DISPLACEABILITY INDEX

By R. G. MARKHAM

Technical Services Division

Hulett's S.A. Sugar Mills & Estates, Ltd.

Abstract

A method and apparatus for determining the availability of sucrose in prepared bagasse is described. A relationship is postulated between this figure and mean particle size determined by sieve analysis.

Introduction

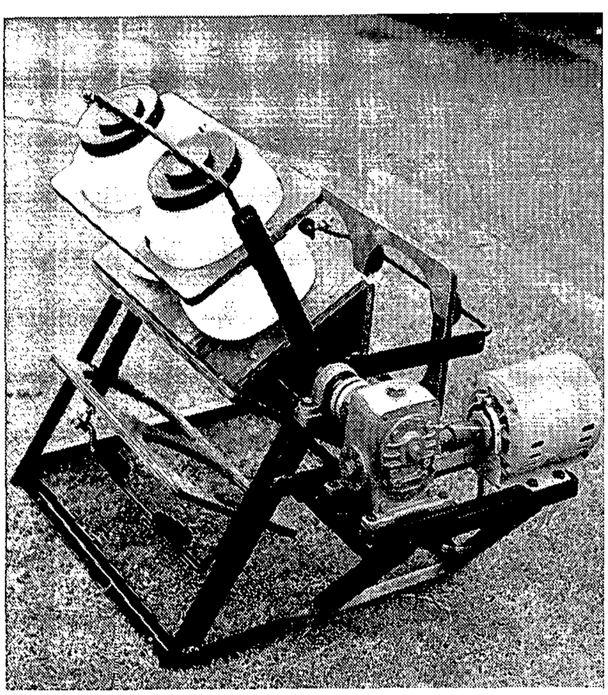
Payne[1] mentioned the determination of Displaceability Index (D.I.) a direct measure of the availability of sucrose in diffuser bagasse. Work has also been done in South Africa relating sucrose availability to milling performance.[2]

Recent investigations, as yet unpublished, have found that during the extraction of sucrose from bagasse by the diffusion process, the degree of preparation of the bagasse is the greatest single factor affecting the rate of extraction. A method for determining D.I. was developed and used in conjunction with particle size analysis as a means of characterising preparation during these investigations.

Apparatus

The apparatus is essentially the same as that shown in Figure 1 which was designed and constructed by the Sugar Milling Research Institute. A wooden framework of triangular cross-section with a horizontal axle passing through its centre is mounted through two roller bearings to a metal stand.

FIGURE 1



The frame, which can accommodate six one-gallon plastic bottles, rotates at 20 rpm about this axis, driven by a small electric motor through a reduction gear. The bottles are mounted so that they revolve end over end.

Method

Three thousand grams of water are added to a representative 500 gram sample of the bagasse and the mixture sealed in a plastic container. This mixture is rotated for thirty minutes, after which 100 ml of extract is removed. The extract is clarified with 0.2 grams of basic lead acetate, filtered, and the pol determined in the usual way.

A separate sample of bagasse is analysed for pol and moisture using standard methods.

Notes

1. It is recommended that all tests be performed in duplicate. Tests were initially performed in quadruplicate, the samples being rotated for periods ranging from 15 minutes to two hours. A partial equilibrium was attained after one hour in most cases. With coarser bagasse longer retention times were necessary for equilibrium.

   The results of one of these series of tests are shown in Table II.

   It was decided to use 30 minutes as the rotation time because it coincided with the bagasse residence time in the pilot plant diffuser. For factory tests rotation time could be extended to two hours, or it could be equated to residence time in the particular diffuser.

2. For purposes of accuracy the weight of bagasse used should be as large as possible. This will increase the value and hence the accuracy of the pol determination as well as the representativeness of the sample.

   However, limiting factors are the size of the mixing vessel and the fact that if the bagasse sample becomes too bulky adequate mixing will not take place. Investigations showed that the ratio 500 : 3,000 would best satisfy the demands of accuracy and thorough mixing.

