CANE VARIETY EFFECTS ON MILLING OPERATIONS

V. Mason
Sugar Research Institute
Mackay, Queensland, Australia

ABSTRACT

Within Australia there has been and continues to be considerable concern about the variability of the cane supply and its influence on the milling process. This paper describes and summarises the conclusion of three major investigations undertaken in the 1980s into the milling and handling characteristics of a wide range of cane varieties. The paper describes the response of an operating sugar factory to canes having a wide range of fibre levels. Some control options to accommodate these canes are discussed. Subsequently detailed laboratory scale tests were undertaken, initially to assess the cane supply characteristics that governed the extraction performance of these canes and subsequently to assess the handling characteristics of the canes as they were transported along the milling train and between the milling train and the boilers. The tests showed that milling extraction behaviour could be adequately characterised by the cane fibre content but that this was inadequate to characterise the handling behaviour. The handling behaviour required a measure that represented the bulk ‘strength’ of prepared cane although from a practical point of view a test that assessed the proportion of fine material in prepared cane could suffice. This assessment is now measured routinely by BSES cane breeding staff before a cane is released for general use.

Keywords: Milling, cane variety, extraction, preparation, cane handling characteristics, cane selection

INTRODUCTION

Within Australia, a topic of considerable interest to milling engineers is the identification of cane varieties that cause processing problems along the milling train and the strategies that can be used to overcome those problems. This paper summarises and reviews investigations that the Sugar Research Institute has undertaken to understand the phenomenon and address the issue.

The impression is that in the last two decades there has been an increased variability in cane fibre levels and/or fibre characteristics in some mill areas. The problems experienced include:-
- canes with preparation so coarse that they will not fall down feed chutes,
- other canes whose preparation is so fine that they cannot be easily moved up intermediate carriers,
- canes with high fibre levels that required high milling power to overcome stalling, and
- canes with low fibre levels that produce high bagasse moisture, which inhibit boiler operation.

The extent of the challenge these canes present is illustrated in Table 1 which indicates the operational range experienced by one mill.
Table 1 Variation in milling train operational characteristics

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Variation (%)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cane fibre level</td>
<td>41</td>
<td>11.3 - 15.9</td>
</tr>
<tr>
<td>Cane Processing Rate</td>
<td>6</td>
<td>401 - 425 th⁻¹</td>
</tr>
<tr>
<td>Fibre Processing Rate</td>
<td>35</td>
<td>48 - 65 th⁻¹</td>
</tr>
<tr>
<td>First Mill Extraction</td>
<td>11</td>
<td>67 - 74%</td>
</tr>
<tr>
<td>First Mill Power</td>
<td>41</td>
<td>-</td>
</tr>
<tr>
<td>Overall Extraction</td>
<td>1</td>
<td>95 - 96%</td>
</tr>
<tr>
<td>Final Mill Power</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>Final Bagasse Moisture</td>
<td>17</td>
<td>44 - 51%</td>
</tr>
</tbody>
</table>

This paper outlines an investigation of the behaviour of an operational milling train as it processes these canes. Subsequent laboratory investigations examined the cane characteristics that affect milling performance and the handling behaviour of the same cane varieties. These last two investigations were undertaken in collaboration with staff from the Bureau of Sugar Experiment Stations (BSES) because, as the organisation primarily responsible for cane breeding in Australia, they were interested in test procedures that might assist them in their breeding program.

Problems of this type are not, of course, confined to Australia, although the impression within Australia is that these cane variability effects are of more concern to the Australian industry than to most others. Nor is the problem of recent origin. Prior to the second world war the staff from the Java experiment station had noted that milling performance varied with cane fibre levels (Douwes Dekker, 1959). In Australia the problem has been identified previously. Thus Buzacott (1956) considered cane breeding requirements to achieve acceptable milling performance while Sockhill (1958) reported the results of an investigation into the desirable cane fibre qualities from a milling point of view. Subsequently Foster and Shann (1968) examined the effect of varying degrees of fibre fineness on milling performance, showing that finer preparation results in improved extraction. More recently much of the reported work in this area has been undertaken in the USA. Thus James and Miller (1974), Legendre (1978) and Clarke (1984) all considered various aspects of the problem of understanding the desirable cane properties, primarily with regard to cane breeding selection.

