monogastric animals and small herbivores, in partial or total confinement, will lead to increases in the size and number of sinks for both carbon dioxide and methane.

Deforestation

Livestock production parameters in extensive grazing systems in tropical developing countries are notoriously poor. The average fertility rate in the Latinamerican tropics rarely exceeds 50% and is often less; average stocking rates are less than one mature cattle unit per ha; slaughter age for 450 kg live-weight steers is more than 40 months; mortality rates frequently reach high figures in many regions due to contrasting food supply situations caused by long droughts and dry periods (Salazar and Torres, 1981).

The recent evaluation of a dairying project in Costa Rica provides further confirmation of the unsustainability of tropical pasture-based livestock systems (Holman *et al.*, 1992). Rain forest (4,000 mm rainfall annually) was cut down and burned in 1979-84 to establish Brachiaria pastures for family-farm resettlement. In 1992, it was revealed that incomes had deteriorated (to less than the minimum wage), soil fertility had decreased, weeds had taken over from the Brachiaria and concentrate usage had increased. The authors concluded that tropical pasture milk production was not sustainable and that research was needed to facilitate transition to other systems of land use.

The contrast with Asian livestock production systems is interesting. In Vietnam, for example, erosion is not a serious problem and even the areas desiccated by defoliants during the war are regenerating vegetative cover. The reason for the environmentally-friendly role of livestock in Vietnam is that there is no recognized pasture-based beef industry. The role of cattle and of buffaloes is to supply the power needed by agriculture. They are therefore kept in the cropping areas and are fed almost exclusively on fibrous crop residues and by grazing on fallow and common lands (Preston T R, unpublished observations).

Erosion

Africa's grazing systems are characterized by agro-pastoralism and transhumance. Such systems were apparently sustainable in times of low population density, with little pressure on the natural resource base and with opportunities to move from degraded lands to new territories or to adapt the pastoralist practice (eg: to herd camels and goats instead of cattle); but they have been destabilised by "development" practices, which have removed former "density-dependent" constraints (eg: through veterinary care, reduction in tribal raiding), or added new constraints (eg: reduction of range land area due to encroachment of crops and settlement of pastoralists; and increasing herd sizes) (see Ellis and Swift, 1988).

The impact of this destabilisation was clearly seen in the Dodoma region of Tanzania (Christiansson *et al.*, 1987; Chritiansson, 1988)). Explosive growth of the population resulted in increasing areas of range land being diverted to cropping. At the same time, the livestock herds of the pastoralists were also increasing. The outcome was uncontrolled over-grazing of the non-cultivable areas, leading to severe land degradation, threatening total ecological collapse of the region. The seriousness of the situation resulted in the initiation of a far reaching, and in some respects unique programme - The HADO Project (Hifadhi Ardhi Dodoma - Dodoma Region Soil Conservation Project).

The HADO project was started in 1973 and was initially concerned with arresting the accelerating land degradation occurring in parts of Dodoma Region through physical soil conservation measures. However, it quickly became apparent that the terraces, bunds, cut-off drains etc. that had been constructed were not having the desired effect due to their destruction by grazing animals, and also due to uncontrolled water run-off from higher slopes denuded by over-grazing. As a result, a decision was taken in 1979 to close the most severely affected area, of over 1,200 km² - the so called Kondoa Eroded Area - to all livestock, which involved the eviction of over 85,000 cattle, goats, sheep and donkeys.

A review of the Kondoa area, 10 years after the decision to de-stock (Preston T R, 1989, unpublished data), showed that the regeneration of the vegetation, and the arrest of ecological degradation generally in these areas had been dramatic. Honouring the promise to the farmers that some form of livestock keeping would be allowed when the land had recovered, the government in 1990 with help from SAREC and SIDA introduced a zero grazing scheme for milk production with improved crossbred and local cattle. Results have surpassed expectations (Ogle *et al.*, 1993), with milk yields of up to 10 litres daily being achieved on locally available feed resources, and with major participation of women in the feeding and management of the cows and the use and sale of the milk.

Soil and water pollution

The problem of soil and water pollution has arisen due to excessive use of chemical fertilizers and insecticides in "green revolution" agriculture. Loss of soil organic matter, which increases the need for fertilizer inputs, through monoculture of exploitive crops such as cotton and cassava has been a contributory factor.

A related issue is the effect that excessive chemical fertilizer application and burning of crop residues has had on natural ecosystems. There is increasing evidence that high levels of nitrogen fertilization decreases fixation of atmospheric nitrogen in the rhizosphere of, for example, sugar cane (Patriquin, 1982); and that it increases emissions of nitrous oxides and decreases oxidation of methane (Mosier *et al.*, 1991). By contrast, leaving post-harvest cane trash on the soil as a mulch, instead of burning it, increases sugar cane yields (Mendoza, 1988; Phan Gia Tan, 1994; Nguyen Thi Mui *et al.*, 1995) and soil fertility (Phan Gia Tan, 1994).

The integration of livestock with crops provides both nutrients for the plants and organic matter as an energy source for soil micro-organisms to aid soil fertility. On a specialized crop farm there may be little incentive for planting break crops of legume forages. But if livestock are present then such forages can be turned into income by feeding them to animals. Planting of multi-purpose nitrogen-fixing trees in association with cash crops as in "Alley farming" systems is also more attractive to the farmer if some of the foliage can be used to give added value to livestock (Attah Krah, 1991).

Loss of biodiversity

Genetic selection for livestock of ever increasing productive potential has inevitably lead to decreased biodiversity at the animal level. Intensive feeding systems for monogastric animals, almost exclusively tied to use of cereal grains and soya bean meal, have encouraged replacement of indigenous ecosystems and local strains of cereals with 'more-productive' hybrids. Emphasis on specialized grazing systems in the tropical savannahs has created vast expanses of pasture monocultures of *Brachiaria* spp. In both cases plant biodiversity has been reduced.

The positive side of increasing affluence is the opportunity to choose more on quality and less on price. In Colombia, eggs from scavenging 'local' poultry were preferred and brought higher prices that those from 'battery' birds (Solarte *et al.*, 1994). Local chicken command a higher market price than "broilers" in Vietnam (Luu Trong Hieu, 1994, personal communication). Meat from an indigenous pig breed had a better taste than that from imported 'improved' breeds and was preferred by local inhabitants in Guadeloupe (Depres *et al.*, 1994). The meat from non-ruminant herbivores living in natural ecosystems is considered to be a delicacy (and therefore worthy of a higher price) in many tropical countries.

The search for alternatives to cereal grains and protein-rich oilseed and animal by-product meals (Sansoucy, 1995) is already leading to the identification and promotion of a wide range of indigenous (to the tropics) crop and water plants, trees and shrubs. Biodiversity will be enhanced by these practices which should be encouraged (eg: by more research).

Human aspirations and the resource base

The economic strength and the standard of living of the industrial countries is directly linked with their consumption of fossil fuel (Figure 2). The aspiration of the less-developed countries is to follow a similar route.

But reserves of fossil fuel are finite and have a lifetime measured in decades not centuries. Hydro and nuclear power pose serious threats to biodiversity and to contamination with hazardous wastes, with fewer opportunities for employment.

The only sustainable solution is to promote life styles, and goods (of which energy is a priority), which are derived from activities associated with the development and management of natural biologically-based resources. For the researcher in a tropical country, responding to this challenge should be a privilege and source of satisfaction, long since absent from the agenda of their colleagues in industrialized countries for whom agriculture is of declining importance.

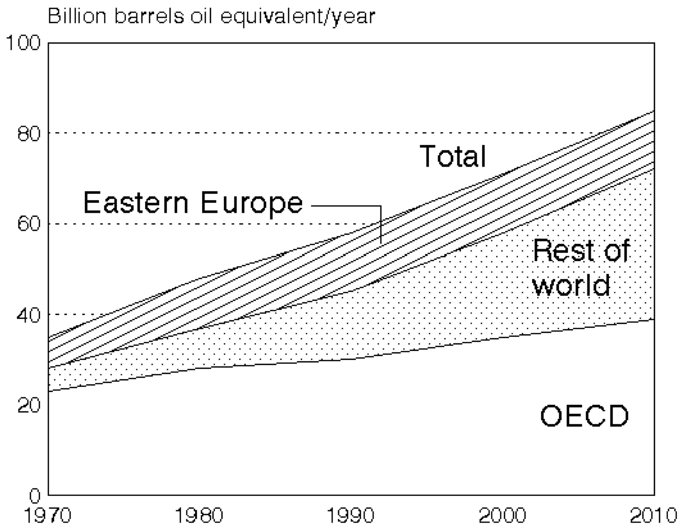

Figure 2: The demand for energy (mostly as fossil fuel) will increase most rapidly in the least-developed countries as they aspire to the living 'standards' of the industrial countries (Source: The Economist, June 18 1994)

Renewable and non-renewable (fossil) energy

The close link between livestock policies and fossil fuel use has been mentioned. Three examples put this in perspective. On the 30,000 ha sugar estate in the Dominican Republic (La Romana), some 18,000 oxen haul the sugar cane from the fields to pickup points on a railway system leading to the sugar mill. This system is highly sustainable since the energy for the oxen is derived from the carbohydrates in the cane tops; nitrogen and minerals in the tops are returned to the soil in their excreta, since the animals eat and rest in the recently harvested areas.

