SUGAR CANE BY-PRODUCTS AS LIVESTOCK FEED

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INTRODUCTION

Sugar cane is one of the most successful tropical crops, with ny agronomic factors in its favour such as high yield, tolerance of wide range of soils, resistance-to pests, a perennial growth habit, d a sophisticated supportive technology providing improved varieties d cultural practices. It is still grown almost exclusively for sugar oduction; however, a number of alternative uses have been proposed the last decade, many of them stimulated by the effects of the ergy crisis.

END USES AND BY-PRODUCTS

Raw and refined sugar

The different technologies available, or being proposed, for the e of sugar cane are summarised in Table 1, which indicates the incipal by-products associated with each process. From factory sugar oduction the most important by-product is final molasses (Figure 1) ich is produced at the rate of about 3 tonnes for every 100 tonnes stalk entering the factory. The filter mud is usually returned to e cane fields as fertilizer/soil conditioner; while the bagasse (the sidual fibre) is burned to produce the energy needs of the factory. pending on the fibre content of the cane, and the efficiency of the ilers, up to 20% of the bagasse may be surplus. In an increasing mber of countries, this is being converted into electricity using isting factory equipment, and then fed into the national grid stem. This is almost certainly the most appropriate-way of using it.

ble 1 Sugar cane processing technologies and by-products

imary product	Scale	By-products
w and refined sugar	Industrial	Final molasses Filter mud Bagasse
r/panela	Farm	Scum (cachaza)
rticle board	Industrial	Ground derinded stalk
ice (animal feed)	Farm	Pressed stalk

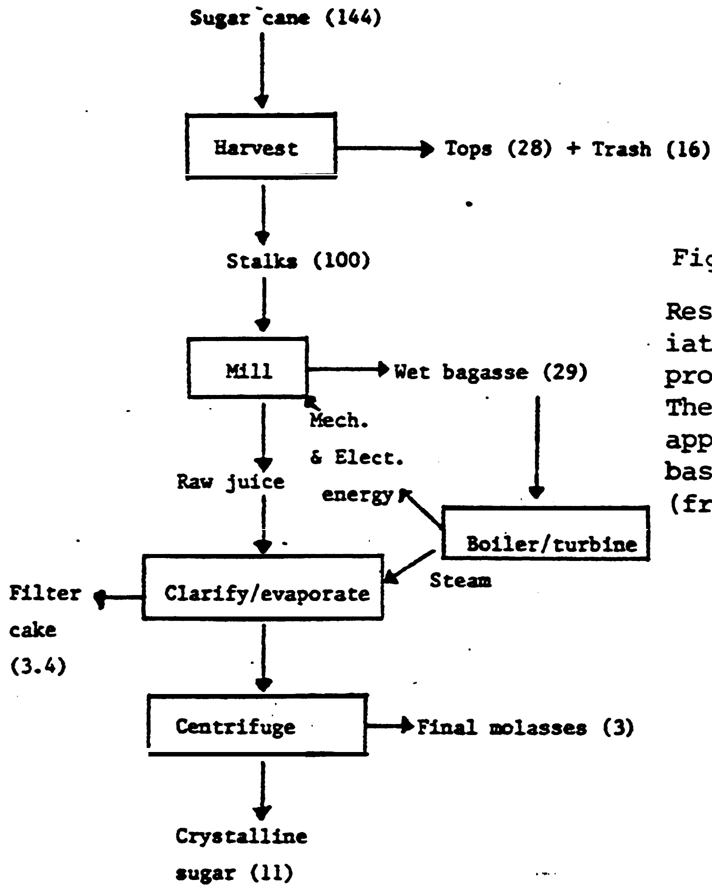

Fig. 1

Residues and by-products associated with conventional factory production of crystalline sugar. The numbers in brackets indicate approximate quantities (fresh basis) relative to stalks = 100 (from MSIRI 1965,1977)

