WASHING SUGAR IN BATCH A-CENTRIFUGALS

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Abstract

The washing of A-sugar in the baskets of batch A-centrifugals was studied at three factories. The level of various impurities in A-sugar was found to decrease linearly with the sugar purity, while crystal dissolution increased exponentially. At the minimum VHP sugar specification of 99,3 pol, about 3 per cent of the crystal was dissolved by the centrifugal washing.

No improvement in washing efficiency was obtained by the double wash operation and steam and water were found to be equal as a washing medium.

Introduction

Since the 1969/70 season the South African sugar industry has been producing VHP (very high pol) sugar with a minimum polarisation of 99,3°. This is achieved by fairly extensive washing of the sugar in the centrifugals which causes some crystal dissolution and additional sucrose re-cycling in the boiling house. This certainly has an adverse effect on the sucrose recovery, the magnitude of which is extremely difficult to quantify at this stage. This investigation into the A-centrifugal washing operations which was partly based on the work carried out by the Hawaiian Sugar Producers Association,[1] can be seen as the first step of an extensive technical evaluation of VHP sugar production.

Equipment

The investigation was carried out on batch A-centrifugals at DL (Broadbent 1220 mm × 762 mm, 1 500 rpm), UK (Western States 1372 mm × 1016 mm, 1 000 rpm) and UF (as UK). At each factory only one centrifugal in the station was used for the tests and was modified as follows:

DL and UK

(a) a quick opening 75 mm valve was fitted about halfway up the molasses casing,

(b) the molasses outlet pipe was modified so that the molasses could be isolated from the factory molasses and diverted to a separate container.

UF

Facilities as at (b) above already existed and a 50 mm pipe was fitted for the admission of steam into the basket.

The water and steam conditions at the three factories are given in Table 1 below. Water was measured by calibrating flow against time and steam by a pressure gauge on centrifugal steam washing line.

TABLE 1
Steam and Water Conditions in A-Centrifugals

	Water		Steam	
	Temperature (°C)	Spraying Rate (l s⁻¹)	Quality	Pressure (kPa g)
DL	75	0,30	exhaust	90
UK	104	1,08	exhaust	80
UF	104	1,08	V 1	40

Experimental Procedure

The investigation was carried out under factory conditions with the tests being repeated a number of times over many weeks of the 1982/83 season to ensure that the results would be representative of average industrial conditions. The investigation had two main objectives.

The first was to determine the amount of impurity removal and sugar crystal dissolution which take place when A-sugar is washed to different purity levels. The data were used to calculate an index representing the efficiency of the washing process at different sugar purities. The procedure consisted in using the quick-opening valve mentioned above to sample separately the pre-wash (green) and wash molasses. The A-sugar and molasses from the test machine were also sampled. The molasses samples were analysed for brix and pol and the A-sugar for pol, moisture, ash, reducing sugar, grain size and gums using the methods recommended by the South African Sugar Technologists Association.[2]

The amount of crystal dissolution was obtained by using the material balance relationships given in Appendix 1 and the washing efficiency index was calculated by differentiation as shown in Appendix II.

The second objective of the investigation was two-fold and consisted of assessing firstly the centrifugal performance with double washing as compared to the more commonly practised single wash and secondly the use of steam as a washing medium.