By contrast in Cuba, some 80% of the sugar cane is harvested mechanically by diesel-driven combines and loaded onto trucks which transport the stalks and attached trash to cleaning centres. Here, electrical power is used to blow off the trash, and the stalks are elevated onto rail wagons or trucks for continued transport to the factory. This system is not sustainable. At the time of writing this paper the problem of de-mechanization of Cuba's agriculture was the subject of keen debate and the re-introduction of draught oxen a matter of high priority for the Government (Rena Perez, 1995, personal communication).

The example of Vietnam has already been mentioned, where agricultural power is supplied almost exclusively by buffaloes and oxen, and bicycles are the major means of personal transport. Vietnam's rating in terms of GNP may be one of the lowest in the world but if it were assessed in terms of sustainable agriculture it would be among the leaders. By contrast, in most tropical countries in Latinamerica, oxen have been replaced by tractors and forests are burned to develop pastures for beef cattle. These policies are highly unsustainable.

A specific problem of less-developed countries is the provision of domestic fuel for the more than 2,000 million families that use firewood from woods and forests for this purpose. In Colombia, it is estimated that 29% (240,000 ha) of the annual rate of deforestation (800,000 ha) is caused by domestic fuel wood consumption, half of which is in rural households, a third in poor urban communities, the remainder divided between charcoal production (9%) and rural handcrafts (11%). The amount consumed varies from region to region, but it is calculated that a rural family of 8 persons uses 18 cubic metres (about 3.6 tonnes) of firewood annually solely for cooking. If this is purchased then it may cost (in Colombia in 1990) up to US$70.00/tonne. When cut from the forest it is estimated that 50 work days are expended annually for this purpose, to a value of US$147.00 (Solarte, L, Personal communication). The situation in much of Africa and in parts of Asia is similar.

Several solutions have been proposed which involve livestock. They are complementary and depend on natural and economic resources available and on cultural acceptance of the technology on offer.

- Biogas digesters
- Establishing energy plantations
- Use of crops that fractionate easily into "feed" and "fuel" components

Biogas technology was first developed in India and China. The mixture of methane and carbon dioxide (biogas), produced by the anaerobic fermentation of livestock and human excreta, has found major uses in cooking. Biodigesters are intimately linked with livestock production, as they depend for substrate on the excreta of animals. Thus, use of this technology strengthens the arguments for partial or full confinement of animals, and thereby forms part of the strategy against uncontrolled grazing. The major constraint to the popularization of biodigesters has been cost and availability of suitable materials for their construction. The recent development of low-cost (less than US$50/family unit) biodigesters using standard polyethylene tubular film (Botero and Preston, 1987) has had a major impact in Vietnam (Bui Xuan An *et al.*, 1994) and Cambodia (Than Soeur, 1994) where the even lower costs (less than US$30.00/family unit) put the technology within reach of the majority of families.

Cereal crops are easily separated into grain and straw. The latter is burned on open fires (with low efficiency) for fuel in many developing countries. But increasingly in industrialized countries, especially those with strong legislation against uncontrolled burning, it is used as fuel in boilers designed for this purpose. In Denmark whole villages are heated in the winter using this technology. In tropical countries, there are even greater opportunities for applying this principle. Production of sugar from sugar cane is one of the few agro-industrial activities which is self-sufficient in energy (and can even be an exporter of energy). In Vietnam, the growing of enough sugarcane to feed four pigs (with the juice) produced fibrous residues (the pressed stalk) sufficient to cover half the fuel needs of a family of six (Nguyen Thi Oanh, 1994). The concept of the multi-purpose biomass refinery, in which the juice is the basis of animal feed or chemicals and the fibre is converted to synthesis gas to power gas turbines for electricity generation (Preston and Echaveria, 1991), promises to be more viable, economically, sociologically and ecologically, than the single-purpose production of alcohol as in the Brazilian model. Multi-purpose trees can also be fractionated easily into feed (the leaves) and fuel (the branches and trunks) and can thus be part of the same "integrated" model.

Energy plantations are important for the arid and semi-arid regions as they are complementary to pastoral-forestry schemes. Many species that can be used also fix atmospheric nitrogen and produce edible foliage and/or fruits. They include: Acacia, Prosopis, Leucaena, Gliricidia, Guazuma, Inga, Albizia, Cassia, Pithecellobium and Alnus spp. They may be sources of food, feed, fuel, timber and protection against erosion and desertification. These systems can also be the basis of biomass refineries as described above.

Thus the promotion of sustainable systems of agricultural production, in which livestock play a fundamental role, can also contribute to the solution of the domestic energy crisis. The use of multipurpose crop plants and trees, and the recycling of livestock excreta, provide not only much needed domestic fuel, but also control erosion, reduce contamination and act as sources of fertilizer.

Ethological issues

Animal behavior studies were originally conceived as a means of exploiting livestock more efficiently through greater understanding of their habits and activities in different environments. The approach today is quite different. Behavior studies are done so as to develop less exploitive methods of animal production. The aim is to reduce stress to the animal and the attendant so that the quality of life of both is improved (Fox, 1988).

The deliberate promotion of contentment through natural means can be reflected in higher productivity. The calf, lamb or kid, that is suckled by its mother will grow faster, be healthier and have a better feed efficiency than if it receives its milk from a bucket. The dam will also respond to the more natural environment of having her offspring present at milking, and having it suck the residual milk from the udder. Milk yield will be higher and udder diseases less than if calves are weaned permanently soon after birth (Preston, 1983; Preston and Vaccaro, 1989). Calves suckled naturally do not have the urge to suck the navels of their neighbours and thus can be managed in groups instead of being confined to individual pens. Sows fed fibrous feeds during gestation are less prone to develop anti-social behavior (eg: biting of tails and ears) than when high nutrient density feeds are given. They can then be managed in (more social) groups rather than in separate individual stalls.

Stressful systems of livestock management, such as raising animals in cages and stalls, are already being legislated against in many countries in Europe. Practices such as debeaking of birds housed in cages, amputation of the tails of pigs and castration, reduce productivity and invite cannibalism.

Embryo transplants have been heralded as a means of increasing beef cow profitability by inducing multiple births and thus raising prolificacy (King, 1989). However, this technology can result in a high degree of stress in both the cow and her attendant. The long term effects are likely to be reduced lifetime fertility. Stimulation of cow milk yield by injecting recombinant growth hormone appears to reduce longevity and to increase stress (Kneen B, 1994 Personal communication) through accelerated partitioning of nutrients from body tissues into milk. The welfare of these cows is certainly decreased and cannot be considered to be sustainable.

The direct economic cost of stressful systems of management will ultimately be reflected in the market place with premiums for products from contented and well cared-for animals and penalties for products of animals that are ill-treated.

The transformation of both extensive cattle ranching and the highly intensive methods practiced in monogastric animal production, into more integrated systems in which the livestock play a symbiotic and complementary role rather than being the primary goal, will bring with it related advantages in terms of animal welfare.

Wholesome (natural) foods

In an increasing number of supermarkets and stores in the industrialized countries, premiums are paid for food produced in "environmentally-friendly" farming systems. Crops that are grown according to "organic" farming principles are in this category; as are animal products (eg: meat and milk) derived from such cropping systems.

The ban on imports to EU countries of beef from cattle treated with synthetic hormones shows how this concern for more natural food translates into economic criteria.

Inappropriate models derived from industrialized countries

The issue here is that, in contrast with crop production, livestock systems in tropical developing countries have been highly influenced by practices developed in the industrialized countries, most of which are in temperate climatic zones. For example, most "modern" methods of pig, poultry and dairy production in tropical countries are almost exact copies of those practiced in industrialized countries, using the same germ plasm and feed resources. The term 'assembled' is often used to describe the products derived from such systems to emphasize their dependency on imported inputs.

Such practices have been justified by the need to respond to the aspirations inherent in a 'better standard of living' through increased consumption of food of animal origin. In fact, they exacerbate the basic problems since they result in:

- Minimum employment opportunities.
- An increase in the foreign exchange deficit, due to high imports (some countries import 100% of their feeds for industrial-scale pig and poultry production)
- More pollution as usually the animal population in such units is high and there are no associated crops for recycling the excreta.
- Impoverishment of the small scale farm family which cannot compete in the purchase of the required inputs and may not have the skills for the more sophisticated management that is required.

Countries such as Nigeria and Venezuela, which built up sophisticated intensive animal industries in times of high oil revenues, found that these were not sustainable when oil prices fell and agricultural subsidies had to be reduced.

Indicators of sustainability

Indicators of sustainability are derived from measurements which describe the effect of the system on the sustainability of the resource. While this topic is presently the subject of much discussion, the following parameters are proposed as criteria on which the sustainability of resource utilization can be measured. The items (not in order of priority) include:

- Total biomass yield
- Soil organic matter content
- Soil pH
- Soil content of P, N, K, and Ca
- Degree of diversity of animal genetic resources and their use at the level of small scale users
- Water quality
- Production and use of renewable energy
- Energy balances
- Diversity in fauna and flora at plant and soil level
- Greenhouse gas emissions and sinks (carbon and methane)
- Employment generation

- Involvement of women and children
- Food security.
- Maintenance of lifestyle of households in rural areas
- The catalytic role of livestock in the integration of crops, livestock and forestry.
- Protection against erosion and desertification

Using the above criteria it has been the experience in several tropical countries that the production and use of feed resources derived from sugar cane (small scale - not industrial), African oil palm, sugar palm, forage trees and shrubs, and most water plants, can be sustained. The use of cereal crop residues (but not always the production) is also a sustainable feeding system as the primary product will always be produced for human consumption. By contrast, cultivation of cassava, cotton and "introduced" tropical pasture species is unsustainable due to negative effects on soil fertility and, in the case of tropical pastures, due to negative effects on socio-economic indicators (eg: employment, and persistence of households in rural area). The issues here are that exploitive crops which are not sustainable as monocultures should be rotated with crops that restore soil fertility.

