

DETERMINATION OF SUCROSE LOSS IN STORAGE OF CLEAN UNBURNT BILLET CANE

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ABSTRACT

A series of tests were carried out to measure sucrose loss in storage of hand-cleaned green (unburnt) cane billets, and its weight loss. Five tests were also organized in a sugar factory, where in addition to the twenty-four hour storage in the cane yard, some damage or loss of cane may be expected from handling the cane with front-end loaders. Because of very slow heat transfer rates, temperature could not be kept constant within stacked billet cane throughout an experiment. Therefore, the conditions in each tests were characterized by the time (hours) within four temperature ranges, < 17 °C, 17-22 °C, 22-27 °C and > 27 °C, representing cold, cool, moderate and warm conditions. The mass loss of sucrose was found reasonably well represented with a linear model. The predicted relative sucrose loss in tons of sucrose for each 100 tons of initial sucrose per hour, in the four temperature ranges was 0.01, 0.01, 0.03 and 0.32, respectively. Invert in cane generally increased during storage and the juice pH and purity dropped. The changes were bigger at higher temperature storage conditions. A model analogous to that for sucrose loss was applied to cane weight loss. The predicted relative weight loss (tons of cane per 100 tons initial per hour) in the two high temperature ranges were 0.08 and 0.22, respectively. The five factory cane yard tests gave results that broadly agreed with the conclusions from the pilot storage tests done at ASI. However, deviations were found that may relate to inherent errors in the core-press Pol-based total recoverable sugar (TRS) analysis used in the factory tests, or other unknown factors. TRS (lb/t cane) increased in three out of the five tests, presumably because of moisture loss from cane during storage, but total sugar during storage dropped in each test. The financial impact of the sucrose loss predicted for storage of cane at high temperatures (3.2% in 10 hours) is very high, and considerations should be given to improving through their design the natural or forced ventilation of cane wagons and piles, to monitoring delivered cane temperature, and to better scheduling of harvest and storage of cane.

INTRODUCTION

It is generally agreed that storage of cane particularly if harvested with combines as short billets is best avoided or kept to minimum; and much improvement has been achieved in Louisiana in delivering fresh cane to the mills. Few mills now avoid cane storage on the ground by holding cane overnight in wagons or trailers. Those that still do store cane on the ground use front-end loaders to first build the piles and then load the cane onto the cane carrier. The very high cost to operate the heavy equipment and some unavoidable physical damage to cane provide additional incentives to convert to cane storage in wagons. However, reliable estimate whether

such an investment will be cost-effective requires quantitative data on sucrose loss during storage.

Several studies to that effect have been undertaken in Louisiana in the past but the quantitative data about the actual sucrose loss is still sparse. Clarke (1991) carried out factory tests at three mills processing at that time whole-stalk cane. The TRS (total recoverable sugar) data – a Pol-based analysis generated by the factory core lab – was inconclusive, in part presumably because cane was being washed during the test. The analysis also did not include any cane weight changes that may have occurred in storage. Pol analysis is well known to be affected by changes in invert and dextran and it cannot therefore provide an accurate measure of sucrose loss. More recent studies by Godshall (1999), Legendre et al. (2000) and Eggleston et al. (2000, 2001, 2004) focused mostly on dextran and other indicators of cane deterioration, rather than sucrose loss, or relied on the TRS Pol-based data. The focus on the indicators is understandable because of their much larger relative changes during storage, but they are of limited value unless reliable correlations can be established between the indicator level and the actual sucrose loss. It is clear that an accurate sucrose balance requires very accurate information on the cane weight changes in storage and very precise true sucrose analysis of the cane before and after the storage.

In these tests the focus was on determining directly the affect of time and temperature on sucrose loss. It is well known that the length of the billets also affects the rate of cane deterioration, as does any physical damage to the billets from handling, insects or disease, cane variety, etc. Furthermore, it is likely that trash in cane accelerates sucrose loss; from higher microbial count in trash and the higher enzyme (invertases) activity in cane tops than in clean billets (Lingle 2004; and Lingle, SRRC, USDA-ARS, New Orleans, pers. commun.). Therefore, the results of this work refer to the hand-cleaned, trash-free billet cane, of an average condition as harvested during the 2007 season at the Sugar Research Station. None of the cane in the experimental plots at the Sugar Research Station was treated with chemical ripeners.

MATERIALS AND METHODS

The program that was carried out during and shortly after the 2007 Louisiana harvest consisted of three independent parts designed to determine precise sucrose loss in well controlled storage tests at ASI, cane weight loss in separate tests with larger cane quantities at ASI, and TRS loss in twenty-four hour storage tests at a Louisiana sugar mill.

Twenty-four hour storage tests at ASI

After three initial exploratory tests, the experimental protocol was as follows. About 200 kg of billeted cane were loaded on a pick-up truck at the Sugar Research Station directly from the discharge belt of a CH-2500 cane combine (John Deere, Thibodaux, LA) and transported immediately to ASI. There, the billets were randomly separated by hand into three equal batches, each weighing 30 – 45 kg, within 30 minutes after being brought from the field. In the process, all loose dirt, leaves and tops were removed so that the cane storage involved only clean de-trashed billets. The batches were held in heavy duty 120 L plastic cans covered with lid to prevent physical loss, but placed on the can loosely enough to allow some air circulation. The

measured moisture loss in storage was therefore less than would be expected in open containers or cane piles.

Batch A was used to determine the initial cane composition. The cane was crushed by five passes through a three-roll sample mill with no water added. The crushing was finished within 2 hours after the cane was harvested. In each test, the billet cane, the extracted juice and the residual bagasse were accurately weighed with a PM30-K digital scale (Mettler-Toledo, Columbus, OH) with a 1 g resolution. The pH, Brix and sugar composition of the juice were determined. An HPLC (Waters Corp., Milford, MA) with an Aminex® HPX-87K column (Bio-Rad Laboratories, Hercules, CA) and a Waters 410 RI detector were used for the sugar determination. Fifty grams of bagasse were disintegrated with 400.0 g of ice water in a four-liter Waring® blender (Waring Laboratory, Torrington, CT) for six minutes at 18,000 rpm, and the extract analyzed with the HPLC as before. The fiber was transferred quantitatively from the disintegrator bowl into pre-dried and pre-weighed cotton bags. The bags were tightly closed with a plastic tie and the solubles removed by washing in four consecutive cycles in a standard household washer. The closed bags with the retained fibers were first pre-dried by one cycle in a clothes dryer and then dried to constant weight at 105 °C under vacuum. The procedure is similar to the one used among others at the Tucuman sugarcane experiment station (S. Zossi, Estacion Experimental Agroindustrial Obispo Colombres, Tucuman, Argentina, pers. commun.) who provided the bags for the tests.

The batches B and C were stored overnight for about twenty four hours; batch B in a covered outside area at ambient temperature, while the container holding batch C was in most experiments immersed in a constant temperature water tank to simulate warm-weather storage. The air temperature and the cane temperature inside each of the storage cans were recorded over the storage period with battery operated HOBO® U12 recorders (Onset Computer Corp., Pocasset, MA) placed directly in the middle of the can holding the billets. After storage, batches B and C were processed following the same protocol as with batch A. Obviously the cane temperature during the overnight ambient temperature tests varied, but even in the constant water bath tests the cane temperature required a long time to adjust (Figure 1). In order to characterize the temperature conditions during storage, the time that the cane was within four temperature intervals was read from the recorded temperature traces such as the one Figure 1:

Interval 1: below 17 °C

Interval 2: between 17 °C to 22 °C

Interval 3: between 22°C to 27°C

Interval 4: above 27 °C

Other temperature intervals and models are of course possible, and some were tested as well, including those based simply on an average temperature or minimum and maximum temperatures during storage, but none was found superior to the “17-22-27” model. A total of 15 tests were completed; the three initial tests were excluded from the correlations because of incomplete data or other inconsistencies.

Determination of cane weight loss

Mass sugar losses in storage are sometimes inferred from changes in pol in cane or TRS, but the weight loss data is needed to correct this kind of information to obtain the true sucrose mass change. In order to provide this data, six tests were carried out with 450 kg batches of billet cane each. A “cane box” was designed and constructed for these tests with angle iron frame and sides of expanded $\frac{3}{4}$ ” metal allowing free passage of air. The box was filled with fresh green billet cane at Lula factory (Belle Rose, LA), brought immediately to ASI and put and kept for up to four days on a precision digital scale (Sartorius, Corp., Edgewood, NY, model CAPP40-5000RN-LU) with a 0.5 kg resolution. The scale and the storage box were located in an outside roofed and shaded area. The temperature during storage was again recorded with the U12 recorders, and the weight loss data correlated as for the sucrose loss. Unlike in the cane deterioration tests, the measured temperature was one of the air in close vicinity of the storage box.

Factory cane yard storage tests

A total of five tests were done at St. Mary Sugar Cooperative mill (Jeanerette, LA) by SMSC personnel. Each tests involved ten double-wagons holding about 240 tons of billet cane in total. The weight and TRS of each of the ten double wagons were determined by the factory core lab following the standard core sampling and core lab procedures. At about 4 pm on the day of the test, the billets were stacked in the yard in a pile as usual but separated from other cane. Temperature and relative humidity recorders were installed; one outside and two within the cane while the pile was being built. After 24 hours of storage, at about 4 pm the next day the cane was re-loaded into the wagons with a front end loader following the usual procedures at SMSC. The wagons were then weighed and core-sampled again. The recorded cane temperature profile (inside the pile) was evaluated again with respect to the total time (hours) at temperature below 17 °C, between 17 and 22 °C, between 22 and 27 °C and above 27 °C.

RESULTS AND DISCUSSION

Twenty-four hour cane storage tests at ASI

All raw data from tests 4 to 15 are given in the Appendix A, and the examples of the calculations of the mass sucrose loss in the Appendix B. The sucrose loss (Table 1) during storage ranged from +2.3 (gain) to -8.9 % (loss). The loss was obviously higher in the higher temperature storage experiments. Because the experiments accurately accounted for water loss in storage and crushing, the sucrose and invert sugar changes in Table 1 represent the mass of sugars lost or gained. In none of the tests was the storage temperature constant throughout the test; it obviously varied in the batches held at ambient conditions, as the air temperature dropped at night, but it varied even in the controlled temperature water bath experiments. Because of slow heat transfer within the billet cane, it took up to twelve hours for the interior of the cane batch to reach the final temperature (Figure 1). Based on the recorded temperature inside the cane storage container, the effective conditions were characterized (Table 1) with the 17-22-27 model. An example of the actual temperature record from the experiment 15/C is given in Figure 1. After the initial drop when the recorder quickly cooled to the temperature of the cold billets (approximately 6 °C), cane warmed up but it took more than 12 hours before it reached the final 30 °C temperature.

