

MOLASSES EXHAUSTIBILITY STUDIES BASED ON SUGARS ANALYSIS BY GAS-LIQUID CHROMATOGRAPHY

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Abstract

Exhaustibility tests were carried out by concentrating molasses to 4 000 poise (determined at 40°C), adding refined sugar, crystallising at 40°C for 48 hours and carrying out on the separated molasses a series of analyses which included sugars by gas-liquid chromatography (GLC) as well as Lane and Eynon methods. Regression analysis of the results showed that purity of the exhausted molasses was strongly dependent on the ratios of non-sucrose to water and of reducing sugars to ash. Some small but in some cases consistent differences in exhaustibility of molasses from different mills were noted, which may have been due in part to differences in organic non-sugar components. A reference purity formula for use with the accurate GLC sugars analyses is presented. Purity values given by this formula are substantially lower than those derived using the target purity formula currently in use in South Africa, for two reasons: the higher viscosity aimed for in this work and the significant over-estimation of sugars by the Lane and Eynon methods on which the current formula molasses from different mills were noted, which may have is based. The new formula is

$$\text{GCP} = 33,9 - 13,4 \log (F+G)/A$$

in which

- GCP = GLC Sucrose/dry solids purity.
- F = GLC Fructose % molasses.
- G = GLC Glucose % molasses.
- A = Sulphated ash % molasses.

Introduction

Many correlations between equilibrium purity and individual impurity constituents, and groups of constituents, in cane final molasses have been proposed (Moritsugu¹⁰). Exhaustibility test work carried out by the Sugar Milling Research Institute (SMRI) in 1972 (Bruijn *et al*⁴) led to the introduction of a target purity formula¹ applicable to South African final molasses. This formula has been routinely used since then and has proved invaluable in assessing molasses exhaustion performance.

Since that time accurate GLC sugars methods have been developed (Brokensha *et al*³, Morel du Boil *et al*⁹) and introduced on a routine basis in South Africa. These methods have highlighted the significant inaccuracies for both sucrose and reducing sugars of the Lane and Eynon methods on which the SMRI target purity formula is based.

In the past there has been some doubt as to whether variations in molasses purities at the different Hulett's mills are due to differences in the exhaustibility of molasses, or due to differences in installed equipment or operational procedures. This is particularly important since molasses exhaustion is of considerable economic significance in South Africa.

For the above two reasons, it was decided to undertake an extensive series of exhaustibility tests on molasses from different mills, with the inclusion of sucrose, fructose and glucose by GLC among the analyses on the exhausted molasses samples.

Apparatus and Procedure

The boiling down apparatus used was almost identical to that described by Bruijn⁵ and was constructed by the SMRI. The basic component is a 630 ml jacketed vessel which acts in turn as an evaporator, crystalliser and Nutsch bomb.

The standard procedure used is as follows. 1 000 ml of molasses is mixed with 800 ml of water. 300 ml of this diluted molasses is transferred to the vessel, vacuum applied and evaporation started by feeding steam to the jacket. A further 1 200 ml is fed in during the evaporation stage, with the remaining 300 ml in reserve to make up any entrainment losses which sometimes occur due to foaming. A chain tension measurement device on the stirrer drive is used to indicate when the aim viscosity level has been reached. Evaporation is then stopped and 300 ml of the concentrated molasses removed for viscosity determination which is carried out at 40°C, using a Brookfield RVF viscometer with No. 6 spindle at 2 rpm. 250 cm³ of bakers' sugar is added to the remainder and the vessel transferred to the crystallisation stage. Water at 40°C is now circulated through the jacket for 48 hours while the "massecuite" is stirred continuously. The bottom cover is then removed, exposing the perforated plate covered by a screen, and the vessel pressurised with air to extract a sample of the exhausted molasses. This is analysed for sucrose and reducing sugars by both Lane and Eynon and GLC methods, solids by vacuum oven drying, and sulphated ash.

The aim viscosity level, i.e. the viscosity to which the molasses is concentrated, can have a significant effect on the mother liquor purity. The SMRI has recommended a procedure of three boilings on each sample, respectively above, below and as close as possible to 2 000 poise (read at 40°C) (Koenig⁶). Exhausted purity would then be determined by the interpolation on a plot of purities against viscosity. While this procedure overcomes the problem of deviation of actual from aim viscosity for a single boiling, it also generates a much higher analytical load. The dependence of purity on viscosity was thus investigated by boiling down sub-samples of the same mill molasses sample to different aim viscosity levels. The results indicated that purity was independent of viscosity above 3 000 poise. An aim range of 3 500 to 4 000 poise was thus selected and used for the boiling down tests on molasses from the 1978/79 season. The purity/viscosity exercise was subsequently repeated, giving results suggesting that viscosity could still have some effect on purity up to 4 000 poise as shown in Figure 1.