Calculation

Let pol % bagasse = P
Let moisture % bagasse = M
Let pol of extract = J
Assume the weights mentioned above.

$$\text{Total moisture in vessel} = 3{,}000 + \left(500 \times \frac{M}{100}\right) \text{ g}$$

This is (100—J)% of juice weight

$$\text{Therefore total juice weight} = (3{,}000 + 5M)\frac{100}{100 - J} \text{ g}$$

Therefore weight of pol extracted

$$= \frac{J}{100}(3{,}000 + 5M)\frac{100}{100 - J} \text{ g}$$

Displaceability Index (by definition)

$$= \frac{\text{weight of pol available}}{\text{total weight of pol in bagasse}} \times 100\%$$

$$\text{Total weight of pol} = 500 \times \frac{P}{100} \text{ g} = 5P \text{ g}$$

Therefore displaceability index

$$= \frac{\frac{J}{100 - J}(3{,}000 + 5M)}{5P} \times 100\%$$

Note.—This calculation does not take into account the moisture in the bagasse which is not available for mixing, i.e. that which is associated with the unavailable sucrose. However, the correction is so small that it can be ignored for all practical purposes.

Particle Size Analysis

All bagasse samples were sieved through a series of seven screens, with openings ranging from 12.7 mm down to 0.35 mm.

Mean particle size was taken as the 50% line when % undersize was plotted against screen size on semi-log paper.

Results

Preliminary work on the pilot plant diffuser involved four distinct levels of preparation. There were a number of samples at each level. The averages for displaceability index and mean particle size for each of these four levels are shown on Table I.

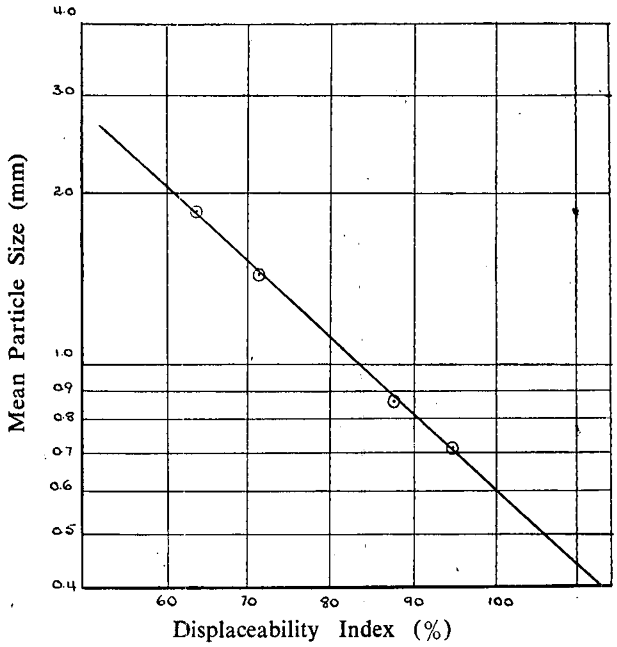
Figure 2 is a plot of the displaceability index against logarithm of mean particle size. It can be seen that there is a straight line relationship of the form

$$\text{D.I.} = k^* \log r + c^*$$

$$\text{or } r = e^{k\,\text{D.I.} + c}$$

where r = mean particle size
k, k^*, c, c^* are constants.

FIGURE 2



Discussion

It can be seen from Figure 2 that a mean particle size of 0.59 mm should result in 100% sucrose availability. However, this degree of fineness would lead to numerous other problems, such as poor percolation, and is not practical.

Acknowledgements

The author would like to thank the staff of Hulett's Research and Development, in particular Mr. G. T. Schumann, for their assistance.

References

1. Payne, J. H. (1960). New Concepts in Cane Diffusion. Repts. Hawaiian Sugar Technol. 19 Ann. Meeting, 1960, 107-113.
2. Buchanan, E. J. (1961). S.M.R.I. Quart. Bull., 19 & 20, 1961.