While the work reported in this paper has a cane breeding and selection component (and did indeed lead to changes in the assessment procedures used by BSES), the main focus is on the sugar factory.

**FACTORY MEASUREMENTS**

The investigation of cane variety effects on milling behaviour began with a detailed study of the behaviour of a milling train as it attempted to process cane with widely varying characteristics (Mason et al, 1983). The milling train contained:-

- A 1.44 m diameter heavy-duty shredder.
- A No 1 mill with six rolls nominally 2.13 m by 1.05 m. When these tests were performed, the underfeed roll was relatively small. Both the top and delivery roll were hydraulically loaded.
- Three intermediate mills with six rolls with a nominal length of 1.98 m.
- A final mill with six rolls nominally 2.13 m long. Again, both top and delivery rolls were hydraulically loaded.

The Donelly feed chutes were all of fixed geometry. Twenty eight tests were performed with cane that varied in fibre content from 9.3% to 16.5%.
MEASURED MILLING TRAIN PERFORMANCE

The product that the shredder produces has a marked effect on milling performance. The cell breakage fell slightly with increasing fibre level from about 85% POC in open cells (POC) for the low fibre canes to about 78% for the high fibre canes. This changing POC was accompanied by an increase in prepared cane particle size (as defined by Foster and Shann, 1968) from just under 4 mm for low fibre canes to just under 6 mm at the other extreme. To a large extent, this variation in particle size is the factor that has a major effect on milling performance.

The average crushing rate during these tests was just above 400 tonnes cane per hour (about 10,000 tonnes per day). While there are marked changes in processing rate for individual tests, there is no overall trend to higher or lower processing rate as the cane fibre level increases. While the cane rate may not change much, the fibre processing rate inevitably changes greatly (Figure 1).

![Fig.1 : No.1 Mill Fibre Processing Rate](image_url)

The implications of this behaviour for the first mill are quite profound and in some ways surprising. The surprising aspect is that the mill fed at a more-or-less constant cane rate. The increase in mean particle size with increasing fibre level size would have been expected to produce reduced fibre compaction at the bottom of the feed chute. This would have reduced feeding effectiveness. More detailed analysis indicated that the higher fibre canes fed more-or-less as expected whereas the feeding of the low fibre canes fell below expectations.

The consequence of this was that the compactions within the mill and hence the power demands on the mill turbine increased as the cane fibre levels increased. Figure 2 shows this effect. At high fibres the power demand was about 40% greater than for low fibre canes. For the pressure feeder this trend is hardly surprising because the settings are fixed. However the pressure feeder only takes about 20% of total power, so the main mill made a significant contribution to this trend in spite of the fact that the mill had floating top and delivery rolls. When high fibre canes were being processed, the delivery nip work opening was about 15 mm (30%) greater than for the low fibre canes. Ideally the hydraulics would have maintained a constant roll load as the work opening increased. In practice this does not happen.
The first mill pol extraction is shown in figure 3, which also shows the overall extraction for the milling train. First mill extractions fell as fibre levels increased. This is to be expected because the pol-to-fibre ratio is greater for low fibre canes. However on a reduced extraction basis there is little change in extraction with fibre levels, again as would be expected. These trends do not carry through to the overall extraction where the extraction is in effect independent of cane fibre level. The final bagasse moistures (Figure 4) are not independent of fibre level. The higher fibre canes (i.e. larger particle size) produce lower final bagasse moistures. In practice it appears that the problem lay with poor feeding of the final mill by the low fibre canes. The result is that the overall extraction does not see the benefit of the higher Brix-to-fibre ratio in the low fibre canes.

The bagasse moisture data in Figure 4 includes the effect of changing maceration levels. In Figure 4 there are generally two or three moisture readings for each cane fibre sample, which reflect the different maceration levels used. In every case a lower applied maceration resulted in a lower bagasse moisture. However the pertinent point is that the changes that result from changes in maceration are not great enough to overcome the changes associated with variable cane fibre levels.

