EFFECTS OF DEGREE OF PREPARATION ON THE QUEENSLAND EXPERIMENTAL MILLS

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INTRODUCTION

Earlier writers\textsuperscript{11, 14}, when referring to cane preparation, often make comparisons between substantially unprepared cane and cane prepared by high speed knives. As long ago as 1940, JENKINS\textsuperscript{10} found it necessary to point out that this comparison did not, in general, apply to Queensland conditions where "...disintegration of cane prior to milling has become general practice". Since 1940, intensive preparation by high-speed knives has become common practice in Queensland and many factories use, in addition to two sets of knives, a SEARBY-type shredder.

This followed the findings of BEHNE\textsuperscript{6, 7} that finer preparation gave improved results, but that an optimum fineness of preparation could be reached beyond which extraction and capacity would drop. Preliminary investigations of the effects of preparation on a 2-roll mill crushing fresh cane at the University of Queensland, reported by BULLOCK\textsuperscript{6, 7}, agreed in general with BEHNE's findings, although no optimum preparation was found.

Further investigations both at the University of Queensland using the 2-roll experimental mill, and by the Sugar Research Institute at Mackay using a 3-roll experimental mill, have given additional information for prepared fresh cane which has already been reported in some detail\textsuperscript{10}.

This paper sets out to collect this detailed information from the Queensland
experimental mills* and to show the agreement between the results from the 2-roll and the 3-roll mills.

**MEASUREMENT OF PREPARATION**

In the investigation to be discussed in this paper, the evaluation of the fineness of preparation is limited to the measurement of the degree of sub-division of the particles of cane. It will be realised that this is not a complete evaluation of the properties of a sample of prepared cane and, indeed, attempts have been made by previous workers to extend the properties included in the measure.

The measurement of fineness alone is a matter of some difficulty, and the need for a quantitative measure of fineness has long been felt. Spoolstra developed a fineness figure based on the pneumatic separation of bagasse into fractions, and a similar figure obtained from sieving tests was used by Behne. More recently, Bullock suggested that the power absorbed in preparing the cane was related to the fineness, and that this power could be used as a measure of preparation. Bullock also showed that preparations could be compared accurately by eye.

The measure of fineness of preparation used in this paper is the bulk density of a sample of prepared cane at an arbitrarily selected test pressure. It has been established that this measure correlates linearly both with fineness figures from sieving tests and with the power consumption of a "standard" preparatory device. These correlations are shown graphically in Figs. 1 and 2. It has also been established that the bulk densities at different arbitrary pressures are linearly correlated, as in Fig. 3.

For the bulk density determinations carried out in conjunction with the 2-roll mill experiments, the pressure used was 7.5 p.s.i., and consolidation time 20 seconds.

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* See Appendix 1 for references and brief specifications of the experimental mills.

References p. 137.
For the 3-roll mill experiments, bulk density determinations were carried out with pressures of 15.4 p.s.i., and consolidation times of 5 minutes. The values of pressure and time in the practical range are of little importance, provided some standard is set and adhered to.

Although these correlations are statistically significant, it should be pointed out that all these methods of measuring fineness of preparation are of an arbitrary nature, and that they can be used strictly only for comparison of the fineness of preparations from the same or, at the best, similar varieties of cane with similar fibre contents.

**EFFECT OF PREPARATION ON EXTRACTION**

"Factorial" experiments using the 2-roll mill have shown that extraction is a function of preparation and that a preparation-compression ratio interaction
exists; that is, that the response of extraction to changes in fineness of preparation is different at different compression ratios. These experiments have been reported by

BULLOCK. Recent experiments using bulk density as a measure of preparation have shown that the relationship is linear and the results are shown in Fig. 4, which clearly illustrates the interaction. Similar results have been obtained from the 3-roll mill and are shown in Fig. 5. Relevant data pertaining to Figs. 4 and 5 are given in Tables I and II.

Since the 3-roll results have been obtained in the "practical" compression ratio range (greater than about 2.5), the interaction cannot be observed, and this agrees with the results of the 2-roll mill in the same range. The increase in extraction with increasing fineness of preparation is definitely established.

