SOME DOWNSTREAM EFFECTS RESULTING FROM DIFFUSION COMPARED WITH MILLING AS PUBLISHED BY THE SOUTH AFRICAN SUGAR INDUSTRY

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Introduction

The South African sugar industry can be regarded as mainly a diffusion industry with 76% of all cane now handled by diffusers. With the conversion from milling to diffusion, concerns were expressed that higher temperatures, imbibition levels and improved extraction in itself would result in various processing difficulties. Among these were expected clarification problems associated with the extraction of gums, waxes and starch and the production of more molasses due to non-sucrose extraction. The effect on sugar quality was another unknown.

Some downstream changes have occurred and been dealt with over the years, while others have not materialised to a significant degree. This review examines data published by the South African sugar industry over a five year period in an attempt to highlight some of the reported differences with respect to performance, extraction of non-sucrose and colour, and the effects on clarification and filtration.

Performance

Extraction

Over the last 10 years, industry records show that conversion to diffusers has created substantial performance gains in terms of extraction, corrected reduced extraction (CRE), and bagasse pol. During the reviewed five year period, the average sucrose extraction of diffusers was 97,85 versus 97,47 by the remaining milling trains. Assuming a boiling house recovery (BHR) of 76 is obtained with the marginal juice, the difference in extraction is estimated to be worth 6700 tons/season in additional sugar to the industry.

Improved performances of this magnitude and more are now seen as an expected norm in the industry, where over the years, new diffuser installations were usually justified on previous poor performance of old and inefficient milling trains. However in cases where efficient milling trains operate side by side with diffusers the performance difference is almost negligible and in achieving their higher extraction, diffusers have required an average of 46% more imbibition on fibre than the mills (Table 1).

Table 1

Performance and bagasse composition

	Diffusers	Mills	Diffusers - mills	Significance
Sucrose % cane	13,26	13,18	0,08	NS
Fibre % cane	15,12	15,19	−0,07	NS
Imbibition % fibre	390	344	46	S
Extraction	97,85	97,47	0,38	S
CRE	97,64	97,32	0,32	NS
Pol % bagasse	0,87	1,03	−0,16	
Moisture % bagasse	51,41	51,93	−0,52	NS
Gledhow extraction	97,92	98,09	−0,17	

Effect on overall recovery and sucrose balance

No statistically significant difference can be found between milling train and diffuser factories in overall recovery, despite the extraction advantage of diffuser factories. This is to be expected with the large disparity in cane quality and boiling house efficiency across the industry. A significant difference does exist in corrected reduced boiling house recovery (CRB), where diffuser factories are 0,5 unit higher, probably due to consistently lower cake losses. The other losses affecting CRB, [undetermined loss, target purity difference (TPD), non-sucrose ratio] are not significantly different (Table 2).

Table 2

Recovery results and indicators

	Diffusers	Mills	Diffusers - mills	Significance
Boiling house recovery	87,53	87,85	−0,32	No
Overall recovery	85,56	85,32	0,24	No
Corrected reduced boiling house recovery	86,53	86,01	0,52	Yes
Cake loss	0,23	0,42	−0,19	Yes
Undetermined loss	1,98	2,16	−0,18	No
Target purity difference (Mixed juice)	6,3	6,6	−0,3	No
Non-sucrose ratio	1,00	1,00	0,00	No
Mixed juice minus direct analysis of cane extract purity difference	0,14	0,71	−0,57	Yes
Lactic acid ppm on brix	380	540	−160	Yes

Extraction of non-sucrose

The possibility of extracting more non-sucrose in diffusion than milling, and thereby producing more molasses and undoing the sucrose extraction gains, has been a point which has been debated by technologists for some time.

According to Illovo Sugar's reported figures, a small, but significant difference does exist in molasses quantity per unit of non-sucrose in cane, diffusers producing 1,63 tons molasses compared with 1,55 tons from milling factories. Over the five year period, diffusers performed a non-sucrose extraction of 88,6% against 86,9% by milling trains, leaving behind residual juice of 48,8 and 49,9 purity respectively.

