EVALUATION OF THE HUNTERLAB COLOUR MEASURING INSTRUMENT

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Abstract

Preliminary work done by the Sugar Milling Research Institute (SMRI) showed that the HunterLab colour measuring system could possibly be used to estimate the colour of raw sugar. With this system it was possible to measure the colour within a short time (less than one minute).

The instrument (ColorQuest LAV 45°/0°) has been used for several seasons at the Transvaal Sugar Limited Malelane (ML) factory for measuring the colour of brown sugar. Work was also done on refined and C-sugars. This paper summarises the evaluation of this instrument by both the SMRI and ML.

Introduction

Due to market requirements, ML produces two types of raw sugar, namely light (1000 ICUMSA 420 colour) and dark (1500 ICUMSA 420 colour) and the same equipment (pans, crystallisers, etc.) in the raw sugar factory is used to make the two types of sugar. In order to assist the packaging department personnel to decide which type of brown sugar has to be bagged, a rapid indication of raw sugar colour is required. The thirty minutes required to determine colour by the ICUMSA method is too long and it was therefore decided to evaluate instruments that could measure the colour of sugar "on-line".

There are a number of instruments available which are suitable for this task (Nielson, 1996 ; Anon, 1996). The SMRI evaluated two HunterLab instruments during 1995 and 1996, namely the **Miniscan** which is a portable instrument (Dunsmore, 1995) and the **ColorQuest LAV 45°/0°**, which is a laboratory model, with a view to their suitability for use in the South African sugar industry. The laboratory model was subsequently evaluated by the Malelane factory and used in the factory during the past three seasons.

Description and basis of operation of the ColorQuest system

The ColorQuest spectrophotometer (Figure 1) is a colour measurement system with a choice of optical sensors depending on the application. Each sensor has its own illumination and viewing geometrics. The system evaluated was the ColorQuest LAV 45°/0°.

Figure 1.

The spectrally based system is considered to measure 'what the eye sees' and utilises the measurement of three parameters, the tristimulus values. These parameters are represented by three axes, which are illustrated in Figure 2. The vertical axis depicts the lightness "**L**" of the sample expressed on a scale of 0 to 100 where black = 0 and white = 100, the horizontal axis runs left to right and depicts "**a**" the redness or greenness, where the redness is positive and the greenness is negative, and the third axis runs from front to back and represents "**b**", the yellowness (positive), or blueness (negative). In addition, the instrument's software allows these three parameters to be combined and expressed in one of three indices. These are "**Z**", the brightness index, "**WI**", the whiteness index and "**YI**", the yellowness index.

The system consists of a sensor and a detector. The sensor uses circumferential illumination, which is provided by a fibre optic ring, to accommodate a variety of samples. Light from the fibres illuminates the sugar sample (400 grams) to be analysed at an angle of 45°. The diffused light reflected from the sample is collected at 0° and then directed to a dif-

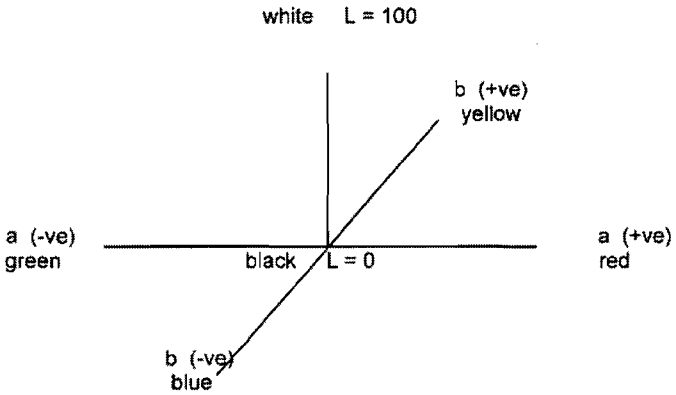

Figure 2. Graphical representation of the HunterLab parameters

fraction grating, which divides the light into its component wavelengths. A diode array measures the light across the visible spectrum (400 to 700 nm). The information is then processed to give the lightness (L), the yellowness index (YI) and the a and b values. Figure 3 illustrates the operation of the instrument.

