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PRELIMINARY INVESTIGATIONS ON THE FEASIBILITY OF CO-PRODUCTION OF CANE PULP AND RAW SUGAR

N. B. Clark, July 1990

TABLE OF CONTENTS

Title	Preliminary investigations on the feasibility of co-production of cane-pulp and raw sugar.
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OBJECTIVE

To study the feasibility of producing both cane-pulp and raw sugar from sugar cane, by applying the mechanical refining technology used by the pulp and paper industry.

SUMMARY

Laboratory-scale mechanical refiners were used to prepare four varieties of sugar cane for depithing, and for the production of refiner mechanical pulp (RMP) and chemi-mechanical pulp (CMP) from depithed canes and from cane rind. Pulp quality was assessed and the amount of raw sugar recovered was measured to determine if co-production of cane pulp and raw sugar might be feasible on an industrial scale. The tests showed that simple RMP pulps with strength properties adequate for commercial purposes cannot be prepared from sugar cane, but CMP pulps with strength properties equivalent to hardwood CMP are feasible, at least at brightness levels below 60% ISO. The yield and quality of CMP pulps prepared from depithed canes and cane rind were influenced by the sugar cane variety. The use of brightening agents such as hydrogen peroxide, sodium metabisulphite and sodium hydrosulphite improved overall pulp brightness but did not remove dark coloured plant fragments. CMP pulps prepared from sugar cane rind had slightly poorer pulp strength properties and lower brightnesses than pulps made from depithed whole cane. Raw sugar recovery from the mechanical pulping processes was c.22% lower than that achieved by modern sugar mills, probably because cell-wall

disruption was reduced and the washing method was crude.

FUTURE WORK

If funds are available, the areas of study with the most potential for development are:

1. Optimization of bleaching conditions
2. Improvement of sugar extraction

1. INTRODUCTION

Bagasse, the fibrous residue left when sugar cane is milled, has been used for papermaking for many years (the first reported trials were in 1856, Atchison 1952). However, compared with wood, bagasse suffers from several disadvantages. Although the sugar cane fibres themselves are useful for papermaking, bagasse includes pith or parenchyma cells which contribute little to paper strength. Equipment to remove the pith efficiently is required. In addition, since sugar cane is not harvested year round, storage facilities are needed which are capable of preserving the properties of the bagasse over the intervening months between harvests. Transport costs can be a limitation too, as the low density of bagasse can make long distance transport expensive, so reducing the possible scale of the pulp mill. Finally, although chemical pulping gives a useful pulp, chemical recovery is complicated by the silica and pith content of bagasse.

With current technology, none of these disadvantages is insurmountable. Efficient depithing equipment is now available from respected pulp and paper industry supplier companies such as Beloit. Bagasse storage schemes such as the Ritter and Bagatex-20 processes are now successfully used in mills around the world. Transport costs have been lowered by using high density baling equipment, producing round or rectangular bales weighing as much as

700 kg. Chemical recovery efficiencies of up to 90% are routinely achieved in many modern bagasse pulp mills. Indeed, such has been the pace of development, some authorities claim that bagasse pulping technology is now at a comparable state of development to that of wood-based processes (Atchison 1989).

Why, then, has bagasse not been used as a source of papermaking fibre in Australia? One answer to this question relates to fibre quality and the availability of other sources of papermaking fibre. Conventional sugar cane milling processes damage the bagasse fibres, reducing the strength of the paper produced. (Gartside and Langfors 1981). Since there are substantial volumes of hardwoods available in Australia which can be made into pulps which are stronger than those made from bagasse, there has been little incentive for the utilization of bagasse in paper. However, this situation might change if the fibre damage caused by conventional sugar extraction equipment could be avoided.

It has been suggested by Dr. G. Gartside of this Division that it might be possible to extract the raw sugar from the cane, without damaging the cane fibre, by applying of the refiner mechanical pulping processes used by the pulp and paper industry. The feasibility of such a process would depend on the properties of the pulp produced and on the efficiency of the recovery of the raw sugar. This project was initiated to study these factors. For a full discussion of the background of the project, see the Appendix.

2. EXPERIMENTAL

2.1 Sampling

Four varieties of sugar cane were collected for the project from plots supervised by the Bureau of Sugar Experiment Stations. The first variety, Q135, was obtained by Mr. K.F. Miller of the Sugar Research Institute and came from the Mackay area. This variety is a hard cane (see Figure 1) and has the potential for significant future plantings. To quote Mr. Miller (1989), "The cane variety, Q135, is one developed by the Bureau of Sugar Experiment Stations (BSES) in Queensland. The BSES advise that it is a fairly recent release, particularly suited to better class soils. As a variety it is presently in the ascendancy and shows good potential to become a major variety in the central region (up to say 20 percent maximum over the next few years). It gives good standing heavy crops with high sugar content and ratoons well."

The second and third varieties, Q108 and Q103, came from the Bundaberg area and were obtained for the project by Mr. A.G. Noble of the BSES. Q108 is also a hard cane, whereas Q103 is a very much softer cane, and has a higher proportion of pith. (See Figure 1 for a comparison of the relative strength properties of the canes and Table 1 for the proportions of pith and fibre).

The fourth variety, Q113, is a hard cane from Tully in Queensland, and was sampled for the project by Mr. J. Reghanzani of the BSES. This cane is similar in appearance to Q108 and has similar strength properties. However, the amounts of pith and fibre in the two canes are different, although the ratios are similar.

All the samples were cut into billet lengths and transported to CSIRO's Clayton laboratories under refrigeration. On arrival, the billets of each cane variety were separately mixed and placed in double-walled plastic bags and stored in a freezer room at $-10^{o}C$. Sub-samples were taken at random for each experiment and cut into about 2 cm lengths with a guillotine before being pulped.

2.2 Apparatus

The equipment used initially was a 203 mm (8 inch) diameter Bauer laboratory disk refiner. This machine consists of an electric motor driving one of a pair of steel disks, set face to face. The disks have patterns of grooves and bars on their faces and the gap between the disks is adjustable in the range 3.75 mm to 0.125 mm (0.150 inches to 0.005 inches). The disks are removable and a variety of disks with different patterns can be substituted. The material to be pulped is manually fed from a hopper through the axis of rotation of the disks, then centrifugal force impels the material toward the periphery, where the disk pattern breaks up the material into progressively finer fragments.

A second refiner was also used. This machine was a Sprout Waldron laboratory refiner, which is similar to the Bauer refiner, but has a screw feeder. With a diameter of 303 mm (12 inches) the Sprout Waldron is 50% larger than the Bauer refiner and can be controlled to finer tolerances.

2.3 Procedure

2.3.1 Refiner mechanical pulping

This first series of tests investigated the feasibility of using a simple refiner mechanical pulping (RMP) procedure, combining fibre separation with raw sugar extraction. The simplest configuration of this process would be a single pass through the refiner, using wash water to extract the raw sugar.

To test this configuration, c.2 cm lengths of cane Q135 were fed through the Bauer refiner. The plate pattern, the plate gap and the consistency were varied. These tests were not successful. Since the cane pieces are large compared with the woodchips normally used as feedstock for the refiner, coarse disk patterns and wide gaps (2.5 mm) were needed before the cane would pass through the refiner. The resulting pulp was coarse and unsuitable for papermaking. Multistage processes were considered to have more potential.

To test the multistage approach, the cane Q135 was first broken down to a coarse mass of fibres, using two passes through the Bauer refiner with disk gaps of 2.5 mm and 0.25 mm respectively. The pith was then separated from the fibre by wet screening through a stainless steel plate with 3 mm diameter holes. To remove any pith still adhering to the fibre, the fibre was disintegrated in water for 10 minutes at 2850 rev/min and then screened again. Refining was carried out at 5% consistency using the Bauer refiner's fine pattern disks at a narrow gap (0.125 mm) and 10 passes through the refiner.

Although a pulp was produced with a high freeness (c.500 CSF), it proved to be impossible to prepare a lower freeness pulp, possibly because the gap between the disks could not be controlled to a low enough tolerance. Accordingly, the Sprout Waldron refiner was used in place of the Bauer to prepare a pulp with a freeness of c.250 CSF. A consistency of 5%, a plate gap of 0.05 mm and 5 passes were used to produce this pulp.

2.3.2 Chemi-mechanical pulping

In this series of tests, the cane Q135 was first broken down into fibre and pith and the pith removed using the method outlined above. Portions of the separated fibre were then impregnated with sodium hydroxide (NaOH) at a range of concentrations, alone or in combination with 4% (o.d. fibre basis) hydrogen peroxide (H_2O_2). This peroxide concentration is high by pulp industry standards and was chosen in an attempt to maximize the increase in pulp brightness. After impregnation, the residual chemical concentrations were measured by titration. The effects of other brightening agents were investigated, either as a pretreatment to the sodium hydroxide impregnation (in the case of sodium metabisulphite- $Na_2S_2O_5$) or as post-treatments (in the case of sodium hydrosulphite- $Na_2S_2O_4$ and sodium hypochlorite- NaOCl). The concentrations used were again at the upper end of the range used by the pulp industry. No attempt was made to measure the residual concentrations of sodium metabisulphite and sodium hydrosulphite, as the required analytical methods are complex. The conditions used in the eight trials are summarized in Table 2.

