COMPARING CANE VARIETIES FOR SOME FACTORS THAT AFFECT SUGAR PROCESSING

By

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Abstract

The most important cane varieties growing in Reunion Island were tested for fibre, brix, pol, pH, sucrose, glucose, fructose, starch, colour, ash and lactic acid. Tests were conducted on cane from different geographical zones representative of the different climates and soils on the island. Results of the eastern coast of the Island are discussed here and proposals made to choose the 'best' variety for the grower as well as the miller.

Introduction

Since 1929, the Centre d'Essais, de Recherche et de Formation (CERF) has been creating new varieties of sugarcane for the industry of Reunion Island. As usual for breeding purposes, the varieties are selected according to several factors including field yield, disease and parasite resistance, and sugar content. In the same way, sugar cane delivered to the factories is analysed and paid for its sugar content rather than the sugar that can really be made from each consignment. In Reunion, growers are paid according to pol % cane, assuming that the losses in the factory are constant and equal to 2.80 sucrose % cane, whatever the quality of the cane.

It is well known that sugar content (expressed as pol % cane) does not accurately reflect the quantity of sugar that should be produced by a factory. During some periods, there is a significant discrepancy between theoretical sugar and real production. This gap seems to vary 'randomly' and not necessarily according to factory performance (breakdowns, strikes). Rather, it may depend on the non-sugar components of delivered cane. Indeed, the different sugar losses occurring during processing depend widely on the different non-sugars present in cane. Some of these relationships are now as well documented as the influence of fibre on bagasse losses or the influence of reducing sugars and ash on final molasses losses. Other non-sugars such as starch or colouring substances, which influence the quality of commercial sugar, and in some extent the process, are also interesting to follow. For these reasons, it was decided to begin a study of some non-sugars having a known effect on sugar processing during the 2000 crop.

The aim of this work was to measure the composition of cane according to some variable parameters (essentially variety and location) and to extrapolate the behaviour of each analysed cane when used industrially.

Factors studied

Table 1 shows the factors analysed and the reasons why they were chosen in this study.

Table 1—Factors studied, their interest for the study and their known influence on sugar processing.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Interest in this study</th>
<th>Influence on the process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brix</td>
<td>Base of calculations, concentration of dry matter coming into factory</td>
<td>Positive</td>
</tr>
<tr>
<td>Pol</td>
<td>Concentration of sugar</td>
<td>Positive</td>
</tr>
<tr>
<td>Sucrose</td>
<td>Comparison and validation parameter</td>
<td>Positive</td>
</tr>
<tr>
<td>Glucose and Fructose</td>
<td>Indicators of deterioration for sucrose Trash indicators</td>
<td>Negative (as products of sucrose inversion) Positive (as helping molasses exhaustion)</td>
</tr>
<tr>
<td>Ash</td>
<td>Trash indicator (not influenced by cane deterioration)</td>
<td>Negative (hinders molasses exhaustion)</td>
</tr>
<tr>
<td>Colour</td>
<td>Trash indicator (not influenced by cane deterioration)</td>
<td>Negative (sugar quality)</td>
</tr>
<tr>
<td>pH</td>
<td>Deterioration indicator</td>
<td>Negative (inversion, RS destruction)</td>
</tr>
<tr>
<td>Dextran</td>
<td>Deterioration indicator</td>
<td>Very negative (filterability, losses in molasses, sugar quality, pol measurement)</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>Deterioration indicator</td>
<td>Negative</td>
</tr>
<tr>
<td>Starch</td>
<td>Trash indicator Deterioration indicator</td>
<td>Very negative (filterability, losses in molasses, sugar quality)</td>
</tr>
</tbody>
</table>

KEYWORDS: Cane Juice, Industrial Performance, Target Purity, Sugar Yield.
Parameters investigated in the study

- Geographical provenance of the sample (including mean temperature, rainfall, irrigation, sunshine, wind, soil type, altitude, etc.): four different locations supplied the cane for this study, namely 'St Benoit', 'La Mare', and in a less extent 'Bel-air' and 'Beauvallon'.
- Period of the season: the sampling was made at two different periods, viz. June–July for the first run (beginning of the season) and September–October for the second run (end of the season for the East).
- Variety: Naidoo and Lionnet (2000) showed that cane variety has an effect on some constituents of cane juice. Table 2 shows the distribution of the main varieties on Reunion Island. It appears that R570, still by far the most important variety in the island, tends to be overtaken by the challenger R579 which is becoming more and more popular among growers, particularly on the eastern coast.