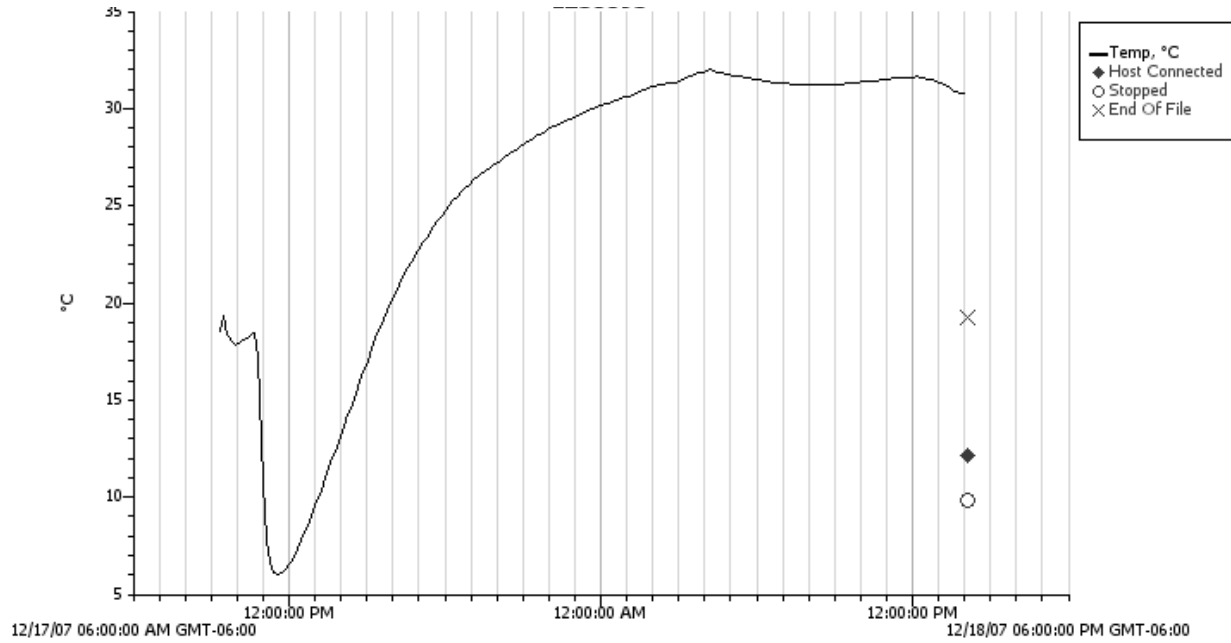
Table 1. Summary of tests 4-15. For each test, the upper line corresponds to the storage at ambient conditions (batch B) and the lower line (batch C) corresponds to the storage done mostly in the heated water bath. Values of sucrose change (% initial) in the last column were calculated from the eq. 1 with the parameters listed in Table 2

| Test | Sucrose change (ΔS) % initial | Invert change % initial | Juice pH change | Juice purity change | Time (hr) at temperature °C | | | | Sucrose change calculated |
|--------|---|-------------------------|-----------------|---------------------|-----------------------------|----------------------------|----------------------------|------------------------|---------------------------|
| | | | | | < 17 (T ₁₇) | 17-22 (T ₁₇₂₂) | 22-27 (T ₂₂₂₇) | >27 (T ₂₇) | |
| 15 / B | -0.8 | 10.8 | -0.04 | -0.1 | 23.5 | 1.5 | 0 | 0 | -0.5 |
| / C | -5.9 | 25.5 | -0.31 | -1.8 | 4 | 1.5 | 3.5 | 18 | -5.9 |
| 14 / B | -0.7 | 18.0 | -0.12 | -1 | 0 | 1 | 22.5 | 0 | -0.2 |
| / C | -5.1 | 56.9 | -0.33 | -2.5 | 0 | 0 | 2 | 22 | -7.0 |
| 13 / B | -3.1 | 5.6 | -0.25 | -1.2 | 0 | 13 | 11 | 0 | -0.2 |
| / C | -7.0 | 34.8 | -0.41 | -2.8 | 0 | 0 | 2 | 22.5 | -7.2 |
| 12 / B | 0.1 | 2.4 | 0.02 | 0.5 | 23 | 0 | 0 | 0 | -0.5 |
| / C | -3.8 | 33.9 | -0.23 | -1.7 | 4 | 1 | 4 | 15.5 | -5.1 |
| 11 / B | -0.3 | -3.8 | -0.05 | 0.1 | 25 | 0 | 0 | 0 | -0.6 |
| / C | -3.4 | 28.5 | -0.37 | -2.3 | 1.5 | 2.5 | 5 | 14.5 | -4.7 |
| 10 / B | 1.3 | 23.8 | -0.11 | 1.5 | 23 | 0 | 0 | 0 | -0.5 |
| / C | -2.5 | 31.1 | -0.21 | -0.2 | 22.5 | 0 | 0 | 0 | -0.5 |
| 9 / B | -1.0 | 21.9 | -0.13 | -1.4 | 0 | 16 | 11.5 | 0 | -0.2 |
| / C | 1.9 | 34.8 | -0.29 | -2.5 | 0 | 5 | 25 | 0 | -0.2 |
| 8 / B | -2.3 | 11.4 | -0.13 | -1.0 | 3 | 7 | 14 | 2 | -0.8 |
| / C | -0.8 | 3.0 | -0.05 | -1.0 | 0 | 0 | 25 | 0 | -0.2 |
| 7 / B | 1.6 | -7.6 | -0.01 | 0.2 | 0 | 23 | 2 | 0 | -0.2 |
| / C | -3.8 | 8.7 | -0.16 | -2.6 | 0 | 4 | 4 | 17.5 | -5.6 |
| 6 / B | 2.3 | 4.8 | -0.08 | -0.2 | 16.5 | 8 | 0 | 0 | -0.4 |
| / C | -6.2 | 15.7 | -0.42 | -3.5 | 0 | 5 | 4 | 16 | -5.2 |
| 5 / B | -1.7 | 6.3 | 0.00 | 0.3 | 2 | 13.5 | 8.5 | 0 | -0.2 |
| / C | -8.5 | 18.8 | -0.07 | -3.1 | 0 | 4.5 | 3.5 | 18.5 | -5.9 |
| 4 / B | 0.3 | -5.4 | 0.00 | 0.2 | 13.5 | 10.5 | 0 | 0 | -0.4 |
| / C | -8.9 | 9.6 | -0.19 | -3.4 | 4.5 | 2.5 | 4.5 | 12.5 | -4.1 |

The data summarized in Table 1 was fitted with a linear correlation

$$\Delta S = a_1 * T_1 + a_2 * T_2 + a_3 * T_3 + a_4 * T_4 \quad \text{Eq.1}$$

between ΔS , the change in sucrose mass in storage in kg of sucrose lost or gained per 100 kg of initial sucrose, and the storage times T in the four intervals. The fitting parameters a_1 , a_2 , a_3 and a_4 thus correspond to per cent mass sucrose loss per hour in the temperature range x and the T_s are again the times in hours within the four temperature ranges. The NLIN regression procedure (SAS Institute Inc. Cary, NC) was used to obtain the parameters, their standard errors of estimates and confidence limits (Table 2). The relative errors of the parameters are large,



Error! Reference source not found.Figure 1. The measured temperature profile in experiment 15/C, and the approximate times in hours within the four temperature intervals.

particularly at low temperatures and reflect the random errors of testing, of which the most serious is probably the assumption of identical composition of the three batches prior to the storage, and perhaps other factors such as the cane variety or cane conditions that were not included in the simple model.

The four parameters obtained from the correlation of the experimental data (Table 2) can be used to calculate the expected true sucrose mass loss in storage of billet cane if the temperature and time in storage are known or can be estimated. For instance, over ten hours of storage above 27 °C (81 °F) the model predicts a loss of 3.2 % of the initial sucrose; in a ten hour storage of five hours between 22 °C to 27 °C and five hours above 27 °C, the sucrose loss is predicted to be 1.7 %, etc.

Table 2. The value of the parameters and their confidence limits of the sucrose loss model, equation 1

| Parameter | Estimate | Approx. std error | Approximate 95% confidence limits | |
|----------------|----------|-------------------|-----------------------------------|---------|
| a ₁ | -0.0079 | 0.0348 | -0.0804 | 0.0647 |
| a ₂ | -0.0107 | 0.0577 | -0.1312 | 0.1097 |
| a ₃ | -0.0305 | 0.0448 | -0.1240 | 0.0630 |
| a ₄ | -0.3181 | 0.0378 | -0.3970 | -0.2392 |

There are reasons to expect that the sucrose loss might be non-linear with respect to time if the microbial action predominates. Therefore, other models than equation 1 were tested, i.e. a quadratic model

$$\Delta S = a_1 * T_1^2 + a_2 * T_2^2 + a_3 * T_3^2 + a_4 * T_4^2 \quad \text{Eq.2}$$

and a mixed one,

$$\Delta S = a_1 * T_1 + a_2 * T_2 + a_3 * T_3 + a_4 * T_4^2 \quad \text{Eq.3}$$

but the correlations between the calculated and measured sucrose were found inferior, with R^2 of 0.586 and 0.592, respectively, compared with R^2 0.681 for the linear model.

Increasing dextran during cane storage has been well documented in cane literature as an evidence of microbial action leading to sucrose loss. The glucose/fructose ratio in the extracted juice in our tests decreased slightly during storage (Table A5), from an average of 1.01 in fresh cane (batch A), to 0.90 on average in batch B and 0.85 in batch C, as would be expected from dextranase activity. However, other microorganisms using as substrate sucrose and invert, as well as sugarcane invertases and other cane enzymes must play a more prevalent role in cane deterioration.

