LOSSES ASSOCIATED WITH CANE YARD OPERATIONS AND CANE WASHING

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Abstract

In Louisiana all cane is mechanically harvested and loaded as whole stalk. Cane delivery is by road over a 9-10 hour period, with some cane being sent directly to the mill tandem and the remainder stored in the yard. All cane is extensively washed before entering the carrier. In an attempt to determine the losses involved, prepared cane was sampled as frequently as possible for extended periods (up to three days) and analyzed by the (core)-disintegrator-press system used for incoming cane. At the same time cane wash water was analyzed for sucrose by HPLC. These tests indicate higher than expected losses in this part of the factory and are being used to assess the feasibility of modifying the system.

Introduction

The agricultural operations of the Louisiana sugarcane industry are now completely mechanised and this has a major impact upon the quality of cane delivered to the mill. Standard practice is to cut the cane unburnt with a whole stick soldier harvester and lay it across the row to form a heap-row from three or four rows of cane. This cane is burnt in the heap-row and then loaded onto wagons for transportation to a transloading station (where it is transferred to a truck) or directly to the mill. Under rainy conditions the cane cannot be burnt and is milled with the leaves and trash. Several loading systems are used, but they all bring in more field soil than is acceptable. Cane washing is necessary to minimize process problems associated with high soil levels. It is not the purpose of this paper to discuss the effects of trash and dirt on factory operations but rather to describe the impact of the unavoidable cane washing.

Upon receipt at the factory the cane is weighed and sampled by the core/press procedure (Birkett, 1979). The loads analysed vary widely, from almost 100% to as low as 30%. Cane is delivered to the factory for ten to twelve hours per day and during this period some is unloaded directly into the carrier, and the remainder is unloaded into the yard where it is stacked for grinding overnight. Under normal conditions it is unusual for much cane to be left in the yard when deliveries begin the following day. Most factories use front-end loaders to move and stack the cane and this is a well known cause of damage and potential sugar loss. Some mills use the front-end loaders to supplement gantry or derrick systems but these were not part of the study.

The work described in this paper is supported by the American Sugar Cane League and seeks to measure the magnitude of losses incurred between delivery of the cane and its entry to the extraction system. The cane handling system currently used is far from ideal but the cost of changing would be very high and would have to be justified by recovering additional sugar and/or by minimizing other problems associated with the current system. Large volumes of water are used in the cane washing systems and this water leaves the factory with a far higher biological oxygen demand (BOD) than is acceptable for discharge into local rivers or lakes. Environmental regulations are becoming more strict and it is no longer possible to ignore the loss of sugar into the water, which in the past has been assumed by the mill to be negligible.

An attempt is made to quantify handling losses of sucrose so that mill management can make better decisions on how to improve the system. These losses can be thought of as chemical due to deterioration during storage and damage during handling, or as physical from the cane being crushed under the tyres of the loaders or in the washing system. Ideally, the experimental system should be able to distinguish between these two and losses in the yard and on the wash table. The approach taken was to use the same analytical procedure for the prepared cane entering the mill as that used for the cane analysis upon receipt at the mill. There are some inaccuracies in the core/press system but these partially balance each other and it should be possible to observe changes in the cane composition. Other measurements were made directly on the sugar content of the water used in the wash system.

The press analysis allows determination of the percentages of pol (P), soluble juice solids (B) and 'fibre' (F) in the cane. The assumption is made that the residual juice in the filtercake has the same brix and purity as the expressed juice. This is not the case and the magnitude of the error introduced is largely dependent on the degree of preparation of the cane. The 'fibre' in this case is the total insoluble solids, including field soil. The theoretically recoverable sugar (TRS, expressed as kg of sugar per ton of cane) is calculated from these factors, using assumptions about average mill extraction and boiling house efficiencies, by the following equation:

$$TRS = (0{,}14*P - 0{,}04*B)*(100 - 56{,}67*F/(100-F))$$

The first part of the equation is a modification of the Winter-Carp formula and the second part relates the expected extraction to the fibre content.