It was decided to focus on the comparison of the two main varieties: R570 and R579. Ten full trials were conducted representing 40 repetitions in all, analysed for both varieties investigated.

Other parameters

The following factors varied incidentally in the study. They may interfere with the results unintentionally and so were recorded thoroughly:

- Sample to press delay: due to the integration of our study in the normal operation of varietal selection, it was not always possible to obtain totally fresh cane. The precise delay was always known and recorded, which is not easy when trials are performed on the industrial scale with grower’s cane.
- Age of the cane was as close as possible to 12 months, but not always so, due to harvest constraint. This factor is precisely known and was recorded.
- Ratoon number was generally between 0 and 3. Low ratoon numbers were preferred, as they would permit the same trial to be followed for several years.

Protocol of operation

Each variety was planted in 2 or 3 rows, 10 metres long, (depending on the stage of selection) with 3 to 5 repetitions spread randomly on the field area. Each variety was sampled randomly as 10 upper parts and 10 bottom parts, which constitute 10 full virtual stalks. The samples were collected at the central laboratory of the CERF (La Bretagne), where they were chopped into small pieces (1–3 cm width), shredded in a Jeffco cutter-grinder, then 500 g of homogenous pulp was pressed in a Pinette Emideca press (60 seconds at 150 bars). The juice was then analysed for brix and pol for normal selection purposes, and the press cake was weighed. Another 1000 g of pulp was pressed in order to get enough juice to perform the special analysis necessary for the present study. This second press cake was weighed again in order to check the repeatability of the press operation.

The juice had 0.5 mL potassium mercuric iodide added and was immediately frozen in an alcohol bath at -25°C. A separate 100 mL was also frozen for lactic acid analyses, as both organic acids and sugars could not be analysed at the same time on the high performance liquid chromatography (HPLC) system. Preliminary tests showed that the protocol resulted in good conservation of juice for all the parameters analysed (with special care for deterioration indicators such as glucose and fructose, lactic acid, dextrins).

For analysis, 3 or 4 juice samples were thawed using a microwave oven.

Analysis protocol

- Brix: performed at 20°C with a Dür-S Schmidt & Haensch, after filtration of the juice on a Fioroni No. 2 filter paper.
- Polarisation: using a Polartronic Universal Schmidt & Haensch, at the conventional 589 nm wavelength, in a flow cell kept at 20°C by a water bath, after clarification with 1 g lead acetate for 100 mL juice, and filtration on Fioroni No. 2. Calculation of pol % juice (g%g) using Schmidt table.
- pH: direct reading on the juice at 20°C with a Consort C531 using a combined electrode.
- Sucrose, glucose, fructose and total polysaccharides: using a Waters Alliance HPLC system, equipped with a numeric pump and an automated sampler. Column: Waters Sugarpack, eluant: distilled water with 1% Ca2+. Detector: refractometer 410. The juice was previously filtered through Fioroni No. 2 filter paper, then diluted to 10% w/vol., and filtered on a 0.45 µm membrane. No internal standard was used, but a calibration curve using three different concentrations of the standard (sucrose, glucose and fructose, chromatographic quality) was performed each day. One standard was checked every 10 to 20 injections.
- The result reported as 'total polysaccharides' is the height of the peak seen just before sucrose and quoted as representing undifferentiated polysaccharides (Kolekar and Keskar, 1998).

| Table 2—Distribution of varieties (hectares) on the eastern coast of Reunion Island (source Centre Interprofessionel de la Canne et du Sucre). |
|---|---|---|---|---|---|---|
| Cultivated area (ha) | R570 | R573 | R575 | R577 | R579 | Others |
| % | 787 | 67.2 | 22 | 15 | 3621 | 138 |
| Total | 11675 |

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• Conductivity ash: this was performed on the press juice according to ICUMSA method GS 1/347/78-13 (1994), with a conductimeter Consort C531 at 20°C.

• Colour: this was analysed according to the method ICUMSA GS 1-7 (1994), the juice being diluted to 5° brix, filtered on a Sartorius 0.45µm cellulose nitrate membrane, adjusted to pH 7.00 ± 0.02. The absorbance reading was made at 420 nm and at 20°C on a spectrophotometer Milton Roy Spectronic 320 or Haake DR 4000.

• Starch: the quick and simple method proposed by Chavan et al. (1991) was slightly modified to take account of the individual juices colour.

