THE EFFECT OF TWO LOUISIANA SOILS ON CANE JUICE QUALITY

Mary An Godshall*, Scott K. Spear, and Richard M. Johnson*****

* Sugar Processing Research Institute, New Orleans, LA.
**Center for Green Manufacturing, The University of Alabama, Tuscaloosa, AL
*** Southern Regional Research Center, ARS, USDA, New Orleans, LA

ABSTRACT

As part of ongoing investigations on the effect of various field practices on the quality of cane juice in Louisiana, we noted that cane juice color decreased significantly when soil was added to assess the effect of soil on cane juice quality. In a study of the 1999/00 crop in Louisiana, with addition of 5% and 10% soil to the cane juice, it was noted that polysaccharide was also removed, the first time this had been reported. These observations run contrary to expectations that soil will degrade the quality of cane juice. Raw juice from green cane, which had been topped, but still retained side leaves, was treated with 10% added soil. Two soils from the Louisiana cane growing area, Sharkey clay and Norwood silty clay loam were tested. The juice was treated for 30 minutes in a shaker either at room temperature (25°C) or heated (80°C). Changes in pH, color, total polysaccharide, ash and filtration rate were noted. Both soils decreased color and total polysaccharide and increased the filtration rate. pH and ash were not significantly changed.

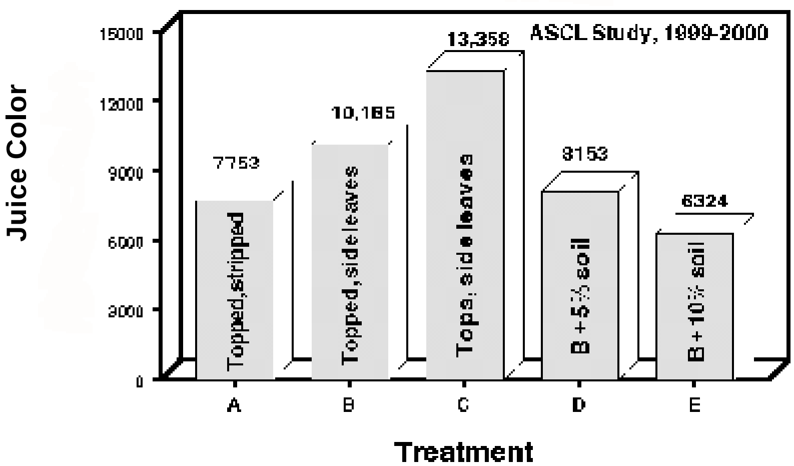
INTRODUCTION

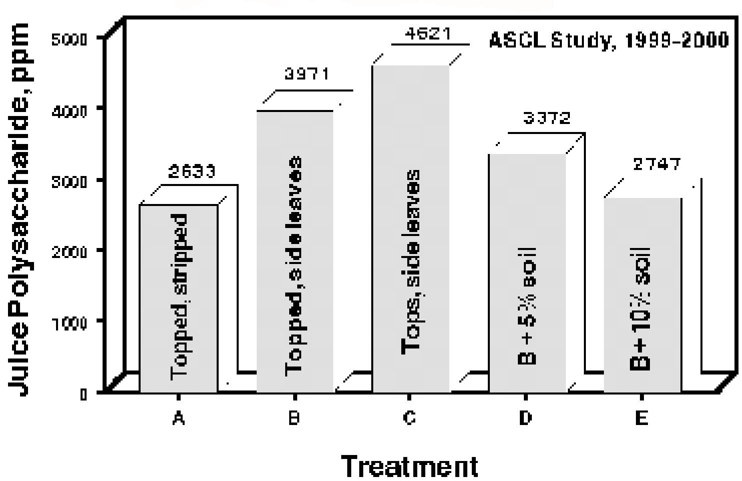
The goal of cane harvesting is to obtain the highest quality cane juice possible in order to facilitate production of raw sugar, and to obtain the highest yield, in order to maximize raw sugar production. The quality of cane juice is affected by many factors -- the variety and maturity of the cane, weather conditions, diseases, harvesting conditions, cut-to-crush delays, and the amount of trash incorporated into the crushed cane.