In Louisiana the mixed juice is not usually weighed and, if it is, the accuracy is poor. For mill balance purposes the juice mass is estimated from sugar and molasses yields and composition, and the cane composition is calculated from the estimated juice quantity. This system tends to minimize the reported juice production, lowering the apparent mill extraction, and increasing boiling house efficiency. There is a fairly good inverse correlation reported between boiling house efficiency and the difference between pol % cane determined from the core laboratory and from the mill balance estimation. If the press system could be used to determine the prepared cane composition, this would be a useful check against mill calculations.

Experimental procedures

Prepared cane analyses were carried out at the mills, using the same equipment and procedure as for routine incoming cane quality determination. Variations in procedure made by the factory laboratory staff were used by Audubon Sugar Institute (ASI) personnel. In most cases the daytime sampling of prepared cane was done by factory personnel. The factory laboratory normally performed 100-300 press analyses per day.

Dry lead subacetate was used as the clarification reagent for the 1989 tests and the new ABC reagent was used exclusively during the 1990 tests, by both the factory laboratory and ASI (Clarke and Bourgeois, 1990).

For the 1989 tests samples of prepared cane were used in the press without further preparation, except in cases where parallel samples were run through the disintegrator system of the core sampler. For the 1990 tests a Reitz pre-breaker was modified and used with all samples of prepared cane to ensure more uniform preparation.

Runs began in the morning with the first delivery of cane onto the mill carrier and continued for at least 24 hours, and in some cases up to 72 hours. Prepared cane was sampled as often as possible during this time, usually at intervals of about 20 minutes. All samples were analyzed immediately with no compositing. When water samples were taken from the wash table, the same sampling frequency was used.

Water samples were frozen in dry ice for storage until run on a Dionex Ion Chromatograph to determine sucrose, glucose and fructose. No dilution of the samples was necessary and the only pre-treatment was filtration using a 0,45 micron syringe filter. With standards the relative deviations were 3% for sucrose (at 600 ppm) and 10% for glucose and fructose (at 30 ppm).

Results and Discussion

Comparison of prepared cane composition with incoming cane composition

Five runs were carried out at three mills during the 1989 season and eight runs at three mills during the 1990 season. Except when mill stoppages occurred, samples were taken and analyzed continuously. The results of a 72 hour test in the 1989 season are shown in Figure 1.

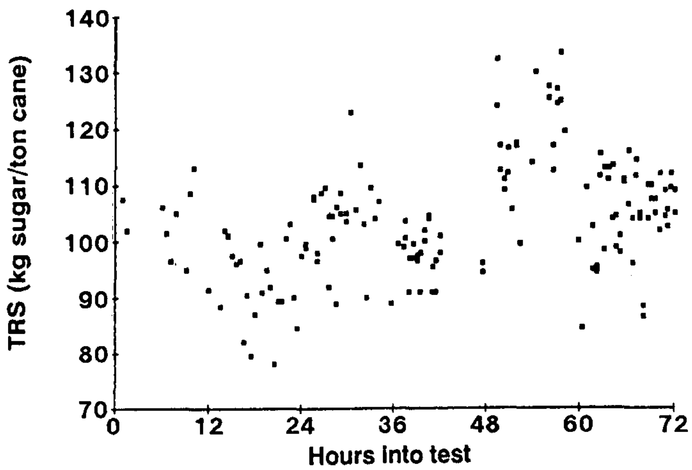

FIGURE 1 TRS of prepared cane during 72 hour test at St. Mary Sugar Co-operative. Gaps in data are due to short mill stoppages. Some duplicate samples are included.

The test began at six am and there was a marked difference between the TRS values obtained during the day (cane being delivered directly onto the wash table) and during the night (cane taken from the yard). The difference in predicted recoverable sugar per ton of cane was at least five kg. Similar results, but with varying differences between day and night, were observed for all tests during 1989. However, the tests performed during the 1990 season did not show this characteristic feature and Figure 2(B) is more typical of the results obtained.