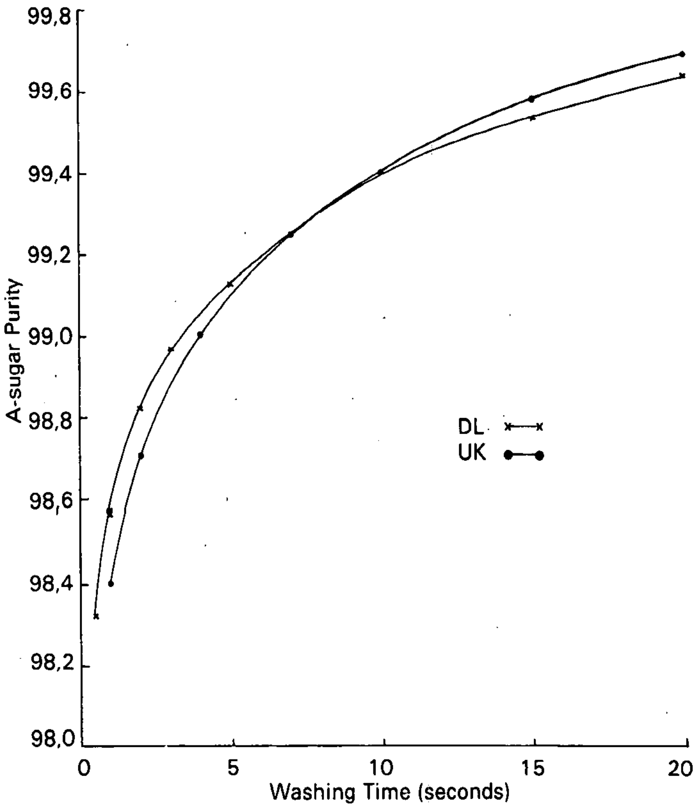

FIGURE 1 A-Sugar purity versus washing time.

Results

4.1. *A-Massecuite and Sugar Characteristics*

The average characteristics of the A-massecuite (at the feed to the centrifugals) and A-sugar at DL and UK during the period of the tests are shown in Table 2.

TABLE 2

Characteristics of A-Massecuite and A-Sugar at DL and UK

	DL	UK
A-massecuite °Brix	91,9	90,3
°Purity	85,1	86,2
Temp. °C	62	55
A-sugar - SGS (mm)	0,62	0,67
MA (mm)	0,74	0,80
C.V.	37	37

4.2 *A-Sugar Purity versus Washing Time*

The relationship between the A-Sugar purity (P_s) and the water spraying time in seconds (T_w) for DL and UK is illustrated in Figure 1. The equations to the two curves are:-

DL: $P_s = 98,57 + 0,36 \ln T_w$ (n = 17, r = 0,99)

UK: $P_s = 98,40 + 0,44 \ln T_w$ (n = 26, r = 0,82)

4.3 *The Removal of Impurities During the Washing Process*

Sugars of different purities were produced from the same massecuite by changing the water-spraying time. The content of reducing sugars, ash and gums in the A-sugar is shown in Figures 2 and 3 for DL and UK respectively. The relationship between the impurity content and the sugar purity was found to be linear, some typical equations being shown in Table 3.

TABLE 3

Regression Equations Between Impurity Content and Sugar Purity (P_s)

	DL	UK
Reducing sugars	% = 39,71 − 0,40 P_s (n = 5, r = 0,99)	% = 30,13 − 0,30 P_s (n = 6, r = 0,99)
Ash	% = 29,99 − 0,30 P_s (n = 5, r = 0,99)	% = 31,99 − 0,32 P_s (n = 6, r = 0,99)
Gums	ppm = 46518−460 P_s (n = 5, r = 0,98)	ppm = 45672−450 P_s (n = 6, r = 0,99)

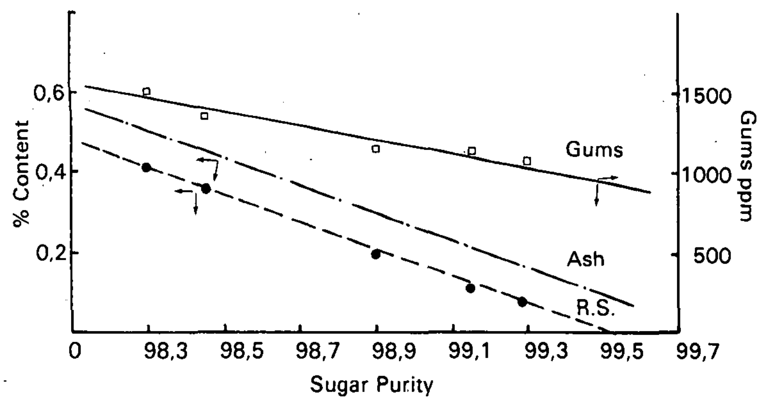

FIGURE 2 Impurity content of A-sugar at DL.