After impregnation, the fibre was washed in water to remove free alkali and then refined in the Bauer using a plate gap of 0.125 mm and a consistency of 5%. The resultant pulp was washed in sulfurous acid (pH 4) to change inherent pH-sensitive dyes back to the less yellow acid form. Finally, the pulp was washed in water and screened through a Packer screen with 0.2 mm slots.

CMP pulps were also produced from the other three cane varieties. The impregnation conditions were standardized to 12% sodium hydroxide and 4% hydrogen peroxide (o.d. fibre basis) at a temperature of 25^{o}C over a reaction time of 3 hours. The impregnated fibre was refined using a single pass through the Bauer at 5% consistency and a plate gap of 0.125 mm This approach was necessary because a single refiner pass often gave a pulp with a freeness lower than 250 CSF, precluding any possibility of controlling to a target freeness by changing the number of refiner passes.

Following a suggestion by Mr. J.D. Coleman of this Division, the properties of chemi-mechanical pulps prepared from the rind of the canes Q108, Q103 and Q113 were investigated. The sugar cane billets were stripped using a spokeshave with the blade set to remove the rind to a depth of about a millimetre, corresponding to the natural horizon between the cane rind and pith. The rind thickness was then measured with a micrometer. After air drying for 3 days, CMP pulps were prepared from the dried rind under the conditions described in the previous paragraph for whole cane.

Handsheets were prepared from selected CMP pulps according to Australian Standard As1301.203s-80. The effect of beating in a PFI mill (Australian Standard As 1301.209rp-82) on pulp strength was studied where pulp sample sizes permitted. Paper testing was carried out according to Australian Standard As 1301.208s-83 after conditioning the sheets in an atmosphere of 50 percent relative humidity and 23^{o}C. The brightness of the pulps was measured with a Technibrite Micro TB-1C.

2.3.3 Extraction of raw sugar

A prerequisite for a feasible co-production process is efficient extraction of the raw sugar from the cane. The current technology used by the sugar industry extracts about 97% of the sugar content of raw cane, and the concentration of the sucrose extract is about 18% solids. Obviously, it would be very difficult to match this efficiency with new processes, which would be necessarily less developed. In co-production of raw sugar and cane pulp, the value of the pulp produced from the cane might mean that less efficient sugar extraction could be tolerated, but the scope for such trade-offs is limited. As an interim target, an efficiency of 92% and a solution concentration of 10% was nominated as acceptable for co-production.

The fibre, sugar and water content of the cane Q135 was determined. In the absence of a high-speed disintegrator as used by the sugar industry, a weighed sample of raw cane was defibrated in the Bauer refiner with a known quantity of water. Several passes at narrow gaps were used in an effort to ensure that all the sugar in the cane was liberated. The refractive index of the solution was measured, the fibre was collected, washed and weighed, and the moisture contents of the cane and the fibre were determined by drying in an oven at 105°C.

Trials were then carried out to measure the amount of sugar extracted from the cane, broken down with the Bauer refiner as in the first stage of the chemi-mechanical pulping procedure. Two variations of this refining procedure were used to test the effect of refining intensity on sugar recovery. In the first trial, a weighed sample of cane was passed through the Bauer refiner twice at disk gaps of 2.5 mm and 1.5 mm respectively. The defibred cane was transferred to a pneumatic press and any free liquid squeezed out of the fibre. A quantity of hot (90°C) water equal to half the mass of the defibred cane was added to the press and allowed to stand for 2 min. The fibre was then pressed and the liquid collected and weighed. This extraction procedure was repeated and the refractive index of the combined extracts measured after cooling to 20°C, allowing calculation of the amount of sugar recovered from the cane. The second trial doubled the number of refiner passes to four, at disk gaps of 2.5, 1.5, 0.5 and 0.25 mm respectively. The extraction procedure was the same as that used in the first trial.

3. RESULTS AND DISCUSSION

3.1 Refiner mechanical pulping

Of the two RMP pulps prepared (at c.500 and 250 CSF), neither were strong enough to make handsheets. The high freeness pulp had insufficient bonding strength for acceptable sheet formation, while the low freeness pulp had a high proportion of short fibres, resulting in a low tear strength. (By Kajaani test, more than 93% of fibres were shorter than 0.5 mm). Pulp brightness was also low, probably because of the high number of refiner passes needed to achieve the required freeness. These results are comparable with those of hardwood RMP's, which are too weak for commercial purposes.

3.2 Chemi-mechanical pulping

The CMP pulping trials were more successful. The uptake of chemicals by the depithed fibre from cane Q135 was rapid in the first 20 minutes, then leveled out, sodium hydroxide particularly (see Figure 2). This high initial rate of absorption was probably caused by the small cross-section of the individual fibre bundles, resulting in a high surface area per unit mass. Note that the curves in Figure 2 relate to the rate of absorption and are not direct measures of the rate of reaction. The slow change in the apparent stiffness of the fibres suggested that the reaction rate was slower than the absorption rate at the temperature at which the tests were carried out ($25^{o}C$).

The apparent sodium hydroxide and hydrogen peroxide absorptions, together with the brightness of each pulp produced from the eight trials on cane Q135, are given in Table 3. Treating the cane fibre with 36% sodium hydroxide alone gave the lowest pulp brightness (Trial 1). Using sodium hydroxide and hydrogen peroxide together in the ratio of 3:1 improved pulp brightness markedly (Trial 2), and reducing the alkali to peroxide ratio to 2:1 (Trial 3) resulted in further improvement, in agreement with work by Peng and Simonson (1989) on bagasse. A pretreatment using sodium metabisulphite (Trial 4) also improved pulp brightness compared with 3:1 alkali and peroxide, but not if the peroxide was omitted (Trial 5). Using a sodium hydrosulphite post treatment also improved pulp brightness but the effect was slightly less than that of the sodium metabisulphite pretreatment. The trials using sodium hypochlorite (Trials 7 and 8) were not successful, as all the hypochlorite was consumed before the end of the heating time, causing alkali darkening. This result is also in line with work on bagasse (Falk 1981) which showed that a certain amount of delignification is necessary before hypochlorite can have an appreciable positive effect.

Overall, it was evident that hydrogen peroxide was the most effective brightening agent, although none of the pulps had a brightness higher than 60% ISO. (Note that the target brightness for newsprint in Australia is c.65% ISO). It was observed that although the brightening agents improved the brightness of the bulk of the pulp, there was little effect on the dark fragments from the cane rind, which were scattered throughout. Higher impregnation temperatures may be required to remove these dark fragments, which may otherwise be a significant barrier to the utilization of cane pulps in paper products.

The yield of CMP from Q135 was about 50 kg of o.d. pulp per tonne of green cane, which is equivalent to about 30% of the weight of the o.d. fibre and pith in the cane. Losses of fibre occurred both in the depithing process and during pulping. Only about 54% of the material was separated as fibre after depithing and only about 56% of this depithed fibre was collected as pulp. Note that since depithing efficiency affects pulp yield considerably, and the optimum delignification required for the intended paper product is not known, these figures may not accurately reflect mill-scale CMP yields.

The handsheet properties of the pulps from Trials 1 and 2 are given in Table 4, together with those of a mixed hardwood CMP for comparison. The cane CMP pulps are higher in bulk and tear strength than the hardwood CMP pulp, but lower in freeness and tensile strength. These results suggest that the CMP cane pulps would be strong enough for newsprint, although the low freeness emphasizes the need for efficient separation of the pith from the fibre. The good tear strength of the cane pulps is of particular interest, as this has been the fibre property most degraded by conventional sugar milling processes (Gartside and Langfors 1981).

Table 5 compares the chemical absorptions and the unbeaten handsheet properties of the four different cane varieties. The pulp made from cane Q103 had a substantially lower freeness and tear strength than the pulps made from the harder canes, although tensile strength was a little better. It is apparent that Q103 suffered more fibre damage on refining than the harder canes. The overall yield of pulp from cane Q103 was also much lower, because of the higher content of pith (see Table 1).

The properties of the strips of rind skived from the outside of the different canes also emphasize the differences between Q103 and the hard canes. Table 6 shows the average thicknesses and standard deviations of the rind strips. Statistical analysis suggests that at the 95% confidence limit, the strips from Q103 were significantly thicker than those from Q113 and Q108, while the thicknesses of the strips from Q113 and Q108 were not statistically different. It is likely that the thicker strips taken from Q103 were a consequence of the softer structure of this cane.

The results of the pulping tests on the strips of rind are given in Table 7, together with properties of the unbeaten handsheets. The differences between the chemical absorptions of the canes were small, but Q103 gave a lower fibre yield than the other two varieties and fewer shives. The lower fibre yield may reflect the lower fibre content of this cane, while the lower shive yield suggests that Q103 was more easily defibred under the test conditions than the other two varieties. The tear and tensile indices of the pulps made from the cane rind were somewhat lower than the pulps made from the depithed whole cane, while bulk was higher. Pulp brightness was also reduced in two of the three cane varieties, which was probably related to the increase in the number of dark fragments in the pulps.

If the moisture contents of the original canes are considered, the yields of o.d. fibre from the green canes would be only 2.1, 3.2 and 3.0 percent for Q103, Q113 and Q108 respectively. A pulp mill based on cane rind and producing 50 000 tpa of o.d. pulp would therefore need to skive 5 million tonnes of green cane per year, or about one fifth of Australia's annual sugar cane crop.