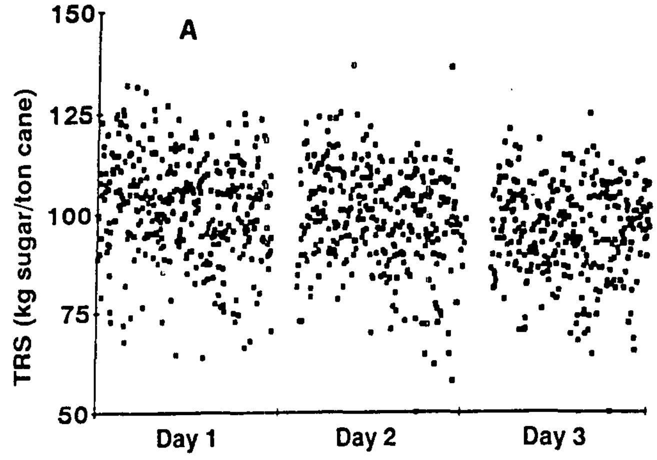

FIGURE 2(A) TRS values of incoming cane sampled during the 72 hours of the test at Raceland Factory. All data plotted in order of receipt of samples, with days separated.

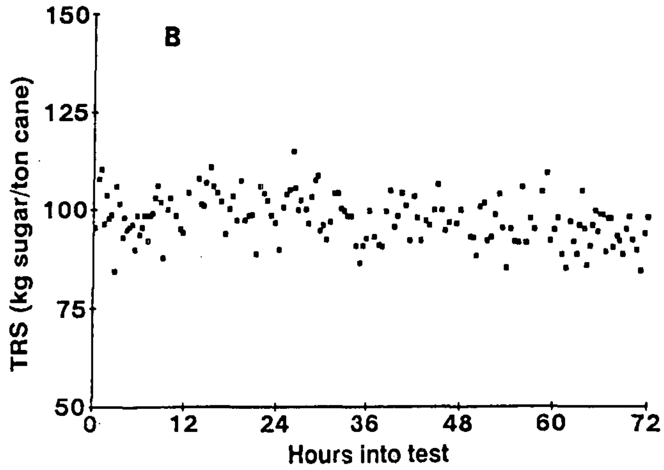

FIGURE 2(B) TRS values of prepared cane during the same test.

In some cases there was a higher average TRS for prepared cane during the day and in others no difference, or even a small increase during the night. In 1989 the difference was initially attributed to cane deterioration, but conditions were similar in 1990 and there was no difference. It is possible that the difference was due to sampling and/or analysis procedure changes made for the 1990 crop. The changes involved both the sample preparation and the reagent used for polarisation measurements.

In 1989 samples of prepared cane were run through the pre-breaker of the core sampler whenever possible. This was not possible at night. To check the effect of the additional preparation on the TRS values obtained, some samples were divided and pressed, with and without the use of additional preparation. The results of these tests are shown in Figure 3. The average increase in TRS was about 3 kg/ton for the cane with increased preparation.

Another factor is the use of the ABC clarification reagent. Although use of this reagent usually results in a slightly lower value for the polariscope reading (by 0,2-0,4) than with dry lead subacetate, the reagent quantity does not greatly affect the reading. However, increasing the quantity of lead subacetate results in a marked increase in the reading. In 1989 factory laboratory staff performed the daytime analyses and ASI staff the nighttime analyses. Some mill personnel tended to be quite liberal with the use of lead subacetate whereas