The aim viscosity was therefore changed to 4 500 poise from 1979. However the viscosities actually achieved averaged 4 200 in 1978 and 4 600 poise in 1979, with very few samples below 3 500 poise. The change in viscosity does not appear to have influenced the relationship between purity and characteristics of impurity on average, although it may have contributed to the greater variability of results in 1979.

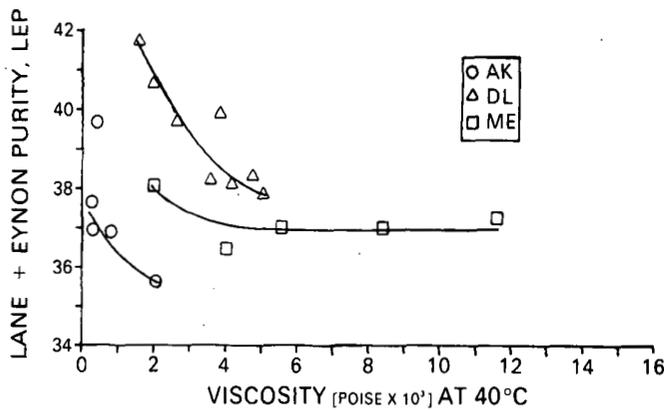


FIGURE 1 Purity of three samples of molasses boiled down to different viscosity levels.

Results and Discussion

The programme covered 93 samples in 1978 and 40 samples in 1979. These originated mainly from the five Huletts mills although there were a few from other mills. Statistical analysis was carried out on the results at the end of the 1978 series and then again when the 1979 results were all available. Means and range of primary determinations on boiled down molasses samples for both years are shown in Table 1.

TABLE 1

Average and variability data for analyses on boiled down molasses samples (1978 and 1979 combined)

	Maximum Value	Minimum Value	Mean	Standard Deviation
Total solids %	90,01	84,48	86,78	0,89
L & E sucrose %	34,96	27,63	31,79	1,70
L & E reducing substances %	28,68	11,98	19,56	3,50
GLC sucrose %	33,83	26,45	30,21	1,62
GLC fructose %	13,45	5,14	8,69	1,70
GLC glucose %	10,86	2,29	5,93	1,89
Sulphated ash %	19,47	14,23	16,75	1,12
Viscosity at 40° C, poise	5 200	3 200	4 300	360

There is no point in detailing the numerous forms of regression done since most were either non-significant or less significant than those discussed below. It need only be noted here that the ratio of sucrose to water was no improvement on purity, correlations with fructose and glucose separately were worse than in combination (nor was the fructose/glucose ratio significant), and ash was a better ratio "base" than either total solids or non-sucrose.

The regression analysis program produced tables of linear correlation coefficients for all possible pairings of variables. One such correlation matrix, incorporating the more important primary and derived values, is shown in the Appendix.

Effect of non-sucrose/water ratio

The significant influence of total solids, and more particularly non-sucrose/water ratio, on equilibrium purity of molasses is well known and has recently been shown to apply under South African conditions (Lionnet and Rein⁷). This was confirmed in the work reported here, in that introduction of a non-sucrose/water ratio term into purity regressions significantly increases correlation coefficients above the levels found using reducing sugars/ash ratios alone. The following regressions were derived from the 1978 data

only, to avoid any possible effect of the change in aim viscosity.*

$$\text{GCP} = 40,5 - 6,5 (F+G)/A \quad r = 0,89 (1)$$

$$\text{GCP} = 48,2 - 4,8 (F+G)/A - 2,2 \text{ GCNS}/W \quad r = 0,93 (2)$$

The second equation can not be applied to mill final molasses due to the effect of centrifugal dilution water which changes non-sucrose/water ratio drastically from its level in the crystallisers. It could, however, find some use for Nutsch molasses provided the correct analyses are available, e.g. total solids and not brix.

Comparison with previous SMRI work

Purity of boiled down molasses is plotted against reducing sugars/ash ratio (Lane and Eynon sugars for both values) in Figure 2. The fitted regression against log of reducing sugars/ash ratio is