3.3 Extraction of raw sugar

The tests carried out on cane Q135 inferred a moisture content of 65.9%, a fibre content of 13.6% and a sugar content of 20.5% (w/w). Using these figures, the raw sugar extracted after two passes through the Bauer was 64% of the total, compared with 76% after four refiner passes.

These sugar recovery results are unacceptable as a basis for a commercial process, but show the dependence of extraction efficiency on the degree of fibre disruption. This dependence was emphasized by a measurement of the sugar content of the fibre from the first trial after the extraction step. The residual sugar content was 16.7%, suggesting that much of the sugar was still trapped within the fibres. This implies that extraction efficiencies approaching those of modern sugar mills may require a refining intensity higher than is consistent with maximum fibre strength, or perhaps more sophisticated washing techniques than those applied in the laboratory tests.

4. CONCLUSION

The tests have shown that simple RMP pulps with strength properties adequate for commercial purposes cannot be prepared from sugar cane, but CMP pulps with strength properties equivalent to hardwood CMP are feasible, at least at brightness levels below 60% ISO. The yield and quality of CMP pulps prepared from depithed cane were strongly influenced by the variety of sugar cane, as the softer Q103 gave a lower fibre yield and had poorer pulp properties than the other cane varieties. The use of brightening agents such as hydrogen peroxide, sodium metabisulphite and sodium hydrosulphite improved overall pulp brightness but did not remove dark coloured plant fragments. CMP pulps prepared from sugar cane rind had slightly poorer pulp strength properties and lower brightnesses than pulps made from depithed whole cane, probably because of the increase in the number of dark fragments. Raw sugar recovery from the mechanical pulping processes was c.22% lower than that achieved by modern sugar mills, probably because cell-wall disruption was reduced and the washing method was crude.

5. ACKNOWLEDGMENTS

This work arose from a proposal by Dr. G. Gartside of this Division, and was carried out for the Sugar Research Institute, which provided the funding. The sampling of the cane samples was coordinated by Mr. P. G. Atherton of the Bureau of Sugar Experiment Stations. Thanks are also due to Mr. A.W. McKenzie, Mr. M.D. Williams and Mr. C.P. Garland of this Division for their helpful suggestions throughout the course of this investigation.

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Table 1

Milling properties of sugar cane varieties

Variety	Impact reading	Shear strength (kg)	% Pith	% Fibre
Q103	0.21	10.5	82.0	11.50
Q113	0.71	36.4	46.7	15.59
Q108	0.72	36.2	55.6	19.28

Source: Noble 1989

Table 2

Conditions used to prepare Q135 CMP pulps

Trial	1	2	3	4	5	6	7	8
% $Na_2S_2O_5$				5	5			
Temperature (^oC)				25	25			
% Consistency				14	14			
Time (hrs)				3	3			
% NaOH	36	12	8	12	12	12	12	12
% H_2O_2	0	4	4	4	0	4	4	0
Temperature (^oC)	25	25	25	25	25	25	25	25
% Consistency	14	14	14	14	14	14	14	14
Time (hrs)	3	3	3	3	3	3	3	3
% $Na_2S_2O_4$						1		
Temperature (^oC)						60		
% Consistency						4		
Time (hrs)						2		
% NaOCl							1.5	1.5
% NaOH							0.5	0.5
Temperature (^oC)							40	40
% Consistency							10	10
Time (hrs)							2	2

Chemical concentrations calculated on o.d. fibre basis

Table 3

Chemical absorption and brightness of Q135 CMP pulps

Trial	1	2	3	4	5	6	7	8
$Na_2S_2O_5$	N	N	N	Y	Y	N	N	N
% NaOH	7.4	7.6	6.1	7.2	6.2	7.6	7.6	7.6
% H_2O_2	N	3.5	3.2	2.0	N	3.5	3.5	3.5
$Na_2S_2O_4$	N	N	N	N	N	Y	N	N
% NaOCl	N	N	N	N	N	N	1.5	1.5
Brightness (% ISO)	29.5	54.9	57.4	58.6	54.3	56.0	45.7	42.9

Table 4

Papermaking properties of cane Q135 cold soda pulps

Sample	Beating revs. (PFI)	Freeness (CSF)	Drainage time (s)	Handsheet properties (60 g/m2 o.d. grammage)					
				Bulk (cm3/g)	Tear index (mN.m2/g)	Tensile index (N.m/g)	Stretch (%)	Burst index (kPa.m2/g)	Air resistance (s)
Trial 1	0	222	11.3	2.09	5.0	39	1.6	1.8	87
Trial 2	0	256	7.6	2.34	5.1	38	1.6	1.7	33
	2000	149	12.0	2.19	5.0	42	1.5	2.1	92
Mixed eucalypt cold soda	0	575	N/A	2.31	2.8	21	1.3	0.8	1
	N/A	447	N/A	2.10	3.6	38	1.7	1.7	2
	N/A	357	N/A	1.96	3.7	45	1.9	2.0	4
	N/A	166	N/A	1.71	4.0	59	2.2	3.0	51

Table 5

Chemi-mechanical pulping of varieties of depithed sugar cane

Cane Variety	% NaOH absorbed*	% H2O2 absorbed*	Freeness (CSF)	Bulk (cm3/g)	Tear Index	Tensile Index	Brightness (% ISO)	% Yield* Pulp	% Yield* Shives	%Yield# Total
Q135	7.6	3.5	256	2.34	5.1	38	54.9	N/A		N/A
Q108	7.2	2.1	279	2.11	6.3	41	50.4	46.3	32.8	27.8
Q103	7.0	2.9	88	2.17	4.3	47	54.6	52.7	24.0	15.4
Q113	7.4	2.2	208	2.35	5.8	43	50.5	45.5	32.8	27.5

* o.d. fibre basis
\# o.d. cane basis

Table 6

Dimensions of rind strips

Variety	Mean thickness (mm)	Standard deviation (mm)	Proportion of billet mass (%)
Q103	1.2	0.20	15.2
Q113	1.0	0.19	16.0
Q108	1.1	0.17	15.5

Table 7

Chemi-mechanical pulping of rind from varieties of sugar cane

Cane Variety	% NaOH absorbed*	% H2O2 absorbed*	Freeness (CSF)	Bulk (cm^3/g)	Tear Index	Tensile Index	Brightness (% ISO)	% Yield* Pulp	% Yield* Shives	%Yield# Total
Q108	5.5	2.2	233	2.57	4.7	29	48.2	51.0	11.2	9.6
Q103	6.0	1.9	251	2.68	3.9	31	51.4	45.9	4.4	7.6
Q113	5.9	2.1	160	2.51	5.0	39	50.5	44.6	17.7	10.0

