NUTRITIONAL CHARACTERISTICS OF TROPICAL FEED RESOURCES: NATURAL AND IMPROVED GRASSLANDS, CROP RESIDUES AND AGRO-INDUSTRIAL BY-PRODUCTS

by

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INTRODUCTION

Numerous studies and reviews have already been completed on this topic, e.g. Osbourn (1976), Minson (1976), Stobbs (1976), Balch(1977), Chenost and Meyer (1977), Jarrige (1979), Göhl (1981), Lane (1981), Preston (1982) and Devendra (1988). In the context of the present consultation, we will therefore restrict ourselves to reviewing the main characteristics of the tropical feed resources which should be taken into consideration when defining diets and feeding systems in accordance with the new principles of ruminant digestive physiology and nutrition.

RUMINANT INTAKE AND DIGESTION

The individual cow's daily production depends not only on its genetic characteristics and its stage of lactation but also a great deal on the quantity and quality of nutrients to its intermediary metabolism. This supply is the result of the voluntary intake and the nutrient density of feed intake.

Voluntary intake depends both on:

- the appetite of the animal which varies according to the animal itself (age, physiological stage, former nutritional status, etc.) and to the environmental conditions (temperature, humidity, etc.) under which the animal is kept, and

- the specific characteristics of the feed.

The voluntary intake of feed depends essentially on the rate of degradation of its digestible matter into particles of a size small enough to enable their passage from the reticulo-rumen to the lower gut. This degradation is achieved by means of the chewing process (eating and rumination) and the microbial fermentation which takes place in the reticulo-rumen. The cell wall content and the magnitude and nature of lignification of these cell walls are amongst the most important factors which govern the degradability and the rate of passage of a forage.

Good microbial activity will require:

- adequate nutrition of the rumen microorganisms: energy in the form of ATP released from soluble and structural carbohydrates of the plant, thanks to the anaerobic fermentation; nitrogen in the form of ammonia generated by the hydrolysis of the fermentable nitrogen; minerals and vitamins;

- good chemical and physico-chemical rumen environment: pH (which should be as constant as possible and not below 6.5 to favour the cellulolytic microorganisms) and a regular outflow from the rumen. These conditions are not only dependent on the properties of the feeds but also on their rationing (number and frequency of meals, physical form of their presentation).

Nutrients required at the tissue level for both maintenance and milk synthesis are supplied by the end products of rumen fermentation (amongst which are the volatile fatty acids (VFAs) and microbial cell proteins) and by the dietary nutrients which have escaped rumen degradation and are digested in the intestine. Depending on the level of production of the host animal, it may be necessary to provide, in addition to the forage, dietary supplements in order to meet its nutritional requirements. These supplements should be administered in a certain amount and should possess characteristics, such that the rumen ecosystem is not impaired and generates the proper amount and relative proportions of microbial protein, VFA energy and glucogenic energy.

In order to define an optimum diet it will therefore be necessary to choose the feeds according to the quality and quantity of energy and nitrogen available. These characteristics cannot be determined by the classical routine analysis. In addition to Crude Protein content and Organic Matter (or energy) digestibility it is important to know:

- an estimate of intake, more particularly for those feeds which compose the basic part of the diet. A good indicator is the rate of their dry matter degradability in the rumen. This can be approached through the nylon bag "in sacco" technique which uses rumen-fistulated animals;

- an estimate of the respective parts of rumen degradable and undegradable ("by-pass") proteins available, respectively, for the rumen microorganisms and the host animal. This can be also approached with the nylon bag technique which can give an estimate of the extent and rate of protein fermentability. The French PDI (Protein Digestible in the Intestine) system (INRA, 1988) can distinguish between the various parts which are finally digested in the intestine, i.e. PDIA (Protein Digestible in the Intestine from dietary origin), microbial protein allowed by available fermentable N (PDIMN) and microbial protein allowed by available fermentable energy (PDIME). The sum of PDIA + PDIMN on the one hand, and the sum of PDIA + PDIME on the other hand give, respectively, the PDIN and PDIE values of a feed. Balancing a diet by supplementing the basic feed with the appropriate supplementary feeds is achieved when PDIN and PDIE values of the diet are equal and meet the production requirements. This system is being adapted, for instance, to the Caribbean feedstuffs (Xandé and Trujillo, 1985).

