ALKALI TREATED BAGASSE - POTENTIAL AS FEED FOR RUMINANTS

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SUMMARY

Spraying fresh raw bagasse with a 30% solution of sodium hydroxide (5% on dry fibre) increased the *in vitro* DM digestibility from about 30% to 55%. Treated alkali bagasse (TAB) fed with both molasses (20-40% wt:wt) and urea (1.5-2.0%) (TAB/M) maintained the live weight of weaner cattle, and when fed with cottonseed meal, allowed gains of up to 0.7 kg/d. In addition TAB has been fed successfully to cattle in a commercial feedlot at a level of 10% of the diet while TAB/M has been used as a drought ration for pregnant cows.

The concentrations of kidney, liver and muscle serum enzymes indicate there are no health problems associated with the feeding of predominantly TAB-based diets provided the maximum concentration of NaOH does not exceed 5% on dry fibre.

Bales of TAB and TAB/M can be stored for up to six months with no significant effect upon quality or acceptability by cattle. Storage beyond this period should be possible for unsealed bales because of their low moisture content at this stage. Although the bales were prepared at an initial moisture content of about 40 per cent, the high residual pH ensured effective inhibition of microbial growth and production of deleterious metabolites. The lengthy "shelf life" of these products greatly enhances their potential as drought fodder.

Economic analysis suggests TAB-based roughages would be very competitive with currently available stockfeeds, especially in north Queensland. Future commercialization of these products appears to be assured on the basis of the ready availability of markets and the low costs of production.

INTRODUCTION

In 1986, 307,000 ha of sugar cane was planted in Queensland and northern NSW. This crop yielded 3.2 x 10^6 tonnes of sugar valued at \$928 x 10^6 and 693,000 tonnes of molasses. At the same time, approximately 7.4 x 10^6 tonnes of fibrous bagasse residue containing about 50% moisture was produced.

Most of the bagasse is used as fuel in deliberately low efficiency boilers to generate steam to operate the factories. However, about 5-10% of the bagasse is in excess of requirements and therefore available for use as a by-product. At present this excess bagasse is either burnt or dumped.

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The average composition of bagasse (in g/kg) is; cellulose 410, hemicellulose 310, lignin 200-220, sugars 20-40, protein 10-20 and ash 20-40. The high concentration of structural carbohydrates generally precludes its use as a feed for cattle or sheep. Beames (1961) suggested using excess bagasse in the form of "bagomolasses" (a mix of 30% raw bagasse and 70% molasses by weight) as a fattening ration for cattle. However, due to the low digestibility of the bagasse fraction (about 30% *in vitro* DM digestibility) and since "bagomolasses" could comprise only about 50% of the ration little interest was shown in the material.

The nutritive value of low quality roughages can be improved by chemical, physical and enzymic processes. Increases in digestibility and voluntary consumption of low quality roughages (Jackson 1977; Kellaway 1980) and bagasse (Randel et *al.* 1972; Andrels and De Stefano 1978) have resulted from alkali (sodium hydroxide) treatment. The alkali dissolves lignin and silica, hydrolyses uronic acid and acetic acid esters (Jackson 1977) and swells cellulose probably by electrostatic repulsion followed by H-bonding with the entering water molecules.

This paper outlines the procedures associated with: 1. improving the nutritive value of bagasse (*in vitro* and *in* vivo studies); 2. the practicality of using treated bagasse in commercial situations; 3. ascertaining the keeping quality of the treated, packaged material; 4. the packaging of the treated bulky material (110-120 kg/m^3 on a wet basis) in a form suitable for storage and transport; and 5. determining the costs associated with improving the feeding value and packaging of bagasse.

NUTRITIVE VALUE OF BAGASSE

Method of Treatment

Treatment with sodium hydroxide was selected at the commencement of the research programme in 1979 over other procedures to upgrade the digestibility of bagasse for the reasons detailed in Table 1. Research findings published subsequently have indicated that this was a wise decision.

TABLE 1 Basis for selection of sodium hydroxide

Treatment	Comments
H_2SO_4	Possible inhibition and palatability problems associated with aromatic residues released by hydrolysis; now confirmed (Martin and Akin 1988).
NH_4OH	Weaker base than NaOH and unlikely to achieve same increase in digestibility (Bales *et al.* 1979). Lengthy reaction time, sealed conditions necessary, easier to add NPN as urea.
Steam explosion	Lower increase in digestibility and similar results expected to H_2SO_4 treatment *viz* dilute acid hydrolysis.
NaOH	Strong base leading to improved digestibility at relatively low concentrations (Jackson 1977).

In vitro studies

Fresh bagasse was sprayed with appropriate amounts of a 30% (w/v) sodium hydroxide solution (alkali) to give final concentrations of 0, 2.5, 5.0 and 7.5% alkali on dry fibre. To test the penetration of the alkali, the sprayed material was either mixed by hand or passed through a small experimental roller mill without extrusion of liquid. Samples were held for different periods of time to allow the alkali to react before drying. The potential effect of the alkali treatment was ascertained using the in vitro digestion technique of Tilley and Terry (1963).