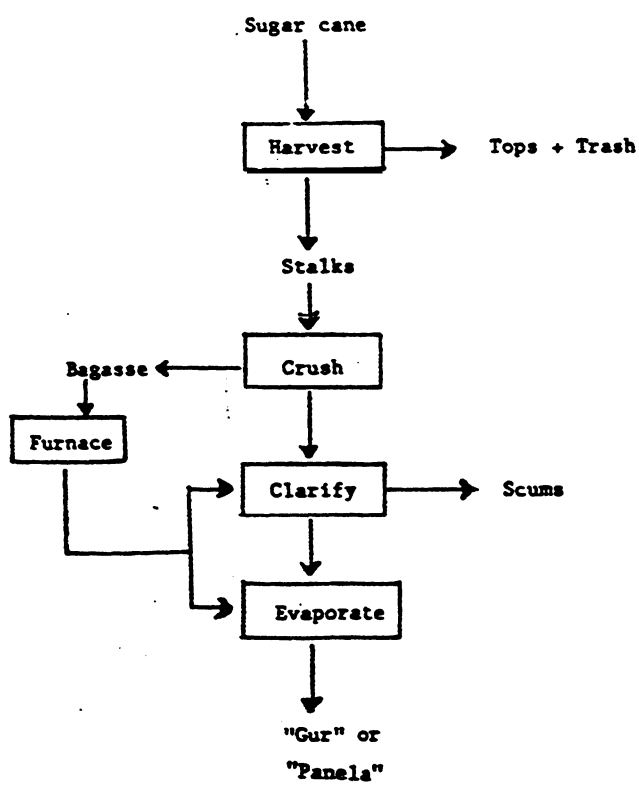

Fig. 2

Residues and by-products associated with "artesan" production of Gur or Panela

Gur or Panela

In the "artesan" production of-sugar on the farm (Figure 2), actised still in many developing countries, the only product surplus the operation, is the scum or "cachaza". As the name implies, this the material skimmed off the surface of the boiling cane juice fter addition of some flocculating agent to remove the proteins and nerals. It is traditionally fed to the draught animals, used to rive the cane press or to' transport the cane from the fields. In tinamerica, it is frequently fed to pigs.

Particle board

The derinding process invented by Tilby and Miller (Figure 3) as designed to separate the rind fibre as raw material for particle ard: the by-product is the milled central portion of the cane stalk hich can be used as livestock feed or for sucrose extraction, llowing the normal factory process.

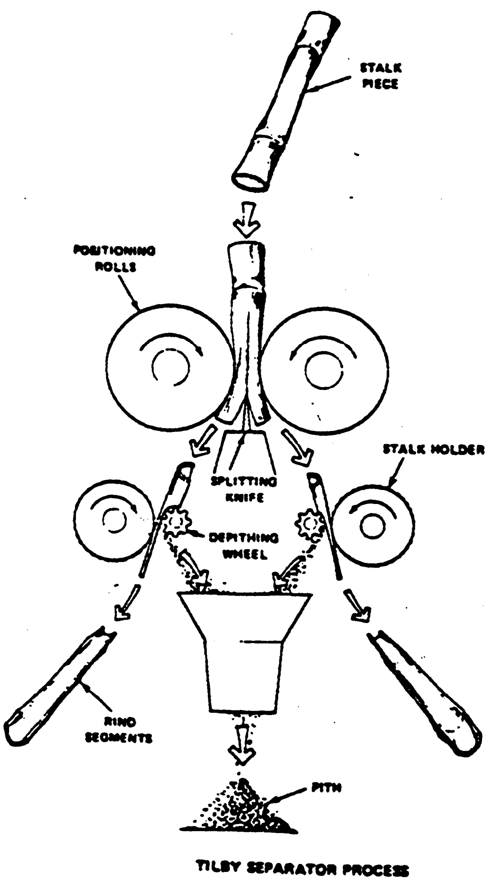

Fig. 3

Simplified diagram of the Tilby (1971) separator process (from Lipinsky and Kresovich 1982)

Fuel

Growing of "energy cane" (Figure 4) according to the scheme put forward by Alexander _et_ **al. (1979)** has as the main objective the production of electrical energy, via the combustion of the fibrous components of the cane, including the tops and leaves. The by-product from this process, carried out in a slightly modified sugar factory, is "high-test" molasses, derived by extracting, concentrating and partially inverting the cane juice. In Puerto Rico, where this technology is being developed, there is a ready demand for molasses for rum production which enjoys a protected market on the nearby US mainland.

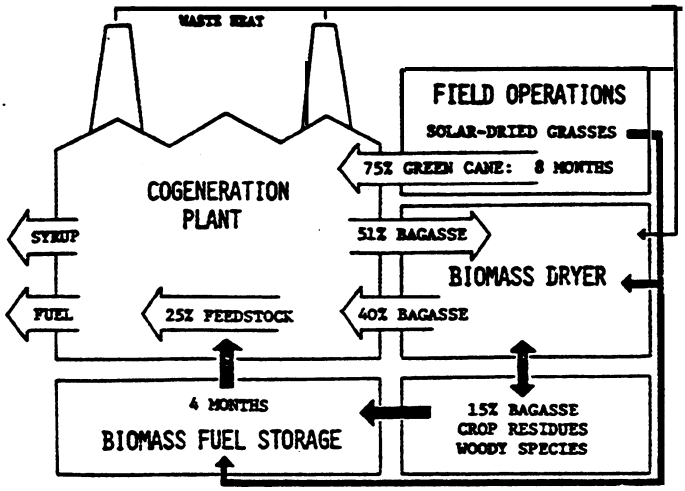

Fig. 4

Integration of energy cane and AGRI-FUEL technologies for year-round production of fuel and syrup (high-test molasses) (from Alexander 1982)

