TRUE SUCROSE VERSUS POL – THE EFFECT ON CANE QUALITY AND FACTORY BALANCE DATA

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Abstract

The official method in South Africa for the estimation of sucrose in mixed juice for cane payment purposes, and sucrose in molasses for the factory balance, is direct polarisation. The results of an extensive comparison between direct pol and sucrose determination by gas chromatography on these two materials are analysed. Differences between pol and sucrose are variable and can be large, resulting in some inequity in cane payments. Much of the variation in a number of cane quality, factory balance and performance values can be attributed to the inaccuracy of direct pol as a measure of sucrose. Polarisation due to the non-sucrose component can change during processing, resulting in errors in the estimation of Undetermined Loss of sucrose via the pol balance of up to one per cent of input sucrose. Anomalous values for recovery of impurities across the factory are explained in terms of inaccuracy of method and analytical error. Overall performance yardsticks that adjust for impurity content or purity of incoming material are particularly affected by pol/sucrose differences, resulting in some cases in a completely erroneous picture of performance change. Further investigation of pol/sucrose differences, and the development of an analytical method for monosaccharides in factory input, are desirable.

Introduction

For the past few years, direct polarisation has been used in South Africa as the official method for the estimation of sucrose in mixed juice for cane payment purposes, and of sucrose in molasses for the factory balance. It has long been known that this method is inaccurate in that it normally underestimates sucrose. Its use despite this shortcoming has been justified on the following grounds:

(1) Difference between pol and sucrose in mixed juice is small. Moreover, under the cane payment system in South Africa there would be no financial difference if the ratio of pol to sucrose was constant for all cane, regardless of the actual level of this ratio.

(2) If direct pol is used for all streams required for the factory balance, the resultant undetermined loss figure will be accurate even though the sucrose estimates for the known streams may be erroneous.

It is now possible to test the validity of these two assumptions, using the results of intensive programmes of sucrose determination in mixed juice and molasses by gas chromatography (GC) carried out over the past two seasons. Information on cane quality, the balance of impurities across the factory and overall factory performance can also be derived.

Experimental

The analytical procedures used are described elsewhere [1,2,3]. It is shown that accuracy and precision of the GC method are sufficiently high to provide a valid assessment of the disparity between sucrose and pol, even at the normally low levels of difference between sucrose and pol % mixed juice of 0 to 0,2 units. A preliminary comparison of pol and GC sucrose was carried out in 1975[1]. In the 1976/77 season, 20 samples each of Mount Edgecombe crusher juice and mixed juice were analysed over one week in each month. Averages of the GC sucrose results and the pol figures on the corresponding samples are shown in Table 1.

TABLE 1

Pol and GC sucrose content of Mount Edgecombe mixed juice and crusher juice – 1976/77 season.

	CRUSHER JUICE			MIXED JUICE		
	Pol % A	GC sucrose % B	Difference B - A	Pol % A	GC sucrose % B	Difference B - A
June	14,88	15,23	0,35	11,56	11,79	0,23
July	15,13	15,63	0,50	11,40	11,72	0,32
August	16,65	16,85	0,20	11,95	12,12	0,17
September	16,20	16,33	0,13	11,66	11,75	0,09
October	16,52	16,67	0,15	11,71	11,84	0,13
November	16,63	16,80	0,17	11,41	11,53	0,12
December	15,71	15,83	0,12	10,87	11,06	0,19
January	13,82	13,94	0,12	10,55	10,74	0,19

The variable and sometimes large differences between sucrose and pol shown by this exercise led to the more extensive 1977/78 programme, carried out jointly by the Sugar Industry Central Board and Huletts Research and Development at Empangeni and Mount Edgecombe. The results on mixed juice have been reported by Brokensha *et al*[2]. GC sucrose (and also glucose and fructose) were determined on weekly composite molasses samples from these two factories throughout the season[3]. Although the analytical frequency for molasses was thus much lower than for juice, the effect of any resultant errors on the sucrose balance will only be one-tenth of the same *relative* error for juice. Pol/sucrose differences are also generally much larger in molasses.