The 12th Edition of the Cane Sugar Handbook (Chen and Chou, 1993) defines field trash as leaves, tops, dead stalks, roots, soil, etc., delivered together with cane.

In South Africa (Chen, 1985) it was reported that for each 1% addition of tops to clean cane, the color of clear juice was increased by 1.3%, while with each 1% addition of mud to clean cane, the color of clear juice was increased by 3.6%. Purchase, *et al*., (1991) confirmed the deleterious effect of leafy trash on the color and turbidity of juice. Ivin and Doyle (1989) in Australia, documented the harmful effect of leafy trash on cane juice quality. Legendre, *et al*., (1996) showed a 1.6% decrease in raw juice color for each 1% added increment of a silty clay loam (Mhoon) from Louisiana, and a 13% increase in juice color for every 1% leafy cane trash added, up to the 10% level. When mixtures of leafy trash and soil were added to juice, the competing effects of the mud (removed color) and the leafy trash (added color) were clearly evident. Godshall, *et al*., (2000) studied the effects of various harvest practices in Louisiana on the color and polysaccharide concentration in cane juice. The presence of green leaves, especially tops, significantly increased both color and polysaccharides in cane juice.

Figures 1 and 2 show the results of a previously unpublished study conducted on samples for the American Sugar Cane League. Addition of 5% Sharkey clay to cane juice from topped cane with side leaves decreased color to the level of hand stripped clean cane juice. Addition of 10% Sharkey clay to the same juice decreased polysaccharide to the level of hand stripped clean cane juice, representing a decrease of 20% color and 30% polysaccharide.





Polysaccharides in Cane Juice

Polysaccharides are naturally present in milled cane juice. They include starch and soluble cell wall polysaccharides that are released when cane is crushed and the cells disrupted. Sugarcane polysaccharides are associated with high molecular weight color in cane juice, may increase viscosity, and contribute to increased color and turbidity in raw sugar. The levels of polysaccharides in cane juice range from 0.4-0.8% dissolved solids, with leaves and tops contributing to the higher levels (Godshall, *et al*., 2000). The concentration of polysaccharide in cane juice is also influenced by the cane variety, but not as much as whether or not green leaves are included in the crush.

Louisiana Soils

Sugarcane in mainly grown in the soil areas known as the Subtropical Mississippi Valley Alluvium, with the dominant soils being Sharkey, Mhoon and Commerce. Some cane is also grown in the extreme southern part of the Red River Valley Alluvium in Norwood soil. Commerce and Mhoon soils are friable silt loams and silty clay loams. Sharkey soil is clayey. The Sharkey series consists of very deep, poorly drained, very slowly permeable soils that formed in clayey alluvium. These soils are on flood plains and low terraces of the Mississippi River. Norwood soils occupy low natural levees at the highest elevations of the flood plains. The reddish-brown color of Norwood is a characteristic of the geological sediments of the Permian Red Bed deposits on the eastern slope of the Rocky Mountains which were carried into Louisiana by the Red and other rivers. Norwood is a silty loam soil (Lytle).

MATERIALS AND METHODS

Norwood (fine-silty, mixed, superactive, hyperthermic Fluventic Eutrudept) and Sharkey (very-fine, smectitic, thermic Chromic Epiaquerts) soils were provided by Chris Finger at the USDA Sugarcane Research Unit in Houma, Louisiana. The soils were washed and decanted of trash and dried and sieved (<2 mm) before using.

Raw cane juice consisted of 6 samples from green cane, topped, with side leaves, left on a heap for 1, 2 or 3 days (2 samples of each), provided by the American Sugar Cane League. Samples had been kept deep frozen prior to use and were microwave defrosted.

To test the effect of the soil, 5 g of soil was added to 50 ml of cane juice, then placed on a gyratory shaker for 30 min. Experiments were conducted at 25°C and 80°C. Treated juice was analyzed for pH, color, total polysaccharides (TPS), ash and filtration rate. Color and conductivity ash were measured using standard ICUMSA methods (ICUMSA 1998). Total polysaccharides were determined by the SPRI method (Roberts, 1980). Filtration rate was determined as ml cane juice that passed through a 47 mm diameter, 0.45µ pore-size membrane in 5 minutes, using vacuum at 30 in Hg, and reported as ml/min.