Preston (1980) proposed a similar strategy, but aimed at a farm scale of operation with end products being cane juice for livestock feed and the fibrous residue for fuel, using gasification technology (Figure 5). In this process, a simple 3-roll mill is used to crush the cane. This extracts only some 60% of the total juice, the remainder being in the fibrous residue, making this material considerably superior to conventional bagasse, as a potential livestock feed.

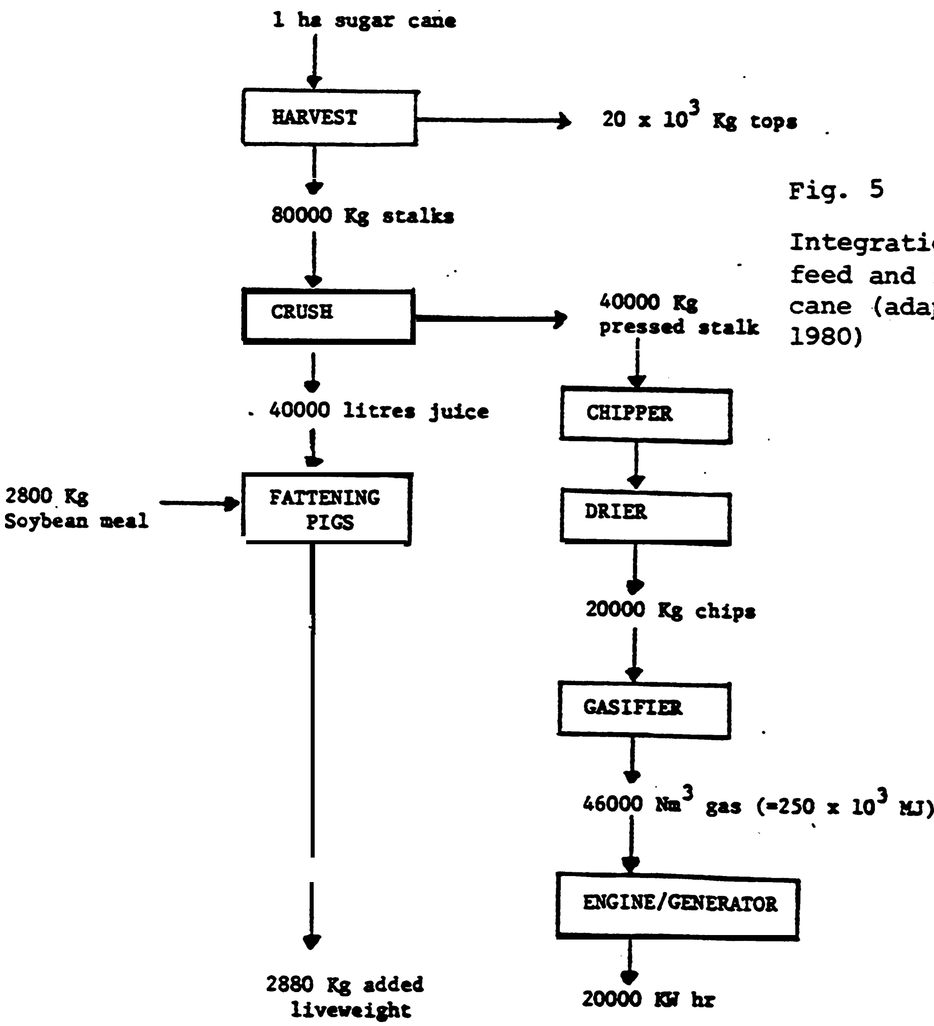

Fig. 5

Integration of livestock feed and fuel from sugar cane (adapted from Preston 1980)

SUGAR CANE BY-PRODUCTS AS LIVESTOCK FEEDS

From the different processes described above, the by-products considered to have most commercial significance are the following:

* Final molasses
* High test molasses
* Derinded cane stalk
* Cane juice
* Pressed cane stalk residue
* Sugar cane tops

Bagasse and filter mud have been studied in many experiments, with a view to assesssing their potential in livestock feeds. Both materials have low nutritive value, even after chemical treatment to partially hydrolyse some of the cell wall components. In almost all cases, bagasse will have a higher opportunity value as fuel, to run the factory (otherwise another fuel would have to be purchased), while excess bagasse should be converted into electricity. The high moisture and ash (from soil contamination) contents of the filter mud preclude its use as livestock feed other than in exceptionalcircumstances.