$$\text{LEP} = 37,7 - 17,6 \log \text{RS}/A \quad r = 0,85 (3)$$

compared to the SMRI target purity formula, also drawn in on the graph, of

$$\text{LEP} = 39,9 - 19,6 \log \text{RS}/A \quad r = 0,85 (4)$$

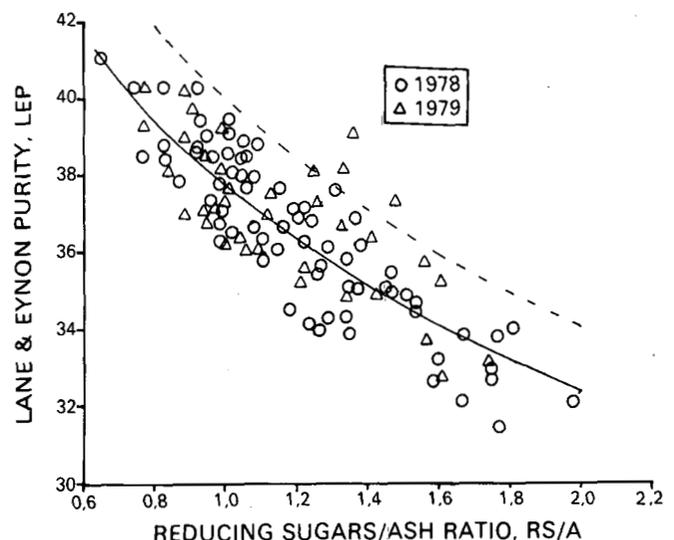


FIGURE 2 Purity against reducing substances/ash ratio (Lane and Eynon sugars basis). Solid line — fitted regression. Broken line — SMRI target purity formula.

The two equations are very similar but the formula derived from this work gives purities around 2 units lower than the SMRI formula. This reflects the effect of the higher aim viscosity of around 4 000 poise at 40°C for this work as opposed to 1 000 poise for the SMRI tests (Bruijn *et al*⁴). In addition, a 48 hour crystallisation period was allowed in this work, as opposed to 24 hours for the SMRI tests.

The size of this difference raised the question: have we moved too far away from the practical operating situation? Purity of mill final molasses is typically slightly above the SMRI target but negative target purity differences are occasionally recorded. This is in spite of the fact that molasses is diluted and the molasses purity is raised on curing by the addition of wash water and steam. A full analysis of mother liquor prior to curing is not normally available to assess molasses exhaustion. However in 1976 and 1977 full analyses were carried out on a total of 41 Nutsch samples extracted from Mount Edgecombe C massecuite after passage through the crystallisers. The distribution of differences between actual purity and SMRI target for these

* Nomenclature used is listed at the end of the paper.

samples, the corresponding Mount Edgecombe final molasses samples, and the exhausted molasses samples from the work reported here, is shown in bar chart form in Figure 3.

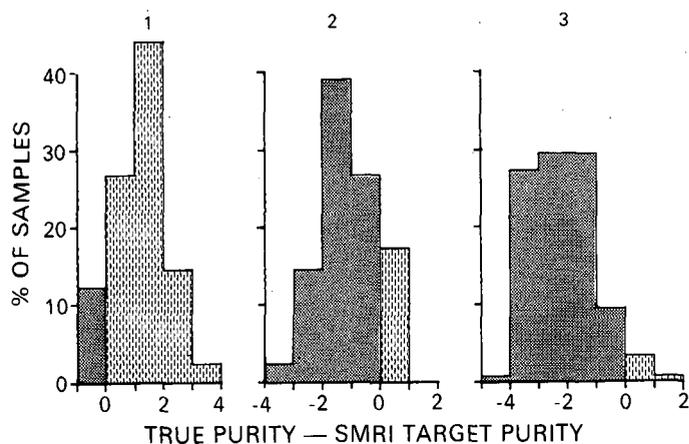


FIGURE 3 Distribution of (true purity - SMRI target purity) differences. 1 — Mount Edgecombe final molasses, 1976 and 1977. 2 — Mount Edgecombe Nutsch after crystallisers, 1976 and 1977. 3 — Boiled down molasses, 1978 and 1979. Heavy shading: purities below SMRI target. Light shading: purities above SMRI target.

It is obvious that the factory molasses, prior to the purity increase on centrifuging, was in this case exhausted to a level intermediate between those given by the two respective sets of boiling down conditions. It could be argued that the SMRI formula represents a good performance level taking into account the losses on centrifuging. We believe it preferable that the formula used reflects what should be aimed for *before* such losses are incurred — particularly if the word “target” is used.

It is not known how close the boiled down molasses is to true equilibrium (i.e. supersaturation of 1). Other workers (Broadfoot², Miller and Wright⁵) have preferred to approach equilibrium from an undersaturated state by crystal dissolution because of very slow crystallisation rates from the highly viscous molasses. The boiled down purities found in this work do however agree well with equilibrium purity predictions given by a model based on pilot scale crystalliser investigations (Lionnet and Rein⁷). Also, in one case where invert syrup blended with mill molasses gave a purity before boiling down slightly below the equilibrium level predicted from the normal boiled down samples, a rise in purity after equilibration was recorded. This evidence is far from conclusive but does suggest that the boiling down procedure used gives purities not far from true equilibrium. In any event, even if they only represent a pseudo equilibrium where crystal growth rate reduces effectively to zero, this would still represent the practical situation in factory crystallisers.