- Data on energy sources: rate (see above) and type of fermentation. The slowly fermentable energy released from the structural carbohydrates or the more easily fermentable energy released from high digestible cell walls (e.g. citrus, beet or fruit pulps, which both favour a cellulolytic ecosystem. The fast degradable carbohydrates of "sugar type" (molasses) or of "starch type" (cereals, roots and tubers, banana) which both hamper the cellulolytic ecosystem (drop in pH). The end products of the former are essentially C2 whereas those of the second favour C3 VFA. Other important information, but of course difficult to predict, is the good timing of the release of NH_3 and ATP for optimum microbial nutrition and thus synthesis and microbial activity. Finally, an assessment of the undegraded part of energy in the rumen (e.g. rice polishings or maize, rather than wheat or cassava) usable in the intestine for the tissue requirements (glucogenic function) is also important (Preston, 1982; Van Es, 1985).

All these considerations are undoubtedly more important in tropical than in temperate regions even if the levels of animal production are lower. In fact, shortages of nitrogen (tropical feeds also contain less by-pass protein) and of digestible cell-wall energy may occur quite often in tropical countries. It is therefore important to be able to choose the proper missing components among the other locally available resources. As already discussed in several instances, supplements of the tropical basic diets have often more than an additive effect on both intake and animal performances (Preston, 1982; Van Es and Taminga, 1987).

We will briefly distinguish between the basic resources which compose the main parts of the diet and the other various resources which can supplement them.

The former are pastures and green fodders which are of course the principal natural ruminant feed. They are also crop residues, including the fibrous agricultural residues (FAR) which can be used as a substitute (partly or entirely) for herbage in those populated regions like South East Asia where land must firstly be devoted to production of food for man. Another group is the perennial food crops (e.g. sugarcane, bananas), and also roots and tubers which were formerly grown for man and are now more and more considered as feed, either for the dry season or even as the basis of the diet for new feeding systems.

Table 1. Main nutritional characteristics of the principal categories of tropical feed resources.

Feeds	Rumen fermentation		Observations
	Energy	Nitrogen	Utilization
Pastures Green fodders Forages	slowly fermentable VFA - C_2	fair CP content fermentable	-fair intake -lignified -rumen function and rumination Basis of diet
Crop residues: straws stovers canetops	slowly fermentable	very low CP content	-increased OMD and intake with treatment -need fermentable N + PDIA Basis of diet
Feed crops: sugarcane (whole)	slowly) fermentable quickly)	low CP content	-need fermentable + PDIA nitrogen Basis/supplement
Foliages - tree crops including Leucaena, Glyricidia, etc.	fermentable C_2 - C_3	very high CP unfermentable* (by-pass)	-rumen function -aa sources(PDIA) -good intake Supplement/Basis
Agro-industrial byproducts:			
energy			
molasses	easily fermentable ("sugar" type)	low N	Supplement/Basis
pulps (citrus)	easily fermentable ("cell wall" type)	low N	
energy + N			
bran/polishings	fermentable + lipids LCFA	unfermentable N source	Supplement -PDIA + bypass energy,glucogenic
nitrogen			
oil cakes + seeds		high CP	
animal/fish	lipids	PDIA a.a.	Supplement
NH_3 - urea		fermentable	industrial NPN

*Further research is needed regarding the tannin effect on digestion (enzymatic) in the intestine

The other category is roughly made-up of the agro-industrial and various by-products which can be utilized only as part of the diets.