By using the conversion graph (Fig. 3), it can be shown approximately that the slopes of the lines from the 2-roll mill are somewhat steeper than those from the 3-roll mill.

* For definition of compression ratio see Appendix 3.

References p. 131.
 mill. These small differences might be due to differences in the mills or in the cane crushed, or both.

All juice extractions reported in this paper are calculated on a weight basis, i.e.,

\[
\text{Juice extraction} = \frac{\text{Wt. of juice extracted}}{\text{Total wt. of juice in cane}} \times 100\%.
\]

**EFFECT OF PREPARATION ON ENERGY CONSUMPTION**

Figs. 6 and 7 show the relationship between energy consumption per ton of cane crushed and fineness of preparation for the experimental mills. It will be seen that, in

### TABLE III

(Refers to Fig. 6)

<table>
<thead>
<tr>
<th>Regression line No.</th>
<th>Work opening in.</th>
<th>Compression ratio</th>
<th>Correlation significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>20 F.P.M.</td>
</tr>
<tr>
<td>W1</td>
<td>0.27</td>
<td>3.65</td>
<td>—</td>
</tr>
<tr>
<td>W2</td>
<td>0.42</td>
<td>2.60</td>
<td>0.020</td>
</tr>
<tr>
<td>W3</td>
<td>0.57</td>
<td>1.95</td>
<td>0.010</td>
</tr>
<tr>
<td>W4</td>
<td>0.72</td>
<td>1.60</td>
<td>—</td>
</tr>
<tr>
<td>W5</td>
<td>0.87</td>
<td>1.30</td>
<td>0.050</td>
</tr>
</tbody>
</table>
general, the energy consumption decreases as the fineness of preparation increases. The rate of decrease is about the same in both mills except for the highest compression ratio in the 2-roll mill where it is thought that the bagasse is moving forward through the minimum opening at speeds considerably in excess of the roll surface speed. Relevant data pertaining to Figs. 6 and 7 are given in Tables III and IV.

**Fig. 6.** Showing correlation between energy consumption and bulk density in the 2-roll mill.

**Fig. 7.** Showing correlation between energy consumption and bulk density in the 3-roll mill.

The energy consumptions reported for the 2 mills show a rather higher figure for the 3-roll mill, but it should be noted that the energy reported for the 3-roll mill is the output of the driving motor, while that of the 2-roll mill is calculated from the torque on the roll shafts and the roll surface speed. Energy consumption in trash plate and scrapers, and differences in the cane crushed and in the roll grooving, might account for the rest of the difference.

The roll-loads measured in the 2-roll mill follow similar trends to the power consumption.

*References p. 131.*
ENERGY CONSUMPTION OF MILL-SHREDDER COMBINATIONS

The small shredder used before the 3-roll mill further prepares cane taken from a factory carrier after preparation by 2 sets of knives. From measurements of its energy consumption, Table V may be deduced.

TABLE V

<table>
<thead>
<tr>
<th>Shredder speed</th>
<th>Energy consumption of mill + shredder (H.P.-h. per ton cane)</th>
<th>Mill extraction (J % f)</th>
<th>Energy per ton juice (H.P.-h.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1400 R.P.M.</td>
<td>5.40</td>
<td>70.8</td>
<td>8.75</td>
</tr>
<tr>
<td>800 R.P.M.</td>
<td>4.75</td>
<td>68.6</td>
<td>7.94</td>
</tr>
</tbody>
</table>

Compression Ratio 3.02
Crushing rate 4.1 t.c.h./foot width of roll
Average fibre = \(
\begin{align*}
13.2\% & \text{ (1400 R.P.M.)} \\
12.75\% & \text{ (800 R.P.M.)}
\end{align*}
\)

It can be seen from Table V that the improved extraction from the finer cane is accompanied by an increased total energy consumption of preparation devices and 1st mill (assuming the consumption of the factory knives constant). The energy consumed to produce 1 ton of juice is greater with finer preparation.