Comparison between sugars methods

It has been shown that the conventional Lane and Eynon methods over-estimate both sucrose and reducing sugars in cane final molasses (Morel du Boil and Schaffler⁹). Average values of analyses performed and some derived values are shown in Table 2.

The regression equations (log form) for purity against reducing sugars ash ratio are as follows:

$$\begin{aligned} \text{LEP} &= 37,7 - 17,6 \log \text{RS/A} & r &= 0,85 \quad (5) \\ \text{GCP} &= 33,9 - 13,4 \log (\text{F}+\text{G})/\text{A} & r &= 0,84 \quad (6) \end{aligned}$$

TABLE 2
Average direct and derived composition of boiled down molasses on Lane and Eynon and GLC sugars basis

Basis	L & E Sugars	GLC Sugars	L & E Error	% L & E Error
1. Sucrose % molasses	31,8	30,2	+ 2,6	+ 5
2. Reducing sugars % molasses	19,5	14,6	+ 4,9	+34
3. Total sugars % molasses (1) + (2)	51,3	44,8	+ 6,5	+15
4. Solids % molasses	86,8	86,8		
5. Non-sucrose % molasses (4) - (1)	55,0	56,5	- 1,6	- 3
6. Non-sugars % molasses (5) - (2)	35,5	42,0	- 6,5	-16
7. Ash % molasses	16,8	16,8		
8. Organic non-sugars % molasses (6) - (7)	18,7	25,2	- 6,5	-26
9. Purity (1) × 100 (4)	36,6	34,8	+ 1,8	+ 5
10. Reducing sugars/ash ratio (2) (7)	1,16	0,87	+ 0,19	+34
11. Non-sucrose/water ratio (4) - (1) / 100 - (4)	4,17	4,29	- 0,12	- 3

Regression lines for each basis are shown in Figure 4, with the length of each line against the RS/A and (F+G)/A axis corresponding to the respective range between minimum and maximum values found in the work.

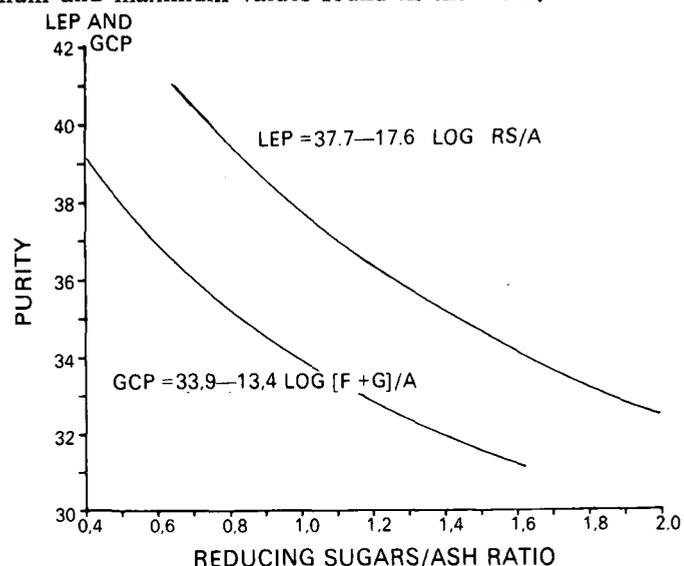


FIGURE 4 Comparison between Lane and Eynon sugars and GLC sugars basis for purity against reducing sugars/ash ratio.

The shape of the two regression lines is very similar but the GLC regression is offset to lower purity and (fructose + glucose)/ash ratio levels. Correlation coefficient is slight lower for the GLC regression but the difference is not material.

Comparison between seasons

The above two sections consider combined data for the 1978/79 and 1979/80 seasons. The data was also evaluated separately for each year, and regression equations, in linear form for this comparison, are as follows:

$$\begin{aligned} 1978: & \text{GCP} = 40,5 - 6,5 (\text{F}+\text{G})/\text{A} \quad r = 0,89 \quad n = 93 \quad (7) \\ 1979: & \text{GCP} = 40,1 - 5,6 (\text{F}+\text{G})/\text{A} \quad r = 0,67 \quad n = 40 \quad (8) \\ 1978 \text{ and } 1979: & \text{GCP} = 40,5 - 6,4 (\text{F}+\text{G})/\text{A} \quad r = 0,83 \quad n = 133 \quad (9) \end{aligned}$$

