Nutritional potential of fodder trees and shrubs as protein sources in ruminant nutrition

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INTRODUCTION

Fodder trees and shrubs represent an enormous potential source of protein for ruminants in the tropics. Until relatively recently, these feed resources have been generally ignored in feeding systems for ruminants, mainly because of inadequate knowledge on various aspects of their potential use, as well as initiatives associated with the development of more innovative systems of feeding.

Throughout the tropics, and especially in the humid regions, there exist a variety of feed resources. These include a variety of forages and abundant supplies of crop residues, agro-industrial by-products and also non-conventional feed resources. Among these, approximately 50 to 60% of the feeds produced are dry bulky roughages, mainly cereal straws and stovers. In Asia, the volume of production is increasing at about 3% annually. However, not all these feeds are put to maximum and efficient use. Inefficient utilisation is identified with low levels of animal production in which the contribution from ruminants (buffaloes, cattle, goats and sheep) compared to non-ruminants is especially low.

The use of fodder trees and shrubs has been secondary to these efforts, despite their potential value in prevailing small farm systems (Devendra, 1983). These alternative feeds merit increased research and development in the future (Devendra, 1990a). This paper highlights the potential value of fodder trees and shrubs as sources of feeds, draws attention to results of work where there are clear demonstrable benefits, practical technologies that are potentially important, and emphasises the need to accelerate their wider utilisation in feeding systems for ruminants.

NUTRITIONAL CONSIDERATIONS

It is appropriate to keep in view several fundamental aspects of nutrition which are associated with the use of tree fodders and shrubs. These are voluntary feed intake (VFI), which determines the amount of dry matter intake (DMI), and digestibility. These aspects are briefly reviewed.

Dry Matter Intake

Maximum DMI is very important factor in ensuring the release of adequate nutrients for maintenance and production. With temperate grasses, voluntary food intake (VFI) directly affects their digestibility, but the relationship is less definitive for tropical species (Milford, 1967) because of the different lengths of time required to digest tropical feeds. VFI has been shown to decrease with decreasing digestibility of dry matter within species for *Chloris guyana* (Milford and Minson, 1968), *Panicum* spp. (Minson, 1971a) and also for legumes (Minson, 1971b). Minson (1971b) also reported that tropical grasses decrease in dry matter digestibility at a daily rate of 0.1 to 0.2 digestibility units.

In terms of VFI, considerable variation exists between and within tropical grasses. Some of the variations are due to differences in digestibility but other unrelated factors such as those recorded for *Panicum* varieties may be involved (Minson, 1971a). Rate of decrease in digestibility of younger tropical herbages is as high as in temperate species (Minson, 1971a). The decline in digestibility with age of tropical grasses was more rapid than with tropical legumes which retained relatively high digestibilities at maturity (Milford and Minson, 1968). Differences in *in vitro* digestibility have been reported between genotypes of *Digitaria* (Strickland and Haydock, 1978). Selection for high *in vitro* digestibility was successful in producing a high *in vitro* digestibility of dry matter and superior VFI of *Cenchrus ciliaris* (Minson and Bray, 1985).

In the humid tropics, DMI is limited by the water content of, or the free water on, the ingested herbage. In the West Indies for instance, the dry matter content of herbage during the wet season was very low in Pangola grass (*Digitaria decumbens* Stent) with a dry matter content of

23.4%, compared to 39.3% in the dry season, such that the herbage contributes a high proportion of the total water consumed (Butterworth *et al.*, 1961). Similar observations have also been made in Thailand (Holm, 1973). Inadequate dietary energy arises from reduced DMI and is likely to occur when the DM content falls below 25%.

Digestibility

Associated with VFI of the forage is digestibility. Digestibility of a feedstuff is affected by stage of maturity of the crop, botanical composition, DMI and dietary supplements, processing, and chemical treatment. In general, the more digestible a feedstuff is, the more it is eaten by the ruminants (Blaxter, 1962). Such is the case that high digestibility increases DMI. Increasing digestibility means that high proportion of the food is absorbed and digestion is more complete, with the volatile fatty acids (VFA) showing a lower proportion of acetic acid, the energetically lowest and least useful VFA, and with the presence of higher proportions of the more useful acids such as propionic and butyric acids.