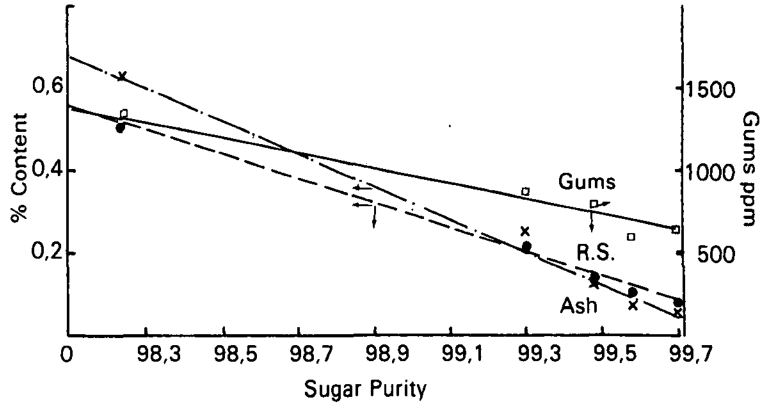

FIGURE 3 Impurity content of A-sugar at UK.

4.4 *Crystal Dissolution at Different A-Sugar Purities*

The amount of sugar crystal which is dissolved by the washing process when A-sugars of different purities were produced at DL and UK is graphically shown in Figure 4. (The % crystal dissolution (X_d) was calculated from the material balances of Appendix I).

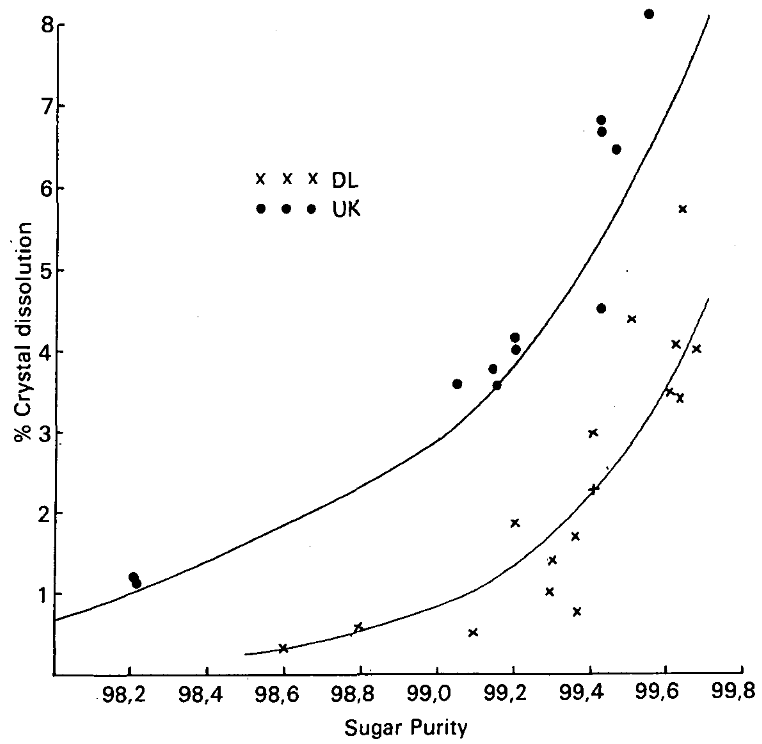

FIGURE 4 Crystal dissolution at different A-sugar purities.

The equations to the curves are:

DL: $\ln X_d = 2,452\ P_s - 242,90$ (n = 12, r = 0,93)

UK: $\ln X_d = 1,464\ P_s - 143,82$ (n = 12, r = 0,90)

The increase in A-molasses purity which accompanied the crystal dissolution when the A-sugar purity was improved by additional washing is shown in Figure 5.

4.5 *The Washing Efficiency Index at Different A-Sugar Purities*

The washing efficiency index is defined as the rate of impurity removal as a per cent of the rate of sucrose crystal dissolution at any given sugar purity level i.e.

