A REVIEW OF CANE DETERIORATION AND RELATED PROCESSING PROBLEMS

By D. H. Foster

This review does not pretend to be an exhaustive examination of the sugar industry literature relating to cane deterioration and the subsequent effects on processing. It tends to emphasize the factors which seem important in the writer’s experience and is biased towards the experiences and solutions to problems obtained under Australian conditions. The writer’s objective has been to present an introductory statement for this ISSCT panel discussion and it is hoped that shortcomings can be remedied by contributions from participants with more varied experience.

In discussing cane deterioration and subsequent processing problems it is essential to note that deterioration which is always time dependent can be minimized by establishing an efficient and well scheduled cane transport system. It is also desirable to roster harvesting operations to extend over the greatest possible time in a daily cycle. This also reduces the capital cost of transport equipment when transport containers are used for storage purposes. A well integrated harvesting and transport operation is in general, not only the least costly but also provides cane with a minimum of deterioration.

A great deal has been published over the years on deterioration in whole stick and chopped cane both burnt and green. In much of this work the cane has been cut for periods of 3, 7, 14 and even up to 20 days. Knowing as much as we do now about cane deterioration, the effects of these long delay periods should be only of academic interest, except in rare instances of strikes, bad weather, or other such catastrophe. In a well organized harvesting and transport system, all cane should be crushed within 24 hours of harvesting, yet there is only a small amount of information describing deterioration for periods less than this.

PRIOR TO HARVEST

Although deterioration of millable cane is generally considered as commencing from the time of burning, it can occur beforehand in green standing cane producing possible problems in processing. For example, sarkaran was identified by Brujin (1966) as a polysaccharide formed in cut cane following very long delays in transportation to the factory. A similar polysaccharide was implicated (Fulcher and Inkerman, 1976) and subsequently identified (Blake, 1979) in molasses derived from freshly-cut two year old cane. It has been suggested that this is a microbial polysaccharide which has entered through cracks in the internodes of the overmature cane. Difficulties in sugar boiling and high viscosity of syrups have sometimes been described by sugar mills in Queensland when processing this cane.
Attempts are being made to develop a laboratory heat transfer test to detect syrup abnormalities and to simulate the gumming of vacuum pan heating surfaces which has been experienced in mills.

Abnormal polysaccharides have also been found in canes infected with red rot (Foster, 1969)\(^4\) and in apparently sound canes. These were sufficient in quantity to give up to 1600 ppm on Brix by the "dextran haze" test. However, insubsequent hydrolysis of crude alcohol precipitates from such canes, glucose, galactose and mannose were found to be present. It appears that these polysaccharides do not occur extensively. Whether they are removed in clarification or what effects they have on processing are unknown. Because of these occasional variations it is desirable to make control checks, using treatment with dextranase, when the haze test is being used to measure dextrans.

**CANE FIRES**

The severe damage done to the outer portions of cane sticks in a cane fire is not generally appreciated. It has been concluded (Foster, 1979)\(^5\) that the outer one millimeter of a 25 mm diameter cane stick containing 15 per cent of the cane weight is held between 98\(^0\) and 400\(^0\)C for several seconds. More recent experiments have shown that in fierce fires 102\(^0\)C is reached 1 mm below the surface and of course, this may extend further towards the center. The juice in the outer parenchyma and vascular bundles actually boils and perforates the epidermal tissue. While there must be an immediate sterilizing effect the plants own system for protection from microbial attack must be severely impaired in the epidermis. If juice can escape then surely microorganisms can enter. Little has been done to identify those organisms which infect through these perforations immediately after burning although McNeil and Inkerman (1977)\(^6\) have identified a wide range of organisms in cane where harvesting had been prevented by heavy rain for 10 to 20 days after burning.

The high temperatures reached in the fire must also destroy appreciable sucrose and promote a number of other reactions, some of which are colour forming. Reference is made here to the mode of sucrose degradation at high temperatures as described by Richards et al. (1979)\(^7\) in another paper at this congress.

Colour is substantially greater in syrups from clean burnt cane than from clean green cane. Eight comparisons of clean green and burnt cane were made in which the cane was crushed and processed to syrup (Foster, 1979)\(^5\). Color of the

\[
\text{colour} = \frac{1000}{\left(\frac{a_{420}}{b} - 2s_{720}\right)}
\]

where

\[
a = \frac{A}{bc}
\]

\[
b = \text{cell length in cm}
\]

\[
c = \text{concentration in g/ml}
\]
syrup from burnt cane averaged 8570° as against 7390 from the green cane. Processing was carried out as rapidly as possible through to the clarification stage to minimize enzymic browning which has been demonstrated by Gross and Coombs (1976). Of course, large amounts of extraneous matter in green cane may outweigh the effect of burning and promote increased color as shown by Sloane and Rhodes (1972). The point to be emphasized is that burning causes a serious deterioration of cane and ideally it should be avoided. In practice, harvesters are not adequate to produce clean green cane at a sufficient rate to be economically acceptable and this is an area that warrants substantial agricultural engineering research.