The amount of non-sucrose extraction per unit of sucrose extraction was 0,906 for diffusers and 0,891 for mills (Table 3). This apparent tendency by the diffusers towards higher non-sucrose extraction can probably be explained by the level at which sucrose extraction occurs rather than by any preferential selection of non-sucrose by the diffusers. In order to try to establish this from reported data, the same set of results were compared with a five year period (1981-86) when the average extraction of sucrose was 0,5 unit lower (see Table 4). In this comparison, the industrial rise in su-

Table 3

Extraction of non-sucrose

	Diffusers	Mills	Difference
Sucrose extraction	97,85	97,47	0,38
Brix extraction	96,32	95,76	0,56
Non-sucrose extraction	88,61	86,87	−1,74
Non-sucrose extraction per unit sucrose	0,906	0,891	0,015
Purity of residual juice	48,83	49,89	−1,1
Molasses % cane	4,07	3,86	0,21
Molasses non-sucrose in cane	1,63	1,55	0,08
Molasses non-sucrose in juice	1,84	1,79	0,05

Table 4

Extraction of non-sucrose due to improved sucrose extraction

	Diffusers	Mills	Industry
Sucrose extraction 1981-86	97,35	97,00	97,18
Sucrose extraction 1990-94	97,85	97,47	97,66
Improvement	0,50	0,47	0,48
Purity of residual juice 1981-86	52,55	51,45	52,00
Purity of residual juice 1990-94	48,83	50,67	49,36
Purity of marginal juice	78,2	61,9	70,3
Increase in brix extraction extraction	0,55	0,63	0,59
Increase in non-sucrose extraction	0,98	1,26	1,12

crose extraction of 0,48 unit resulted in change in non-sucrose extraction of 1,1 (86,6 to 87,7). Purity of residual juice dropped from 52 to 49,4, implying a purity of 70,3 for the marginally extracted juice.

Diffusers improved by 0,50 in sucrose extraction over the same period, lowering residual juice purity from 52,5 to 48,8, and increasing non-sucrose extraction by 1,0 unit, while mills showed a greater increase in non-sucrose extraction (+1,3) for a smaller (0,47) increment in sucrose extraction (see Figures 1 to 3).

