A SURVEY OF COLOUR INPUT AND FORMATION IN PROCESS

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Abstract

Colour of evaporator syrup, product sugar and final molasses was determined on weekly composite samples from five factories over a full season. High values early and late in the season were found for both syrup and sugar. This is considered to be an effect of cane quality and not of factory conditions. There was a major increase, averaging over 50%, of colour from input syrup to output (sugar plus molasses). Additional measurements at one factory did not indicate any material colour increase across clarification, evaporation or continuous A pan boiling. The colour formation appears to arise in low grade boilings as a result of Maillard-type reactions. Returns of B and C sugar typically comprised less than 30% of brix but over 40% of colour in A massecuite. Processing conditions that contribute to low sugar colours include high A massecuite exhaustion and a low level of Maillard reaction. Elimination of high-colour sugar would require attention to cane quality factors.

Introduction

Colour of raw sugar, as the main determinant of refining quality, has become increasingly important in recent years. Product sugar colour levels often vary due to causes which are not controllable or even fully understood. To give some perspective, season average figures for all VHP sugar (Refinery and Terminal receipts combined) produced by Tongaat-Hulett mills over three seasons appear in Table 1.

Table 1
Colour of total VHP sugar (ICUMSA 420 units)

	FX	AK	DL	MS	ME
1986/87	1310	1300	960	1300	1050
1987/88	1440	1380	1060	1340	1090
1988/89	1400	1460	1150	1520	1050

While the figures for DL and ME have been comfortably within the specification of 1350, those for the other mills are marginal or over.

During the 1988/89 season requests were made for the high colours at MS in particular to be investigated. Although the Sugar Milling Research Institute (SMRI) have recently done much work in the colour area (Getaz and Bachan,[3] Lionnet,[5,6] Reid and Lionnet[8]) it was felt worthwhile to carry out directed colour surveys with a view to bringing sugar colours within specification if possible.

Recent Australian work (Paton and McCowage[7]) indicated that alkaline degradation reactions during clarification can increase colour levels. A survey of colour in process streams was carried out at MS to establish whether this could be a material contributor to the problem. In addition it was possible to obtain information in two other important areas:

- seasonal variation of input colours, and
- colour formation in the boiling house,

mainly through colour analyses on composite samples of evaporator syrup and final molasses that had already been collected for other analytical programmes.

Procedures

Three separate programmes were implemented as outlined below. In all cases colour was determined according to the SASTA Laboratory Manual (Anon[2]), i.e. at 420 nm on filtered samples adjusted to pH 7,0 with the results corrected for brix and expressed as ICUMSA units.

Factory Control

Samples of mixed juice, clarified juice, syrup, remelt and pan feed were frozen in sachets by MS staff. These were sent weekly to the Tongaat-Hulett Sugar Technology Department (STD) laboratory where they were thawed and composited for colour analysis. This programme ran for six weeks in August and September 1988.

A Massecuite boiling

Possible colour increase in the MS continuous A pan was evaluated by measurements on massecuite from the first compartment, pan feed and strike massecuite. Ten sets of daily composites were collected and analysed in December 1988.

Overall balances

Colour was determined on weekly composites of syrup and final molasses from all Tongaat-Hulett mills. Samples were already available from other routine analytical programmes. It was therefore possible to cover the whole 1988/89 season retrospectively. Product sugar colours were weight-averaged from Terminal and Refinery weekly analyses and tonnages. Colour balances were calculated using brix tonnages derived from factory data.

Results and Discussion

Colour input

This work did not include direct measurement of colour in cane juice. However, available evidence indicates that syrup colours are similar to colour in cane where the extraction plant is a milling tandem. Certainly seasonal variations in syrup colour mainly reflect changes in cane. The weekly syrup colours are plotted in Figure 1.

High early-season colours are a feature, reducing progressively to the end of May. During mid-season there was not much in the way of consistent trends, until November when colours rose again. This evidence of seasonal trends is not new but confirms earlier findings.

Factory front end

The programme of colour analysis on MS weekly composites gave the figures shown in Table 2.

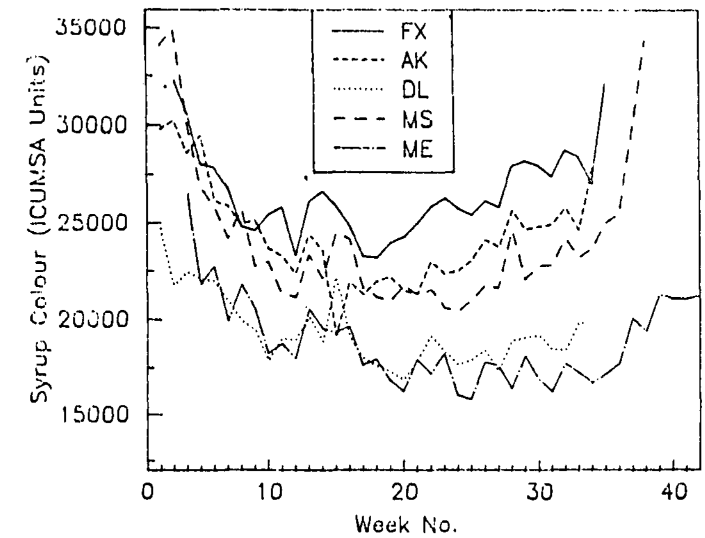

FIGURE 1 Colour of weekly composite syrup samples.