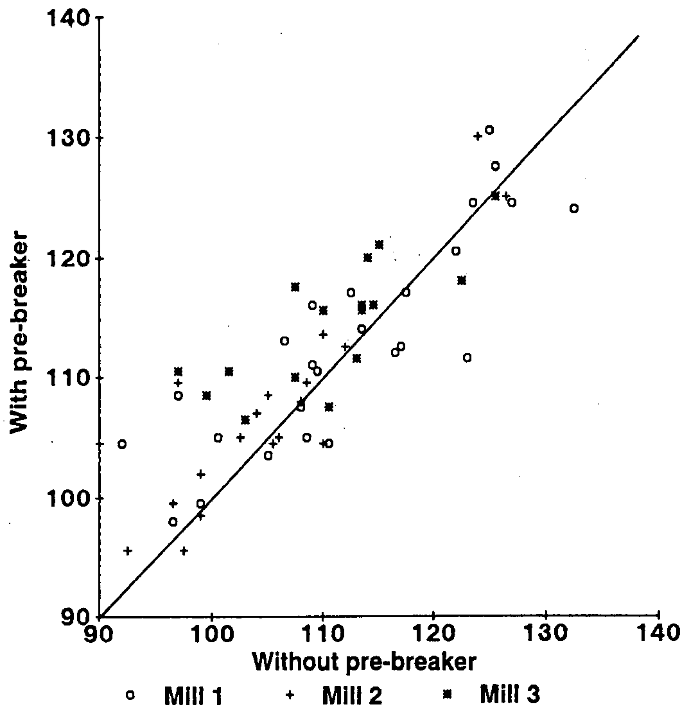

FIGURE 3 TRS values for prepared cane samples with and without additional preparation. Note results from Mills 1 and 2 fit better than Mill 3, where preparation was relatively poor.

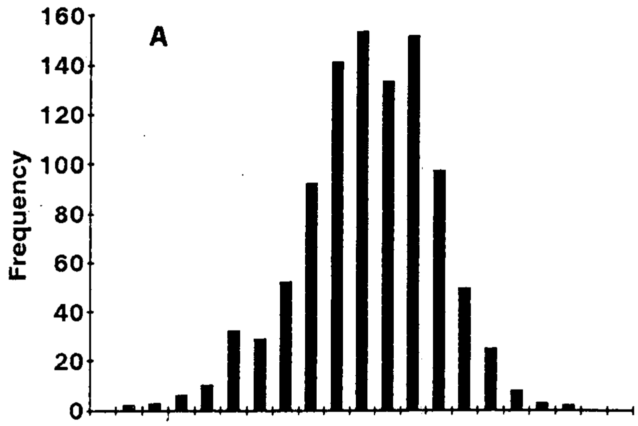

FIGURE 4(A) Distribution of TRS values for incoming cane for a 72 hour period at Raceland Factory.

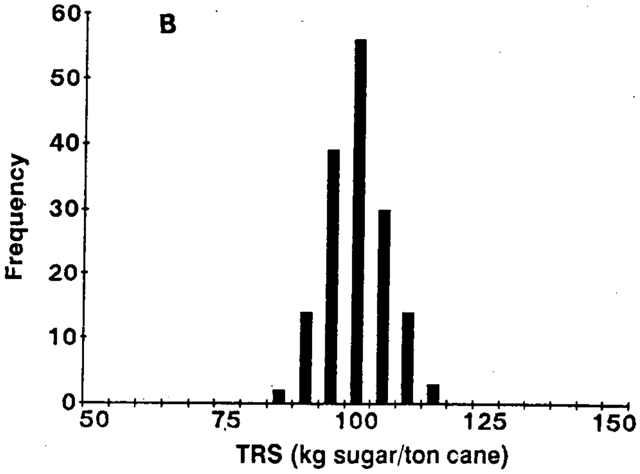

FIGURE 4(B) Distributions of TRS values for prepared cane during the same test.

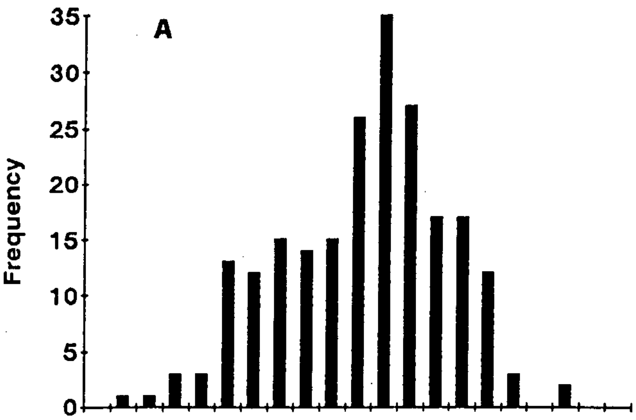

FIGURE 5(A) Distribution of TRS values for incoming cane for a 24 hour period at Enterprise Factory.

the ASI technicians consistently used less. In tests on the new reagent system it was found that excessive use of lead subacetate could increase the polariscope reading by up to two points. Calculation of the consequential increase in TRS shows it to be up to 4 kg/ton. Combining these two factors negates the large day to night difference in cane quality found in 1989.