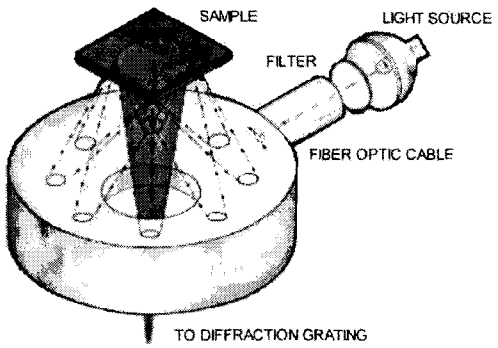

Figure 3.

Calibration of the instrument used at the Malelane factory

The instrument was calibrated at least once per shift (8 hours) with polished white and black tiles. Included in the software are other reference and set-up programmes. There is also a system whereby several instruments may be standardised to read samples of similar colour in the same way. Furthermore, standard values may be entered into the memory beforehand, or a standard may be read, and comparisons made. The instrument can measure and average up to 25 samples and the liquid crystal display (LCD) can be set to read the sample or its difference from the standard. Tolerances can also be set so that a "PASS" or "FAIL" will be indicated.

Results and discussion

SMRI results

Braunschweig standards

The Braunschweig Research Institute in Germany has developed colour standards, which give an indication of the visual appearance of refined sugars according to their Colour Type. The standards consist of a set of seven refined sugars which have been coloured and numbered from 0 (pure white) through to 6 (slightly yellow/brown). Using the white tile as reference, these standards were read on the instrument to give the results in Table 1.

Table 1. Values Obtained for the Braunschweig Standards.

Standard	L	a	b	WI
Tile	94,91	-0,79	-0,12	88,63
0	87,61	-0,76	1,96	62,23
1	87,40	-0,48	4,33	50,62
2	86,42	-0,25	5,38	44,51
3	85,71	0,45	8,11	31,42
4	85,61	0,62	8,46	29,42
5	83,88	1,20	10,08	20,66
6	79,46	1,67	11,82	10,08

These results show that, with increasing colour type

- the lightness (L) decreased
- the whiteness index (WI) values decreased
- there is progression from greenness (-ve) to redness (+ve)
- there is no blueness (-ve) but the yellowness (+ve) increases.

The lightness indices versus the Braunschweig standards are plotted in Figure 4.

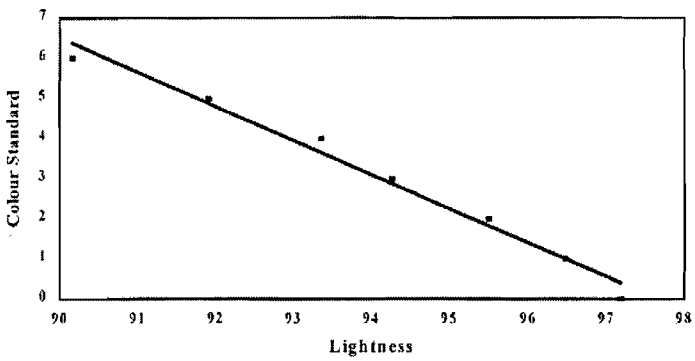

Figure 4. Braunschweig Standards versus Lightness

The results indicate that there is a direct relationship between the lightness index and the Braunschweig standards.

A selection of refined and raw sugars was read and the results, together with their ICUMSA 420 colour measurements, are given in Tables 2 and 3 respectively.

Refined sugar results

The results in Table 2 show that the **a** and **b** parameters of sample number 8 were negative showing the sugar to be green/blue, while all of the other sugars showed only the **a** to be negative and therefore green/yellow. The **L** and **WI** values did not follow a regular pattern. There was a poor apparent relationship between the whiteness indices and the ICUMSA 420 colour values which may be due to the fact that the pH of the solution on which the ICUMSA 420 colour is read is adjusted to 7.

Table 2. Values Obtained on the Refined Sugars.