We will now consider the way these feed resources can be utilized in the appropriate combination so that:

- intake of the basic components is maximized,
- animal performances are optimized, and
- cost of diets is minimized.

Although pastures and green fodders are the principal natural feeds for ruminants, there are also other feed resources which can be used as substitutes during the dry season (e.g., crop presidues), supplements (agro-industrial by-products: cereal brans, molasses, oilcakes, etc.) or as the basis of the diet (sugar cane, roots and tubers, bananas).

GREEN FODDERS, HERBAGES AND PASTURES

It is well recognized that the tropical herbaceous and shrub plants become high in lignified carbohydrates and low in total nitrogen when they mature. In addition their mineral content is low and unbalanced; phosphorous is amongst the most frequent deficient macro-elements.

The digestibility of tropical forages decreases at a lower rate than that of temperate ones but this decrease starts earlier and from a lower value at the young vegetation stage (Chenost, 1975; Evans, 1977). As a result, tropical grasses, and to a lesser extent legumes, always have a lower digestibility than the temperate ones (Minson, 1976) as shown in Table 2. In fact, the high content and the type of encrustation of lignin in the plant tissues and cell walls and the low N supply to rumen microbes are reasons which lead to a slow rate of breakdown and passage of particles to the lower gut and reduced intake of tropical grasses.

However, except in the case of natural pastures in dry tropical areas, tropical pastures have a tremendously high dry matter productivity. This productivity enables maintenance of high stocking rates (carrying capacity) as shown in Table 3.

The yields of tropical C4 grasses (e.g. *Digitaria decumbens*) responds linearly to annual rainfall (or water supply when irrigated) when fertilized with nitrogen up to 400 kg N/ha (Salette, 1970). Nitrogen fertilization however does not increase the animal's daily production since it has very little or no effect on digestibility and voluntary intake.

Milk production per area unit can thus reach high levels, thanks to the stocking rate, but with low individual production per animal,

Table 2. Examples of digestibility, intake and rumen fermentation by sheep of some tropical grass hays. (from O. Kawamura *et al.*, 1985)

Nature of grasses (*)	Regrowth number	Vegetative stage	Dry matter intake g/kg LW 0.75	Dry matter digestibility (per cent)	Crude Protein content (per cent DM)	ADF	VFA mm/100ml	C2 percent	C3 VFA
Green panic	1	flowering	47.7	58.9	10.2				
	2	heading	45.9	53.4	13.5				
	3	heading	52.9	54.4	11.9				
Sudan grass	1	flowering	42.0	53.7	11.9				
	2	vegetative	50.7	55.0	15.6	37.5	5.62	75.1	13.0
	3	vegetative	48.0	58.0	14.9	to	to	to	to
						49.1	8.96	82.6	18.2
Rhodes grass	1	vegetative	44.2	56.3	10.0				
	2	vegetative	42.4	60.7	13.2				
	3	flowering	47.4	59.6	12.2				
African millet	1	vegetative	49.5	60.7	14.0		10.24		
Italian Ryegrass	1	heading	70.1	72.5	13.6	28.1	12.24	70.1	22.3
	2	heading	59.1	58.6	11.1	41.8	10.20	71.6	21.0

(*) wilted and air dried
ADF = Acid Detergent Fibre; VFA = Volatile Fatty Acids; C2 = Acetic Acid; C3 = Propionic Acid.

as shown by numerous authors quoted by Evans (1977) (Table 4). Such low daily milk production levels (seldom higher than 12 kg) may hamper the duration of the lactation curve.

Many studies have shown that trying to increase individual production by exploiting the grass cover at an earlier stage of growth is wasteful and uneconomic. A recent study on buffaloes has also lead to the same conclusions (Wanapat and Topark-Ngarm, 1985). In fact, the loss in DM production/ha is not compensated for by the very small benefit, in terms of DOM intake, which could be expected from a faster turn-over.