Results

Consideration will be given mainly to the results of the 1977/78 programme as it was more intensive, covered two mills and included molasses as well as mixed juice. Some reference will however be made to the 1976/77 data since the large variation in pol/sucrose difference, while possibly reflecting an abnormal situation, provides a better illustration of certain points.

Pol/sucrose ratios

The most convenient form in which difference between pol and sucrose can be shown is that of pol/sucrose ratios. Average values of these ratios for the 1977/78 investigation appear in Table 2.

TABLE 2

Pol/sucrose ratios – June 1977 to January 1978

	Empangeni	Mount Edgecombe
Mixed juice	0,998	0,984
Molasses	0,967	0,905

The relative difference between pol and sucrose is much greater in molasses than in mixed juice. This is to be expected since molasses contains only about one-tenth of the incoming sucrose but nearly all the polarising impurities. It is further evident that the deviation between pol and sucrose is larger at Mount Edgecombe than at Empangeni for both mixed juice and molasses.

Plots of the pol-sucrose ratios across the season appear in Figure 1. Sucrose in Empangeni juice was marginally higher than pol for three months in mid-season. The other notable feature is the sharp peak in Mount Edgecombe's ratio in molasses, with the October value in fact slightly above the ratio for juice. Morel du Boil[3] has shown that these wide variations in pol/sucrose ratio in molasses can be attributed to changes in fructose and glucose content plus a relatively constant "unaccounted pol" component which is positively polarising.

Cane quality

The sucrose-based figures in Table 3 give a more favourable picture of cane quality in terms of higher sucrose and juice purity, and lower non-sucrose. The purity advantage enjoyed by Empangeni over Mount Edgecombe is only 0,4 units as against 1,6 units for the pol-based data.

Sucrose balance

Provided that consistent analyses are used in calculating the factory balance, in terms of either pol or sucrose in *both* mixed juice and molasses, the Undetermined Loss figure is not necessarily affected by whether pol or sucrose are used for these two streams. If on the other hand sucrose in molasses is compared with pol in mixed juice, as was done from 1972 to 1974, then totally erroneous and misleading Undetermined Loss figures can result. This is borne out by Figure 2 in which sucrose/sucrose losses estimated from the data in Table 1 are plotted together with the pol/pol and sucrose/pol values which were reported in parallel during that season (1976/77). The consistent pol/pol and sucrose/sucrose data, while not identical, both show a steady pattern of Undetermined Loss in the 0,5 to 1,5% range. The hybrid sucrose/pol values however show anomalous undetermined *gains* which approach 2% in July. This is due to the underestimation of sucrose in mixed juice by the direct pol method, which was at a maximum in that month.

TABLE 3

Cane quality, factory balance and performance data based on pol and sucrose — June 1977 to January 1978

	Empangeni		Mount Edgecombe	
Basis	Pol	Sucrose	Pol	Sucrose
% in:				
Mixed juice	11,49	11,51	11,66	11,85
Molasses	30,0	31,0	25,5	28,2
Cane quality:				
Pol, sucrose % cane	12,84	12,86	13,01	13,22
Non-pol, non-sucrose % cane	2,58	2,56	2,84	2,63
Purity of mixed juice	85,2	85,4	83,6	85,0
Losses % in cane in:				
Bagasse	4,15	4,15	2,94	2,89
Filter cake	0,38	0,38	0,58	0,57
Molasses	9,90	10,22	7,68	8,36
Undetermined	0,95	0,80	1,65	2,39
Recoveries:				
Extraction	95,85	95,85	97,06	97,11
Boiling House Recovery	88,29	88,11	89,79	88,35
Overall Recovery	84,62	84,45	87,15	85,79
Impurity recovery:				
Non-pol, non-sucrose ratio	1,03	1,02	0,91	0,95