Conclusions

The issues discussed in this paper provide a conceptual basis for the sustainable use of renewable natural resources in livestock-based farming systems for the tropics. The interpretation of this strategy in the form of practical farming systems has profound implications both for the type of feed resources that will be on offer, the species of livestock most suitable for their utilization, the most appropriate way to evaluate them and the manner in which such feeds should be incorporated into the diet of the animal. These themes are the basis of "research into the better use of tropical feed resources for livestock" which is the primary theme of this conference.

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Aquaculture Feeds and Feeding in the Next Millennium: Major Challenges and Issues

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The Dilemma: What Approach

If aquaculture is to play a major role in the food security of low-income developing countries (LIDCs) as a much needed and affordable source of high-quality animal protein then it is essential that the farmed species be produced en masse using low-cost sustainable farming methods. In this respect China (an LIDC) stands out alone in that it has been producing food fish for home consumption for over 3000 years!; China being the world's largest producer of aquaculture products (58.7% of the world total of 22.63 million metric tonnes (mmt) in 1993), including farmed finfish (58.4% of the world total of 11.19 mmt in 1993). The Chinese finfish farming system is based on the polyculture of complementary freshwater herbivorous/omnivorous fish species at low fish stocking densities within closed (ie. static water) integrated fish farms; aquaculture usually being the predominant farming activity and combined with the production of farm livestock and crops. Within these semi-intensive farming systems (SIFS) fish growth and production is achieved through the integrated use of low-cost locally available nutrient inputs in the form of pond fertilizers and low-protein agricultural by-products. India, the second largest aquaculture producer in the world (total aquaculture production of 1.44 mmt in 1993, including 1.39 mmt of finfish) also employs similar polyculture farming techniques (both these countries producing over 65% of total world aquaculture production). In fact it is interesting to note that whereas only 46.2% of world meat production (ie. cattle meat, pigmeat, poultry meat, sheep meat, goat meat etc.) was produced within developing countries in 1993, over 85.0% of total world aquaculture production by weight (70.7% by value) was produced within developing countries, including 86.7% of all farmed farmed finfish.

In marked contrast to China and India, Japan (the third largest aquaculture producer in the world, and the largest aquaculture producer of the developed countries with a total production of 1.43 mmt in 1993) employs high-cost intensive farming methods for the production of food fish. The farming system is based on the monoculture of high-value (in marketing terms) marine carnivorous fish species at a high stocking density within open (ie. high water exchange) intensive pond, tank, raceway or cage-based farming systems; Japan producing 342,000 mt of finfish in 1993. Within these intensive farming systems (IFS) fish growth/production is achieved through the use of high-cost nutrient inputs in the form of high-protein nutritionally-complete diets or in the form of a natural foodstuff of high nutrient value such as fresh or frozen trash fish or shellfish.

Although both of the above mentioned farming systems operate as economically viable operations within their respective countries they both have their share of advantages and disadvantages; depending upon one's viewpoint (ie. economic, socio-economic, environmental, technical, or biological) and position in society (ie. resource-poor farmer, resource-rich farmer, private investor, politician, government official, scientist, environmentalist, conservationist, angler, or layperson). However, whether these and other alternative farming strategies will continue to be sustainable in the coming decade or the long-run is another matter. For example, due largely to population pressure for resources (including land and water) there is now an emerging global trend in agriculture towards intensification of farming systems, and aquaculture is no exception to this. However, although the intensification process may increase production per unit area and bring short term economic gains in terms of increased profits or a faster return on investment, intensification by its very nature is dependent upon increased resource inputs (including feed) and as such has its drawbacks and risks. The aim of this paper is to highlight some of major issues and challenges related to aquaculture nutrition and feed development which will dictate the future sustainability or not of SIFS and IFS within developing countries.

Major Issues and Challenges

1.Dependency of aquaculture on agricultural and fishery resources as fertilizer and feed inputs and the increasing competition of aquaculture with humans and the traditional animal livestock production sector for these resources

Availability and increased demand for feed resources
All finfish and crustacean farming systems are dependent upon the market availability of `feed resources' for the provision of nutrient inputs, either in the form of fertilizers, agricultural wastes and by-products as supplementary feeds, or formulated pelleted aquafeeds. It follows therefore that if the finfish and crustacean aquaculture sector is to maintain its current growth rate (increasing by 11.2% from 10.90 mmt to 12.12 mmt from 1992 to 1993) then it will have to compete with other users (ie. humans and/or farm livestock) for these feed resources. Although the aquaculture sector may have been successful in the past in obtaining the necessary fertilizer and feed inputs, this may not be so in the future as farming systems intensify and the demand for a finite pool of valuable feed resources increases. It has been estimated that the total world production of manufactured compound animal feeds exceeded 550 mmt in 1994 (valued at over 55 US$ thousand million), of which poultry feeds constituted 32%, pig feeds 31%, dairy feeds 17%, beef feeds 11%, aquatic feeds 3%, and others 6%.

Dependency upon fish meal and other fishery resources as feed inputs

At present the production of carnivorous finfish species (1.26 mmt or 11.3% of total farmed fish in 1993) and marine shrimp (0.80 mmt in 1993) is totally dependent upon the use of fishmeal and fish oil as the sole or major source of dietary protein and lipid within farm-made or commercial aquafeeds; these two fishery products generally constituting about 70% by weight of compound aquafeeds for most farmed carnivorous fish species and about 50% (together with shrimp meals and squid meal) by weight of compound aquafeeds for marine shrimp.

Although the production of carnivorous fish species and shrimp species will continue to be profitable for those countries with ready access to fishery feed resources and/or international credit facilities, this will be only possible as long as fishmeal and fish oil stocks last and prices remain stable or within competitive limits. However, an unknown factor which could upset the balance is the growing global interest and demand for health foods (primarily within `developed' countries) and the recognition that fish and fishery products (including fish oils) could play a key role in the diet of `modern man'; the latter either driving up the market price of fish and fishery products (including small pelagics) or diverting the use of small pelagics for direct human consumption rather than for rendering into fishmeal.

2. Need to sustain and further increase aquaculture production in the face of increasing feed and farm production costs, and increasing degradation of the aquatic environment

Increasing raw material and farm production costs

Increasing raw material and farm operating costs, coupled with an often static and/or decreasing market value for many farmed species (ie. and in particular the high-value carnivorous fish and shrimp species) necessitates that the farmer reduce production costs so as to maintain profitability. Since food and feeding (including fertilization) usually represent the largest single operating cost item within SIFS and IFS, particular attention must be focused on the development of research and farming strategies aimed at reducing fertilizer/feed costs and improving on-farm fertilizer/feed management techniques. A logical step therefore is to make a detailed appraisal of the fertilizer and feeding strategies currently employed by the fish farming community within the country in question (through the use of farm questionnaires and field visits) so as to identify the fertilizer/feeding deficiencies and constraints; these in turn serving as the subject of future on-farm field research investigations.

Furthermore, so as to ensure the applicability and rapid transfer of research data to farmers it is recommended that where ever possible that fertilization and feeding/nutrition-based research trials be conducted *in situ* on representative fish farms and that the data generated from these on-farm research studies be also evaluated from an economic, socio-economic, and environmental impact viewpoint. Emphasis within government/public aquaculture support staff (including researchers) must be placed on trying to find local solutions and improvements for the existing problems of the aquaculture sector within member countries by supporting on-farm research (participatory systems approach) rather than just conducting pure or fundamental research within the laboratory. However, the key to the success of on-farm research is the participation of the farmers themselves, not only assisting in the identification of research needs and priorities (usually overlooked), but also in the actual implementation of on-farm research programmes. Sadly, in many instances the aquaculture R & D programmes of public agencies are aimed more on the particular research interests of individual government scientists and/or donor agencies rather than to the farmers or existing farming community they are there to support.

Choice of cultured species: herbivores, omnivores or carnivores?

At present all IFS and SIFS for carnivorous finfish species (ie. salmonids, eels, marine fish species - seabreams, yellowtail, seabass, grouper etc.) and penaeid shrimp are net fish protein `reducers' rather than net fish protein `producers'; the total input of fish and fishery resources as feed inputs far exceeding the output of new fish protein by a factor of 2 to 5 depending upon the farming system and fishery resource used (ie. fishmeal-based diets or `trash fish' as major feed inputs). This is in sharp contrast to the net fish protein producing status of the majority of SIFS and IFS employed by farmers for the production of herbivorous/omnivorous fish and prawn species; the culture of herbivorous/omnivorous fish species being generally realised by `developing' countries (the two largest producers being China and India) and constituting 88.7% of total finfish aquaculture production in 1993. It is also of interest to note here that whilst the average increase in global production of cultivated carnivorous finfish species (ie. rainbow trout, Atlantic salmon, yellowtail, Japanese seabream etc.) was 9.37% from 1992 to 1993, the average increase in production of the non-carnivorous fish species (ie. silver carp, grass carp, common carp, bighead carp, milkfish, rohu, nile tilapia, catla, mrigal carp, crucian carp etc.) has remained higher at 13.35% from 1992 to 1993. On a country basis, it is perhaps of interest to also compare the recent statistical data on aquaculture production from China and Japan; finfish production in China (97.9% of total being omnivorous/herbivorous fish species) reportedly increasing by a staggering 21.4% from 5,387,107 mt to 6,536,620 mt from 1992 to 1993 and finfish production in Japan (94.5% carnivorous fish species) decreasing by 2.7% from 353,140 mt to 343,714 mt from 1992 to 1993 (FAO, 1995).