Whereas a 4,500 kg milk lactation needs, in addition to a typical temperate forage-based diet, an average of 150 g concentrate for each kg of milk produced, the same level of milk production requires an average of 300 to 350 g concentrate in the case of a typical tropical forage-based diet. Such amounts are uneconomic (except when concentrates are subsidized) and illogical (substitution effect of concentrate depresses the DM intake of forage). It is therefore necessary to resort either to an improvement of the basic diet or to design a strategy of supplementation taking into account other local feed resources (see below).

In areas where rainfall is higher than 750 mm per year, it is possible to oversow natural pastures with legumes which, most of the time, are not present in the primary grass cover. The effect of legumes is two-fold: firstly fixation of substantial amounts of N and therefore increase of the production of the associated grasses, and secondly an increase in the feeding value of the grass cover resulting from the higher N content and by-pass protein, the higher OMD and intake of legumes. A lot of research work has shown the importance of fodder legumes (Table 4) on the individual cow's daily production. The strategy to be finally adopted regarding the type of pasture (pure grasses versus grass/legume association) is however not only a nutritional problem but also an agronomical and managerial one.

But tropical green fodder, which represents the cheapest sources of forage, cannot in general ensure high individual milk secretion levels. The main limiting factors are intake and N content and quality.

CROP RESIDUES

The fibrous agricultural residues (FAR) represent a considerable potential forage resource in the populated countries where land must be devoted to human food production as a priority. A comprehensive review of their potential in the developing countries and of the strategies for expanding their utilization has been achieved respectively by FAO (1985) and IDRC and ICAR (1988).

Table 3. Carrying capacity and milk production per hectare from various pasture systems (from Stobbs, 1976, quoted by Jarrige, 1979).

Pasture system	Stocking rate (cows/ha)	Milk production (kg/ha/year)
- unfertilized grass	0.8 - 1.5	1,000 - 2,500
- grass-legume	1.3 - 2.5	3,000 - 8,000
- nitrogen fertilized grass (+P, S, K)	2.5 - 5.0	4,500 - 9,500
- nitrogen fertilized grass, irrigated (+P, S, K)	6.9 - 9.9	15,000 - 22,000

Table 4. Milk production from tropical pastures without supplementary feed (extracted from Evans, 1977)

Pasture	Stocking rate	Breed	Milk yield	
	(cow/ha)		kg/cow/day	kg/ha/yr
Unfertilized pastures				
P. maximum	1.1	Jersey	6.8	2,667
M. miniflora				
P. maximum	1.0	Jersey/Criollo	6.9	2,667
D. decumbens	1.5	Friesian/Zebu	6.9	3,760
Grass-legume fertilized pasture				
P. maximum/ Glycine	1.3-2.5	Friesian	12.4-13.7	4,954-8,221
D. decumbens/ Centro	1.7	Friesian/Zebu	7.3	4,530
Nitrogen fertilized pure grass				
D. decumbens	2.5	Jersey	6.8	6,014
D. decumbens	6.9	Friesian/Zebu	10.9	17,408
D. decumbens	8.0	Jersey	6.5	22,466

Amongst the world's total crop residues maize yields the largest amount and wheat, rice and paddy and pulses each yield about half the amount of maize. The remainder consists of sorghum stovers, barley straws, sugarcane tops and leaves, roots and tubers, oil plants stovers and foliage (Kossila, 1985). They are still underutilized as feed resources, except in Asia where they form the first component of the ruminants' diet.

Their feeding value is limited by their poor voluntary intake, low digestibility and low nitrogen, mineral and vitamin content. In addition they are very slowly fermented in the rumen. In fact, they consist essentially of lignified structural carbohydrates, since they represent the dead aerial part of the mature plant after harvest.

The use of FAR as cattle feed has generated considerable research work in the last 20 years but unfortunately much less development application. However, they can represent the basic part of ruminants' diet provided:

- conditions for their good cellulolysis are met (rumen activity), and
- additional nutrients required for productive functions (host animal), e.g. PDIA and energy escaping rumen fermentation are properly supplied (do not impair the above condition as stated in para. II).