The act of burning not only destroys sugar to an extent which varies with the severity of the fire, but also pre-disposes the cane to deterioration while waiting to be harvested and during the subsequent period between harvesting and crushing. Five to seven per cent more recoverable sugar has commonly been observed in matched samples of green versus burnt cane harvested at a northern mill in Australia (Foster, 1979). The difference is partly due to the effect of the cane fire and the subsequent deterioration but also to a dilution effect due to the well known ability of burnt cane to take up water and increase in weight after burning. In the experiments described above, harvesting was carried out in the day after burning when weight increase had been generally less than one per cent. However, water uptake can be up to four per cent as noted by Young (1962).

Results of processing 2000 tons of green cane which was matched as closely as possible with 2000 tons of burnt cane are shown in Table I (Foster, 1979). The green cane was chopper harvested and crushed on one day, then the matched cane was burnt that evening and harvested and processed on the following day. Delays between cutting and crushing averaged about 8 hours and the burnt cane contained seven per cent extraneous matter as opposed to eight per cent in the green cane. The CCS (recoverable sugar) in the green cane was 15.35 per cent compared with 14.6 per cent in the burnt cane. The results in Table I are the averages of many analyses on samples taken through an eight hour processing period. They show slightly less color and much less ethanol in the products from the green cane. The reduced level of ethanol has interesting implications for treatment of effluents which contain surplus water distilled off at the evaporators (Blake and McNeil, 1978). Syrup from burnt cane was of a slightly lower purity than that from green cane. If the differences in recoverable sugar were due chiefly to microbial deterioration, much greater purity differences would be observed. Possibly the cane loses substantial amounts of sugar in juice which is expelled during the cane fire and maybe some is converted to insoluble char. Careful measurements of weight changes in sticks have indicated little difference between green cane and cane 18 hours after burning. This may have been masked by juice losses being counteracted by water uptake.
COMMITTEE REPORTS AND SECTION MEETINGS

TABLE I. Quality of juice and syrup from green and burnt cane

<table>
<thead>
<tr>
<th></th>
<th>Burnt</th>
<th>Green</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clarified Juice</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbidity 975 nm</td>
<td>15.2</td>
<td>9.6</td>
</tr>
<tr>
<td>Ethanol mg/l</td>
<td>270</td>
<td>52</td>
</tr>
<tr>
<td><strong>Syrup</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purity (\frac{sucrose}{dry sub})</td>
<td>91.25</td>
<td>91.45</td>
</tr>
<tr>
<td>Ash</td>
<td>1.84</td>
<td>1.76</td>
</tr>
<tr>
<td>Reducing sugars</td>
<td>1.30</td>
<td>1.23</td>
</tr>
<tr>
<td>rs/ash</td>
<td>.706</td>
<td>.699</td>
</tr>
<tr>
<td>Filterability (Nicholson test)</td>
<td>57</td>
<td>63</td>
</tr>
<tr>
<td>Colour 420 nm</td>
<td>10420</td>
<td>10300</td>
</tr>
<tr>
<td>Dextran</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

A similar observation has been made by Holder and De Stefano (1977)\textsuperscript{13}. They reported yields of sucrose five per cent greater in cool burnt cane as compared with hot burnt cane and they also found little difference in purity of juice.

BURNT CANE STANDING IN THE FIELD

It is difficult to lay down definitive rules for predicting rates of deterioration for burnt standing cane since they depend on the quality of the cane and weather conditions. For example, greater attention must be given to minimize the time between burning and cutting in northern tropical areas of Queensland than on the sub-tropical coast. In the former, it is common practice to burn cane on the evening of one day and to harvest completely on the next day. To avoid deterioration by standing cane over week-end periods when harvesting and milling cease for a two day period, some farmers burn less than their quota of cane on Thursday and complete their delivery to the mill with a number of bins of freshly-cut green cane.

Fulcher and Inkerman (1974)\textsuperscript{13} have found 1900 ppm on Brix of dextran in sound-standing burnt cane after a period of only four days during the hot part of the crushing season in north Queensland. This is evidence of earlier microbial infection. Investigations in South Africa (Wood and Du Toit, 1972)\textsuperscript{14} and in Mauritius (1974)\textsuperscript{15} seem to indicate negligible deterioration in burnt standing cane for one day after burning, but purity was falling and reducing sugars increasing after
two days. Deterioration which occurs at this stage can be expected to accelerate during post harvest storage especially when the cane is cut into short pieces and the microbial population is spread over the cut surfaces.

Fulcher and Inkerman (1974)\textsuperscript{13} have drawn attention to the fact that no one parameter is adequate to specify deterioration in burnt standing cane. It is necessary to measure pH, purity and dextran. To this list might also be added reducing sugars.