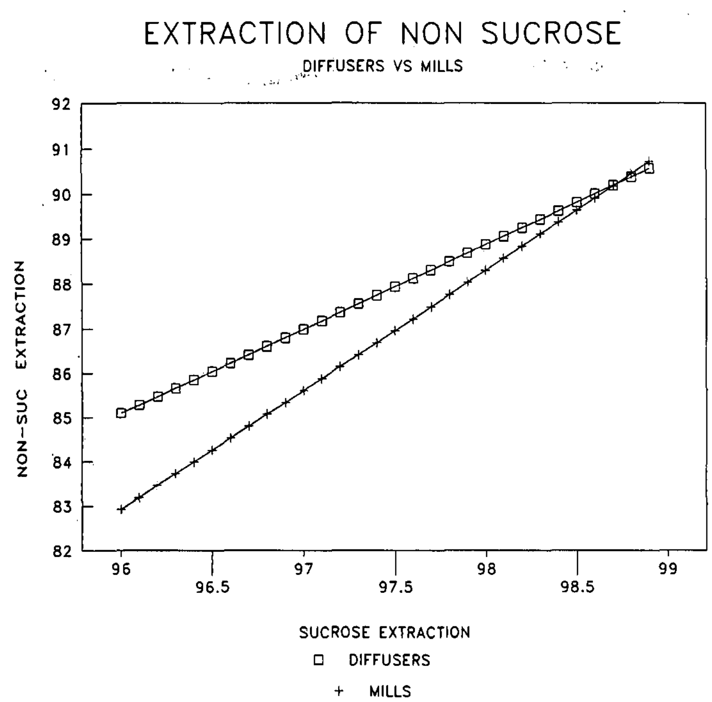

FIGURE 1

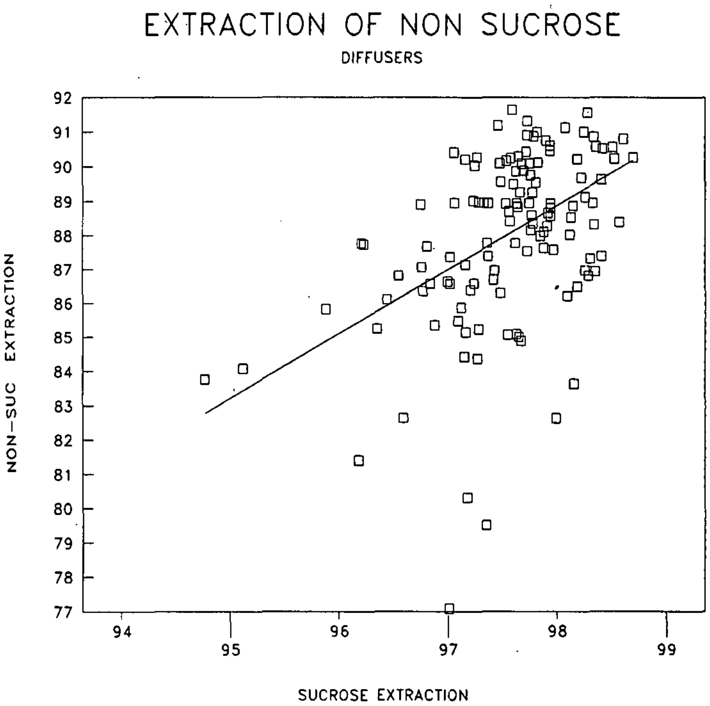

FIGURE 2

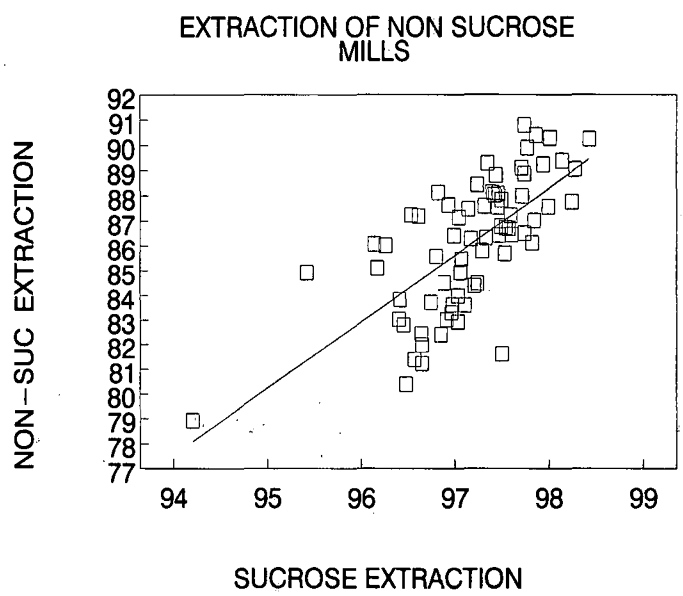

FIGURE 3

These results are dependent on routine analyses of highly diluted bagasse extract in which the margin for error must be fairly large, and should therefore be seen as an indication of non-sucrose extraction trends, rather than an absolute measure. It can, however, be said that from the available data, there is no reason to believe that diffusers extract preferentially more non-sucrose per unit of sucrose than mills.

Effects on clarification and the filter station

Due to the reduced suspended solids content of diffuser juice (0,22% compared with 0,75%) the most visible downstream effect seen at diffuser factories is the low quantity of cake and extent of mud filtration that is required. In coping with the smaller quantities of mud, various modifications and sizing changes have been made to juice preparation plants at diffuser factories mainly aimed at reducing residence time and consequently exposure to sucrose degradation.

For example: trayless clarifier mud boots have been reduced in volume by 60% and utilised Oliver filter screen area has dropped from around 0,7 m2/*tons cane per hours to 0,3m2*/tons cane per hour (S North-Coombes, personal communication). Mud mixers have been downsized proportionally.

More subtle differences have been reported regarding the quality of mud produced by diffuser factories, Lionnet (1983) measured the specific cake resistance of muds from diffusers and mills and found mud from milling factories to have a markedly lower specific resistance and therefore better filterability than diffuser mud. This could account for the proportionally high flocculant usage and the higher pol content, despite more washing, of diffuser cake.

An apparently significant difference is visible in the clear juice-filtrate purity drops where mills report 1,07 units compared with 1,98 for diffusers. However, with mills producing more than twice the quantity of filtrate as diffusers, there is a dilution effect to be taken into account and it is unlikely that diffusers are any worse off regarding sucrose inversion around the filters (Table 5).

Table 5

Effects on filter station

	Diffusers	Mills	Difference - mills
Suspended solids in mixed juice	0,22	0,75	−0,53
Cake % cane	2,4	5,6	−3,2
Sucrose loss in cake % sucrose in cane	0,23	0,42	−0,19
Pol % cake	1,22	0,96	0,26
Specific cake resistance	3,2	0,8	2,4
Filtrate % mixed juice	9,1	19,3	−10,2
Brix % filtrate	8,5	9,7	−1,2
Clear juice - filtrate purities	1,98	1,07	0,91
Flocculant used (ppm mixed juice)	3,9	4,4	−0,5
Bagacillo % cane	0,4	1,35	−0,95
Wash water % cake	128	104	23

Energy data

Energy value of bagasse produced

It is well known that diffuser beds tend to retain suspended mud solids, usually providing a clearer mixed juice as a result, while milling trains produce a muddier juice with less ash in the bagasse. This affects the colorific value of bagasse on the one hand while the presence of large quantities of mud in juice demand more bagacillo for mud filtration, effecting the quantity of bagasse available to burn. The nett effects, based on five year reported figures show that milling trains have an overall disadvantage, with kilojules available for steam production at 96% of that in diffusers (Table 6).