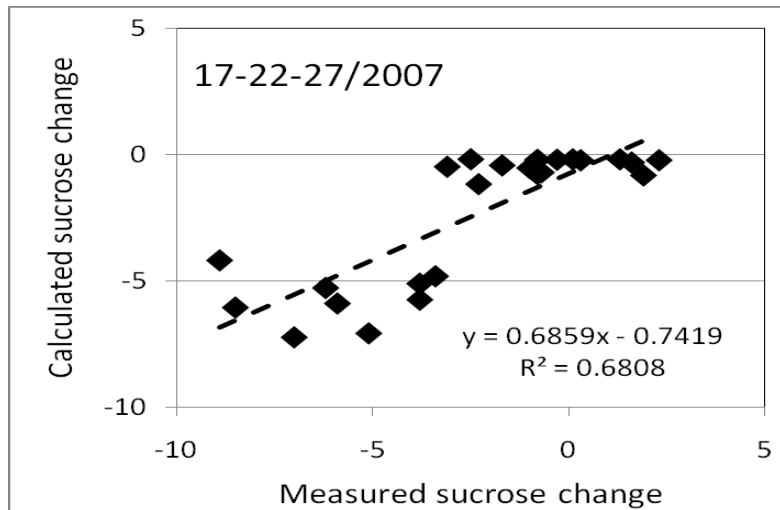


Figure 2. The measured and calculated sucrose loss from equation 1, in per cent of initial sucrose.

Each of the other three juice quality parameters listed in Table 1, viz. invert, pH and purity changes in storage does also correlate to some degree with the times T and equations similar to the equation 1 can be derived for them. By the same token, correlations also exist between the sucrose loss ΔS and any of these three parameters, confirming that the juice pH and juice purity drop are practical if limited indicators of cane deterioration as has been suggested before (Eggleston et al. 2001; Eggleston et al. 2004). However, the focus of this work was the sucrose loss in storage; therefore these and other indicators of cane deterioration are not discussed in

detail in this paper. In short, however, invert almost always increased in storage, and pH and purity of juice dropped. The changes were clearly larger at higher temperatures.

Cane weight loss determination

The raw data collected in the six tests are summarized in Figure 3. As in the cane deterioration tests, the temperature was again characterized by the time within each of the four intervals (Table 3) the same way as in the sucrose loss tests, with the exception that the recorded temperature was in this case of the air adjacent to the storage bin, rather than the interior cane temperature.

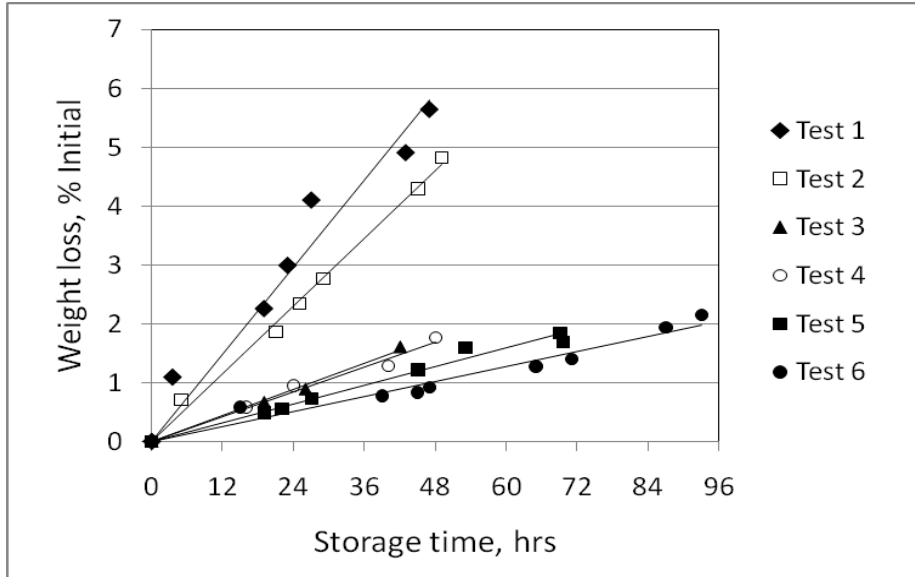


Figure 3. The measured cane weight loss during storage. The temperature profiles in each test are given in Table 3.

The relative weight loss per hour (Table 3) in each test was set equal to the slope of the data trend lines in Figure 3, and an equation

$$\Delta W = b_1 * T_1 + b_2 * T_2 + b_3 * T_3 + b_4 * T_4 \quad \text{Eq. 4}$$

analogous to the one describing the sucrose loss was used to correlate the data. ΔW is now the total relative weight loss (per cent of the initial weight) during storage, and the parameters b are the relative weight loss per hour in the four temperature ranges. The values of the parameters, their errors and confidence limits were determined as before with the SAS NLIN procedure (Table 4).

Table 3. Temperature profile during the six weight loss tests and the measured cane weight loss

| Test | Time (hours) at temperature °C | | | | Total time (hr) | Weight loss % initial/hr | Total weight loss (ΔW) % initial |
|------|--------------------------------|--------------|--------------|-----------|-----------------|--------------------------|--|
| | < 17 (T1) | 17 – 22 (T2) | 22 – 27 (T3) | > 27 (T4) | | | |
| 1 | 0 | 11 | 14 | 22 | 47 | 0.123 | 5.78 |
| 2 | 4 | 7 | 28 | 10 | 49 | 0.096 | 4.70 |
| 3 | 3 | 22 | 15 | 2 | 42 | 0.037 | 1.55 |
| 4 | 0 | 24 | 19 | 5 | 48 | 0.035 | 1.68 |
| 5 | 54 | 14 | 2 | 0 | 70 | 0.026 | 1.82 |
| 6 | 47 | 38 | 8 | 0 | 93 | 0.021 | 1.95 |

Table 4. The value of the parameters and their confidence limits of the cane weight loss model, equation 4

| Parameter | Estimate | Approx. std. error | Approximate 95% confidence limits | |
|-----------|----------|--------------------|-----------------------------------|--------|
| b_1 | 0.0404 | 0.0097 | -0.0012 | 0.0819 |
| b_2 | -0.0221 | 0.0173 | -0.0967 | 0.0525 |
| b_3 | 0.0840 | 0.0220 | -0.0106 | 0.1786 |
| b_4 | 0.2194 | 0.0266 | 0.1049 | 0.3339 |

The correlation between the measured and calculated values in Figure 4 is quite good. Obviously, it is much better than that found for sucrose loss because no sampling and its errors are involved in determining the cane weight. Below 22 °C, the weight loss coefficients are statistically nil, and about 0.08 and 0.22 per cent per hour for the 22-27 °C and > 27 °C temperature intervals, respectively.

It is probable that most of the weight loss is from moisture loss through evaporation. However, other volatiles e.g. ethanol, carbon dioxide, etc. from either cane deterioration or cane metabolism contribute to the overall measured weight loss. It is of interest to note that the linear behavior in Figure 3 holds well up to four days of storage, indicating that the rate of transport of water through the cane tissue is not be the limiting factor for water evaporation from cane during green billet storage. In principle, the relative humidity of the air should affect the water loss, but the very good correlation found here indicates that its role or its variations were not significant in these tests.

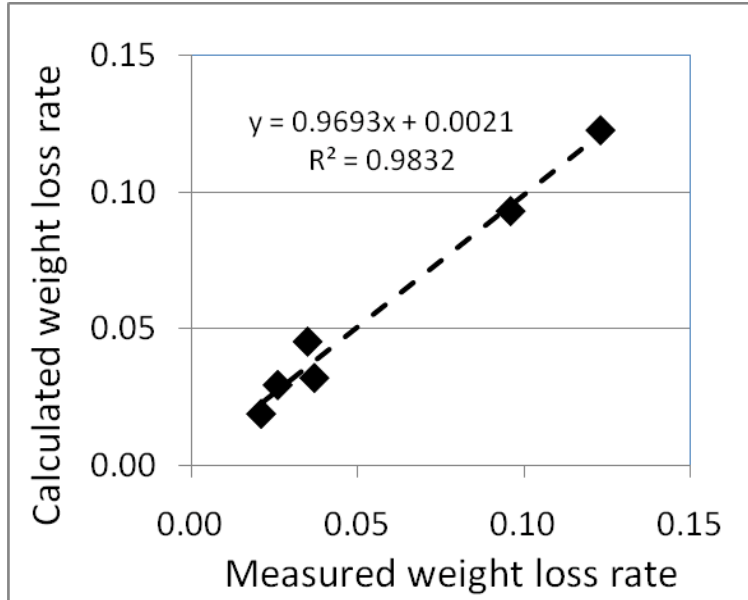


Figure 4. The measured and calculated cane weight loss rate from eq. 4, in percent initial weight per hour.

The factory cane yard storage tests

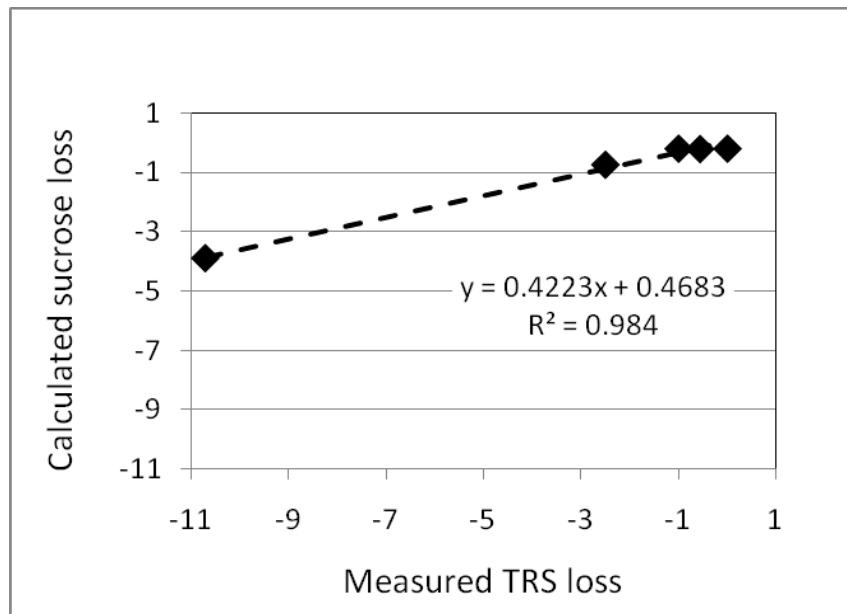
The weather was mostly cool during the factory tests with the exception of test 4 (Tables 5 and 6). Therefore, the TRS loss was only moderate in four out of five tests. The correlation against the expected sucrose loss calculated from equation 1 is fairly good (Figure 5), however the calculated loss is less than half of the measured TRS loss. This may be in part because equation 1 was derived from experiments with hand-cleaned cane; in part perhaps because of the affects of changing invert concentration in storage (invert increases) and juice purity (decreases) on the Pol reading and on the TRS formula. The variability of the core - press method of sampling and analyzing billet cane is known to be quite high and although each of the TRS and cane weight measurements in Figures 5 and 6, and in Table 5 are based on ten measurements, the errors can be expected to be substantial.