Level of Dietary Protein

VFI is influenced to a very large extent by the dietary crude protein content. The protein content of tropical forages is generally low (French, 1957; Bredon and Horrell, 1961; Butterworth, 1967). The protein content falls rapidly with growth and reaches a low level before flowering. During the dry season, the crude protein levels fall to very low critical levels, even below 7% in the dry matter. The level of protein in the diet affects voluntary intake of food (Campling *et al.*, 1962; Blaxter and Wilson, 1963; Elliott and Topps, 1963) and low protein diets are not readily eaten by ruminants. In sheep, a 7% crude protein begins to limit intake (Milford and Minson, 1968). Leibholz and Kellaway (1984) have estimated that the minimum required crude protein of a poor quality diet with a digestibility of organic matter of 50% would be between 6.1 to 7.4%.

Quantity of Net Energy Available

The quantity of net energy (NE) available for production is controlled by three related factors (Minson, 1985): the quantity of feed eaten (I), the proportion of each unit of feed that is digested (D), and the efficiency of utilization of the products of digestion (E). This is represented by the equation:

$$NE = I \times D \times E$$

The quantity of NE available and its utilization is dependent on the type of feed, nutrient balance, extent of VFI, animal species, and function.

IMPORTANT FODDER TREES AND SHRUBS

Diversity

There is considerable diversity in the forage supplements that are of value to ruminants. Table 1 brings together the more commonly used shrubs and tree fodders in different parts of the developing countries. The list is not exhaustive, but is meant to focus on those feeds that are emerging as important in feeding systems for various ruminants. Of the 12 more important feed sources listed, *Acacia* spp., *Ficus* spp., cassava (*Manihot esculenta* Crantz), *Erythrina* spp., *Gliricidia* spp., *Leucaena leucocephala*, *Prosopis cineraria* and *Sesbania* spp. are widely used in the tropics.

Nutritional advantages

The value of these forages is associated with a number of advantages. With *Leucaena* for example, it provides a valuable source of protein, energy and sulphur for the rumen bacteria. It is also valued in multipurpose use in fence lines and as a fuel. With specific reference to their value in animal feeding, the advantages include *inter alia* (Devendra, 1988): availability on the farm; accessibility; provision of variety in the diet; source of dietary nitrogen, energy, minerals and vitamins; laxative influence on the alimentary system; reduction in the requirements for purchased concentrates; and reduced cost of feeding.

TABLE 1.
Important tree fodders and shrubs for feeding ruminants.

Common name	Botanical name
1. Acacia	*Acacia catechu*
	Acacia nilotica
	Acacia siberiana
2. Cassava	*Manihot esculenta* Crantz
3. Calliandra	*Calliandra calothyrsus*
4. Erythrina	*Erythrina variegata*
5. Ficus	*Ficus exasperata*
- Banyan	*Ficus bengalnensis*
- Peepul	*Ficus religiosa*
6. Gliricidia	*Gliricidia sepium*
	Gliricidia maculata
7. Jackfruit	*Artocarpus heterophyllus*
8. Leucaena	*Leucaena leucocephala*
9. Pigeon pea	*Cajanus cajan*
10. Prosopis	*Prosopis cineraria*
11. Sesbania	*Sesbania grandiflora*
	Sesbania sesban
12. Tamarind	*Tamarindus indica*

Nutritional characteristics

Table 2 presents some of the nutritional characteristics of principal tree fodders and shrubs. The data has been assembled from various sources, but in particular Devendra (1979), N.R.C. (1981), Kearl (1982) and Devendra (1990b). In the absence of data on cell wall contents, the average crude fibre level is indicated.

The table indicates that the crude protein (CP) contents of many of these feeds (cassava, *Calliandra, Erythrina, Leucaena* and pigeon pea) is high and in the range 22.2 - 25.8%. *Ficus, Acacia, Gliricidia,* jackfruit and *Prosopis* had crude protein contents in the range 14.0 - 15.1%. The metabolisable energy (ME) content, with the exception of acacia was in the range 11.2 - 14.4 MJ/kg. It is of interest to note that the Ca content of many of these feeds is also relatively high. These include, in particular, cassava, *Calliandra, Prosopis,* tamarind and

Gliricidia, in which the range was 1.57 - 2.81%.

TABLE 2.
Nutritional characteristics of principal tree fodders and shrubs.