Sugar cane tops are potentially available irrespective of the end uses of the cane (except for '*energy cane"), as most harvesting systems separate out the stalks in the farmers' fields. However, when cane is burned prior to mechanical harvesting, most of the leaf material is lost. It only constitutes a significant feed resource under conditions of hand harvesting.

Final molasses

The first widespread use of molasses in livestock feeds was in balanced feeds in the industrialised countries. It was valued more for the palatability attributes it conferred on ground feeds by its sweetness and viscosity, the latter reducing dustiness which has economic as well as organoleptic consequences. For this useage, only low concentrations (< 10%) are needed, indeed higher levels make mixing more difficult. The situation in most tropical countries, which are the primary producers of sugar cane, is quite the opposite. Most of the molasses is usually exported at low prices (< $80/tonne) while cereal grains are imported at high prices (>$150/tonne). There is therefore strong economic pressure to develop feeding systems in which molasses plays the major role.

The first report on the successful substitution of cereal grain by molasses in high energy cattle fattening rations came from Cuba (Preston et al 1967). Growth rates *exceeding 800* g/day were obtained in crossbred Zebu bulls given rations in which up to 80% of the energy and the nitrogen was derived from a liquid molasses/urea mixture. This finding stimulated an intensive research programme which led to the development of large scale commercial feeding systems for cattle in both conventional feedlots (Table 2) and in semi-confinement (Table 3). The use of "catalytic" amounts (<400 g/day) of fish meal in this system was the first practical demonstration of the role of "by-pass" protein in diets with high concentrations of non-protein nitrogen . (Preston and Willis 1974).

Table 2 Effects of changing from the traditional forage/concentrates to a high molasses ration in a commercial feedlot in Cuba (Munoz *et al*.1979)

	Forage	Molasses
Total liveweight gained daily in the feedlot (kg)	3,724	8,295
Daily liveweight gain (kg) per:		
Animal	0.43	0.88
Worker	14.3	51.8
Tractor	86	420
Unit feed DM	0.065	0.093
Deaths (%)	0.1	1.0
Emergency slaughter (%)	0.4	3.0

Table 3 Input-output data for 3,500 crossbred bulls in 11 commercial units. The animals were confined for 18 hr daily where they had free access to the molasses/urea and 400 g/day of fish meal. Grazing was restricted to 6 hr daily on pangola or guinea grass pastures (Morciego *et al*.1979)

allunit	Best	Average units	Worstunitfor
Liveweight gain (kg/d)	1.04	0.83	0.74
Conversion rate			
Molasses/urea	5.9	9.1	14.7
Fish meal	0.32	0.45	0.54
Emergency slaughter (%)	-	0.44	1.33
Deaths (%)	-	0.38	1.33

The technology of high level molasses feeding to cattle has been introduced in a number of other sugar cane producing countries and continuing research has led to technical and economic improvements in the system; the use of high quality forage to supply both the protein and the roughage (Tables 4 and 5) and the supplementation of poor quality roughage with poultry litter (Table 6).

ble 4 Substitution of native grass and groundnut cake by fresh leucaena forage in molassses-based diets for growing bulls in Mauritius (Hulman et al.1978)

	Leucaena (% LW/d)		Groundnut (g/d)	
	2	5	500	1,300
gain (g/d)	790	847	597	742
conversion[1]	9.2	9.7	10.5	10.4
lasses (%diet)	79	62	73	53

eed dry matter per unit LW gain

ble 5 Forage from cassava or sweet potato as a combined source of protein and roughage in molasses/urea diets for cattle fattening in the Dominican Republic. Additional soybean meal promoted better animal performance on sweet potato forage but not on cassava forage (from Ffoulkes and Preston 1978)

rage source	Cassava		Sweet potato	
ybean meal (g/d)	0	400	0	400
gain (g/d)	853	'944	570	784
Conversion	6.28	7.19	8.28	6.74

ble 6 Poultry litter (18% of diet DM) increases cattle performance on a basal diet of molasses/urea, wheat bran (12% of diet DM) . and sugar cane tops in the Dominican Republic (from Meyreles . and Preston 1982)