The in *vitro* digestibility of bagasse increased and cell wall (Moir 1971) decreased as the concentration of alkali applied increased (Fig. 1). Digestibilities of the order of 50 to 55% were obtained at alkali concentrations of 5 and 7.5% (on dry fibre), respectively.

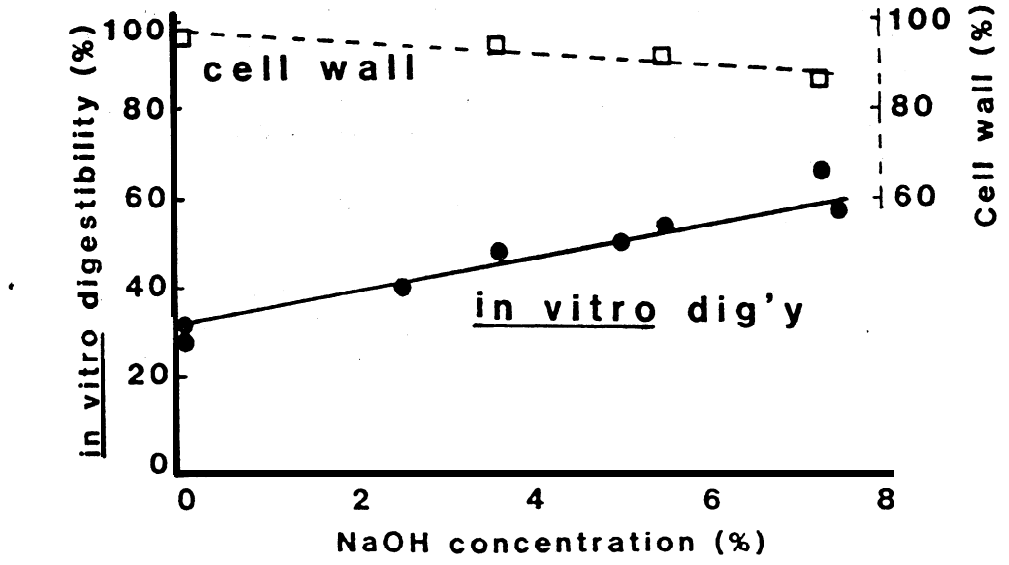

Figure 1. Effect of sodium hydroxide concentration on ***in vitro*** digestibility and cell wall content of bagasse

Harked differences in the rate of reaction were observed between samples hand mixed or passed through the roller mill (Tudor ***et al.*** 1985). The reaction of alkali with bagasse was slower when the material had not been milled; but, was approaching maximum digestibility after 24 h. The rapid increase in digestibility with the roller mill would be due to the high moisture content of bagasse ($\approx$ 50%) resulting in a rapid diffusion of alkali as a result of the high pressure. Although the reaction was more rapid when the roller mill was used the digestibility after 24 hrs with the mixed bagasse was slightly higher. All experiments have been conducted using bagasse that was sprayed and mixed.

In vivo studies

Preparation of alkali-treated feeds.

Fresh raw bagasse (150 kg) was added to a horizontal mixer (5,400 L) and sprayed with 14.3 L of a 30% alkali solution. The alkali solution was sprayed through a single nozzle attached to the side of the mixer. The

applications of the alkali solution took 3 to 4 minutes with the material being mixed for a further minute to ensure adequate mixing. The treated material (TAB) was stored for at least 24 h before feeding. The preparation of TAB/M (basal diet) was carried out by spraying TAB with a pre-mixed solution of molasses and urea using the same horizontal mixer and spray line. The addition of molasses and urea took approximately 13 minutes and was carried out 2 to 3 times each week. Jackson (1977) suggests that the upper limit for final alkali concentration in ruminant feeds is about 6% because of the high sodium intake and load on the kidneys. TAB with 6% alkali (on dry fibre) was initially selected to determine maximum animal response. This was later reduced to 5% because the improvement in digestibility with the extra 1% alkali was marginal and it does allow for some leeway for possible variation in. application that could occur due to variation in DM of bagasse.

General experimental procedure.

All cattle, with the exception of those used in the digestibility trial, were weighed every 7-days prior to the morning feed. Fasted live weight (FLW), 24 h off feed and 16 h off water, were recorded for each animal at the start and end of each experiment. They were fed TAB/M (with 1.5 - 2.0% urea) once daily to appetite, and feed residues were collected weekly. Dry matter percentage of the feed was determined weekly on bulked fed-out samples collected daily. Spilled or wet feed was dried and recorded with weekly dried residues. Water was available free choice.

The data were analysed by ANOVA with the average daily gains being estimated from differences in FLW between start and finish, divided by days on experiment. A regression of weekly full LW against time was not used to determine growth rate because of possible differences in gut fill between animals.

Experiment 1.

