REFEREED PAPER

INVESTIGATION INTO THE HIGH ASH CONTENT IN MOLASSES AT NAKAMBALA, ZAMBIA

MUNSAMY SS

Zambia Sugar Plc, Nakambala Estate, P.O.Box 670240, Mazabuka, Zambia
smunsamy@Illovo.co.za

Abstract

The sucrose loss in molasses as a percentage of sucrose in cane ranges between 7-13% in the southern African sugar industry and is the highest of all the processing losses. It is well known in sugar technology that the mass of molasses is a function of the mass of non-sucrose in the cane juice and the sucrose content of the molasses is a function of the type of non-sucrose in the cane juice.

At Nakambala sugar factory in Zambia, about 30% of the molasses non-sucrose is made up of ash. The ash content of Nakambala molasses is on the high side compared to other factories in the southern African sugar industry. Detailed analyses of the molasses showed that potassium was the biggest contributor to the high ash content. Since potassium is not added in the sugar manufacturing process, the investigation turned to agricultural practices on the estate. Soil analyses showed that the soil was rich in potassium and this was confirmed by cane leaf analyses. Since potassium is an expensive component of fertiliser the reduction in potassium application will result in cost savings. Potassium in cane is also expressed as non-sucrose in cane and this affects the cane quality and the ERC % cane.

Keywords: ash in molasses, potassium in molasses, cane leaf analysis, soil analysis, effect of non-sucrose on molasses exhaustion, effect of ash on ERC

Introduction

Most sugar factories in Southern Africa send weekly molasses samples to the Sugar Milling Research Institute (SMRI) for analysis and calculation of the molasses exhaustion index called target purity difference (TPD). Ash content was one of many analyses performed on the molasses. Mathematically, it can be shown that for a given reducing sugar content increasing the ash content decreases the exhaustion of the molasses. Smith (1995) showed a relationship between target purity, reducing sugars and ash. Ash is part of the non-sucrose component of molasses, and it is well known in sugar technology that one part of non-sucrose makes around two parts of molasses. In the 2012 season, the Illovo Group factories averaged 1.97 tons molasses per ton of non-sucrose in juice. The sucrose loss in molasses expressed as a percentage of sucrose in cane ranged between 7.54-12.76% for these same factories. Sucrose loss in molasses is the single biggest processing loss in cane sugar factories. Understanding the non-sucrose components is a good starting point for decreasing sucrose losses in molasses.

The soluble ash content of Nakambala molasses is compared with other Illovo Group factory molasses in Table 1. The data was extracted from the SMRI molasses report (SASA week 40, 2011).

Table 1. Ash content of various sugar factory molasses in the Illovo Group, and the South African industry average.

Factory	% ash	% dry solids	Ash % dry solids
Nakambala	15.03	80.16	18.75
Ubombo	10.66	78.66	13.55
Dwangwa	12.85	80.12	16.04
Nchalo	15.23	77.46	19.66
Msolwa	10.51	77.44	13.58
Ruembe	10.95	76.64	14.29
Maragra	14.99	78.16	19.18
Sezela	13.38	77.89	17.18
Noodsberg	11.72	76.25	15.37
Eston	12.52	76.62	16.34
South African industry average	13.81	78.34	17.62

The ash % dry solids show a large variation, ranging from 13.55-19.66%. The Nakambala ash % dry solids was 1.13% higher than the South African sugar industry average and 5.2% higher than the lowest value of 13.55%. An investigation was carried out to determine the reasons for the high ash content in the Nakambala molasses.

Detailed analysis of Nakambala molasses

During the 2012 season, Nakambala composite molasses samples were sent to the SMRI for detailed analysis. The molasses was analysed for a large number of elements. Some of the important elements are shown in Table 2. The results are arithmetic averages of 14 composite samples. The results are compared with results reported by Davis and Schoonees (2006) for three South African mills across the 2004/05 season.

Table 2. The ash constituents of Nakambala molasses expressed as percentages.

Element	Nakambala average	Nakambala range	Davis and Schoonees range
Calcium	1.16	0.68 – 1.36	0.80 – 1.50
Magnesium	0.58	0.35 – 0.77	0.50 – 0.80
Potassium	5.00	4.44 – 5.38	2.80 – 4.80
Sodium	0.77	0.43 – 1.26	0.00 – 0.20
Phosphate	0.25	0.02 – 0.94	0.10 – 0.30
Sulphate	1.51	1.18 – 1.86	0.90 – 2.20
Chloride	1.17	1.00 – 1.38	1.40 – 4.20

It can be seen from Table 2 that the largest component of ash in molasses is potassium. The average potassium content of Nakambala molasses is at the higher end of the range reported by Davis and Schoonees (2006). The ash constituents of Nakambala molasses are expressed as percentages of sulphated ash in Table 3.

