SOME IDEAS ON THE USE OF CHEMICAL METHODS FOR IMPROVING THE COLOUR OF A-SUGAR

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Abstract

The use of chemical agents as clarification and decolorising aids in order to obtain a lower coloured A-sugar have been investigated. The chemicals tested include bentonite, sulphur dioxide and some sulphurous acid salts. Colour levels in various factory products have been surveyed. From this information, together with that obtained in specific decolorising tests, an attempt has been made at an economic assessment of chemical means for improving A-sugar colour.

Introduction

In recent years there has been a growing awareness of the importance of the local market to the S.A. sugar industry and as a consequence emphasis has been placed on improving the quality of the refined sugar. Since colour is one of the most important refined sugar quality criteria, this aspect has come under scrutiny. When it is further realised that the quality of the raw product is following a deteriorating trend (Getaz;[2] Lionnet and Vanis[5]) it becomes natural to investigate methods of improving the situation.

Recent attempts at improving the colour of A-sugar have been centred around operational and process modifications to such aspects as the pan boiling techniques used, syrup clarification, the washing in the centrifugals etc. The present concern with sugar colour and the interest that the syrup clarification process has aroused, have prompted thoughts that the use of chemical agents to reduce factory product colours and consequently that of the sugar should be re-evaluated.

Before any investigation into methods of improving raw sugar colour is begun it is important that the economic incentives are clearly understood. For the purpose of this work three categories are considered on which the economic importance of raw sugar colour for a factory can be judged.

Raw sugar for export

The latest penalties for raw sugar colour applied by the Sugar Terminal are based on the formula:
Colour penalty (cents/ton) = 0,132* (Sugar colour - 1350).
Table 1 details the value of the colour penalty for various sugar colours.

The problem of colour for export raw sugar is mainly a seasonal one, with most factories encountering no problems meeting the specified colour during peak periods, while many factories do face difficulties at the beginning and end of a season.

Table 1

Colour penalties at various sugar colour levels (as applied by the sugar terminal)

VHP sugar ICUMSA 420 Colour	Percentage above the 1350 ICU level specification	Penalty amount (cents/ton sugar)
1400	3,7%	7 cents
1450	7,4%	13 cents
1500	11,1%	20 cents
1560	14,8%	26 cents
1600	18,5%	33 cents

Raw sugar for supply to a local refinery

The quality of the raw sugar in this case has a direct bearing on subsequent refining costs, therefore for mills with back-end refineries a direct gain is achieved by producing better raw sugar. For mills having no back-end refinery but which supply Hulett Refinery with raw sugar, the situation is similar. The HR raw sugar payment scheme attempts to relate the payment as closely as possible to the subsequent cost of refining that sugar (Bervoets, A, Personal communication).

Present clarification/decolorising costs, in terms of chemical consumption, in South African refineries are in the range between R2,00 and R8,00 per ton of refined sugar made. Costs incurred in reducing raw sugar colour should ideally reduce the refinery decolorising costs by a greater margin. However, the situation is affected by progressively deteriorating raw sugar colours on the one hand and an increasing and growing demand for better quality refined sugar on the other.

Raw sugar for direct consumption

The large relative price differential between refined and "brown" sugar (approximately R100,00 per ton) on the local market has led to a growing demand for VHP sugar, particularly by manufacturers who are using VHP as a replacement for refined sugar wherever possible. In these circumstances it appears reasonable that an intermediate product to bridge this gap both in terms of colour and cost should be sought. Although mill white sugar is not entirely what is envisaged it falls into the same category. No premium is paid at present for production of direct consumption raw sugar with lower colour, therefore investigations into this area should receive a low priority.

A colour balance in a raw sugar factory

The level of colour in the various streams in a factory is an obviously important factor to be considered when investigating decolorisation. It was therefore decided to survey the colour levels in the factory products and to draw up some sort of mass balance to quantify their value.

Three mills representing a good cross-section of raw sugar factories (UK, IL and DL) were chosen for this survey, which was conducted at the beginning, middle and end of the crushing season to cover seasonal variations in colour levels. In the balances developed from the surveys, the colour quantity used is calculated as follows:
(Tons product) * (Brix % product) / 100 * (Colour of product).
This quantity is termed "Colour Load" in the present report.