A more important difference was between delivered (incoming) cane and the prepared cane. Data for both are plotted in Figure 2. Figure 2(A) shows the spread of TRS values for incoming cane to be much larger than for prepared cane. The distribution of TRS values for these data are shown in Figure 4.

In this case, both the incoming and prepared cane show close to normal distribution. However, wide variations, especially at one mill, can be seen in Figure 5.

Laboratory practices play a part in the difference and are a matter for further investigation. Mean and standard deviations for TRS values (incoming and prepared cane) for all tests performed in 1990 are given in Table 1.

Table 1

Mean and standard deviations for TRS (kg sugar/ton cane) for incoming and prepared cane – 1990

Run number	Date	Mill	Duration of test	Incoming cane TRS			Prepared cane TRS		
				Mean	Std. dev.	Number	Mean	Std. dev.	Number
1	31/10/90	Raceland	24 hours	99	14	275	94	6	59
2	07/11/90	Raceland	24 hours	97	12	277	93	5	64
3	14/11/90	Enterprise	24 hours	98	16	216	101	68	
4	20/11/90	Enterprise	20 hours	104	15	359	117	15	54
5	29/11/90	Enterprise	38 hours	83	17	369	96	10	110
6	06/12/90	St. Mary	38 hours	105	14	305	104	9	94
7	12/12/90	St. Mary	24 hours	111	11	134	102	8	73
8	18/12/90	Raceland	72 hours	99	12	986	97	6	173

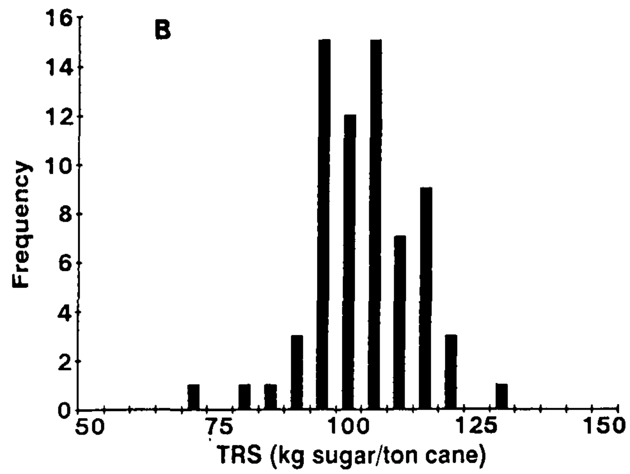

FIGURE 5(B) Distribution of TRS values for prepared cane during the same test.

Inspection of these data indicate no difference between the quality of incoming and prepared cane as determined by the TRS value. This is confirmed by application of standard statistical tests. The higher TRS values for prepared cane and high deviations at the second mill are almost certainly influenced by laboratory procedures.

One of the problems with this approach is that TRS is a derived value that can be influenced by fairly small variations in the input data. For example, if cane of composition P=12,0, B=14,1 and F=15,0, in which the true fibre is 12,5% with 2,5% field soil on cane, is washed without loss of juice solids to give composition P=12,0, B=14,1 and F=12,5, with water making up the difference, the TRS increases from 100,4 to 102,6 kg/ton.

It may be more reasonable to consider actual values obtained for pol, brix and fibre % cane and, for the tests at Raceland (where the most complete data were obtained) the composition of incoming and prepared cane and the factory report (Table 2).

It is possible to estimate factors involved in the change in cane composition due to cane yard operations and cane washing. These include:

- Loss of sucrose by inversion - ignored in this case since purity changes are small
- Loss of juice solids by leaching
- Removal of field soil - measured in the system as 'fibre'
- Retention of water by the cane.

Since there are only two data points (brix % cane and fibre % cane) for the samples, it is not possible to obtain a specific value for each factor. However, if the quantity of retained water is assumed, the effect of the other factors can be calculated as shown in the Appendix. Results are shown in Figure 6.