Table 3. Ash constituents of Nakambala molasses expressed as percentages of sulphated ash.

Element	% molasses	% sulphated ash
Sulphated ash	15.49	
Calcium	1.16	7.49
Magnesium	0.58	3.74
Potassium	5.00	32.28
Sodium	0.77	4.97
Phosphate	0.25	1.61
Sulphate	1.51	9.75
Chloride	1.17	7.55

Potassium, the largest component of sulphated ash, is not used in the manufacture of sugar. Only calcium in the form of calcium hydroxide (lime) is used in the factory. At the time of the molasses survey, the Nakambala factory was liming the clear juice to a pH of 6.8, the lower end of the recommended range. Any lower pH might result in sucrose inversion in the manufacturing process. Kingston (1982) found that the inorganic composition of first expressed juice at Rocky Point factory in Australia was significantly affected by soil potassium, magnesium, sodium, chlorine and electrical conductivity, but not by soil calcium. Whitbread *et al.* (2004) found that soil potassium was significantly and positively correlated with ash in juice and that soil cations up to a soil depth of 60 cm were significantly and positively correlated with their respective cations in the juice except for magnesium. It is clear that potassium in juice is related to potassium in the soil.

Nakambala soil survey

As part of a broader study to improve cane yields and to improve cane quality, a comprehensive soil mapping exercise was commissioned. The exercise involved digging a total of 1015 soil pits and sampling the soil profile at three different depths down to 900 mm below the surface. A large number of the soil samples showed high levels of potassium. The recommended potassium level is dependent on the clay content of the soil. About 70% of the Nakambala estate soils are classified as having an average clay content of 33%. The recommended potassium level for these soils is 150 ppm. The potassium contents, measured as K, of the soils sampled are given in Table 4.

Table 4. Potassium content of Nakambala soils with 33% clay content (70% of estate).

No of samples	Soil depth (mm)	Recommended value (ppm)	Highest value obtained (ppm)	Lowest value obtained (ppm)
462	0 – 300	150	743	186
166	300 – 600	150	513	154
163	600 – 900	150	417	167

Samples taken from the remaining soil profiles on the estate had potassium levels in the recommended range, and some even showed deficient levels.

Leaf analysis

High levels of potassium in the soil might not necessarily translate to high levels of potassium in the cane plant. A large number of leaf samples were sent for analysis. The potassium content, measured as K, of the leaf samples is shown in Table 5.

Table 5. Potassium (K) content of Nakambala cane leaves.

Number of samples	Recommended K value (%)	Highest K value obtained (%)	Lowest K value obtained (%)	Average K value of samples (%)	% samples below 1.05% K
221	1.05	2.26	1.07	1.46	0

The results in Table 5 show that all the samples returned potassium values above the recommended value. This indicates that the soil potassium was available to the cane plant and the plant was taking up luxury levels of potassium. It is not clear whether the high soil potassium levels are due to the inherent soil quality or due to over-application of potassium fertiliser in the past. It is interesting to note that Hughan and Booth (1966) found no growth response to potassium application in early sugarcane trials in the Nakambala area. This early study could indicate that the soil, even in 1963, had sufficient potassium and that additional potassium had no growth response. The Nakambala estate development started in 1964.

Effect of ash on estimated recoverable crystal (ERC) % cane

It is important to note that reference to ash in this paper refers to soluble ash, and will be reflected as non-sucrose. Insoluble ash, such as sand, will be included in the fibre % cane computation. Although both soluble and insoluble ash components affect ERC % cane, the effect of soluble ash is more severe. The ERC formula, as applied at Nakambala, is shown below, together with the inputs for 2012 season.

$$\text{ERC \% cane} = (a \times S) - (b \times NS) - (c \times F)$$

where S = sucrose % cane (14.68)
NS = non-sucrose % cane (2.62)
F = fibre % cane (13.86)
$a = 0.97384$
$b = 0.459401$
$c = 0.045245$
ERC % cane = 12.47

A good starting point for decreasing the ash component of non-sucrose will be decreasing the potassium content of the cane juice, since potassium constitutes 32% of the ash. Since no potassium is added in the factory, it must be assumed that all the potassium in the molasses came from the cane that was processed. A potassium balance can be constructed across the factory. Some of the potassium in the cane will leave the factory in the bagasse and some in the filter cake. A small amount will leave in the sugar produced. For the sake of simplicity, the potassium in the filter cake and in the sugar will be ignored in the potassium balance. An assumption is also made that the potassium in the expressed juice is proportional to the juice extraction. A simple potassium balance and its effect on the ERC % cane is shown in Table 6.