Their better digestive utilization can be achieved either through an appropriate supplementation (legumes, molasses, fruit pulps, poultry manure, urea, etc.) or chemical pre-treatments (urea/ammonia treatments) which both facilitate the microbial breakdown of the cell-walls. Appropriate supplements which enable a good cellulolysis can be chosen among the local feed sources on the ground of the characteristics listed in Table 1: the appropriate fermentable N supply can be of natural (poultry manure) or industrial (urea) origin; the fermentable energy (of the "digestible cell-wall" type) is typically fresh grass or good quality foliage and, of course, all the easy digestible agro-industrial pulps, e.g. citrus,pineapple, etc. The breakdown of FAR can also be improved by chemical treatments (Sundstøl and Owen, 1984) among which urea-generated NH_3 is probably the technique which best fits in with the socio-economical conditions found in tropical developing countries where inputs must be kept at the lowest level possible.

Treated or not, FAR must be combined with feed supplements which provide adequate nutrients to the rumen microorganisms. The former, however, still require to be known with a better accuracy than at present. Recent research works (Silva and Ørskov, 1988; Ramihone, 1987) have shown the importance - in addition to NH_3-N - of true protein sources on the cellulolytic microbial growth. This is another reason for supplying any cheap protected protein source (e.g. legume trees and foliages, ricebran), which, as seen above, are necessary for the production requirements of the host animal.

FOOD CROPS

Various perennial food crops which were formerly grown only for human consumption are now more and more considered as feed sources for the dry season and even as the basis of feeding systems. The main ones are sugarcane, cassava, banana, etc.

Amongst the various reasons for such their increasing use, two are probably most important. The first is the tremendous dry matter productivity/ha of these crops. The second one lies in the fact that, as opposed to conventional fodder crops, their nutritive value is not affected by the age of the plant which has already reached its stage of maturity. Their exploitation is therefore very flexible and easier than that of herbage.

1) The most typical example is probably the sugarcane, exploited as a whole plant. Sugarcane could play the same role in tropical animal production as the forage maize - whole plant - in the temperate countries. First considered in experiments by Preston in the 1970's, the sugarcane (whole plant) is typically the addition of two opposite types of forage components: structural carbohydrates of low and slowly digestible energy and soluble carbohydrates (sucrose) rapidly fermentable. In addition its N content is very low.

Whole sugarcane-based systems have proven to be technically and economically a very attractive solution for small to average dairy or dual purpose units in sugarcane producing countries where areas for fodder pastures are limited. As described by Preston and Leng (1978) the deficient nutrients may essentially be provided by locally grown (or available) feed resources:

- fermentable N (PDIN) by green fodder or crop foliages and leaves (e.g. those of cassava) or by urea,(industrial NPN source);

- "by-pass energy" by rice polishings and/or roots, tubers (cassava) and fruit (bananas - banana rejects);

- unfermentable nitrogen ("PDIA"/"by-pass N") by legume-trees, namely *Leucaena leucocephala*, *Gliricidia*, *Erythrina*, and when necessary by oil cakes, e.g. cotton seed cake.

2) Cassava (*Manihot esculenta*) is another fodder crop of great interest as a feed resource (Devendra, 1977). Its tubers are a valuable energy source which can also provide glucose at the intestine level as its starch can partially escape the rumen fermentation. Its leaves, exploited either as a green fodder (several cuts before harvesting tubers have proved to be still compatible with a satisfactory tuber yield) or, at the time of harvesting, the tubers

are valuable sources of both PDIN and, to a reasonable extent, PDIA.