Table 2

Percentage change in colour over MS front-end

Week Ending	Mixed Juice to Clarified Juice	Clarified Juice to Syrup
21-8-88	+8	+1
28-8-88	−1	+3
6-9-88	0	+3
13-9-88	−4	+1
20-9-88	+2	+1
27-9-88	+2	+3
Average	+1	+2

Changes are small, and in two cases an anomalous drop from mixed juice to clear juice is indicated.

The Australian test work (Paton and McCowage[7]) showed actual colour increase figures from 1000 to 1500 units for the conditions that obtain in our clarification process. This is around 10% of the input colour in the Australian situation but, because of our much higher input colours, this figure is closer to 5% for SA mills. Therefore while some colour formation no doubt can occur due to alkaline degradation, it seems too little to pick up against background "noise" due to process and determination variability.

A Pan Boiling

Average colours of 12 sets of daily composites across the MS continuous A pan are given in Table 3.

Table 3

Colour analyses over MS A Pan

	ICUMSA 420 units
Compartment 1 massecuite	31200
Syrup/remelt feed	30700
Strike massecuite	31000

There is no significant difference between the figures in Table 3, and colour formation during A boiling does not appear to be a problem, at least in the case of the MS continuous pan.

Factory back end

The all-mill data body of syrup, molasses and sugar colours was used to provide figures for overall colour increase. Weekly colours were arithmetically averaged to give season figures. Brix tonnages were calculated from factory data, equating brix in syrup to brix in MJ as an approximation. "Season" here was taken as to- date end November, due to problems after that with sampling irregularities over boil-off and protracted despatch of small sugar tonnages in some cases.

In order to do the balance calculations, a "colour mass unit" was defined as:

$$(\text{tons brix}) \times (\text{ICUMSA units}) / 10^6$$

This is a purely arbitrary unit; the divisor of one million was introduced only to avoid excessively large numbers.

ICUMSA colour units, brix tonnages and colour mass units are shown by product and for each mill in Table 4.

There is a major increase in colour across the boiling house. A few measurements by SMRI gave a similar colour increase figure (70%) and also showed that around half of this occurred in the C station (Getaz and Bachan[3]). Degradation products of the Maillard reaction are known to include coloured compounds.

If all colour formed in the back end went out with C molasses, this effect would be of no significance in sugar production. However, remelted B and C sugars are returned to A massecuite. Colours of raw syrup, remelt and the mixture of the two are shown in Table 5 (average of 6 weekly composites ex MS).

Colour of remelt is over 50% higher than in raw syrup. An additional figure that can be calculated is the proportion of remelt in pan feed, which at 28% (brix basis) agrees with figures derived from brix balances. Because of their higher

Table 4

Overall Colour Balance Data 1988/89

	FX	AK	DL	MS	ME
ICUMSA Colour Units:					
Syrup	26400	24200	19200	23400	18600
Molasses	181000	151000	145000	158000	128000
Sugar	1400	1480	1150	1560	1090
Tons Brix (*10³):					
Syrup	306,0	223,6	194,6	208,8	115,8
Molasses	73,5	47,9	43,0	48,3	24,7
Sugar	222,4	167,1	145,1	151,8	86,5
Colour Mass Units:					
Syrup	8070	5410	3740	4870	2150
Molasses	13290	7220	6220	7610	3170
Sugar	310	250	170	240	90
Output	13600	7470	6390	7850	3260
% Change	69	38	71	61	52

Table 5

Colours of syrup, remelt, pan feed at MS

	ICUMSA 420 units
Raw syrup	21100
Remelt	37700
Pan Feed (Syrup + Remelt)	25800

colour, these returns from the back end account for about 40% of total colour in A massecuite.

Data on change in sugars across the boiling house was also obtained, this in fact being the original reason for collecting the syrup samples. With ash as a base, the weekly colour increase values are plotted in Figure 2 against corresponding figures for reduction in glucose for one mill (DL).

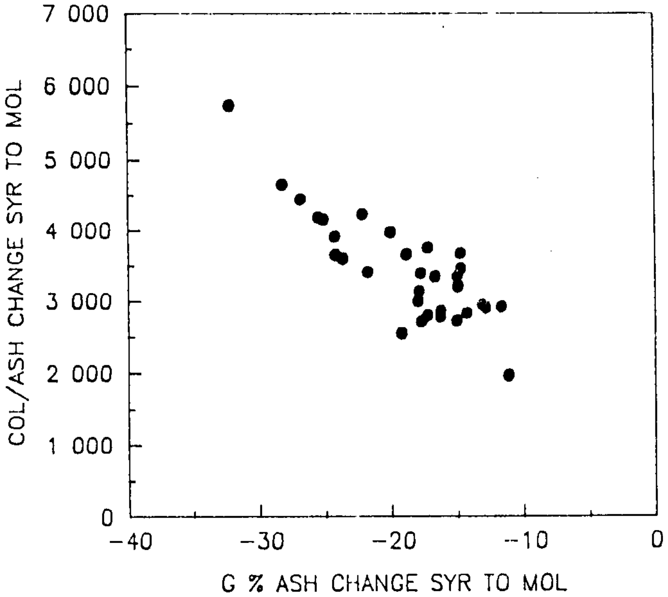

FIGURE 2 Colour increase vs. glucose loss - DL.

