CLARIFICATION AND THE NON POL RATIO: STATISTICAL ANALYSIS

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Abstract

It is shown by means of a statistical analysis of factory figures that the non-pol ratio is adversely affected by low phosphates in juice and overloading the clarifiers. The amount of ash going to molasses is shown to be a function of the non-pol ratio.

Introduction

The biggest sucrose losses in sugar factories usually occur in the final molasses. It results from the non sugars present in the molasses, and the effect is both quantitative and qualitative. The greater the amount of non sugars the more molasses is produced, and the greater the amount of ash the greater the proportion of sucrose in the molasses. It is therefore of the utmost importance to minimize the quantity of non-sugars and ash going to the molasses.

Non-sugars enter the boiling house with the mixed juice, and consist of the soluble non-sugars and insolubles in suspension. More non-sugars are added during liming and with other chemical additives such as flocculants and phosphate. In addition, non-sugars may be formed during the process as a result of the degradation of sucrose and reducing sugars.

The only part of the boiling house where non-sugars are removed is during clarification. A certain amount may also be removed from the process with undetermined losses such as entrainment and spillage. The remaining non-sugars leave in the sugar and in the molasses.

In this paper it is shown by means of a statistical analysis of figures from South African factories for the past six years that the amount of non-sugars and ash in the products is mainly a function of the clarification efficiency, and more specifically of the retention time in clarifiers, and of the phosphate content of the juice. All the factories considered use the simple defecation process.

The non-pol ratio

A measure of the efficiency of the removal or of the non formation of non-sugars in the factory is given by the non-sugars ratio which is expressed as follows :

$$\text{Non-sugars ratio} = \frac{\text{non-sugars in sugar and in molasses}}{\text{soluble non-sugars in mixed juice}}$$

This concept is similar to the non-sucrose ratio which was introduced to the South African sugar industry by Perk[6] in 1966.

However, calculation of the non-sugar ratio requires data on dry solids, sucrose and reducing sugars in mixed juice, sugar and molasses. When applied to factory conditions these data must be averaged over fairly long periods to minimize errors in stocktaking. In addition, for the statistical analysis to be meaningful, information must be obtained from many factories operating under widely different conditions.

In this country the sucrose and dry solids of mixed juice are not measured on a routine basis by factories, and the values given for reducing sugars in mixed juice are often incorrect as shown by Perk[7] and confirmed by work done at the Sugar Milling Research Institute. Because of the lack of suitable data it is therefore impossible to calculate an accurate non-sugar ratio.

Values of brix and pol, however, are available for all the factories and using these the non-pol ratio may be calculated where

$$\text{Non-pol ratio} = \frac{\text{non-pol in sugar and molasses}}{\text{non-pol in mixed juice}}$$

and the non-pol is the difference between brix and pol.

The non-pol ratio is of course not as accurate as the non-sugar ratio as a measure of the non-sugars balance during the process, because, apart from the differences between pol and sucrose and between brix and dry solids which are known to be variable, an error is introduced, for no distinction is made between reducing sugars and non-sugars. Thus in the context of this study any change in reducing sugars will appear as a change in non-sugars.

When applying the non-pol ratio as a measure of the clarification efficiency a further source of error is introduced by the formation of non-sugars between clarified juice and molasses, As a result the efficiency of clarification will appear to be less than it is.

Keeping this in mind it will be shown that the non-pol ratio may be used to indicate the trends in the non sugars balance during the clarification process.

Phosphates and clarification

The effect of phosphates in improving clarification has been recognized for many years. The precipitate formed is an amorphous calcium phosphate in which are entrapped and absorbed other non-sugars.

All the phosphate present in the juice is not available to form the precipitate, as tests done in Hawaii have shown that only about 90 percent forms a precipitate with lime. For old and deteriorated cane the amount reacting may be as low as 75 and 65 percent respectively[5].

The effect of available phosphate in mixed juice on the non-pol ratio is shown in Figure 1. This graph is based on the average monthly figures for Pongola and Sezela from 1976 to 1978 and for Gledhow during 1977 and 1978. The phosphate was measured by the colorimetric molybdate method[2]. All three factories have trayless clarifiers with a retention time based on mixed juice volumes varying between 35 and 50 minutes.

As can be seen the non-pol ratio shows an inverse relationship to the amount of phosphate in the mixed juice, increasing with decreasing phosphate content. The multiple correlation coefficients of the non-pol ratio against the phosphate content of the mixed juice, its brix and the residence time in the clarifiers is 0,69.