The effect of reducing the potassium in molasses from 5% to 3% is an increase in ERC % cane from 12.47 to 12.59%. It is very important to note that potassium is in ionic equilibrium with the other ash elements in the juice. A 2% decrease in potassium will, in all probability, bring about more than a 2% decrease in the ash content. However for the sake of simplicity and to demonstrate the effect rather than the absolute number, the calculation uses a 2% decrease in potassium as a 2% decrease in the ash content. The computation is shown in Table 6. The calculation makes an assumption that a decrease in non-sucrose % cane will show a corresponding increase in sucrose % cane.

Table 6. Potassium balance and its effect on estimated recoverable crystal (ERC) % cane for the 2012 season.

Tons cane processed	3 246 082
Tons molasses produced	130 996
ERC % cane	12.47
Tons potassium in molasses at 5%	6550
Tons potassium in cane adjusted to 95.15% extraction	6883
Tons potassium in molasses at 3%	3930
Tons potassium in molasses at 3% and adjusted for 95.15% extraction	4130
Difference in tons potassium in cane at 5% and 3%	2753
Original tons non-sucrose in cane	85 209
Adjusted tons non-sucrose in cane (85 209 – 2753)	82 456
Adjusted non-sucrose % cane	2.54
Original non-sucrose % cane	2.63
Difference in non-sucrose % cane	0.09
Original sucrose % cane	14.68
Adjusted sucrose % cane (14.68 + 0.09)	14.77
Adjusted ERC % cane (0.97384×14.77) – (0.459401× 2.54) – (0.045245 × 13.86)	12.59

Potassium in cane products

A large number of studies across the globe have shown that potassium is the main contributor to soluble ash in sugarcane products. Meyer and Wood (2001) state that potassium is the biggest ash constituent of cane juice, ranging between 30-50% of the ash in the juice. Naidoo and Lionnet (2000) showed that potassium accounts for approximately 26% of sulphated ash in cane juice. Irvine (1978) and Kingston (1982) stated that potassium is the dominant cation in cane juice. Whitbread *et al.* (2004) found that potassium was the dominant cation in Nchalo (Malawi) cane juice. Turner *et al.* (2002) showed that the potassium content of concentrated molasses stillage (CMS) could be as high as 38% of total ash. Davis and Schoonees (2006) showed that potassium content of molasses ranged between 2.4-4.8%. Day-Lewis (1993), in a survey of literature on ash components in molasses, found that the potassium concentration of molasses ranged between 3-6% m/m.

Conclusion and Recommendations

The major contributor to the high ash content in Nakambala final molasses was potassium. The potassium content of Nakambala molasses at 5% was on the high side. The high potassium content of the molasses was a result of soil composition on the estate. Soil analysis showed very high levels of potassium on about 70% of the estate soils. Cane leaf analyses showed potassium levels above the recommended levels in 100% of the samples. A simple potassium balance across the factory showed that reducing the potassium content of molasses from 5 to 3% increased the ERC % cane from 12.47 to 12.59%. However, it must be noted that this is a simplistic assumption. The actual effect of a 2% decrease in potassium on the ERC % cane might be higher, and the calculated ERC % cane might be higher than 12.59%.

The cane plant seems to be selective with absorbing the other ash elements in the soil but absorbs luxury levels of potassium where this nutrient is available. The ash content of final molasses is available on a weekly basis from the SMRI for participating factories in southern Africa and this information should be used to judge potassium levels in the cane. One can safely assume that potassium will be the major contributor to the ash content of molasses.

The Nakambala cane supply area uses about 4 200 tons of potassium fertiliser at USD 800 per ton. Should the potassium application be reduced by 40%, the potential saving would be USD 1.34 million, and a reduction of 60% would result in a saving of USD 2.02 million for the cane supply area.

One of the functions of potassium in the cane plant is to resist drought stress. Since cane stressing (drying off) is an important practice on irrigated estates, high levels of potassium in the cane might prevent proper drying off and negatively affect cane maturity. There is a good relationship between high ERC % cane and low moisture % cane.