* o.d. fibre basis
\# o.d. cane basis

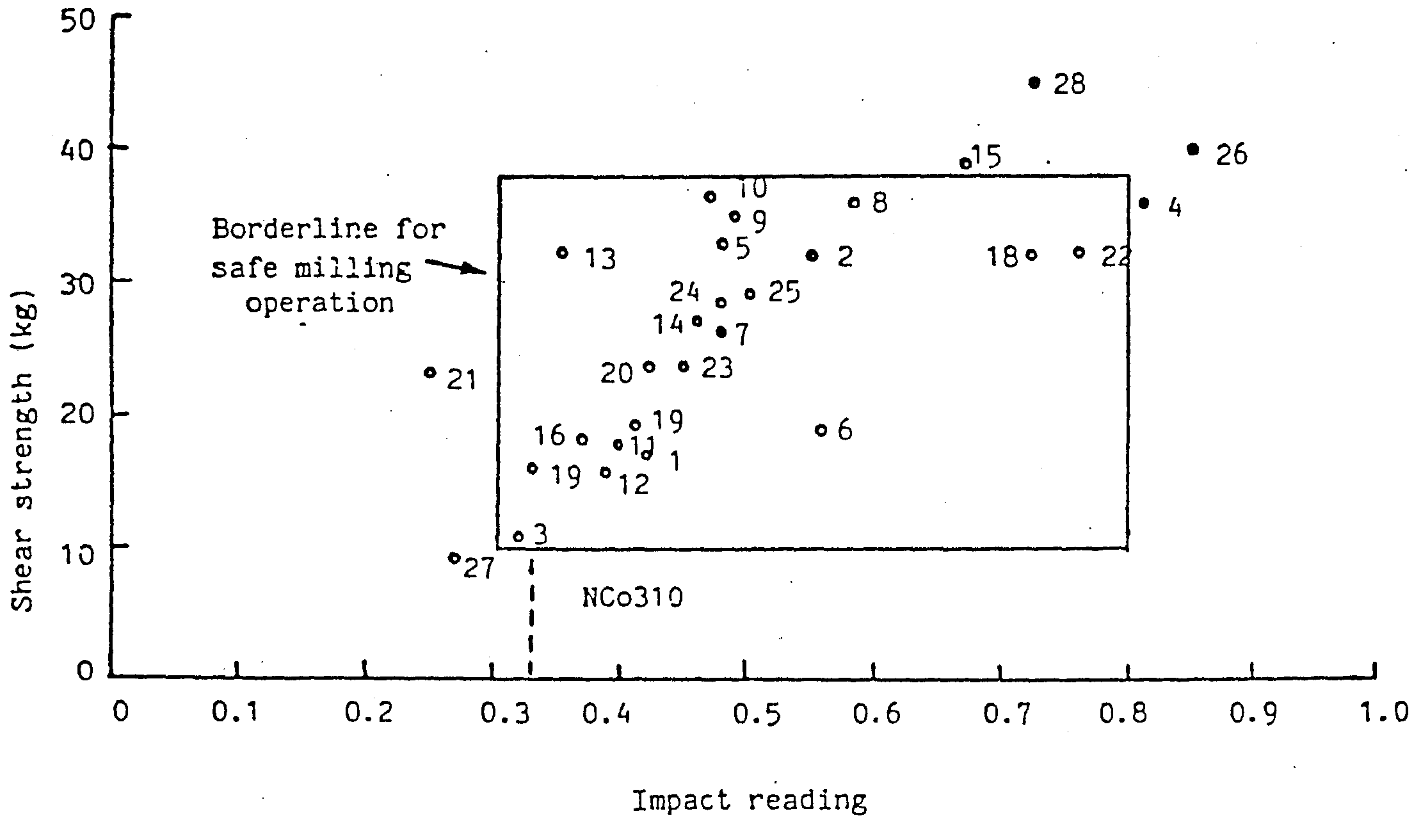
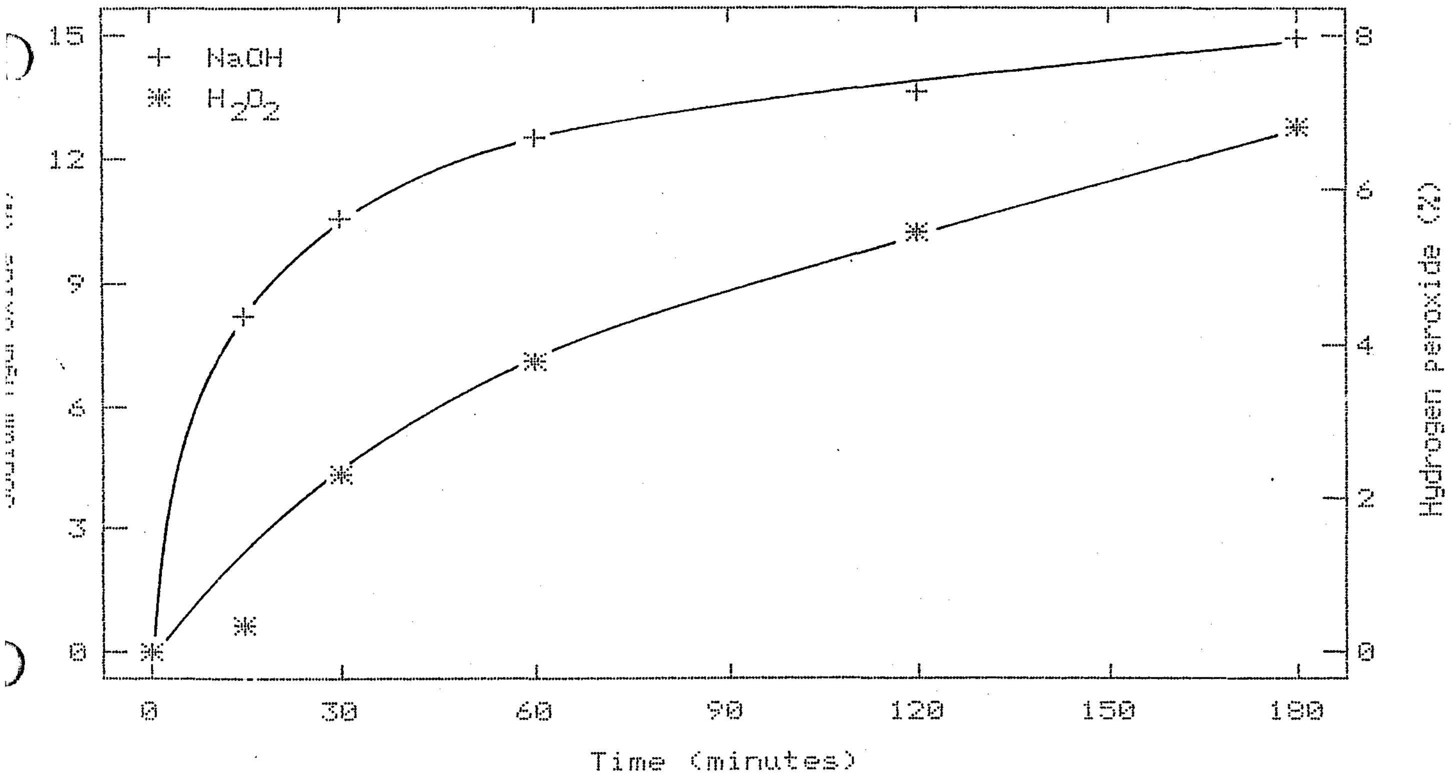


FIGURE 1 - Relationship between shear strength and impact reading

Source: Rural Industry Research Funds new project application "The influence of cane variety on the suitablity of bagasse for use as a paper resource." Bureau of Sugar Experiment Stations (1989).

Code	Variety
1	CP51-21
2	CP44-101
3	Q141
4	Q140
5	70S868
6	Q133
7	Q96
8	Q110
9	H56-752
10	Q135
11	66C760
12	75S1299
13	Q145
14	75C326
15	74C256
16	Q87
17	73C22
18	Q136
19	78N430
20	Q124
21	Q117
22	Q130
23	79A357
24	79A362
25	79A412
26	Q113
27	Q103
28	Q108

Figure 2
Chemical absorption by depithed Q135



APPENDIX

THE FEASIBILITY OF CO-PRODUCTION OF CANE-PULP AND RAW SUGAR

The sugar industry depends heavily on the export of raw sugar and consequently on a highly volatile world market price. It has been able to sustain its markets by being able to improve production efficiency to very high levels whilst maintaining quality and security of supply. However, the technology used by the industry is at such a mature stage that further reduction in costs are very difficult to realise. Consequently, some attention is being given to by-products in order to increase industry financial returns; this activity seems most pronounced when sugar prices are low. In the long term, the competition from alternative sweeteners may increase the industries need to develop a broader product base to increase returns.

Sugar cane bagasse is used in many parts of the world for making paper. (In this regard sugar cane has an advantage over sugar beet). However, the milling process severely damages the fibre and consequently the quality of paper produced is inferior to that produced from a wide variety of wood species. Therefore, paper production from bagasse is generally restricted to those countries where wood supplies are scarce and importation of paper is economically unattractive. The production in Australia of paper pulp from bagasse has attracted interest from time to time. The disadvantages are that large scale pulp production requires a substantial proportion of the bagasse thus threatening the energy independence of the sugar mill; the inferior quality of pulp produced limiting market opportunities; and the distance from markets. These disadvantages have tended to outweigh the advantage to the industry.

The quality of fibre in sugar cane for papermaking is undoubted (Gartside, Tappi Nonwood Plant Fibre Pulping Report No. 14, 1983). If this quality is to be realised alternative processes to preparation and milling for the extraction of sugar will have to be used. The pulping industry has a wide range of technologies for separating fibres in a form suitable for making a considerable variety of paper products. However, many of these processes, particularly chemical pulping, involve chemical and temperature conditions that could be detrimental to sugar quality. The compromise may well be to use high-yield processes that are becoming widely used and introducing new wood pulps into the open market.

The objective of this proposal is to optimise on the profitability of the whole sugar cane rather than on its sugar content. Some aspects of this later approach are very attractive. On the assumption that only 25% of the sugar cane fibre is converted into pulp and the sugar yield remains at 97%, the value of the sugar product is about $34 and the value of pulp is about $24 per tonne of cane; the value added would be increased by 70%. If all the fibre was converted to pulp the value added would be increased by nearly 300%. In essence, this investigation would examine the costs needed to generate this added value so that the profitability of the concept may be gauged. With improved economics the industry would be better able to ride out the cyclical nature of the sugar market. Another attraction is the capital savings that would come from the integration of the pulping and sugar extraction processes.

Principally, the fibre separation stage and the milling stages would be one and the same. Disadvantages could include: problems of obtaining material for year round operation of the mill; and fuel and power sources, depending on the proportion of fibre converted to pulp.

The aim of the proposed project is to conduct a technical analysis of possible technological approaches to co-production of good quality fibre and raw sugar. The target of the project is to determine the effect of using pulping technology on the efficacy of the separation of fibre and sugar. If this study is successful priorities and targets for further work will be identified.

The majority of the work would be done in the CSIRO Division of Forestry and Forest Products with their expertise on pulping processes. Assistance will be available from SRI on sugar quality and testing aspects of the study.

The next phase is likely to include a techno-economic analysis of the effect of a new process on the sugar milling industry which would include such aspects:

- effect on added value and profit
- investment required
- possible markets
- interaction between sugar and paper industries
- possible long term economic effects

TESTS AT THE SUGAR RESEARCH INSTITUTE ON THE EXTRACTION POTENTIAL OF SUGAR CANE PREPARED BY A DISC REFINER

by

B.P. Edwards

(October, 1990)

IR.19/90

TESTS AT THE SUGAR RESEARCH INSTITUTE ON THE EXTRACTION POTENTIAL OF SUGAR CANE PREPARED BY A DISC REFINER

INTRODUCTION

As part of a Sugar Research Council grant, the CSIRO Division of Forestry and Forest Products investigated the paper making properties of sugar cane. In this investigation, carried out entirely in the Division's Laboratories at Clayton, cane was prepared with a disc refiner and samples of paper made. This work has been reported to the SRC (Clark and Gartside, 1990). A brief conclusion was that the paper made had similar properties to papers made from hardwood. The concept behind the investigation was the co-production of fibre (for paper production) and sugar in a sugar factory. This co-production is suggested since the fibre in cane could have the same or greater value than the sugar. While the tests showed that the paper making was possible, the tests conducted at the Division suggested that the sugar extraction from the cane prepared by the disc refiner was not high.