The concentration of phosphate in mixed juice depends not only on the amount that was originally present in the cane, but also on the quantity of imbibition water added at the extraction plant. For a given phosphate content in the cane, the phosphate concentration in the juice decreases as the imbibition rate is raised. Figure 2 shows the effect of

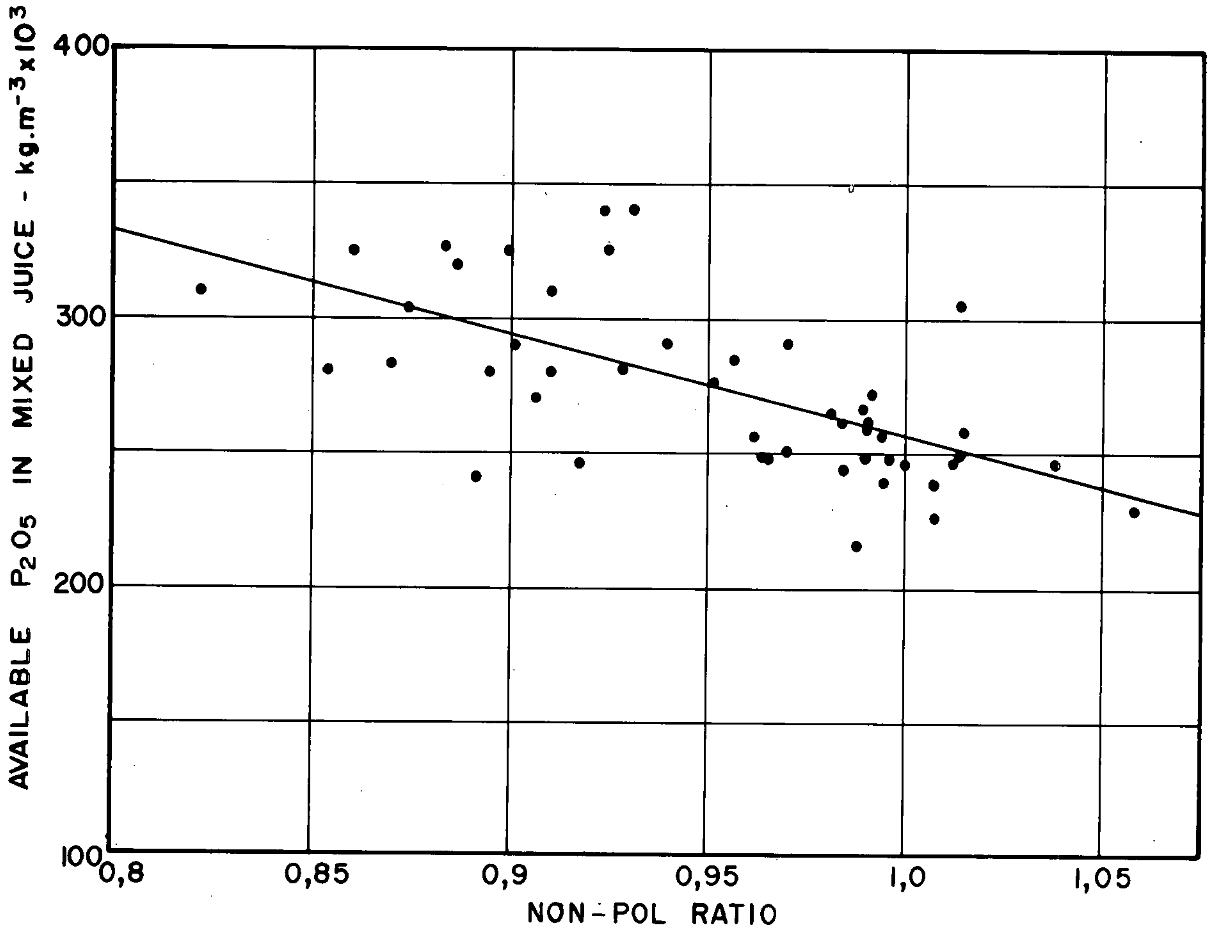

FIGURE 1 Effect of available phosphate content of mixed juice on non-pol ratio.