It follows from the above that if aquaculture production is to maintain its current high growth rate and continue to play an important role in the food security of developing countries as an `affordable' source of high quality animal protein, herbivorous or omnivorous finfish/crustacean species (feeding low on the aquatic food chain and therefore being less demanding in terms of feed inputs) should be targeted for production rather than high-value carnivorous fish/shrimp species; the latter being less energy efficient in terms of resource use and dependent upon the use of high-cost `food grade' protein-rich feed inputs. In this respect it is also high time that we learn from our terrestrial counterparts whose farming systems are based on the production of non-carnivorous animal species (ie. poultry, ducks, pigs, sheep, rabbits, goats, cattle).

Absence of information on nutrient requirements and importance of natural food organisms

Despite the fact that silver carp, grass carp, common carp, bighead carp, and the giant tiger prawn were the top five cultivated fish and crustacean species in the world in 1993 (totalling 5.97 mmt or 49.3% of total farmed finfish and crustacean production), and are all mainly cultivated within SIFS, little or no information exists concerning their dietary nutrient requirements under practical semi-intensive pond farming conditions; the majority of dietary nutrient requirement studies to date having been performed under controlled indoor laboratory conditions (these in turn only being restricted to common carp and the giant tiger prawn). Whilst the information generated from laboratory-based feeding trials maybe useful for the formulation of complete diets for use within IFS this information cannot be applied to the formulation of diets for use within SIFS since the fish/shrimp also derive a substantial part of their dietary nutrient needs from naturally available food organisms; this is particularly true for those species which are capable of filtering fine particulate matter from the water column (ie. bacterial laden detritus, phyto-plankton, zooplankton etc.), including silver carp, bighead carp, catla, rohu, mrigal carp, kissing gourami, Thai silver barb, milkfish, nilem carp, and last but not least marine shrimp.

For example, despite the dietary essentiality of vitamins for *Tilapia* sp. under indoor laboratory conditions, field studies in Israel have shown no beneficial effect of dietary vitamin supplementation with Tilapia sp. in ponds, cages or concrete tanks at densities of 100 fish/m2 with yields of up to 20 tonnes per hectare. Moreover, crustaceans researchers have recently been able to reduce feed costs by half using lower dietary protein and micronutrient levels with no loss in the growth and feed efficiency of shrimp within pond-based SIFS. Unfortunately, in the absence of published information on the dietary nutrient requirements of finfish/crustaceans within SIFS almost all of the commercially available aquafeeds produced for these farming systems are usually over formulated as nutritionally complete diets irrespective of the intended fish stocking density employed and natural food availability. Clearly, this situation will have to be rectified if farmers are to reduce production costs and maximise economic benefit from their semi-intensive pond farming systems.

Polyculture and use of natural pond food resources
At present the bulk of world finfish and crustacean aquaculture production within developing countries is realised within pond-based SIFS. However, although the nutritional and economic importance of natural food organisms within the diet of pond raised finfish has been well recognised and utilized by farmers in China with the development and use of complex polyculture-based farming strategies, with the possible exception of India, such practices have not met with the same degree of success outside China. Polyculture-based farming systems are based on the stocking of a carefully balanced population of fish species with different (ie. non- competitive) and complementary feeding habits within the same pond ecosystem and so maximizing the utilization of natural available food resources (ie. phytoplankton, zooplankton, bacterial-laden detritus, macrophytes, benthic algae, invertebrate animals etc.) and available water resources (ie. surface, mid- and bottom-water) with a consequent increase in pond productivity and fish yield per unit area. For example, polycultures in China commonly include the use of filter feeding fish species (ie. silver carp, bighead carp; 26-52% of total fish stocking weight), herbivores (ie. grass carp; 30-37% of stocking weight), omnivores (ie. common carp, crucian carp, Chinese bream, tilapia; 18-25% of stocking weight), and carnivores (ie. black carp; 0-11% of stocking weight); stocking weights and patterns varying with the financial resources of the farmer. Thus, within low-productivity provinces (ie. low-income provinces/resource-poor farmers; net fish yields averaging 3.3 mt/ha/yr) fish stocking densities are low (initial stocking weights averaging 444 kg/ha) and the proportion of filter feeding fishes is high (52%), whereas in the high-productivity provinces (ie. higher-income/resource-rich farmers; net fish yields averaging 7.9 mt/ha/yr) fish stocking densities are

about three times higher (initial stocking weights averaging 1,481 kg/ha) and the proportion of `feeding fishes' (ie. herbivores, omnivores and carnivores) are the dominant species stocked.

Importance of farm-made aquafeeds within SIFS

As mentioned previously the bulk of world aquaculture production within developing countries is currently realised within SIFS and is small-scale in nature with nutrient inputs supplied in the form of fertilizers and supplementary `farm-made' aquafeeds; the latter ranging from the use of fresh grass cuttings, cereal by-products, to sophisticated on-farm pelleted feeds. In contrast to industrially produced compound aquafeeds (more commonly used within IFS), farm-made aquafeeds allow the small-scale farmer to tailor feed inputs to their own financial resources and requirements, and facilitate the use of locally available agricultural by-products which would otherwise have limited use within the community. In addition to their ability to use locally available waste streams, farm-made aquafeeds are also potentially much cheaper for farmers than commercial aquafeeds (although farmers whose initial success was based on farm-made aquafeeds often shift over at a later date onto commercial feeds).

Need for increased environmental and social compatibility

Particular emphasis has been placed on the environmental compatibility and central role played by polyculture-based integrated farming systems in aquaculture development within developing countries and the need to carefully balance exogenous supplementary feed inputs with the endogenous supply of natural food organisms (achieved through the use of fertilizers) within the pond ecosystem. Furthermore, as mentioned previously, in addition to their minimal effects on the environment, in terms of resource use SIFS are less dependent upon high-cost `food grade' exogenous feed inputs (ie. fishery resources), facilitate maximum use of locally available agricultural resources (ie. by-products and wastes), have lower production costs, are less prone to disease problems, and are usually net fish protein producers and more energy efficient compared with IFS.

By contrast, the negative reported impacts of aquafeed usage within IFS on the aquatic environment have been largely due to the use of poor on-farm husbandry and management techniques (including on-farm feed management practices) and lack of appropriate aquaculture planning measures limiting the size of existing farms or groups of neighbouring farms to the `environmental carrying capacity' of the water body or coastal area in question. Despite this, increasing attention is now being given by farmers, feed manufacturers, and researchers alike to the development of farming systems and feeding strategies which maximize nutrient retention by the cultured fish or shrimp and minimize nutrient loss and negative environmental impacts.

It is also important to mention here the critical role played by nutrition (ie. undernutrition) and farm management (ie. on-farm feed, water and pond management) on fish/shrimp health and the incidence or not of disease outbreaks within IFS (and to a lesser extent SIFS) and the need to satisfy not only the dietary nutrient requirements of the farmed species for maximum growth but also to satisfy their additional dietary requirements for increased immunocompetence and disease resistance.

Finally, the dietary value and importance of aquaculture products in human nutrition as a much needed source of `affordable' animal protein should not be overlooked; fish being one of the cheapest sources of animal protein within rural and coastal communities. For example, at present freshwater aquaculture (ie. mainly cyprinids and tilapia) offers one of the cheapest sources of high quality animal protein within the major rural inland communities of Asia, including China, India, Indonesia, and the Philippines.

Need for information and training

Finally, but not least, one of the major factors limiting aquaculture development in most developing countries is the lack of ready access to up-to-date information, either through publications within libraries and electronic bibliographic databases, or through in-country training opportunities (ie. for farmers, extensionists, researchers, or the trainers) on aquaculture, and in particular concerning aquaculture nutrition and feed technology. Clearly, since information and training (ie. the dissemination of information and knowledge through education) are fundamental to any research, learning or development process, it is essential that this issue be addressed if farmers (the ultimate beneficiaries) are to improve their skills and farming operations. Sadly, information is often overlooked as being an integral part of the learning or research process; the net result being the re-invention of the wheel and the unnecessary duplication of research effort rather than building upon the knowledge base already available and learning from past mistakes and experiences.

Closing Remarks

Despite the fact that China has the longest history and experience in aquaculture development the sector has recently faced serious difficulties with the `intensification' phenomenon and the shift of the more resource-rich provinces and farmers from traditional farming practices to more `Western-style' market-oriented farming practices; farming practices shifting from the use of low-cost and low-input (and therefore low output) polyculture-based SIFS (aimed at the mass production of `food fish' for local consumption) at one end of the spectrum to the production of high-cost and high input (and therefore high output) monoculture-based IFS (aimed at the production of high-value (in marketing terms) `luxury food fish' (ie. carnivorous fish/shrimp) for export at the other end of the spectrum. The particular case in point is the spectacular `rise and fall' of the shrimp farming industry, with shrimp production collapsing from a high of about 200,000 mt between 1988 and 1992 (China then being the largest producer of farmed shrimp) to under 50,000 in 1994. The collapse of the shrimp farming sector in mainland China was almost identical to that which had occurred in Taiwan five years earlier in 1988 and was largely due to the progressive degradation and deterioration of the aquatic and pond environment (due to pollution, poor feed and pond management, and inadequate planning and concern for the environment) and consequent massive disease outbreaks.