3) Another interesting plant is the banana, either considered as a whole plant (when blown down by tropical winds and hurricanes) or as a fruit (starch source) when considering the discarded bananas which remain available on the premises of the conditioning exportation units (Le Dividich *et al.*, 1976). The banana as a basis of the diet is more adapted to beef production in view of its high starch and poor N content. As seen above it may however remarkably complement sugarcane. The whole plant can also be envisaged as the basis of the diet for milk producing animals.

AGRO-INDUSTRIAL BY-PRODUCTS

They can be classified into 4 groups:

- By-products providing essentially easily fermentable energy through digestible cell-walls, starch or sugars. They may constitute the basis or the major part of the diet. They derive mainly from sugarcane, citrus, roots and tubers, bananas, coffee...

- By-products which are mainly used as a source of supplementary protein: oil-seed cakes, animal wastes from slaughterhouses and fisheries, by- products from pulses, single cell proteins.

- By-products providing both energy and protein: eg: cereal milling by-products, brewer's and distiller's grains and whey.

- other by-products coming from fruit, bakery and other food industries which provide various kinds of nutrients.

All these by-products have been reviewed by various authors (Chenost and Meyer 1977, IDRC and ICAR 1988). We will therefore restrict to a brief account of the more important ones taken as examples.

Molasses

This is a feed which is rapidly and entirely fermented in the rumen. Between 10 and 30% of the diet, as is traditionally the case there is no particular problems with molasses for all types of livestock. However when the diet is based on molasses (eg: >70%) the behavior of cattle is different and the management of the herd must be more careful (Preston and Willis 1974). A small amount of fibre is vital for ensuring the normal physical function of the rumen. Non-protein nitrogen is essential for the development of the micro-organisms of the rumen. Furthermore the animal responds dramatically to small amount of protein like fish meal, which can escape the rumen fermentation (Preston 1985).

However it has never been possible to incorporate as high levels of molasses in the diet of lactating cows as in the case of fattening cattle. The reason is that diets high in molasses lead to insufficient amount of glucose and glucose precursors (low propionate and high butyrate) in the end products of digestion (Leng and Preston 1976).

Molasses which is an excellent carrier for urea as a source of non protein nitrogen for ruminants can be more easily used as a supplement and distributed to small farmers when is part of solid multinutrient blocks (Leng 1984, Sansoucy 1986, Sansoucy et al 1988).

Citrus and sugarbeet pulps

Due to the high digestibility of their non lignified cell walls they favor, as opposed to molasses, the cellulolytic activity of the rumen. Due to the relatively moderate rate of fermentation (as opposed to sugars) they also represent good carriers of NPN and ensure an efficient microbial synthesis (synchronization of both ATP and NH_3 releases). They can constitute the major part of the diet as well as an excellent energy supplement for diets based on fibrous crop residues.

Oil cakes and seeds and by-products of animal origin

They have been comprehensively reviewed in the 1988 IDRC and ICAR's publication. They constitute the largest source of supplementary protein. As mentioned earlier in this paper, the assessment of their potential use as protein supplement will be based on the degree of degradability of their nitrogen in the rumen.

As they represent a source of foreign exchange and of high quality protein for human and non ruminant animals, their use as protein supplement for ruminants should be considered against the local availability of legumes and or legume trees.

Cereal milling by-products

They are very well known and their use is expanding. Their major asset is the fact that they supply at a time, moderately fermentable energy, dietary protein and neoglucogenic nutrients. As an example, rice polishings can play a remarkable role in balancing sugarcane based diets.

CONCLUSIONS

As a main concluding remark and as clearly observed by Preston and Leng (1987), the tropical basic feed resources have in common the fact that they are poor in nitrogen (namely in protected dietary PDIA) and rich in carbohydrates. These carbohydrates are however either structural and slowly fermentable or too easily fermentable compared to those of the temperate fodder plants, rich both in cell wall type and in less fermentable type of energy. As a result, taken alone or in combination with each other, they will be fermented in the rumen at very different rates. In addition there is another drawback in that fermentable N (predominant in the main tropical feedstuffs) may also be released too quickly and not in time with the energy. Supplementing tropical feeds with crop residues, feed crops and agro-industrial by-products, will therefore have to take into consideration not only the above described characteristics but also the kinetics of release of the various nutrients. Attention to the rationing aspects will be of major importance.