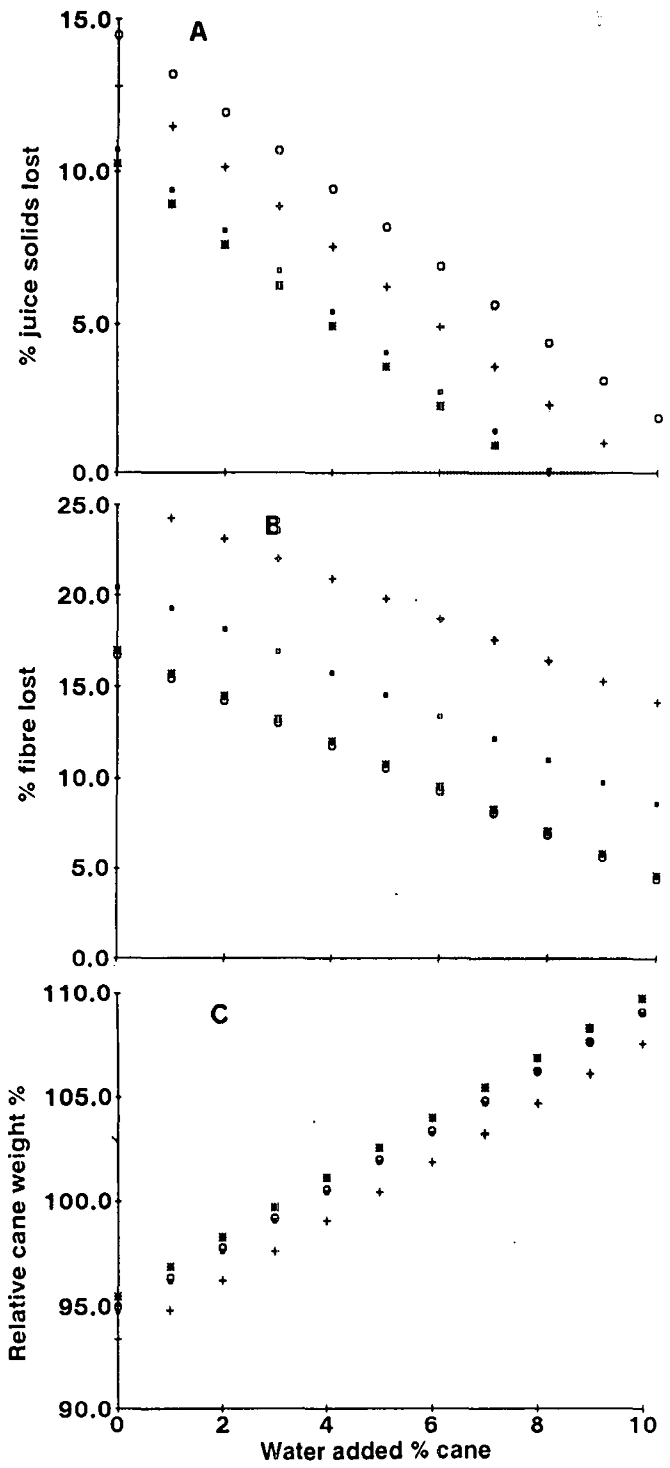

FIGURE 6 Calculations for three 1990 and one 1989 tests at Raceland Factory. For an assumed quantity of water added to achieve the desired change in cane composition, loss of juice solids (A), loss of 'fibre' (B) and gain in cane weight (C) are calculated. Shaded area is the most reasonable set of conditions.

Table 2

Cane composition - Raceland Factory - 1990

	Incoming cane				Prepared cane				Factory report			
Run number	Pol % cane	Brix % cane	Fibre % cane	Juice purity	Pol % cane	Brix % cane	Fibre % cane	Juice purity	Pol % cane	Brix % cane	Fibre % cane	Juice purity
1	12,3	15,5	17,4	79,4	11,6	14,6	14,6	79,3	11,5	14,3	12,2	80,0
2	12,1	15,1	18,4	80,1	11,4	14,1	14,7	80,4	11,0	13,7	13,5	80,1
8	12,5	15,0	17,7	83,3	11,8	14,1	15,4	83,5	11,4	13,6	15,4	84,1

Given data on the direct measurement of sucrose lost in the wash system (see the next section), the most reasonable values are 2-4% loss of juice solids, 10-15% loss of 'fibre' and an increase in cane mass of 3-5%. These results are in agreement with previously determined values, e.g. loss of field soil.