It is evident from the above economic and environmental disasters that although `intensification' and modern `high-tech' high-input and high-output IFS (ie. feedlot systems) can bring considerable economic gain to farmers with access to resources (ie. finance, land, water, trained manpower, feed and other off-farm inputs) these farming systems are highly `stressed ecosystems' whose stability is entirely dependent upon `human factors' and `the farmers control and use of resources' rather than by natural `ecological factors' as in the case of low-input polyculture-based SIFS. Despite this, whether we like it or not, intensification and IFS are here to stay and aquaculture (like all other forms of animal production) will increasingly be constrained by increasing competition for land and resources, including feed. For example, at present China's economy is one of the most dynamic and fastest growing economies in the world (GDP growth in 1993 being 13.4% and the highest amongst Asian countries), in which livestock and farmed fish production is increasing at double digit figures. By contrast, cereal and oilseed production (used as feed for humans and livestock) is only increasing at an average annual growth rate of 2-3% per year (China being a net importer of cereals for one-quarter of a decade). Coupled with an average annual population growth rate of 1.3% per year and a huge population resource base of 1.2 billion people, it follows that, if China (like the majority of other developing countries) is going to sustain and improve the nutritional and economic welfare of it's people, traditional farming systems will have to be improved and/or upgraded.

Clearly, if the intensification process from extensive and semi-intensive to intensive farming systems is to proceed in a sustainable manner, it is essential that research be aimed at developing farming systems which produce more fish or shrimp, but that the production be based on the use of sustainable ecological/environmental balances and the efficient `integrated' use of resources rather than just on a purely economic basis. It follows therefore that, for the survival of the industry the overall efficiency of resource use should be improved and that the aquatic environment be preserved, thus ensuring that long term sustainability prevails over the desire for rapid gains and short term profits.

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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 livestoc k feeding in Central Tanzania

Tree/shrub species	Respondents (Percentage)	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 meso-phyllic 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	Leaf- -ness (0-10)	Leaf- drop (0-10)	Green- ness (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

Local Name (Kigogo)	Botanical Name	Family
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

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 feed 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).

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*	DT, 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*	HT
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
Govania 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.

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

Species	Propagation		Cuttings maturity		Time of planting
	Cuttings	Seeds	Young	Mature	
	------- % 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.

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.

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).

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.

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/3	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.

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.

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		
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.

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 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

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). 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.

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

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 than 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
Ficus sp.	0,5/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+ Molasses	Green banana	Yam
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).

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.

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.

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*., 1993a). 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).

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

	--- Planting position ---			
	Horizontal		Vertical	
Species	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 (mt/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 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.

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).

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.

Table 16. *Erythrina* and King grass dry matter deposited, exported and total (mt/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*., 1993a

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 (NH_4NO_3). 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).

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

	Amount of manure/1			NH_4-NO_3/1	
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,/8a

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.

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 sepium* 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 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

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 *et al.*, 1991

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).

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).

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).

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.

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.

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.

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

Description	Years 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			

Oviedo *et al*., 1993

1/ NPV = Net Present Value

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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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 livestock 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 chlorofluorocarbon 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.

Appendix

Azolla

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(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

	DM	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

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	"

Molasses/Urea Blocks

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Extract from FAO Tropical Feeds Database

Ruminant diets in most developing countries are based on fibrous feeds: mainly mature pastures (particularly at the end of the dry season) and crop residues (e.g. wheat and rice straw, maize and sorghum stovers). These feeds are imbalanced and particularly deficient in protein, minerals and vitamins; they are highly lignified their digestibility is low. These characteristics keep intake and productivity low.

The principles for improving the use of these poor quality roughages by ruminants include:

- satisfying the requirements of the rumen microorganisms to ensure efficient fermentation of fibre and increased production of microbial protein relative to volatile fatty acids;
- balancing the products of fermentative digestion with dietary nutrients (mainly through the use of bypass protein) to meet the needs of growth, milk, meat and wool production.

In practice this can be achieved by supplying, in order of priority:

1. A supplement of fermentable nitrogen and minerals.
2. A small amount (10 to 20 percent) of good quality forage, preferably a legume or grass cut at an early stage.
3. A small amount of a supplement containing materials that bypass the rumen: these include protein meal (e.g. toasted soya cake, solvent extracted groundnut cake) or starch based supplements (e.g. maize and sorghum).

This strategy is applicable in developing countries, e.g. in the Sahelian region of Africa, where ruminants are fed on pastures throughout the year with limited access to supplementary crop residues, or in Asia where they are fed mainly on rice straw and their diets are low in true protein for prolonged periods.

Mixtures of liquid molasses and urea, which provide fermentable nitrogen and are a good source of minerals, have been used for many years by ranchers in Australia and Southern Africa. Mineral licks (sometimes including urea) have also been extensively used in various parts of the world. However, small farmers have rarely benefitted from these supplements usually because of difficulties of handling these in small quantities. Molasses in the liquid form is difficult to transport (requiring expensive tanker trucks), to store (requiring tanks), to handle (it is highly viscous) and to distribute to animals (troughs or other receptacles being needed). Mineral licks which are usually imported are highly expensive and their cost/benefit ratio is often questionable.

By-pass nutrients, with the exception of legume leaves, come generally from rather expensive feeds which are either in demand for human nutrition (cereals) or exported for foreign exchange (oil cakes). However, because recent research has generally shown that their inclusion at a low rate in the diets is efficient, they should be economical to use in many situations.

Block Formulation

The blocks can be made from a variety of components depending on their availability locally, nutritive value, price, existing facilities for their use and their influence on the quality of blocks. They can also include specific components.

- Molasses provides fermentable substrate and various minerals and trace elements (but low amounts of phosphorous). Because of its pleasant taste and smell, it makes the block very attractive and palatable to animals. The degree Brix of the molasses should be as high as possible, and preferably higher than 85, to ensure solidification.

- Urea, which provides fermentable nitrogen, is the most important component of the block. Urea may increase the intake of straw by cattle by about 40 percent and its digestibility by 8 units (or 20 percent). The intake of urea must be limited to avoid toxicity problems but sufficient to maintain ammonia levels in the rumen consistently above 200 mg N/l for growth of microorganisms and high rates of degradation of fibre. Blocks are an excellent way of controlling intake and allow continual access.
- Wheat or rice bran has a multiple purpose in the blocks. It provides some key nutrients including fat, protein and phosphorus, it acts as an absorbent for the moisture contained in molasses and gives structure to the block. I may be replaced by other fibrous materials such as dry and fine bagasse or groundnut hulls which are finely ground but some loss of nutritive value occurs.
- Minerals may be added where appropriate. Common salt is generally added because this is often deficient in the diet and it is inexpensive. Calcium is supplied by molasses and by the gelling agent, calcium oxide or cement. Although phosphorus is deficient, there is no evidence that its addition is beneficial where animals are at below maintenance when grazing on dry mature pastures or fed low-quality forage. Mineral requirements are reduced at maintenance or survival levels. Deficiencies will generally become a problem only when production is increased, particularly when a bypass protein supplement is given and in these cases phosphorus should be included in that supplement.
- A gelling agent or binder is necessary in order to solidify the blocks. Although the mechanism of gelling is unknown, various products have been tried successfully: magnesium oxide, bentonite, calcium oxide, calcium hydroxide and cement.

The use of cement has raised some questions, from various nutritionists and extension workers, about possible negative effects on animals. In fact, research on the use of cement or its by-product, cement kiln dust, as a mineral supplement have not shown such adverse effects at levels of 1 to 3 percent of the total diet dry matter. (Nevertheless, the USDA has restricted the use of cement kiln dust since it could cause a deposit of heavy metals in animal tissue.)

- Various chemicals or drugs for the control of parasites or for manipulation of rumen fermentation (e.g. anti-protozoal agents, ionophores) can be added to the molasses blocks which can be an excellent carrier for these products.

Recent work has shown that the addition of small amount of rumen- insoluble calcium salts of long chain fatty acids could further increase the efficiency of the use of fibrous residues.

Finally, the formulae may vary according to the process adopted in manufacturing the block (Table 1).

Table 1. Examples of formulae according to manufacturing process

Process	Hot	Warm	Cold	Cold
Molasses	60	55	50	50
Urea	10	7.5	10	10
Common salt	-	5	5	5
Mg0	5	-	-	-
$C0_3Ca$	4	-	-	-
Bentonite	1	-	-	-
Ca0	-	10	5	-
Cement	-	-	5	10
Cottonseed meal or bran	20	22.5	25	25

The Manufacture of Molasses-urea Blocks

Different processes have been tried and can be grouped in three categories:

The "hot" process

This is the process which was first recommended in Australia. The molasses (60 percent) and urea (10 percent) were cooked with magnesium oxide (5 percent), calcium carbonate (4 percent) and bentonite (1 percent) at a temperature of 100-120 deg C for about 10 minutes. The content was brought to a temperature of about 70 deg C and mixture was left to cool slowly which enhanced solidification. It settled after some hours. The cooking was done in a double-jacketed rotating boiler with circulating water and steam.

