AN INVESTIGATION INTO THE LOW POL FACTOR AND THE PURITY DIFFERENCE BETWEEN MIXED JUICE AND CANE (DAC) AT THE TRANSVAAL SUIKER BEPERK MALELANE FACTORY

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Abstract

Analyses carried out by the Cane Testing Service (CTS) laboratory at Malelane have in recent years shown a drop in purity from DAC (direct analysis of cane) to mixed juice. The pol factor (ratio of mill balance pol and DAC pol) has also been lower than the industry mean. Investigations have been undertaken over the past few years to identify and eliminate potential sources of the problem. Some of the key areas which were investigated are highlighted. These include laboratory audits, extraction plant operating strategy and design considerations. The effects of evaporation of DAC samples and sand removal have also been examined. While the final results indicate that the problem still remains the investigation has yielded positive results in other areas such as reduced retention times and better extraction.

Keywords: juice purity, low pol, DAC, Malelane

Introduction

This paper is based on the premises that:

- Mixed juice purity should be greater than DAC purity because the DAC sample preparation process extracts a greater quantity of impurities than the factory extraction plant and it is these impurities that depress the DAC purity.
- The pol factor should be 100 ± 0,5% because mass balance derived pol (mixed juice and bagasse combined) should equal DAC derived pol.

Present South African sugar industry agreements on circumstances relating to a reduction in the mixed juice minus DAC purity difference fall into two broad categories:

- where the reductions in purity difference are clearly associated with some observed incident which is known to lead to sucrose destruction. In such circumstances a sucrose adjustment is made to the mill balance sufficient to compensate for the decline in purity.
- where the reasons for the reduction in purity difference are unclear. Under this circumstance it will be necessary to investigate potential physical and chemical loss areas.

Only factors existing at Malelane that can impact on the latter condition are covered. No consideration is given to the DAC as a payment system or its effect on factory recoveries.

Historical

Weekly mass balance statistics at Malelane have shown a drop in purity from DAC to mixed juice in recent years. In addition, season average pol factors indicate a downward trend from the 1992-93 season. Statistics for Malelane versus the rest of the sugar industry for the past 10 years are illustrated in Figure 1(a) and 1(b).

In reviewing investigations carried out for the past five seasons it is apparent that several in-depth studies have been carried out, by the Cane Testing Service as well as by Transvaal Suiker Beperk (TSB), Malelane. A detailed internal TSB investigation was carried out in 1991 to try to quantify front end losses (Damms *et al.*, 1991).

The longer than normal retention time in the diffusers, and the large draught juice tank volumes were of concern since large losses could occur if adequate temperatures were not maintained. DAC samples and mixed juice (MJ) samples