Soil chemical analysis was done by the Soil Testing Laboratory at Louisiana State University. Organic matter was determined by Walkley-Black wet oxidation (Nelson and Sommers, 1982), soil pH by a 1:1 soil:water ratio in deionized water, and ions were extracted with 1M ammonium acetate, pH 7.0, and analyzed by ICP. Soil texture was determined by the hydrometer method (Day 1965).

RESULTS AND DISCUSSION

Properties of the Soils

Tables 1a and 1b show the properties of the two soils under test. The cation exchange capacity (CEC) is the sum of the basic cations present on the soil matrix. It is used as an index of the total exchange capacity of the soil. The magnitude of the CEC is strongly correlated to the soil's content of clay and organic matter. The greater CEC for the Sharkey soil is associated with this soil's higher clay content and the predominance of smectite (principally montmorillonite) minerals in the clay fraction. Montmorillonite, and other smectite clay minerals, are expansible layer silicates. They possess a high CEC, large surface area and due to their ability to adsorb large quantities of water have a significant shrink-swell potential (Borchardt, 1977).

Table 1a. Chemical properties of Louisiana soils

Soil	pH	CEC* meq/100 g	P	Na	K	Ca	Mg
			mg/kg soil (ppm)				
Sharkey	6.0	30.5	162	68	325	4215	1007
Norwood	7.5	9.4	175	31	201	1307	269

Table 1b. Physical properties of Louisiana soils

Soil	Organic Matter, %	Sand, %	Silt, %	Clay,%	Texture & Color
Sharkey	0.51	28.5	22.2	49.3	Clay, brown
Norwood	0.98	46.8	39.6	13.6	Loam, red

*CEC = Cation Exchange Capacity.

Effect of Heat on Cane Juice

Table 2 reports the composition of the cane juice at room temperature, and Table 3 shows the composition of the juice after 30 min at 80°C. Heat decreased the juice color by 4.33% and total polysaccharide concentration by 6.05%. Ash increased 4.69% and filtration rate increased 14.9%. There was essentially no change in pH (0.02 pH unit decrease at 80°C). The data are summarized in Table 4.

Note should be made of the fact that the total polysaccharide concentration did not change during the 3 days the green cane stalks were on the heap. An earlier study had shown that whole, green stalks, piled in a small heap in cool weather remained stable for 3 days (Godshall, et al., 2000).

Table 2. Analytical results on cane juice before soil treatment. (Control, 25°C)

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.64	11,091	4717	2.72	0.98
G-36, 37 (Day 1)	5.68	9,281	5795	2.52	0.70
G-49, 50 (Day 2)	5.60	12,150	5688	2.69	0.78
G-51, 55 (Day 2)	5.66	9,372	5463	2.35	0.94
G-81, 83 (Day 3)	5.62	9,127	4814	2.51	0.95
G-82, 84 (Day 3)	5.50	9,752	5184	2.59	0.88
Mean	5.62	10,129	5277	2.56	0.87

ICU = ICUMSA Color Units
TPS = Total polysaccharide

Table 3. Analytical results on heated cane juice before soil treatment. (Control, 80°C, shaken 30 min)

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.41	11,170	4569	2.77	1.1
G-36, 37 (Day 1)	5.66	9,098	5474	2.66	0.74
G-49, 50 (Day 2)	5.58	11,015	5359	2.80	0.95
G-51, 55 (Day 2)	5.66	8,666	4796	2.50	1.0
G-81, 83 (Day 3)	5.62	9,072	4473	2.65	1.1
G-82, 84 (Day 3)	5.58	9,118	5076	2.67	1.1
Mean	5.59	9,690	4958	2.68	1.0

Table 4. Summary of cane juice, heated and not heated. (The effect of heat on cane juice.)

Sample	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
25°C	5.62	10,129	5277	2.56	0.87
80°C	5.59	9,690	4958	2.68	1.0

% change in heated	-0.53%	-4.33%	-6.05%	+4.69%	+14.9%

Effect of Soil on Cane Juice

Tables 5 and 6 report the effect of Sharkey clay on cane juice at 25°C and 80°C.