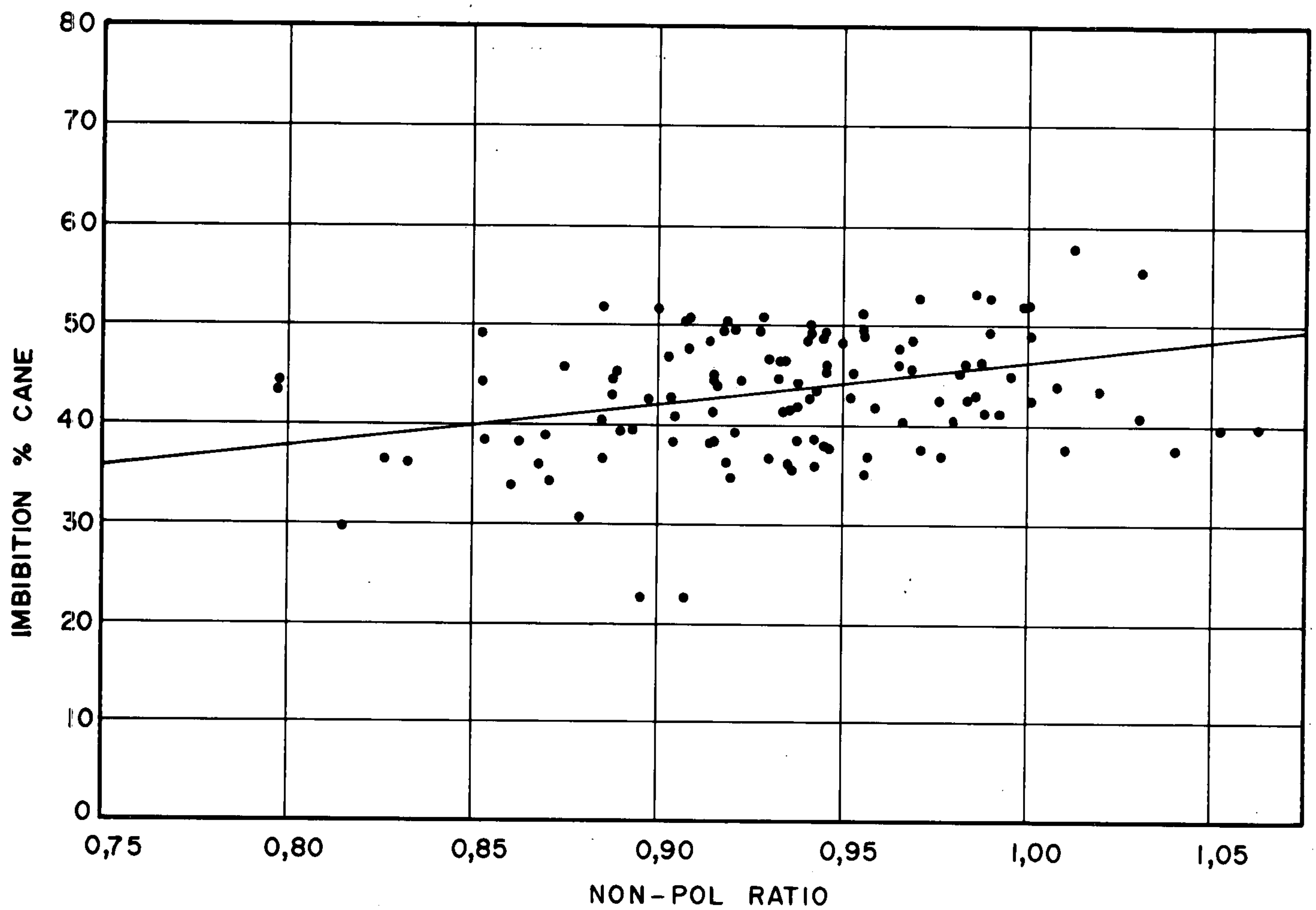

FIGURE 2 Rise in non-pol ratio with increased imbibition rates.

the imbibtion rate on the non-pol ratio. It is based on data from all factories between 1972 and 1978. It shows an increase in the non-pol ratio with the imbibition rate. It must be noted here that variations in the phosphate content of the cane and the effect of retention time in the clarifier increase the spread of the data. The concentration of phosphates in the juice fed to the clarifiers is also lowered by return of filtrate from the filters. Thus phosphate measurement should be done on the juice going to the clarifiers and not on mixed juice.

Residence time in clarifiers

All text books on cane sugar manufacture are vague with regard to the residence time required in clarifiers. According to Honig[5] a settling time of 1,5 hours is low, 2 to 2,5 hours is average and 3 hours is high. Hugot[4] gives a residence time of about 3 hours for Dorr Multifeed clarifiers and 1,5 to 3 hours for the Rapidorr depending on the juice quality. (Based on mixed juice volume and assuming a mixed juice per cent cane of 100).