It should be noted from Table 2 that the pol % cane reported by the factory is considerably less than that determined by direct analysis. Furthermore, delivered cane weight is used as milled cane weight, ignoring the increase in cane due to water. For the data on prepared cane composition reported here, the decrease in pol % cane is somewhat offset by the increase in cane weight.

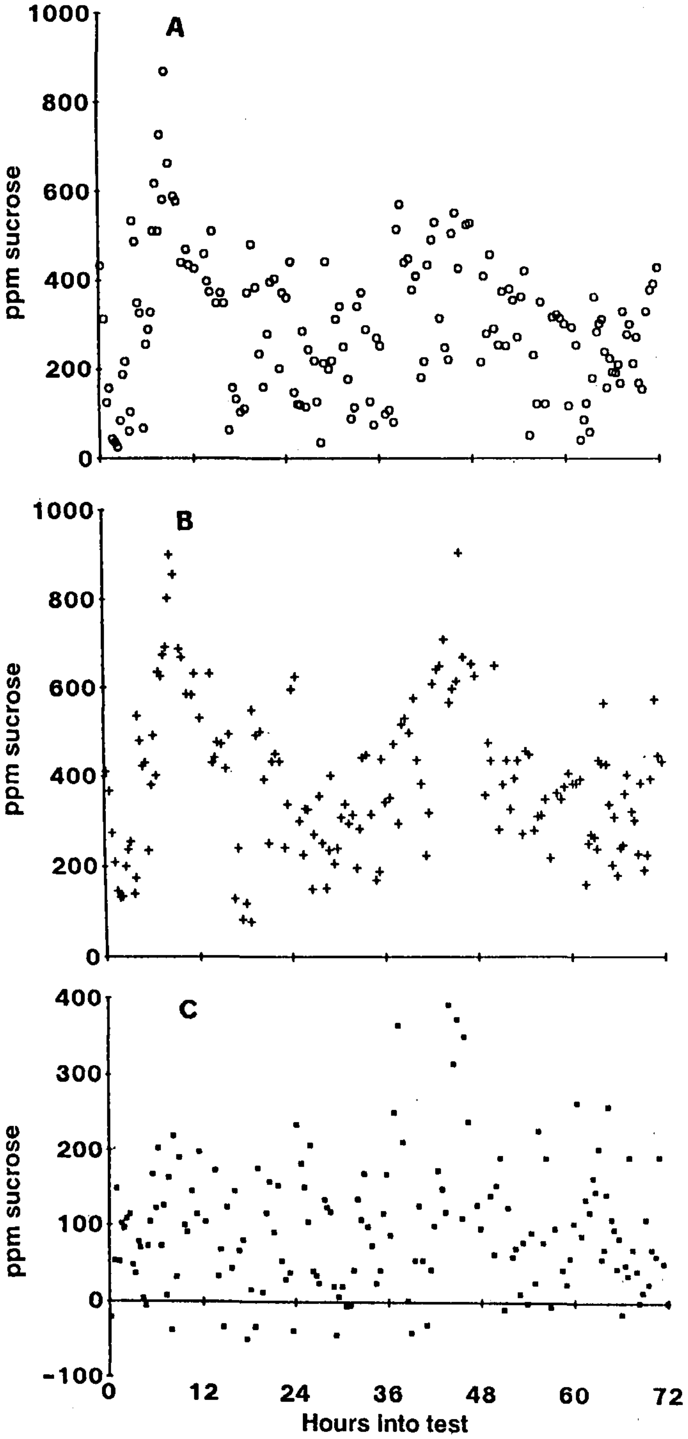

FIGURE 7 Variation with time of sucrose levels in make-up water going to wash table (A), water leaving system (B) and net sucrose concentration increase (C).

Sugar losses in wash water

Only one extended determination of sugar levels in cane wash water was made in 1990, but the results were similar to those obtained the previous year. Sucrose content of the wash water over a 72 hour period is shown in Figure 7.

No periodicity is shown in the data, especially for the net change in sucrose concentration (Figure 7(C)). Net water flow through the system is 35 m^3/minute and, with an average sucrose concentration increase of 94 ppm, this amounts to about 3 kg of sucrose per minute. At a grinding rate of 5 ton cane/minute this gives 0,6 kg sucrose lost per ton cane. Similar and higher values (up to 2,5 kg/ton) were obtained the previous year.