Table 5. The total recoverable sugar (TRS), cane weight and calculated sugar weight at the beginning and after twenty four hours of storage during the five factory tests. Each test result is an average of ten core sample analyses

| Test | Date | TRS, lb/t cane | | Cane, t | | Sucrose, lb | |
|------|--------|----------------|------------|---------|------------|-------------|------------|
| | | Time 0 | Time 24 hr | Time 0 | Time 24 hr | Time 0 | Time 24 hr |
| 1 | 7-Nov | 216.3 | 220.5 | 239.8 | 233.7 | 51,834 | 51,545 |
| 2 | 14-Nov | 207.2 | 206.1 | 242.5 | 237.6 | 50,263 | 49,026 |
| 3 | 27-Nov | 178.1 | 180.0 | 230.0 | 227.2 | 40,934 | 40,932 |
| 4 | 12-Dec | 205.1 | 188.0 | 231.2 | 225.5 | 47,412 | 42,351 |
| 5 | 16-Dec | 197.4 | 198.7 | 225.1 | 221.9 | 44,450 | 43,998 |

Table 6. Temperature conditions and the measured and calculated sugar and weight loss data in the five factory tests

| Test | Time (hr) at temperature °C | | | Cane weight change % initial | | Sucrose weight change % initial | |
|------|-----------------------------|----------------------|------------------------|---------------------------------|-------|------------------------------------|-------|
| | <17 | 17 – 27 | >27 (T ₂₇) | Measured | Model | Measured | Model |
| | (T ₁₇) | (T ₁₇₂₇) | | | | | |
| 1 | 20 | 4 | 0 | -2.5 | -0.6 | -0.6 | 0.3 |
| 2 | 0 | 24 | 0 | -2.0 | -0.6 | -2.5 | -0.5 |
| 3 | 24 | 0 | 0 | -1.2 | -0.6 | 0.0 | 0.4 |
| 4 | 0 | 13 | 11 | -2.5 | -3.1 | -10.7 | -3.4 |
| 5 | 24 | 0 | 0 | -1.4 | -0.6 | -1.0 | 0.4 |

**Figure 5.** The measured TRS loss and the calculated sucrose loss (eq. 1), in percent initial in the five factory tests.

On average (Figure 6), the measured cane weight loss was close to the one predicted by the model equation 4. Exceptions were the tests 1 and 4 that deviated from the predicted trend. This may be related to an additional physical loss from handling the cane with a front-end loader or other factors.

In three out of the five tests TRS increased (Table 5 and Appendix C), but because of the cane weight loss, the total sugar, equal to cane weight multiplied by TRS, decreased. This emphasizes the need to include the cane weight changes in any reliable estimates of sucrose loss.

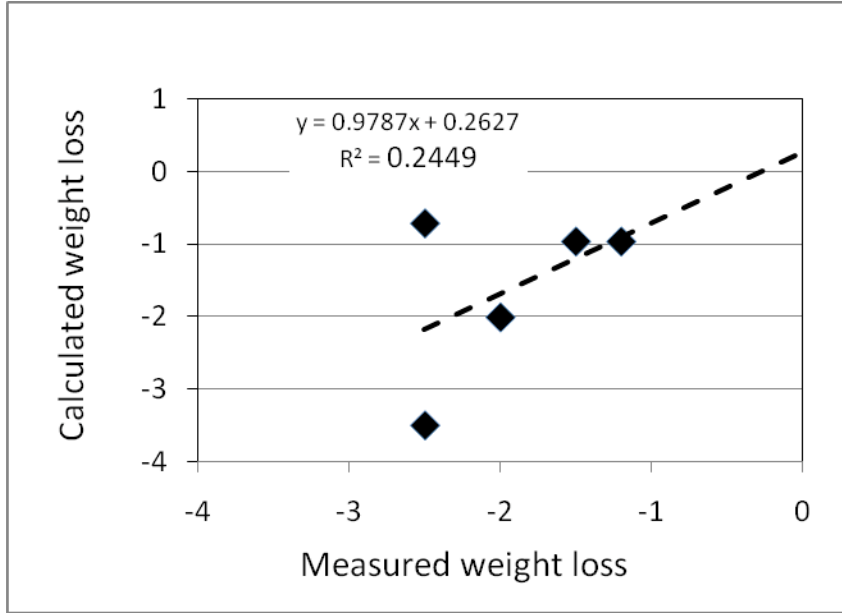


Figure 6. The cane weight loss, measured and calculated from eq. 4, in per cent initial weight in the five factory tests.

Dextran was analyzed with the antibody method (Midland 2003) in the factory core lab in the juice pressed from cane after storage. As expected the highest dextran was in the juice from test 4 that also recorded the highest sugar loss, but the correlation (Figure 7) against the sugar loss based on the TRS data is highly non-linear.

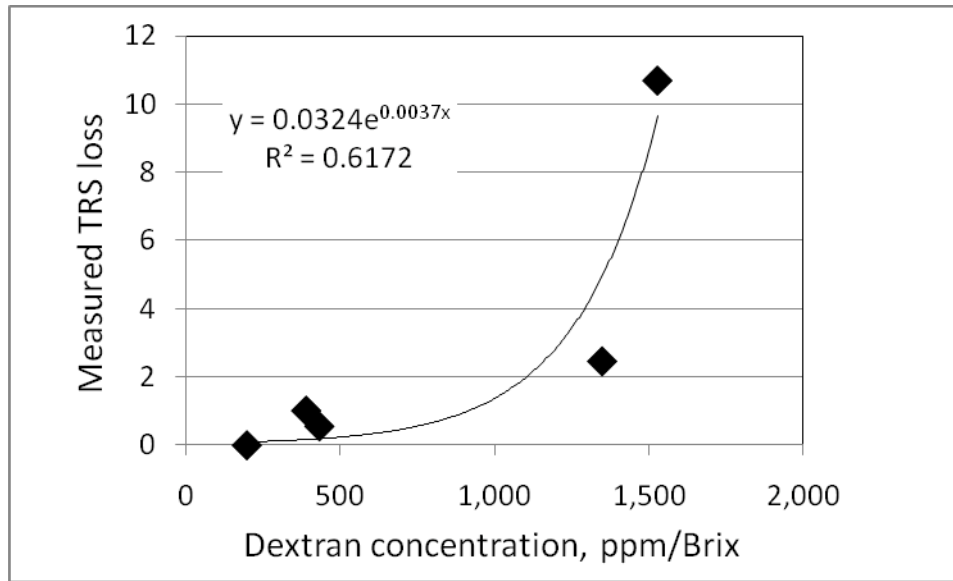


Figure 7. Measured TRS loss (% initial) vs. dextran in juice after storage.

The temperature profile recorded during the test 4 (Figure 8) clearly shows exothermic activity within the pile which is consistent with the large sucrose loss observed in this test. The initial temperature drop exhibited on the “inside cane pile” curves (two temperature probes in two different locations inside the pile) is from the temperature recorders adjusting to the initially somewhat cooler temperature inside the freshly laid pile.

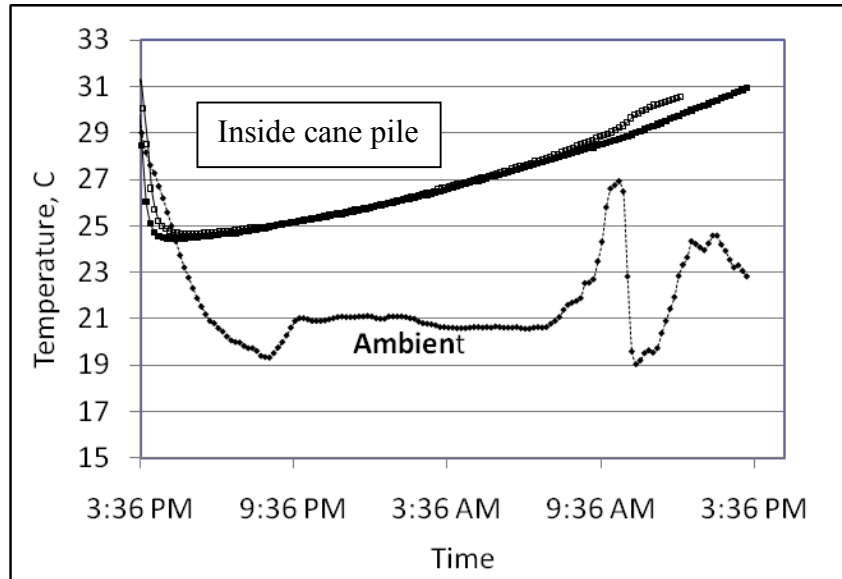


Figure 8. The temperature profile during the factory test 4. The steady temperature rise inside the cane pile is evidence of an exothermic activity related to cane deterioration and sucrose loss.

CONCLUSIONS

It is obvious that the temperature of the cane is a major factor for sucrose loss in cane storage. The cane temperature may be quite different than the temperature of the air because of good insulating properties of the billet cane pile and exothermic activity within the cane. The mass sucrose loss in storage of green billets of twenty-four hours or less was found to be adequately represented by a linear model based on the length of time (hours) within four temperature ranges, $< 17^{\circ}\text{C}$, $17\text{-}22^{\circ}\text{C}$, $22\text{-}27^{\circ}\text{C}$ and $> 27^{\circ}\text{C}$, representing cold, cool, moderate and warm conditions. The predicted relative sucrose loss (tons of sucrose lost for each 100 tons of initial sucrose per hour) in the four temperature ranges are 0.008, 0.011, 0.031 and 0.318, respectively. As an example, based on the model and taking the storage capacity as 5,000 tons cane and a cumulative seasonal total of 250 storage hours at $> 27^{\circ}\text{C}$, that is twenty five nights of ten hours each at over 27°C , the total cumulative loss in one crushing season is predicted to be $500 \times 0.318 \times 250 / 100$ or 400 tons of sucrose.