Thirty-five Brahman-cross steers with mean initial fasted live weight (FLW) of 150 ± (S.D.) 7.2 kg were randomly allocated on a FLW basis to seven treatments each with five animals. The animals were housed on concrete in individual stalls in a roofed animal house and kept free of internal and external parasites. TAB/M (with 1.5% urea) was fed as described and the supplements were supplied daily in separate feeders. The intake of TAB/M, supplements and live weight change were recorded over 84 days. All the supplements were consumed and are not included in the intake data in Table 2. The seven treatments were:

1. Basal (TAB/M, 80:20)
2. Basal + molasses (600 g/d)
3. Basal + molasses (600 g/d) + urea (27 g/d)
4. Basal + formaldehyde (HCHO)-treated casein* (35 g N/d)
5. Basal + HCHO-casein (35 g N/d) + molasses (200 g/d)
6. Basal + mixed protein meal (35 g N/d) consisting of HCHO-cottonseed meal+, fish meal and meat and bone meal in the ratio of 8:1:1, respectively, and
7. Rhodes grass (Chloris gayana) chaff (10% crude protein on DM) with similar *in vitro* digestibility to alkali-treated bagasse.

* 1 g pure HCHO per 100 g crude protein (DM basis)
+ 2 g pure HCHO per 100 g crude protein (DM basis)

The organic matter (OM) digestibility of TAB/M with selected supplements was measured with 12 Brahman-cross steers with mean initial LW of 283 ± 5.8 kg over two periods. The digestibility of four treatments (TAB/M, TAB/M + HCHO-casein, TAB/M + mixed protein meal and Rhodes grass chaff) were measured with three animals in each period. The cattle were held in metabolism cages and were kept free of internal and external parasites. They were fed TAB/M (with 1.5% urea) to appetite each day after residuing the previous day's food. Water was available free choice. Faeces was collected daily for seven days, bulked for individual animals, and at the end of each period mixed and sub-sampled in preparation for analysis.

The intake of TAB/M when expressed per kg LW shows a depression in roughage intake when supplemented with molasses or urea/molasses compared with no additional supplement (Table 2). This would probably be due to partial substitution of the roughage by the energy supplement and insufficient urea to maximise utilisation of the extra molasses. The lack of intake stimulation, when cattle were supplemented with extra urea suggests that the basal diet containing 1.5% urea satisfied the ruminal requirements for N and that the extra 13 g N was not required. Rumen ammonia concentrations in animals four hours after feeding and receiving the urea supplement were 9.8 mM/L. Although this is higher than the minimum concentration necessary for maximal microbial performance (Satter and Roffler 1977), it is below a concentration that may adversely affect intake.

TABLE 2 Intake, live weight change and organic matter (OM) digestibility of cattle fed alkali-treated bagasse with various supplements

	Treatments		OM intake (TAB/M)		Live weight change	OM
	Diet	Supplements	(kg/d)	(g/kg)	(kg)	digestibility
1.	Basal	None	1.99^{d}	13.7^{c}	-2.8^{c}	0.56^{ab}
2.	Basal	Molasses	1.57^{d}	10.9^{d}	2.2^{c}	-
3.	Basal	Molasses, urea	1.69^{d}	11.5^{d}	-5.6^{c}	-
4.	Basal	Formaldehyde-treated casein	2.21^{c}	14.5^{c}	12.2^{b}	0.57^{ab}
5.	Basal	Formaldehyde-treated casein, molasses	2.25^{c}	14.4^{c}	13.4^{b}	-
6.	Basal	Mixed protein meal	2.95^{b}	17.9^{b}	31.8^{a}	0.54^{b}
7.	Rhodes grass	None	4.40^{a}	25.9^{a}	29.8^{a}	0.62^{a}
	Ave. S.E. of mean		0.121	0.22	2.93	1.283

Means in the same column with different superscripts are different at $P < 0.05$.

Cattle fed TAB/M, with or without extra molasses and urea, maintained weight or suffered a small weight loss over the feeding period (Table 2). The LW response in the animals fed TAB/M plus HCHO-casein, with and without molasses, over those animals with only NPN would be a response to the amino

acids supplied post-ruminally as there was no change in intake (13.7, 14.5 and 14.4 g/kg). These data show the microflora were unable to satisfy the tissue amino acid requirements of the animals. The increased gains when the mixed protein meal was used compared with those supplemented with casein could be attributed to the higher intake (17.9 vs. 14.4, respectively), a better amino acid profile as well as the lipids and minerals in the mixed protein meal.

Cattle fed the alkali-treated basal diet and supplemented with the mixed protein meal converted food to live weight 38% more efficiently than the animals fed the higher protein, more digestible Rhodes grass chaff. Cattle fed TAB/M supplemented with mixed protein meal consumed 7.8 kg of organic matter for each kg of live weight gain (8.9 kg DM) compared with 12.6 kg per kg live weight (14.0 kg DM) for cattle fed Rhodes grass. Chicco et *al.* (1983) report a feed conversion of 13.4 kg DM in sheep fed a 60% DM digestibility bagacillo:molasses (70:20) diet. The better feed conversion reported in this experiment could result from the availability of amino acids, lipids and minerals from the mixed protein meal.