Visual inspection of the cane prepared by the refiner by Sugar Research staff suggested that this last conclusion was unlikely, as the prepared cane appeared to be as fine as anything produced in the sugar industry. A possible explanation was the analysis methods used. So a disc refiner was transported to Mackay in September 1990 with the intention of measuring extraction properties of the cane prepared by the refiner.

TESTS

Tests on five parcels of cane comprising three 'hard' and two 'soft' canes (where the 'hard' and 'soft' terminology refers loosely to the strength of the cane) were conducted in the first week of October 1990.

The disc refiner used was a Sprout Waldron machine with a disc diameter of 304 mm. The machine has one stationary disc and the other disc rotates at 2600 rpm. Cane is fed into the centre of the discs with a screw feeder and is prepared between the two discs before leaving the refiner. The size of the screw feeder required that the billets be cut into approximately 50 mm lengths before processing. There are two 'discs' and the discs are 'faced' with plates that can have many different patterns. The plate pattern used in these experiments is shown in Figure 1.

PROCEDURE

A quantity of billets were taken from a mill in the Central district and subsampled into two parcels. One sample was prepared in two passes through the disc refiner, and the other by the shredder at the Sugar Research Institute. That shredder is known to prepare cane to a similar degree as that achieved in a sugar factory. The two parcels of cane were then analysed for moisture, sugar and brix* by standard sugar industry methods (Anon, 1970), and tests on the level of preparation were conducted, generally in duplicate.

Two tests were used to measure the level of preparation. In one (the POC or pol in open cell test) the prepared cane is tumbled in ambient temperature water for ten minutes. The pol (sugar content is estimated from the polarisation of the extract, called 'pol' in the sugar industry) extracted in this process is compared with the pol extracted from completely prepared cane (i.e. cane prepared in a 'disintegrator'). The result is expressed as a percentage, where a result of 100 per cent would indicate completely prepared cane. The other test (the hot POC test) differed in that the mixture was tumbled at 80°C for twenty minutes to assess the potential for extraction at high temperature. The two times (ten and twenty minutes) were chosen as the two extractions are both asymptoting to their final values at these times. More detail on these tests is given in Appendix A.

In addition to the pol results, the analogous measurements of brix were made resulting in a 'Brix in Open Cells' number.

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* The brix of a solution is the concentration of a solution of pure sucrose in water having the same density as the solution at the same temperature.

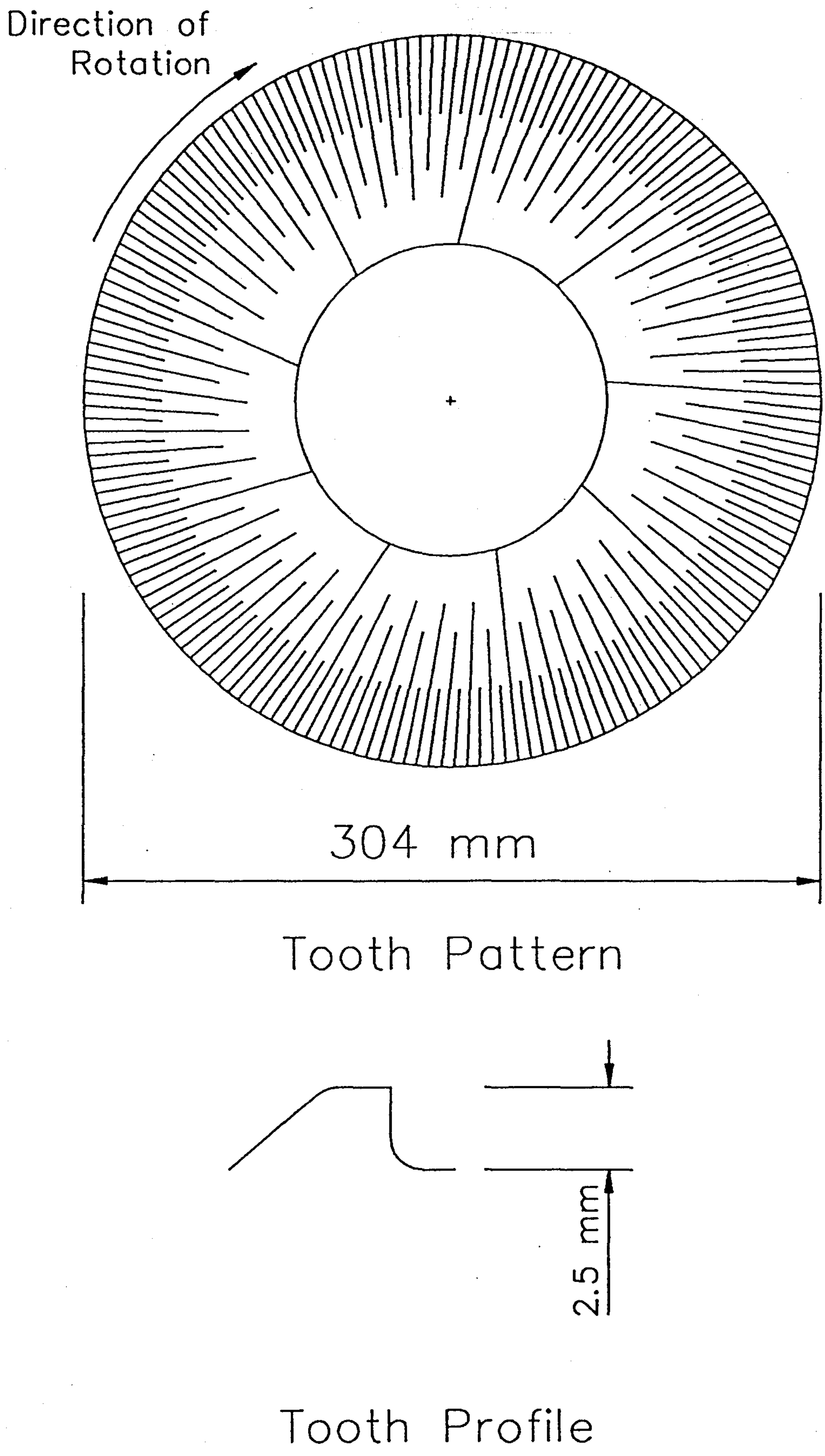


Figure 1. Plates Used in Disc Refiner.

RESULTS

Each parcel of cane collected has four measurements of POC associated with it, two for the refined cane and two for the shredded cane. In some cases there was insufficient cane and all four measurements were not made. Figure 2 shows the results of the POC test at ambient temperature. The square symbols in Figure 2 are the POC measurements of the cane prepared in the Institute shredder and the POC is generally in the high eighties. One parcel of cane was deliberately underprepared by running the Institute shredder at low speed (1800 rpm) and that is represented by the pair of points at around 79 POC. While the refiner gap for the second pass has no relevance for the cane prepared in the Institute shredder, by plotting all points on the same graph the comparison of preparations can be seen. When the refiner gap for the second pass is below 3 mm the preparation of the refined cane is superior to that of the shredder prepared cane.

The results for the POC measurements made at high temperature (the 'hot' POC tests) are given in Figure 3. In this case apart from the cane prepared at low speed in the shredder, and the cane prepared at the refiner gap of 7.6 mm, all canes resulted in a hot POC of around 100 per cent and no differentiation between preparations was possible.

The results for the brix in open cells tests were less informative for some reason as yet unknown. The results of the 'brix in open cells' tests are shown in Figure 4. While the general result that the refiner prepared cane results in a greater preparation than shredder prepared cane when the second pass refiner gap is below about 3 mm is still true, the brix in open cells for the shredded cane is much less consistent than was the case for the pol in open cells of shredded cane. As for the hot pol in open cells, the hot brix in open cells (Figure 5) was generally around 100 per cent and no differentiation between samples was possible. It is unnerving that brix in open cells of significantly greater than 100 was recorded.

All results are tabulated in Appendix B.