Washing efficiency index =

$$\frac{\text{Rate of impurity removal}}{\text{Rate of crystal dissolution}} \times 100$$

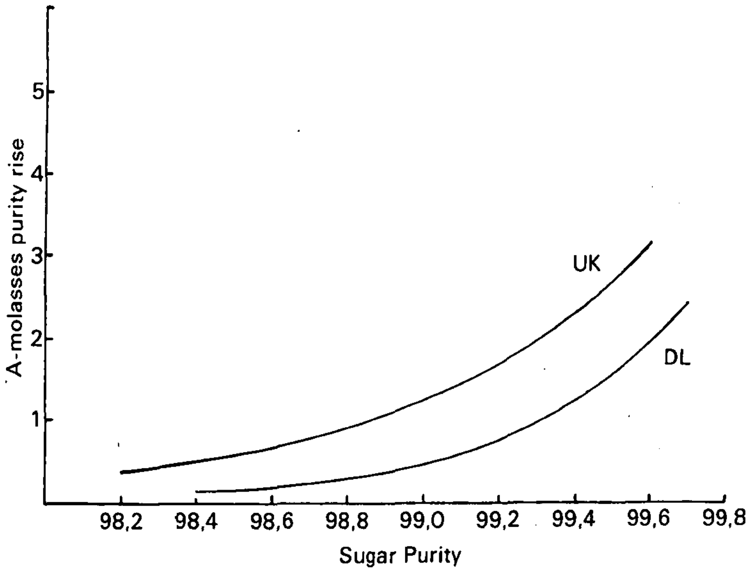

FIGURE 5 A-Molasses purity rise at different A-sugar purities.

For simplicity sake only the two most important impurities quantity-wise have been considered, namely reducing sugars and ash. The index was obtained by differentiating the equations given in 4.3 and 4.4 as shown in Appendix II and the results for DL and UK are illustrated in Figure 6.

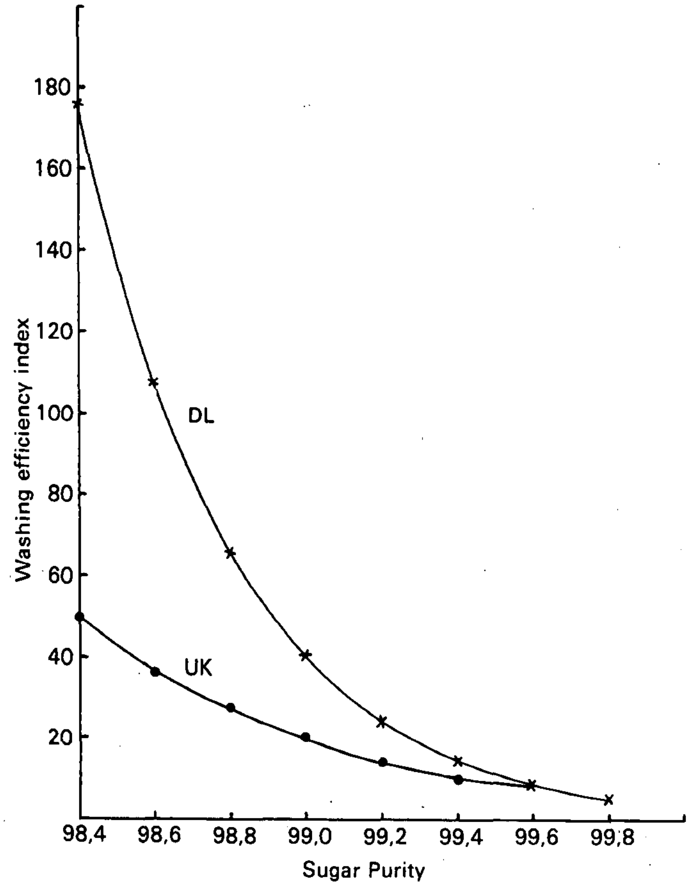

FIGURE 6 Washing efficiency index for DL and UK.

4.6 *Double versus Single Wash*

Two series of tests made up of 14 runs were carried out at DL. In part of the tests centrifugal cycles with 2 washes of 5 seconds each, 5 seconds apart, alternated with a single 10 second wash and in the others, 2 washes of 10 seconds each, 10 seconds apart, alternated with a single 20 second wash. The A-sugar and A-molasses results are summarised in Table 4.

TABLE 4

A-Sugar and A-Molasses Average Results for the Single and Double Wash Tests at DL

	Double Wash	Single Wash
A-sugar purity	99,45	99,46
A-molasses purity	66,43	65,63

The difference between the two washing methods on the centrifugal performance based on A-sugar and molasses purity was found to be statistically non-significant.

