NUTRITIVE VALUE OF SUGAR CANE FOR RUMINANTS

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Introduction:

The feeding of sugar cane to cattle has been practised by farmers for many years, but mainly as an emergency measure in time of feed shortage. Serious interest in the potential of this crop as the basis of animal feeding systems in the tropics began with the project on sugar cane derinding carried out in Barbados by the Government in collaboration with the Canadian International Development Agency (CIDA 1973),

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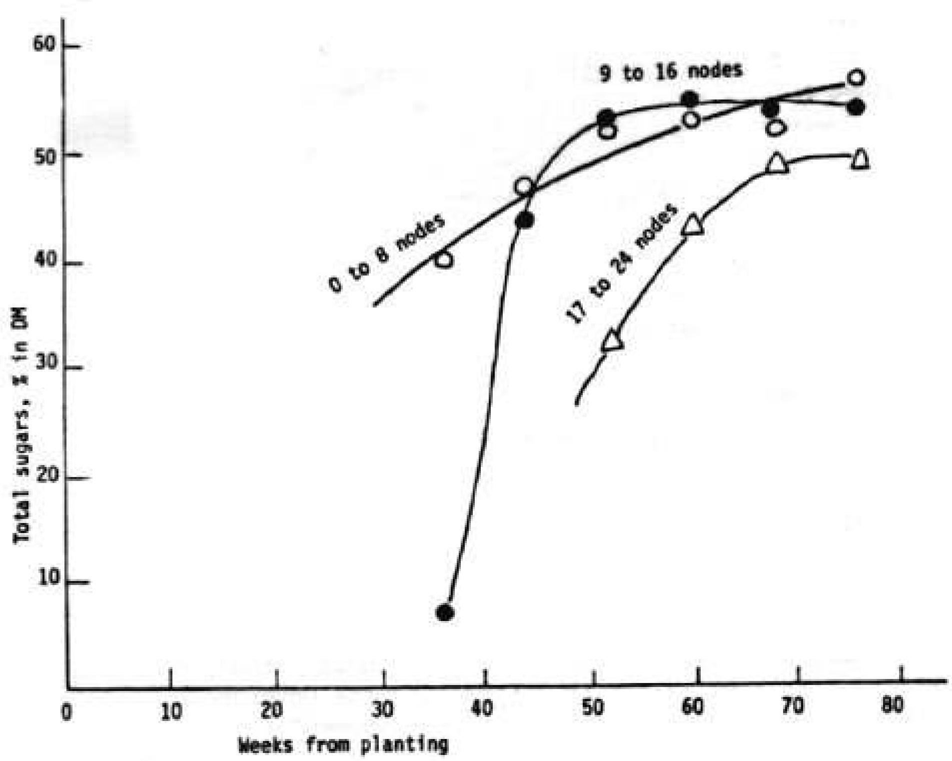
Stimulated by the work in Barbados, feeding trials with sugar cane have been made in several countries during the last two to three years. Unfortunately, the results of many of these trials have not been as positive as the original findings from Barbados led us to expect (Donefer et al 1975). This paper will try to explain these variable and often conflicting findings in the light of recent knowledge and thinking on the constraints governing the nutritive value of sugar cane. An attempt will also be made to set out guide lines within which predictable responses from sugar cane feeding can be expected.

Nutritional Aspects:

Composition of Sugar Cane: The traditional growing cycle of sugar cane for production of sugar is from 12 to 18 months during which the following changes take place (figures 1 and 2): an increase in stem relative to leaf ; increase in concentration of total sugars in the juice; conversion of reducing sugars to sucrose; increasing lignification of the structural cell wall carbohydrates. Unlike almost all other grasses, the overall digestibility of sugar cane does not decrease with maturity; rather there is a slight increase since accumulation of soluble cell con tents (sugars) more than offsets the decline in cell wall digestibility.

Figure 1:
Changes in sugar content of sugar cane with increasing age (from MSIRI 1975)



This ability to maintain high digestibility with increasing maturity confers an important advantage on sugar cane as an animal feed crop, particularly in the critical dry season when all other grasses and forages decline in both quality and availability.

Composition data for sugar cane, fractionated according to the Canadian separation process (see Pigden 1976) highlights the overall low content of nitrogen and of lipids (table 1). It is noteworthy that there are more of these nutrients in both rind and tops than in the sugar rich pith; and that the rind contains more sugar in the dry matter than the tops.