Fig.2 : No.1 Mill Total Milling Power
Fig. 3: First Mill and Overall Extraction

(a) Overall Extraction

(b) No. 1 Mill Extraction
General Implications of these Results

The information presented above is very interesting but must be treated with some caution when drawing general conclusions for other milling trains because all data was not recorded at constant conditions. For example, the lower moistures produced from canes with higher fibre levels involved higher roll loads and compactions, and variable milling speeds. These factors all effect milling performance to a greater or lesser extent and could be confounding the results.

An attempt was therefore made to allow for these variations by applying milling theory to the results. This showed quite clearly that under the same milling conditions, high fibre canes will produce significantly lower moistures than low fibre canes. When the theory was applied to roll loads and torques, the conclusions were not so clear cut. The main conclusion must be that with current theory it is only possible to predict loads and torques to an accuracy of ten to twenty per cent. In spite of this the data suggests that at the same roll load a greater compaction is possible with high fibre canes than with low fibre canes.

The other general conclusion is that changing maceration levels before the final mill has an effect on final bagasse moisture but the effect is not large. A change in maceration by about 20% (in the region of 200% maceration on fibre) is likely to result in moisture changes of about two percentage units.

Implications for Milling Train Control

As emphasised previously, the actual performance of the first mill used for the investigation is very dependent on the physical settings of that mill. The fixed feeding arrangement resulted in increasing fibre processing rate as the cane fibre level increased. Consequently the compactions and torques at the pressure feeder and in the main mill rolls also increased. In any other first mill with only a floating top roll experiencing the same variation in fibre levels, the top roll would undoubtedly have hit the stops, at which point the roll loads and torques would have increased dramatically. Such a mill would (and some did) have major processing problems.
What are the options to overcome difficulties of this type? The requirement is to limit fibre feeding to control compactions and torques. This implies that the mill feeding must be adjustable. Since the pressure feeder has a fixed setting, one way to achieve this control is to control the torque at the pressure feeder. Means for measuring pressure feeder tailbar torque are available and, at the time these investigations were made, the adjustment in feed could be achieved by installing an adjustable feed chute so that the feed is reduced as the pressure feed torque rises.

Under these circumstances, a paper study showed that this strategy should result in a controlled mill torque without any reduction in extraction. The delivery nip compactions would still rise as cane fibre levels increase, because of the compaction characteristics of the canes, while roll lift would be much more reasonable. The reduction in required top roll lift reduced to about a third of that required with a fixed feeding geometry. In general, this was the approach adopted by Australian mills to address this problem although with the more recent advent of independent pressure feeder drives, another option is becoming available.

**Laboratory Investigation of Milling Behaviour**

While the investigation described in the previous section provided some indication of the consequences to the milling train of large variability in the cane supply, there was still thought to be a need to explore the problems further. In particular there was a feeling that some ‘rogue’ canes behaved in an unpredictable manner which needed to be explored. Discussions with mill engineers indicated that the same cane grown in different location could have markedly different characteristics. Under these circumstances, BSES needed guidance for their cane breeding selection process to meet the industry’s needs. An extensive collaborative laboratory-based test program was therefore undertaken to determine simple tests that could be easily performed early in the cane breeding process, which would characterise factory shredding, feeding and milling processes.

**Test Program**

The overall intention was to investigate varietal and location effects on milling behaviour using a factorial experimental design. To this end, BSES planted special plots each of eight cane varieties in three cane growing areas in Queensland. In each growing area, the canes were planted at three sites - one on better than average irrigated land, one on better than average unirrigated land, while the third was in a poorer growing area. The eight varieties were chosen to include canes thought to have a wide range of milling properties. Unfortunately it was not possible to plant exactly the same varieties in each area. Only four varieties were represented in all areas. About 100 kg of cane was available for each variety from each of the nine sites.

For the experimental program, two major items of test equipment were constructed and one was reinstated. The intention was to produce equipment that represented as closely as possible the milling extraction process in an operating sugar mill. The equipment was sized so that duplicate tests could be performed.