For trayless clarifiers Hale and Whayman[3] give a residence time of between 50 and 35 minutes making the same assumptions as above.

It is not stated on what criteria the retention times in conventional clarifiers were based. Those for trayless clarifiers were based on turbidity of clarified juice.

The two usual yardsticks for assessing clarification efficiency are juice clarity and the rise in purity between mixed and clarified juice but to quote Honig[5] "The clarity of clarified juice is often considered a good indication of the effectiveness of clarification. This is not necessarily true. Quantitatively the amount of material that remains suspended in a turbid juice is small and turbidity represents only material in a limited range of particle size", and again "the most misleading if all figures determined in clarification studies is purity increase".

In this statistical analysis the residence time in clarifiers based on mixed juice volumes was plotted against the non-pol ratio. Filtrate returns and other recycles were not taken into consideration as this data was not available. Only data from factories which used the same clarifiers continuously during the year were used. Those that put additional clarifiers in service when clarification is difficult were not considered.

The results are shown in Figure 3. The clarifiers fall into two groups : the trayless type and the conventional type. In both cases there is an increase in non-pol ratio with a decrease in residence time showing that there is a decrease in efficiency with shorter residence time. In the case of conventional clarifiers the average non-pol ratio for a settling time of 3 hours is 0,91 and it is 0,96 for 2 hours. The precision of the data is not good enough to detect a difference in efficiency between the five types of clarifiers considered or between the clarifiers with modified juice outlets and the others. The correlation coefficient is 0,53.

The data for trayless clarifiers do not cover a sufficient range of residence times for definite conclusions to be reached as regards the relation between non-pol ratio and residence time, but the drop in efficiency appears to be rapid between 45 and 30 minutes.

Factories with high P_2O_5 content probably lie at the bottom part of the curves and those with low phosphate at the upper