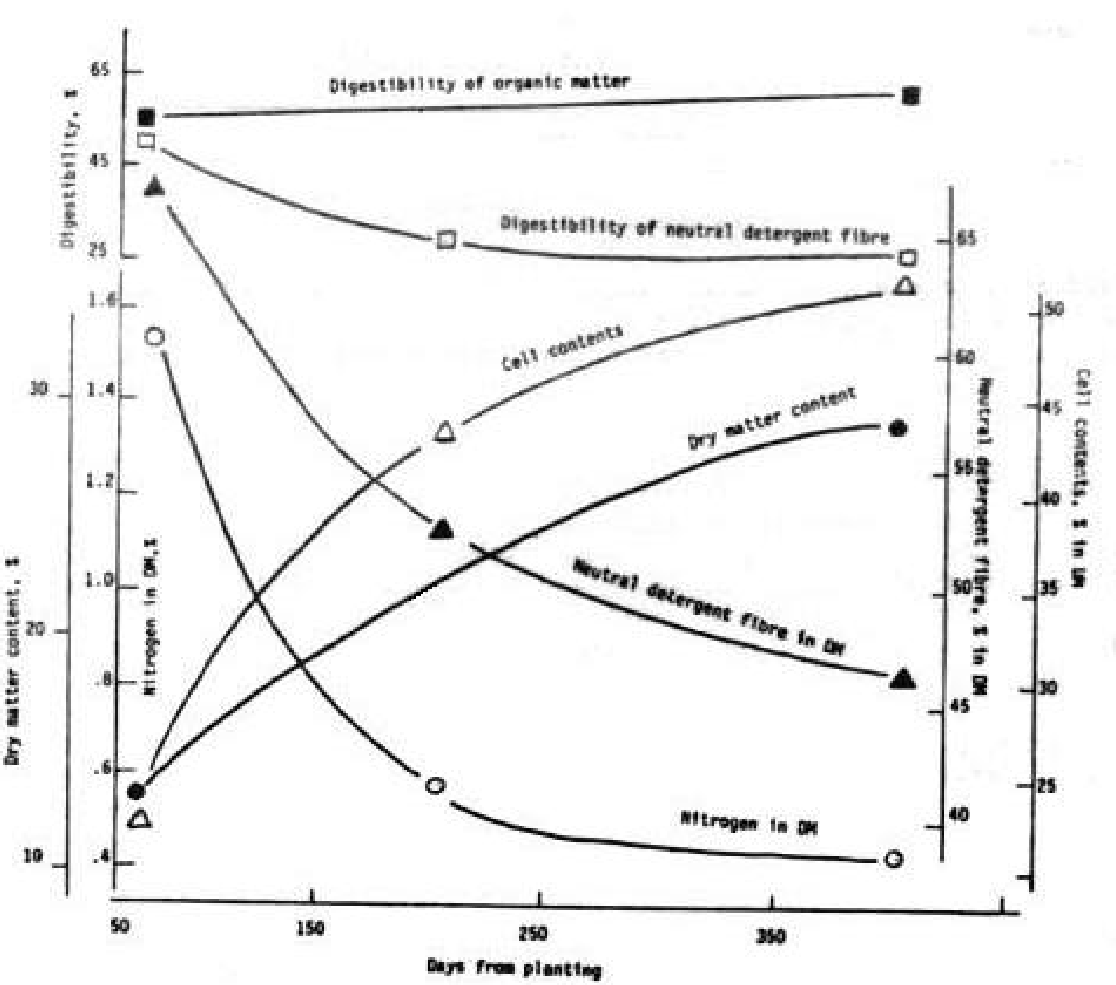


Figure 2:
Changes in composition of sugar cane with age (from Pate 1977)

Table 1:
Composition of sugar cane fractions (Anon 1974)

	Derinded Stalk	Rind	Tops
Dry matter, %	22.2	39.1	26.9
Composition of DM, %			
Nitrogen	0.22	0.51	0.43
Ether extractives	0.19	1.04	0.84
Non-water soluble residue[1]	45.9	69.9	56.9
Total sugars	46.0	23.6	26.0
Sucrose	37.9	21.1	24.3
Sulphur	0.19	0.25	0.40
Ash	3.10	7.87	5.28

[1] Residue after repeated extraction with water

Factors determining nutritive value of feeds for ruminants: Results of recent research, much of it with sugar cane and its by-products, have given us a clearer picture of the nutritional constraints to animal performance when low-protein high-sugar containing feeds are used.