Experiment 2.

An experiment was carried out to determine whether an "off-the-shelf" protein supplement such as cottonseed meal could produce a similar response to a complex protected protein mix.

Twelve Brahman-cross steers with mean initial FLW of 184 ± 6.4 kg were randomly allocated on a FLW basis to three treatments each with four animals. They were individually housed in roofed, concrete floored pens and kept free of internal and external parasites. They were fed TAB/N (with 1.5% urea) as described with the protein supplements (35 g N/d) being mixed with the top portion of the TAB/M in the feed trough. The intake and growth rates were recorded over 78 days. It was assumed animals ate all the protein supplement and the intake data in Table 3 is TAB/M. The protein supplements were:

1. The mixed protein meal used in the first experiment (treatment 6) (500 g/d).
2. Untreated cottonseed meal (CSM) (520 g/d).
3. HCHO-treated CSM (520 g/d).

No difference in intake and only a small difference in daily gain were recorded between cattle fed the mixed protein meal and untreated cottonseed meal (Table 3).

TABLE 3 Effect of type of protein supplement on performance of steers fed TAB/M (80:20)

Type of protein supplement	OM intake (kg/day)	Av. daily gain (kg/d)
Mixed protein meal	4.1	0.44
Untreated cottonseed meal	4.1	0.48
HCHO-treated cottonseed meal	3.8	0.39
Av. S.E. of mean	0.21	0.070

The equivalent performance of cattle on all treatments suggests there is no need to protect protein meals against rumen digestion when animals are fed high sodium diets. The sodium from the alkali-treated bagasse would increase rate of passage of digesta from the rumen (Potter *et al.* 1972). Figure 2 illustrates the rapid loss of protein in untreated CSM compared with HCHO-treated CSM and the mixed protein meal when suspended in nylon bags in the rumen of fistulated cattle fed chaff

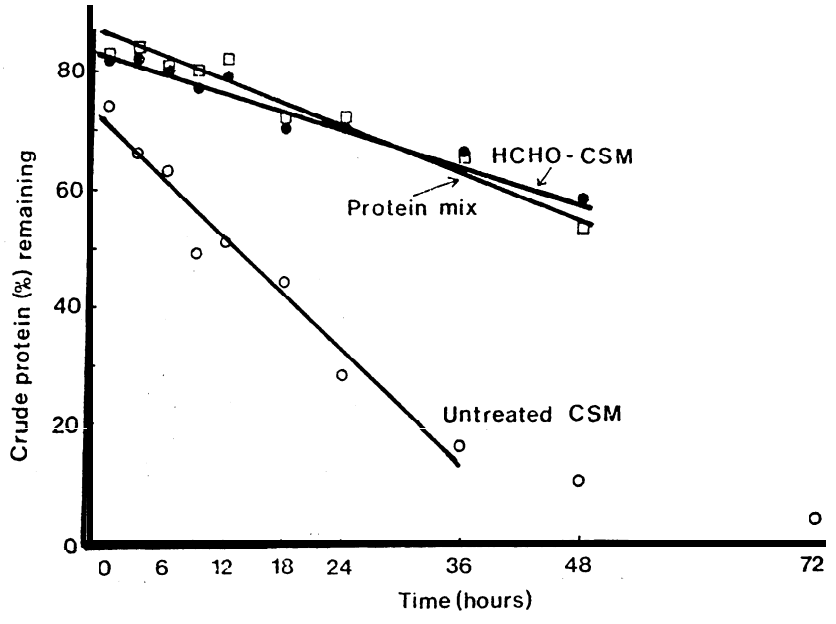

Figure 2. Protein (N x 6.25) remaining in protein mixes suspended in nylon bags in the rumen of fistulated cattle

Experiment 3.

Forty-eight Brahman-cross heifers with mean initial FLW of 185 ± 8.8 kg were kept free of internal and external parasites in open, concrete-floored yards. Animals were randomly allocated on a FLW basis to 12 groups, each of four animals. The 12 groups of four were then randomly allocated to each of six treatments, so that one replicate of each treatment contained four heavy animals while the other replicate contained four light' animals. They were group fed TAB/M (80:20 or 60:40) (with 2% urea) to appetite and either 500 or 1000 g CSM per animal per day for 84 days. The protein supplement was fed separate to the TAB/M so that appropriate levels of supplement could be determined. It was assumed all animals ate their daily quota and the intake data presented in Table 4 is TAB/M. The six treatments were:

1. 6% TAB/M (80:20) + 500 g CSM,
2. 5% TAB/M (80:20) + 500 g CSM,
3. 5% TAB/M (80:20) + 1000 g CSM,
4. 5% TAB/M (60:40) + 500 g CSM,
5. 5% TAB/M (60:40) + 1000 g CSM, and
6. 5% TAB/M/grain (60:17:23) + 500 g CSM.

