EXHAUSTIBILITY OF MOLASSES WITH VERY LOW REDUCING SUGAR LEVELS

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Abstract

Molasses produced by certain South African factories in the middle of the 1994 season had unduly low ratios of (fructose (F) plus glucose (G)) to sulphated ash (A). The current Target Purity formula indicated an abnormally close approach to equilibrium for these samples. The formula has the form

$$\text{Target Purity} = a - b \log ((F + G)/A)$$

The purity calculated using this formula has the characteristic of tending to infinity as the reducing sugar (F+G) level approaches zero, which is unrealistic. A more appropriate formula of the form

$$\text{Target Purity} = a - b (1 - \exp(-c(F + G)/A))$$

was fitted to the body of exhaustibility test data that had been used to derive the current log formula. Applying the revised formula to the 1994 analyses gave a minimum Target Purity Difference (TDP) of 1,5 units versus the 0,5 unit for the log formula. This result is more in line with known levels of molasses purity rise across C-centrifugals. Replacement of the log formula by the exponential form is desirable to avoid an overly optimistic indication of exhaustion performance when reducing sugar contents are exceptionally low.

Introduction

Good exhaustion of final molasses is necessary to maximise sucrose recovery, especially where the input of impurities is high as in South Africa. The type of impurity present is known to affect the purity of molasses. To compensate for this effect a target purity is calculated based on the ratio between reducing sugars and ash in the particular molasses. The difference between this target and the actual purity represents the level of exhaustion performance.

In South Africa reducing sugars are determined chromatographically as fructose (F) and glucose (G) and the sum of the two is expressed as a ratio to sulphated ash, denoted by (F+G)/A.

Target purity formulae have been reviewed by Moritsugu (1974) and those used in South Africa by Ravnö and Lionnet (1982). The formula currently in use in South Africa was derived by regression analysis on the results of extensive boiling down test work carried out by the Research and Development Department of Huletts Sugar Ltd (Rein and Smith 1981). The formula reads

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

A logarithmic form of equation was chosen as it had previously been found to be more appropriate for South African molasses than a linear form (Anon 1973). Its suitability at high values of (F+G)/A was confirmed by exhausting samples with their reducing sugar contents artificially elevated by "spiking" (Rein and Smith 1981). The logarithmic form was originally introduced in Australia after test work in the late 1950's (Miller and Wright 1977).

During the 1994 season a number of very low (F+G)/A ratios were encountered and these were accompanied by Target Purity Difference figures that were also abnormally low. It was queried whether the low TPD results reflected exceptionally good exhaustion performance or whether the formula was inaccurate in the region of low (F+G)/A. This led to the investigation reported here.

Data from 1994

Trends in (F+G)/A over the 1994 season are plotted in Figure 1 for four coastal mills. Low levels were recorded in mid-season, particularly at UF where values were below 0,4 for 12 consecutive weeks.

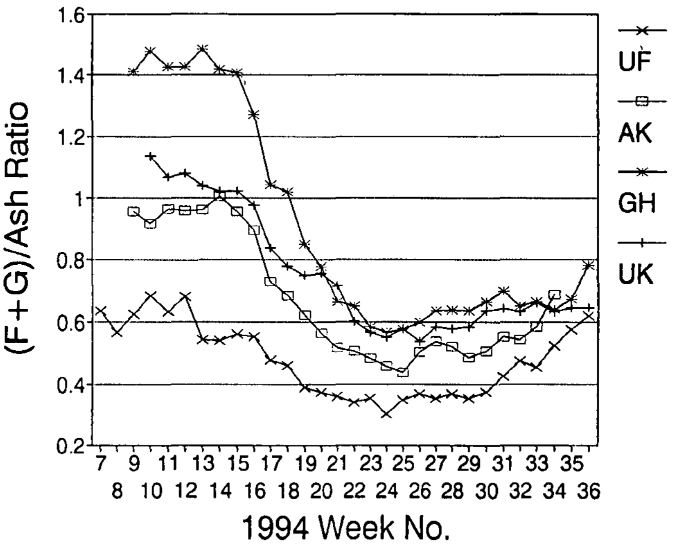

FIGURE 1 (F+G)/ash ratio in molasses, 1994.