An analogous model was found to apply to the cane weight loss during storage. The predicted relative cane weight loss (tons of cane lost per 100 tons initial per hour) in the temperature ranges $17\text{-}22^{\circ}\text{C}$ and $22\text{-}27^{\circ}\text{C}$ were 0.08 and 0.22, respectively. The results in the

six factory cane yard tests broadly agreed with the conclusions from the pilot storage tests done at ASI. The observed deviations from the expected patterns may be related to the core-press Pol based methods of analysis, and physical losses of the cane, and other unknown factors.

The financial impact of the sucrose loss predicted for storage of sugarcane at high temperatures (3.2% in 10 hours) is serious, and considerations should be given to improving through their design the natural or forced ventilation of cane wagons and piles, and to the scheduling of harvest and storage of cane. Monitoring cane temperature when delivered to the mill is recommended to avoid storing cane with high temperature.

ACKNOWLEDGMENTS

Funding from the American Sugarcane League is gratefully acknowledged. Appreciation is also extended to Dr. Gravois and the staff of the Sugar Research Station for providing the cane, Drs. Legendre and Birkett (ASI) for their input, Dr. Lingle (USDA-ARS, New Orleans) for useful discussion regarding enzymatic processes in sugarcane, and the staff of the ASI analytical laboratory for sugar analysis.

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Appendix A

Appendix A1. Cane variety and weights of cane before and after storage, and after crushing. In two experiments marked with (*) some water entered the storage containers when removing from the warm water bath. This does not affect the sugar and solids mass balances

| Test no. | Batch | Cane variety | Cane (kg) | | Juice (Kg) | Bagasse (Kg) | Weight loss (kg) | | Total loss (kg) |
|----------|-------|-----------------|-----------|--------|------------|--------------|------------------|----------|-----------------|
| | | | Initial | final | | | storage | crushing | |
| 4 | A | Ho95-988 | 31.707 | | 22.849 | 8.497 | ----- | 0.361 | 0.361 |
| | B | 2 nd | 30.413 | 30.235 | 22.701 | 7.222 | 0.178 | 0.312 | 0.490 |
| | C | stubble | 30.220 | 30.078 | 22.423 | 7.251 | 0.142 | 0.404 | 0.546 |
| 5 | A | Ho95-988 | 28.382 | | 19.840 | 8.421 | ----- | 0.121 | 0.121 |
| | B | 2 nd | 30.550 | 30.337 | 21.029 | 9.005 | 0.213 | 0.303 | 0.516 |
| | C | stubble | 29.079 | 29.362 | 19.539 | 9.455 | -0.283* | 0.368 | 0.085 |
| 6 | A | LCP85-384 | 28.077 | | 20.517 | 7.096 | ----- | 0.394 | 0.394 |
| | B | Mix | 27.302 | 26.976 | 18.774 | 7.962 | 0.240 | 0.326 | 0.566 |
| | C | | 28.195 | 28.091 | 20.086 | 7.379 | 0.104 | 0.626 | 0.730 |
| 7 | A | Ho95-988 | 30.933 | | 21.605 | 8.891 | ----- | 0.437 | 0.437 |
| | B | 1 st | 29.680 | 29.540 | 21.669 | 7.648 | 0.140 | 0.223 | 0.363 |
| | C | stubble | 28.583 | 28.501 | 21.226 | 6.920 | 0.082 | 0.355 | 0.437 |
| 8 | A | L97-128 | 25.260 | | 17.764 | 7.276 | ----- | 0.220 | 0.220 |
| | B | Plant | 25.284 | 25.078 | 17.326 | 7.166 | 0.206 | 0.586 | 0.792 |
| | C | cane | 26.417 | 27.155 | 19.284 | 7.110 | -0.738* | 0.761 | 0.023 |
| 9 | A | Ho95-988 | 30.857 | | 22.901 | 7.607 | ----- | 0.349 | 0.349 |
| | B | 1 st | 30.420 | 30.311 | 22.764 | 7.404 | 0.109 | 0.143 | 0.252 |
| | C | stubble | 31.987 | 31.794 | 23.477 | 8.055 | 0.193 | 0.262 | 0.455 |
| 10 | A | L97-128 | 57.897 | | 42.281 | 15.267 | ----- | 0.349 | 0.349 |
| | B | 2 nd | 54.960 | 54.711 | 40.017 | 14.342 | 0.249 | 0.352 | 0.601 |
| | C | stubble | 55.868 | 55.745 | 39.062 | 15.942 | 0.123 | 0.741 | 0.864 |
| 11 | A | L97-128 | 52.646 | | 37.962 | 14.422 | ----- | 0.262 | 0.262 |
| | B | 2 nd | 56.542 | 56.445 | 40.819 | 15.245 | 0.097 | 0.381 | 0.478 |
| | C | stubble | 54.503 | 54.357 | 38.813 | 14.737 | 0.146 | 0.807 | 0.953 |
| 12 | A | HoCP96-540 | 62.151 | | 44.287 | 17.469 | ----- | 0.395 | 0.395 |
| | B | 1 st | 61.499 | 61.385 | 43.864 | 17.327 | 0.114 | 0.194 | 0.308 |
| | C | stubble | 59.306 | 59.117 | 41.991 | 16.514 | 0.189 | 0.612 | 0.801 |
| 13 | A | L97-128 | 59.414 | | 43.063 | 15.723 | ----- | 0.628 | 0.628 |
| | B | 1 st | 57.217 | 56.931 | 40.909 | 15.401 | 0.286 | 0.621 | 0.907 |
| | C | stubble | 56.489 | 56.032 | 35.449 | 19.680 | 0.457 | 0.903 | 1.3604 |
| 14 | A | L97-128 | 58.778 | | 37.806 | 20.541 | ----- | 0.431 | 0.431 |
| | B | 2 nd | 58.882 | 58.807 | 41.144 | 17.137 | 0.075 | 0.526 | 0.601 |
| | C | stubble | 60.669 | 60.361 | 42.107 | 17.565 | 0.308 | 0.689 | 0.997 |
| 15 | A | LCP85-384 | 62.308 | | 44.119 | 17.674 | ----- | 0.515 | 0.515 |
| | B | 3 rd | 60.612 | 60.477 | 42.641 | 17.391 | 0.135 | 0.445 | 0.580 |
| | C | stubble | 62.198 | 61.955 | 44.058 | 17.113 | 0.243 | 0.784 | 1.027 |

Appendix A2. Bagasse compositional analysis: bagasse moisture determination, weights of sample and water for disintegration, and the weight of recovered dry fiber

| Test No. | Batch | Bagasse before drying (g) | Bagasse after drying (g) | Sample weight (g) | Water weight(g) | Fiber (dry weight, g) |
|----------|-------|---------------------------|--------------------------|-------------------|-----------------|-----------------------|
| 4 | A | 50.78 | 23.17 | 50.25 | 400.50 | 17.05 |
| | B | 50.28 | 24.42 | 50.25 | 400.40 | 18.42 |
| | C | 50.61 | 24.80 | 50.35 | 400.40 | 18.38 |
| 5 | A | 50.61 | 23.41 | 50.35 | 400.40 | 16.67 |
| | B | 52.36 | 24.42 | 50.35 | 400.20 | 17.25 |
| | C | 52.11 | 22.41 | 50.35 | 400.25 | 15.74 |
| 6 | A | 51.84 | 27.33 | 50.15 | 400.30 | 20.92 |
| | B | 52.42 | 25.31 | 50.25 | 400.25 | 18.50 |
| | C | 51.75 | 26.76 | 50.45 | 400.10 | 20.66 |
| 7 | A | 50.67 | 22.74 | 50.45 | 400.15 | 16.74 |
| | B | 50.68 | 24.84 | 50.35 | 400.30 | 19.03 |
| | C | 50.26 | 25.35 | 50.35 | 400.70 | 19.96 |
| 8 | A | 50.58 | 25.57 | 50.40 | 400.35 | 19.67 |
| | B | 51.27 | 25.48 | 50.25 | 400.35 | 19.54 |
| | C | 50.57 | 26.02 | 50.40 | 400.60 | 20.75 |
| 9 | A | 50.33 | 24.40 | 50.45 | 400.50 | 18.66 |
| | B | 50.75 | 24.93 | 50.45 | 400.60 | 18.65 |
| | C | 50.62 | 24.50 | 50.55 | 401.85 | 17.80 |
| 10 | A | 50.19 | 25.79 | 50.35 | 400.95 | 19.98 |
| | B | 51.56 | 27.55 | 50.60 | 400.65 | 20.95 |
| | C | 50.86 | 25.96 | 50.25 | 401.50 | 19.37 |
| 11 | A | 51.45 | 24.54 | 50.30 | 401.00 | 16.29 |
| | B | 52.02 | 26.29 | 50.30 | 401.40 | 17.50 |
| | C | 52.08 | 25.92 | 50.70 | 402.10 | 16.95 |
| 12 | A | 51.80 | 25.45 | 50.75 | 400.95 | 17.39 |
| | B | 51.39 | 25.79 | 50.45 | 401.55 | 17.84 |
| | C | 50.56 | 25.35 | 50.60 | 402.00 | 18.18 |
| 13 | A | 52.47 | 26.50 | 50.40 | 400.80 | 19.54 |
| | B | 50.65 | 25.16 | 50.55 | 401.60 | 18.78 |
| | C | 51.35 | 21.40 | 50.60 | 401.50 | 13.93 |
| 14 | A | 51.08 | 23.40 | 50.40 | 401.40 | 16.62 |
| | B | 50.79 | 25.71 | 50.55 | 403.45 | 18.19 |
| | C | 50.62 | 25.49 | 50.60 | 401.65 | 18.76 |
| 15 | A | 51.72 | 23.46 | 50.35 | 401.75 | 17.07 |
| | B | 51.35 | 23.59 | 50.40 | 403.40 | 17.37 |
| | C | 51.20 | 24.32 | 50.65 | 401.75 | 18.38 |