To test the effect of the high intake of sodium on animal health, half the animals in each treatment were bled to monitor kidney, liver and muscle functions, *e.g.* creatinine (kidney), ganmaglutamyl tranferase (gamma-GT;

liver), glutamic-oxaloacetic transaminase (GOT; liver and muscle), creatine phosphokinase (CPK; muscle) and alkaline phosphatase (AP; liver, bone and gut). At the end of the 84-day feeding experiment, eight representative animals were continued on the 5% TAB/M diet plus 500 g CSM to further monitor the blood profile for an extra 42 days.

The intake and live weight change of cattle fed the various bagasse mixes and CSM are presented in Table 4.

TABLE 4 The intake, average daily gain and feed conversion of heifer cattle fed various alkali-treated bagasse diets

Treatment			OM intake	Average	
	Diet	CSM (g/d)	TAB/M (kg/d)	daily gain (kg/d)	Feed conv. (kg/kg)
1.	6% TAB/M (80:20)	500	4.04[b]	0.47[a]	8.6[a]
2.	5% TAB/M (80:20)	500	3.92[b]	0.48[a]	8.4[a]
3.	5% TAB/M (80:20)	1000	4.26[b]	0.61[a]	7.0[a]
4.	5% TAB/M (60:40)	500	4.23[b]	0.71[a]	6.0[a]
5.	5% TAB/M (60:40)	1000	4.36[b]	0.62[a]	7.0[a]
6.	5% TAB/M/grain (60:17:23)	500	5.35[a]	0.69[a]	7.8[a]
	Av. S.E. of mean		0.188	0.077	0.90

Means in same columns with different superscripts are significant at $P < 0.05$.

All cattle gained live weight with the best gains, 0.71 kg/d, being recorded in cattle fed the 60:40 mix with 500 g CSM or the mix containing a portion of grain (0.69 kg/d). The intake of cattle fed a 80:20 mix responded positively to the higher levels of CSM but not when the 60:40 mix was fed. This suggests they had attained their maximum intake.

Analyses of kidney, liver and muscle enzymes shows after 84 days, creatine phosphokinase (CPK) in cattle fed bagasse treated with 6% alkali was higher and outside the "normal" range compared with those fed 5%-treated bagasse (Table 5). All other enzymes were within the "normal" range. After 127 days CPK was still higher than "normal" although it was less than the high for 6% TAB.

TABLE 5 Biochemical tests of kidney, liver and muscle functions in cattle fed TAB for 84 and 126 days

	Creatinine µ mol/L	Gamma GT IU/L	GOT IU/L	CPK IU/L	AP IU/L
Start	173	14	46	95	111
84d (5%)*	134	11	89	109	114
(6%)+	146	9	79	206	105
126d	168	13	62	156	128
Normal	40-220	10-25	20-110	5-130	15-210

* Animals fed on 5% TAB

\+ Animals fed on 6% TAB

COMMERCIAL FEEDING OBSERVATIONS

Several small field trials were conducted to determine the suitability of using TAB on a commercial basis. TAB, with and without, 20% molasses was prepared at Pioneer Sugar Mill in the Burdekin District of north Queensland during the 1986 crushing season. A quick, simple and effective method of alkali treatment was devised whereby raw bagasse coming off a continuous belt at a defined rate was sprayed with concentrated alkali. Thereafter, the treated material passed through an elevated rotating drum for l-2 min. and then was stored overnight prior to use. In addition TAB/M was made into small bales (750 x 450 x 250 mm) and supplied to properties in north Queensland up to 800 km away from the site of manufacture either in a relatively fresh state or, alternatively, after storage for up to 3 months prior to feeding. By this time the latter had dried to a moisture content of approximately 15%.

In the first field trial, alkali-treated bagasse was successfully fed to cattle as the roughage component in two commercial Burdekin feedlots at a level of 10% of the grain-based diet. Ready acceptance by animals was also observed with bales of TAB/M (without CSM) fed under feedlot and open paddock conditions. No obvious preference was exhibited by the animals for bales of different ages, *i.e.* possessing different moisture contents.

In a second feeding trial TAB/PI (80:20) (with 2% urea) containing CSM at 10% of the diet was fed to grazing pregnant cows during a drought in southern Queensland. Approximately three tonnes of this feed was prepared and transported about 50 km in loose form to the farm, dumped on the ground and covered with plastic sheets. About 200 kg were withdrawn daily and fed *ad lib.* to the cows. Another mob of similar cows were fed whole cottonseed to appetite. The cows consumed about 7 kg/hd per day of TAB/M whereas animals fed whole cottonseed consumed about 3 kg/hd per day. An assessment by the farmer and field advisory staff suggested the cattle performed better on the TAB/M ration as they had better coat colour and stronger calves. About half the animals fed TAB/M commenced eating immediately while the remainder took one to two weeks to come on to the ration. In contrast, some animals would not eat the whole cottonseed. Though green pick was available for the last month of the three month trial, no significant decrease in intake of TAB/M was observed.