• Dextrins: this was made according to ICUMSA GS 1-15 (1994) haze method.

The use of ethanol as an indicator of cane deterioration (Lionnet and Pillay, 1988) has been studied in previous work at the CERF (Bacci and Guichard, 1994; Eudes, 1994). It was found not to be applicable in Reunion due to very different harvesting methods. Burnt or green cane, chopped or wholesstalk cane produced ethanol at very different rates. However, we were conscious of the difficulty of finding a common indicator in such conditions.

Calculations

Fibre was expressed as a constant factor of cake weight. As the average fibre % cake was empirically measured to be 49%:

\[
\text{Fibre } \% \text{ cake} = F = 49 \times b
\]

where 'b' represents the ratio of bagasse (press cake):

\[
b = \text{cake weight/pulp weight}
\]

The percentage of extractible juice was calculated assuming a 25% ratio of brix free water:

\[
\% \text{ Extractible juice in cane} = 100 - 1.25 \times F
\]

Quality of extracted juice (analysed) and of extractible juice (derived)

Subsequent calculations assume that the quality of extractible juice is the same as that of the extracted juice. It must be said that this assumption may not be strictly correct. The solids kept inside the press cake are NOT in the same proportions as those that were extracted. Previous studies made at the CERF (Lebon, 1997) showed that non-sugars are extracted in different proportions, according to their localization in cane cells. For instance, for a press extracting about 85% of sucrose, only 50% of colour in cane is extracted, and almost 60% of ash. Glucose and fructose are the second best extracted constituents (about 70%). A complete study would have to look at the total constituents in the cane, by total extraction in a wet-disintegrator, but such a time consuming method was not possible in this particular study.

Tables 3a and 3b summarise the extraction of some non-sugars by the Emidecau press and by the old press of the CERF. The very wide standard deviation observed for ethanol data may be caused by evaporation of this volatile component during wet-disintegration.

As this study is operating on a comparative basis, we may assume that the higher the concentration of the constituent in the original cane sample, the higher its concentration in the extracted press juice. The results are thus comparable.

To relate the different analysed non-sugars with their impact on sugar processing, the following calculations were then made:

Purity: apparent purity (pol % brix) was used here.

Pol in extractible juice % cane, taking into account the assumption made, can be expressed as:

\[
R = \text{Pol } \% \text{ extracted juice } \times \text{ extractible juice } \% \text{ cane/100}
\]

This represents the pol extracted in mixed juice % cane.

Target purity of molasses: this calculation, assessed by the Sugar Milling Research Institute (SMRI) in South Africa (Smith, 1995), is generally used for final molasses. However, it can be used on juice, keeping in mind that the process will change the ash content (which should increase with lime or other additives) and the reducing sugars content (which is decreased by heat and chemical reactions).

**Target purity of molasses**

\[
M = 43.1 - 17.5 \times (1 - \exp(-0.74\times (\text{Glucose} + \text{Fructose})/\text{Ash}))
\]

### Table 3a—Extraction ratios for different components with the old press of the CERF (1997).

<table>
<thead>
<tr>
<th></th>
<th>Extracted juice</th>
<th>Brix</th>
<th>Pol</th>
<th>Non-Pol</th>
<th>Sucrose</th>
<th>Glucose</th>
<th>Fructose</th>
<th>Ethanol</th>
<th>Colour</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>71.8%</td>
<td>81.6%</td>
<td>83.4%</td>
<td>74.6%</td>
<td>85.7%</td>
<td>78.1%</td>
<td>72.2%</td>
<td>55.7%</td>
<td>55.3%</td>
<td>71.8%</td>
</tr>
<tr>
<td>Standard Dev.</td>
<td>2.41%</td>
<td>2.06%</td>
<td>2.31%</td>
<td>5.37%</td>
<td>5.83%</td>
<td>6.34%</td>
<td>11.70%</td>
<td>24.8%</td>
<td>5.95%</td>
<td>3.97%</td>
</tr>
<tr>
<td>Variation Coef.</td>
<td>3.4%</td>
<td>2.5%</td>
<td>2.8%</td>
<td>7.2%</td>
<td>4.5%</td>
<td>8.1%</td>
<td>16.2%</td>
<td>44.6%</td>
<td>10.7%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Number</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>