Ignoring the supply of minerals and vitamins which are easily provided for, we can list the major nutritional factors as follows:

1. Maximum voluntary intake of fermentable organic matter
2. A requirement for approximately 3 g fermentable nitrogen per 100 g of fermentable organic matter.
3. Appropriate quantities of "by-pass" protein and gluconeogenic precursors in accordance with animal production rate

The principles governing the need for by-pass protein have been discussed in detail by Kempton et al (1977) and for glucose precursors by Leng and Preston (1976). The main features of these relationships are summarised in figure 3. When production rates are low at maintenance or during slow adult growth, early pregnancy and late lactation, little or no by-pass protein is needed; glucose needs are also minimal and probably can be met from products of rumen fermentation. But at high productive rates such as early rapid growth, late pregnancy and early lactation, there is an important dietary need for both by-pass protein and glucose precursors (principally starch). Since sugar cane contains neither bypass protein nor starch, it is readily apparent why results from feeding it to ruminants are largely determined by the nature of the accompanying supplements, rather than any intrinsic factor, such as its relative digestibility.

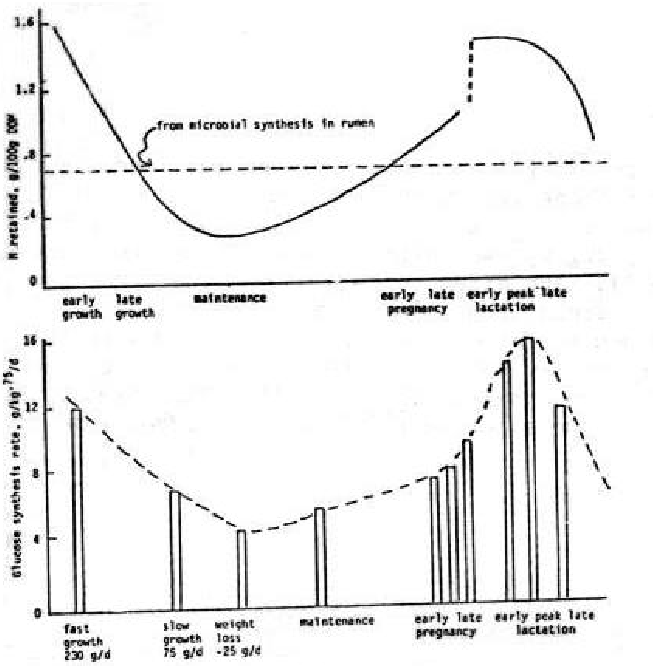


Figure 3:
Pattern of requirements (in sheep) for amino acids and glucose in relation to phase of production; the first is expressed as nitrogen retained per unit digestible organic matter (Orskov 1970) and the latter as the rate of synthesis of glucose per unit metabolic body weight(Leng 1975) (see Leng and Preston 1976)

Processing of sugar cane: The development of the derinding machine (CIDA 1973) for processing sugar cane for animal feeding was based on the concept that digestibility and voluntary feed intake would be enhanced by eliminating the more lignified outer rind of the sugar cane stalk. Digestibility was certainly improved by eliminating the rind (table 2) but voluntary intake was reduced; and to correct the latter (by feeding sugar cane tops) there was a reduction both in the over-all level of digestibility and the relative advantage to be derived from derinding. Surprisingly, the rind per se was as digestible as the tops; however, it is supported much lower voluntary intakes indicating specific advantages associated with the long fibres present in the sugar cane leaves.

Table 2:
Digestibility and voluntary intake of the different fractions of sugar cane (Montppellier & Preston 1977a)

	Digestibility of DM	Voluntary intake
	(%)	Kg DM/100 kg LW/d
Rind	59.6	1.86
Derinded stalk	71.3	1.98
Tops	61.5	2.78
Whole cane	60.3	2.32

Although, chopping and grinding invariably improves the -feeding value of dry roughages, this is not the case with fresh sugar cane. Neither digestibility nor voluntary intake varied over a wide range of particle size from 20-30 mm (chopping by hand with machete) to 2-3 mm (fine grinding by machine) (table 3). The effect of including the sugar cane tops on voluntary intake has already been mentioned. Confirmatory evidence on this topic was provided by Ferreiro and Preston (1977) when they showed stimulation in voluntary dry matter intake of 15% caused by the addition of 30% tops to cane stalk. This more than compensated. the drop in digestibility to give a net gain in intake of digestible dry matter of 8%.