Table 2 gives the average results and range of the values of the colours of the various products sampled during the surveys. Table 3 shows the mass balance colour load units calculated per 100 units in clear juice.

Table 2
Colour surveys - colours of factory products

Product	Average	Range
Clear Juice	18765	15417 - 22633
Syrup	19716	15182 - 23728
Remelt	29622	23098 - 42098
A-Massecuite	22960	19348 - 30829
A-Molasses	51067	40800 - 66063
B-Massecuite	60170	49385 - 74214
B-Molasses	97866	71900 - 112880
C-Massecuite	105205	80600 - 131333
C-Molasses	131650	101250 - 159068
A-Sugar	1096	904 - 1498
B-Sugar	16496	9620 - 24300
C-Sugar	31415	22875 - 38400

Table 3
Mass balance calculations product colour load units per 100 units in clear juice

Product	DL av	IL av	UK av	Total av	Range
Juice	100	100	100	100	–
Syrup	100	113	112	109	90–129
Remelt	28	27	31	29	8– 47
A-Pan Feed	128	145	144	139	98–165
B-Magma	23	12	10	15	8– 29
A-Massecuite	154	190	169	171	121–216
A-Sugar	5	4	5	5	3– 7
A-Molasses	156	169	162	162	97–219
B-Massecuite	148	163	152	154	96–225
B-Sugar	26	19	22	22	8– 38
B-Molasses	123	128	121	124	99–164
C-Footing	36	32	25	31	7– 55
C-Massecuite	184	190	183	186	116–264
C-Sugar	23	16	20	20	10– 32
C-Molasses	148	175	145	156	103–198

The values in Table 3 show that the balances tie up surprisingly well, particularly considering the relatively short sampling periods of 5 hours for each survey. Some preliminary observations which can be made are:

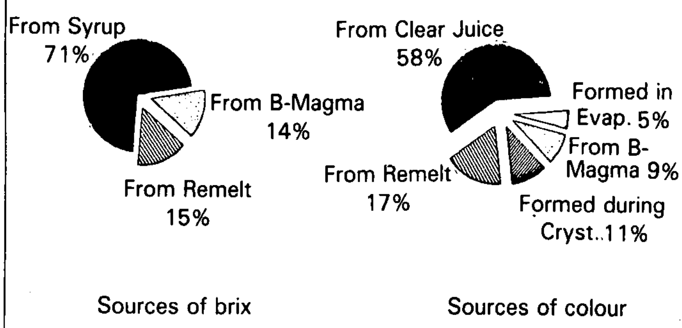
(a) A colour increase, averaging 9%, was found to have occurred across the evaporator stations. The results span a range from -10% to $+29\%$. Other tests carried out at SZ showed colour increases averaging only 2,5%.

(b) The following colour increases during crystallisation were found (the massecuite was sampled at the outlet of the crystallisers):—
A-Massecuite: Average 11%, range -5% to $+24\%$.
B-Massecuite: Average 18%, range $+1\%$ to $+35\%$.
C-Massecuite: Average 20%, range $+3\%$ to $+41\%$.

(c) The average quantity of colour leaving the factories in A-sugar and C-molasses was calculated as 161% of that entering in clear juice. This figure ties up reasonably well, again especially considering the short period over which the sampling was carried out, with the sum of the average quantities of colour in clear juice and that formed in the factory (per 100 units in clear juice) which equals 149, i.e. an error of 8%.

(d) The contribution of each of the constituents of A-massecuite to its final colour can be gauged. This is illustrated graphically in Figure 1.

FIGURE 1
A-Massecuite – Sources of Brix and Colour



Bentonite

On several occasions in the history of sugar manufacturing clay, and in most cases a special technical clay, bentonite, has been used as an auxiliary defecant in raw sugar clarification (Honig,[3] Mallea[6]).

