INVESTIGATIONS WITH THE WET DISINTEGRATOR
FOR THE DIRECT ANALYSIS OF CANE

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INTRODUCTION

In Queensland, cane is evaluated, for payment purposes, in terms of its Commercial Cane Sugar content (C.C.S.). This system of payment has been described by CLAYTON. The C.C.S. is a quality figure based on the concentration of pol and brix in the cane, the pol and brix being calculated from the analysis of the first expressed juice by means of empirical formulae involving certain arbitrary constants, and the fibre content of the cane.

It will, therefore, be appreciated that there exists in Queensland a necessity for a direct and reliable method of analysis of cane for factory control and for payment purposes. In this regard a programme of research involving the direct analysis of mill feed was undertaken by the Bureau of Sugar Experiment Stations in 1957. A wet disintegrator of the type designed by the Sugar Research Institute and described by FOSTER, was used during the initial investigations. This device incorporates fixed blades attached to a shaft rotating at high speed in a suspension of the sample in water. Various names for such a unit are currently in use and the author has chosen the term "wet disintegrator". The Sugar Research disintegrator consists of a vertical shaft spun at 6,000 r.p.m. in a container 13 in. high and 11 in. diameter. The shaft carries 3 spring steel blades 5 in. in length. They are spaced 1/4 in. apart, set on the end of the shaft almost at the bottom of the container.

In general, the operating technique specified by the Sugar Research Institute was followed and in most regards proved to be quite satisfactory. However, the results of some minor investigations carried out in conjunction with the Colonial Sugar Refining Company indicated that the blade design was critical. Consequently a detailed study of the performance of the wet disintegrator was undertaken. Although the extraction in the Sugar Research machine appeared to be complete in 45 minutes, the tolerance on the extraction time was small, and it was considered that larger blades, six to seven inches in length would improve this performance.

DETAILS OF INVESTIGATIONS

The investigations carried out had a two-fold purpose, namely: (a) to establish the extent of extraction of cane with the Sugar Research machine operated for 45 minutes, and (b) to design a simple modification for the machine to increase the extraction rate.

Experience with the wet disintegrator during the mill tests in 1957 suggested that mechanical principles mainly controlled the extraction. Therefore, in contemplating a reference machine by which to judge the normal unit, mechanical features were emphasised. Of a number of suggestions, the provision of dual spindles appeared to have most merit, and a standard machine was modified accordingly to accommodate two spindles, with 5-in. blades, in the normal 11-in. diameter container.
With this machine the agitation was so intense that the temperature of the slurry was raised to the boiling point within 30 minutes with counter-rotating blades, and to 70°C with blades rotating in the same direction.

All the cane used during the investigation was standover C.P. 20/116, approximately 18 months old, taken from the same plot. This was considered to be the hardest variety available locally at the time. The cane was prepared in a Waddell hammer-mill before being used. Preliminary tests indicated that so long as the quantity of cane in any bulk sample was limited to approximately 10 kilograms and attention was paid to mixing after hammer-milling, an average variation not greater than 0.1% pol in cane (approximately 0.15 in pol reading of the extract) could be expected between the analysis of two kilogram portions which were taken from the bulk sample, were sealed in polyethylene bags, and stored at -10°C until they could be analysed. There appeared to be no significant difference between the results for the freshly hammer-milled cane and the samples stored at -10°C even for periods up to 10 days.

Tests in 1957 indicated that the purity of the extract remained fairly constant throughout the extraction process with the wet disintegrator. Consequently during the main investigation, attention was focused on the pol of the extract, for it was assumed that both pol and brix would approach a maximum together. Since it was possible to determine pol rapidly and with an assured precision, it was selected as the prime measurement. Simple pol-readings-of-extract vs. time curves were therefore taken to characterise both the dual spindle and the Sugar Research machines. From a normal charge, which comprised 2 kilograms of cane and 8 kilograms of water, approximately 75 ml. portions of extract were withdrawn into conical flasks at intervals during the disintegration. These were stoppered immediately because evaporation was found to be appreciable, especially at the elevated temperatures encountered with the dual spindle machine. After cooling, the pol of each lot was determined following clarification with dry lead.