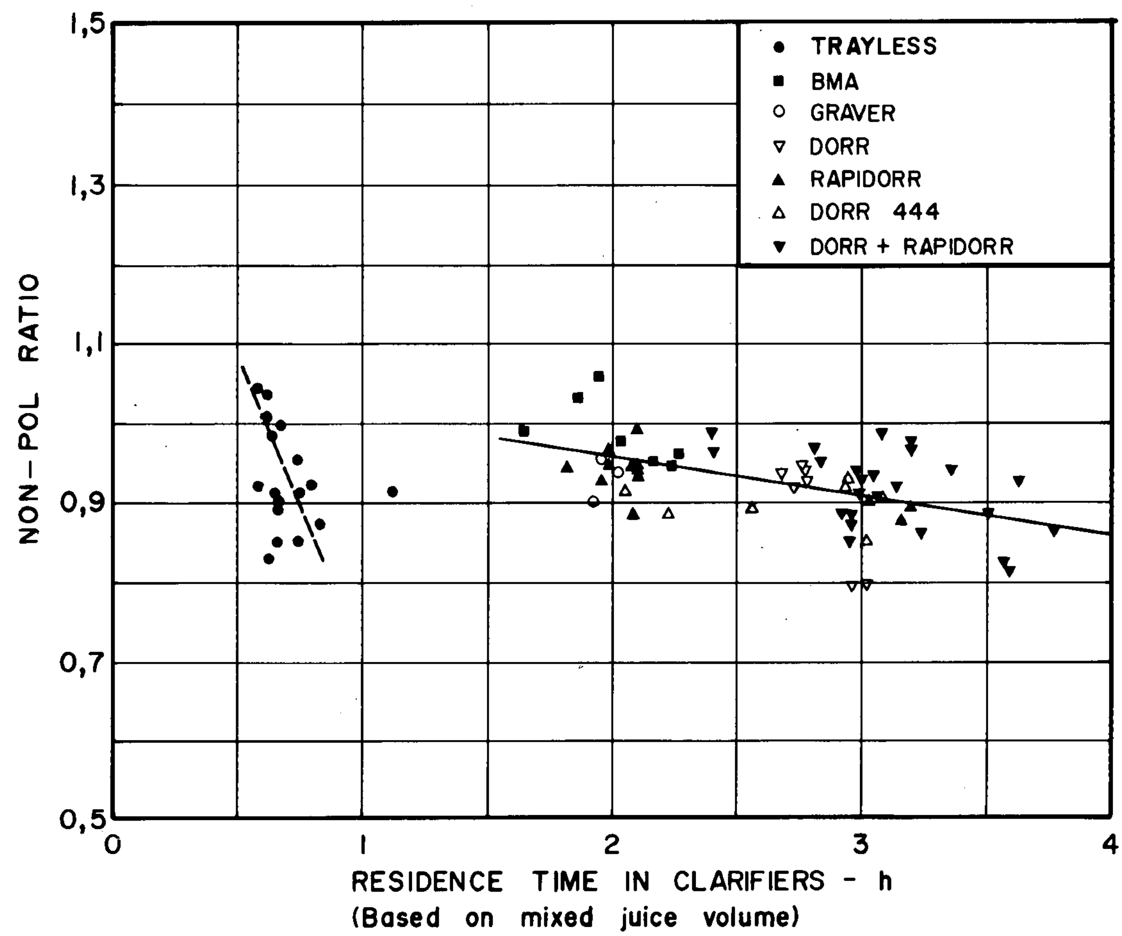

FIGURE 3 Effect of residence time in clarifiers on non-pol ratio.

part. Unfortunately data on phosphate content was not available for conventional clarifiers, but some figures were available for trayless clarifiers. These are shown in Table 1, and seem to confirm this supposition.

TABLE 1

Effect of phosphate content of mixed juice and residence time on non-pol ratio for trayless clarifiers

Phosphate content (mg/ℓ)	Residence time (h)	Non-pol Ratio
240	0,63	0,986
246	0,63	1,032
251	0,74	0,956
280	0,59	0,918
287	0,65	0,900
325	0,64	0,909

Non-pol ratio and sulphated ash in molasses

Non-pol ratio and sulphated ash in molasses

Since non-pol ratios appear to give an indication of clarification efficiency the amount of ash going to the process should also vary with the non-pol ratio. This was verified by calculating the amount of sulphated ash in molasses percent non-sugars in mixed juice and relating the values obtained to the non-pol ratio. The non-sugars in mixed juice was obtained by subtracting pol and reducing sugars from the brix. However, since, as was said previously, data for reducing sugars in mixed juice are incorrect in many cases, reducing sugar in mixed juice was calculated from reducing sugar in molasses less two percent.

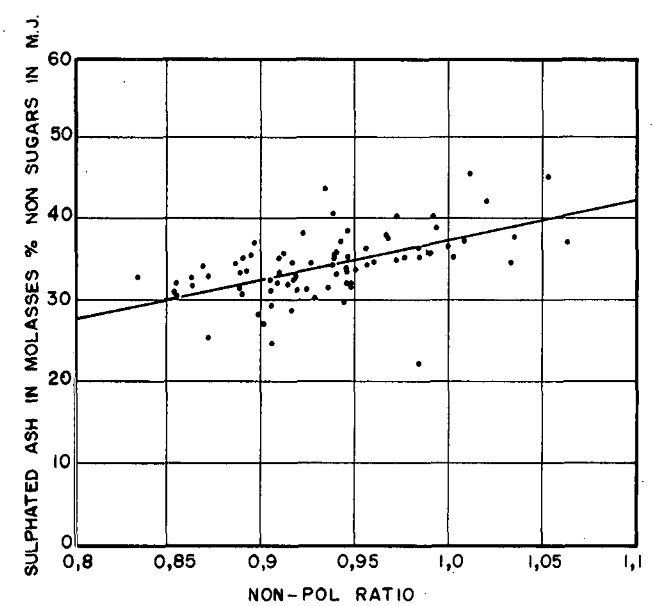

FIGURE 4 Increase of sulphated ash in molasses with non-pol ratio.

The results are shown in Figure 4 as a plot of sulphated ash in molasses percent non-sugars in mixed juice against non-pol ratio. As can be seen there is an increase in ash in molasses with increasing non-pol ratios. The correlation coefficient is 0,59. But as for phosphate in juice there is probably a wide variation in the ash content of the cane juice and an additional error is introduced by assuming a gain of reducing sugars of two percent for all factories.

Average yearly figures

In Table 2 are listed average values of non-pol ratios, residence times and imbibition rates for the past seven years. The industrial average for non-pol ratio is shown in column 2 and figures for factories with conventional and trayless clarifiers are tabulated separately.

The non-pol ratio for the industry has risen steadily during the period reviewed from 0,890 to 0,958. This was matched closely by figures for conventional clarifiers and may have been caused by the steady decrease in clarifier capacity and increase in imbibition rate. The residence times indicated are based on installed clarifier capacity. Clarifier usage, however, which was about 85 percent in 1972 has dropped to about 81 percent during 1978 so that actual residence times for that year were about 2,3 hours.