The effect of bentonite on the clarification process has been tested on a laboratory scale at the SMRI and on a factory scale at Illovo. It was found that the use of bentonite as an aid to mixed juice clarification produces optimum results at about 0,2% dosage rates. During the factory trials it was found that bentonite gave a 10–15% improvement in clear juice turbidity. However, with a corresponding operational cost of R0,70 per ton of cane it does not present a promising economic process.

If bentonite is used in conjunction with syrup clarification the operational cost will be around R1,10 per ton sugar. Laboratory syrup clarification tests carried out at the SMRI indicate that turbidity removal can be increased by about 2 to 4 percentage points with bentonite use. In these circumstances the use of bentonite as a syrup clarification aid also does not appear to present any promising economic advantage.

Sulphites and Sulphitation

Sulphur dioxide and sulphurous acid salts are used extensively as decolorising agents. They are effective in not only destroying colour but also in inhibiting its formation.

Sulphur dioxide. In raw sugar factories the application of sulphitation is nowadays, generally restricted to use in the production of mill white sugar. In South African refineries three of the seven (ML, PG and GH) use a light sulphitation as an additional, mainly decolorising step following carbonation, while one (UF) uses it as the sole clarification/decolorising agent.

The use of sulphitation as a clarification process in a raw sugar factory, despite producing lower coloured sugars, suffers from the disadvantage that severe juice heater and evaporator scaling are encountered. These adverse effects and the cost would be reduced if SO_2 was used for decolorisation only. Neutralization with lime and removal of the $CaSO_3$ precipitate would, of course, still be required. However, if this is carried out in conjunction with syrup clarification the $CaSO_3$ precipitate could be removed with the scum.

Rein[8] has reported on laboratory syrup clarification tests where reductions in syrup colour of 20 - 25% were obtained using dosages of 0,3% lime, 300 ppm phosphate on brix and gassing with SO_2 to a pH between 6,0 and 6,5.

Sulphurous acid salts. Of the three sodium salts of sulphurous acid discussed in this section, sodium sulphite (Na_2SO_3) is reportedly the least effective in reducing colour or inhibiting its formation. Nevertheless the application of this chemical for colour inhibition has been tested, reportedly successfully, at beet sugar factories in Russia. (Bobrovnik *et al*[1]).

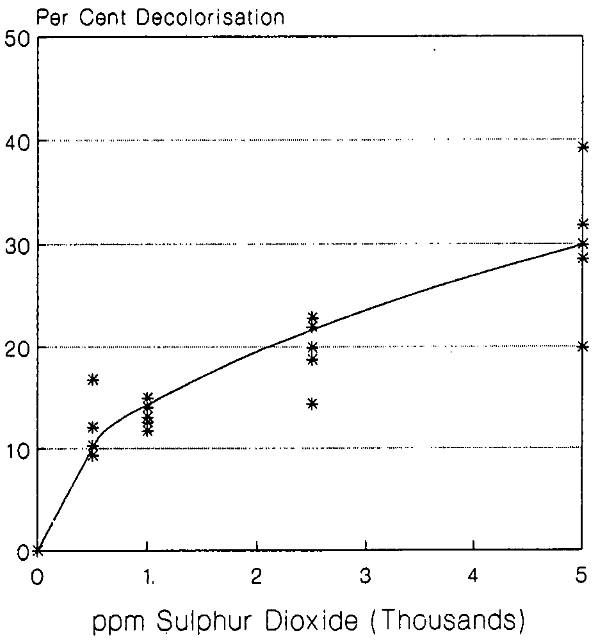
Vaccari *et al.*[10] have used sodium bisulphite ($NaHSO_3$) to eliminate colour formation during the evaporation of beet juice.

In the cane sugar industry of former days, sodium hydrosulphite ($Na_2S_2O_4$), which is also called sodium dithionite or blankite, was used to a considerable extent to improve the colour of mill white sugar. Riffer[9] observed colour removals in refinery liquors of between 30 and 40% with 500 ppm dosage rates of sodium hydrosulphite. A further advantage attributed to blankite (and sulphites in general) is that it diminishes the viscosity of the syrup or molasses.

Laboratory Tests

Laboratory testing of syrup sulphitation in combination with syrup clarification has been performed. The results of the decolorisation achieved in these tests are illustrated graphically in Figure 2. The quantity of SO_2 added was determined by stoichiometry. There could be large errors in this approach. An indication of the scatter in the results obtained can be seen in Figure 2.