Table 3:
Effect on digestibility and voluntary intake of chopping sugar cane into parameters of different sizes (Montppellier & Preston 1977b)

		Chopping by machine	
	Machete (approx 20 mm)	Coarse (5-10 mm)	Fine (2-5 mm)
Without rice polishings			
Digestibility of DM, %	66.7	68.2	67.2
Voluntary intake[1]	1.64	1.55	1.61
With rice polishings			
Digestibility of DM, %	68.7	-	67.3
Voluntary intake[1]	3.19	-	3.20

[1] Daily intake of DM (kg)/100 kg LW

The final effect of processing on animal performance is almost entirely attributable to effects on voluntary intake. Thus derinded sugar cane gave the same results as chopped whole sugar cane except at high levels of supplementation when there was a tendency for derinding to be slightly better (figure 4: Gonzalez and Williams 1976). Degree of grinding (different particle sizes) of whole sugar cane had no effect on animal performance (Silvestre et al 1976a; Montppelier et al 1977); however, the addition of tops stimulated live weight gain both with derinded cane stalk (James 1973) and chopped whole cane stalk (Ferreiro and Preston 1976).

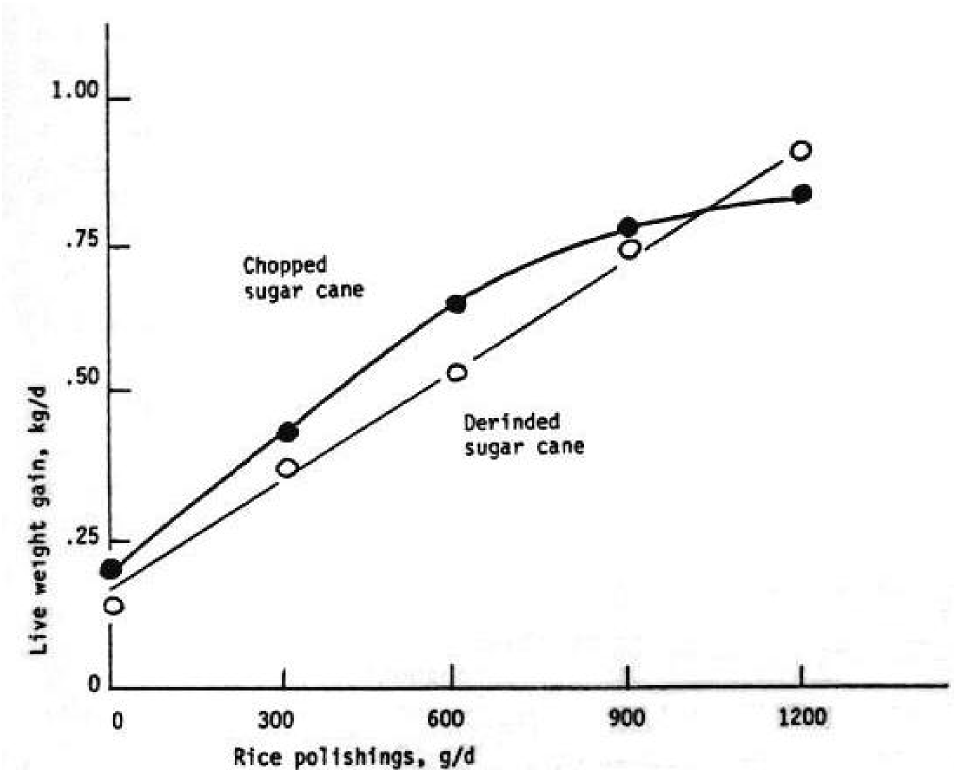


Figure 4:
Effect of supplementation with rice polishings on growth rate of cattle fed sugar cane and urea (from Preston et al 1976)

Supply of fermentable nitrogen: From a number of experimental approaches - mean yield of microbial cell nitrogen per unit organic matter digested in the rumen (see Egan and Walker 1975); relating fermentable nitrogen content of the diet to microbial growth (Hume et al 1970; Allen and Miller 1976) it can be deduced that there is a mean requirement for some 3 g fermentable nitrogen per 100 g carbohydrate fermented in the rumen. Practical confirmation of this ratio can be found in the results of Alvarez and Preston (1976a) where the best urea level in a sugar cane diet was found to be 30 g/kg sugar cane dry matter (equivalent to 2.9 g total N/100 g digestible organic matter). It is interesting, however, that in the absence of supplementation with by-pass protein and gluconeogenic precursors, urea addition had no effect on intake and gave only a marginal improvement in digestibility (Ferreiro et al 1977a).