The figures in Table 3 show that use of direct pol did not give rise to any significant error *on average* in Undetermined Loss es-

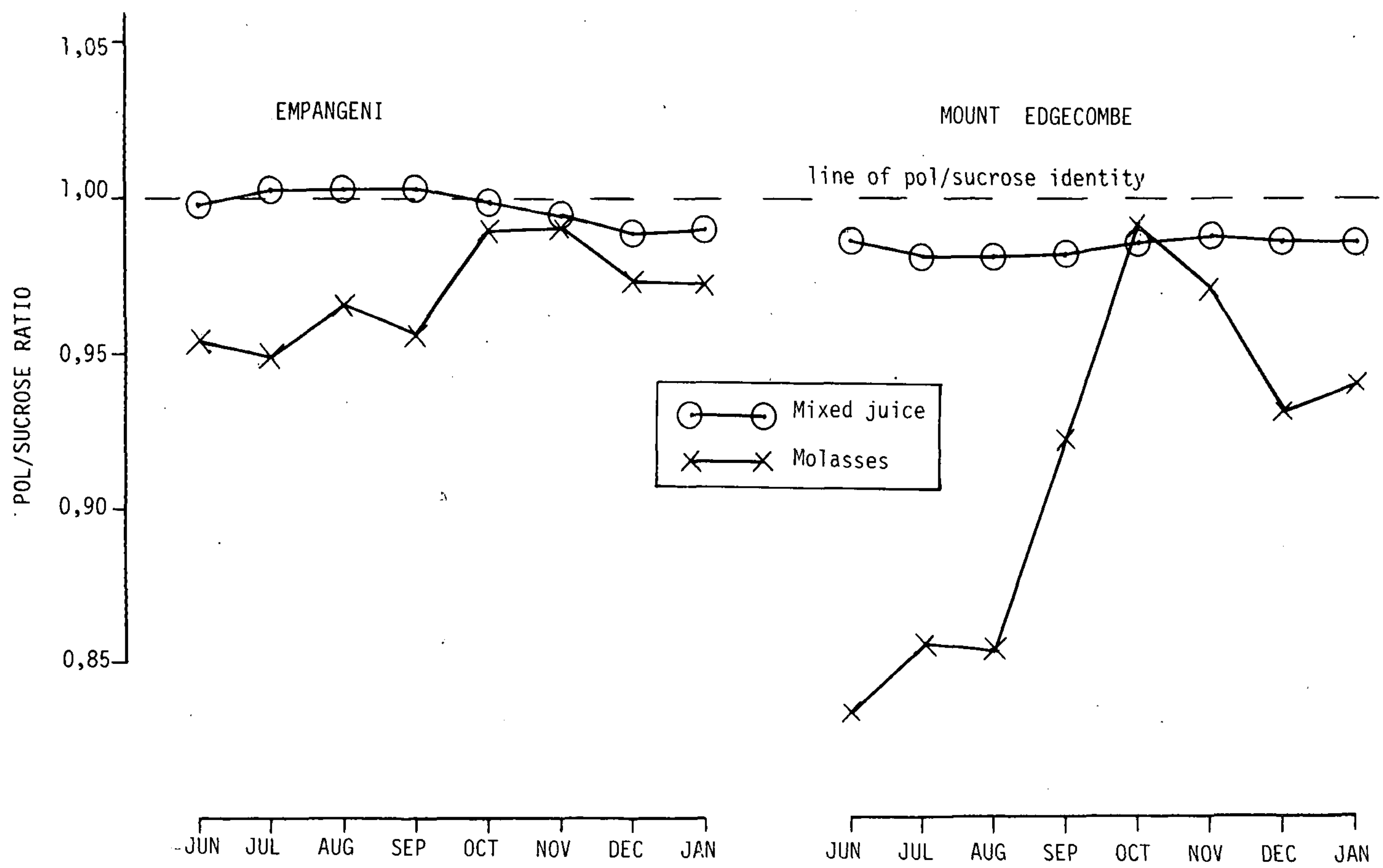

Figure 1: Pol/sucrose ratios, 1977/78 season.

timation at Empangeni in 1977/78 but that the loss was underestimated by 0,7 units at Mount Edgecombe. Reference to Figure 3 shows that the good agreement at Empangeni was due to an underestimation later in the season largely cancelling out an overestimation earlier on.