Cane preparation, mill feeding and extraction at the delivery nip were modelled. For cane preparation, an experimental shredder was constructed with half the usual diameter but operating at twice normal rotational speed. The hammer tip diameter was 900 mm with a rotor 300 mm long operating at a no load speed of 2021 rpm. A mill feeding rig was constructed with a vertical feed chute above a pair of rolls representing the top pressure feed and under feed rolls. The rig had a feed chute 2.4 m tall feeding a pair of grooved rolls 655 mm diameter and 229 mm long. To assess extraction performance, the experimental two roll milling unit that was constructed in the 1960s by the University of Queensland for their original milling research was renovated. The rolls were 474 mm diameter and 203 mm long. A data logging system automatically recorded a wide range of parameters for each test.
RESULTS

A comprehensive statistical analysis of the data was undertaken. This showed that all the measured parameters showed a significant variation with cane variety while about two thirds of the data showed significant variation with location (using only the four cane varieties that were common to all cane growing sites). A further examination of the correlation coefficients between all parameters showed that overall the best predictor of most parameters was cane fibre level. For the 318 tests carried out, the average cane fibre level was 12.52% with extremes of 9% and 19.5%. These conclusions are illustrated by the following graphs of selected milling parameters plotted against cane fibre level.

From a milling point of view Brix per unit fibre is an important parameter since it indicates the potential extraction efficiency that could be obtained. The data in Figure 5 displays this result. It can be seen that a quadratic relationship in cane fibre level fits the data quite well with no indication that any variety or cane grown at any particular location is exceptional.

Some of the data relevant to shredding is displayed in Figures 6 and 7, which show the variation in POC and shredding power respectively. The POC data is displayed as the mean value for each cane variety plus the ellipse of confidence around the mean. These ellipses would be expected to enclose about 68% of the data points. POC measurement has an inherently large variability but, with the exception of Q82, there is no evidence of a varietal effect. There are only six measurements with Q82, so its displacement from the regression line cannot be taken as significant. When the shredding power consumption per unit fibre is examined in Figure 7, all varietal means (including Q82) are very close to the regression line.

Mill feeding behaviour as indicated by the compression ratio at the bottom of the feed chute again showed no evidence of varietal effect. Finally Figure 8 supplies evidence that fibre level alone is also an adequate predictor of milling performance. The load parameter presented here is the proportionality constant in the relationship between roll diameter, roll length and nip compression ratio that predicts roll load (Murry and Holt, 1967).

The overall conclusion is that milling behaviour of all the canes used in these tests can be quite adequately predicted from the cane fibre content.

![Figure 5: Brix Variation with Cane Fibre Level](image-url)
Feedback from sugar factory practitioners about the work described in the previous section indicated that the study did not cover all aspects of the problem. Specifically factory staff considered that there were differences between cane varieties with respect to the handling properties of prepared canes and bagasses which were not brought to light in the milling and shredding trials. They commented that at one extreme, mills would experience bridging of mill feed chutes, excessive carry over on drag elevators, bending of elevator tynes, choking of transfer points on bagasse conveyors and stalling of bagasse stacker/reclaimer drives. At the other extreme there was difficulty in conveying prepared canes and bagasses with drag elevators, and combustion problems because of high moisture bagasse. These effects were being countered by adjusting shredder operation and changing maceration quantities to suit individual cane varieties, by fitting rollers at the head of mill feed chutes to prevent bridging of the chute, modifying elevator tynes, modifications to bagasse transfer points and boiler feed drums. The extent of these changes indicates the seriousness of the problems being experienced.