Appendix A3. Bagasse compositional analysis: composition of the disintegration extract. Each measurement is an average of two or three replicate measurements

| Test No. | Batch | Brix | Sucrose g/100g | Glucose g/100g | Fructose g/100g | Total sugars g/100g |
|----------|-------|------|----------------|----------------|-----------------|---------------------|
| 4 | A | 0.92 | 0.716 | 0.041 | 0.040 | 0.797 |
| | B | 0.83 | 0.666 | 0.030 | 0.028 | 0.724 |
| | C | 0.80 | 0.606 | 0.036 | 0.038 | 0.680 |
| 5 | A | 0.99 | 0.839 | 0.023 | 0.021 | 0.883 |
| | B | 0.97 | 0.822 | 0.021 | 0.021 | 0.864 |
| | C | 0.97 | 0.807 | 0.025 | 0.025 | 0.857 |
| 6 | A | 0.72 | 0.59 | 0.052 | 0.041 | 1.169 |
| | B | 0.86 | 0.71 | 0.058 | 0.059 | 1.406 |
| | C | 0.77 | 0.53 | 0.059 | 0.054 | 1.240 |
| 7 | A | 0.97 | 0.793 | 0.027 | 0.028 | 0.848 |
| | B | 0.89 | 0.718 | 0.023 | 0.026 | 0.767 |
| | C | 0.89 | 0.671 | 0.027 | 0.030 | 0.728 |
| 8 | A | 0.82 | 0.624 | 0.021 | 0.021 | 0.666 |
| | B | 0.87 | 0.652 | 0.023 | 0.024 | 0.699 |
| | C | 0.77 | 0.575 | 0.018 | 0.020 | 0.613 |
| 9 | A | 0.92 | 0.730 | 0.019 | 0.020 | 0.769 |
| | B | 0.96 | 0.754 | 0.021 | 0.025 | 0.800 |
| | C | 1.09 | 0.872 | 0.025 | 0.032 | 0.929 |
| 10 | A | 0.98 | 0.818 | 0.017 | 0.015 | 0.850 |
| | B | 0.99 | 0.811 | 0.017 | 0.017 | 0.845 |
| | C | 1.01 | 0.806 | 0.017 | 0.021 | 0.844 |
| 11 | A | 0.99 | 0.787 | 0.019 | 0.021 | 0.827 |
| | B | 0.96 | 0.755 | 0.019 | 0.021 | 0.795 |
| | C | 1.00 | 0.770 | 0.023 | 0.027 | 0.820 |
| 12 | A | 1.03 | 0.860 | 0.017 | 0.013 | 0.900 |
| | B | 0.99 | 0.811 | 0.014 | 0.015 | 0.852 |
| | C | 1.01 | 0.807 | 0.018 | 0.023 | 0.848 |
| 13 | A | 0.87 | 0.654 | 0.019 | 0.022 | 0.695 |
| | B | 0.91 | 0.670 | 0.018 | 0.025 | 0.713 |
| | C | 1.12 | 0.820 | 0.035 | 0.037 | 0.892 |
| 14 | A | 1.12 | 0.933 | 0.014 | 0.012 | 0.959 |
| | B | 0.98 | 0.777 | 0.014 | 0.015 | 0.806 |
| | C | 0.97 | 0.760 | 0.019 | 0.017 | 0.796 |
| 15 | A | 0.97 | 0.772 | 0.023 | 0.016 | 0.811 |
| | B | 0.95 | 0.757 | 0.023 | 0.019 | 0.799 |
| | C | 0.90 | 0.696 | 0.025 | 0.022 | 0.743 |

Appendix A4. Bagasse compositional analysis. Each measurement is an average of two or three replicate measurements

| Test No. | Batch | Moisture g/100g | Fiber g/100g | Brix g/100g | Sucrose g/100g | Glucose g/100g | Fructose g/100g | Total sugars g/100g |
|----------|-------|-----------------|--------------|-------------|----------------|----------------|-----------------|---------------------|
| 4 | A | 54.38 | 33.93 | 7.80 | 6.10 | 0.35 | 0.34 | 6.79 |
| | B | 51.43 | 36.65 | 7.01 | 5.65 | 0.25 | 0.24 | 6.14 |
| | C | 50.99 | 36.51 | 6.78 | 5.12 | 0.30 | 0.32 | 5.75 |
| 5 | A | 53.75 | 33.10 | 8.39 | 7.12 | 0.20 | 0.18 | 7.49 |
| | B | 53.36 | 34.27 | 8.21 | 6.97 | 0.18 | 0.18 | 7.32 |
| | C | 56.99 | 31.27 | 8.26 | 6.88 | 0.21 | 0.21 | 7.30 |
| 6 | A | 47.28 | 41.71 | 6.10 | 4.99 | 0.44 | 0.34 | 5.77 |
| | B | 51.72 | 36.81 | 7.27 | 6.02 | 0.49 | 0.50 | 7.01 |
| | C | 48.29 | 41.02 | 6.48 | 4.47 | 0.50 | 0.45 | 5.42 |
| 7 | A | 55.12 | 33.19 | 8.24 | 6.72 | 0.22 | 0.24 | 7.18 |
| | B | 51.00 | 37.80 | 7.51 | 6.07 | 0.19 | 0.22 | 6.48 |
| | C | 49.56 | 39.64 | 7.23 | 5.67 | 0.23 | 0.25 | 6.15 |
| 8 | A | 49.44 | 39.02 | 6.88 | 5.26 | 0.17 | 0.17 | 5.61 |
| | B | 50.30 | 38.88 | 7.35 | 5.52 | 0.19 | 0.20 | 5.92 |
| | C | 48.56 | 41.17 | 6.49 | 4.85 | 0.15 | 0.16 | 5.16 |
| 9 | A | 51.53 | 36.99 | 7.79 | 6.17 | 0.16 | 0.17 | 6.50 |
| | B | 50.89 | 36.97 | 8.11 | 6.37 | 0.18 | 0.21 | 6.76 |
| | C | 51.60 | 35.22 | 9.20 | 7.38 | 0.21 | 0.27 | 7.86 |
| 10 | A | 48.62 | 39.69 | 8.25 | 6.91 | 0.14 | 0.13 | 7.18 |
| | B | 46.57 | 41.39 | 8.33 | 6.80 | 0.14 | 0.14 | 7.08 |
| | C | 48.96 | 38.54 | 8.55 | 6.83 | 0.14 | 0.18 | 7.16 |
| 11 | A | 52.31 | 32.39 | 8.41 | 6.69 | 0.16 | 0.17 | 7.02 |
| | B | 49.46 | 34.80 | 8.15 | 6.39 | 0.16 | 0.17 | 6.72 |
| | C | 50.24 | 33.42 | 8.45 | 6.49 | 0.19 | 0.23 | 6.91 |
| 12 | A | 50.88 | 34.27 | 8.66 | 7.23 | 0.14 | 0.11 | 7.48 |
| | B | 49.82 | 35.35 | 8.40 | 6.86 | 0.12 | 0.13 | 7.10 |
| | C | 49.87 | 35.93 | 8.50 | 6.81 | 0.15 | 0.19 | 7.16 |
| 13 | A | 49.49 | 38.76 | 7.35 | 5.52 | 0.16 | 0.18 | 5.86 |
| | B | 50.32 | 37.15 | 7.67 | 5.66 | 0.15 | 0.21 | 6.02 |
| | C | 58.32 | 27.52 | 9.51 | 6.98 | 0.30 | 0.32 | 7.60 |
| 14 | A | 54.20 | 32.98 | 9.54 | 7.94 | 0.12 | 0.10 | 8.16 |
| | B | 49.37 | 35.98 | 8.33 | 6.58 | 0.11 | 0.13 | 6.82 |
| | C | 49.64 | 37.08 | 8.18 | 6.41 | 0.16 | 0.14 | 6.71 |
| 15 | A | 54.65 | 33.91 | 8.23 | 6.58 | 0.19 | 0.13 | 6.90 |
| | B | 54.06 | 34.46 | 8.09 | 6.47 | 0.19 | 0.16 | 6.82 |
| | C | 52.51 | 36.28 | 7.57 | 5.88 | 0.21 | 0.18 | 6.27 |

Appendix A5. Juice compositional analysis. Each measurement is an average of two or three replicate measurements

| Test No. | Batch | Brix | Sucrose g/100g | Glucose g/100g | Fructose g/100g | Total sugars g/100g | pH |
|----------|-------|-------|----------------|----------------|-----------------|---------------------|------|
| 4 | A | 16.68 | 14.543 | 0.600 | 0.564 | 15.707 | 5.34 |
| | B | 16.57 | 14.488 | 0.556 | 0.585 | 15.629 | 5.34 |
| | C | 15.76 | 13.211 | 0.632 | 0.677 | 14.520 | 5.15 |
| 5 | A | 17.93 | 16.360 | 0.344 | 0.328 | 17.032 | 5.34 |
| | B | 17.93 | 16.355 | 0.347 | 0.397 | 17.099 | 5.34 |
| | C | 17.15 | 15.119 | 0.399 | 0.421 | 15.939 | 5.27 |
| 6 | A | 15.64 | 13.454 | 0.645 | 0.533 | 14.632 | 5.39 |
| | B | 16.30 | 13.993 | 0.641 | 0.555 | 15.189 | 5.31 |
| | C | 15.75 | 12.994 | 0.664 | 0.709 | 14.367 | 4.97 |
| 7 | A | 17.27 | 15.423 | 0.459 | 0.489 | 16.370 | 5.44 |
| | B | 17.37 | 15.540 | 0.398 | 0.465 | 16.403 | 5.43 |
| | C | 16.86 | 14.618 | 0.471 | 0.537 | 15.625 | 5.28 |
| 8 | A | 16.50 | 14.250 | 0.354 | 0.350 | 14.953 | 5.34 |
| | B | 16.58 | 14.163 | 0.383 | 0.419 | 14.964 | 5.21 |
| | C | 16.27 | 13.891 | 0.333 | 0.390 | 14.613 | 5.29 |
| 9 | A | 17.56 | 15.903 | 0.288 | 0.312 | 16.502 | 5.36 |
| | B | 17.43 | 15.548 | 0.320 | 0.411 | 16.278 | 5.23 |
| | C | 18.15 | 15.965 | 0.326 | 0.476 | 16.766 | 5.07 |
| 10 | A | 18.70 | 16.817 | 0.267 | 0.243 | 17.326 | 5.47 |
| | B | 18.78 | 17.186 | 0.330 | 0.322 | 17.837 | 5.36 |
| | C | 18.80 | 16.872 | 0.303 | 0.397 | 17.572 | 5.26 |
| 11 | A | 17.77 | 15.859 | 0.315 | 0.320 | 16.494 | 5.46 |
| | B | 17.84 | 15.926 | 0.292 | 0.316 | 16.533 | 5.41 |
| | C | 17.88 | 15.540 | 0.350 | 0.481 | 16.370 | 5.09 |
| 12 | A | 18.87 | 17.429 | 0.244 | 0.266 | 17.938 | 5.40 |
| | B | 18.91 | 17.564 | 0.264 | 0.260 | 18.088 | 5.42 |
| | C | 18.58 | 16.952 | 0.323 | 0.360 | 17.635 | 5.17 |
| 13 | A | 16.28 | 14.092 | 0.297 | 0.328 | 14.716 | 5.51 |
| | B | 16.04 | 13.689 | 0.285 | 0.379 | 14.353 | 5.26 |
| | C | 16.02 | 13.419 | 0.374 | 0.451 | 14.243 | 5.10 |
| 14 | A | 18.83 | 17.186 | 0.181 | 0.178 | 17.544 | 5.46 |
| | B | 18.73 | 16.908 | 0.166 | 0.256 | 17.329 | 5.34 |
| | C | 18.90 | 16.242 | 0.272 | 0.300 | 16.814 | 5.13 |
| 15 | A | 17.53 | 15.875 | 0.247 | 0.251 | 16.373 | 5.42 |
| | B | 17.52 | 15.834 | 0.277 | 0.281 | 16.392 | 5.38 |
| | C | 17.05 | 15.127 | 0.298 | 0.339 | 15.764 | 5.11 |