A typical set of comparative curves for the two machines is given in Fig. 1. No allowance has been made for the material withdrawn at intervals, and consequently

Fig. 1. The rate of pol extraction with the Sugar Research disintegrator and the modified dual spindle machine. • Dual spindle disintegrator; × Sugar research disintegrator (5" blades).
the maximum obtained does not represent the true level of polarisation for disintegration with fixed quantities of cane and water. However, since an extraction of approximately 97% was generally obtained by the time the first sample was withdrawn, the effect on the final level of polarisation was considered to be negligible.

It will be noted from Fig. 1 that the extraction, with the dual spindle machine with counter-rotating blades, reached a near maximum within 15 minutes, but with the standard Sugar Research unit 40 to 45 minutes were required. Similar curves were obtained for the dual spindle machine with the blades rotating in the same direction. The maximum extraction was again nearly reached in 15 minutes even though much less heat was generated in the container.

Further comparative tests were carried out with both machines running for set periods, and typical results are given in Table I. It will be seen that similar polarisations were obtained with both machines on samples from the same batch.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>A COMPARISON OF THE POL EXTRACTION WITH THE SUGAR RESEARCH DISINTEGRATOR AND THE MODIFIED DUAL SPINDLE MACHINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disintegrator</td>
<td>Sample No.</td>
</tr>
<tr>
<td>Single spindle (5&quot; blades)</td>
<td>A. 1</td>
</tr>
<tr>
<td>Double spindle (counter-rotating blades)</td>
<td>A. 2</td>
</tr>
<tr>
<td>Single spindle (5&quot; blades)</td>
<td>B. 1</td>
</tr>
<tr>
<td>Double spindle (counter-rotating blades)</td>
<td>B. 2</td>
</tr>
<tr>
<td>Single spindle (5&quot; blades)</td>
<td>C. 1</td>
</tr>
<tr>
<td>Double spindle (blades rotating in the same direction)</td>
<td>C. 2</td>
</tr>
<tr>
<td>Single spindle (5&quot; blades)</td>
<td>D. 1</td>
</tr>
<tr>
<td>Double spindle (blades rotating in the same direction)</td>
<td>D. 2</td>
</tr>
</tbody>
</table>

In general, the results indicated that the wet disintegrator designed by the Sugar Research Institute achieved what was assumed to be complete extraction in 45 minutes, but that a modification was desirable to allow a greater margin of safety without extension of the operating time.

Since the dual spindle machine was mechanically unsuitable for routine application, longer blades were fitted to the single spindle unit, in an attempt to increase the extraction rate. The results obtained indicated that the extraction was complete within 15 minutes with 7-in. blades, and within 30 minutes with 6-in. blades. Some comparative results are given in Table II.

Seven-inch blades were consequently adopted, the time of disintegration being set at 30 minutes. Subsequently it was found necessary to install baffles within the container in order to direct occasional pieces of hard nodal tissue back into the cutting zone of the blades. In all, three small baffles, each ¾ in. wide and 1¼ in. high, were used. These were attached to the sides of the container at the bottom, and set at an angle so
that the flow was directed towards the centre. With this baffling, the temperature of the slurry was generally between 50° and 60° C after 30 minutes of disintegration. For the routine application contemplated for the machine, it was considered desirable to limit the upper temperature to between 35° and 40° C in order to prevent excessive evaporation from the extract whilst being sampled and prepared for analysis. A cooling jacket was accordingly fitted and the temperature level restricted to approximately 40° C.

In studying the performance of the wet disintegrator further, purity-time curves were taken for the extract from the single spindle machine. For these tests, 150 ml samples of extract were withdrawn at intervals during the disintegration, and analysed for both pol and brix. The results obtained for machines fitted with 6-in. and 7-in. blades, are given in Table III. In these specific investigations, since an analytical tolerance of ± 0.4 units of purity must be allowed, it will be appreciated that the purity remained relatively constant and little selective extraction was indicated. A purity at zero time has been quoted because it was generally found that, with cane prepared in the Waddell hammer-mill, approximately 75% of the total pol was available before the cane was subjected to any further subdivision in the wet disintegrator.