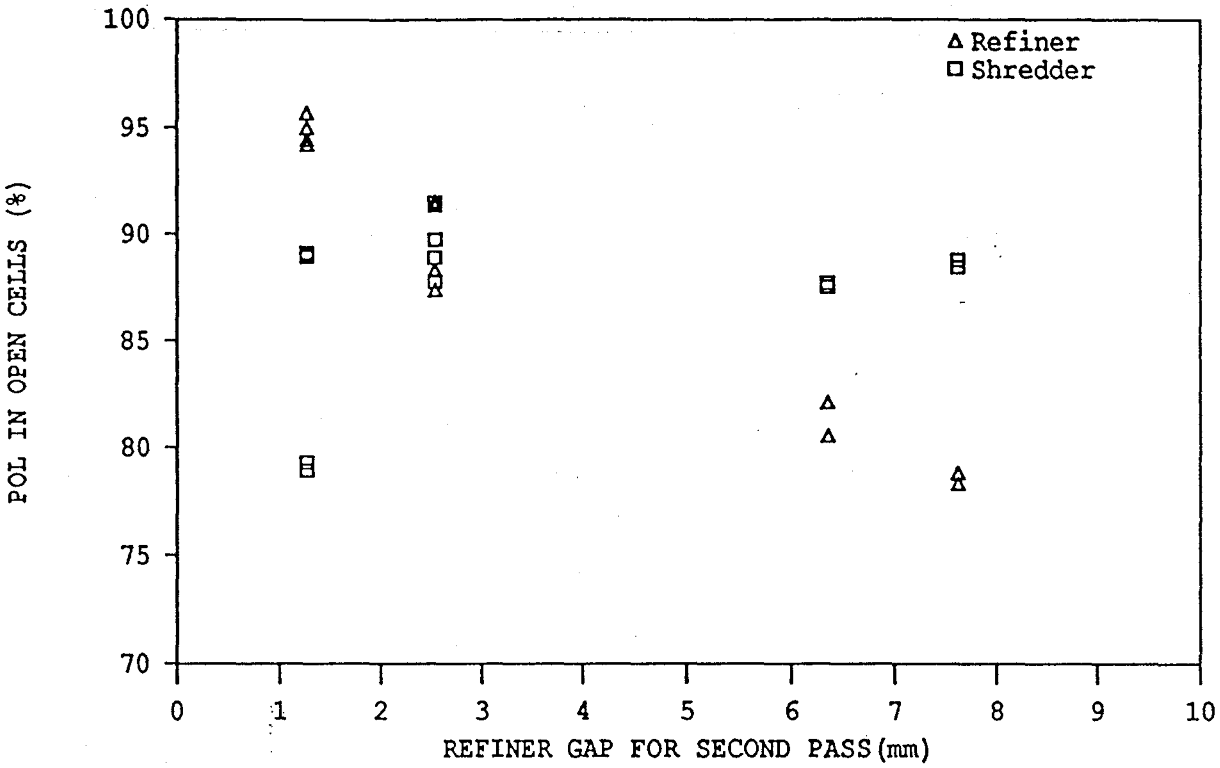


Figure 2. Pol in Open Cells.

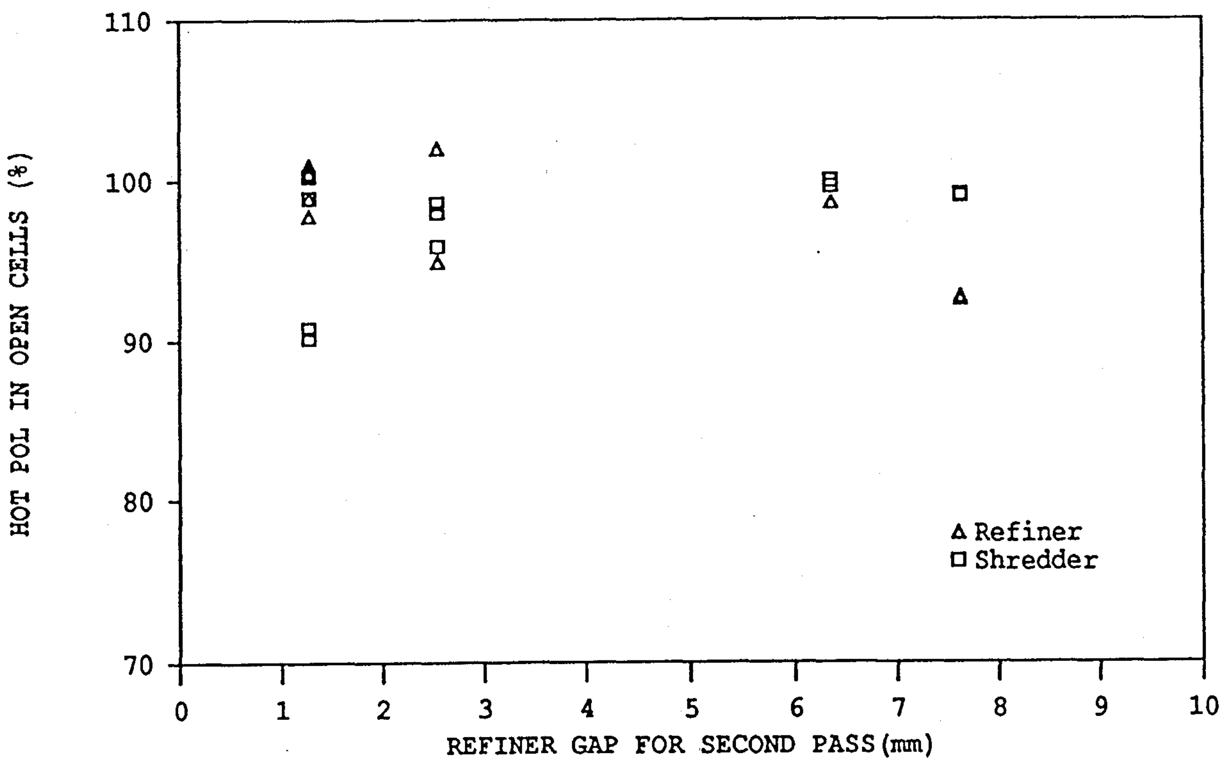


Figure 3. 'Hot' Pol in Open Cells.

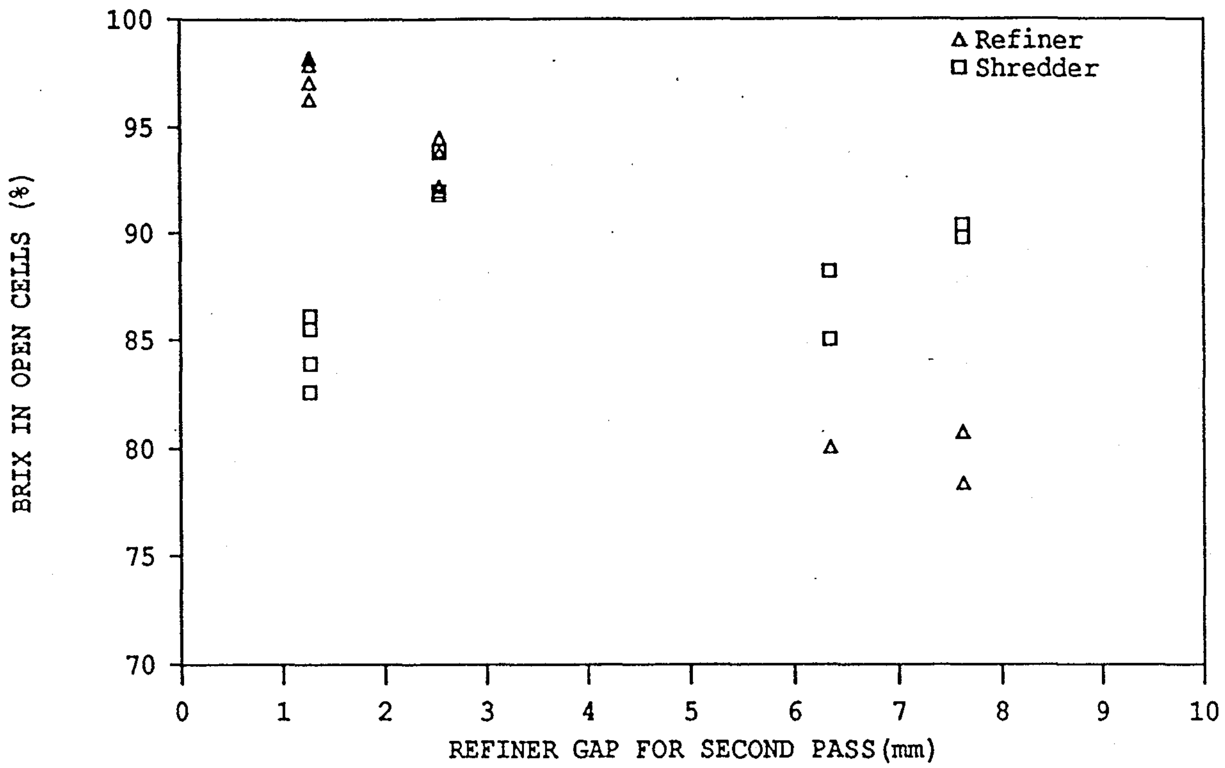


Figure 4. Brix in Open Cells.