This data shows that polarising properties do in fact change in process, and that these changes can result in significant errors in estimation of undetermined loss via the pol balance. It is also of interest that optical rotation can change in different directions – usually more dextrarotatory but sometimes more laevorotatory.

Impurity balance

The ratio of impurities leaving the factory in molasses and sugar to impurities entering in juice is of importance in factory control. Variations in the ratio can be due to real formation (or loss) of non-sucrose, or to determination errors. Recently, ratios persistently larger than unity (which thus imply an increase in impurities) have been cause for concern at a number of factories. Table 3 shows that Empangeni is one of these factories, with Mount Edgecombe towards the other end of the scale. The ratios using sucrose are much closer together but the Empangeni figure is still disturbingly high.

It is however possible in this case to quantify a further potential cause of variation in the ratio. This is the bias between laboratories in the determination of pol and brix in molasses. Such discrepancies can be large, especially for brix. Analytical results from the Huletts R&D Laboratory are available for molasses from both mills. Their use instead of the mill analyses for calculating impurity recovery would eliminate any inter-

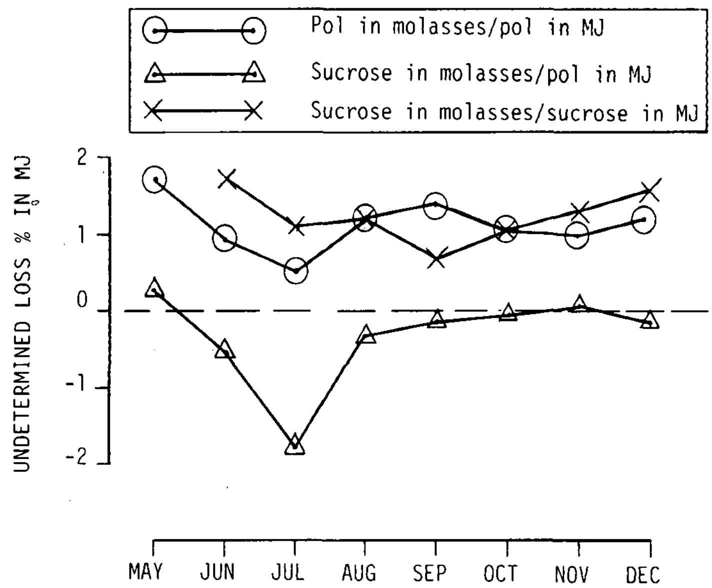

Figure 2: Undetermined Loss, Mount Edgecombe 1976.