	Basal diet	Poultry litter
W gain (g/d)	730	1,010
M intake (kg/d)	6.52	8.04
M conversion	9.11	8.14

Commercial use of molasses as the basis of feeding systems has usually only been feasible in developing countries in the tropics which are the primary producers of molasses and where FOB factory prices are relatively low (< $40/tonne) relative to imported grain (>$150/tonne). Molasses is almost as rich in digestible energy (13 MJ/kg DM) as cereal grain (eg: sorghum has 14.6 MJ/kg DM) and theoretically should be of comparable feeding value. In practice, its potential value is only realized when it is maintained at a low level in the diet (< 10%). Its real value relative to grain declines as its contribution to the total diet increases. This negative trend is more serious for milk (Clark *et al.* 1972) than for beef production (Redferne and Creek 1973). It has been suggested (Preston and Leng 1980) that the problem relates to both energy and protein supply. Rumen microbial protein available to the animal appears to be reduced by high protozoal populations (Bird and Leng 1978) while the energy constraint is thought to be due to inadequate amounts of glycolytic compounds, because of the dominance of butyrate in the rumen fermentation (Marty and Preston 1970) and the fact that the highly fermentable sugars cannot "escape" the rumen fermentation and contribute glucose directly, as happens when cereal grains are fed. The fall in the real feeding value of the molasses at high levels of incorporation in the ration, appears to be more of a problem in molasses produced in countries with highly efficient sugar factories (eg: Australia and Mauritius), possibly because less sucrose and more soluble ash is left in the molasses.

High-test molasses

This is the concentrated (80-85% soluble solids) partially inverted cane juice from which no sucrose has been extracted (Figure 4). Probably because of its lower ash content, it is superior to final molasses for feeding to pigs (Table 7) and ducks (Table 8). High-test molasses was apparently as good as maize for fattening turkeys in one comparison (Table 9). There were no differences between high-test and final molasses for liveweight gain in fattening cattle, although feed converson tended to be better for the former (Preston *et al.* 1970).

Table 7 Pigs grew faster and had drier faeces on high-test molasses than on final molasses plus 20% sugar; addition of higher levels of sugar to the final molasses appeared to simulate results with the high-test molasses (MacLeod *et al.* 1967)

	Final molasses plus:			High-test molasses
	20% sugar	40% sugar	60% sugar	
LW gain (g/d)	511	555	586	575
DM conversion	3.70	3.57	3.37	3.10
Faecal DM (%)	26	34	40	47

ble 8 Final, **"A"** or high-test molasses compared with maize as the energy source for fattening ducks (Perez and San Sebastian 1970)

	Maize	Molasses		
		High-test	"A"	Final
nal LW (kg)	2.09	1.84	1.71	1.53
conversion	5.02	5.00	5.93	6.99

" molasses is the non-crystallizable solution remaining after the rst centrifugation. Normally, it is recycled for a second and then a irdcentrifugation, the non-crystallizable residue from which is nal molasses

ble 9 Fattening turkeys with maize of high- test molasses (feeding period was 56 **days)(Valarezo** and Perez 1970)

	Maize	High-test molasses
itial LW (kg)	5.88	5.83
nal LW (kg)	8.86	8.83
conversion	6.48	4.74
rcass weight (kg)	6.74	6.80

Derinded cane stalk

In a series of experiments carried out in Barbados by Donefer nd his colleagues (see **Pigden 1972),** very high rates of growth were btained in young Holstein cattle fed ground derinded sugar cane talk, supplemented with chopped cane tops, urea and **rapeseed** meal Table 10). The ground derinded stalk was also fed successfully at **low** medium levels in rations for pigs and chickens (James 1973).

Surprisingly, these promising developments have still not eached the stage of commercial application. The major constraint is hat the machinery for separating the cane stalk into rind and pith is ophisticated and expensive; and not really appropriate for farm scale ctivities especially in developing countries which is where the echnology has most potential. The second factor is that the ground erinded stalk is little. or no better than chopped whole sugar cane hen both are adequately supplemented (Figure 6). This is surprising n view of the higher DM digestibility of tghe derinded cane stalk ompared with the whole plant (70 vs **61%; Montpellier** and Preston