Figure 2
Laboratory Testing of Simultaneous Syrup Clarification and Sulphitation



The amount of Sulphur Dioxide was determined from the Lime dosed.

In the use of sulphitation for mill white sugar production the literature reports that the quantities of sulphur used amount to 0,3–0,45 kg per ton of cane, which is approximately equivalent to 3000 - 8000 ppm SO_2 on syrup (Hugot[4]). From the results in Figure 2 it appears unlikely that sufficient decolorisation would be achieved by syrup sulphitation for mill white sugar production. This indicates that mixed juice sulphitation, particularly at the higher SO_2 dosage rates, achieves better decolorisation than does syrup sulphitation.

Laboratory tests have been conducted to measure the decolorisation that can be achieved when applying various dosages of Na_2SO_3 and $Na_2S_2O_4$ to factory products. A large number of samples had to be analysed before any clear conclusions could be drawn, because the precision of colour analysis is only about 5%. In these tests a total of 257 colour analyses were carried out and the averaged results were illustrated graphically in Figure 3.

Figure 3
Results of Laboratory Decolorising Tests Using Various Sulphurous Acid Salts.

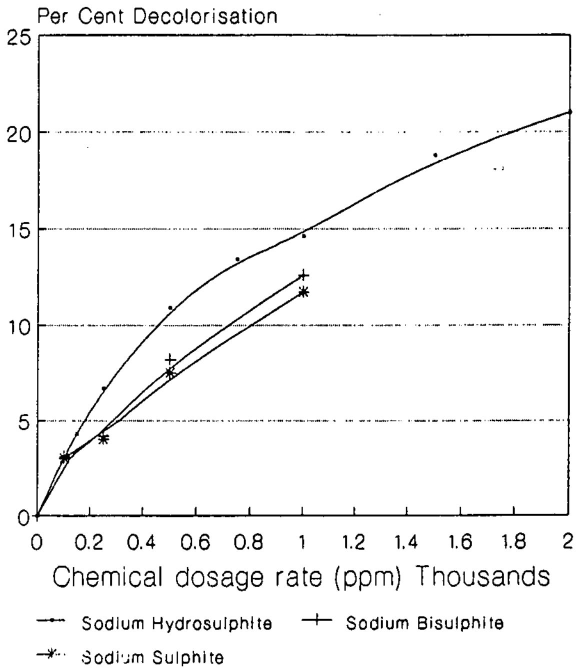


FIGURE 3 Results of Laboratory Decolorising Tests Using Various Sulphurous Acid Salts.

Factory Experiments

Decolorisation of remelt with sodium hydrosulphite. It has been suggested that in order to reduce A-sugar colour it might be more effective to concentrate on a more highly coloured stream, such as remelt, as opposed to attempting syrup or A-massecuite decolorisation. This was tested with sodium hydrosulphite (SHS) as the decolorising agent, on plant trials at UK. A dosage rate of 500 ppm SHS on remelt was chosen with corresponding cost of R0,60 per ton of sugar made. As is to be expected in a test of this nature the results, being influenced by a variety of other factors, are difficult to interpret. However, any positive change, in A-sugar colour appears to be small.

The use of sodium hydrosulphite during A-pan boiling. In most cases where SHS is used as a decoloriser (or viscosity reducer) it is dosed into a vacuum pan. It was therefore decided to test the decolorising effect of dosing SHS into a pan boiling A-massecuite. Four tests have been conducted, one at SZ and three at UK, where SHS was dosed at 250 ppm. The averaged results are illustrated in Table 4. Since feed syrup colour changed during the tests no firm conclusion can be drawn. However, it once again appears that any positive effects on sugar colour appear to be small, the differences in colour being generally within the analytical error.