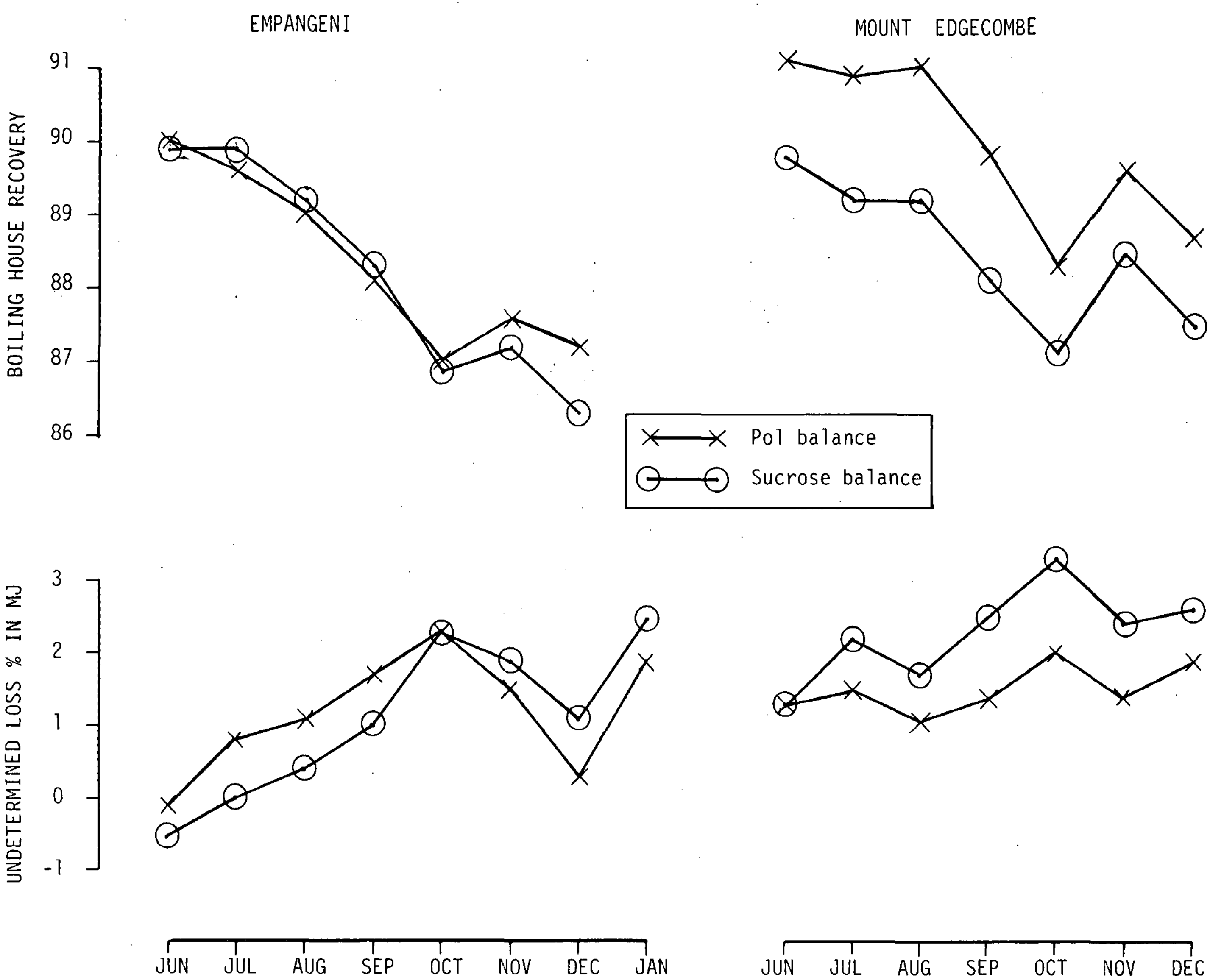

Figure 3: Boiling House Recovery and Undetermined Loss via pol and sucrose balances, 1977/78 season.

laboratory bias and should also give more accurate figures in absolute terms. The ratios found after adjustment along these lines are shown in Table 4. This is referred to as the adjustment for analytical *error* whereas the replacement of pol with sucrose adjusts for analytical *accuracy*. Adjustment for both error and inaccuracy reduces the Empangeni figure to well below the "impurity gain" area, and moreover raises the Mount Edgecombe value so that difference between the two mills is only one quarter of that for the original figures.