REFERENCES

Balch, C.C. The potential of poor-quality agricultural roughages for
1977 animal feeding. In "New Feed Resources". Proceedings of a technical consultation held in Rome, 22-24 November 1976. FAO Animal Production and Health Paper No. 4, pp. 1-15.

Chenost, M. La valeur alimentaire du Pangola (*Digitaria decumbens*) et
1975 ses facteurs de variation en zone tropicale humide. *Annales de Zootechnie* 24: 327-349.

Chenost, M. and Mayer, L. Potential contribution and use of
1977 agro-industrial by-products in animal feeding. In "New Feed Resources". Proceedings of a technical consultation held in Rome, 22 - 24 November, 1976. FAO Animal Production and Health Paper No. 4, pp. 87-110.

Devendra, C. Cassava as a feed source for ruminants. In "Cassava as
1977 Feed". Proceedings of a workshop held at the University of Guelph, 18-20 April 1977. pp. 107-119. Ed. Nestle, B. and Graham, M., IDRC.

Evans, T.R. The potential for increasing cattle production in
1977 Malaysia from improved tropical pastures. In Feedingstuffs for Livestock in South-east Asia: pp 37-55. ed. Devendra, C. and Hutagalung, R.I.

FAO. Better utilization of crop residues and by-products in animal
1985 feeding: research guidelines 1. State of knowledge. FAO Animal Production and Health Paper 50.

Göhl, Bo. Tropical Feeds. FAO Animal Production and Health Series, No.
1981 12, 529 pp.

IDRC and ICAR. Non-conventional feed resources and fibrous
1988 agricultural residues. Strategies for expanded utilization. Proceeding of a consultation held in Hisar, India, 21-29 March 1988. Ed. Devendra, C.

INRA. Alimentation des bovins ovins et caprins. Ed. INRA, 147, rue de
1988 l'Université, 75007 Paris, 471 pp.

Jarrige, R. Place of herbivores in the agricultural ecosystems. In:
1979 Proceedings of the 5th International Symposium on Ruminant Physiology, held at Clermont-Ferrand, on 3-7 September, 1979. Ed. Y. Ruckebush and P. Thivend, pp. 763-823.

Kawamura, O., Tanaka, S. and Miaki, T. The digestibility, intake and
1985 rumen fermentation by sheep of some tropical grasses in Japan. Proceedings of the XV Internat. Grassl. Cong.: Kyoto 24-31 August 1985. pp. 1034-1036.

V.L. Kossila. Global review of the potential use of crop residues as
1985 animal feed. In: Better utilization of crop residues and by-products in animal feeding: research guidelines 1. State of knowledge. pp. 1-13.

Lane, I.R. The use of cultivated pastures for intensive animal
1981 production in developing countries. In A.J. Smith and R.G. Gunn (eds.) Intensive Animal Production in Developing Countries, pp. 105-143. Occasional Publication No. 4. British Society of Animal Production..

Le Dividich, J., Geoffroy, F., Canope, I. and Chenost, M. Using waste
1976 bananas in animal feeding. *World Animal Review*, 20: 22-30.

Leng R.A., The potential of solidified molasses-based blocks for the
1984 correction of multinutritional deficiencies in buffaloes and other ruminants fed low quality agro-industrial by-products. In Proceedings of the FAO/IAEA meeting on the use of nuclear techniques to improve domestic buffalo production, 30 Jan.-3 Feb. 1984, Manila, the Philippines, pp. 135-150.

Leng R.A. and Preston T.R., Sugarcane for cattle production: present
1976 constraints, perspectives and research priorities. *Tropical Animal Production* 1: 1-22.