KEEPING QUALITY

Preparation of Bales

Although TAB shows excellent commercial potential, eventual commercialization depends on developing suitable methods for marketing of these products. Because of its very low bulk density (110 - 120 kg/cm^3 loose moist bagasse) a bagasse-based product would have to be compressed in order to overcome the considerable freight costs associated with the loose material. Preliminary investigations indicated that baling was both cheaper and faster than pelleting. However, due to the high moisture content, some reservations were expressed about the long term storage of these roughages, especially TAB/M. Consequently, the keeping qualities of bales of TAB and TAB/M were assessed under conditions likely to be encountered in a commercial process. In preparation for baling TAB and TAB/M, a quantity of bagasse was treated with alkali and stored. The material was mixed prior to baling.

Bales of TAB and TAB/M of approximately 40% moisture were made in an experimental baling machine in which wafers measuring 650 mm square by approximately 50 mm deep were produced sequentially through the machine then pressed into bales of the required size. Large bales measuring 650 mm square by 400 mm deep with densities varying from 418 to 662 kg/m^3 were either sealed into large plastic bags or left in an unsealed state. Bales of each type of mix were stored for up to six months (November to April) at ambient temperatures in an open shed at the Animal Husbandry Research Farm in Brisbane. Samples were withdrawn from both the centre and edge of the bale with a different bale being used for each of the sampling times recorded in the table. The measurement of pH, moisture content, low molecular weight sugars (mainly sucrose, glucose and fructose), microbial activity and numbers were described by Inkerman *et al.* (1988a,b).

Changes in Bales During Storage

The changes in moisture of sealed and unsealed bales of TAB/M (80:20) during storage are shown in Fig. 3. Moisture levels in the sealed bales remained unchanged at about 43% at both sampling sites. In comparison, the moisture content of the unsealed bales decreased slowly with time. After two months, the moisture content at the edge had fallen to about 15% which is similar to that of air-dried bagasse. However, in the centre of the bale, rate of moisture loss was slower and moisture content at the end of the six month storage period was about 20%.

In the absence of molasses, the pH of TAB remained unchanged at approximately pH 11.3 during the six month storage period. A similar consistency of pH (9.5 - 10.5) was observed with the unsealed bales of TAB/M (both 80:20 and 60:40) during the prolonged storage. However, as significant variability in pH occurred in some of the sealed bales of TAB/M, sealing of bales was not pursued for marketing this product.

No significant changes in the content of the low molecular weight carboydrates (10 mg/g) were observed in the bales of TAB over the six-month storage period. In comparison, in both the 80:20 and 60:40 mixes, the original levels decreased about 25% in the first month and 50% by the second month. Thereafter, the decrease slowed considerably as expected from the low water content of the bales at this stage (Fig. 3).

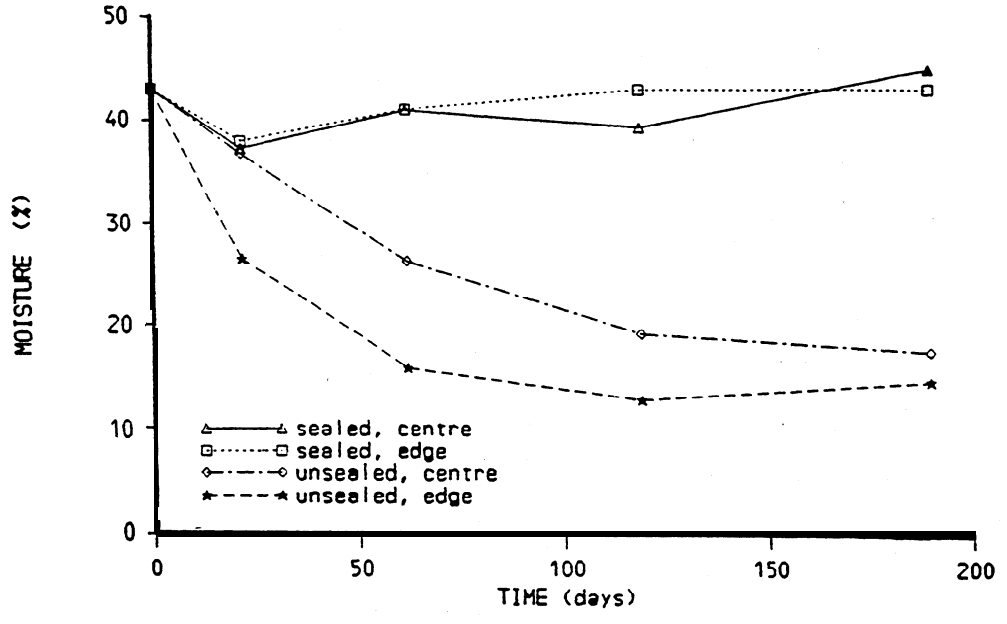

Figure 3. Moisture content of bales of TAB/M (80:20) during storage

The total number of viable microorganisms present in the bales varied from 10^7 to 10^{10} per gram of moist bagasse (Inkerman *et al.* 1988a,b). The cultured microorganisms were almost exclusively bacteria. The higher numbers are of the same magnitude as had been found in fresh bagasse during the first day of storage, while the lower numbers are similar to those found after about 10 weeks of storage. The numbers of *Thermoactinomyces spp.* remained approximately constant in all bales during storage. Similar levels of these filamentous bacteria have been found in fresh bagasse (Lacy 1980). Unidentified yeast was present on the outside of some bales, but no other fungal growth was observed.