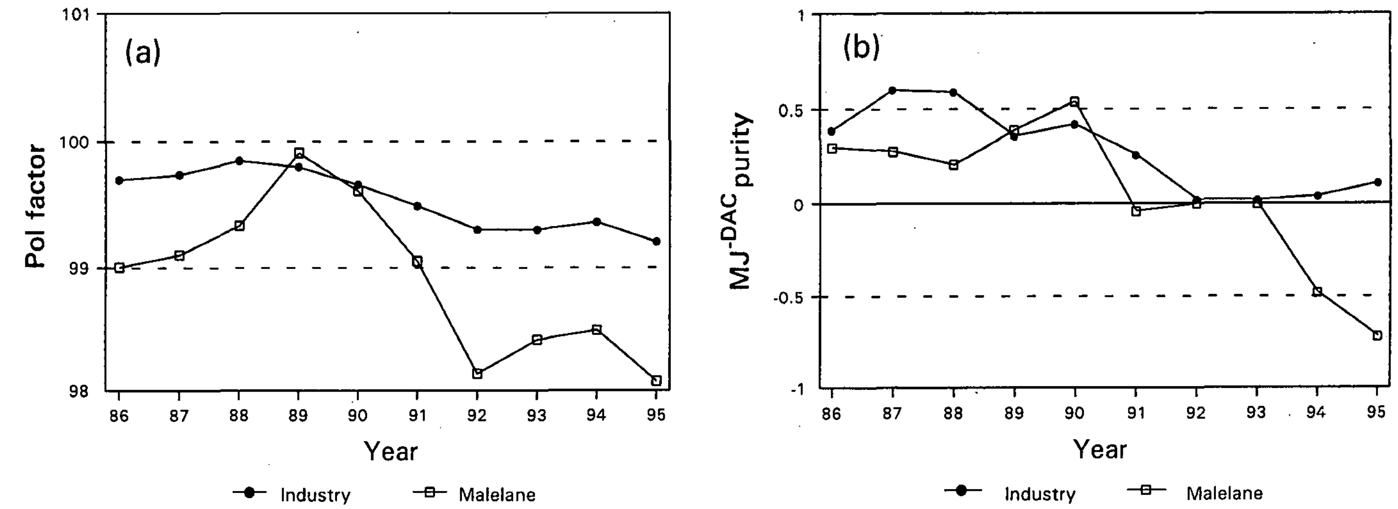

FIGURE 1: Mass Balance Statistics (10 Year Trend)

were analysed for glucose, fructose and lactic acid. The results of the tests indicated a maximum sucrose loss of 0,075%.

Intensive investigations conducted in 1992-93 into all facets of pol determination in both mill balance and DAC streams revealed no explanation for the low pol factor. In addition a linearity test was carried out on the mixed juice scale in September 1992, which showed the scale to be accurate (Bamber, 1992). The mixed juice scale was changed from a servo balans to a load cell design in July 1993 because of throughput and maintenance cost constraints. Normal assizing procedures were made and the scale performance was certified to the South African Sugar Association specification.

Windage at the mill shredder, coupled with the excessively dry atmospheric conditions and long conveyor belts, was then investigated as the basis for excessive moisture loss from the prepared cane. Such loss would give rise to an elevation in the DAC pol % cane and thus depress the pol factor. Tests were conducted by analysing cane samples taken before and after the mill shredder and there was a strong indication of an elevation in the DAC pol % cane between the shredder and the DAC sample hatch. Conversely, the moisture % cane showed a reduction. Results of these tests are given in Table 1. This preliminary work offers an explanation for a potential 0,3% drop in pol factor.

The low pol factor persisted during the 1994-95 season and Malelane mill management had made arrangements for the Sugar Milling Research Institute (SMRI) to inspect and advise on possible modifications to the shredder.

Table 1

Moisture drop across shredder (N=13) at Malelane mill

	Pol	Brix	Purity	Moisture	Fibre
Before shredder (B)	13,00	16,52	78,76	**69,20**	14,28
After shredder (A)	13,33	16,85	79,14	**68,86**	14,29
Difference (A-B)	0,33	0,33	0,39	**-0,34**	0,01
Standard deviation	0,26	0,32	1,13	**0,73**	0,88
Standard error	0,07	0,09	0,31	**0,20**	0,24

Shortly before the SMRI's planned visit to Malelane, the CTS arranged for a linearity test to be conducted on the mixed juice scale. This test entails progressively adding certified test masses to the scale's weigh hopper and at intervals comparing the mass indicated by the scale with the mass actually added to the scale. This is continued up to the scale's maximum capacity (ML 6000 kg). This test identified a nonlinear performance error of 0,87% which was eventually traced to distortion of the steel channels onto which the loadcells had been mounted as well as cracks in the loadcell mounting plates (Brokensha, 1995).

The investigations into the shredder design were postponed pending completion of the mixed juice scale investigation so as not to blur the pol factor trend immediately after the mixed juice scale repairs. Agreement was reached on an adjustment to the mass balance to compensate for the weighing error. The trend of low pol factors and high DAC to mixed juice purity drop continued to be a feature of the 1994-95 season. Shredder windage loss in moisture % cane was revisited in 1994 as part of the SMRI technical audit. The reasoning is that significant moisture loss could occur as a result of the wind tunnel effect created by the shredder and the covers over the discharge conveyor. This wind remains in contact with the shredder cane for about seven seconds prior to the CTS sample hatch. Data recorded by the SMRI and the calculated mass of water entrained by the air stream are shown in Appendix 1. The amount of moisture taken up by the air as a percentage of cane throughput was found to be 0,4%, and for higher ambient temperatures (40°C dry bulb and similar humidities) should be 0,5% on cane. The magnitudes of these figures are similar to those obtained during the evaporation loss trials discussed earlier. These experiments indicate that the loss in moisture in the cane preparation plant could affect the pol factor by 0,3 to 0,5%. This only partly accounts for the 1,5% pol factor discrepancy and therefore the management at TSB strengthened its resolve to determine the cause of the problem. In 1995-96 several investigations were undertaken which are discussed under the relevant headings. The investigations concentrated on potential loss areas which are illustrated in Table 2.