TABLE I

Preparation	No. of Samples	Mean Particle Size (mm)	Displaceability Index
P1	4	1 86	63.6
P2	5	1 45	71.4
P3	7	0.86	87.4
P4	8	0.71	94.5

TABLE II

Pol of extract against time indicating attainment of partial equilibrium and reproducibility of analyses

Sample Number	1	2	3	4
Time				
½ hour	1.19	1.23	1.21	1.23
1 hour	1.28	1.32	1.28	1.32
1½ hours	1.31	1.37	1.32	1.35
2 hours	1.31	1.37	1.32	1.35

Discussion

Dr. Graham (in the chair): All the work described in this paper was done on final bagasse but I think the feed to the mills should have been included.

Mr. Markham: All the determinations were performed on 1st mill bagasse at Mount Edgecombe, which would correspond to bagasse entering a diffuser in a diffusion mill.

Mr. Jullienne: How were the different levels of preparation achieved?

Mr. Markham: We used a hippo mill, the principle of which involves fixed blades cutting against screens of various mesh sizes.

Mr. Renton: At Empangeni this season we have introduced a test of displaceability index of cane after the knives and after the first mill every shift. This should indicate day to day variations in cane preparation.

Mention is made of extracting for periods of half an hour, one hour and two hours but some diffusion presumably occurs during this time, which will affect the results.

Mr. Markham: From Table 2 it will be seen that after the first hour there is very little sucrose coming out of the bagasse. These readings are for comparison with the previous weeks readings and the other mills preparation so they need not be, and are not, exact. They are comparable, provided the same extraction time is used in each case.

Mr. Jennings: There will not be diffusion through the cell walls of unruptured cells as heat is not applied.

Mr. Buchanan: When an accumulated weight distribution is plotted against a numerical count distribution the mean particle size obtained from the median is a mean weight particle and not the normal mean diameter of a particle.

It is rather complicated to calculate the mean diameter particle.

Dr. Preen: Mr. Buchanan is quite correct but the fact that you get a correlation using this sort of parameter does indicate that there is a relationship between particle size and displaceability.

Dr. Graham: What is the reproducibility of the test?

Mr. Markham: Table II indicates the pol actually obtained. A pol of 1.19 gives a displaceability of 70.19 and a pol of 1.35 gives 78.72.

The variation is from 76.39 to 79.89.

Mr. Jullienne: Does the relationship between mean particle size and displaceability index hold good for shredded cane?

Mr. Markham: Yes, because displaceability index is a ratio of juice extractable to total juice present.

Dr. Preen: Since the data have been analysed more completely it has become apparent that the greatest single factor affecting the rate of extraction is not the particle size but the flow rate, or the wetting rate.

Particle size is very important, particularly in connection with the ultimate amount that can be extracted.

Mr. Buchanan: Dr. Preen's comments agree with our experience at the S.M.R.I. in diffusion research.

When a diffusion column was filled with canc, if we started recirculating the water up and down, the percolation rates were relatively small compared to an alternative of upward flushing the bed first to get rid of all the air and then recirculating. Our rate then was up to three times better than without the back washing. The increase in wetting of the cane surface does increase the diffusion rate, or the leaching rate.

In most cases when this was done results were reproducible.

Dr. Matic: Dr. Preen, shouldn't this be qualified by saying it should be in a certain range? If the pieces are very big will the rate of wetting be more important than the size of particle?

Dr. Preen: I am talking within the range of particle sizes mentioned here. The actual preparations are physical ones that we have used in a pilot plant diffuser. I should point out that the P1 preparation corresponds to first mill bagasse, which is the coarsest preparation one would expect in practice. The P4 preparation was much finer than one would ever realise in practice. Our aim was to bracket the practical results.

We did find that we were not able to percolate through a very fine preparation at a very high rate. We found a finer preparation gave a higher extraction rate at equivalent wetting rates, but because we could not wet it at the higher rates possible with a coarse preparation, we could not take full advantage of the fine preparation.