Sample	L	a	b	WI	Colour Type	ICUMSA 420 Colour
1	88,60	-0,93	5,67	47,04	2	51
2	96,96	-0,34	6,13	42,21	-	48
3	85,28	-0,65	5,30	43,50	-	47
4	85,95	-1,32	7,55	34,91	4	65
5	82,66	-0,92	4,16	44,58	3	60
6	83,48	-1,92	3,38	49,42	2	52
7	86,85	-0,30	5,26	45,98	2	42
8	84,91	-0,82	-0,43	25,50	-	73

Raw sugar results

The results in Table 3 show that, as expected, all of the **a** and **b** values tended to be red/yellow to various degrees. The **L** values showed a fair relationship with the ICUMSA 420 colour values although, as with the refined sugars, the pH of the solution on which the colour is measured is adjusted to 7. The above data indicate that, although not suitable for measuring the actual colour, the instrument is capable of being used for factory control purposes.

Table 3. Values Obtained in the Raw Sugars.

Sample	L	a	b	YI	ICUMSA 420 Colour
1	70,26	3,90	23,06	40,11	924
2	84,63	5,20	24,84	45,05	2300
3	51,68	9,72	29,38	58,68	3510
4	61,54	5,18	25,99	144,25	-
5	50,36	5,91	25,44	53,26	2432
6	55,87	6,44	25,75	50,68	-
7	55,35	5,39	25,60	151,93	2037

The results of some tests done on brown sugar of different colours are plotted in Figure 5.

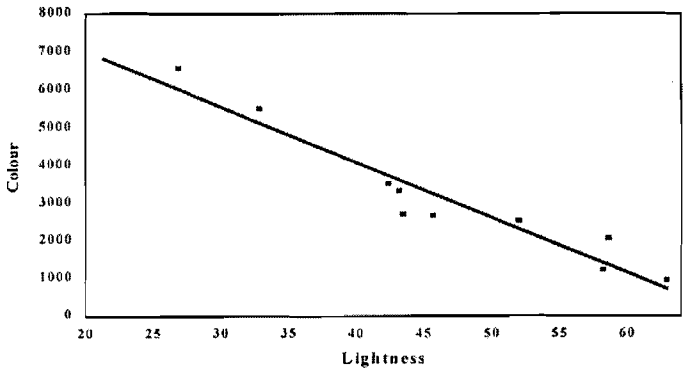

Figure 5. Colour of brown sugars (SMRI results) versus Lightness.

From this figure it is evident that a direct relationship (r=0,96) exists between the lightness and the colour of brown sugar.

The results, i.e. the lightness versus the ICUMSA 420 colour, of the tests at the SMRI using the laboratory instrument resulted in the decision by ML to evaluate this instrument further, the objective being to see if this instrument could be used on-line to measure the colours of raw and refined sugars.

Malelane factory results

Brown sugar

Samples of brown sugar, on which the ICUMSA 420 colour had been determined, were also analysed with the HunterLab instrument. The lightness and colour value results of the 335 samples analysed were plotted and these are shown in Figure 6.

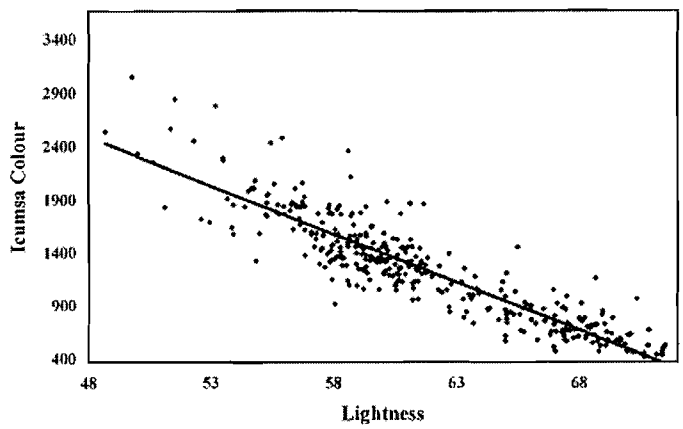

Figure 6. Colour of brown sugars (ML results) versus lightness.