Table 2

Loss areas investigated

Stream	Factors investigated	Type of loss
Factory mass balance pol	Mixed juice scale accuracy Physical losses Sampling and analytical error Inversion losses Bio-degradation	Mechanical losses Mechanical losses Sampling and analytical error Retention time losses Microbiological losses
DAC pol	Road-weighbridge accuracy Sand/spillage removal Evaporation of DAC sample Analytical error	Mechanical losses Mechanical losses Sampling and analytical error Sampling and analytical error

Mechanical losses

Mixed juice scale

Linearity tests were carried out on the mixed juice scale at the start of the 1995-96 crushing season, and also midway through the season. Both tests showed the scale to be weighing accurately. During week No. 29 the weekly check mass tests did, however, show an error, and subsequently one load cell had to be replaced.

Road weighbridge

A mid-season additional weighbridge assizing was undertaken by SA Scale and, except for minor modifications, there was no evidence of weighing errors of any significance. Weekly routine checks between bridges are carried out as a standard practice to test the accuracy of the weighbridge.

Physical losses

Gland leaks on interstage pumps were treated as a high priority and repaired on an ongoing basis. As a long term strategy these pumps are being replaced with vertical spindle pumps to eliminate gland leaks completely. The draught juice and scalding juice tanks were drained and thoroughly cleaned on stop days. As a standard procedure the diffuser was emptied during long stoppages. Overflows from the diffuser draught juice and/or mill swirl tanks were strictly monitored and pumpings were returned to the diffuser.

Sand removal

The quantity of sand entering the factory appears to be on the increase. This is generally associated with the push-piling type of in-field loading practised in the Lowveld.

In order to evaluate the significance of this mass all spillage (mainly sand and some trash) from the cane yard is weighed prior to dumping onto the solid waste disposal site. The average sand loading for Malelane for the period weeks 22-38 was 0,7% on mass of cane.

Weekly statistics are given in Table 3. The mass of sand/spillage is surprisingly high for the unsophisticated sand removal system at Malelane. The effect of this sand removal accounts for a 0,7 drop in pol factor.

The explanation for this effect is that the DAC pol % cane is applied to a higher mass of cane than is actually the case. The difference in mass is equivalent to the sand/spillage removed.

Table 3

Tons sand and percentage spillage relative to tons cane received at Malelane mill over weeks 22 to 38, and rainfall (mm) for the same period

Week	Tons sand	Tons cane	% spillage	Rainfall (mm)
22	231	32 881	0,70	0
23	152	22 543	0,67	0
24	61	27 055	0,23	0
25	146	34 393	0,42	0
26	181	31 166	0,58	0
27	130	28 642	0,45	0
28	62	33 616	0,18	0
29	286	28 432	1,01	4
30	124	27 397	0,45	37
31	242	20 913	1,16	17
32	355	26 305	1,35	1
33	242	21 117	1,15	59
34	107	27 431	0,39	9
35	117	8 096	1,45	36
36	248.	29 555	0,84	0
37	243	18 263	1,33	24
38	278	32 968	0,84	0

Sampling and analytical errors

Laboratory audit

A laboratory audit was conducted by the SMRI on the CTS laboratory from 10 to 14 July 1995 (Simpson and Dunsmore, 1995). In general the audit was very favourable and confirmed that laboratory sampling and analytical techniques were sound. Furthermore, the auditors concluded that the problem with the low pol factor at Malelane was not in any way likely to be as a result of analytical error.

The following recommendations were made:

- Badly chipped end glasses on pol tubes to be replaced.
- Quartz plates to be stored at 20°C.
- Bagasse sampling in its present form (catch sampling using a scoop) is hazardous and could be biased.

Corrective action has been taken in the case of pol tubes and quartz plates. Bagasse sampling will be improved by the installation of a swing sampler in the coming season.

Inter laboratory comparison

As a further effort to determine analytical confidence, a three-way ring test was performed. DAC samples were collected and sub-sampled into three portions. These samples were analysed by the CTS laboratory, the TSB mill laboratory, and the SMRI. The results illustrated in Figure 2 confirmed that the CTS laboratory analytical practices are sound.