Trayless clarifiers were introduced in 1975. With a residence time of 50 minutes and imbibition rates of 40 percent the non-pol ratio was 0,893; much lower than the industrial average of 0,94. Since then residence time has dropped to 38 minutes and imbibition rate has risen to 48 percent. It is possible that as a consequence the average non-pol ratio reached 0,968 in 1978; above the industrial average of 0,958.

Economic effect of non-pol ratio

The economic aspect of non-pol ratio was reviewed by the SASTA Chemical Control Committee in 1970[1]. The calculations shown, however, were not correct, for the Boiling House Recovery was assumed to be constant whereas it can be calculated from the non-pol ratio. Also, no account was taken for changing reducing sugar/ash ratios in molasses or losses in muds.

In Table 3 is shown the effect of varying non-pol ratios on the material balance of the boiling house. It is based on the figures for the 1977-78 crop. The reducing sugar/ash ratio was obtained from Figure 4 and the corresponding apparent purity obtained from a correlation of the apparent and true purities of 31 samples of molasses.

TABLE 2

Average Yearly Figures

Year	Non Pol Ratio	Conventional			Trayless		
		Non-Pol Ratio	Retention Time (h)*	Imbibition % Cane	Non-Pol Ratio	Retention Time (h)	Imbibition % Cane
72 . . .	0,890	0,890	3,3	41			
73 . . .	0,911	0,911	3,3	42			
74 . . .	0,935	0,935	3,4	43			
75 . . .	0,937	0,946	3,3	44	0,893	0,84	40
76 . . .	0,942	0,951	3,3	41	0,910	0,70	44
77 . . .	0,957	0,968	2,9	44	0,929	0,68	47
78 . . .	0,958	0,955	2,8	45	0,968	0,63	48

* Based on installed capacity.

TABLE 3

Effect of non-pol ratio on material balance of boiling house

Mixed juice				
Pol	2 338 493 Tons			
Reducing sugars	132 593 „			
Soluble non sugars	299 969 „			
Suspended solids	133 673 „			
Lime added	13 116 „			
% gain of reducing sugars during process	0,27			
Undetermined losses	1,64			
Non-pol ratio	1,00	0,95	0,90	0,85
Muds				
Pol	10 772 Tons	12 355 Tons	13 938 Tons	15 522 Tons
Reducing sugars	590 „	677 „	764 „	850 „
Non-sugars	146 556 „	168 098 „	189 639 „	211 180 „
Pol lost % pol in mixed juice	0,46	0,52	0,59	0,66
Sugar				
Pol	2 059 616 Tons	2 076 601 Tons	2 093 197 Tons	2 109 392 Tons
Reducing sugars	2 832 „	2 855 „	2 878 „	2 900 „
Non-sugars	5 864 „	5 912 „	5 959 „	6 005 „
Boiling House Recovery	88,07	88,80	89,51	90,20
Molasses				
Pol	229 754	211 186 Tons	193 007 Tons	175 228 Tons
Reducing sugars	129 523	129 413 „	129 304 „	129 196 „
Non-sugars	294 326	272 738 „	251 151 „	229 566 „
Reducing sugars/ash	1,17	1,25	1,35	1,46
Apparent purity	35,15	34,43	33,66	32,81
Pol lost % pol in mixed juice	9,82	9,03	8,25	7,49
Molasses at 85 Bx % cane	4,05	3,80	3,54	3,30

As the non-pol ratio decreases, less molasses are formed but at the same time more muds are produced. The net gain in sugar produced during that year would have been about 17 000 tons of sugar for a drop of 0,05 in the non-pol ratio. The rise in the boiling house recovery would have been 0,71 percent.

Such a drop in non-pol ratio is within the reach of the industry. It could be obtained by increasing the residence time in clarifiers to about 3 hours for conventional units and 1 hour for the trayless type. All factories should also monitor the phosphate in the juice fed to the clarifiers and additions of phosphate should be made when necessary.

No trend could be observed between either colour or filterability of affinated raw sugars and non-pol ratio or residence time in clarifiers.

Conclusions

This study seems to indicate that the non-pol ratio is a function of the clarification efficiency and that it is adversely affected by a low phosphate content in mixed juice and by overloading the clarification station. Further work will be necessary to confirm this. It would be of particular interest to determine what are the lowest values of non-pol ratios that could be obtained.

Acknowledgements

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