The "warm" process

The molasses (55 percent) was heated to bring the temperature to about 40-50 deg C and the urea without water (7.5 percent) is dissolved in the molasses (Choo, 1985). The gelling agent was calcium oxide (10 percent). The rest was made up of common salt (5 percent) and bran (22.5 percent).

The inconvenience of these processes, particularly the "hot" one, is the necessity for providing energy for heating. However, if it is possible to use the hot molasses as it leaves the sugar factory or if an excess of steam is available, the cost of energy may be acceptable. The advantages are the reduction of time for setting and the finals product is not hygroscopic.

The "cold" process

It has been noted that, in tropical conditions, it was not necessary to heat the molasses in order to obtain a good block when 10 percent of calcium oxide was used as a gelling agent. This observation is of primary importance when blocks are manufactured in a unit separate from the sugar factory as was the case in Senegal.

The "cold" process involves a horizontal paddle mixer, with double axes, which is used to mix, in the following order of introduction, molasses (50 percent), urea (10 percent), salt (5 percent), calcium oxide (10 percent) and bran (25 percent). The mixture is then poured into moulds (plastic mason's pails or a frame made of four boards 2.5 m x 0.2 m). After about 15 hours, blocks may be removed from the mould and they may be transported by truck after 2 days.

Calcium oxide may be replaced by cement, but when cement is used it is important to mix it previously with about 40 percent of its weight in water, and common salt to be included in the block. This ensures its binding action, as the water in molasses does not seem to be available for the cement. The quality of the cement is of primary importance. Mixing the salt with cement accelerates hardening.

The disadvantage of the "cold" process is that it needs some time to set and the final product is somewhat hygroscopic. The advantages are the saving in energy, and the simplicity and ease of manufacture.

Independent of the process, the hardness of the block is affected by the nature and proportion of the various ingredients. High levels of molasses and urea tend to decrease solidification. The concentration of gelling agents and bran is highly important in the hardness of the final product. For example if the urea percentage is as high as 20 percent, molasses should be reduced to 40-45 percent and the gelling agent needs to be increased. Quick lime produces harder blocks than cement.

Feeding Molasses-urea Blocks to Ruminants

Factors affecting the intake of blocks

The hardness of the block will affect its rate of intake. If it is soft, it may be rapidly consumed with the risk of toxicity. On the other hand if it is too hard its intake may be highly limited.

High levels of urea may reduce intake of the block as well as of straw, urea being unpalatable (Table 2).

Table 2. Effect of urea content on intake of block and straw by lambs

Urea content of block, %	10	15	20
Block intake g/lamb/day	136	112	18*
Straw intake g/lamb/day	441	550	326

*4 out of lambs did not lick any of their block
Source: 621

The level of inanition or imbalance in minerals which lead to pica may result in excessive consumption in a short time also leading to urea poisoning. This has been noticed in at least one case in Senegal. Precautions should be taken to avoid this problem of over-consumption in drought prone countries particularly towards the end of the dry season when feed is scarce. The block should be introduced progressively, and it should be clear that the block, as it is presently formulated, cannot constitute the only feed and a minimum of roughage is necessary.

Where there is a bulk of dry feed the risk of toxicity from overconsumption is not apparent. In India, several thousand buffaloes in village herds have been fed blocks containing 15 percent urea without problems (625) and there is some indication that buffaloes learn to regulate their intake.

Finally, the intake of block obviously varies with the type of animals (Table 3).

Table 3. Intake of blocks for different types of animals fed a basal diet of straw

Type of animal	Animals weight	Block intake per 100 kg LW	Ref.
Lambs	22	400	622
Calves	66	250	623
Young buffaloes	100	380	624
Jersey bulls	300	185	625
Jersey bulls	350	150	"
Zebu heifers	280	110	626

Effects of blocks on intake of basal diet

Feeding blocks usually results in a stimulation of intake of the basal diet. With a basal diet of straw without any supplementary concentrate, the increase of straw consumption due to molasses urea blocks is between 25 and 30 percent. When some high protein concentrate is also given with the basal diet, the increase of straw consumption is less and varies between 5 and 10 percent (Table 4).

Effects of intake of blocks on digestibility of straw and some parameters of digestion

The digestibility of straw dry matter in dacron bags measured after 24 hours in the rumen of lambs increased from 42.7 to 44.2 percent when 100 g of molasses urea block was consumed, and to 48.8 percent by an additional supply of 150 g cottonseed meal.

Ammonia concentration in the rumen of lambs receiving molasses urea blocks increases to levels which are much higher than those generally recommended for optimal microbial development (60 to 100 mg NH_3/1 of rumen fluid). This concentration increases with the urea content of the block (Table 5) and when a by-pass protein is added (Table 6). The digestibility of straw in sheep increased even up to 250 mg NH_3 - N/1.

Table 4. Effect of block on intake of straw

Type of animals	Animal weight kg	Increase in straw intake %	Ref
STRAW WITHOUT CONCENTRATE			
Lambs	22	26	622
Jersey bulls	300	29.5	625
Dairy buffaloes	-	24	"
Young buffaloes	100	23	624
STRAW WITH HIGH PROTEIN MEAL SUPPLEMENTS			
Lambs	22(1)	8	622
Jersey bulls	350(2)	6	625
Crossbred cows	- (3)	10	"
	- (4)	5	"
Preston, Leng and Nuwanyapka, unpublished data, quoted in 576			

(1) with 150g cottonseed meal (2) with 1kg concentrates (3) with 1kg noug cake (*Guizotia abyssinica*) (4) with 2kg noug cake

The total volatile fatty acids in rumen fluid is increased when lambs consume the blocks with or without additional by-pass protein. There is a small but significant shift toward a higher propionate and butyrate production, and a lower acetate production.

Effects of blocks on ruminant growth

Dry mature pasture or straw given alone are unbalanced in nutrients to provide for an active and efficient rumen and to ensure an efficient utilization of the nutrient absorbed. Feed intake and the nutrient absorbed from such diets are insufficient to ensure even maintenance requirements and animals lose weight if they do not receive any nitrogen and mineral supplement. Molasses-urea blocks added to such an unbalanced diet allow for maintenance requirements because they ensure an efficient fermentative digestion. When some by-pass protein is added (e.g. cottonseed meal, noug cake) there is a synergistic effect which further improves considerably the average daily gain of ruminants and they become much more efficient in using the available nutrients. In addition total nutrients are often increased because feed intake is increased.

Compared to urea supplied by spraying on straw, urea from blocks give superior results. It is assumed that part of the response may be due to the small amount of supplementary energy supplied by the molasses but also by a stimulatory effect of other ingredients in the blocks on the rumen ecosystem (576).

Effects of blocks on milk production

The use of multinutrient blocks has allowed for a substantial reduction in concentrate in the diet of buffalo cows fed on rice straw. The fat corrected milk yield was not diminished by replacing part of the concentrate with block. But the amount of straw in the diet and thus the profit per animal per day were greatly increased.

Considerable commercial experience has now been acquired in the use of blocks for supplementing dairy buffaloes fed rice straw under village conditions in India. Reducing the amount of concentrate give to buffalo cows from 5 to 3.5 or 4 to 2.5 kg/day, and distributing blocks, did not reduce milk production but increased fat percentage by about 10 percent and reduced the cost of feeding. In other observations the addition of blocks to the diet increased milk production by about 10 to 25 percent and fat content of milk by 13 to 40 percent. In one village where the initial production level was lower the increase was even grater.

Subsequent trials were conducted in Ethiopia with crossbred cows given meadow hay of low quality with two levels of noug cake. They showed that milk yield was increased by 28 percent when feeding 2 rather than 1 kg of noug cake in the absence of blocks. However, there was no difference between the two levels of noug cake when the cows had access to blocks (containing 10 percent urea). It was then possible to save 1 kg nough cake by providing blocks without lowering milk production.

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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 22-30°C 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 edble 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))]

Colombian Forest Plants

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Local people on forest farms in the Choco Region of Colombia use a large number of adapted species which fit into sustainable systems in the forest.. This list was prepared and presented by the author at a lecture given at Oxford in November 1994.