The resultant equation was found to be:

$$\text{ICUMSA colour} = -91{,}094 \times \text{lightness} + 6894 \qquad -(1)$$
$$(n = 335,\ r = 0{,}91)$$

The figure shows that there is a direct relationship between

the lightness and the ICUMSA 420 colour and so this parameter has been used at ML during the 1998 season to obtain a quick indication of the colour of the brown sugar being packed. This was done by the operator taking a sample of brown sugar from the conveyor belt and measuring the lightness of the sample. This value was then entered into a computer programme incorporating equation 1 and a colour value was obtained. The time taken to do this was less than one minute compared with that taken to determine the ICUMSA 420 colour (30 minutes). The advantages for the operating personnel are obvious.

Comparison of colour results obtained by the ICUMSA method and the HunterLab method

The lightness of one sample of brown sugar was read 10 times using the instrument. The results in Table 4 indicate that the instrument gives very precise values.

Table 4. Lightness of one sample of sugar read ten times.

Description	Result
Mean	53,5
Standard error	0,024
Standard deviation	0,077
Minimum	53,3
Maximum	53,5

A sample of brown sugar was split into 10 sub-samples, each of which was analysed using the ICUMSA analytical method and the HunterLab instrument. Equation 1 was used to predict the colour of the brown sugar using the lightness value from the HunterLab instrument. The results are in Table 5.

Table 5. Comparison of the ICUMSA and HunterLab Methods on ten sub-samples of brown sugar.

Description	ICUMSA	HunterLab
Mean	1613	2066
Standard error	139	15
Standard deviation	440	48
Minimum	1295	2013
Maximum	2727	2180

There is a difference of about 20% on the sugar colour as measured by both methods but this is considered to be insignificant for on-line control purposes. There is, however, a wide variation in the individual colours as measured by the ICUMSA 420 method (minimum = 1295 and maximum = 2727). This may be due to the fact that a small sample (30 grams) is taken for the analysis and if the sample is not homogenous, the colour reading will be adversely affected. The results predicted by the HunterLab instrument are very close (minimum = 2013 and maximum = 2180). This may be due to a larger sample (400 grams) being taken for the measurements.

Refined sugar results

Individual refined sugars

Samples of first, second, third and fourth boiling refined sugars were taken from the centrifugals and analysed by both methods. The results were plotted and are shown in Figure 7.

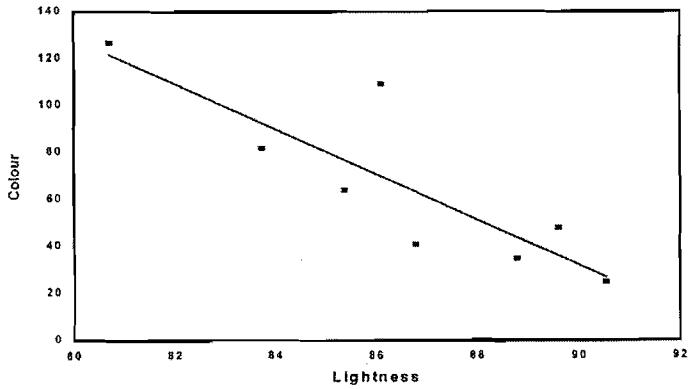

Figure 7. Colour of ML refined sugars (1st,2nd,3rd and 4th) versus lightness

These results confirm those found by the SMRI for the Braunschweig Colour Standards (Table 1) in that the instrument was able to detect the differences between the various sugars. The instrument therefore could be used on-line to optimise the washing at the centrifugals.

Composite refined sugar results

Preliminary results indicate that there is no correlation between the lightness and the ICUMSA 420 colour values.

C-Sugar results

Govender (personal communication, 1999) is investigating methods to optimise the washing at the C-centrifugals on a continuous basis. Some preliminary work was therefore undertaken to investigate whether there is a correlation between the lightness and the purity of C-sugar. To this end, the lightness values of a number of samples of C-sugar were measured. These values and the corresponding purities were processed by the HunterLab Instrument and the results are shown in Figure 8.