TABLE 4

Ratio of impurity in (molasses + sugar) to impurity in mixed juice – June 1977 to January 1978

	EM	ME	(EM-ME)
Pol basis	1,03	0,91	0,12
Adjusted for:			
Inaccuracy of method	1,02	0,95	0,07
Analytical error	0,99	0,90	0,09
Inaccuracy **and** error	0,97	0,94	0,03

Recoveries and performance

Unlike Undetermined Loss, recovery figures necessarily *are* affected by any differences between pol and sucrose. This is because the denominator of sucrose in mixed juice (or cane) changes, whereas the estimate of sucrose in sugar via direct pol in the numerator remains fixed. Table 3 shows a 1,4 unit lower Boiling House Recovery (BHR) figure for Mount Edgecombe on a sucrose basis, reducing its advantage over Empangeni from 1,5 to 0,2 units. Changes in Overall Recovery are similar although the remaining gap between the two mills is larger due to the much higher extraction at Mount Edgecombe.

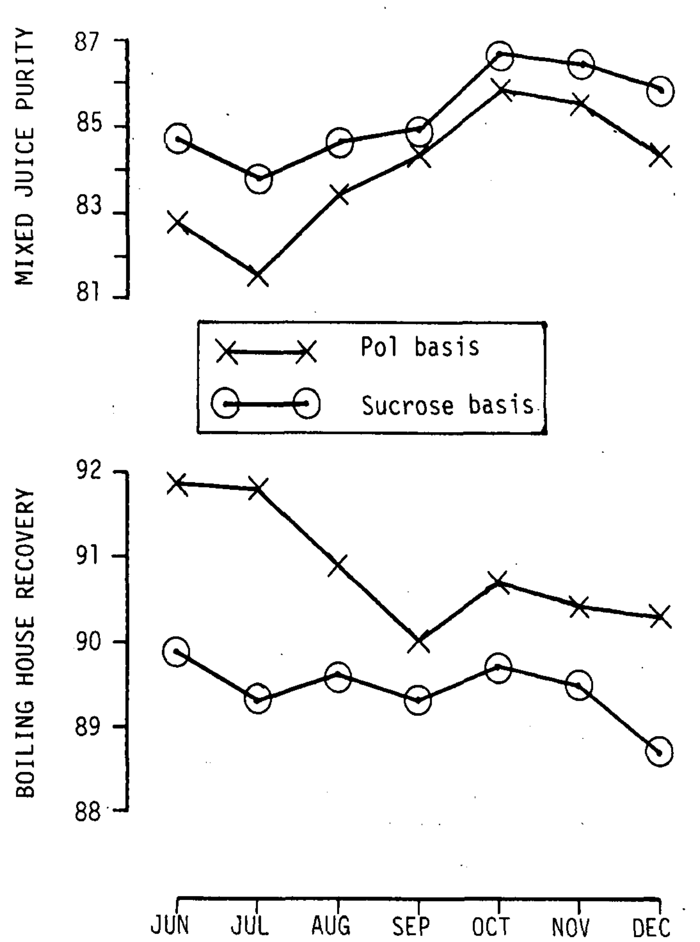

Figure 4: Purity of mixed juice and Boiling House Recovery, Mount Edgecombe 1976.

Figure 4 shows mixed juice purity and BHR by month over the 1976/77 season. The apparently beneficial effect of low juice purity on recovery, which is the reverse of the normally accepted relationship, is obviously due in large measure to the error involved in using direct pol to estimate incoming sucrose. It is also apparent that difference between pol and sucrose tends to be higher at low juice purities.

The effect of pol/sucrose differences is even more pronounced for Factory Performance Index (FPI)[4] than for recoveries. The reason is that FPI requires an estimate of non-sucrose as well as sucrose in cane. Underestimation of sucrose also results in *overestimation* of non-sucrose, which is found by difference from brix. The two effects work in the same direction in the ERC % cane formula and hence the FPI error is compounded. Table 5 shows FPI values for Empangeni and Mount Edgecombe for 1977/78, as reported, and recalculated using sucrose instead of pol. Mount Edgecombe's 2,7 unit lead reduces to 0,3 despite the 1,2 unit lower extraction at Empangeni.