**BURNT—CUT WHOLE—STICK CANE**

It is difficult to sample with sufficient precision to obtain reliable data on the changes occurring in harvested whole-stick canes over one or two days. Waddell (1952)\textsuperscript{16} obtained little change in purity over two days of storage of cut burnt cane and this is in agreement with the results of Wood (1976)\textsuperscript{17}. Mauritius Sugar Industry Research Institute (1974)\textsuperscript{16} results seem to show an apparent purity drop in a two day interval but this may have been marked by experimental error. On the other hand, Young (1962)\textsuperscript{10} from extensive investigations indicated a sugar loss of about two per cent and Sayed et al (1977)\textsuperscript{18} obtained a small purity drop. After two days these authors recorded a marked increase in sugar loss in final molasses.

If whole stick burnt cane is processed within two days of being harvested, there should be little or no problem with dextran formation according to Wood and Du Toit (1972). Some of their trials were carried out in the hot humid part of the South African summer.

**GREEN CUT WHOLE STICK CANE**

A series of investigations over the years from Waddell (1952)\textsuperscript{16} to Sayed et al (1977)\textsuperscript{18} have concluded that green cane deteriorates more rapidly than burnt cane in cut whole sticks. There is a greater fall in purity and a more rapid increase in reducing sugars. No detrimental polysaccharides seem to have been noted in periods of less than two days. The chief processing problem is that the quantity of sugar lost in final molasses is greatly increased. This is to be expected from molasses exhaustion formulae such as

\[
\text{True purity} = 41 - 18 \log \frac{\text{reducing sugars}}{\text{ash}}
\]

because the increase in quantity of molasses exceeds the effects of reduced solubility coefficient.

From an examination of the literature available to the writer, it is not clear as to the relative contribution of natural invertase and microbial attack to the observed deterioration of whole stick green cane. Recent investigations on chopped green
and burnt cane generally show a marked reduction in deterioration rate in the green cane. Inkerman (1979) has suggested that for periods of 24 hours there is negligible deterioration in chopped green cane when microorganisms are excluded.

**CHOPPED CANE**

The deterioration of chopped burnt cane does not need any detailed comment here for it has been extensively reviewed in other papers. (Keniry et al, 1967, Foster, 1969, Egan, 1971, Wood, 1976, Ivin and Foster, 1977). From these papers it is clear that chopped burnt cane requires to be processed within 12 hours in hot humid conditions if dextran formation is to be avoided. Longer delays may be permitted in cool dry weather. Such weather conditions also coincide with the cane being relatively immature and it may well be that the plant has more effective defense against microbial attack at that time.

Production of dextran occurs very much more rapidly in damaged and mutilated pieces of cane. Hence it is particularly important to maintain and operate harvesters to produce good quality billets. Again this matter requires extra attention in hot humid conditions late in the harvesting season, especially when cane is cut only during daylight hours. In Australia, some chopped cane must be stored for 16 to 18 hours overnight to span the period until fresh deliveries arrive from early morning harvesting. Under these conditions, billet quality standards must be watched closely. This is also important to the farmer since CCS falls more rapidly in the poor quality billets. For example, Ivin and Bevan (1973) measured CCS losses of 5.8 per cent of original CCS in short and mutilated billets and 3.4 per cent in sound long billets in cane stored 24 hours. At 18 hours the values were 3.5 and 1.3 per cent respectively.

The effects of dextran on processing have received extensive documentation. Dextran inhibits growth on certain crystal faces (Day, 1971) and causes needle shaped crystals. This reduction in growth rate can cause extensive delays in sugar boiling. For example, the crystallization rate of sugar from chopped-burnt two-day old cane may be halved. This slow crystallization, together with the increased molasses viscosity, greatly increases losses in final molasses. Keniry et al (1987) suggest three units purity increase for each 0.1 per cent dextran in cane juice Brix (i.e. 1000 ppm on Brix solids).

James (1972) showed a correlation between dextran level of raw sugar and a reduction in filterability. Subsequently, Fulcher and Inkerman (1978) found that fully dissolved dextran had only a slight effect on filtration rates and suggested that decreased filterability of raw sugars containing dextrans was more likely to be due to a decreased efficiency of juice clarification. Likewise, Whayman and Meredith (1977) showed some reduction in filtration rate after phosphatation when dextran is present but more problems are caused by production of raws from ...
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deteriorated cane than those due to the presence of dextran alone.

If delays between cutting and crushing cannot be shortened sufficiently, other alternatives may be sought. Most of the occurrences of dextran and its associated deleterious effects would be largely eliminated if cane could be harvested green. This applies both to whole stick cane (Wood and Du Toit, 1972) and to chopped cane (Ivin and Foster, 1977). Unfortunately, harvester development has not yet reached the stage where this is practical and economic in all crops. In particular, the harvesting rate is generally too slow when the requirement of a low level of extraneous matter is imposed. However, this is an option which has been chosen by some farmers in the hot and high rainfall section of the Queensland coast.

Finally, if no other alternative is available, one very effective method of overcoming most of the processing difficulties with Leuconostoc infected cane is to use the enzyme, dextranase (Inkerman and James, 1976; Inkerman and Riddell, 1977). This results in much improved rates of crystallization and improved molasses exhaustion. In addition, crystals are not elongated and better filterability results from improved clarification. However, the use of dextranase should be regarded only as a last resort when extraordinary events have seriously delayed cane deliveries.

REFERENCES