Relative evaporative requirements

The higher imbibition rates used in diffusers (390% compared with 344%) result in larger mixed juice quantities and lower brixes. This higher evaporator load is offset to a small extent by the increased dilution which takes place at the filter stations of milling train factories. Mills report an average filter wash index of 104,8 compared with 102,4 for diffusers.

Table 6

Energy value of bagasse

	Diffusers	Mills	Difference
Moisture % bagasse	51,41	51,93	−0,52
Ash % bagasse (calculated from ash % cane)	3,44	2,66	0,78
Brix % bagasse	1,75	2,04	−0,30
Lower calorific value: kJ/kg	6906	6942	−36
kg bagasse/ton fibre cane	2103	2066	37
kg bagasse, available for boilers	2076	1975	101
kJ/kg fibre in cane	14339	13710	628
Relative fuel value	100	96	4

Table 7

Relative evaporative requirements

	Diffusers	Mills	Difference
Imbibition % fibre	390	344	46
Imbibition per ton cane	0,571	0,485	0,09
Mixed juice % cane	127,5	120,7	7
Brix % mixed juice	11,96	12,58	−0,62
Filter wash index	102,4	104,8	−2
Wash water/ton cane	0,031	0,058	−0,028
Brix % evaporation feed	11,68	12,00	−0,32
kg water to evaporate/ton cane	1081	1045	35
Relative evaporation load	100	97	3

Water to be evaporated in order to produce 68 brix syrup has been calculated as 1050 kg/ton cane for diffusers compared with 987 kg/ton cane for mills, i.e. the evaporation requirement of mills is 94% of that of diffusers (Table 7).

Extraction of colour and sugar quality

A large amount of data has been published confirming higher juice, syrup, and sugar colours from diffusers. Very high pol (VHP) sugar delivered to the sugar terminal from diffuser factories during the five year period averaged 30% higher in whole sugar colour and 36% higher in affinated sugar colour. Starch levels were surprisingly 25% lower in diffuser factory sugar.

During 1993 various colour tests were done at Gledhow where the milling train and diffuser are fed by essentially the same cane. In this work an increase in colour from direct analysis of cane extracts to mixed juice of 90% was reported for the diffuser with only an 8% increase to milling train juice (N Kalidass, personal communication).

Experiences at Umzimkulu, which switched from milling to diffusion in 1991, have been a 30% increase in clear juice and syrup colour and approximately 50% increase in VHP and affinated sugar colour (L Bachan, personal communication). These results were probably exacerbated by the drought of 1993 (Table 8).

Process chemicals

Chemical usages tend mostly to vary from factory to factory according to specific needs such as final product specification and the process used as well as through geographic variations in cane quality, e.g. phosphoric acid is only added in the midlands.

Table 8

Colour and sugar quality

VHP sugar to terminal 1989 to 1994

	Diffusers	Mills	Diffusers - mills
Colour of whole sugar	1546	1191	355
Affinated sugar	845	618	227
Starch (ppm Bx)	124	165	−41
Gums (1989)	714	813	−99

Gledhow extraction plants 1993

	Diffusers	Mills	Diffusers - mills
Direct analysis of cane sample	42000	52000	−10000
Mixed juice	80000	56000	24000
% increase	90	8	82

UK factory : milling 1985 - 1990, diffuser 1991 to 1995

	Diffusers	Mills	Diffusers - mills
Clear juice	28100	21700	6400
Syrup	30000	22200	7800
VHP sugar	1900	1200	700
VHP affinated colour	1000	600	400

Table 9

Process chemicals

	Diffusers	Mills	Diffusers - mills
Flocculants (ppm mixed juice)	3,9	4,4	−1
Enzymes (ppm sugar)	12,5	7,3	5
kg lime as CaO per ton cane	683	667	17

Using only the meaningful data (refineries eliminated) there is no discernable differences between mills and diffusers in the use of lime, enzymes or flocculants, despite the known differences in juice quality and quantity (Table 9).

Conclusions

The use of diffusers in the South African sugar industry has produced the following downstream effects.

- Higher average extractions at a cost of increased imbibition application.
- A potentially higher boiling house recovery (BHR) is achievable for a standard juice purity due to lower cake losses.
- No preferential extraction of non-sucrose or production of additional molasses.
- No difference in the quantity of basic process chemicals.
- A reduction in capital plant requirements for clarifiers, mud filters, bagacillo separation and conveying.
- Fifty percent less clarifier mud, but with inferior filtration characteristics.
- A ± 30% increase in sugar colour.
- Four percent more energy in available bagasse.
- Six percent more evaporation work to produce syrup.

REFERENCES

Lionnet, GRE (1983). Investigations into mud and filtrate qualities. SMRI Technical Report. No. 1357.