Statistical tests (t-tests) show that the purity differences are not significant at 95% confidence level.

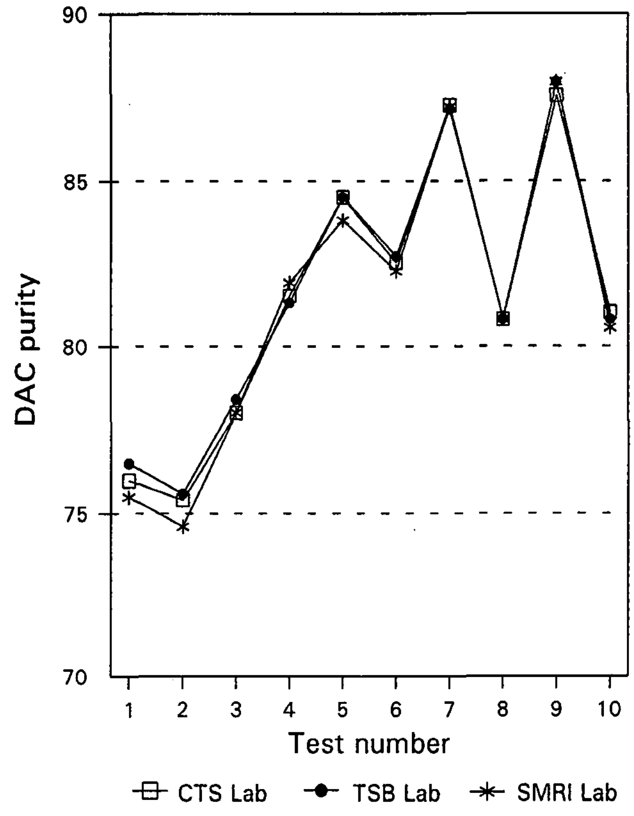

FIGURE 2: Ring Test (DAC Purity)

Microbiological losses

As part of the current survey to reduce sucrose losses, either by micro-biological activity and/or inversion, attention focused on juice retention times and temperatures within the diffusers and associated holding tanks. The first action involved reducing diffuser capacity from two units at 60% loading to a single unit at 100% capacity, ie 270 TCH in two units to 225 TCH in one unit. This was possible due to the reduced cane crop resulting from the prevailing drought conditions in the Lowveld.

Attention next focused on low diffuser temperatures. The course of action involved direct injection of vapour 1 steam into the mid-compartments of the diffuser to eliminate fluctuating temperatures resulting from the low Vapour 2 steam pressure being used for scalding juice heating. This ensured that temperatures were maintained at 80-85°C. The target set for operating staff is to maintain a temperature above 75°C at the discharge end of the diffuser.

Persistent flooding of the diffuser bed simultaneously accompanied by high juice tray levels has been a cause for concern for some time and operating personnel attributed this to excessive recycling. The first attempt at moving the juice distribution launders one metre towards the feed end of the diffuser made no appreciable impact on the above symptoms. The next step involved pumping the juice from its present two stages to three stages forward towards the feed end. Reduced flooding and empty terminal juice compartments were immediately evident. The spin-off of this improvement allowed the diffuser to perform at its design throughput of 225 TCH and 97,5 corrected reduced extraction (CRE) (pol extraction). This is illustrated in Figure 3.