Local name	Botanical name	Uses
Chontaduro	*Bactris gasipaes*	Edible fruits
Yarumo	*Cecropia* spp	Leaf litter[org. mat. recycling]
Balso	*Ochroma* spp	Leaf litter; wood
Sandé	*Brosimum alicastrum*	Medicinal latex, wood, shade
Nato	*Mora megistrosperma*	Wood for canoes
Tangare	*Carapa quianensis*	Wood for canoes
Higuerón	*Ficus* spp	Shade trees
Jobo	*Spondiasmombin*	Edible fruits, shade tree
Totumo	*Crescentia cujete*	Containers and collanders
Palo de cruz	*Brownea* spp	Wood, medicine
Caimito	*Chrysophillum* spp	Edible fruits
Caimo	*Bellucia* spp	Edible fruits
Mango	*Mangifera indica*	Fruits
Punta de lanza	*Viomia* spp	Leaf litter
Cumare	*Astrocanjum* spp	Fibres
Milpesos	*Jessenia polycarpa*	Edible fruit
Coconut	*Cocos nucifera*	Edible fruit
Cuesco	*Attalea* spp	Edible fruit
Zapote	*Matisia cordata*	Edible fruit
Borojó	*Borojoa patinoi*	Fruit pulp for beverages
Papaya	*Carica papaya*	Edible fruit
Avocado	*Persia americana*	Fruit
Pacó	*Grias cauliflora*	Fruit

Local name	Botanical name	Uses
Guamo	*Inga* spp	Fruit
Uvo	*Pourouma* spp	Fruit
Cacao	*Theobroma cacao*	Edible seeds
Palmito	*Euterpe* spp	Edible young leaves
Bijao	*Calathea* spp	Leaves for packaging
Zapotolongo	*Pachira acuatica*	Edible seeds [nuts]
Nacedero	*Trichanthera gigantea*	Fodder, medicine
Achiote	*Bixa orellana*	Spice, food colouring
Sugar cane	*Saccharum officinarum*	Sugar, animal feed
Mafafa, Papachina	*Xanthosoma* spp	Tubers and fodder
-	*Colocassia* spp	Tubers and fodder
Ortiga	*Urera* spp	Edible leaves and medicine
Pineapple	*Ananas* spp	Fruit
Banana	*Musa* spp	Fruit
Plantain	*Musa* spp	Fruit
Iraca	*Carludovica* spp	Fibres [packaging, hats]
Name	*Dioscorea alata*	Tuber
Cassava	*Manihot esculenta*	Tuber

Nutritional Value of Palms

Abstract

Atchley, A.A. (1984). Nutritional Value of Palms. *Principes*, 28(3), 138-143

A few comparisons of palm nutritional value with that of other crops from tropical and subtropical regions may be instructive. Seed of *Cocos nucifera* has about twice the protein value of, and over fifty times as much fat, as the root of *Manihot esculenta*, and about twice as much protein as the ripe fruit of *Mangifera* indica. The bud of *Cocos nucifera* has over twice as much protein as the average reported for the ripe fruit
of *Carica papaya*, over seven times as much fat, almost three times as much phosphorus, and over twice as much niacin, although it has only about a tenth as much ascorbic acid and presumably, since no data are reported here has relatively little carotene. (The palms are generally reported to be relatively low in ascorbic acid compared to *Capsicum* spp. and *Carica* spp., as well as many other tropical and subtropical sources of that nutrient.) However, *Elaeis* oil seems to be a source of carotene richer than ripe *Carica papaya* fruit, and at least comparable to the fruit of *Capsicum* spp. as reported by several sources. Interestingly, the bud of *Geonoma edulis* is reported to be over four times as rich in protein as that average ripe fruit of *Carca papaya*.

Such intriguing comparisons, which will it is hoped, become more accurate as the database expands, suggest a potential usefulness of palms in developing countries. Confirming the existence of this potential would appear to require intensive, standardized analysis which adequately explores variation in populations. The full range of ecological factors which influence the variation in time and space of nutritional value must also be investigated.

Extract from table of chemical analysis:

As % of dry matter

	CP	CF	Ash	EE	NFE
Acrocomia mexicana F	9.1	27.8	4.4	28.6	57.9
Areca catechu S	6.8	18.1	1.7	12.3	79.1
Arecastrum romanzoffuznum S	12.8	-	-	64.7	-
Arenga pinnata SH	1.9	9.4	1.9	3.8	92.5
Astrocaryum standleyanum F	6.0	20.3	5.0	2.5	86.5
Bactris guineensis F	5.9	10.3	5.9	1.0	87.3
Borassus fabellifer F	6.5	16.1	4.8	0.8	87.9
Butia capitata S	15.7	-	-	-	56.5
Butia eriospatha S	12.9	-	-	1.8	44.1
Calamus ornatus F	2.9	2.4	2.9	5.7	88.6
Chamaedorea sp. -	26.7	8.0	13.3	4.7	55.3
Chamaerops humilis S	5.0	-	-	8.7	-
Chrysalidocarpus lutescens S	6.9	-	-	7.2	-
Chrysalidocarpus madagascariensis var. *lucubensis* S	2.9	-	-	8.2	-
Cocos nucifera S	6.3	11.5	1.7	67.9	24.0
Corypha utan F	3.7	6.8	2.1	0.5	93.7
Elaeis guineensis F	7.9	3.9	1.7	54.4	-
Erythea sp. S	5.8	-	-	6.6	-
Euterpe oleracea F	5.8	30.5	2.0	20.7	71.5
Geonoma edulis SH	27.1	12.7	11.0	2.5	59.3
Hyphaene thebaica S	4.1	10.0	3.3	6.8	85.7
Hyphaene turbinata S	8.1	-	2.3	13.4	-
Jubaea chilensis S	8.2	6.8	1.0	75.3	15.5
Mauritia vinifera F	11.0	41.9	4.4	38.6	46.0
Orbignya cohune S	6.9	-	-	52.2	-
Orbignya speciosa S	9.4	-	-	62.9	-
Phoenix dactylifera F	2.9	6.5	5.7	1.0	90.4
Prestoea longepetiolatao SH	24.4	6.7	15.6	2.2	57.8
Pseudophoenix sargentii S	6.2	-	-	19.2	-
Pseudophoenix vinifera S	6.4	-	1.3	21.4	-
Ptychosperma macarthurii S	5.9	-	1.4	1.6	-
Raphia hookeri S	8.7	9.1	10.3	1.1	79.9
Salacca zalacca F	1.8	-	3.2	0.0	95.0
Vetchia merrillii S	4.1	-	1.5	1.3	-
Zombia anomala S	4.9	-	1.6	1.8	-

F = fruits; S = seeds; SH = shoot or vegetative bud

Information on Palm Species

Abstracts

Nutritional evaluation of the *Jessenia bataua* palm: source of high quality protein and oil from tropical America. Balick, MJ and Gershoff, SN. 1981. *Economic Botany*. 1981, 35: 3, 261-271.

Samples of fresh fruit, oil and dried outer pulp (mesocarp and epicarp) were collected in the Amazon Valley in 1976, 1977 and 1978 and analysed. The composition of the oil was similar to olive oil, and the mesocarp pulp protein was similar in quality to good animal protein and better than most grain and legumes. Rats fed diets with mesocarp oil and pulp showed weight gains comparable with those fed on diets of corn oil and casein. The tree occurs in forests up to an alt. of 1000 m in N. South America, including Panama and Trinidad, and the fruit is used by indigenous peoples as a source of oil and a milk-like beverage.

Subsistence benefits from the babassu palm (*Orbignya martiana*). May, PH, Anderson, AB, Balick, MJ and Frazao, JMF. 1985. *Economic Botany*. 1985, 39: 2, 113-129.

Stands of babassu occupy an area of Brazil estimated at 200,000 km^2 concentrated in the States of Maranhao, Piaui and Goias. The babassu's cryptogeal germination, establishing the apical meristem of the plant below ground for its early growth and development, enables it to survive human disturbance. The fruit kernels are used as food, the husks for charcoal production and the mesocarp for animal feed. Other uses and those of the leaves (including medicinal uses) and stems are listed.

Understanding how the babassu is used by rural families will help to make current efforts at domestication and whole-fruit processing more responsive to human needs.

Pejibaye palm (*Bactris gasipaes*, Arecaceae): multi-use potential for the lowland humid tropics. Clement, CR and Mora-Urpi, JE. 1987. *Economic Botany*. 1987, 41: 2, 302-311; 30 ref.

Pejibaye palm can be used for: whole fruit for direct human consumption; palmito; fruit for flour and meal production; use as animal ration; and fruit for oil production. It is concluded that *B. gasipaes* has high potential for regaining its importance as a crop in the humid neotropics.

In the short term, perhaps the greatest potential of the pejibaye is for use as animal ration. The high starch levels, along with existing protein, oil, and carotene, are an excellent base for this use, and the ration can be enriched with soybean or lsh meal to augment protein levels as required. All the other uses of pejibaye, too, will provide residues that can be processed as animal ration.

In Costa Rica, flour and meal production programs are intimately related to the production of animal ration. There are already some privately owned plantations that put their first-quality fruits onto the internal market and prepare animal ration from second-rate fruits. One advantage of use as ration is that the skin and seed can be ground with the mesocarp. Chickens readily accept this mixed ration after it has been cooked.

Processing for oil production also will leave a high-quality byproduct. Since up to 40-60% of the dry weight of the mesocarp in oily cultivars will be oil, there will be a corresponding increase in levels of protein, starch, and fiber after extraction. High levels of protein are obviously desirable, but those of fiber may not be, especially if the kernel has been ground with the mesocarp (Arkcoll and Aguiar 1984).

In well-maintained plantations with adequate fertilization, and with cultivars selected for meal production, it should be possible to produce 15-25 tons/ha/yr of dry matter suitable for animal ration. Residues from oil production should vary between 2-5 tons/ha/yr. Both these figures are far above what is possible with maize in the humid tropics, although maize is the principal animal ration at present.

The potential significance of these production figures is well illustrated by the city of Manaus, in Amazonas, Brazil, which imported approximately US $1,000,000 worth of cereals for animal ration in 1982, while its own region's production of maize, rice, and soybeans did not begin to supply its human needs. Although Costa Rican production of these cereals is good, grains are still imported for animal feed. In both regions, chicken and pork for domestic use are more expensive than they would be if each area produced its own animal rations.

***Attalea colenda* (Arecaceae), a potential lauric oil resource. Blicher- Mathiesen, U and Balslev, H. 1990. *Economic Botany*. 1990, 44: 3, 360-368.**

Attalea colenda, a palm tree native to the coastal plain of western Ecuador, produces from 1 to 4 infructescences per tree every year, each with an av. of 5065 fruits. The oil content of the seeds is 56.9% dry weight. Kernel oil production per infructescence is 7-16 kg. A hectare with 50 trees could produce 0.35-3.2 tons of oil per year. The kernel oil is chemically similar to coconut oil and kernel oil from the African oil palm, with a high concentration of lauric acid. The increasing demand for lauric oil crops makes *A. colenda* a potential oil source.