Feed source	DM (%)	% DM basis CP*	CF*	EE*	Ash	ME (MJ/kg)	Ca (%)	P (%)
Acacia	29.0	15.1	22.6	8.9	8.2	8.4	1.21	0.06
Cassava	21.1	24.2	15.6	4.0	6.6	14.4	2.62	0.22
Calliandra	26.4	24.0	21.7	2.4	8.0	12.6	1.6	0.2
Erythrina	32.0	25.8	17.4	5.8	6.7	14.3	-	-
Ficus	17.0	14.0	22.4	4.5	5.8	12.0	1.31	0.17
Gliricidia	25.0	14.7	19.9	5.4	4.7	12.84	1.58	0.29
Jackfruit	36.6	14.0	22.1	3.8	11.5	14.2	1.46	0.15
Leucaena	30.0	22.2	19.6	6.9	4.4	12.1	0.27	0.12
Pigeon pea	25.2	22.8	20.1	5.6	5.8	13.4	0.37	0.17
Prosopis	23.4	14.0	17.8	1.9	6.8	11.2	2.73	0.15
Sesbania	18.0	22.6	18.4	2.1	9.3	13.6	1.48	0.34
Tamarind	28.0	14.0	21.0	4.6	8.6	14.4	2.81	0.20

* CP - crude protein, CF - crude fibre, and EE - ether extract

DEMONSTRATION OF BENEFICIAL EFFECTS

The potential value of these forages for ruminants has recently been reviewed (Devendra, 1990b). Tables 3 and 4 demonstrate the benefits in buffaloes and goats concerning feeding systems in which cereal straws were used. The review enabled the following main conclusions:

(i) The use of forage supplements consistently increased live weight gain or milk production.

(ii) Of the forage supplements that have been used, the leguminous types have been especially advantages.

(iii) The beneficial responses (meat or milk production) was associated with a reduced cost of feeding.

(iv) With large ruminants, research on the utilization of forage supplements for draught is very sparse.

TABLE 3.
Results of economic benefits of forage supplements in diets for buffaloes

Feeding regime	Forage supplement	Location	Significant response	Result	Reference
Wheat straw* + conc.	Lucerne + berseem	India	Milk	Reduced cost/kg SCM milk	Gupta *et al.* (1983)
Rice straw**	*Gliricidia* or *Leucaena*	Sri lanka	Milk	Increased margin over costs	Perdok *et al.* (1984)
Rice straw***	Berseem	India	Milk	Reduced cost/kg milk	Agarwal *et al.* (1989)
Rice straw**	*Gliricidia*	Sri Lanka	Milk	Increased milk production	van der Hock *et al.* (1988)

* Wheat straw
** Urea-treated rice straw
*** Urea-treated or untreated rice straw

TABLE 4.
Results of the benefits of forage supplements to goats

Breed	Major feed	Type of forage supplement*	Significant response**	Location	Reference
Native	Maize stover	LE	L.W.I.	Philippines	Linggodjiwo (1976)
Native	Concentrate	LE	L.W.I.	Philippines	Abilay and Arinto (1981)
Crossbreds	Napier grass	LE	L.W.I.	Malaysia	Devendra (1982)
Kachang	*P. purpureum*	CL	L.W.I.	Indonesia	Djajanegara *et al.* (1983)
Native	Browse	PR	L.W.I.	India	Parthasarathy (1983)
Native	Para grass	LE	L.W.I.	Philippines	Abayan and Boloran (1984)
Kachang	*P. purpureum*	CL	L.W.I.	Indonesia	Mathius *et al.* (1984)
Kachang	*P. purpureum*	GL	L.W.I.	Indonesia	Rangkuti *et al.* (1984)
Kachang	*P. purpureum*	GL	L.W.I.	Indonesia	Rangkuti *et al.* (1985)
Kachang	*P. purpureum*	CL	L.W.I.	Indonesia	Mathius *et al.* (1985)
Kachang	Native	CL	L.W.I.	Indonesia	Sitorus (1985)
Kachang	*P. purpureum*	LE, GL, S	L.W.I.	Indonesia	van Eys *et al.* (1986)
Native	Concentrate	PR	L.W.I.	India	Parthasarathy *et al.* (1986)
Kachang	*P. purpureum*	GL	L.W.I.	Indonesia	Haryanto (1988)

* CL = *Manihot esculenta* Cranz. GL = *Gliricidia maculata* S = *Sesbania grandiflora*
LE = *Leucaena leucocephala* PR = *Prosopis cineraria*

** L.W.I. = Liveweight increase

In Sri Lanka, a supplement of 1.5kg of rice bran with 3.0kg *Gliricidia maculata* per head to Surti buffaloes on urea treated rice straw in two systems of production (open system in which the straw from two systems of production was kept unsealed in stacks, and closed system in which the straw was kept in cement pits and sealed with polythene) showed that supplementation significantly increased ($P < 0.05$) the difference in milk and butterfat production. There was no effect on live weight gain of cow and calf (van der Hock *et al.*, 1988).