Minson, D.J. Nutritive differences between tropical and temperate
1976 pastures. In: F.H.W. Morley (ed.). World Animal Sciences. Vol. 16. Grazing animals Ch. 7. Amsterdam: Elsevier.

Osbourn, D.F. The utilization of natural grasslands in the tropics.
1976 In: A.J. Smith (ed.). Beef cattle Production in Developing Countries, pp. 184-203. Centre for tropical Veterinary Medicine, University of Edinburgh.

Preston, T.R. and Leng, R.A. Sugarcane as cattle feed. Part 1:
1978 Nutritional constraints and perspectives. World Animal Review 27: 7-12; Part II: Commercial application and economics. *World Animal Review* 28: 44-48.

Preston, T.R. Nutritional limitations associated with the feeding of
1982 tropical forages. *Journal of Animal Science* 54: 877-884.

Preston T.R., Validity of feeding standards and development of feeding
1985 systems based on crop residues and agro-industrial by-products. In: Better use of crop residues and agro-industrial by-products in animal feeding: Research guidelines - 1. State of knowledge. Animal Production and Health Paper No 50 pp 197-213. FAO, Rome.

Preston, T.R. and Leng, R.A. Matching ruminant production systems
1987 with available resources in the tropics and sub-tropics. Penambul Books: Armidale Australia. pp 245.

Preston T.R. and Willis M.B. Intensive beef production (2nd edition)
1974 Pergamon Press Oxford.

Ramihone, B. Facteur limitant la fermentation dans le rumen des
1987 pailles de céréales (à petit grain) traitées à l'ammoniac anhydre. Thése, Université des Sciences et Techniques du Languedoc, Montpellier, France, 85 pp.

Salette, J.E. Nitrogen use and intensive management of grasses in the
1970 wet tropics. Proceedings of International Grassland Congress. Surfers' Paradise. pp. 404-407.

Sansoucy R. The Sahel: Manufacture of molasses-urea blocks.
1986 *World Animal Review* 57:40-48.

Sansoucy R., Aarts G. and Leng R.A. Molasses-urea blocks as a
1988 multinutrient supplement for ruminants. In: Sugarcane as feed. Animal Production and Health Paper No 72 (Sansoucy R., Aarts G. and Preston T.R., editors) pp 263-278. FAO, Rome.

Silva, A.T. and Ørskov, E.R. The effect of five different supplements
1988 on the degradation of straw in sheep given untreated barley straw. *Animal Feed Science and Technology*, 19: 289-298.

Stobbs, T.H. Factors limiting milk production from grazed tropical
1976 pastures (Limitations to milk production). International Seminar Animal Production, Acapulco, pp. 183-198.

Sundstøl, F. and Owen, E. Straws and other fibrous by-products as
1984 feed. Elsevier, Amsterdam, pp. 604.

Van Es, A.J.H. Nutrition and feeding aspects of using lignocellulosic
1985 materials for animal feed - Proceedings of a OECD Workshop on "Improved utilization of lignocellulosic materials with special reference to animal feed", pp. 54-64, held in Braunschweig 19-21 September 1984.

Van Es, A.J.H. and Taminga, S. Intake and composition of tropical
1987 feeds. In "Milk - The vital force" pp. 573-583. Proceedings of the XXII International Dairy Congress: The Hague 29 September - 30 October 1986. ed. D. Reidel Publishing Company.

Wanapat, W. and Topark-Ngarm, A. Voluntary intake and digestibility
1985 of two selected tropical grasses by swamp buffaloes. Proceedings XV International Grassland Congress. Kyoto. pp. 959-960.

Xande, A. and Garcia-Trujillo, R. Adaptation of the INRA system of
1985 determination and expression of the nutritive value of forages to the tropical conditions in the Caribbean islands. Proceedings of the XV Internat. Grassl. Cong.: Kyoto 24-31 August 1985: pp. 1062-1063.