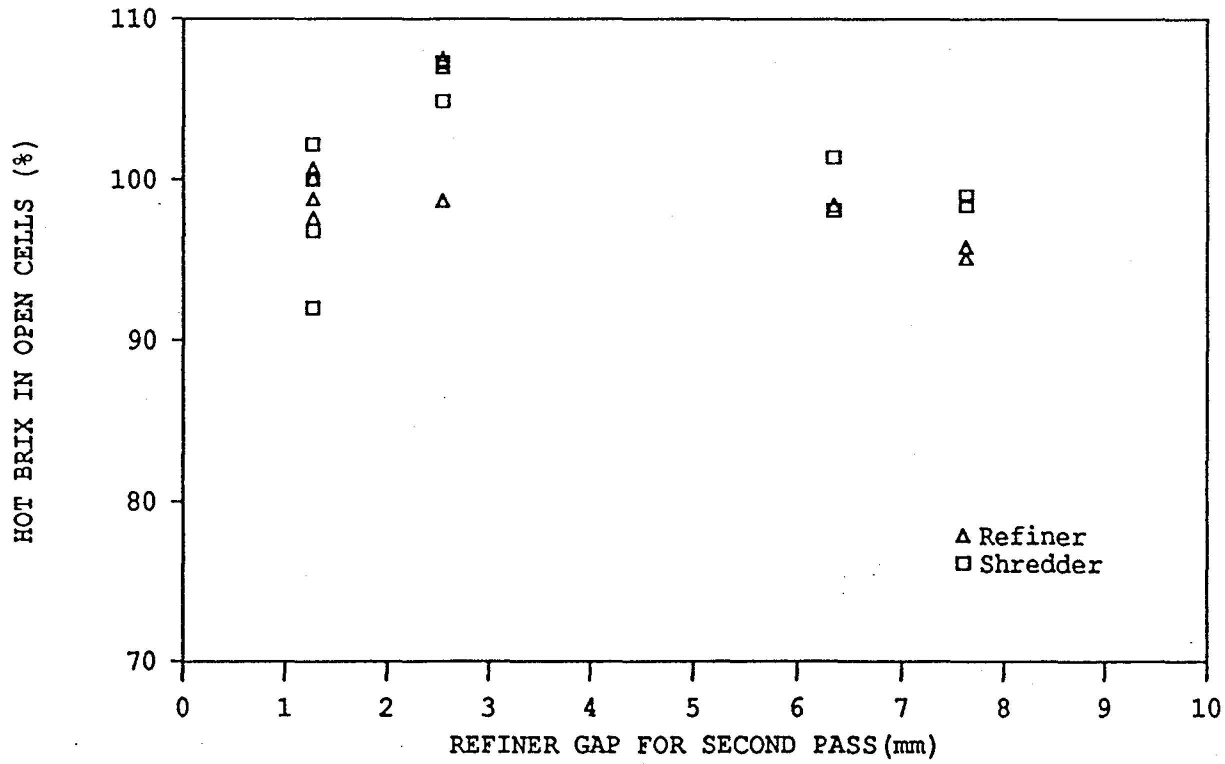


Figure 5. 'Hot' Brix in Open Cells.

CONCLUSION

The disc refiner can prepare cane to a standard equal to or greater than that achieved in the Institute shredder. This shredder represents a good sugar industry preparation. There seems no reason to believe that good sugar extractions could not be achieved from cane prepared by a disc refiner. Questions of processing rate and the suitability of the refiner prepared cane for extraction by mills or diffusers must be held back until a full size refiner is constructed. Such a machine may produce a prepared cane of different quality than the cane produced by the laboratory size machine used here. However the laboratory size machine did produce long thin strands of cane that would be regarded as good for either milling or diffusion. There may be problems with dirt and tramp iron.

REFERENCE

Anon. (1970). Laboratory Manual for Queensland Sugar Mills. Bureau of Sugar Experiment Stations, 5th Edition.

Clark, N. and Gartside, G. (1990). Private Communication.

APPENDIX A

The Tests Used to Measure the Extraction Potential

Two tests were used to measure the extraction potential of the prepared cane. The first is a standard test in routine use in sugar factories, called the 'Pol in Open Cells (POC)' test. The second is a test developed specifically for these trials. The second test was developed because while the POC test gives a good indication of the sugar available for extraction by a cold water wash, there may be a different result if a hot water wash is used. Extraction machines using hot water are now common (called diffusers) and a hot water test seemed appropriate.

Both tests gently mix a sample of prepared cane with water (cold in one case, hot in the other) for a prescribed time and measure the concentration of pol in the water after that time. The pol is then compared with the pol in the water which results when another sample is destructively mixed in water, i.e. disintegrated in sugar industry terminology.

The two tests are described below.

THE POL IN OPEN CELLS (POC) TEST

In this test 1 kg of cane and 10 kg of water at ambient ('cold') temperature are placed in a 15 litre bottleneck can and, after sealing, the contents are rotated in a jar roller at 70 rev/min for 10 minutes. The extract is immediately strained through a fine wire gauze funnel to avoid further extraction. The pol reading of the extract is taken. That is the standard procedure. For these tests the Brix reading of the extract was also taken.

To determine what this extract might be, given 'ultimate' preparation, 2 kg of cane is placed in what the sugar industry calls a disintegrator with 6 kg of water. This disintegrator has three 150 mm blades which are sharpened and rotate at 5 600 rev/min. The machine further prepares the cane for forty minutes to slush. The time has been chosen as no further increase in the pol in the extract occurs after this time.

The pols of the two extracts are compared by formulae given in Ivin and Edwards (1987), to give the POC number. 100 per cent POC would be cane which had all pol accessible to a ten minute cold wash.

For these trials the Brix in Open cells (BOC) was also calculated by the same formulas with brix substituted for pol.

THE 'HOT' POL IN OPEN CELLS TEST (HPOC)

This test was intended to be identical to the previous test with the change being that for the agitation period the cane/water mix was to be at 80°C.

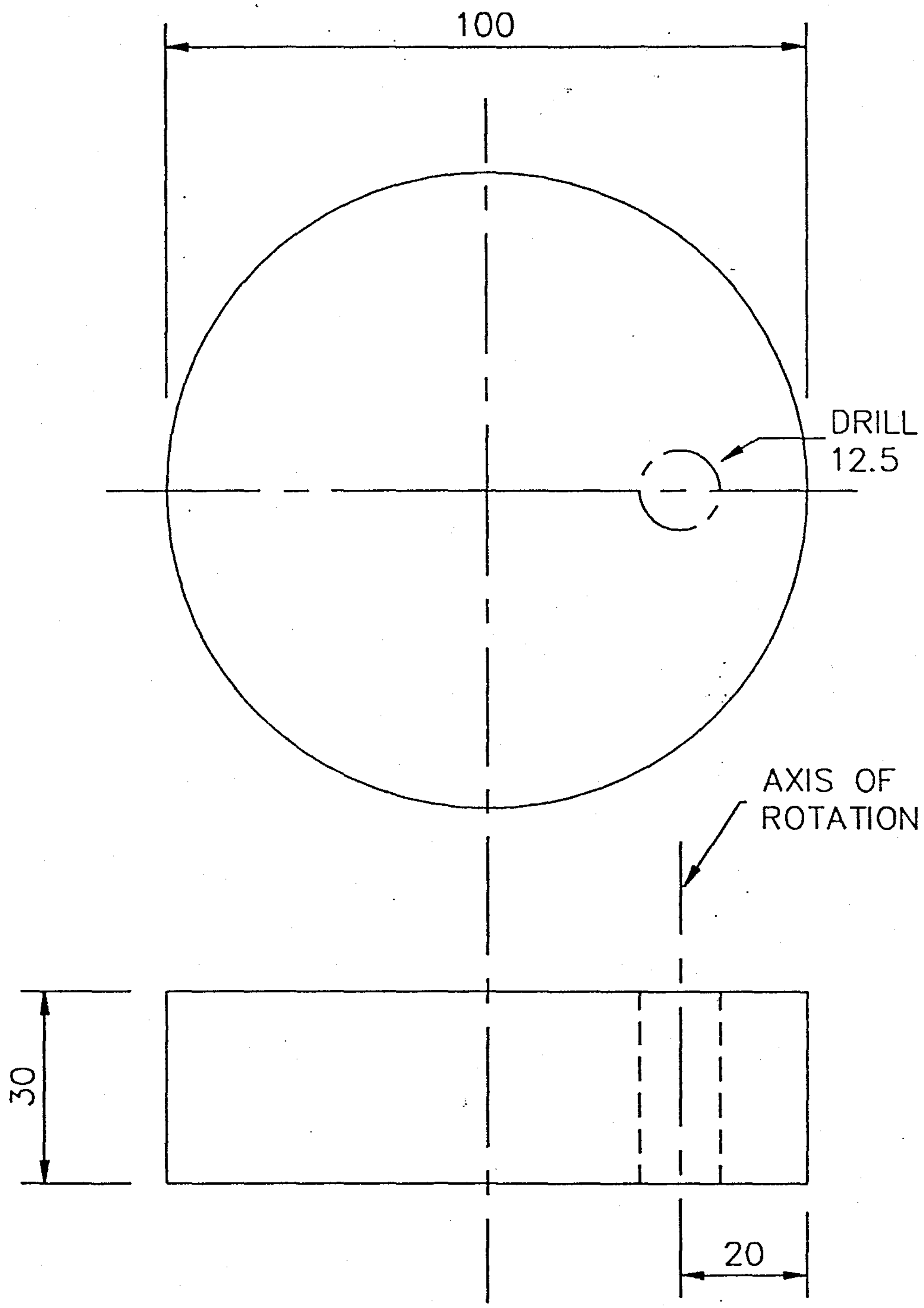
The high temperature was chosen because at this temperature the cell walls are rendered permeable and a diffusion process can access the material in all the cells. This is the basis for the 'diffusion' method of extraction.

The POC equipment was not easily modifiable for hot operation, and so two disintegrators were modified. The water jackets on the disintegrators which normally run with cold water were connected to a supply of water at near 80°C and the 10 kg of water added to the cane was heated to 90°C before adding to the cane. The combination of ambient cane and 90°C water resulted in an 80°C mix, and the hot water in the jacket was sufficient to maintain this temperature for the twenty minute agitation. Agitation was achieved with the stirrer shown in Figure A.1, rotating at 170 rev/min. This agitation resulted in no real bulk movement of the bagasse, but tests showed that a drop of dye was dispersed in one or two minutes.