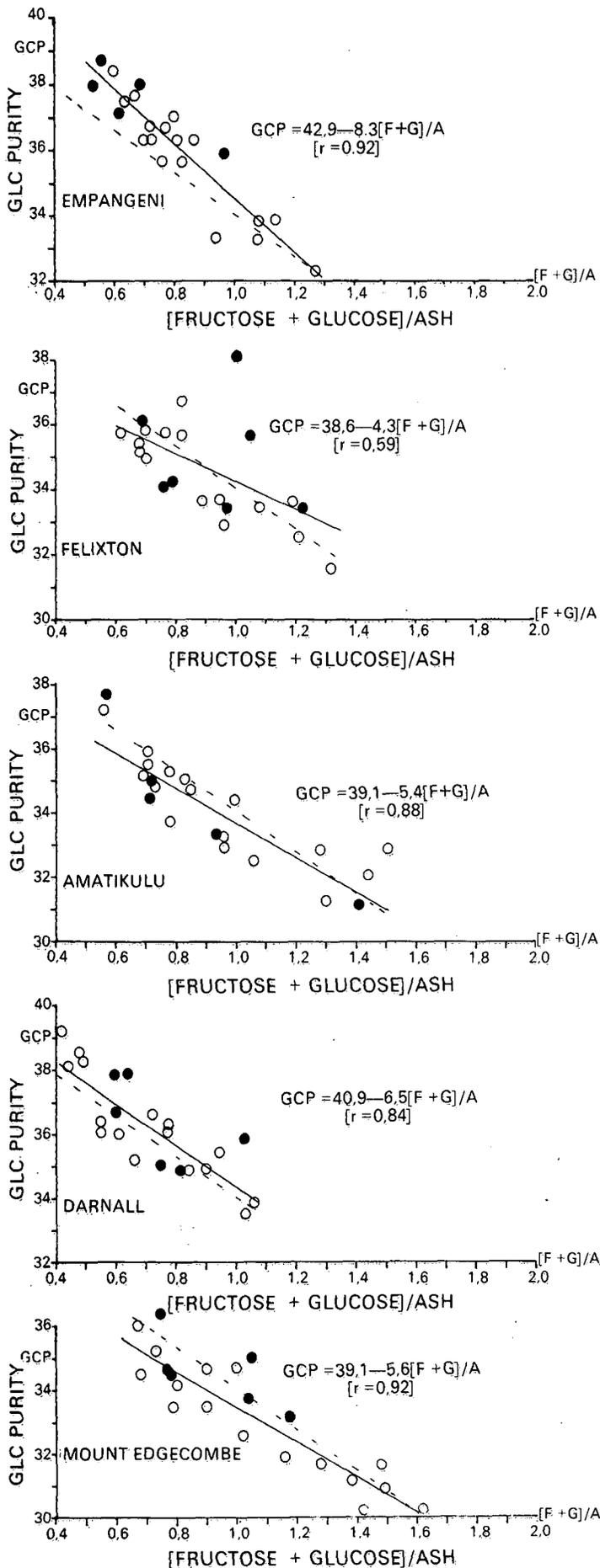


FIGURE 5 Boiling down results for individual mills.
 Open points — 1978. Solid points — 1979.
 Solid lines — individual mill regressions.
 Broken lines — overall regression,
 $GCP = 40,5 - 6,4 (F + G) / A$

The reason for the poorer fit for the 1979 data is not certain. The individual formulae give very similar predictions at low (fructose + glucose)/ash ratios, rising towards one unit difference (1979 higher) at high ratios. Taking into account the smaller range of independent variables, smaller numbers of data sets and change in aim viscosity for the 1979 data, it is not believed that this reflects any real difference in average exhaustibility between the two seasons. A limited number of boiling down tests on molasses in the 1980 season substantiate this view.

Comparison between mills

Regression analysis was carried out on individual groups of results for each of the five Hulett's mills. The results are shown graphically in Figure 5.

Statistical comparison of the individual regressions showed that the differences were significant in some cases. This is most evident in respect of Empangeni where equilibrium purities average some 1 unit higher than the levels indicated by the general regression. During the 1980 season target purity differences of Empangeni molasses were abnormally high and it was suspected that exhaustibility was even worse than normal due to processing of severely drought-afflicted cane. A programme of boiling down tests on weekly composites of Empangeni molasses was therefore carried out. The results on both Lane and Eynon sugars and GLC sugars basis are plotted in Figure 6 together with regression lines for the 1978 and 1979 Empangeni data.