The changes in nitrogen levels and *in vitro* digestibilities of bales during storage are presented in Table 6. Nitrogen levels in the sealed bales remained unchanged whereas decreases of about 20 and 40 per cent were observed for the unsealed bales of 60:40 and 80:20 TAB/M, respectively. The rises and falls in N concentration that occurred in the sealed bales with storage would be due to mixing and sampling errors. A strong smell of ammonia was detected with the 80:20 bales. Digestibilities of bagasse in unsealed bales stayed constant while significant decreases were recorded for the sealed bales except in the case of the 80:20 TAB/M. The reason for the large decrease in the digestibility of the sealed bales of TAB is not known.

TABLE 6 Nitrogen concentration and *in vitro* digestibilities of OM in sealed and unsealed bales upon storage

Type of Bale (TAB/M)	Period of Storage (days)	Sealed		Unsealed	
		Nitrogen*	Digestibility	Nitrogen*	Digestibility
100:0	12	0.3	0.51	0.3	0.51
	27	0.3	0.52	0.3	0.51
	67	0.3	0.31	0.3	0.52
	124	0.3	0.36	0.3	0.50
	195	0.3	0.31	0.3	0.52
80:20	7	1.7	0.52	1.5	0.56
	22	1.7	0.54	1.2	0.56
	62	1.9	0.51	0.9	0.58
	119	1.8	0.50	1.0	0.54
	190	2.4	0.51	0.9	0.54
60:40	6	1.8	0.65	1.7	0.64
	21	1.6	0.63	1.6	0.62
	61	2.3	0.61	1.7	0.64
	118	2.0	0.51	1.7	0.61
	189	2.0	0.52	1.4	0.62

* Expressed as per cent on dry matter

Assessment of Keeping Quality

The quality and composition of bales of TAB-based roughages is not significantly affected during storage for up to six months. Storage beyond this period should be possible, especially of unsealed bales, because of their low moisture content at this stage. In particular, TAB would appear to possess an almost indefinite shelf life. Though there is evidence of some changes in the composition of TAB/M (e.g. decreases in the levels of nitrogen and soluble carbohydrates), these appear to have negligible effect on the digestibility of the products or their ready acceptance by cattle fed under a variety of conditions. In this regard, the decreases in pH obtained with some bales would have been associated with the production of organic acids which are readily utilized by the rumen microflora (Inkerman *et al.* 1988a,b). Furthermore, because TAB-based roughages are prepared to a given formulation, the consistent quality of the product can be guaranteed at, all times. In contrast) this does not apply to most other commercial feedstocks where quality is known to vary widely with the season and time of harvest.

Microbial activities and numbers in these roughages are similar to levels found in fresh bagasse. This, together with the absence of fungal growth, indicates that the high residual pH has effectively inhibited microbial growth and production of any deleterious metabolites such as aflatoxins. Though microbial activity would be expected to be very low under these conditions, the pH is not high enough to prevent some hydrolysis of urea by cell-bound ureases and the subsequent evolution of ammonia and carbon dioxide. The latter did not appear to affect the animals ' willingness to eat TAB/M.

Contrary to the storage of untreated bagasse which deteriorates rapidly, the successful long-term storage of TAB-based roughages has been achieved without prior drying of the bagasse to a moisture content of about 15%. In fact this step should be avoided as drying results in a significant decrease in digestibility if carried out rapidly (G.D. Tudor unpublished data) as well as adding about $10 per tonne to the cost of the final product. During prolonged storage, bales should be arranged in a manner which allows adequate ventilation and evaporation of moisture from the surface.

The production of TAB and TAB/M would be most efficiently accompli shed) with least cost, if performed by the sugar mill. The bagasse required for treatment could be separated from the bagasse line before the storage area, sprayed with sodium hydroxide and, if required, molasses and urea could be added soon after. Preliminary results show that adding molasses/urea straight after spraying with sodium hydroxide will not reduce the response obtained from treated with alkali. This procedure would be cheaper than that proposed by Sankat *et al.* (1988) who proposed both drying and grinding before pelleting.

COST OF PRODUCTION

The costs of production of TAB-based roughages both in loose and baled forms are summarised in Table 7 and given in detail by Inkerman *et al.* (1988a,b).

The costs of production of the TAB-based roughages show a strong dependence on the level of throughput. This is due to the high capital recovery component in the total operating costs. In the case of baled

products, the throughput of the plant is governed by the rate of baling which has been set at 10 tonnes per hour. For markets in close proximity to the factory, it would be cheaper to-supply the product in a loose form. In this regard, the product could be compacted to 200-250 kg/m^3 which is about one-third the density achieved by baling.