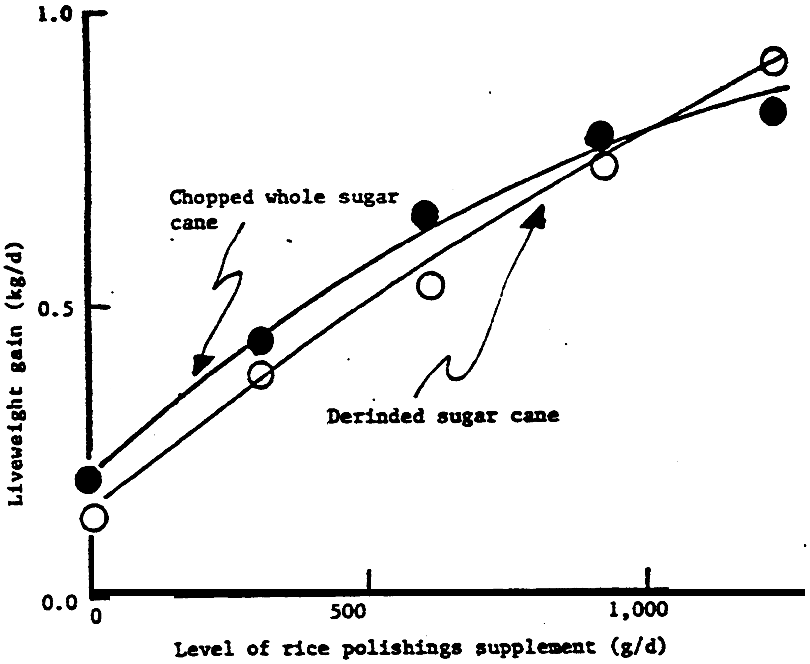

Fig. 6

A large scale experiment in Mexico with 400 cattle showed little apparent difference between chopped whole sugar cane and derinded sugar cane. There was an indication that the derinded cane was inferior at low levels of s upplementation but better at high levels (from Preston et al. 1976)

Table 10 Performance of Holstein steers fattened on a basal diet of derinded sugar cane stalk supplemented with cane tops, rapeseed meal and urea. 'Additional molasses slightly 'increased liveweight gain but made feed conversion worse; maize had a positive effect on both parameters. The trial was carried out in Barbados (Pigden 1972)

		Additional energy[2]	
	Basal[1]	Molasses	Maize
DM intake (kg/d)	9.6	11.4	10.8
LW gain (kg/d)	0.99	1.07	1.25
DM conversion	9.7	10.7	8.6

[1] Ground derinded sugar cane stalk plus chopped sugar cane tops and 2 kg/d of a supplement of rapeseed meal and urea

[2] The maize/molasses was fed at 1% of LW

)77). The poorer performance of cattle given derinded cane, compared ith whole cane, when only urea and minerals were given was ibsequently confirmed in the Dominican Republic (Fernandez et al)79). Apparently, in the absence of other forms of supplementation, ie rind provides some nutrients (or physical attributes) not present i the pith. The rind is certainly richer in protein and ether extract Table 12) and probably also in minerals and vitamins. The physical ffect of the rind fibre appears to be another factor. Cattle fed the erinded stalk, even when 'supplemented with protein, minerals and tamins., increased their 'voluntary intake and liveweight gain when

able 11 Supplements of sweet potato forage(SPF) arid cottonseed eal(CSM) stimulate growth rate, feed intake and response to rea in' Zebu cattle given a basal diet of derinded sugar ane stalk (from Meyreles *et al*.1979)

upplement	None		SPF		CSM		SPF+CSM	
rea level	L	H	L	H	L	H	L	H
eed intake (kg/d)								
Derinded cane	8.6	8.7	11.1	11.4	10.8	12.9	13.0	13.5
Urea	0.05	0.21	0.06	0.28	0.06	0.32	0.07	0.34
W gain (g/d)	10	-61	343	585	351	444	697	984

able 12 Composition of sugar cane tops and of the rind and pith ractions produced by the Tilby (1971) separator process Unpublished data from Division of Animal Production, inistry of Agriculture, Mauritius)

	Stalk		
	Pith	Rind	Tops
M (%)	22	39	27
omposition of DM (%):			
Protein (N X 6.25)	1.4	3.2	2.7
Ether extract	0.19	1.04	0.84
Total sugars	46.0	23.6	26.8
Fibre[1]	45.6	69.9	56.9
Ash	1.87	3.1	5.28
Sulphur	0.19	0.25	0.40

[1] Non-water soluble residue

chopped cane tops were also given. However, feed conversion was **worse (Pigden 1972),** indicating that the beneficial factor reduced overall feed utilization efficiency. A similar result was obtained in Mexico when chopped cane tops were added **to a basal** diet of chopped cane stalk (Ferreiro and Preston **1976).**