### Table 3b—Extraction ratios for different components with the Emidecau press (1998).

<table>
<thead>
<tr>
<th></th>
<th>Extracted juice</th>
<th>Brix</th>
<th>Pol</th>
<th>Non-Pol</th>
<th>Sucrose</th>
<th>Glucose</th>
<th>Fructose</th>
<th>Ethanol</th>
<th>Colour</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>70.6%</td>
<td>85.7%</td>
<td>88.8%</td>
<td>64.3%</td>
<td>88.2%</td>
<td>71.0%</td>
<td>73.4%</td>
<td>73.8%</td>
<td>66.7%</td>
<td>66.4%</td>
</tr>
<tr>
<td>Standard Dev.</td>
<td>4.32%</td>
<td>3.39%</td>
<td>3.53%</td>
<td>9.81%</td>
<td>3.84%</td>
<td>18.75%</td>
<td>17.28%</td>
<td>69.83%</td>
<td>25.85%</td>
<td>5.93%</td>
</tr>
<tr>
<td>Variation Coef.</td>
<td>6.1%</td>
<td>4.0%</td>
<td>4.0%</td>
<td>15%</td>
<td>4.4%</td>
<td>26%</td>
<td>24%</td>
<td>94%</td>
<td>39%</td>
<td>8.9%</td>
</tr>
<tr>
<td>Number</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>
Sugar yield and sugar lost in molasses

If J is the purity measured on the juice, according to SJM formula, sugar % cane (expressed as pol) should reasonably be approximated as:

Sugar yield = \( R \times \left( \frac{J - M}{J - (100 - M)} \right) \)

Therefore, assuming for this study that other industrial losses are negligible, molasses losses are obtained by:

Sugar lost in molasses % cane = \( R - \text{sugar yield % cane} \).

Results

For each of the parameters studied, a statistical test using the Analysis of Variance (ANOVA) technique was carried out in order to show varietal effects. The results are presented in Table 4.

Using the Student test, it is possible to test a value different from zero as hypothetical difference between two averages. For instance, it can be tested if the difference between average fibre of R570 and average fibre of R579 is equal to 1% (instead of classically 0). If the test is significant, that means that (according to the level of the test) not only the two averages are different, but also the difference is at least 1 point of fibre. The last column in Table 4 reports the maximum value having given a positive test for each significant parameter.

Cane variety seemed to have no significant effect on brix, purity and the concentration of lactic acid in the extracted juice. The other factors were statistically dependent on variety: the varietal effect was highly significant for pol % cane, fibre % cane and ash % brix, less important for colour, and weakly significant for reducing sugars % brix, polysaccharides and starch.

Fibre

The more highly significant effect of variety was found for fibre % cane. For each of the 40 trials (except one), fibre was higher for the R570 variety. This result is shown in Figure 1.

The maximum average difference (at 5% level) represents 1.35 units of fibre % cane. This quite high difference could be due to the fact that dry leaves fall easily from R579, whereas leaves of R570 adhere more tightly to the stalk.

Lactic acid

No significant link between varieties and the rate of formation of lactic acid was found. In fact, lactic acid is above all an indicator of degradation, so the important variations in the results were due to different deterioration time and conditions, even if all harvested cane was supposed to have been kept for a short time.

Dextrans

Very quickly, it was found that the method of analysis was unsatisfactory, specially in this case, where rather fresh cane was used, leading to incoherent and unusable results. Due to the time consuming and poor sensitivity of this method, it was decided not to use it anymore, and to wait for a better method.

Target purity of molasses

Variety was weakly statistically significant if the result of the whole season is considered. Nevertheless, the effect for part of the season was very important.

At the beginning of the season, varietal effect was very highly significant (level lower than 0.00001%).
During this part of the season, target purity was lower for R570 on each trial, as is visible on Figure 2. Then, at the end of the season, the trend seemed to be inverted. The effect of variety was no longer significant. In most cases, R570 appeared to have a better target purity.

The formula for the target purity of molasses is based on ash and reducing sugar concentrations. In fact, ash % cane is significantly higher for R570 for the whole season as was said previously; but the trend for reducing sugars, significantly higher for R579 at the beginning of the season, changes completely in the second period to become insignificant.

Figure 3 underlines the change of the curve of reducing sugar concentrations during the season.

Yield of sugar in the factory

It was found that the theoretical quantity of sugar produced by the process was statistically dependent on the variety.

On Figure 4, each trial is plotted with the result of sugar % cane of R579 versus R570 for each pair of tests. This is a visual way to see a significant difference between two paired experiments. This Figure shows that, in most cases, processing is able to produce more sugar from variety R579 than R570.