TABLE 5

Factory Performance Index – 1977/78 season

	EM	ME
Pol basis	99,5	102,2
Sucrose basis	99,2	99,5

An even more striking change is seen in the normal and adjusted FPI values for Mount Edgecombe across the 1976/77 season (Figure 5). There is moreover additional evidence which indicates that the trend of declining factory performance over the season is entirely spurious and not a genuine effect that is merely exaggerated by the normal FPI figures. It has previously been shown[5] that if molasses exhaustion efficiency as measured by the SMRI log target purity formula is assumed to remain constant, then FPI will increase by about 0,3 units for every 0,1 unit rise in reducing sugars/ash ratio in molasses. As for mixed juice purity, reducing sugars/ash ratio appears to be interrelated with pol/sucrose ratio in juice, being in general high when the latter is low. Reducing sugars/ash ratios for Mount Edgecombe in 1976 were 1,9 in July and 1,1 in October. This difference suggests an artificial inflation of the July FPI figure by over 2 units relative to the October level. Since after adjustment to a sucrose basis the October FPI is only 1,6 units below the July figure, the indication is that true controllable performance in October had in fact *improved* slightly from the July level – a completely different picture to that of drastic performance reduction given by the normal FPI figures.

The consideration of some indicator of the nature of impurities has received little attention in the derivation of overall factory performance yardsticks. One exception is the recovery formulae proposed by Buchanan[6], which include reducing sugars in mixed juice as a variable. The present authors do not however recommend direct adoption of these formulae, for two reasons. In the first place, the formulae were derived by statistical analysis of factory data over a period when sucrose in mixed juice was estimated via double polarisation, which differs from the estimates using either direct pol or gas chromatography. Secondly, the specified titrimetric reducing sugars determination is not regarded as being very reliable when applied to mixed juice in the factory situation. With GC sucrose determination on juices now proved to be both accurate and practical, extension of GC techniques to determination of individual monosaccharides in factory input seems the logical next step. Current GC methodology development in the authors' laboratory is thus being concentrated on the simultaneous determination of sucrose, fructose and glucose in expressed juices.

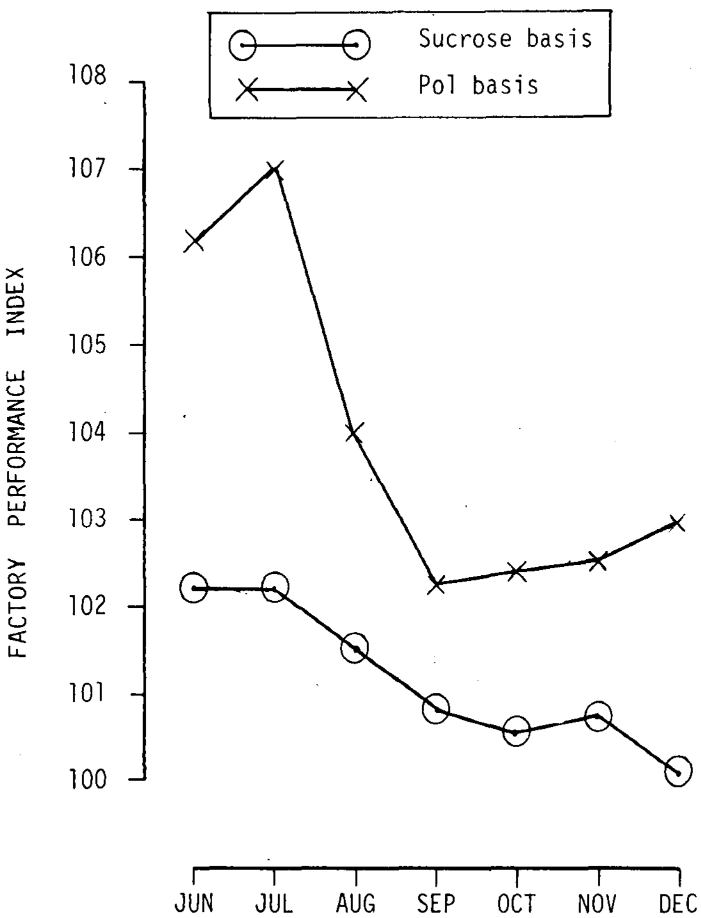

Figure 5: Factory Performance Index, Mount Edgecombe 1976.