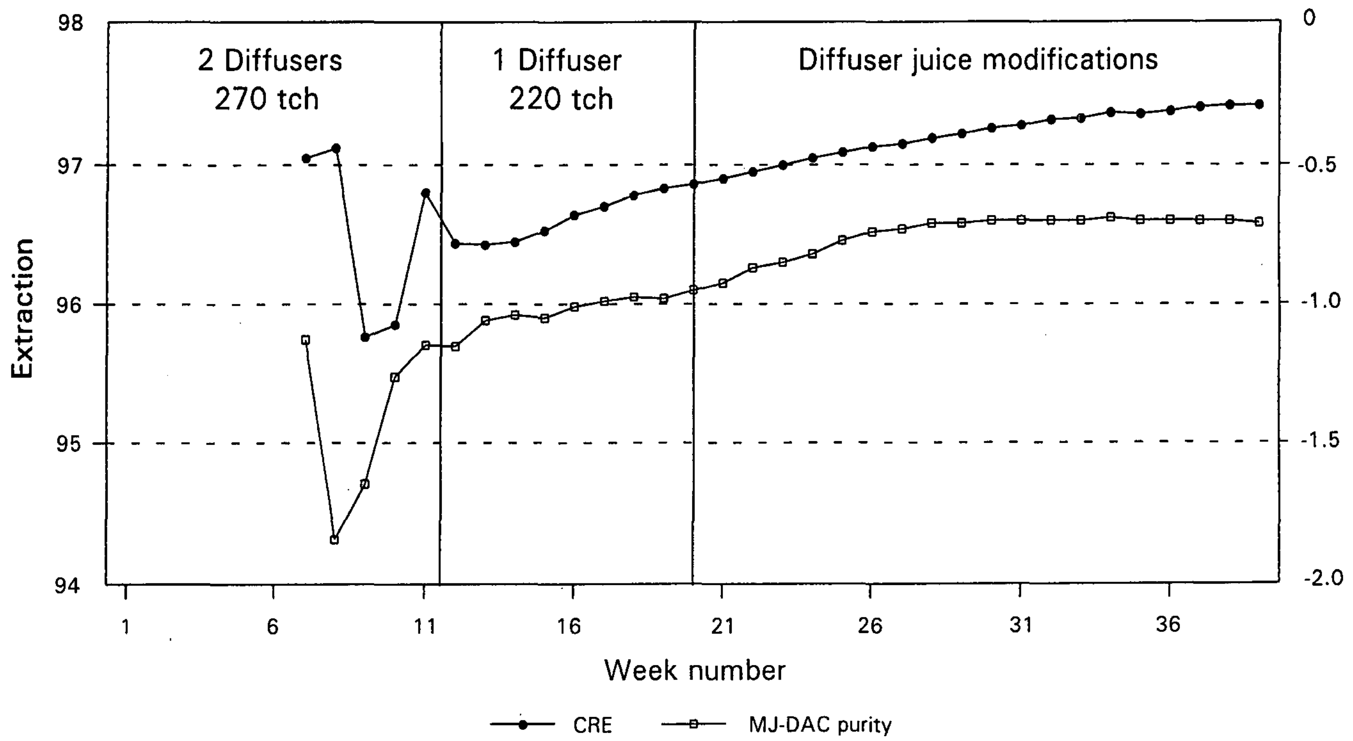

FIGURE 3: CRE and MJ – DAC Purity – TSB Malelane 1995

Experimental

To assess the benefits of these modifications a one week survey (31 July to 6 August) was undertaken to compare the pol, brix, glucose, fructose, sucrose and lactic acid levels in the following streams:

- mixed juice – sub-sample of hourly composite
- scalding juice – hourly catch sample
- diffuser stage 4 – hourly catch sample
- diffuser stage 12 – hourly catch sample
- press water – hourly catch sample.

The preservation and storage of juice samples was as per the South African Sugar Technologists' Association Laboratory Manual (Anon, 1993).

Table 4

Lactic acid (ppm on brix) results obtained in diffuser. Survey conducted over seven days at Malelane mill

Day	DAC	Stage 4	Press water	Stage 12	Scalding juice	Mixed juice
1	309				239	289
2	251	431	1 159	1 095	294	281
3	314	337	881	662	–	244
4	246	343	924	594	193	200
5	162	339	948	920	161	201
6	205	422	1 310	–	163	235
7	227	398	1 333	946	160	202
Average	245	378	1 093	835	202	236

Results and discussions

Most of the micro-organisms present in juice consume sucrose and are therefore responsible for sucrose loss. One of the products of microbiological activity is lactic acid. McMaster and Ravnö (1975) has shown that two parts of sucrose form one part of lactic acid. The lactic acid results are given in Table 4. A survey done by Mackrory *et al.* (1979) showed lactic acid values in MJ ranging from 240 to 370 ppm. A diffuser survey carried out by Lionnet (1989) showed an average of 220 ppm lactic acid in mixed juice. The value for Malelane mixed juice was 240 ppm, with the highest being 475 ppm. The results in Table 4 indicate no significant accumulation of lactic acid from DAC to MJ.