The disturbing conclusion from these data is that the sucrose level in wash table make-up water is very high, averaging 304 ppm. Condenser water is used as the make-up and flow at a total rate of 80 m^3/minute, with only a portion being sent to the wash table. This is a more serious loss of sucrose than the wash table but is easily remedied.

Figure 8 shows the level of invert in and out of the wash table. In this instance there is a definite increase when cane is being taken from the yard. Damage to cane and storage time are the causes, and the average level of invert lost is similar to that of sucrose at about 100 ppm. Figure 8(B) confirms that the source of invert is the wash table. For this case, from the wash table alone, the load on the environment is at least one kg of BOD per ton of cane ground. If condenser water was taken into account, the total load would be much higher. These data are in line with other published data from a wide variety of sources.

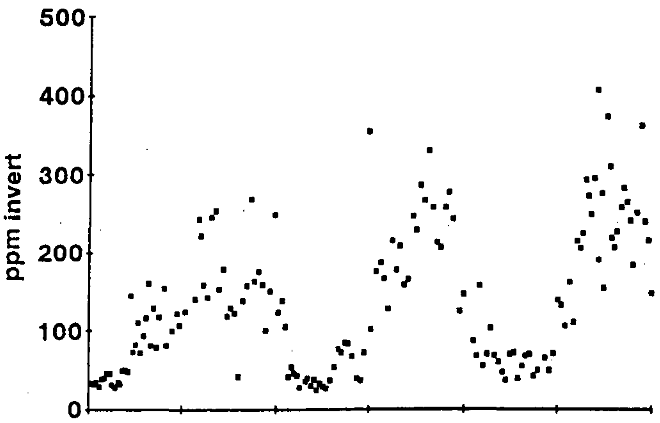

FIGURE 8(A) Net concentrations of invert in water leaving wash system over time of test.

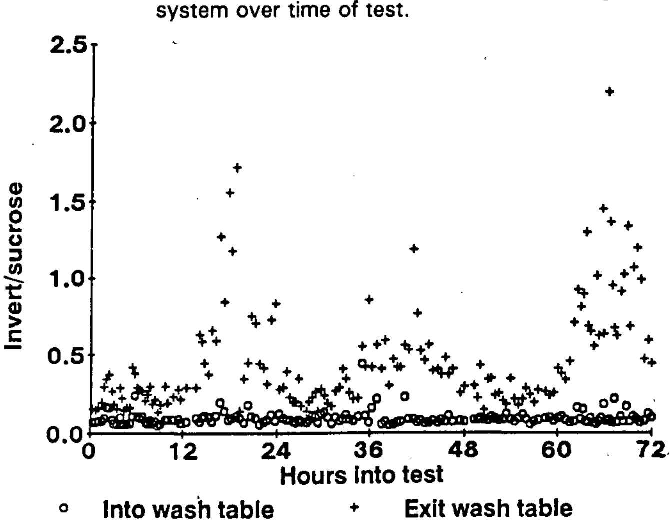

FIGURE 8(B) Invert/sucrose ratios for samples entering and leaving wash system.

An example of sucrose lost during cane washing, measured in 1989, is:

To the wash table:
19 m^3/min fresh water
34 m^3/min from pond with 420 ppm sucrose
= 14,3 kg sucrose/min

From the wash table:
53 m^3/min with 460 ppm sucrose
= 24,4 kg sucrose/min

Difference of 10,1 kg sucrose/min; at 3,5 ton cane per min (5 000 ton/day).

Loss per ton cane = 2,9 kg.

Conclusions

The utility of the press system for comparison of the composition of prepared cane with that of both delivered and factory reported cane is demonstrated. The use of derived cane quality parameters for estimating sugar loss is of doubtful validity. Considerable care must be exercised in setting up experimental procedures.

From cane composition data and directly determined losses at the wash table, sucrose lost in handling and washing is in the range of 1-2% of the sucrose in the incoming cane, and sometimes more. HPLC or ion chromatography are ideal systems for determining the magnitude of these losses.

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