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### TABLE II

A COMPARISON OF THE POL EXTRACTION WITH 5- AND 7-IN-BLADES ON THE SUGAR RESEARCH DISINTEGRATOR WITH THE DUAL SPINDLE MACHINE

<table>
<thead>
<tr>
<th>Disintegrator</th>
<th>Sample No.</th>
<th>Time of disintegration (min.)</th>
<th>Temperature °C</th>
<th>Pol. reading of extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single spindle (5&quot; blades)</td>
<td>1</td>
<td>45</td>
<td>43</td>
<td>15.55</td>
</tr>
<tr>
<td>Single spindle (7&quot; blades)</td>
<td>2</td>
<td>30</td>
<td>37</td>
<td>15.60</td>
</tr>
<tr>
<td>Double spindle</td>
<td>3</td>
<td>17</td>
<td>56</td>
<td>15.60</td>
</tr>
</tbody>
</table>

(Blades rotating in the same direction)

### TABLE III

THE PURITY OF THE EXTRACT TAKEN AT VARIOUS TIMES DURING THE DISINTEGRATION WITH 6- AND 7-IN. BLADES

<table>
<thead>
<tr>
<th>Time from start (min.)</th>
<th>Purity of extract</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7&quot; Blades (Single spindle)</td>
</tr>
<tr>
<td>0</td>
<td>82.6</td>
</tr>
<tr>
<td>5</td>
<td>83.8</td>
</tr>
<tr>
<td>10</td>
<td>83.5</td>
</tr>
<tr>
<td>15</td>
<td>83.7</td>
</tr>
<tr>
<td>20</td>
<td>83.6</td>
</tr>
<tr>
<td>30</td>
<td>82.9</td>
</tr>
<tr>
<td>40</td>
<td>82.7</td>
</tr>
<tr>
<td>50</td>
<td>82.6</td>
</tr>
</tbody>
</table>
FACTORY

CONCLUSION

The investigations indicated that the wet disintegrator designed by the Sugar Research Institute does give the maximum possible extraction with cane, but its performance is enhanced by the provision of blades 6 to 7 in. in length. The results suggest that the cutting action of the blades is non-selective, with high and low purity cells being ruptured at random. Further, it has been possible to postulate that mechanical effects are predominant in the extraction in the machine. With a single spindle disintegrator, the geometry of the vortex formed is undoubtedly critical, and the improved rate of extraction obtained with larger blades is possibly due to the establishment of flow patterns which bring the cane particles more readily into the zone of action of the blades.

REFERENCES


APPENDIX I

TENTATIVE METHOD FOR DETERMINATION OF POL, BRIX AND FIBRE IN CANE WITH THE WET DISINTEGRATOR

The following method has been tentatively adopted for the analysis of mill feed. Cane is sampled from the hopper to the first mill of the tandem with a long handle fork and composited for a desired period. This is then well mixed, quartered and subsampled to approximately four kilograms. From this subsample a 2 kg portion is taken for pol and brix analysis with the disintegrator and the remainder is prepared in a Waddell hammer-mill for moisture determination.

Moisture

Moisture is determined by drying a convenient quantity of the hammer-milled cane in a Spencer oven at 105°C for 3 hours.

Disintegration

The 2 kilogram sample of cane and 8 kilograms of water are placed in the disintegrator and subjected to the action of the blades for 30 minutes. The flow of water through the cooling jacket is adjusted to maintain the temperature of slurry below 40°C.

After the disintegration, the container is removed and a 2 litre sample of extract is collected by straining the slurry through a fine gauze funnel. The extract is then filtered under vacuum with a filter aid of standard super-cel, and analysed for pol and brix.

Brix

The brix of the extract is determined in a 500 ml pycnometer. The brix of water used in the disintegrator is determined and a correction made to the brix of the extract if necessary.