Table 5

Gravity purity results obtained in diffuser survey conducted over seven days at Malelane mill

Day	DAC	Stage 4	Press water	Stage 12	Scalding juice	Mixed juice
1	81,65				79,7	81,35
2	81,92	77,7	76,8	76,7	80,9	79,66
3	81,82	78,1	77,4	76,9	81,3	81,20
4	79,18	76,0	68,1	74,4	80,8	80,03
5	80,39	74,0	67,2	72,4	78,1	79,91
6	80,16	77,3	77,4	-	79,7	81,26
7	80,06	76,7	76,7	75,7	78,2	79,91
Average	80,7	76,6	73,9	75,2	79,8	80,5

There is, however, some build-up of lactic acid in press water. The press water is returned to stage 11 of the diffuser and this accounts for the increase in lactic acid at stage 12.

The temperature of the press water in the swirl tank is 55-60°C. This low temperature would encourage lactic acid producing bacterial activity. This prompted Malelane staff to embark on a biocide dosage programme whereby a thiocarbamate based biocide was routinely slug-dosed into the mill juice tray, diffuser sump and draught juice tank.

Table 6

Glucose and fructose results (on Bx) obtained in diffuser survey conducted over seven days at Malelane mill

Day	DAC	Stage 4	Press water	Stage 12	Scalding juice	Mixed juice
1	9,78				10,1	9,29
2	9,72	11,3	10,9	11,4	10,3	10,91
3	8,76	10,4	10,1	10,2	8,5	9,68
4	10,49	10,7	9,2	10,5	8,5	9,83
5	9,08	11,7	10,3	12,1	10,2	10,12
6	9,92	10,8	10,7	-	8,7	9,94
7	10,05	12,6	12,2	11,5	9,8	10,01
Average	9,7	11,3	10,6	11,1	9,4	10,0

The gravity purity results given in Table 5 indicate no significant difference in DAC and MJ purity. The reducing sugar results are given in Table 6. The total reducing sugars (on brix) in DAC and mixed juice are similar. These results indicate no abnormal loss of sucrose due to inversion. The findings of the one week diffuser survey indicate no significant loss of sucrose due to microbiological activity or by inversion (Moodley, 1995).

Retention time losses

Experimental

In order to estimate the juice residence time in the diffuser a tracer test was performed in October 1995 using lithium chloride as a tracer. During the test period mixed juice flow was held constant at 315 m^3/h and the level of draught juice was held at 50%. Samples were taken at four points (Figure 4) and analysed by the SMRI for lithium by atomic absorption spectrophotometry.

Discussion of tracer test results

Points A, B and D in Figure 4 represent juice from the diffuser's first three under-trays. Point C represents the total residence time in the diffuser and holding tanks. The results of this test (Davis, 1995) show a severe under-recovery of lithium (20% recovery), with broad peaks and long tails. Most of the recovered lithium emerged within 12-25 minutes but no definite conclusions regarding residence time could be drawn. The long tails indicate recycling.

The addition of the by-pass line (point D) from the diffuser first under-tray to the No. 2 draught juice tank has no doubt improved the situation over the previous configuration and is a pointer to by-passing of the No. 1 draught juice tank completely.

Conclusions

The work done at Malelane in recent years has indicated that the factors that influence the mass balance are very wide ranging. Although the past season's results indicate that the problem still persists, benefits such as reduced retention time and improved extraction have been realised. The results of the diffuser survey indicate no significant loss of sucrose due to microbiological activity or by inversion. The laboratory audit confirms that sampling and analytical practices are sound. The long retention times and re-cycling due to the large diffuser holding tank capacity predicates design changes to the diffuser scalding juice stage. The evaporation loss and effect of sand suggest a depressing of the pol factor, the effect of which can be in the magnitude of 1%. If Malelane's pol factor of 98,5 is corrected by this amount the revised factor is then within the industry accepted norm. This work therefore accounts for part of the discrepancy in the low pol factor and MJ-DAC purity difference at Malelane.