The detailed costings presented in this study confirm our earlier findings (Tudor et *al.* 1985) that the alkali component is the major expense item associated with the production of TAB-based roughages. To date, attempts to find a cheaper source of sodium hydroxide have been unsuccessful. However, with the recent interest shown in intensive animal production, a lower level of alkali such as 2.5% could be used for the feedlot industry *i.e.* in addition to the 5% product. Though the *in vivo* digestibility of the former product has not been determined, *in* vitro studies suggest it should perform as well as cereal stubble (see Tudor *et al.* 1986a,b). Furthermore, the storage characteristics of this product are expected to be similar to that of 5% TAB.

TABLE 7 Costs[a] of production of TAB and TAB/M as at May 1988

Product	Amount (tonnes)[b]	Cost/tonne ($A) 50% Moisture[b]	Cost/tonne ($A) 10% Moisture[c]	Alkali Component (%)[d]
Loose 2.5% TAB	20000	16	26	41.5
	5000	34	57	18.9
Baled 2.5% TAB	20000	23	40	27.8
	5000	51	84	12.9
Loose 5% TAB	20000	22	37	58.6
	5000	41	68	31.8
Baled 5% TAB	20000	30	50	43.5
	5000	57	95	22.8
Loose TAB/M (80:20)	12000	34	56	31.7
	6000	44	74	24.2
Baled TAB/M (80:20)	12000	44	73	25.3
	6000	59	98	18.3

[a] No charge made for bagasse
[b] Based on products of 50% moisture content
[c] Based on products of 10 per cent moisture i.e. similar to commercial roughages
[d] Expressed as a percentage of total operating costs

Markets envisaged for TAB would be as the roughage component in high grain feedlot diets and for TAB/PI (80:20), as a drought feed, for acclimitisation of cattle in feedlots, or with the addition of a protein meal, for slow fattening. The lengthy shelf life of TAB/M should allow

storage for long periods. TAB/M is safe and would be an ideal alternative to molasses-urea. By replacing 20% of the TAB/M with grain, daily gains of 0.9 kg per head per day can also be achieved (G.D. Tudor, unpublished). A large potential overseas market exists for these TAB-based roughages especially in Japan. However, problems in the areas of transport and product acceptance need to be overcome before entry into this market can be achieved.

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REFERENCES

ANDRELS, H.J. and De STEFANO, R.P. (1978). Sugar J. 41: 13.
BALES, G.L., KELLOG, D.W. and MILLER, D.D. (1979). J. Anim. Sci. 49: 1324.
BEAMES, R.M. (1961). Qld. J. Agric. Sci. 18: 425.
CHICCO, C.F., GARCIA, G., FERNANDEZ, C. and PRAYS, C.R. (1983). Sth Afr. J. Anim. Sci. 13: 18.
INKERMAN, P.A., TUDOR, G.D., ASHBOLT, N.J., BROWN, C.F., LUCAS, S.R. and WEBSTER, M. (1988a). Proc. Aust. Soc. Sugar Cane Tech. 10: 69.
INKERMAN, P.A., TUDOR, G.D., ASHBOLT, N.J., BROWN, C.F., LUCAS, S.R. and WEBSTER, M. (1988b). Sugar J. 51: 4.
JACKSON, M.G. (1977). Anim. Feed Sci. Technol. 2: 105.
KELLAWAY, R.L. (1980). Rec. Adv. Anim. Nutr. 10 (ed. D.J. Farrell) N.E. Univ. Publ. Unit.
LACEY, J. (1980). Proc. Inter. Soc. Sugar Cane Tech. 17: 2442.
MARTIN, S.A. and AKIN, D.E. (1988). Appl. Environ. Microbial. 54: 3019.
MOIR, K.W. (1971). J. Sci. Fd Agric. 22: 338.
POTTER, B.J., WALKER, D.J. and FORREST, W.W. (1972). Br. J. Nutr. 27: 75.
RANDEL, P.F., RAMIREZ, A., CARRERO, R. and VALENCIA, I. (1972). J. Dairy Sci. 55: 1492.
SATTER, L.D. and ROFFLER, R.R. (1977). Trop. Anim. Prod. 2: 238.
SANKAT, C.K., SINGH, R.H., LAUCHNER, B. and OSUJI, P.O. (1988). Proc. XXIII West Indies Sugar Tech. Assoc. Conf., p. 395.
TILLEY, J.M.A. and TERRY, R.A. (1963). J. Br. Grass. Soc. 18: 104.
TUDOR, G.D., MARTIN, P.K. INKERMAN, P.A., BROMAGE, E.K. and FOSTER, D.H. (1985). Proc. Aust. Soc. Sugar Cane Tech. 7: 59.
TUDOR, G.D., INKERMAN, P.A. and BROMAGE, E.K. (1986a). Proc. Aust. Soc. Sugar Cane Tech. 8: 25.
TUDOR, G.D., INKERMAN, P.A. and BROMAGE, E.K. (1986b). Sugar J. 49: 12.