Animal performance was the same when urea was mixed with sugar cane as a solution in water or in molasses or given as a concentrated (1096) solution in molasses which was then fed ad libitum separately from the sugar cane (Alvarez et al 1976). However, mixing the urea in protein meal supplements which were also sources of urease (e.g rice polishings or soya bean) had a detrimental effect on animal performance due to physical loss of ammonia and reduced palatability (free ammonia in the feed) (Alvarez FJ, unpublished data, Ramirez et al 1974).

Under many conditions (and particularly if some molasses is also fed) there may be no need to give supplementary sulphur (the content of sugar cane in one report was 0.3% in DM; Anon 1974) however, an apparent response to inorganic sulphur was found by Ferreiro et al (1977a) and it is probably a wise precaution to provide the supplementary nitrogen for sugar cane diets as an 80:20 mixture of urea and ammonium sulphate to give a S:N ratio of 1:10.

Since sugar cane varies in sugar content throughout the year, as well as according to stage of maturity it is obvious that the requirement for urea per unit of fresh sugar cane will also vary. A simple method of determining this on a field basis is by use of the formula: urea in cane (g urea/kg fresh cane) = 0.6Brix(94.8 - 1.12Brix)/(100 - Brix) (see Ferreiro et al 1977d).

The basis of this approach is that Brix (total sugars in juice) is easily measured by hand refractometer and is related both to the percent dry matter in the cane (r^2 = .93) and to percent total sugars in dry matter (r^2= .54) (Ferreiro et al 1977d).

By-pass protein and gluconceogenic precursors: It is apparent from table 1 that the content of protein in mature sugar cane is almost negligible it is also almost certain that the protein which is present will be highly soluble since most of it is concentrated at the growing point and in the leaves. Thus, for all practical purposes, sugar cane can be assumed to contain no by-pass protein.

Gluconeogenic precursors arise from two components in feed: the most important is starch which can contribute directly to glucose by escaping rumen fermentation and passing intact to the duodenum; and indirectly via propionic acid which is generally produced in greater quantities when starch containing feeds are fermented. Glucose can also arise from the degradation of certain amino acids, when these are provided in excess of requirements.

It is fairly obvious why gluconeogenic precursors are likely to be in short supply on sugar cane diets. First there is no starch in sugar cane; secondly, protein supply is almost always limiting; thirdly, the normal level of production of propionic acid is moderate in terms of proportions of the total VFA, and low because of low turnover rate in the absence of other supplementation (Priego et al 1977).

A deficiency in glucose supply on unsupplemented sugar cane/urea diets has recently been confirmed by direct estimation of glucose entry rate using tritium labelled glucose. Furthermore, giving rice polishings as a supplement to the basic diet of sugar cane/urea was shown to increase glucose entry rate by 14 mg/min for every 100 g of rice polishings (Ferreiro et al 1977c).

It is therefore to be expected that cattle fed sugar cane based diets are likely to respond to supplements which provide both by-pass protein and gluconeogenic precursors.

Practical results confirm this. Addition of 1.2 kg/d of rice polishings (containing 13% of high biological value protein and 30% of starch), increased live weight gain from 150 g/d (when no rice polishings were given) to 900 g/d (Preston et al 1976a);this effect was confirmed subsequently in several other experiments (Lopez et al 1976 Lopez and Preston 1977; Ferreiro et al1977b).

In contrast, meat and bone meal (an excellent source of by-pass protein) had a negligible effect on performance when given as the only supplement to sugar cane/urea (Preston and Bonaspetti 1975); while cotton seed meal (low in by-pass protein of moderate biological value but contains 10% starch) was better than either fish meal (the best source of by pass protein) or meat meal. When maize grain was also fed (a good source of glucose precursors) results were best with fish meal (Silvestre et al 1977a). In another experiment (Silvestre et al 1977b) cassava meal (77% starch) was superior to meat meal but results were best when both were included.

General indications are that the order of importance when supplementing sugar cane/urea diets is first gluconeogenic precursors and then bypass protein; however, more work is required to substantiate this and to define precisely the relationship between rate of animal performance and supply of these two essential nutrients . In practical terms, there are ample indications that vegetable protein sources are superior to animal proteins as supplements for sugar cane, both in the degree and economic feasibility of the response, probably because they often contain both starch and bypass protein.