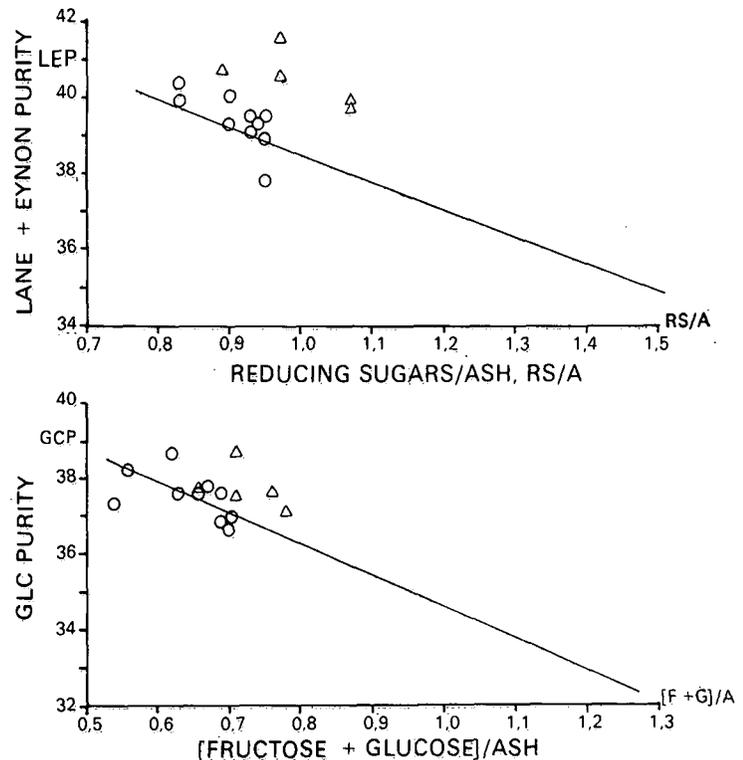


FIGURE 6 Boiled down Empangeni molasses samples 1980.
 Triangles — before 6 July 1980
 Circles — after 6 July 1980
 Lines — regressions for Empangeni 1978 and 1979 data.

Due to workload considerations, only the Lane and Eynon sugars analyses could be carried out immediately and samples were stored under refrigeration for later GLC analysis. Thus only the Lane and Eynon based relationship, as shown in the upper plot of Figure 6, was available immediately for evaluation of exhaustibility characteristics. It was concluded at the time from this data that the molasses was indeed less exhaustible than the norm for

Empangeni from May to early July, with this additional disadvantage tending to disappear thereafter. However the GLC based data gave a different picture when it became available, showing exhaustibility characteristics very much in line with those for the preceding seasons, and no significant difference in the early season results that could not be explained by normal variability of the determination procedure.

It must be concluded that the indication from the Lane and Eynon based data is the spurious one because of the known inaccuracy of these analytical methods. The suggestion from the accurate GLC analyses is that individual differences are basically specific for the mill (whether due to processing conditions or to cane supply area cannot be gauged from these results) and are not affected by season-to-season variations in cane quality.

Form of target purity equation

Linear fits were found to give very similar correlation coefficients to the logarithmic form, as shown below :

$$GCP = 40,5 - 6,4 (F+G)/A \quad r = 0,830 \quad (10)$$

$$GCP = 33,9 - 13,4 \log (F+G)/A \quad r = 0,835 \quad (6)$$

A linear form would have the advantage of simplicity. However the SMRI changed its originally recommended linear form to log after doing further tests at high reducing sugars/ash ratios¹. Unfortunately the work reported here did not cover samples with very high reducing sugars content. This aspect was therefore investigated by boiling down different blends of final molasses and liquid invert sugar. The results are shown in Figure 7 which also includes regression line for the above two equations.

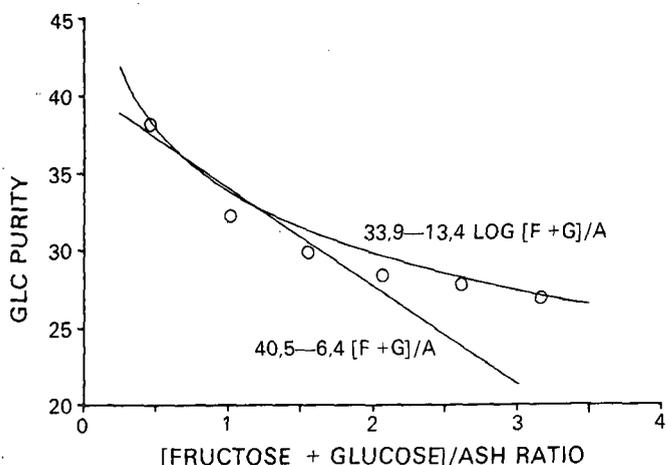


FIGURE 7 Boiling down results for molasses "spiked" with reducing sugars.

It appears that the logarithmic equation is a more appropriate form under conditions of high reducing sugar levels.