Earlier work, also in Sri Lanka, showed that feeding 1600g *Gliricidia sepium* forage (DM/cow/day) increased milk and milk fat yields. With coconut cake supplementation, both milk yield and milk fat yields were significantly increased ($P < 0.05$), whereas *Gliricidia* and *Leucaena* leaves did not affect either component (Perdok *et al.*, 1984).

Supplementation of *Chloris gayana* hay with 200 to 300g of dried *Leucaena* leaves given to goats in Tanzania significantly increased organic matter intake, crude protein intake and daily growth rate compared to the unsupplemented control group. In the digestibility study, *L. leucocephala* supplementation increased total dry matter intake from 42.3 kg $W^{0.75}$ in the control group to 77.9 kg $W^{0.75}$ in hay with leucaena fed *ad libitum*.

Current evidence of the value of supplementary forages and especially the leguminous ones suggests the following pointers for practical application (Devendra, 1988) :

- Optimum dietary level on DM basis : 30 to 50%
- As per cent of live weight : 0.9 to 1.5%

POTENTIAL TECHNOLOGIES

The extension of the value of tree fodders and shrubs for ruminants needs to be identified with practical technologies that can ensure demonstration of the beneficial use and also relevance at the farm level. The following practical technologies are worthy of attention and are potentially important: (i) three-strata forage system; (ii) integrated tree cropping systems; (iii) agro-forestry systems; (iv) food-feed intercropping; (v) relay cropping; (vi) alley cropping, and (vii) grazing and stall feeding systems.

Three Strata Forage System

In dryland farming areas, a major constraint to higher productivity from ruminants is the unavailability of good quality feeds especially during the dry season and periods of drought. The development of feeding systems that can increase the supply of good quality forages and dietary nutrients for the animals is therefore especially important to improve the prevailing low level of animal performance.

This is exemplified by the situation in the island of Bali which has approximately three million people and three rainfall zones. Twenty five *per cent.* of the land area is semi-arid with a rainfall of 900-1500 mm/year. Farmers constitute about 70% of the total population and most of them practice mixed crop-animal farming. Among ruminants, Bali cattle are particularly important and in the dry parts of the island, income from livestock accounts for about 39-43% of total farm income. Farmers generally own 2-3 head of cattle which are used for draught and beef production.

The need for increasing the feed resource base as well as develop sustainable systems of production led to the successful demonstration of the three strata forage system. The system involves grasses and ground legume (first stratum), shrub legumes (second stratum) and fodder trees (third stratum).

Considerable progress has been made in the implementation of this concept and research over the last 6 years has demonstrated considerable benefits. For example, the inclusion of *Stylosanthes*, *Centrosema*, *Acacia*, *Gliricidia* and *Leucaena* increased the supply of forages and enabled higher stocking rates and live weights to be achieved: 3.2 animal units (375 kg)/ha/year in the TSFS compared to 2.1 animal units (122 kg)/ha/year. Additionally, the system promoted increased firewood production as well as reduced soil erosion (Nitis *et al.*, 1990; Lana *et al.*, 1990).

Integrated tree cropping systems

Integrated tree cropping systems with coconuts, oil palm and rubber trees, involving ruminants, is a potentially important production system especially in the humid tropics. The benefits of the system include: increased fertility of the land via the return of dung and urine; control of waste herbage growth; reduced use of herbicides; presence of shade reduces heat stress; easier management of the crop; and distinct possibilities of increases in crop yields, consistent with greater economic including sale of animals and their products.

In these situations, tree crops have a very valuable role in terms of multi-purpose use: supply of feed, fenceline, fuel and soil fertility. Several of the tree fodders identified in Table 1 will fulfil these objectives.

Silvi-pastoral systems

Agro-forestry systems that combine the use of multi-purpose trees and integration of animals is an avenue that has not adequately investigated. The system has considerable importance, especially in upland areas and elsewhere where the role of fodder trees becomes especially important. The wider use of agro-forestry systems has complimentary advantages of forage production, supply of fuelwood, improvement of soil fertility and permanent soil cover and promotion of economic and sustainable land use.