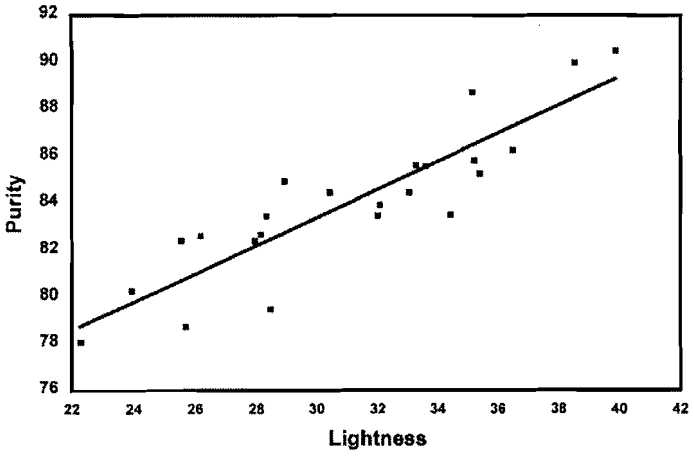

Figure 8. Purity of c-sugar versus lightness.

It can be seen that there is a correlation (r=0,89) between the lightness and the C-sugar purity. The colour values of affinated and whole sugar together with their purities are listed in Table 6.

Table 6. C-sugar colour and purity results.

Sugar Purity	Sugar colour	Crystal colour
78,07	32090	1240
79,48	31520	1220
85,59	19020	1110
88,72	19970	1360

A number of comments can be made regarding these results. Firstly, the sugar colour varies with the purity, which is expected, therefore the correlation between the lightness and the purity of C-sugar is encouraging. Secondly, in order to achieve higher sugar purities, extra washing is required which causes sugar crystals to be dissolved. This increases the final molasses purity and also increases the loss of sucrose to molasses. The average C-sugar purity for ML has been about four units above the typical value (80), which equates to about half a unit of final molasses purity (Jullienne, 1982). This is worth about R700 000 to ML for a season. The installation of an on-line instrument with which the operator could optimise the washing at the C-centrifugals would have major financial benefits.

On-line instrument

All the results of the tests done on brown sugars were sent to HunterLab for processing whereupon it was recommended that ML introduce the on-line ColourTrend HT instrument. This instrument, as illustrated in Figure 9, can be installed over the brown sugar conveyor.

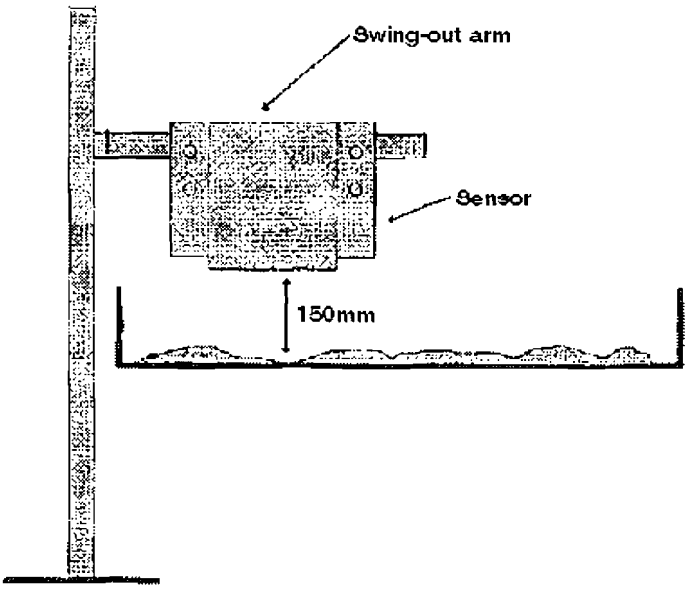

Figure 9. ColourTrend on-line instrument

Conclusions

The following conclusions are made regarding the HunterLab colour measuring system:

- The system can be used to approximate or trend the colour of brown sugar.
- The instrument will detect the difference between colours of first, second, third and fourth boiling refined sugars.
- No correlation was found between the lightness and the ICUMSA colour for ML refined sugars.
- There is a good correlation between the lightness of raw house C-sugar and its purity.

Acknowledgements

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