The experimental program

These problems forced research staff to break new ground to investigate what came to be called the “handleability” of prepared canes and bagasses. The project again was conducted as a collaborative project with BSES. The perceived need was for a cane characteristic, which could be measured early in the cane breeding program and forewarn of handling difficulties within a factory. A number of such likely characteristics were identified and an experimental program established to determine their suitability for that purpose.
Defining such tests was problematical because of the absence of guidance available from the literature or from sugar industry experience. Eventually 14 different tests were tried at various times during the investigation. These were the cane fibre level, seven tests that characterised the degree of preparation of the cane plus six that it was hoped would characterise the handleability of the cane as represented by the “strength” of a block of prepared cane. An additional and most significant difficulty was to “rank” the handleability performance of the canes in the factory. It was not possible to devise small-scale tests which simulated factory “handling”. Eventually this problem was overcome by surveying factory staff to obtain a ranking of the cane varieties. Therefore the challenge that was set the researchers was to find a simple test that would rank the canes in the same order and, if possible, to the same degree of severity as the ranking obtained from factory personnel.

The tests that characterised degree of preparation were generally similar to those used in the varietal investigation described above. The one test that requires some comment is the tumbler test which is used to determine the mass of the fine fraction in prepared cane. The tumbler comprises a cage with rectangular sides (457 x 305 x 305 mm) clad in 12.7 mm mesh (Anon, 1979). A 1 kg sample of prepared cane was placed in the cage, which was then rotated about a diagonal axis at 13 r min⁻¹ for two minutes. The mass of fine fraction is the amount of cane that fell outside the cage.

The “strength” tests, however, were novel. They measured the force required to break up a block of prepared cane. A shear force test required prepared cane to be compressed lightly to form a block of cane 100 x 200 x 450 mm. For tests at constant cane density, 4 kg of cane was used (giving a density of 445 kg cane m⁻³). Constant fibre density tests were performed with a density of 55 kg fibre m⁻³. These cane blocks were placed between two wooden plattens with protruding nails. The force required to shear the top platten from the bottom was measured. A second test used a similar block of prepared cane which was pushed slowly over the edge of a table until a segment of the block fell to the floor. Both the mass of cane that fell to the floor and the average length of that segment were noted.

Experimental Results

Two main test series were undertaken. The first assessed whether it was possible to alter cane preparation treatment so that different canes behaved identically in the above tests. The short answer to this question is “No”. No matter how the preparation treatment was varied, it was not possible to prepare high fibre canes so that they behaved the same as prepared cane from low fibre canes. However it was possible to move toward that objective. This confirmed that the practice adopted by some mills of altering shredder settings for some cane varieties could alleviate problems.

The second test series focussed on tests which could be used to rank the canes in the same order of handleability as experienced by factory staff. Several interim conclusions were made. The first was that good correlations could be obtained between handling characteristics (as assessed by a strength test) and the fineness of the prepared-cane. Figure 9 illustrates the relationship that had the highest regression coefficient (r=0.89). This leads to the conclusion that it could be possible to assess handling characteristics by assessing the level of cane preparation.
The second intermediate conclusion was that it was not possible to represent adequately the data on handling properties such as shear strength by a simple regression using cane fibre level (a conclusion that was fundamentally different from the previous milling tests). There is evidence in Figure 9 that fibre level cannot predict handling behaviour. Thus Figure 9 shows that Q109 cane variety has intermediate ‘handling’ characteristics although its fibre level was on average below that of Q87 and Q103.

Fortunately this conclusion concerning the behaviour of Q109 was supported by the ranking assessment of factory staff. The actual comparison of the rankings from the physical tests and the ranking by factory staff was performed statistically using the Spearman rank correlation coefficient (Walpole and Myers, 1978). The shear force measurement (under either constant cane or fibre density) was the parameter, which most closely matched the factory staff ranking. However such a test is not ideally suited for use as part of a cane breeding program because it is too fiddly and time consuming. The preferred test from this practical viewpoint was to measure the mass of fine fraction in the prepared cane. Statistical analysis supports the visual evidence from figure 9 that this test would be a satisfactory alternative. This test is now applied to all canes that BSES now releases for general use by Australian cane farmers.