Table 5. Analytical results on cane juice after treatment at 25°C with Sharkey clay

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.67	10,222	4731	2.57	2.8
G-36, 37 (Day 1)	5.67	7,585	4012	2.34	1.8
G-49, 50 (Day 2)	5.62	10,080	4204	2.49	2.8
G-51, 55 (Day 2)	5.68	8,028	3780	2.35	2.4
G-81, 83 (Day 3)	5.62	7,726	3135	2.38	3.4
G-82, 84 (Day 3)	5.54	8,578	4019	2.44	2.8
Mean	5.63	8,703	3980	2.43	2.67

Table 6. Analytical results on cane juice after treatment at 80°C with Sharkey clay

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.56	10,139	3534	2.64	1.1
G-36, 37 (Day 1)	5.59	7,891	4531	2.53	0.74
G-49, 50 (Day 2)	5.52	10,254	4305	2.68	0.94
G-51, 55 (Day 2)	5.59	7,991	4014	2.44	1.1
G-81, 83 (Day 3)	5.53	9,420	3911	2.55	1.2
G-82, 84 (Day 3)	5.49	9,439	4188	2.59	1.1
Mean	5.55	9,189	4081	2.57	1.03

The effect of Sharkey on cane juice color in each sample at 80° C is shown in Figure 3 and on polysaccharides in Figure 4. In Figure 3, It is noted that samples 5 and 6 had a slight increase in color compared to the controls. Since this was cane juice from cane left on the heap row for 3 days, it is possible that changes in the type of colorant in the cane had occurred over that period of time. The same effect was noted with the Norwood soil on the day 3 samples. The removal of polysaccharides, however, was not affected in samples 5 and 6.

Figure 3. Effect of Sharkey Clay on Juice Color at 80 C

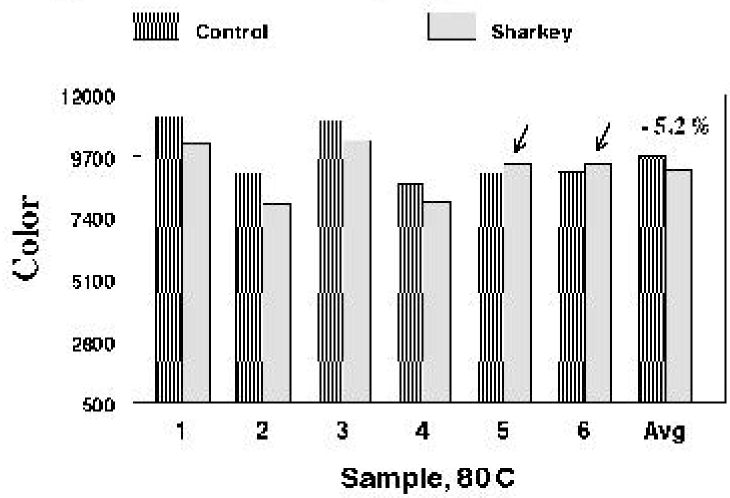
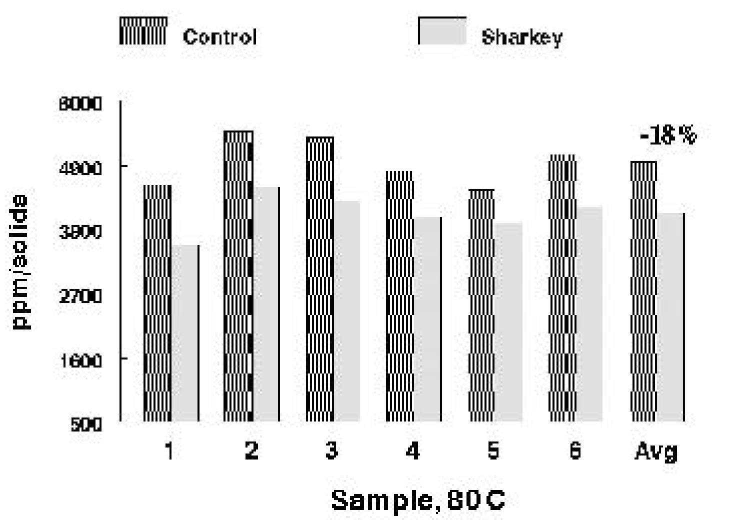


Figure 4. Effect of Sharkey Clay on Polysaccharides at 80 C



Tables 7 and 8 report the effect of Norwood on cane juice at 25°C and 80°C.