Conclusions

(1) Pol/sucrose differences in mixed juice can vary significantly, both between mills and seasonally at one mill. Inequities in sucrose payment thus exist, with underpayment when pol is much lower than sucrose and overpayment when the difference is small or negative. Comparison of pol and sucrose at other mills is indicated, particularly as the only two mills covered so far are probably near the opposite extremes of the industrial pol/sucrose difference spectrum.

(2) Polarising properties of the non-sucrose component can in fact change in process, giving rise to errors of up to one unit in the estimation of Undetermined Loss via the pol balance. The investigation by Morel du Boil[3], carried out in parallel with the work considered here, has shown that contents of the two main polarising impurities, fructose and glucose, do in fact change significantly from syrup to molasses. The extension of this work to mixed juice is obviously desirable.

(3) Anomalous values for recovery of impurities across the factory can be explained in terms of analytical accuracy (sucrose in place of pol) and analytical error (central laboratory instead of mill laboratory analyses for brix in molasses).

(4) Recovery and overall performance figures are distorted by the use of pol to estimate sucrose in mixed juice. In the case of Factory Performance Index, this distortion is enhanced when pol/sucrose differences are large by

(a) overestimation of non-sucrose in cane, and

(b) absence of allowance in the ERC% cane formula for molasses exhaustibility, which is usually better at low pol/sucrose ratios.

The magnitude of these effects is such that FPI can give a totally erroneous picture of controllable performance. The same would be true of any of the numerous alternative overall performance yardsticks which consider juice purity as a variable affecting performance.

This is a disturbing situation. The absence of a reliable measure of overall performance, combined with potential errors in Undetermined Loss estimation, means that a real loss position could arise in a factory without being reflected in any of the routine control figures. Spuriously high recovery and performance figures due to large pol/sucrose differences obviously diminish the incentive for factory staff to concentrate on reduction of sucrose losses, both in known streams and undetermined.

The problem would be partially overcome by use of GC analysis instead of direct pol to estimate incoming sucrose. The residual error due to molasses exhaustibility differences could only be removed by consideration of non-sucrose composition in some way. Determination of reducing sugars in juice, preferably by GC analysis for fructose and glucose individually, would seem to be the optimum course of action in the light of our present knowledge.

REFERENCES

1. Schäffler, K. J. (1976). Preliminary comparison of polarimetric and gas chromatographic methods for the estimation of sucrose in sugar cane mixed juice and molasses, SASTA Proc **50:** 220-223.
2. Brokensha, M. A. Niemeyer, R. H. and Schäffler, K. J. (1978). A comparison of the estimation of sucrose in sugar cane mixed juice by polarimetric and gas liquid chromatographic methods. SASTA Proc **52** — in press.
3. Morel du Boil, P. G. and Schäffler, K. J. (1978). Application of gas chromatography in a preliminary investigation into changes in some non-sucrose constituents during sugar boiling. SASTA Proc **52** — in press.
4. Van Hengel, A. (1974). Proposal for the evaluation of cane and sugar in identical units at standardised factory efficiency. ISSCT Proc **15:** 1446 - 1455.
5. Smith, I. A. (1976). Differences in adjustment for cane quality between three factory performance yardsticks. SASTA Proc **50:** 231-236.
6. Buchanan, E. J. (1973). An analysis of the influence of sugar cane quality on sugar recovery. Int. Sug. J **75:** 299-303 (Part I) and 337-341 (Part II).