Tests showed that after fifteen minutes the brix and pol extracted was not changing rapidly. This was the reason for the choice of twenty minutes for the time of the sample.

REFERENCE

Ivin, P.C. and Edwards, B.P. (1987). Sampling and analysis for evaluating milling train performance, Sugar Research Institute Technical Circular 97.



IMPELLER FOR DISINTEGRATOR SHAFT MODIFICATION.
MATERIAL: 100mm ROUND M.S. BAR.

Figure A.1 Impeller for Hot POC Tests.

APPENDIX B

TABLE B.1 CANE ANALYSIS

Variety	Preparation*	Moisture % Cane	Brix % Cane	Fibre % Cane	Pol % Cane	Purity (%)
Q87	300/300	68.35	19.31	12.35	17.87	92.55
Q87	2000 rpm	67.34	18.91	13.75	17.19	90.91
Q135	400/250	66.42	18.88	14.69	16.79	88.93
Q135	2000 rpm	64.99	17.59	17.45	15.75	89.69
H56	300/100	67.94	19.79	12.27	17.93	90.64
H56	2000 rpm	64.84	17.00	18.16	15.62	91.88
H56	300/50	67.26	20.56	12.18	18.93	92.08
H56	1800 rpm	-	-	18.16	-	-
Q123	300/50	69.54	21.42	9.04	19.46	90.86
Q123	1800 rpm	66.24	18.38	15.38	16.07	87.63
Q135	300/100	71.34	19.84	8.82	19.15	96.51
Q135	2000 rpm	68.24	16.62	15.14	15.13	91.03

*Preparation: '2000 rpm' indicates one pass through Institute 0.91 m diameter shredder at 2000 rpm.

'300/50' indicates first pass through disk refiner at 7.62 mm (0.3 inch) and second pass at 1.27 mm (0.05 inch).

TABLE B.2 COLD POC ANALYSES

Brix % Extract		Pol % Extract		Purity (%)		POC (%)		Brix in Open Cells (%)	
Brix R1*	Brix R2	Pol R1	Pol R2	Purity R1	Purity R2	POC R1	POC R2	BOC R1	BOC R2
1.46	1.42	1.34	1.32	91.78	92.96	78.83	78.34	80.8	78.4
1.58	1.59	1.44	1.45	91.14	91.19	88.45	88.79	89.8	90.4
1.46	1.42	1.30	1.28	89.04	90.14	82.12	80.55	80.1	80.1
1.40	1.45	1.30	1.30	92.85	89.66	87.71	87.52	85.0	88.2
1.72	1.72	1.53	1.53	88.95	89.95	91.55	91.38	93.8	93.8
1.46	1.47	1.29	1.31	88.36	89.12	87.75	88.88	92.0	92.7
1.86	1.84	1.68	1.66	90.32	90.22	95.72	94.45	98.2	97.1
1.34	1.32	1.18	1.17	88.06	88.64	79.31	78.94	83.9	82.6
1.90	1.93	1.70	1.71	89.47	88.6	94.23	95.01	96.3	97.9
1.48	1.47	1.35	1.35	91.22	91.84	89.12	88.94	86.1	85.5
1.69	1.73	1.58	1.57	93.49	90.75	88.29	87.35	92.2	94.5
1.42	1.45	1.27	1.29	89.44	88.97	89.74	91.51	91.8	93.9

* Two subsamples were analysed.

TABLE B.3 HOT POC ANALYSES

Brix % Extract		Pol % Extract		Purity (%)		Hot POC (%)		Hot Brix in Open Cells (%)	
Brix R1	Brix R2	Pol R1	Pol R2	Purity R1	Purity R2	HPOC R1	HPOC R2	HBOC R1	HBOC R2
1.71	1.70	1.54	1.54	90.06	90.59	92.78	92.61	95.8	95.1
1.73	1.72	1.60	1.61	92.49	93.60	98.99	99.16	99.0	98.4
1.72	-	1.54	-	89.53	-	98.59	-	98.4	-
1.60	1.65	1.46	1.47	91.25	89.09	99.60	99.98	98.1	101.4
1.95	-	1.69		86.67	-	101.98	-	107.5	-
1.68	1.65	1.47	1.40	87.50	84.85	98.00	95.90	107.0	104.9
1.87	1.85	1.77	1.73	94.65	93.51	97.79	98.91	98.8	97.6
1.46	1.61	1.34	1.33	93.15	82.61	90.77	90.20	92.0	102.2
1.98	1.97	1.81	1.80	91.41	91.37	100.95	100.48	100.7	100.1
1.65	1.70	1.49	1.50	90.30	88.24	98.95	100.26	96.8	100.0
1.80	-	1.68	-	93.33	-	94.91	-	98.7	-
1.64	-	1.39	-	84.76	-	98.56	-	107.3	-

AN ADDENDUM TO

"TESTS AT THE SUGAR RESEARCH INSTITUTE ON THE EXTRACTION POTENTIAL OF SUGAR CANE PREPARED BY A DISK REFINER"

by N. B. Clark

INTRODUCTION

Following on from the work described in the above report, it was decided to make pulps from cane prepared by a shredder and by a refiner and then compare their papermaking properties. This might establish the relative amount of fibre damage caused by the two methods of cane preparation.

EXPERIMENTAL

Two parcels of cane from the same sample of Q135 were separately prepared using the SRI shredder and the CSIRO refiner. The shredder was operated at 2000 rpm, while for the refiner, two passes were used at gap settings of 7.62 and 2.54 mm respectively.

The two parcels of prepared cane were refrigerated and transported to CSIRO's Clayton laboratories. The pith was separated from the fibre by wet screening through a stainless steel plate with 3 mm diameter holes. Cold soda semichemical pulps (CMP) were prepared from the fibre fractions using the same conditions as those described in the preliminary report for trial 3. These were, for impregnation, 8% NaOH and 4% H_2O_2 for 3 hours at 25°C; for refining, 5% consistency and 0.125 mm plate gap in the Bauer refiner. After refining, the pulps were washed in sulphurous acid and screened in a Packer screen with 0.2 mm slots.

Handsheets were prepared from the cane pulps according to Australian Standard AS1301.203s-80. The effect of beating on pulp strength was studied using a PFI mill (Australian Standard AS1301.209rp-82). Paper testing was carried out according to Australian Standard AS1301.208s-83 after conditioning the sheets in an atmosphere of 50% relative humidity and 23°C. The brightness of the pulps was measured with a Technibrite Micro TB-1C.

RESULTS

The results of the papermaking tests on the two pulps are given in Table 1, together with those of a mixed eucalypt cold soda pulp for reference. The tear-tensile relationships have also been graphed to illustrate the effect of beating on these pulp strength properties.

The papermaking properties of the two sugar cane pulps were very similar. The refiner pulp was marginally stronger in tear, tensile and burst but lower in bulk and freeness. These results suggest that the refiner pulp reacted more with the impregnation chemicals, implying that the refiner cane was a little more thoroughly prepared. However, it should be emphasized that the differences between the two pulps are small compared with the differences between the cane pulps and mixed eucalypt pulp. For example, beating decreased the strength of the cane pulps whereas beating increased the strength of the mixed eucalypt pulp. This suggests that these cane pulps are less flexible and more easily damaged.

Flexibility and strength are heavily dependant on impregnation conditions. In earlier tests, a higher concentration of chemicals gave a higher pulp strength for the same cane variety (refer to Tables 4 and 5 in the preliminary report), but at the price of reduced freeness and bulk.

CONCLUSION

Conventional sugar milling processes can damage cane fibre (Gartside and Langfors 1981). This damage is readily apparent if the fibre is chemically pulped, because the pulping process does little damage to the fibres. However, in chemi-mechanical pulping, the pulping process itself causes significant fibre damage. Because of this damage, hardwood cold soda pulps are generally only half as strong as kraft pulps produced from the same pulpwood resource. Naturally, this limits the usefulness of the pulp and decreases its economic value.

It is clear from the results of the tests described above that the fibre disruption necessary for efficient preparation of cane still allows cold soda pulps of satisfactory strength to be produced. This means that a shredder could be used to prepare cane destined for use in a cold soda pulping process.

One could envisage a co-production process comprising cane preparation with a shredder, raw sugar extraction by diffuser and finally cold soda pulping of the bagasse. The resulting pulp would be as strong as eucalypt cold soda pulp, if slightly lower in brightness.

REFERENCES

Gartside, G. and Langförs, N. G. - Developing the potential of Australian bagasse as a paper resource. Proc. Aust. Soc. Sugar Technol. pp 233-238 (1981).

Table 1

Papermaking properties of Q135 cold soda pulps

Beating revs. PFI	Freeness CSF	Handsheet properties (60 g/m^2 grammage)					
		Bulk cm^3/g	Tear index mN.m^2/g	Tensile index N.m/g	Burst index kPa.m^2/g	Brightness %	Opacity %
Shredder							
0	469	3.48	4.4	17	0.8	47.4	95.4
2000	385	3.07	4.2	21	1.0	48.7	95.1
Refiner							
0	379	2.99	4.6	24	1.1	51.3	94.9
2000	316	2.89	4.5	28	1.2	50.3	95.4
Mixed Eucalypt							
0	575	2.31	2.8	21	0.8	n/a	n/a
n/a	447	2.10	3.6	38	1.7	n/a	n/a
n/a	357	1.96	3.7	45	2.0	n/a	n/a
n/a	166	1.71	4.0	59	3.0	n/a	n/a