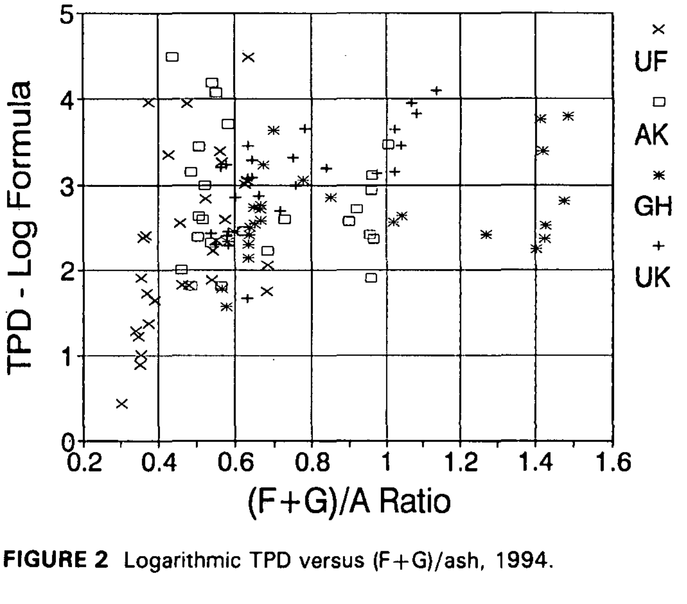

FIGURE 2 Logarithmic TPD versus (F+G)/ash, 1994.

Target Purity Differences calculated by the South African log formula are plotted against (F+G)/A in Figure 2. Logically, if the TPD formula is a fair representation of what can be achieved, the average TPD should be constant, irrespective of the (F+G)/A value. However, a trend of reducing TPD values below 0,4 (F+G)/A is evident, raising the possibility of a bias in the Target Purity formula in this region.

Review of form of equation

The logarithmic form of the equation has the characteristic of tending to infinity as (F+G)/A approaches zero. This is unrealistic as purity cannot exceed 100, which in any event represents pure sucrose and not final molasses. A more suitable exponential form of equation was set up and fitted to the original body of exhaustibility data from which the logarithmic formula had been derived. The resultant equation reads

$$\text{Target Purity} = 43{,}1 - 17{,}5\,(1 - e^{-0.74(F+G)/A})$$

The correlation coefficient (r) is 0,835, which is the same as for the logarithmic regression. In other words, both formulae fit the data equally well.

The boiling down data are shown in Figure 3 together with lines for both equations. There is minimal difference over most of the range although the lines start diverging at the lowest (F+G)/A value of 0,42

Application of the equations to recent data

Purity is plotted against (F+G)/A in Figure 4 for 1994 molasses samples containing low levels of reducing sugars. The log formula increases at an unrealistic rate as (F+G)/A reduces, whereas the exponential formula roughly parallels the actual data with an offset of two or more units.

TPD by the exponential formula is plotted against (F+G)/A in Figure 5. The data appear to be free of bias across the range, unlike the corresponding plot for the log formula TPD (Figure 2).

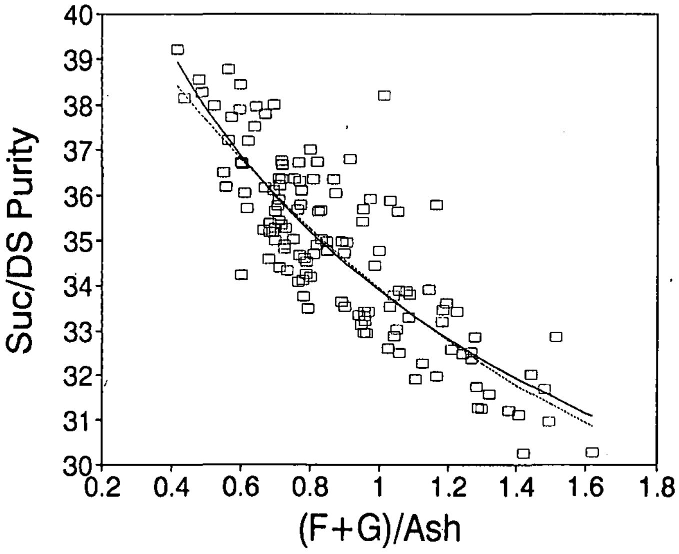

FIGURE 3 Target purity formulae fitted to 1978 and 1979 boiling down data. Solid line = logarithmic formula. Broken line = exponential formula.

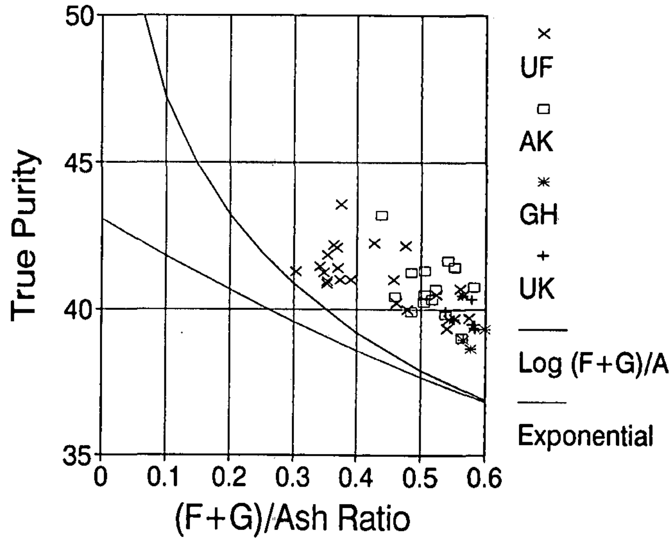

FIGURE 4 Actual and target purities at low (F+G)/ash.