Table 4

Averaged results of tests conducted to determine the effects of sodium hydrosulphite addition to A-massecuite during pan boiling

Product	Run 1 (NO SHS) Product Colour	Run 2 (WITH SHS) Product Colour	Percentage Difference
Footing	19522	19223	1,5%
Pan Feed	21243	19892	6,4%
Massecuite at strike	21762	19365	11,0%
Aff. sugar at strike	427	407	4,6%
Nutsch molasses	47147	43681	7,4%

Operational costing of some decolorising chemicals

Based on the results of the experimental work an attempt has been made to assess the cost effectiveness of using the chemicals on syrup, the details of which are shown in Table 5. From this some preliminary conclusions can be drawn:

- The most cost effective of the chemicals is sulphur dioxide followed by sodium bisulphite, sodium hydrosulphite and sodium sulphite
- The cost of chemicals to effect a reduction in export sugar colour will be far higher than any colour penalty incurred. An export sugar with a colour of 1600 ICUMSA units requires a 15% improvement to bring it in 'spec' and would incur a penalty of 33 cents per ton. To achieve 15% decolorisation with SO_2 application to syrup would incur an operational cost of R1,16 per ton sugar
- It appears to be more cost effective to concentrate chemical decolorising efforts in a refinery.

Table 5

Comparative costing of "sulphites" as decolorising chemicals (for application to syrup in a sugar mill)

Chemical	Dosage on syrup (ppm)	Expected % decolorisation	Cost per ton sugar
Sulphur Dioxide (obtained as elemental sulphur)	100	4%	R0,12
	500	12%	R0,58
	1 000	15%	R1,16
	2 500	22%	R2,90
	5 000	30%	R5,80
Sodium Bisulphite	100	3%	R0,27
	500	7%	R1,36
	1 000	12%	R2,73
Sodium Hydrosulphite	100	4%	R0,68
	500	12%	R3,38
	1 000	15%	R6,77
Sodium Sulphite	100	3%	R0,34
	500	7%	R1,69
	1 000	11%	R3,38

The last conclusion needs to be considered in more detail. If the concept of colour load, as previously defined, is considered then the following points can be made:

- For a syrup of 20 000 ICUMSA units of colour 3000 colour load units must be destroyed or removed to achieve 15% decolorisation
- For a liquor of the same brix and a colour of 1000 ICUMSA units only 150 colour load units of colour need to be destroyed or removed to achieve 15% decolorisation.

Thus in a raw house approximately 20 times more colour must be destroyed or removed than in a refinery to achieve the same percentage decolorisation.

To illustrate the point further, consider the use of SO_2 in sulphitation following carbonatation as applied at ML, PG and GH. In this process the colour of carbonated liquor is generally changed from a value of about 700 to 600 ICUMSA units (i.e. $\approx$ 15% decolorisation) through the application of about 0,10 kg sulphur per ton refined sugar. Applying the same costs as used in Table 5 this 15% decolorisation is achieved at a cost of 11,7 cents per ton refined sugar. As previously shown (Table 5) a 15% decolorisation of syrup by sulphitation, in a raw house, is estimated to cost R1,16 per ton raw sugar. At Umfolozi, where melt sulphitation is applied for refining, typical decolorisation achieved from melt to fine liquor is 55% at an application rate of 7,38 kg sulphur per ton refined sugar. Once again applying the same costs it can be calculated that this 55% decolorisation is achieved at a cost of R8,60 per ton refined sugar, whereas for syrup sulphitation the same percentage decolorisation would be achieved at a conservatively estimated cost of R10,63 per ton raw sugar.

As a last comment on this topic it should be remembered that no consideration has been given to the colour inhibiting properties of sulphites. McGinnis[7] attributes the major use of SO_2 and sulphites in beet sugar factories to their effectiveness in inhibiting colour formation during processing.

Conclusions

Investigations into chemical decolorising processes should be concentrated on refinery operations since this appears to be the most cost effective area of application for these operations.

Further work on colour surveys could contribute to a better understanding of colour formation in a raw sugar mill, particularly if this should include the front end of the factory and the effect of cane quality.

Flotation clarification, in particular syrup clarification, is a new process receiving world-wide attention in the sugar industry. Whilst the boosting of syrup clarification decolorising performance with SO_2 does not appear economical, some preliminary work on the use of polyacrylamide flocculants to achieve this has indicated that this could be a promising area for further investigation.

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