4.7 *Steam versus Water as a Washing Medium*

The investigation was carried out at UF. At DL and UK it was found that the quantity of steam added to the centrifugals was insufficient to cause any appreciable change in the sugar quality. The tests at UF were carried out by alternately running the centrifugal with and without steam addition over the full cycle at different wash water settings.

The correlation between the molasses purity rise (ΔP) and the A-sugar purity (P_s) for the two sets of conditions is

$\ln \Delta P = -237{,}76 + 2{,}3977\, P_s$ (n = 10, r = 0,98)

The curve is shown in Figure 7.

Both sets of data closely fit the curve and it can be concluded based on the molasses purity rise that there is no change in performance when steam is used to replace partly water as the washing medium.

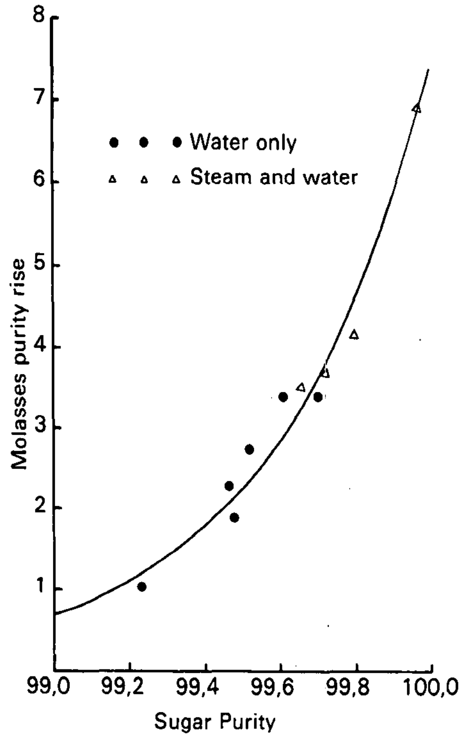

FIGURE 7 Molasses purity rise at UF using water only and steam and water as washing medium

Discussion

The factory investigations showed that under normal operating conditions an A-sugar of about 98,2° purity would be obtained from the centrifugals if no washing was done (see Figure 1). To obtain the minimum pol specifications for VHP sugar of 99,3° it was found that on average ten seconds of wash water spraying were required which corresponded to a water quantity of 0,8 and 1,1 per cent massecuite for DL and UK respectively. As is evident from the curve in Figure 1 the effect of the wash water on the sugar quality decreases as the sugar pol increases.

Ideally, in the sugar washing operation the film of molasses around the crystal should be removed without any crystal dissolution. This of course is not achieved under factory conditions and the amount of dissolved sugar crystal at different sugar purity levels is shown in Figure 2. The dissolution which is slow at the beginning of the washing process increases exponentially with the sugar purity. The amount of dissolution at UK was found to be more important than at DL and two main reasons can be put forward to explain the difference:

(a) the two-second pre-flushing of the basket at UK which dissolves away the washed sugar left over in the basket at the end of a cycle.

(b) UK used about 40 percent more wash water than DL.

From an examination of the UK curve of Figure 4 it can be concluded that the 1 per cent crystal dissolution already existing at 98,2° sugar purity (corresponding to the no wash condition) is probably caused by the pre-flushing. Excluding that 1 per cent dissolution for UK, the quantity of crystal which is dissolved by washing only to different sugar purity levels at DL and UK is given in Table 5 together with the corresponding rise in A-molasses purity across the centrifugal.

It was found that during the washing process the content of impurity in the A-sugar decreased linearly with the A-sugar purity (see Figures 3 and 4). This coupled to the exponential crystal dissolution relationship means that the washing efficiency index decreased exponentially, the index being defined here as the instantaneous rate of impurity removal as a percent of the rate of crystal dissolution. The washing efficiency index results are shown in Figure 6 and the DL results are summarised in Table 6, ignoring the UK results which were affected by the pre-flush dissolution of crystal.