Other relationships

With accurate sugars analysis it is possible to derive a realistic estimate of organic non-sugars in the form of "undetermined material", i.e. dry solids minus the total of GC sucrose, fructose, glucose and sulphated ash. Table 2 shows that this group of constituents is under-estimated by some 25% if Lane and Eynon sugars is used in the calculation. Regression of GC purity against (fructose + glucose)/ash and organic non-sugars/ash ratios for the 1978 data gave the following equation.

$$GCP = 44,7 - 6,4 (F+G)/A - 2,9 ONSUG/A \quad r = 0,90 \quad (11)$$

The contribution of the organic non-sugars/ash relationship can explain part of the inter-mill differences discussed earlier. However its effect is much less significant than that of (fructose + glucose)/ash for the 1978 data, and was not statistically significant for the 1979 or combined 1978 and 1979 data sets. Its incorporation at this stage is thus not justifiable but further investigation could be worthwhile.

Routine GLC analyses on mixed juice are now available. A means of predicting molasses losses based on characteristics of mixed juice could be of value. Recent work has shown that refractometer brix is an accurate estimate of total solids in filtered mixed juice (Mellet¹¹). Analysis of ash is however not normally available for mixed juice. A regression of purity against the ratio of (fructose + glucose) to non-sugars is thus provided to permit indications of the effect of input material composition on loss in molasses to be derived.

$$GCP = 40,3 - 15,5 (F+G)/NSUG \quad r = 0,80 \quad (12)$$

In using this relationship it is essential to allow for the loss of fructose and glucose in process, which is substantial and varies considerably from mill to mill.

Viscosity is of undoubted importance to exhaustion. Although viscosity measurements were done on the exhausted molasses samples, the data cannot be meaningfully included in regression analysis because viscosity was deliberately kept as near constant as possible. Inferences can however be drawn from the relationship between non-sucrose/water and (fructose + glucose)/ash ratios as shown in Figure 8.

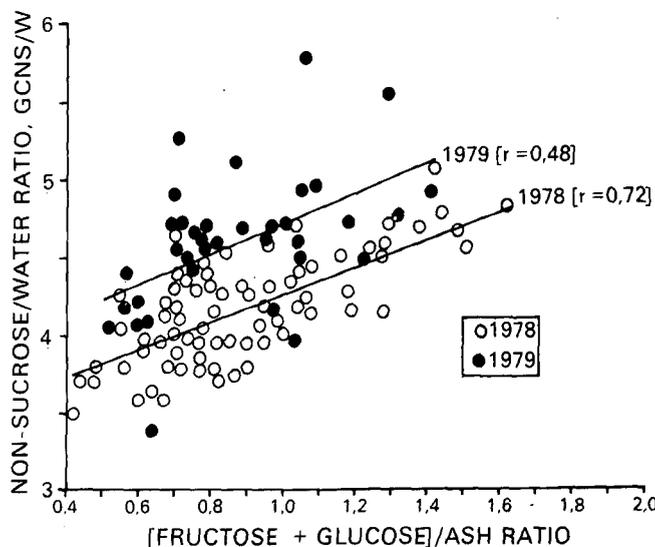


FIGURE 8 Non-sucrose / water ratio versus (fructose + glucose) / ash ratio for boiled down molasses.

The significant positive correlations indicate that part of the benefit of high reducing sugars levels is that a higher NS/W ratio can be achieved at the same viscosity. Non-sugars contribute to viscosity to a much greater extent than do sugars. When reducing sugars levels are high, the proportion of non-sugars relative to total solids in molasses is low. This must contribute to the relationship between viscosity and reducing sugars content, but it cannot be determined from this work whether it is the sole factor.

The correlation between non-sucrose/water and (fructose + glucose)/ash ratios means that regressions containing both variables such as that given earlier will contain an element of inherent correlation.

Conclusion

A reference purity formula for the assessment of molasses exhaustibility is proposed. The formula is :

$$\text{GCP} = 33,9 - 13,4 \log (\text{F}+\text{G})/\text{A}.$$

The formula is based on accurate GLC sugars analyses, which yield purity values some 2 units lower than the conventional Lane and Eynon method. The conditions of the test work under which the data were obtained are such that the formula represents more closely the purity which should be achieved in a cooled crystalliser, and as such gives purities a further 2 units below the currently used SMRI target purity formula.

No significant difference in applicability of the formula between the seasons was found, but there were significant although fairly small differences between mills in some cases, which may be partially explained by variations in the relative proportion of organic non-sugars present.

The ratio of non-sucrose to water also has a significant influence on purity of exhausted molasses. A contributing factor here is a positive correlation between reducing sugars/ash and non-sucrose/water ratios at the same viscosity level, which in turn is due at least in part to the higher average viscosity of non-sugars components relative to sugars.

Equations incorporating non-sucrose/water ratio and with reducing sugars/non-sugars ratio are provided for potential use with analyses of Nutsch molasses and mixed juice respectively.

Acknowledgements

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Nomenclature

All analyses relate to Nutsch molasses after boiling down and equilibration.