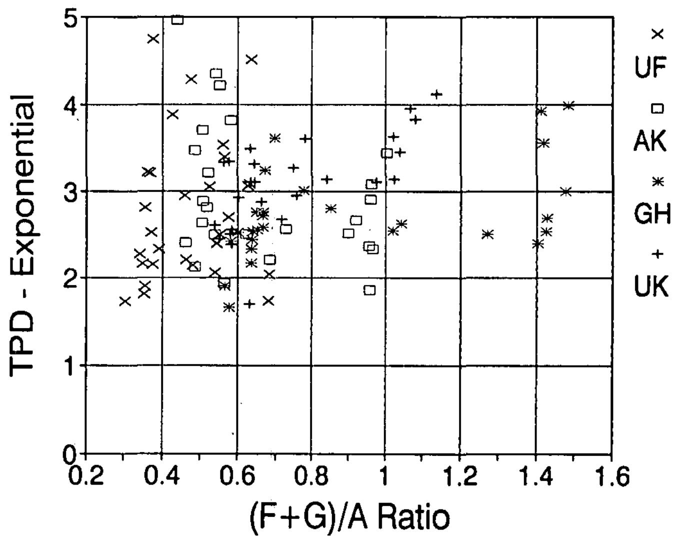

FIGURE 5 Exponential TPD versus (F+G)/ash, 1994.

Practical minimum TPD values

Continuous centrifugals require steam and water addition in order to cure C-massecuites of high consistency. This results in some dissolution of sucrose. The difference between purity of mother liquor (after separation in a Nutsch apparatus) and corresponding final molasses purity is measured routinely. The analytical procedures used are direct polarisation and refractometer brix, which give a purity figure quite different from the true purity derived by gas chromatography sucrose and dry solids. However, the concern here is not with absolute values but with relatively small differences in purity. These differences should be independent of the analytical methods used to determine purity, provided of course that the same procedures are used for both samples.

Season average TPD values are plotted against purity rise on curing in Figure 6. The purity rise is not less than two units on the averaged figures and its level is usually similar to TPD. These data suggest that:

- the "equilibrium" purity reached in the exhaustibility test is closely approached in the factory;

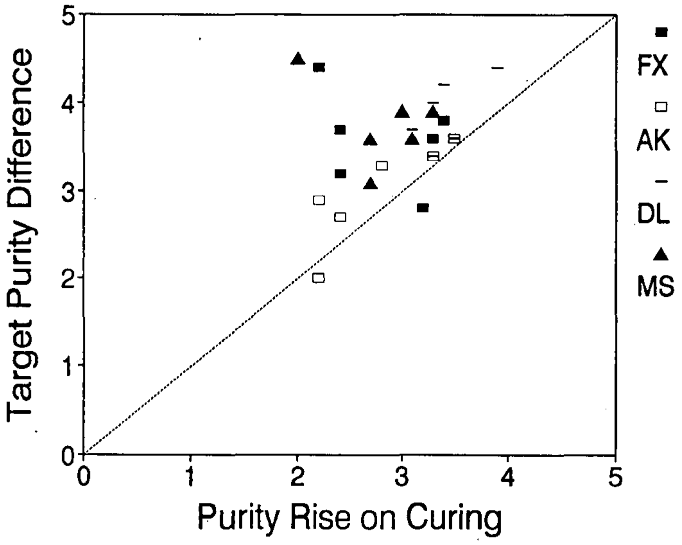

FIGURE 6 TPD versus purity rise on curing, 1989 to 1994.

- a purity increase of two units or more is fairly inevitable with present centrifugation equipment; and
- the TPD values below 1,5 units found last season at very low (F+G)/A are spurious due to the inapplicability of the log target purity formula in that region.

Conclusions

The current logarithmic Target Purity formula is a fundamentally inappropriate and results in erroneously low TPD values at (F+G)/A ratios below 0,5. An alternative exponential form which does not have this deficiency has been derived from the original data. Although slightly more complex this should not be a bar to its use, thanks to the ready availability of computers for carrying out the necessary calculations.

Acknowledgments

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