Appendix A6. Sucrose balance: weight of sucrose in each of the three batches at the beginning and after 24-hour storage. Batch A was used only to determine the initial composition of batches B and C

| Test No. | Batch | Weight sucrose initial (kg) | | | Weight sucrose final (kg) | | |
|----------|-------|-----------------------------|---------|-------|---------------------------|---------|-------|
| | | Juice | Bagasse | Total | Juice | Bagasse | Total |
| 4 | A | 3.323 | 0.518 | 3.841 | ----- | ----- | ----- |
| | B | 3.187 | 0.497 | 3.684 | 3.289 | 0.408 | 3.697 |
| | C | 3.167 | 0.494 | 3.661 | 2.962 | 0.372 | 3.334 |
| 5 | A | 3.246 | 0.599 | 3.845 | ----- | ----- | ----- |
| | B | 3.494 | 0.645 | 4.139 | 3.439 | 0.627 | 4.067 |
| | C | 3.326 | 0.614 | 3.940 | 2.954 | 0.650 | 3.604 |
| 6 | A | 2.760 | 0.354 | 3.114 | ----- | ----- | ----- |
| | B | 2.691 | 0.345 | 3.036 | 2.627 | 0.480 | 3.107 |
| | C | 2.779 | 0.356 | 3.135 | 2.610 | 0.330 | 2.940 |
| 7 | A | 3.332 | 0.598 | 3.930 | ----- | ----- | ----- |
| | B | 3.197 | 0.573 | 3.771 | 3.367 | 0.465 | 3.832 |
| | C | 3.079 | 0.552 | 3.631 | 3.103 | 0.392 | 3.495 |
| 8 | A | 2.531 | 0.383 | 2.914 | ----- | ----- | ----- |
| | B | 2.534 | 0.383 | 2.917 | 2.454 | 0.395 | 2.849 |
| | C | 2.647 | 0.400 | 3.048 | 2.679 | 0.345 | 3.023 |
| 9 | A | 3.642 | 0.470 | 4.111 | ----- | ----- | ----- |
| | B | 3.590 | 0.463 | 4.053 | 3.539 | 0.472 | 4.011 |
| | C | 3.775 | 0.487 | 4.262 | 3.748 | 0.595 | 4.343 |
| 10 | A | 7.110 | 1.055 | 8.165 | ----- | ----- | ----- |
| | B | 6.749 | 1.002 | 7.751 | 6.877 | 0.975 | 7.852 |
| | C | 6.861 | 1.018 | 7.879 | 6.591 | 1.090 | 7.680 |
| 11 | A | 6.020 | 0.964 | 6.985 | ----- | ----- | ----- |
| | B | 6.466 | 1.036 | 7.501 | 6.501 | 0.975 | 7.475 |
| | C | 6.233 | 0.998 | 7.231 | 6.031 | 0.956 | 6.988 |
| 12 | A | 7.719 | 1.263 | 8.982 | ----- | ----- | ----- |
| | B | 7.638 | 1.250 | 8.888 | 7.704 | 1.188 | 8.893 |
| | C | 7.365 | 1.206 | 8.571 | 7.118 | 1.125 | 8.243 |
| 13 | A | 6.068 | 0.868 | 6.936 | ----- | ----- | ----- |
| | B | 5.844 | 0.836 | 6.680 | 5.600 | 0.872 | 6.472 |
| | C | 5.769 | 0.825 | 6.595 | 4.757 | 1.375 | 6.131 |
| 14 | A | 6.497 | 1.631 | 8.128 | ----- | ----- | ----- |
| | B | 6.509 | 1.634 | 8.142 | 6.957 | 1.128 | 8.084 |
| | C | 6.706 | 1.683 | 8.389 | 6.839 | 1.126 | 7.964 |
| 15 | A | 7.004 | 1.163 | 8.166 | ----- | ----- | ----- |
| | B | 6.813 | 1.131 | 7.944 | 6.752 | 1.125 | 7.877 |
| | C | 6.991 | 1.160 | 8.152 | 6.665 | 1.007 | 7.671 |

Appendix A7. Invert sugar balance: weight of invert in each of the three batches at the beginning and after 24-hour storage. Batch A was used only to determine the initial composition of batches B and C

| Test no. | Batch | Initial weight of invert sugars (kg) | | | Final weight invert sugars (kg) | | |
|----------|-------|--------------------------------------|---------|-------|---------------------------------|---------|-------|
| | | Juice | Bagasse | Total | Juice | Bagasse | Total |
| 4 | A | 0.266 | 0.059 | 0.325 | ----- | ----- | ----- |
| | B | 0.255 | 0.056 | 0.311 | 0.259 | 0.036 | 0.295 |
| | C | 0.253 | 0.056 | 0.309 | 0.294 | 0.045 | 0.339 |
| 5 | A | 0.133 | 0.031 | 0.165 | ----- | ----- | ----- |
| | B | 0.143 | 0.034 | 0.177 | 0.156 | 0.032 | 0.188 |
| | C | 0.136 | 0.032 | 0.169 | 0.160 | 0.040 | 0.200 |
| 6 | A | 0.242 | 0.055 | 0.297 | ----- | ----- | ----- |
| | B | 0.236 | 0.054 | 0.289 | 0.225 | 0.079 | 0.303 |
| | C | 0.243 | 0.056 | 0.299 | 0.276 | 0.070 | 0.346 |
| 7 | A | 0.205 | 0.041 | 0.246 | ----- | ----- | ----- |
| | B | 0.196 | 0.039 | 0.236 | 0.187 | 0.031 | 0.218 |
| | C | 0.189 | 0.038 | 0.227 | 0.214 | 0.033 | 0.247 |
| 8 | A | 0.125 | 0.025 | 0.150 | ----- | ----- | ----- |
| | B | 0.125 | 0.025 | 0.150 | 0.139 | 0.029 | 0.167 |
| | C | 0.131 | 0.026 | 0.157 | 0.139 | 0.022 | 0.162 |
| 9 | A | 0.137 | 0.025 | 0.162 | ----- | ----- | ----- |
| | B | 0.135 | 0.025 | 0.160 | 0.166 | 0.029 | 0.195 |
| | C | 0.142 | 0.026 | 0.168 | 0.188 | 0.039 | 0.227 |
| 10 | A | 0.215 | 0.041 | 0.257 | ----- | ----- | ----- |
| | B | 0.204 | 0.039 | 0.244 | 0.261 | 0.041 | 0.302 |
| | C | 0.208 | 0.040 | 0.248 | 0.273 | 0.051 | 0.325 |
| 11 | A | 0.241 | 0.048 | 0.289 | ----- | ----- | ----- |
| | B | 0.259 | 0.051 | 0.310 | 0.248 | 0.050 | 0.298 |
| | C | 0.249 | 0.049 | 0.299 | 0.322 | 0.062 | 0.384 |
| 12 | A | 0.225 | 0.043 | 0.269 | ----- | ----- | ----- |
| | B | 0.223 | 0.043 | 0.266 | 0.230 | 0.042 | 0.272 |
| | C | 0.215 | 0.041 | 0.256 | 0.287 | 0.056 | 0.343 |
| 13 | A | 0.269 | 0.053 | 0.322 | ----- | ----- | ----- |
| | B | 0.259 | 0.051 | 0.310 | 0.271 | 0.056 | 0.327 |
| | C | 0.256 | 0.051 | 0.306 | 0.292 | 0.121 | 0.413 |
| 14 | A | 0.136 | 0.046 | 0.181 | ----- | ----- | ----- |
| | B | 0.136 | 0.046 | 0.182 | 0.173 | 0.041 | 0.214 |
| | C | 0.140 | 0.047 | 0.187 | 0.241 | 0.053 | 0.294 |
| 15 | A | 0.220 | 0.057 | 0.277 | ----- | ----- | ----- |
| | B | 0.214 | 0.056 | 0.269 | 0.238 | 0.061 | 0.299 |
| | C | 0.219 | 0.057 | 0.276 | 0.280 | 0.067 | 0.347 |

Appendix B

The bagasse composition (g/100g bagasse) in Table A4 was calculated from the raw data tabulated in Tables A2 and A3 as follows:

$$\text{Bagasse moisture} = 100 * (\text{weight of bagasse before drying} - \text{weight of bagasse after drying}) / \text{weight of bagasse before drying}$$

$$\text{Fiber} = 100 * (\text{weight of dry fiber}) / (\text{sample weight})$$

$$\text{Brix} = (\text{Water weight} + \text{Sample weight} * \text{moisture} / 100) * \text{Extract Brix} / 100$$

$$\text{Sucrose} = (\text{Water weight} + \text{Sample weight} * \text{moisture} / 100) * \text{Extract Sucrose} / 100$$

$$\text{Glucose} = (\text{Water weight} + \text{Sample weight} * \text{moisture} / 100) * \text{Extract Glucose} / 100$$

$$\text{Fructose} = (\text{Water weight} + \text{Sample weight} * \text{moisture} / 100) * \text{Extract Fructose} / 100$$

The contribution of the soluble compounds (Brix) to the total mass of the disintegration extract is negligible and was neglected in the previous four equations.