TS	Total solids % molasses.
GCS	GLC sucrose % molasses.

F	GLC fructose % molasses.
G	GLC glucose % molasses.
RS	Lane and Eynon reducing substances % molasses.
A	Sulphated ash % molasses.
GCP	GLC sucrose/solids purity.
LEP	Lane and Eynon sucrose/solids purity.
W	Water % molasses = 100 - TS.
GCNS	Non-sucrose % molasses = TS - GCS.
NSUG	Non-sugars % molasses = TS - GCS - F - G.
ONSUG	Organic non-sugars % molasses = TS - GCS - F - G - A.
F/G	Fructose/glucose ratio.
(F+G) or FG	(Fructose + glucose) % molasses = F+G.

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Appendix
BOILING DOWN TESTS — REGRESSION ANALYSIS

Correlation Matrix

	TS	A	GCS	G	F	F + G	GCNS	NSUG
TS	1,0000	- 0,3236	- 0,6195	0,4852	0,5788	0,5520	0,7941	- 0,1853
A	- 0,3236	1,0000	0,7390	- 0,6801	- 0,7488	- 0,7431	- 0,6740	0,6216
GCS	- 0,6195	0,7390	1,0000	- 0,8095	- 0,9012	- 0,8895	- 0,9691	0,5908
G	0,4852	- 0,6801	- 0,8095	1,0000	0,8371	0,9635	0,7793	- 0,8950
F	0,5788	- 0,7488	- 0,9012	0,8371	1,0000	0,9530	0,8797	- 0,7827
F + G	0,5520	- 0,7431	- 0,8893	0,9635	0,9530	1,0000	0,8622	- 0,8787
GCNS	0,7941	- 0,6740	- 0,9691	0,7793	0,8797	0,8622	1,0000	- 0,5158
NSUG	- 0,1853	0,6216	0,5908	- 0,8950	- 0,7827	- 0,8787	- 0,5158	1,0000
ONSUG	- 0,0391	0,1825	0,2999	- 0,7169	- 0,5348	- 0,6588	- 0,2445	0,8836
GCP	- 0,6964	0,7167	0,9947	- 0,8022	- 0,8983	- 0,8839	- 0,9892	0,5627
F/G	- 0,2083	0,3292	0,4331	- 0,7825	- 0,3769	- 0,6179	- 0,4009	0,6671
(F/G)/A	0,5372	- 0,8270	- 0,8911	0,9445	0,9503	0,9882	0,8589	- 0,8618
ONSUG/A	0,2001	- 0,5826	- 0,2952	- 0,0989	0,1143	0,0011	0,2915	0,2727
FG/NSUG	0,5016	- 0,7316	- 0,8456	0,9694	0,9349	0,9945	0,8124	- 0,9162
GCNS/W	0,9597	- 0,5070	- 0,8112	0,6507	0,7511	0,7280	0,9298	- 0,3550

	ONSUG	GCP	F/G	(F/G)/A	ONSUG/A	FG/NSUG	GCNS/W
TS	- 0,0391	- 0,6964	- 0,2083	0,5372	0,2001	0,5016	0,9597
A	0,1825	0,7167	0,3292	- 0,8270	- 0,5826	- 0,7316	- 0,5070
GCS	0,2999	0,9947	0,4331	- 0,8911	- 0,2952	- 0,8456	- 0,8112
G	- 0,7169	- 0,8022	- 0,7825	0,9445	- 0,0989	0,9694	0,6507
F	- 0,5348	- 0,8983	- 0,3769	0,9503	0,1143	0,9349	0,7511
F + G	- 0,6588	- 0,8839	- 0,6179	0,9882	0,0011	0,9945	0,7280
GCNS	- 0,2445	- 0,9892	- 0,4009	0,8589	0,2915	0,8124	0,9298
NSUG	0,8836	0,5627	0,6671	- 0,8618	0,2727	- 0,9162	- 0,3550
ONSUG	1,0000	0,2779	0,6406	- 0,5874	0,6905	- 0,7126	- 0,1425
GCP	0,2779	1,0000	0,4229	- 0,8832	- 0,2962	- 0,8371	- 0,8660
F/G	0,6406	0,4229	1,0000	- 0,5724	0,3057	- 0,6298	- 0,3107
(F/G)/A	- 0,5874	- 0,8832	- 0,5724	- 1,0000	0,1222	0,9839	0,7196
ONSUG/A	0,6905	- 0,2962	0,3057	0,1222	1,0000	- 0,0522	0,2512
FG/NSUG	- 0,7126	- 0,8371	- 0,6298	0,9839	- 0,0522	1,0000	0,6765
GCNS/W	- 0,1425	- 0,8660	- 0,3107	0,7196	0,2512	0,6765	1,0000