Rumen fermentation on sugar cane: Knowledge of rumen fermentation patterns on sugar cane is important in order to be able to predict the nature and relative amount of the final digestion end products available to the animals, and whether or not these can be varied by dietary manipulation. Two components are involved, which may or may not be interrelated: one is the molar ratio of the volatile fatty acids (VFA); the other is the turnover rate of the rumen contents, and the total liquid volume in the rumen.

The mean molar proportions of the principal VFA over a 24 hr period when sugar cane/urea diets were fed, with and without rice polishings (a proven source of by-pass protein and gluconeogenic precursors) are given in table 4. For comparison, typical data for a molasses diet a cereal based diet and pasture are also given. It is apparent that sugar cane is quite different from molasses having higher proportions of acetate and propionate, and less butyrate; it differs from grain diets by having less propionate and more acetate and from pasture by having more propionate and butyrate.

Rumen ammonia is relatively high on sugar cane urea diets; in excess of the minimum recommended levels according to Satter and Roffler (1977) but in line with proposals of 0rskov (1970) and Allen and Miller (1976) as to the optimum concentration required for microbial growth.

A unique feature of rumen fermentation on sugar cane is the high and apparently variable population of large protozoa (mainly Isotrichs and Dasytrichs) (Valdez et al 1977). Their exact role is uncertain It has been postulated that they may be deleterious, from the point of view of protein supply to the host (Leng and Preston 1976), since these organisms apparently do not leave the rumen at least not in intact form (Minor et al 1977); on the other hand, it has also been suggested that their presence may be advantageous in levelling out the energy supply to the microorganisms (Minor et al 1977; Valdez et al 1977).

Since the insoluble cell wall fraction of sugar cane is digested to only a minor degree (about 20% according to Valdez and Leng 1976), it is the behaviour of the liquid phase of digesta which interests us most. Turnover rate (per 24 hr) of the liquid phase appears to be higher on sugar cane/urea supplemented with rice polishings (2.7) (Priego and Sutherland 1976) than on molasses/urea (1.7) (Geerken and Sutherland 1970) or concentrates (1.3) (Topps et al 1968) and was more related with results for dry roughages (3.4) (Topps et al 1968).

Table 4:
Molar proportions of VFA on different diets

	Molar % VFA				Reference
	Acetic	Propionic	Butyric	Others	
Sugar cane/urea	62.5	23.9	13.6	*	Valdez et al 1977
Molasses/urea	31	19	41	9	Marty & Preston 1970
Cereal grain	39	40	21	*	0ltjen & Davle 1965
Alfalfa hay	74	18.5	7.5	*	Templeton & Dyer 1967
Pasture	66	18.5	11.5	*	Balch & Rowland 1957

* Not reported

On diets of sugar cane and urea there was a direct relationship between turnover rate and voluntary feed intake in response to supplementation with rice polishings (Priego et al 1977). Giving animals access to the legume shrub Leucaena leucocephala as a grazing supplement to sugar cane/urea and rice polishings also led to increase in rumen turnover (Alvarez & Alpuche 1977) and improved animal performance (Alvarez and Preston 1976c).

The conclusion from work reported so far in this general area of rumen digestion is that the factor which relates most to animal performance is rumen turnover rate and not the balance of the products of rumen fermentation.

Fermentation and Ensiling:

Fermentation: Sugar cane begins to ferment immediately it is chopped. The changes are induced primarily by growth of yeasts resulting in conversion of sugar into alcohol and organic acids, the extent being determined by the duration of the fermentation, the actual rate of change being accelerated by fine chopping and by supplementation with fermentable nitrogen (Gonzalez and MacLeod 1976). Since such changes will tend to reduce the gluconeogenic potential of the end products of digestion (as happens with ensiling) prefermentation is likely to have a negative effect on animal performance This was proved to be so in a 112 day trial reported by Alvarez et al (1977). Cattle fed sugar cane/urea, prefermented for 24 hr, did not gain weight during the first 14 days of the trial compared with gains of 600 g/d on fresh sugar cane (all animals had 1 kg/d of rice polishings); in the remainder of the trial the prefermented cane continued to be inferior (580 vs 790 g/d). It is recommended that management procedures be arranged in such a way that there is a minimum delay between the time that the cane is chopped and when it is actually consumed by the animals.