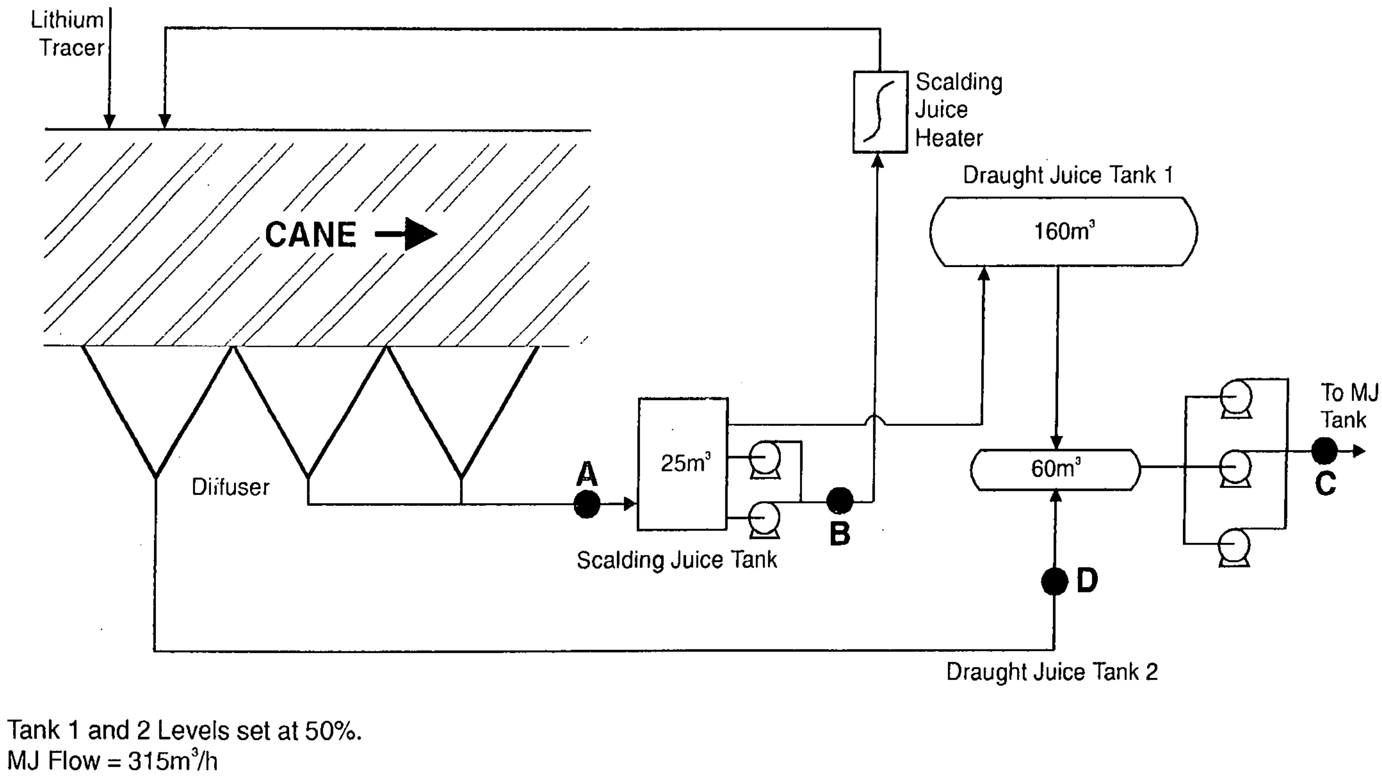

FIGURE 4: Diffuser Scalding Flow Sheet

The effect of the prolonged drought and its associated reduced throughput cannot be ignored. The step change in pol factor and mixed juice minus DAC purity difference in the past three years coincides with this occurrence.

Acknowledgments

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Appendix 1

(Extract from SMRI 1994 Audit Report)
Malelane shredder windage evaporation loss
Date: 19 November 1994 about 11h00

Ambient wet bulb temperature		23,5°C
Ambient dry bulb temperture		33,0°C
Wet bulb in air stream		38,0°C
Dry bulb in air stream		38,5°C
Measured duct area		1,18 m^2
Average wind velocity		4,8 m/s
Thus air flow	=	5,66 m^3/s
From psychometric data:		
Water content of ambient air		0,0163 kg/m^{-3}
Water content of air stream		0,050 kg/m^{-3}
Thus water taken up by air stream	=	566 (0,05 – 0,0163)
	=	0,191 kg/s
	=	687 kg/h
% on cane	=	0,4%
At 40°C dry bulb and same humidity		
Water taken up by air stream	=	900 kg/h
% on cane	=	0,5%