A similar result can be deduced for the 2-roll mill as follows:

From Fig. 2 for the lower speed and the higher fibre cane, we have:

\[
E = 0.217 d - 7.17
\]  

where \(E\) = energy consumption per ton of cane (H.P.-h.)  
and \(d\) = bulk density of cane at 7.5 p.s.i. (lb. per ft.\(^3\)).

From Fig. 6 for compression ratio 2.6 and speed 20 f.p.m. (crushing rate 3.26 t.c.h./foot).

\[
E = 5.79 - 0.091 d
\]  

Therefore, from (1) and (2) the total energy consumption is given approximately by

\[
E_{\text{tot}} = 0.126 d - 1.38
\]  

This is the total energy consumption of preparatory devices and first mill increases. Using the lines of Fig. 4 for the same conditions together with the above result, it may be shown that the energy consumption per ton of juice also increases with increasing fineness. A probable reduction in milling power in subsequent units...
could reduce this initial disadvantage. It is worth mentioning that with finer preparation, a given overall extraction could be obtained with lower roll loads, which would reduce mechanical wear and tear.

EFFECT OF PREPARATION ON ULTIMATE RATE

Attempts have been made to determine the ultimate or maximum crushing rates of the experimental mills under "self-feeding" conditions, that is, without the use of any heavy forced feeding methods. These determinations are difficult, and no really definite ultimate can always be observed. The methods of determination in the 2 mills differ.

The 3-roll mill crushes "continuously", and the crushing rate of successive tests is increased until the mill appears to be about to refuse the feed. The 2-roll mill crushes blocks of prepared cane precompressed at 7.5 p.s.i. A block is presented to the mill under standard conditions and is either accepted or not accepted. On acceptance, a thicker block (or on non-acceptance, a thinner block) is prepared and tried. In this way the maximum rate is determined by a go-not-go procedure.

The experiments conducted in the 3-roll mill using preparations in the "practical" range have not shown any observable improvement in ultimate crushing rate. Using a wider range of preparations in the 2-roll mill, the results of Fig. 8 have been obtained. They show a general, though small, increase in ultimate rate with increasing fineness of preparation. The preparation range is from cane with very little preparation (almost whole sticks) to cane almost as fine as that produced from a laboratory fibrator. The experimental details for this test series are as follows:

<table>
<thead>
<tr>
<th>Cane Precompression pressure</th>
<th>7.5 p.s.i.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal work opening</td>
<td>0.228 in.</td>
</tr>
<tr>
<td>Speed</td>
<td>30 f.p.m.</td>
</tr>
<tr>
<td>Escribed volume</td>
<td>0.57 c.f.m./foot</td>
</tr>
</tbody>
</table>

It is suggested that this gain is due at least in part to the increased density of the material fed to the mill and, indeed, if the mill is assumed to grip the cane with a

References p. 131.
constant angle of contact of 29°, then the line AB on Fig. 8 may be shown to estimate the maximum crushing rate of the 2-roll mill with a fair degree of agreement with the experimental results.

For the range of preparation used in the 3-roll mill, the increase in rate of the 2-roll mill is about 10% and it is doubtful if such a small increase could be detected in the 3-roll mill. The experimental increase agrees fairly well with Hugot’s estimate of 5% increase in the capacity of a train of mills after the installation of a Seaby type of shredder.

CONCLUSIONS

It should be remembered that the results set out above apply strictly only to the experimental mills which have 18-in. diameter rolls. It would be reasonable to expect that larger mills have the same trends, but that their response to a certain change in preparation might be less than that of smaller mills because of the “scale effect”. A further possible scale effect may be that general levels of extraction in a larger mill for given conditions may differ from those reported for the experimental mills. This matter has not yet been investigated.

Within the practical compression ratio range, increasing fineness of preparation shows no drop in extraction or in ultimate rate of the experimental mills in the experiments reported here. That is, no “optimum” preparation has yet been reached (cf. Brain). However, it is felt that very fine preparations of the “sawdusty” type produced from soft canes, might cause a drop in extraction or in ultimate “self-feeding” rate, or in both. Indeed, such a drop in extraction has been observed in one particular experiment in the 2-roll mill.