Other factors

Significant difference between the two varieties can also be found for colour, which is at least 1300 ICUMSA units higher for R579 in the tested conditions. Effect of variety on colour was also established.
recently by Naidoo and Lionnet (2000). Depending on the type of sugar produced by a factory (refined, raw, specialty), this might be considered as an advantage or a disadvantage.

Starch shows higher average for R579, whereas polysaccharides are lower. This should indicate a varietal effect on these factors; alternatively, it could be due to a quicker deterioration of R570, as it was previously found that polysaccharides will rise and starch will decrease as cane deteriorates (Kolekar and Keskar, 1998).

**Effect of other variables.**

The effect of location has been tested between La Mare and St Benoit, taking the average value for each trial (four repetitions for each variety): fibre % cane, ash % brix, brix % press juice have significantly higher contents in cane from La Mare compared to cane from St Benoit.

**Discussion**

This study shows two main results.

1. The difference of behaviour in the mill according to the period of the crop is evident: the R579 variety seems to be advantageous for the miller at the beginning of the season, as it ensures an easier extraction and better exhaustion of molasses. But this statement seems to be no longer valid at the end of the season. R570 should be considered rather as a variety for the early part of the season whereas R570 shows better results at the end of the crop.
Overall, R579 looks a preferable variety for the factory as the results generally show that more sugar is produced with this variety. The maximum average difference between R579 and R570, statistically significant at 5%, is 0.16 of sugar % cane. Considering that the mill crushes one million tonnes of cane per year, it could theoretically produce at least 1600 t sugar more, if using only R579. However, this should be verified with more experiments. Moreover, this study considers only sugar production, not fuel value of the cane or ethanol production with the molasses.

3. From the growers’ point of view, the higher pol content of R579 seems to keep on along the whole season. However, this reflects only the qualitative aspect and other agronomic factors such as field yield have not been investigated here.

Conclusion

This study shows another impact of cane variety, namely not only from the growers’ point of view (sugar content inside the cane) but also on the millers' (potential sugar yield). Previous work, like the establishment of molasses target purity by the SMRI, allows us to predict the behaviour of a specific cane during sugar processing and to compare the values of theoretical main losses and sugar yield. This reasoning could be extended to different comparisons (different crops, locations, varieties, etc) and may be incorporated in the breeding program as a further check before releasing a new variety, as it is made in the beet industry. Moreover, trends to modernise cane-breeding programs in order to consider more industrial conditions are being experimented in different countries (Jackson et al., 2000; Torres et al., 1999).

Acknowledgments

The authors owe much to Messrs S. Hoareau and J.L. Zoide who carried out most of the analytical work at the processing laboratory of the CERF. The whole team of Breeding Division of the CERF must also be warmly thanked for providing the samples of cane, sharing their press, and accepting nicely, if not mutely, the work imposed on their analytical program.

REFERENCES


COMPARING CANE VARIETIES FOR SOME FACTORS THAT AFFECT SUGAR PROCESSING

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Résumé

Les variétés de canne les plus populaires à la Réunion, ont été testées pour leur teneur en fibre, brix, pol, pH, saccharose, glucose, fructose, amidon, couleur, cendres et acide lactique. Les tests ont été conduits sur des échantillons provenant de différentes zones géographiques représentatives de différents climats et sols de l’île. Les résultats de la côte Est de l’île sont ici présentés et discutés, des propositions sont avancées afin de choisir la « meilleure » variété, aussi bien pour l’usinier que pour le planteur.
COMPARACIÓN DE VARIEDADES DE CAÑA SEGÚN ALGUNOS FACTORES QUE AFECTAN EL PROCESAMIENTO DEL AZÚCAR

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Resumen

Las variedades de caña más importantes que se cultivan en la isla de Reunión fueron evaluadas para fibra, brix, pol, pH, sacarosa, glucosa, fructosa, almidones, color, cenizas y ácido láctico.

Las evaluaciones fueron hechas en cañas de las diferentes regiones geográficas por clima y suelos que son representativas de las condiciones de la isla. Se discuten en este artículo los resultados de la costa este de la isla, y se hacen propuestas para escoger la “mejor” variedad, tanto para los agricultores como para el proceso en fábrica.

*Palabras claves:* Jugo de caña, desempeño industrial, pureza objetiva, rendimiento en azúcar.