The brix % cane is then calculated from the corrected brix of extract and the moisture % cane by means of the following formula which has been derived.

\[
\text{Brix} \% \text{ cane} = \frac{\text{Brix of extract } (\vartheta + w)}{\vartheta} \times \text{brix of extract}
\]

where

\[
\vartheta = 100 \left( \frac{x + y}{y} \right) \left( 1 + \frac{x}{100} \right) - \frac{x + y}{y} \left( 1 + \frac{x}{100} \right)
\]

\[
\vartheta = \left( \frac{100}{x + y} \right)
\]

\[
x + y = \frac{100}{x + y}
\]
and

\[ y = \text{Weight of cane} \]
\[ x = \text{Weight of water} \]
\[ z = \% \text{hygroscopic water} \]
\[ w = \text{Moisture \% cane} \]

For 2 kg of cane, 8 kg of water and 25\% hygroscopic water, the above formula simplifies to:

\[ \text{Brix \% cane} = \frac{\text{Brix of extract} \cdot (300 + w)}{80 - \text{brix of extract}} \]

**Fibre**

The fibre \% cane is calculated from the brix \% cane and moisture \% cane as follows:

\[ \text{Fibre \% cane} = 100 - (\text{Brix \% cane} + \text{moisture \% cane}) \]

**Pol**

A portion of the filtered extract is clarified with Horne's dry lead, filtered and polarised in a 400 mm. tube.

With an allowance for 25\% hygroscopic water, the pol \% cane is calculated as follows:

\[ \text{Pol \% cane} = \frac{(\text{Weight of cane} + \text{weight of water} - 1.25 \cdot \text{weight of fibre in cane}) \cdot \text{normal weight} \cdot \text{Pol reading}}{\text{Weight of cane} \cdot \text{Sp. Gr. extract}:: 2 \cdot 100} \]

Alternatively

\[ \text{Pol \% cane} = \frac{\text{Pol \% extract} \cdot (\theta + W)}{\theta - \text{brix of extract}} \]

**DISCUSSIONS**

L. J. Rhodes (Hawaii): Do you think that analysis of juice coupled with a determination of density of fiber plus juice might be used to calculate fiber?

R. Deicke (Australia): No, I said that suspended solids of the extract free of fiber have an influence and if the extract is just drained from the fiber the brix reading of the extract will be in error because of the suspended solids present. It is necessary to filter the extract in order to get an accurate value. Originally, we determined fiber by actually determining the fiber content in a weighed quantity of material taken from the disintegrator. Fiber is now arrived at indirectly, however, by measuring pol and moisture in cane and obtaining fiber by difference. This method is much less difficult than the direct method.

M. H. Shannon (B.W.I.): A very stale bundle of cane with a low sucrose content may yet show a high purity by polarization due to dextrose; can the Mauritius method be used to determine this? In Jamaica, on occasions, there are mills that classify the cane from small growers and sometimes this cane arrives many weeks old at the factory. The factory manager or the superintendent would condemn it as not fit to mill, and yet very often when cane in this condition is milled it gives a pretty high purity juice.

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F. Cordero (Venezuela): Would you please explain the arrangement of the dual spindle disintegrator?

R. Deicke: It is identical to the Sugar Research machine but instead of having 1 spindle there are 2 spindles side by side. The spindles can be rotated both in the same direction or in op-
posite directions. When they are rotated in opposite directions, the heating rate of the sample becomes quite considerable, the temperature rising from 20°C to 95–100°C in less than 15 minutes. Heating is much less with the spindles rotating in the same direction yet the extraction rate is almost as great.

K. Douwes Dekker (So. Africa): In regard to Mr. Shannon’s question about the deterioration of cane, the matter of deciding whether cane is still acceptable for milling was investigated by the Sugar Milling Research Institute in Durban. The criterion of Louisiana published some years ago, based on volatile acids, was found not suitable. More promising are the weight of the alcohol precipitate (gums) and the alcohol content, both determined in a sample of juice extracted from a small cane sample in a hand mill.

P. Halais (Mauritius): What is the maximum length of chopped cane that can be disintegrat-ed by the modified spindle machine?

Mr. Dricker: Pieces 3 in. long and quartered can be handled quite readily. We do hammer-mill in the Waddell hammermill at times; and we analyze mill feed that has gone through knives and Searby shredder, but you can handle stick cane in the wet disintegrator as long as it is chopped up into about 5-in. lengths and quartered. The hammermill can take whole cane about 10-in. long.

Mr. Rhodes: How do you maintain the wet disintegrator bearing?

Mr. Dricker: We operated continuously for about 6 hours a day, 6 days per week for 5 months in the 1957 season. During this time there was no maintenance required on the bearings except for a little greasing.