**CONCLUDING COMMENTS**

This paper has outlined three major experimental programs undertaken in the mid-1980s that form one of the major components of the Australian sugar industry’s understanding of the effect of cane variety on milling performance. The general conclusion is that cane fibre level provides an adequate indication of how an Australian cane variety will behave during the milling extraction process. However fibre level does not adequately characterise the way in which prepared canes and bagasses handle as they are transported to and between milling units and from the milling train to the boilers. A parameter which assesses the ‘cohesiveness’ of a block of prepared cane appears to be the best indicator of handling characteristics, but in practice a test that assesses the
The proportion of fines in a prepared cane sample is used. The test to evaluate the proportion of fine material is now used routinely as part of the cane breeding system in Australia. Cane varieties are not rejected based on this parameter. Rather the test is used to warn the cane breeders and factory staff that a cane might exhibit unusual handling characteristic in a sugar factory.

ACKNOWLEDGEMENTS

The author was Chief Research Engineer at the Sugar Research Institute while the work described in this paper was undertaken. The majority of the research was undertaken by other staff. The author therefore gratefully acknowledges the contribution made by Brian Edwards, Clyde Garson, Jeff Loughran, (the late) Jim McGinn, and (the late) Rod Murry who were at the time employed at the Sugar Research Institute, and Alex Brotherton who was employed by the BSES.

REFERENCES


EFECTOS DE LA VARIEDAD DE CANA SOBRE LAS OPERACIONES DE MOLIENDAS

V. Mason
Instituto de Investigaciones de Azucar
(Sugar Research Institute) Mackay, Queensland, Australia

RESUMEN

Dentro de Australia ha habido y continua habiendo considerable interés acerca de la variabilidad del suministro de caña y sus influencias sobre el proceso de molienda. Este estudio describe y sumariza la conclusión de tres investigaciones mayores llevadas a cabo en la década de 1980, acerca de la molienda y las características del manejo de un amplio rango de variedades de caña. Para acomodar estas variedades de caña, se discutieron algunas opciones relativas al control. Subsecuentemente, análisis detallados a escala de laboratorio fueron realizados, inicialmente para valorar las características del suministro de caña que gobiernan la extracción en estas variedades y posteriormente, paralizar las características del manejo de caña cuando ésta era transportada a través del molino, así como también, entre el molino y el proceso e hervido del ugo. Los análisis demostraron que el comportamiento de la extracción del molino podría ser adecuadamente caracterizado por el contenido de fibra de la caña, siendo éste al mismo tiempo inadecuado para caracterizar el comportamiento del manejo de caña. El comportamiento del manejo de caña requería una medida que representará la mayor parte de cana preparada, aunque desde un punto de vista práctico, un análisis que valorará la proporción de material bueno en la cana preparada podría ser suficiente. Antes que una variedad de caña sea permitida para uso general, esta evaluación es ahora medida rutinariamente por personal de la organización BSES, el cual es especializado en producción de caña.

Palabras claves: Molienda, variedad de caña, extracción, preparación, características del manejo de caña, selección de cana.

L'IMPACT DE LA VARIÉTÉ DE LA CANNE SUR LA PERFORMANCE AUX MOULINS

V. Mason
Sugar Research Institute
Mackay, Queensland, Australia

RESUMÉ

En Australie on s'est toujours soucié de la variation présente dans le bassin canier et de son effet sur la performance aux moulin. On présente dans ce papier les conclusions obtenues par trois investigations faites pendant les années 1980. Ce travail s'applique à la manutention et à l'extraction aux moulin d'un grand nombre de variétés de cannes; on a aussi étudié l'effet de la fibre. On donne quelques idées sur le contrôle voulu pour traiter ces cames. On a étudié, au laboratorio, les caractéristiques de la canne qui influencent l'extraction et qui affectent sa manutention aux moulin et aux chaudières. Les résultats montrent que l'extraction dépend de la fibre mais que ce paramètre n'est pas suffisant pour expliquer la manutention. La manutention demande une mesure de la résistance en gros de la canne préparée; une simplification pourrait être la mesure des petites particules dans la canne préparée; une simplification pourrait être la mesure des petites particules dans la canne préparée. Cette méthode est appliquée couramment par le BSES avant la commercialisation des nouvelles variétés.

Mots clés: Broyage, Varietés des cannes, Extraction, Préparation, Manutention des cannes, Selection des cannes.