Food-feed intercropping

The concept of food-feed intercropping in both lowland and upland small farm systems has two principle advantages: firstly, the system aims to provide sustainability, involving the complimentary role of crops and animals; secondly, and with respect to animals, the use of appropriate forage crops provides fodders and crop residues which are valuable for feeding both ruminants and non-ruminants, as has been demonstrated by work in the Philippines.

The criteria for the choice of the crops to be used in the system include *inter alia*: the type of animals reared, potential forage or crop residue biomass yield, promotion of soil fertility, drought tolerance and extent of the dry season, shade tolerance in upland areas, ease of eradication and resource requirements. The strategy is to integrate, within the rice cropping pattern (inter-cropping and relay cropping), other feed producing crops and also forage crops without, reducing the area of the land used.

Relay cropping

An important means to further increase the supply of feeds for farm animals is to plant a second crop into the first before harvest. Examples of relay cropping are the introduction of legumes (e.g., groundnut and pigeon pea) into the main crop (e.g., rice or wheat). The strategy extends the supply of feeds throughout the year.

Alley cropping

Alley cropping provides an alternative opportunity to integrate crops with animals as well as enhance sustainability. The development of the system has the following advantages: the maintenance and promotion of soil fertility; increasing the supply of animal feeds and fuelwood; and contributing to the development of all-year-round feeding systems.

Grazing and stall feeding systems

Increased and more intensive utilisation of tree forages and shrubs is largely dependent on the type of feeding systems to be practised. Where land is not limiting for intensive pasture production, either grazing and or stall feeding can be adopted. A comparative study of both systems to examine potential milk production in Sahiwal x Friesian cows on *Leucaena leucocephala-Brachiaria decumbens* mixed pasture indicated that rotational grazing was better than stall feeding with mean responses of 8577 and 9180 kg/ha/lactation. Supplementation of concentrates at 4 and 6 kg/cow/day further increased milk production to 13323 and 17070 kg/ha/lactation respectively. The net profit per cow with or without supplementation was lower for rotational grazing on account of higher labour cost for the stall feeding system. The choice of one or the other system is dependent to a very large extent on the cost of the inputs.

DELETERIOUS PRINCIPLES

An area which is emerging to be extremely important in the utilisation of shrubs and tree fodders is the problem of deleterious principles, since they constitute problems in the diet of animals. A variety of these principles are found.

Tannins exist in the condensed or hydrolysable forms at varying levels. The effects of tannins in ruminant feeding is not entirely clear, with possible harmful and beneficial effects, but evidence is increasing that they can have some benefits (Zelter *et al.*, 1970; Barry and Duncan, 1984). High concentrations of tannins can lower voluntary feed intake (Burns and Cope, 1974). More recently, Feng Yu and Leng (1991) have shown that low concentrations of condensed tannins from *Acacia floribunda* provided protection of proteins in lupins and stimulated growth and wool production.

There appears to be an inverse relationship between the protein-precipitating capacity of tannins in tree leaves and their palatability, voluntary intake and digestibilities of crude protein and dry matter in grazing and also browsing animals. The authors have also reported that sulphur and iron become limiting to animals consuming tannin-rich leaves and prolonged consumption of these also induces toxicity. Several of these feeds have deleterious principles and depending on the levels fed, some have side effects on animals. In general, however, these do not present a major barrier to their utilisation by ruminants when used as supplements (about 30% on a dry matter basis).

Under these circumstances, the presence of tannins is an advantage as they protect the proteins from excessive microbial degradation and make these more available posterior to the rumen. Some experiments have shown that supplementation of a basal diet of tropical grass with dried or fresh *Leucaena* resulted in significant quantities of protein leaving the rumen of sheep.

Farmers currently overcome and reduce problems of effects on animals by feeding mixtures of the feeds with or without sun drying. This process not only extends choice of feeds available but also dilutes and reduces problems of palatability and side effects. More information is required on optimum dietary levels of forage supplements either fed alone or in mixtures appropriate to individual ruminants, methods to reduce the incidence and development of suitable mixtures of these in economic feeding systems for individual ruminants. It is possible that between species differences also exist in the response to tannin content in these leaves and these need to be determined.

CONCLUSIONS

Present knowledge on the potential value of fodder trees and shrubs indicates that together with their diversity, these feed resources are extremely useful for feeding domestic ruminants. The demonstrable benefits are improved performance of animals and reduced cost of feeding. These advantages justify more intensive and wider utilisation of fodder trees and shrubs in appropriate feeding systems and represent an important strategy for increasing the current level of contribution from ruminants.

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