The technology of chopping the whole cane plant is simpler and much less sensitive to economies of scale than the derinding process, and became the system of choice in a number of initiatives to **apply** sugar cane feeding of **livestock** under semi-commercial **conditions** (Preston T R unpublished observations; SFC **1980,1981).**

Research has continued in order to identify the constraints associated with the use of derinded sugar cane and a number of discoveries have been made which have contributed to the understanding of the problems. **associated** with the utilization of high carbohydrate-low protein feeds by ruminants in general. The most significant, findings have been that the non-sugar residual fibrous material in sugar cane, whether in the rind, the pith or the leaf has an extremely slow rate of degradability by **rumen** organisms (Fernandez and Hovel1 1978; Santana and **Hovell 1979.** It was postulated by Preston and Leng (1980) that this results in a long residence time of the fibre in the **rumen which** explains the **very low voluntary** intake of sugar cane, whether whole or derinded, when only urea and mineral supplements are given (eg: Fernandez <u>et</u> <u>a1.</u>1979). The first step to remove this constraint appears to be **the incorporation** in the ration of a source of highly digestible forage, for example the foliage of sweet potatoes (Meyreles <u>et</u> <u>a1</u>**.1977,1979).** Apparently, this give rise to an improved **eco-system** in the **rumen** enabling a more efficient microbial activity, as evidenced by increased utilization of urea (Table 11). The second step is to provide **a** highly digestible concentrate supplement containing both energy and protein which will escape (or by-pass) the **rumen** fermentation. This leads to more efficient utilization of the digestion end products of the basal diet, -and consequently to improved feed utilization efficiency, probably by increasing the supply of amino **acids** and glycolytic compounds at the sites of metabolism (Preston and Leng 1980). By contrast, highly digestible concentrates which do not escape the **rumen** fermentation because they are too soluble (eg: molasses) lead to poorer feed utilization efficiency (Table 10). The best results are obtained when derinded cane stalk **is** supplemented with both high quality forage and a by-pass supplement (Table **11).**

It can be concluded that:

* In the absence of supplementation, both chopped whole sugar **cane** and the derinded stalk, are only maintenance feeds:

* That limited supplementation **with** urea and minerals will support some gain in weight **(100-200** g/day) on chopped whole cane (but not **on** derinded stalk unless some long roughage is also fed:

* Growth rates of 9004,000 g/day are **feasible** when good uality **forage and a** source of by-pass nutrients are given in a8**dition** to the urea and minerals.

In practice, whole sugar cane (tops, trash and stalk) collected nd chopped in the field using a strengthened maize harvestor has roved to be an economical solution to the problem of dry season eeding of cattle when the objective is no more than to maintain iveweight and body condition until the onset of the rains. But for roductive purposes, the required levels of supplementation make the ystem uneconomical in the majority of circumstances.

Sugar cane juice

Recognition of the negligible nutritive value of sugar cane ibre and of the negative effect this was having on the utilization of he valuable sugar fraction, especially in systems designed for high roductivity, led to efforts to develop processing systems in which he sugars and the fibre could be treated separately according to heir individual characteristics. Fractionation has always been the ethod used in traditional sugar production with the fibrous component eing used as fuel to provide the energy needed to extract the ugar-containing juice, and later to concentrate this and separate the ugar in crystalline form.

The approach in the "on-farm" fractionation technology was to ccept a low rate of juice extraction (about 60%) which drastically educes the investment and the energy cost of milling (a single pass hrough a 3-roll mill is all that is used compared with 5 sets of ills in conventional sugar factories). The justification for this ecision is that the economic value of sugar and fibre differ little hen the end uses are for fuel or animal feed (Table 13).

able 13 Relative value of biomass for feed and fuel

	Energy concentration (MJ/kg DM)	Price ($/tonne)
or fuel:		
Oil	42	175[1]-350[2]
Biomass	17	70[3]-140[3]
or feed:		
Cereal grain		120[4]-250[5]
Molasses		40[4]-110[5]

[1] Value for exporting country based on $33/barrel(FOB)

[2] Cost to user in rural area

[3] Calculated values pro-rated according to relative caloric value ompared with oil

[4] Exporting country

[5] Importing country

provides. Thus it has been possible to obtain high levels of productivity, especially in terms of feed efficiency, without the need for additional true protein supplementation. The use of a high quality tropical legume, such as leucaena, as the forage supplement appears to be especially appropriate in such a scheme (Table 15).