Ensiling: Perhaps one of the most important advantages that sugar cane has over other crops is the fact that it can be left growing in the field until required with no loss in its nutritive value. In view of this, ensiling is no longer a necessity as it is with conventional forage such as maize, sorghum and elephant grass. In certain situations, however, ensiling could be appropriate: e.g. in the case of cane tops which are available over a relatively short period; or under intensive feeding conditions to preserve cane harvested at optimum nutritive value (in the dry season) for subsequent use throughout the year.

Most forages when they are ensiled present difficulties in ensuring an adequate fermentation, due to low content of soluble sugars. Frequently, molasses has to be added. Sugar cane presents the opposite extreme in that, when ensiled without additives, the abundance of sugars can give rise to an alcoholic fermentation (Preston et al 1976b). This can be controlled by addition of a combined source of fermentable nitrogen or and alkali, the latter to raise and buffer the pH in the silo during the first few days.

Aqueous ammonia in combination with molasses has given better results that urea/molasses in terms of controlling the breakdown of sugars, however the optimum quantity of ammonia to ensure maximum lactic acid values in the silage is less than the amount of fermentable nitrogen required subsequently by the animals (see Alvarez and Preston 1976b). Combinations of slaked lime (Ca(OH)2) with urea were also effective (Boodoo et al 1977).

Feeding trial results with ensiled sugar cane are less conclusive than the laboratory data. Derinded cane ensiled without additives was considerably inferior to the fresh material in all aspects of animal performance (James 1973), particularly at less than optimum levels of supplementation with by-pass protein and gluconeogenic precursors. Differences between fresh and ensiled cane were much less when additional molasses or maize grain were fed, indicating that the negative effect of ensiling may be specifically on the gluconeogenic status of the diet. Such a conclusion is supported by rumen fermentation studies which show a significant reduction in propionic acid production due to ensiling (Alvarez et al 1977).

The inconclusive results with respect to animal performance on ensiled chopped sugar cane may have been due to the relative small scale of the trials. Sugar cane ensiled with urea, ground whole soya beans and rumen. contents, was eaten in significantly greater amounts than sugar cane ensiled without additives (Silvestre et al 1976), there were also indications that ensiling with ammonia/molasses was slightly better than with urea/molasses however, both were inferior to fresh sugar cane, although not to the same extent as was reported by James (1973) for sugar cane ensiled without additives.

Probably the only valid conclusion at the moment, is that ensiling sugar cane with additives, particularly ammonia, will give better results than sugar cane ensiled without additives, however, in general animal performance is likely to be inferior to that on fresh cane.

Commercial Aspects of Sugar Cane Feeding

Commercial use of Sugar Cane: The decision to employ sugar cane as an animal feed will depend on a number of factors, some purely technical and others economic. A number of situations can be identified: drought feeding of a breeding herd; intensive fattening bulls/steers, feeding dual purpose milking cows and calves in the dry season.

In regions with clearly defined wet and dry seasons, sugar cane is most conveniently used as a dry season feed: (a) to maintain a suckling beef herd, (b) for semi-intensive production in a dual purpose herd.

Drought Feeding: In a number of cases, sugar cane has proved a valuable feed source for drought conditions when pasture and conventional forages are largely unavailable. It is preferable that the sugar cane be established as a compact area(approximately 1 ha per 30 head of mature cattle equivalents) and be fed off each year (or every second year), the entire stand being replaced every 7 to 10 years or so . In emergency, the chopped whole sugar cane, supplemented only with salt and phosphorus, be fed free choice. Results will be slightly better if urea is added and also, as a safeguard, ammonium sulphate. In order to avoid pasture damage due to overgrazing and treading, it is recommended that the herd be enclosed in a simple dry-lot (eg a 3 strand fence to make a paddock in one corner of the field preferably where there is natural shade and water). The sugar cane should be fed in the dry-lot from troughs to avoid wastage, and the animals allowed to graze for some 3 hr daily, where this is practical.

Semi Intensive feeding of a dual purpose herd producing milk and weaned calves: The cows should receive chopped whole sugar cane ad libitum supplemented with an aqueous solution of urea ammonium sulphate, and minerals. The cows should be kept in a simple drylot and preferably separated into three groups:(a) first half of lactation, (b) second half of lactation; © dry cows and in calf heifers. Ideal supplementation for all three groups is 3 fur/d of grazing on Leucaena leucocephala. Group (a) should also receive 500 g/d of rice polishings (or its equivalent in supply of by-pass protein and gluconeogenic precursors) and group (b) 250 g/d . If leucaena is not available, then 2 kg/d of supplement must be given to (a), 1 kg/d to (b) and 0.5 kg/d to (c). It is probable that other legumes, and even graminea, could be used to replace leucaena but there are no reports yet in the literature concerning the efficacy of such systems.