The sucrose balance in Table A6 was calculated as follows:

In Batch A, the weight of sucrose was calculated from data in Tables A1, A4 and A5 as

$$\text{Weight of sucrose (kg)} = \text{weight of juice} * \text{sucrose in juice} / 100 + \text{weight of bagasse} * \text{sucrose in bagasse} / 100$$

In Batches B and C the initial sucrose weight was calculated from the composition of Batch A and the initial cane weights in Table A1:

$$\text{Weight of sucrose (kg)} = (\text{weight of sucrose in Batch A}) * (\text{weight of cane initial of Batch B or C}) / (\text{weight of cane initial of Batch A})$$

The final sucrose weights in Batches B and C were calculated directly from the composition of the batches after storage (Tables A1, A4 and A5):

$$\text{Weight of sucrose (kg)} = \text{weight of juice} * \text{sucrose in juice} / 100 + \text{weight of bagasse} * \text{sucrose in bagasse} / 100$$

The invert sugar balance in Table A7 was calculated the same way as the sucrose balance, but substituting the data for invert (glucose + fructose) for sucrose, listed in Tables A4 and A5.

Appendix C

Appendix C1. Factory raw data. Tests 1 to 5

| Test no. | Date | Tons | TRS (lb/t) | Sugar (Lb) | Average TRS | Total Cane, t | Total Sugar (lb) | Juice dextran (ppm) |
|----------|------------|---------|------------|------------|-------------|---------------|------------------|---------------------|
| 1 | 11/6/2007 | 25.27 | 213.20 | 5387.56 | 216.34 | 239.79 | 51,834.36 | - |
| | | 23.49 | 203.90 | 4789.61 | | | | |
| | | 23.41 | 256.00 | 5992.96 | | | | |
| | | 23.95 | 181.20 | 4339.74 | | | | |
| | | 24.34 | 209.10 | 5089.49 | | | | |
| | | 23.95 | 224.30 | 5371.99 | | | | |
| | | 22.81 | 194.40 | 4434.26 | | | | |
| | | 25.01 | 216.60 | 5417.17 | | | | |
| | | 26.06 | 223.80 | 5832.23 | | | | |
| | | 21.50 | 240.90 | 5179.35 | | | | |
| | 11/7/2007 | 22.29 | 209.90 | 4678.67 | 220.51 | 233.69 | 51,545.05 | 432.13 |
| | | 24.85 | 228.40 | 5675.74 | | | | |
| | | 23.16 | 221.60 | 5132.26 | | | | |
| | | 22.26 | 233.00 | 5186.58 | | | | |
| | | 23.52 | 213.80 | 5028.58 | | | | |
| | | 24.52 | 217.20 | 5325.74 | | | | |
| | | 24.34 | 218.60 | 5320.72 | | | | |
| | | 23.97 | 222.50 | 5333.33 | | | | |
| | | 22.92 | 229.10 | 5250.97 | | | | |
| | | 21.86 | 211.00 | 4612.46 | | | | |
| 2 | 11/14/2007 | 24.42 | 190.10 | 4642.24 | 207.21 | 242.50 | 50,263.44 | 186.00 |
| | | 24.81 | 206.20 | 5115.82 | | | | |
| | | 24.71 | 206.40 | 5100.14 | | | | |
| | | 23.97 | 215.00 | 5153.55 | | | | |
| | | 25.12 | 211.70 | 5317.90 | | | | |
| | | 24.94 | 212.30 | 5294.76 | | | | |
| | | 25.48 | 214.80 | 5473.10 | | | | |
| | | 24.20 | 203.50 | 4924.70 | | | | |
| | 22.31 | 206.60 | 4609.25 | | | | | |
| | 22.54 | 205.50 | 4631.97 | | | | | |
| | 11/15/2007 | 18.58 | 201.60 | 3745.73 | 206.12 | 237.63 | 49,026.17 | 1347.58 |
| | | 21.26 | 191.70 | 4075.54 | | | | |
| | | 21.20 | 208.10 | 4411.72 | | | | |
| | | 20.89 | 210.40 | 4395.26 | | | | |
| 21.86 | | 212.20 | 4638.69 | | | | | |
| 22.75 | | 198.70 | 4520.43 | | | | | |
| 21.93 | 212.70 | 4664.51 | | | | | | |
| 22.13 | 209.70 | 4640.66 | | | | | | |
| 20.88 | 193.00 | 4029.84 | | | | | | |
| 23.99 | 214.60 | 5148.25 | | | | | | |
| 22.16 | 214.60 | 4755.54 | | | | | | |

Appendix C1. (continued)

| Test no. | Date | Tons | TRS (lb/t) | Sugar (Lb) | Average TRS | Total Cane, t | Total Sugar (lb) | Juice dextran (ppm) | | | | | | |
|----------|------------|-------|------------|------------|-------------|---------------|------------------|---------------------|-----------|---------|--------|--------|-----------|---------|
| 3 | 11/27/2007 | 22.75 | 196.20 | 4463.55 | 178.07 | 229.95 | 40,934.19 | | | | | | | |
| | | 22.95 | 181.40 | 4163.13 | | | | | | | | | | |
| | | 23.21 | 175.60 | 4075.68 | | | | | | | | | | |
| | | 22.32 | 175.60 | 3919.39 | | | | | | | | | | |
| | | 22.29 | 186.60 | 4159.31 | | | | | | | | | | |
| | | 22.78 | 173.60 | 3954.61 | | | | | | | | | | |
| | | 23.55 | 180.00 | 4239.00 | | | | | | | | | | |
| | | 23.21 | 178.40 | 4140.66 | | | | | | | | | | |
| | | 23.61 | 180.70 | 4266.33 | | | | | | | | | | |
| | | 23.28 | 152.60 | 3552.53 | | | | | | | | | | |
| | | 3 | 11/28/2007 | 22.56 | | | | | 198.70 | 4482.67 | 180.01 | 227.20 | 40,931.59 | 197.40 |
| | | | | 22.74 | | | | | 206.50 | 4695.81 | | | | |
| | | | | 21.58 | | | | | 175.30 | 3782.97 | | | | |
| 22.73 | 164.10 | | | 3729.99 | | | | | | | | | | |
| 21.44 | 149.20 | | | 3198.85 | | | | | | | | | | |
| 22.14 | 187.60 | | | 4153.46 | | | | | | | | | | |
| 23.16 | 152.60 | | | 3534.22 | | | | | | | | | | |
| 22.06 | 205.60 | | | 4535.54 | | | | | | | | | | |
| 23.24 | 170.00 | | | 3950.80 | | | | | | | | | | |
| 25.55 | 190.50 | | | 4867.28 | | | | | | | | | | |
| 4 | 12/12/2007 | | | 22.63 | 205.20 | 4643.68 | 205.09 | 231.21 | 47,411.76 | 63.03 | | | | |
| | | | | 23.45 | 223.80 | 5248.11 | | | | | | | | |
| | | | | 23.06 | 201.90 | 4655.81 | | | | | | | | |
| | | 23.78 | 202.90 | 4824.96 | | | | | | | | | | |
| | | 24.15 | 213.50 | 5156.03 | | | | | | | | | | |
| | | 22.45 | 207.50 | 4658.38 | | | | | | | | | | |
| | | 24.70 | 190.70 | 4710.29 | | | | | | | | | | |
| | | 22.75 | 200.50 | 4561.38 | | | | | | | | | | |
| | | 21.91 | 210.20 | 4605.48 | | | | | | | | | | |
| | | 22.33 | 194.70 | 4347.65 | | | | | | | | | | |
| | | 4 | 12/13/2007 | 19.92 | 189.50 | 3774.84 | | | | | 187.96 | 225.49 | 42,351.30 | 1526.63 |
| | | | | 20.05 | 192.30 | 3855.62 | | | | | | | | |
| | | | | 20.75 | 169.90 | 3525.43 | | | | | | | | |
| 21.12 | 177.00 | | | 3738.24 | | | | | | | | | | |
| 21.08 | 192.10 | | | 4049.47 | | | | | | | | | | |
| 19.82 | 183.00 | | | 3627.06 | | | | | | | | | | |
| 22.23 | 192.50 | | | 4279.28 | | | | | | | | | | |
| 20.80 | 195.70 | | | 4070.56 | | | | | | | | | | |
| 21.18 | 177.30 | | | 3755.21 | | | | | | | | | | |
| 20.46 | 199.30 | | | 4077.68 | | | | | | | | | | |
| 18.08 | 199.00 | | | 3597.92 | | | | | | | | | | |

Appendix C1. (continued)

| Test no. | Date | Tons | TRS (lb/t) | Sugar (Lb) | Average TRS | Total Cane, t | Total Sugar (lb) | Juice dextran (ppm) |
|----------|-------------|-------|------------|------------|-------------|---------------|------------------|---------------------|
| | 12//26/2007 | 23.14 | 225.37 | 5215.06 | 197.37 | 225.13 | 44,450.44 | 82.83 |
| | | 21.85 | 176.74 | 3861.77 | | | | |
| | | 22.77 | 188.24 | 4286.22 | | | | |
| | | 21.76 | 216.08 | 4701.90 | | | | |
| | | 22.58 | 186.44 | 4209.82 | | | | |
| | | 22.67 | 204.57 | 4637.60 | | | | |
| | | 21.47 | 191.41 | 4109.57 | | | | |
| | | 22.74 | 195.52 | 4446.12 | | | | |
| | | 23.00 | 201.08 | 4624.84 | | | | |
| | | 23.15 | 188.23 | 4357.52 | | | | |
| 5 | 12/27/2007 | 23.65 | 180.20 | 4261.73 | 198.67 | 221.90 | 43,997.93 | 389.20 |
| | | 22.97 | 207.10 | 4757.09 | | | | |
| | | 23.46 | 201.50 | 4727.19 | | | | |
| | | 23.65 | 205.80 | 4867.17 | | | | |
| | | 24.03 | 188.00 | 4517.64 | | | | |
| | | 22.83 | 195.90 | 4472.40 | | | | |
| | | 23.49 | 199.90 | 4695.65 | | | | |
| | | 21.66 | 214.90 | 4654.73 | | | | |
| | | 22.10 | 188.20 | 4159.22 | | | | |
| | | 14.06 | 205.20 | 2885.11 | | | | |