Table 7. Analytical results on cane juice after treatment at 25°C with Norwood clay loam

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.68	10,790	3911	2.71	1.2
G-36, 37 (Day 1)	5.86	8,488	4896	2.63	0.7
G-49, 50 (Day 2)	5.80	10,932	4587	2.77	1.0
G-51, 55 (Day 2)	5.85	8,459	4246	2.53	1.2
G-81, 83 (Day 3)	5.78	9,150	3810	2.60	1.3
G-82, 84 (Day 3)	5.74	9,887	4327	2.51	1.3
Mean	5.79	9,618	4296	2.63	1.1

Table 8. Analytical results on cane juice after treatment at 80°C with Norwood clay loam

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.51	10,828	3455	2.74	1.4
G-36, 37 (Day 1)	5.71	8,611	4509	2.61	1.0
G-49, 50 (Day 2)	5.65	10,415	4019	2.82	1.5
G-51, 55 (Day 2)	5.72	8,329	3888	2.51	1.4
G-81, 83 (Day 3)	5.61	9,173	3529	2.62	1.4
G-82, 84 (Day 3)	5.54	9,209	4063	2.68	1.4

Mean	5.62	9,428	3911	2.66	1.35

Table 9a compares the mean results of all treatments. Table 9b shows the percentage changes with soils treatment; comparisons are made for the same temperature of treatment.

Table 9a. Summary of means of treated and untreated samples

Treatment	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
Control, 25°C	5.62	10,129	5277	2.56	0.87
Control, 80°C	5.59	9,690	4958	2.68	1.0
Sharkey, 25°C	5.63	8,703	3980	2.43	2.67
Sharkey, 80°C	5.55	9,189	4081	2.57	1.03
Norwood, 25°C	5.79	9,618	4296	2.63	1.1
Norwood, 80°C	5.62	9,428	3911	2.66	1.35

Table 9b. Summary of changes in treated cane juice samples. Treatments are compared to untreated cane juice at their respective heating regime.

Treatment	pH	Color	TPS, ppm	Ash, %	Filtration rate (ml/min)
Sharkey, 25°C	+0.18%	-14.1%	-24.6%	-5.08%	+207%
Sharkey, 80°C	-0.72%	-5.2%	-17.7%	-4.10%	+3.0%

Norwood, 25°C	+3.02%	-5.0%	-18.6%	+2.73%	+26.4%
Norwood, 80°C	+0.54%	-2.7%	-21.1%	-0.75%	+35.0%

pH. pH showed no significant change for either soil or either temperature. There was a 3% increase in pH in the Norwood treated juice at 25°C.

Color. Sharkey clay removed 14.1% color at 25°C but only 5.2% at 80°C. Norwood removed 5.0% at 25°C and 2.7% at 80°C . Both soils take out more color at 25°C than at 80°C, indicating a release of color at the higher temperature. The higher color retention by Sharkey clay is a function of its higher ion exchange capacity for the charged colorants in cane juice. As previously stated, this retention is probably associated with the montmorillonite present in the clay fraction.

Total Polysaccharides. Both soils removed significant amounts of polysaccharides. Sharkey clay removed 24.6% polysaccharides at 25°C and 17.7% at 80°C . These results are similar to those previously encountered with the Sharkey clay (unpublished results mentioned in the Introduction). Norwood removed 18.6% at 25°C and 21.1% 80°C .

Ash. Sharkey clay gave a 4-5% decrease in ash, which was contrary to what might have been expected. Both soils had been washed, so ash solubilized from the soils was probably already removed. The decrease in ash caused by Sharkey clay may also be a function of the exchange capacity of the Sharkey clay. Whether these soils contribute to the ash load in juice in the field still needs to be investigated. Norwood clay loam caused a small increase of ash, 2.73% at 25°C and a very slight decrease of 0.75%, at 80°C.