The use of surplus molasses or distillery effluent (vinasse or CMS) as a fertiliser is well embraced in other parts of the world. Since the potassium in the molasses is passed into the vinasse or CMS during distillation, distillery effluent is a rich source of potassium. The potassium in the vinasse or CMS will replace the total potassium fertiliser requirement of the cane growing area at Nakambala. At the current potassium level in the molasses, the molasses has sufficient potassium to apply up to 234 kg K/ha across the cane supply area of 28 000 ha.

The effect of ash on final molasses exhaustion has been well researched and documented, and is possibly the most researched topic in the South African sugar industry. The actual gain in sugar production is difficult to quantify but the ERC formula is a good guide. If the potassium content of molasses was 3% instead of 5%, the factory would have produced an additional 3 895 tons sugar using the ERC formula. Other benefits of reduced non-sucrose, e.g increased factory capacity utilisation, have not been accounted for in this calculation. At the time of writing, Nakambala had surplus molasses, thus a decrease in molasses volume would not show a decrease in revenue.

Big sugar estates, operating outside of South Africa, should purchase and operate on-site laboratory equipment to conduct leaf analysis on a routine basis. South African growers are fortunate to have sophisticated facilities at the South African Sugarcane Research Institute (SASRI) that provide rapid turnaround times on soil and leaf analyses. The over-application of fertiliser is expensive and counterproductive. It is well known that over-application of nitrogen fertiliser can negatively affect the ERC % cane, and this investigation has shown that over-application of potassium can have the same effect. Meyer and Wood (2001) cautioned against the over application of fertiliser stating that it is not only wasteful but ‘expensive’ under the current quality based cane payment system.

It is very important to use correct parameters to measure agricultural performance. The use of tons cane per hectare might bring out the wrong behaviours of over-irrigation and overfertilisation. The performance measure should be tons ERC per hectare per annum. In the factory the use of the molasses exhaustion parameter, TPD, might take the focus away from the ash content of molasses since high ash gives a low TPD. The performance parameter should be sucrose lost in molasses.

It is very important to apply the correct amount of fertiliser, particularly potassium, on cane fields. The benefits of correct potassium application are numerous, and range from lower fertiliser costs to higher ERC % cane, higher sugar production and higher factory capacity utilisation. The knock-on effects of higher factory capacity utilisation are better positioning of the crushing season to take advantage of sucrose peaks, and a shorter season which will avoid harvesting during wet weather.

Acknowledgements

The assistance of the Nakambala agricultural staff is acknowledged.

REFERENCES

Davis SB and Schoonees BM (2006). The effect of some impurities on the target purity formulae. *Proc S Afr Sug Technol Ass* 80: 433-447.

Day-Lewis J (1993). The effect of individual ash constituents on molasses exhaustion – A literature survey. Technical Report No.1656, Sugar Milling Research Institute, Durban, South Africa. pp 1-10.

Hughan DS and Booth DRC (1966). Abnormal nitrogen requirements of sugar cane on the Montmorillonitic black clay soil of the Kafue Flats in Zambia. *Proc S Afr Sug Technol Ass* 40: 247-242.

Irvine JE (1978). Variations in non-sucrose solids in sugar cane. *Sug J* 41(5): 28-30.

Kingston G (1982). Ash in first expressed cane juice at Rocky Point – Factors affecting the inorganic composition of juice. *Proc Aust Soc Sug Cane Technol* 52: 11-17.

Meyer JH and Wood RA (2001). The effects of soil fertility and nutrition on sugarcane quality: A review. *Proc S Afr Sug Technol Ass* 75: 242-247.

Naidoo L and Lionnet GRE (2000). The effect of cane variety and other agricultural factors on juice composition. *Proc S Afr Sug Technol Ass* 74: 19-24.

Smith IA (1995). Exhaustibility of molasses with very low reducing sugar levels. *Proc S Afr Sug Technol Ass* 69: 163-165.

Turner PE, Meyer JH and King AC (2002). Field evaluation of concentrated molasses stillage as a nutrient source for sugarcane in Swaziland. *Proc S Afr Sug Technol Ass* 76: 61-70.

Whitbread M, Lionnet GRE, Meyer JH and Wood RA (2004). Ash and sugars in cane juice at Nchalo estate, Malawi: Relationship with inorganic constituents in soil. *Proc S Afr Sug Technol Ass* 78: 349-358.