TABLE 5

Crystal Dissolution and A-Molasses Purity Rise at Different A-Sugar Purities

A-Sugar Purity	% Total Crystal Dissolution		Molasses Purity Rise	
	DL	UK	DL	UK
98,9	0,7	1,6	0,4	0,7
99,4	2,3	4,2	1,2	2,3
99,6	3,7	6,0	2,0	3,2

TABLE 6

Washing Efficiency Index at Different Sugar Purities

A-Sugar Purity	Washing Efficiency Index
98,6	100
99,1	34
99,4	15
99,6	8

As is evident from the table, at high purity levels the removal of impurities from the A-sugar takes place at the expense of rather large amounts of crystal dissolution.

The use of double washing in the centrifugals, which theoretically should be superior to the more commonly practiced single wash, was found to be of no beneficial effect under factory conditions. Steam, when applied in sufficient quantities did improve the washing operations and could partly replace water as a washing medium. However no improvement in performance was evident when steam was used to partly replace water.

Conclusions

Under normal factory conditions between 2 and 4 per cent of the sugar crystal is dissolved by washing in the centrifugal when an A-sugar of 99,3° pol is produced. The corresponding molasses purity increase is 2 points or less.

As shown by the UK results the pre-flushing operations can account for a substantial amount of crystal dissolution.

Acknowledgements

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REFERENCES

1. Sloane, G. E. (1979). Material balance relationships in centrifugal washing. Hawaiian Sug. Tech. 38th Annual Congress, 151-163.
2. Anon. (1977). Laboratory Manual for South African Sugar Factories, S.A. Sugar Technologists Association.

APPENDIX I

Derivation of Crystal Dissolution by Material Balance Relationships

Nomenclature:

P_M = Purity of A-massecuite P_c = Purity of sugar crystal
P_s = Purity of A-sugar P_{mog} = Purity of green molasses
P_{mol} = Purity of A-molasses P_{mow} = Purity of wash molasses

1. Sugar crystal content % A-massecuite solids

$$= \frac{P_M - P_{mog}}{P_c - P_{mog}} \times 100$$

2. Mass of dissolved crystal % solids in wash molasses

$$= \frac{P_{mow} - P_{mog}}{P_c - P_{mog}} \times 100$$

3. Solids in wash molasses % solids in A-molasses

$$= \frac{P_{mol} - P_{mog}}{P_{mow} - P_{mog}} \times 100$$

4. Mass of dissolved crystal % solids in A-molasses

= (2) × (3)

$$= \frac{P_{mol} - P_{mog}}{P_c - P_{mog}} \times 100$$

5. Mass of solids in A-molasses % solids in A-massecuite

$$= \frac{P_s - P_M}{P_s - P_{mol}} \times 100$$

6. Mass of dissolved crystal % solids in A-massecuite

= (4) × (5)

$$= \frac{P_{mol} - P_{mog}}{P_c - P_{mog}} \times 10\,000 \times \frac{P_s - P_M}{P_s - P_{mol}}$$

7. Mass of dissolved crystal % sugar crystal content

= (6) ÷ (1)

$$= \frac{P_{mol} - P_{mog}}{P_M - P_{mog}} \times \frac{P_s - P_M}{P_s - P_{mol}} \times 100$$

APPENDIX II

Calculation of Washing Efficiency Index

Example: DL

The regression equation between the total reducing sugars and ash (impurity) content of A-sugar and its purity (P_s) is as follows (from Table 3):-

Impurity % sugar = 69,70 − 0,70 P_s . . . . (1)

To derive the washing efficiency index impurity % crystal is required. It is however considered that within experimental error, impurity % crystal can be equivalent to impurity % sugar.

From Section 4.4 the regression equation for per cent crystal dissolution (X_d) is

$\ln (X_d) = -242,90 + 2,452P_s$ . . . . (2)

By differentiating equations (1) and (2) with respect to P_s we obtain

$$\frac{d\ (\text{impurity}\ \%)}{d\ (P_s)} = -0,70$$

and

$$\frac{d\ (X_d)}{d\ (P_s)} = 2,452(e^{-242,90\ +\ 2,452P_s})$$

therefore

$$\frac{d\ (\text{impurity}\ \%)}{d(X_d)} = \frac{-0,70}{2,452e^{-242,90\ +\ 2,452P_s}}$$

= washing efficiency index

which gives the following results when values are substituted for P_s (see Figure 6).

P_s	98,4	98,6	98,8	99,0	99,2	99,4	99,6	99,8
W E index	176	108	66	41	25	15	9	6