The relationship between colour formation and glucose loss tends to confirm that Maillard reactions are responsible for the increase in colour in the factory back-end.

These data highlight the importance from a sugar quality point of view of minimising recirculation of impurities, e.g. by maintaining high exhaustions.

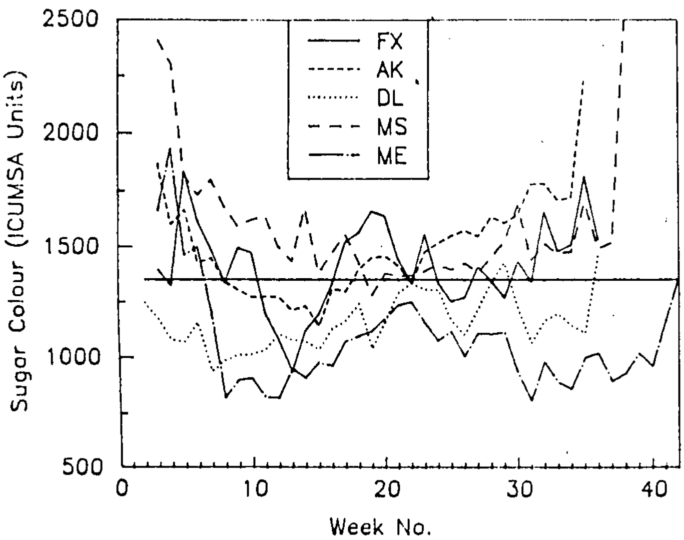

FIGURE 3 Sugar colours (Terminal/Refinery data)

Sugar colour trends

The week whole sugar colour values are shown in Figure 3. Seasonal trends are also evident here, as for syrup (Figure 1). Sugar colours are plotted against syrup colours in Figure 4.

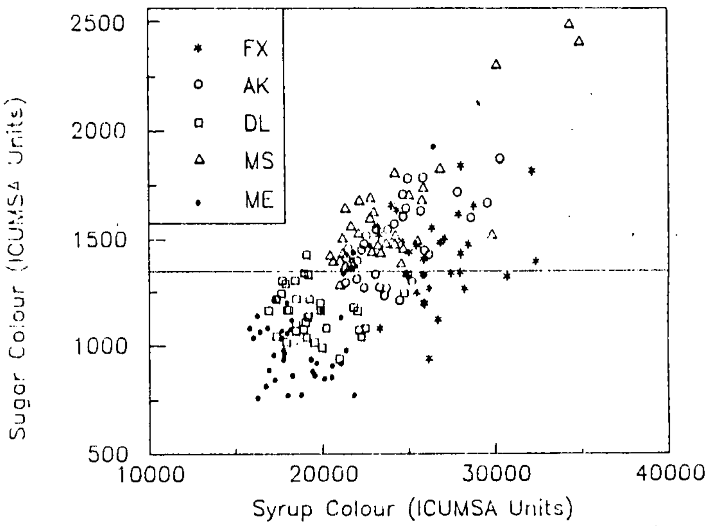

FIGURE 4 Sugar colours versus syrup colours.

The data show a broad correlation, although there is considerable scatter. In general it appears that a syrup colour below 20 000 should result in sugar colours within specification; whereas colour penalties can be expected if the colour of syrup exceeds 25 000.

Conclusions

This was not a fundamental type of study since it did not attempt to distinguish between different types of colour. Gross quantitative data were obtained indicating where in the process colour formation does and does not occur.

No material colour increases across clarification or evaporation were found. The levels of colour increase reported in Australian work are probably too low to be picked up against our high background colours. Likewise, no significant colour changes across the MS continuous A pan were detected.

Colour increased by 40 to 70% in the factory backends, apparently due to degradation products of the Maillard reaction. Some of this returns via remelted low-grade sugars which account for around 40% of the colour loading in A massecuite. High A massecuite exhaustions should therefore be beneficial from the point of view of sugar quality as well as of recovery and plant capacity.

The overriding determinant of sugar colour is the colour level of incoming juice, which in turn is governed by cane quality factors. At the higher levels of input colour it does not appear feasible to meet sugar colour specifications through optimisation of existing process operations. The introduction of decolourising processes into raw sugar manufacture has been investigated by SMRI (Getaz and Bachan[3]) but would not be cost-effective. The only reasonable prospects for eliminating high-colour sugar seem to lie in the area of input colour. Factors which can have a major effect on colour of cane juice are extraneous matter (Reid and Lionnet[6]), water stress (Lionnet[5]), disease (Anon[1]) and variety (Ivin and Doyle[4]).

Acknowledgements

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