Filtration rate. Norwood increased the filtration rate 26.4% at 25°C and 35.0% at 80°C. Sharkey clay doubled the filtration rate at 25°C (207%), but showed no change at 80°C. This result is probably anomalous, as many filtrations with Sharkey clay in cane juice had shown as much as a 10-fold increase in filtration rate at room temperature. However, with this series, the clay was allowed to settle for only a few minutes, and it is possible that the fines clogged the filter membrane. It should be noted that this filtration test is very stringent, as sample is filtered through a very tight medium of 0.45 µ, and a different filtration medium may show different results.

CONCLUSIONS

This study has shown that two soils, Norwood and Sharkey, found in the Louisiana cane growing area have the ability to remove a small amount of color and a significant amount of polysaccharide from cane juice, while improving filterability. At the same time, the ash level of the juice is not changed, or is slightly decreased, and there is no deleterious effect on pH. Sharkey soil, because of its clay content and greater ion exchange capacity, removes slighly more color, but both Norwood and Sharkey remove about the same amount of polysaccharide.

The larger color removal by Sharkey clay in earlier studies is attributed to the fact that the samples had stayed in contact with the soil over a long storage period prior to analysis, whereas the samples in the current study had been exposed to the soil for only 30 min. However, the removal of polysaccharides was not affected by storage.

These results are of interest because they are contrary to the reports from South Africa and Australia, which indicate large color increases in cane juice in the presence of soils.

This work is not intended to advocate or recommend bringing soil in with harvested cane. The cleaner the juice, the better in the long run. Soil has destructive effects on the mills, increases the burden to the clarifier, and contributes to disposal costs. The results are of considerable interest because they can help explain some anomalous behavior in cane juice quality when there is a lot of mud brought into the mill. It may be possible, in the future, to consider how to exploit the beneficial effects of the soils in the cane growing area of Louisiana.

REFERENCES

1. Chen, J.C.P., and Chou, C.C.. (1993) Cane Sugar Handbook, 12th Edition, John Wiley & Sons, Inc., New York, 55, 563, 886-903.

2. Chen, J.C.P. (1985) Meade-Chen Cane Sugar handbook, 11th Edition, John Wiley & Sons, Inc., New York, 59.

3. Day, P.R. (1965) Particle fractionation and particle-size analysis. Pages 545-567, *In* C.A. Black (ed.) Methods of Soil Analysis - Part 1. Agronomy Society of America, Inc., Madison, WI.

4. Fors, A., and Arias, R. (1997) The effects of trash components in factory performance. Sugar J., Dec. 1997, 25-26.

5. Godshall, M.A., Legendre, B.L., Richard, C., and Triche, R. (2000) Effect of harvest system on cane juice quality. Proc. Sugar Processing Research Conf., 222-236.

6. ICUMSA Methods, 1994/ First Supplement, 1998. Methods of the International Commission for Uniform Methods of Sugar Analysis, ICUMSA Publications, Norwich England. Method

GS1-7, Raw Sugar Solution Colour; Method GS1/3/4/7/8-13, Conductivity Ash in Raw Sugar.

7. Ivin, P.C., and Doyle, C.D. (1989) Some measurements on the effect of tops and trash on cane quality. Proc. Australian Soc. Sugar Cane Technol, 1-7.

8. Legendre, B.L., Godshall, M.A. and Miranda, X.M. (1996) A preliminary study on the effect of sugarcane leaves and mud on color in sugarcane juice. Proc. Sugar Processing Research Conf., 447-452.

9. Lytle, S.A. The morphological characteristics and relief relationships of representative soils in Louisiana. http://www.agctr.lsu.edu/hudnall/4058/32.pdf

10. Nelson, D.W. and L.E. Sommers. (1982) Total carbon, organic carbon and organic matter. Pages 539-577. *In* Methods of Soil Analysis. Agronomy No. 9, Part 2, American Society of Agronomy, Madison, WI

11. Purchase, B.S., Lionnet, G.R.E., Reid, M.J., Wienese, A., and DeBeer, A.G. (1991) Options for and implications of increasing the supply of bagasse by including tops in trash with cane. Proc. Sugar Processing Research Conf., 229-243.

12. Roberts, E.J. (1980) Estimation of the soluble polysaccharides in sugar: A rapid test for total polysaccharides. Proc. Technical Session Cane Sugar Refining Research, 130-133.