Table 16 Pigs fed cane juice in the Dominican Republic had similar growth rates, but better feed conversion and carcass yield than controls fed maize and molasses. Starting and finishing weights were 40 and 100 kg respectively (Fermin 1983)

	Cane juice	Maize and molasses
LW gain (g/d)	969	953
DM conversion	3.36	4.00
Dietary protein in DM (%)	11.5	16.1
Carcass yield (%)	82.0	79.8

The most appropriate application for sugar juice feeding, and certainly the one likely to have most commercial. benefits, is in feeding systems for pigs and poultry. Many commercial enterprises for intensive production of these species have sprung up in recent years in almost all tropical countries. But invariably, the feeding systems have been based on imported cereal grains, with the socio-economic constraints of competition with human food resources and excessive dependence on imports and availability of foreign exchange. The early results obtained with pig feeding (Table 16) show comparable levels of performance to what would be expected from the use of cereal grains, and better carcass merit because of the higher dressing percentage. As with ruminants, there are savings in dietary protein. In this case, the saving arises because the required essential amino acids can be concentrated in a smaller total amount of protein, as a result of eliminating the poorly balanced cereal component of the ration.

Experiments have just begun with poultry. The initial observations (Davis J and Preston T R 1983, unpublished data) suggest interesting possibilities for alternate techologies in which ducks, rather than chickens, are the preferred species because they are better adapted to utilize liquid diets. They also have the capacity to "harvest" high protein water plants, such as duckweed and algae, which are not normally considered as feeds for conventional livestock production due to the expense of harvesting and drying.

able 14 Crossbred Holstein X Zebu bulls in Mexico grew faster with better feed conversion on sugar cane juice than on molasses. Initial LW was 260-280 kg and trial period 84d. Fresh forage was also given (African Star grass) at 3% of LW (fresh basis). The molasses or juice, supplemented with urea, was fed free choice (Sanchez and Preston 1980)

	Without sunflower cake		1 kg/d sunflower cake	
	Molasses	Cane juice	Molasses	Cane juice
W gain (kg/d)	0.25	0.80	0.55	1.32
M conversion	21.5	7.42	11.8	6.44

able 15 Zebu bulls in Mexico grew fast and efficiently on basal diet of ad libitum sugar cane juice preserved with ammonia and supplemented with restricted fresh legume forage (Leucaena). 'Fish meal increased growth rate but not feed efficiency (Duarte *et al*.1982)

	Fish meal (400 g/d)	
	Without	With
W gain (g/d)	1,020	850
M conversion	5.7	5.8

The underlying hypothesis was that the easily extractable juice ould be fed to highly productive ruminant or non-ruminant livestock, hile the fibrous component, including the residual sugar, could be sed either as raw material to make producer gas, to substitute asoline and diesel oil in internal combustion engines; or as a aintenance feed for ruminants, probably after chemical treatment 'to mprove its digestibility.

With growing cattle, the levels of-performance achieved on fresh ane juice have been vastly superior to those recorded for molasses nd comparable with the best that could be expected from intensive ereal grain feeding (Table 14). The difference compared with cereals as been the opportunity to save protein (which is used wastefully hen grain is fed to ruminant animals) presumably because of the xcellent medium for microbial protein synthesis that sugar cane juice

Pressed cane stalk residue

The fibrous residue after partial juice extraction already contains some 30% of sugars in the dry matter, due to the incomplete extraction of the juice. Alkali treatment solubilises a further 30% of cell wall carbohydrate (Davis C and Preston T R, unpublished observations), resulting in a feed with over 50% of readily fermentable material. A ration containing (DM basis) 44% pressed cane stalk, 23% legume forage (Canavalia ensiformis) and 24% poultry litter, reacted for 24 hr with 5.7% NaOH and 2.3% urea, had a faster rate of digestion in the rumen than freshly harvested immature elephant grass (Pennisetum purpureum) (Dixon R 'and Preston T R, unpublished observations).

CONCLUSIONS

After two decades of intensive research on the nutritive value of sugar cane and its by-products, it is concluded that final molasses, from conventional factory production of raw and refined sugar, and sugar cane juice from "on-farm" processing of sugar cane, offer the most promise as potential substitutes for cereal grains in intensive animal production enterprises in the tropics.

Research is needed to identify the constraints to high level feeding of final molasses to ruminants, especially for milk production: and to provide practical solutions to this problem. Fewer nutritional constraints are envisaged in developing livestock feeding systems based on sugar cane juice. In this case, the uptake of the technology will depend on the technical and economic feasibility of using the fibrous residue either for fuel or as a feed for ruminants.

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