***Phytelephas aequatorialis* (Arecaceae) in human and animal nutrition. Koziol, MJ and Pedersen, HB. 1993. *Economic Botany*. 1993, 47: 4, 401-407.**

Field observations revealed the consumption of several parts of the vegetable ivory (tagua) palm not previously reported to be eaten by man or animals. The whole male inflorescence provides cattle with a fodder nutritionally similar to ryegrass, while the flower clusters provide man with 102 kcal/100 g of energy, about 4 times the energy density of cauliflower or broccoli. The central mesocarp is similar in composition and energy density to other fruits and is a comparatively rich source of calcium (116 mg/100 g), potassium (841 mg/100 g), and zinc (1.3 mg/100 g). The interior mesocarp, with 22% fat, is a high energy density (288 kcal/100 g) fodder for chickens and is rich in linoleic acid (21%). The immature endosperm, eaten as a snack, is of negligible importance in human nutrition.

The Palmyra or Toddy Palm (*Borassus flabellifer* L.)

Abstract

Morton, J.F. (1988) Notes on Distribution, Propagation, and Products of *Borassus* Palms (Arecaceae). *Economic Botany* (1988) 42(3): 420-441

The palmyra palm is a large tree up to 30m high and the trunk may have a circumference of 1.7m at the base. There may be 25-40 fresh leaves. They are leathery, gray green, fan-shaped, 1-3 m wide, folded along the midrib; are divided to the center into 60-80 linear- lanceolate, 0.6-1.2 m long, marginally spiny segments. Their strong, grooved petioles, 1-1.2 m long, black at the base and black-margined when young, are edged with hard spines.

It grows wild from the Persian Gulf to the Cambodian-Vietnamese border; is commonly cultivated in India, Southeast Asia, Malaysia and occasionally in other warm regions including Hawaii and southern Florida. In India, it is planted as a windbreak on the plains. It is also used as a natural shelter by birds, bats and wild animals.

Each palm may bear 6-12 bunches of about 50 fruits per year. An average crop of B. flabellifer in Ceylon is 350 fruits.

The coconut-like fruits are three-sided when young, becoming rounded or more or less oval, 12-15 cm wide, and capped at the base with overlapping sepals. The outer covering is smooth, thin, leathery, and brown, turning nearly black after harvest. Inside is a juicy mass of long, tough, coarse, white fibers coated with yellow or orange pulp. Within the mature seed is a solid white kernel which resembles coconut meat but is much harder. When the fruit is very young, this kernel is hollow, soft as jelly, and translucent like ice, and is accompanied by a watery liquid, sweetish and potable.

Toddy

The chief product of the palmyra is the sweet sap (toddy) obtained by tapping the tip of the inflorescence, as is done with the other sugar palms and, to a lesser extent, with the coconut. The sap flows for 5-6 mo - 200 days in Ceylon - each male spadix producing 4-5 l per day; the female gives 50% more than the male. The toddy ferments naturally within a few hours after sunrise and is locally popular as a beverage; it is distilled to produce the alcoholic liquor called palm wine, arrack, or arak. Rubbing the inside of the toddy-collecting receptacle with lime paste prevents fermentation, and thereafter the sap is referred to as sweet toddy, which yields concentrated or crude sugar (gur in India; jaggery in Ceylon); molasses, palm candy, and vinegar.

Palmyra palm jaggery (gur) is much more nutritious than crude cane sugar, containing 1.04% protein, 0.19% fat, 76.86% sucrose, 1.66% glucose, 3.15% total minerals, 0.861 % calcium, 0.052% phosphorus; also 11.01 mg iron per 100 g and 0.767 mg of copper per 100 g. The fresh sap is reportedly a good source of vitamin B complex.

Seedlings

The peeled seedlings are eaten fresh or sun-dried, raw, or cooked in various ways. They also yield starch, which is locally made into gruel, with rice, herbs, chili peppers, fish, or other ingredients added. It has been proposed for commercial starch production.

Fruits

Small fruits are pickled in vinegar. In April and May in India, the shell of the seed can be punctured with a finger and the sweetish liquid sucked out for refreshment like coconut water.

Immature seeds are often sold in the markets. The kernels of such young seeds are obtained by roasting the seeds and then breaking them open. The half-grown, soft-shelled seeds for the hollow jelly-like kernels are sliced longitudinally to form attractive loops, or rings and these, as well as the whole kernels, are canned in clear, mildly-sweetened water, and exported. Tender fruits that fall prematurely are fed to cattle.

The pulp of mature fruits is sucked directly from the wiry fibers of roasted, peeled fruits. It is also extracted to prepare a product called punatoo in Ceylon. It is eaten alone or with the starch from the palmyra seedlings. The fresh pulp is reportedly rich in vitamins A and C.

Proximate analyses of leaves, fruit, seedlings, immature seed, and "seed" of B. flabellifer have been assembled from various sources by Atchley (1984) (see below).

Folk Medicine

There are innumerable medicinal uses for all parts of the palmyra palm. Briefly, the young plant is said to relieve biliousness, dysentery, and gonorrhea. Young roots are diuretic and anthelmintic, and a decoction is given in certain respiratory diseases. The ash of the spadix is taken to relieve heartburn and enlarged spleen and liver. The bark decoction, with salt, is used as a mouth wash, and charcoal made of the bark serves as a dentifrice. Sap from the flower stalk is prized as a tonic, diuretic, stimulant, laxative and anti phlegmatic and amebicide. Sugar made from this sap is said to counteract poisoning, and it is prescribed in liver disorders. Candied, it is a remedy for coughs and various pulmonary complaints. Fresh toddy, heated to promote fermentation, is bandaged onto all kinds of ulcers. The cabbage, leaf petioles, and dried male flower spikes all have diuretic activity. The pulp of the mature fruit relieves dermatitis.

Chemical analysis

As % of dry matter

	DM	CP	CF	Ash	EE	NFE	Ca	P	Ref
Leaves	-	13.3	38.0	7.4	4.6	74.7	-	-	*
Fruit	-	6.5	16.1	4.8	0.8	87.9	0.22	0.24	*
Immature Seed	-	5.1	7.9	1.7	0.6	92.7	0.17	0.18	*
Shoot	-	8.9	7.2	3.3	0.7	87.2	0.06	0.46	*
Fruit	-	3.1	-	3.1	0.9	93.4	-	-	*
Seed	-	8.1	-	3.5	1.4	85.1	-	-	*

*Atchley (1984)

Reference

Atchley, A. A. 1984. Nutritional value of palms. *Principes*

28(3):138-143.

The Prickly Pears (*Opuntia* spp., Cactaceae).

Abstract

The prickly-pears (*Opuntia* spp., Cactaceae): a source of human and animal food in semiarid regions. Russell, CE and Felker, P. 1987. *Economic Botany*. 1987, 41: 3, 433-445.

Literature on the uses of *Opuntia* spp. is reviewed. The genus *Opuntia* appears to have its centre of genetic diversity in Mexico where it is widely used as fodder, forage, fruit and a green vegetable. In SW USA, *Opuntia* spp. can be both weeds and valuable forage plants.

During droughts propane torches known as 'pear burners' are used to singe the spines off cactus pads so that they can be eaten by livestock. Although spineless *Opuntia* varieties can be consumed directly by domestic livestock, they are extremely susceptible to herbivory by wildlife. The Cactaceae can be 4- to 5-times more efficient in converting water to DM than the most efficient grasses. Some *Opuntia* strains grow rapidly with fresh fruit yields of 8-12 t/ha year, and DM vegetative production of 20-50 t/ha year.

The Tamaulipan biotic province of South Texas and northeastern Mexico is a semiarid to subhumid environment. Local ranchers maintain that 3 or 4 out of 7 years will be drought years from the standpoint of obtaining a grass crop on rangelands. This unpredictability creates problems for range management that frequently result in rangelands being severely degraded by overgrazing.

Large sums of money are frequently spent to convert coastal plain and chaparral into grassland that can be maintained only for limited periods. Stocking rates based on the estimated forage production of the introduced grasses generally use the average rainfall estimate, which is not predictable for the anticipated growing season.

In the light of the known variability of the precipitation regimen, we believe that prickly-pear should be included in any range management scheme in the Tamaulipan biotic province and similar areas of

the world. During favorable forage production years, these cacti - protected from herbivory by their spines - would sequester minerals and water while producing carbohydrates and vitamins, which could be made available during drought years more economically than alternative feeds by burning off their spines.

In South Texas, prickly-pear (e.g., *O. lindheimeri*) is widely known as an emer- gency drought feed for cattle. In drought periods when grasses have been over- grazed or have become senescent, this cactus remains succulent and green, with a normal complement of vitamins and carotenoids (precursor to vitamin A). During the drought of the 1950s in Texas, prickly-pear was held in high esteem by cattlemen.

We suggest that prickly-pear can be grown as a fodder crop on land presently deemed marginal for other crops (e.g., maize and sorghum) because of its greater water-use efficiency. This fodder can be of either the spiny or spineless varieties. As an alternative to burning off the spines with pear burners, harvested spiny pad s can be mechanically

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