Bearing these limitations in mind, we might conclude that:

i. The results of the 2 experimental mills are in good agreement.

ii. The use of more finely prepared cane increased the extraction when operating in the “practical” compression ratio range (greater than about 2.5).

iii. The energy consumption of a 1st mill is reduced by the use of finer preparation, but all of this energy saving is absorbed by the preparatory device.

iv. A small increase in ultimate self-feeding rate occurs as the fineness of preparation is increased.

APPENDIX I

<table>
<thead>
<tr>
<th>Two-roll mill</th>
<th>Three-roll mill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Department of Mechanical Engineering, University of Queensland, Brisbane.</td>
</tr>
<tr>
<td>Cane Supply</td>
<td>From farm plot kept for the Research Project.</td>
</tr>
<tr>
<td>Roll diameter</td>
<td>18&quot; (nominal)</td>
</tr>
<tr>
<td>Roll width</td>
<td>10&quot;</td>
</tr>
<tr>
<td>V-Grooving</td>
<td>1/3&quot; pitch, 34° included angle, 11/32&quot; deep in both rolls.</td>
</tr>
<tr>
<td>Juice Grooving</td>
<td>1/16&quot; wide X 1/2&quot; deep at every pitch in lower roll only.</td>
</tr>
<tr>
<td>Chevron Grooving</td>
<td>None</td>
</tr>
<tr>
<td>Roll material</td>
<td>&quot;Meehanite&quot; C.I. Grade G.C.</td>
</tr>
<tr>
<td>Roll surface speed</td>
<td>0 to 80 f.p.m.</td>
</tr>
<tr>
<td>Operated as</td>
<td>Fixed Mill</td>
</tr>
<tr>
<td>Opening set by measurement between bearing blocks and corrected later for deflections found from measured roll loads.</td>
<td>Opening set by measurement between shafts. No correction applied for shaft deflections in tests reported.</td>
</tr>
<tr>
<td>References</td>
<td>4, 5, 6, 7</td>
</tr>
</tbody>
</table>
The preparation device used with the 2-roll mill is generally referred to as a 'hammermill' and is based on a design originally due to WADDELL. It consists of a trunnion-mounted drum 20 inches in diameter and 12 in. long inside, which a set of $\frac{1}{8} \times \frac{3}{16}$" mild steel hammers rotate. The 12 hammers are 6 in. long and spaced at axial intervals of 4 in. in a "staggered" array, and the clearance between the tips of the hammers and the inside surface of the drum is approximately $\frac{1}{4}$ in. The drive is from an induction motor through a chain drive which allows nominal speeds of 750 or 500 r.p.m. Six pounds of cane in 12-in. lengths are prepared in a batch process, different degrees of preparation being obtained by varying the treatment time. (See also reference 7.)

**APPENDIX 3**

Compression ratio = \( \frac{\text{volume of cane without voids entering mill in unit time}}{\text{volume escribed by rolls in unit time}} \)

\[ q = \frac{d_u W_r S}{\rho \cdot (\text{roll surface speed})} \]

where
- \( q \) = crushing rate per unit width of roll.
- \( d_u \) = "no void" density of cane = 71 lb/ft\(^3\) approx.
- \( W_r \) = work opening (delivery side of three-roll mill)
- \( S \) = roll surface speed

in consistent units, for example, pounds, feet and minutes.

For further information see references 1, 7, 8.

**ACKNOWLEDGMENTS**

The authors wish to express thanks to the Sugar Research Institute and to the University of Queensland for permission to publish the information given in this paper.

**REFERENCES**


**DISCUSSIONS**

R. N. SELMAN (Australia): We have found by experience that when we wish to increase our crushing rates, it is usually necessary to coarsen the preparation in order to improve feeding. From the viewpoint of extraction, we would be happy to see the preparation as fine as possible, compatible with satisfactory feeding of mills and also compatible with burning the bagasse in the boilers.