Calves: It is assumed that the calves in a dual purpose herd are receiving approximately 2 litres/d of milk by restricted suckling. They should also have free access to sugar cane supplemented with urea and ammonium sulphate and receive up to 250g/d rice polishings (or equivalent). Since suckled milk is the ideal source of gluconeogenic precursors and by-pass protein, there is no need to provide grazing at least not during the first 6 months of life.

Fattening bulls/growing heifers: These should be housed under dry-lot conditions and fed ad libitum sugar cane supplemented with urea/ammonium sulphate and either receive 1 kg/d of rice polishings (or equivalent) or have access to Leucaena leucocephala for 3 hr daily in which case the rice polishings can be reduced to 0.5 kg/d daily or even less if there is ample leucaena available.

In all cases it is important that the sugar cane be as high as possible in Brix (never less than 12°), thus as a general rule it should not be harvested until mature (i.e. at 12 months or more since planting or the previous harvest).

Processing equipment: Although almost any type of forage chopper will process sugar cane that has already been harvested, the more robust machines are preferred . In large units (more than 100 head) it is preferable to harvest and chop the sugar cane in one operation . For this to be successful the cane should be planted on the flat (or with minimum ridges)in land clear of stones. A single row, maize forage harvester should be used, however only certain models have proved to be robust enough to work consistently without breakdown. The important feature is the cutting mechanism used to sever the base of the stalk. This should be of the rotating disc type and not a reciprocating knife. Length of chop is not critical and can be set at about 10 to 20 mm. To encourage maximum speed of regrowth the stumps of the cane stalks should be cut back with a machete when direct harvesting on the field is practised, since most maize forage harvesters leave approximately 8-10 cm of stalk above the ground.

Economic Considerations:

Cost of sugar cane: Sugar cane destined for sugar production is mostly grown under some form of quota or contract arrangement, thus the production cost of sugar cane for cattle feeding should be calculated as for any other forage crop e.g. maize, sorghum or elephant grass. Factors to be taken into account include (1) seed bed preparation and seed cane (about 11 tons/ha) once every 7 to 9 years. (2) weeding once yearly; (3) fertilizing and harvesting every year. With full mechanization, production costs of a 120 ton/ha crop harvested, chopped and delivered to the feed-lot are likely to be in the range US$5 to 10/ton.

Table 5:
Feed inputs, production, costs and margin over deed costs for a dual purpose (milk/ weaned calf) herd

	Intake, kg/d			Unit Cost	Cost
	Cows	Calves	total	(US$)	($/d)
Sugar cane	19	4	23	.008	.184
Molasses	.44	.44	.03	.013	
Urea	.2	.05	.27	.15	.045
Rice polishings	.5	.25	.75	.10	.075
Leucaena	10		10	.008	.080
Minerals	.06	.02	.08	.10	.008
				Total:	.405
Production and sales:					
	Production (kg/d)	Unit price	Value ($/d)		
Milk	5	.20	1.00		
Calf live weight gain	.45	.75	.338		
					1.338

Assume 70% of cows in milk and that the dry cows consume only 17 kg/d sugar cane, .17 kg/d urea and 10 kg/d leucaena (cost is $0.242/d) then daily sales per cow are .7 X 1.338 = 50.937 and feed costs .7 X .405 + .3 X .242 = $0.356. This leaves a margin over feed costs of $0.58 per cow per day.

Table 6:
Feed inputs, production costs and margin over deed costs for semi-intensive fattening

	Intake, kg/d	Unit price($)	$/d
Sugar cane	17	.008	.136
Urea	.17	.15	.0255
Rice polishings	1.00	.10	.10
Minerals	.06	.10	.006
			.2675
Production and sales:			
	Production, kg/d	Unit price ($)	Value ($/d)
Live weight gain	.80	.76	.60
Margin over feed is $0.3325/day per head			

Milk and Beef production: Input/output data for dual purpose cattle fed sugar cane, urea and rice polishings and with restricted grazing on Leucaena leucocephala are given in table 5. Comparable data for fattening of bulls from weaning to a slaughter live weight of 400 kg are set out in table 6. In both cases, the margin of value of sales over feed costs would appear to be of a sufficient order of magnitude to enable such enterprises to be profitable.

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