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Centrifugal Washing Optimisation by Real-Time Colour Measurement

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ABSTRACT

Removal of colour is the main purpose of the refining process in sugar factories and refineries. However, colour measurements from the laboratory are not available until the sugar has reached the silo, so control of the process is based on historical values and statistical process control instead of current product status.

Automatic real-time colour measurement with the in-line ColourQ 800 colorimeter by Neltec Denmark has been tested on wet sugar from second-strike centrifugals and compared with laboratory measurements. The test has focused on the accuracy of the methods and on the influence of real-time measurements on process control. A special investigation was made to reduce the loss of sugar due to superfluous washing in the centrifugals.

The instrument showed a high level of accuracy.

Loss of sugar due to unnecessary melting of good sugar in the centrifugals was reduced by at least 250 tonnes per year, leading to a very favourable payback on the investment.

INTRODUCTION

The main purpose of the refining process in sugar factories and refineries is to remove colour. Frequent measurements of colour are required to control the process and the quality of the final product. Due to the expensive labour requirements for the laboratory colour determinations, the interval between measurements is counted in hours. The laboratory measurements take time and are not available until the sugar has reached the silo; so process control is based on historical values instead of the current status of the product. Sugar with colour above specifications has to be recycled at considerable cost.

In recent years, an instrument for automatic real-time measurement of colour has come into widespread use in European sugar factories (1,2). The instrument measures the colour of crystalline sugar off the conveyor, whether it is of hopper/shaker, belt or scroll/screw type. No sample preparation is required. The instrument works by measuring reflected light, but it gives very good correlation to laboratory colour in solution (3,4,6). Successful measurements on raw and soft brown sugars have also been reported (5).

In this paper, a successful application in a refinery is reported, in which the instrument monitors second-strike sugar after the centrifugals.

METHODS AND MATERIALS

1. Laboratory Measurements

The laboratory measurements were made according to ICUMSA Method GS 2/3-9.

2. The In-line Colorimeter

The instrument is the ColourQ 800 in-line colorimeter manufactured by Neltec Denmark. It works by illuminating the sugar and measuring the reflected light at various wavelengths. The measurements are independent of the light in the factory, so no shielding from ambient light is required. The working distance to the sugar is approx. one metre. There is no contamination of the sugar by the instrument or of the instrument by the sugar.

The spectral values measured are sent to the system's computer. Here the equivalent "colour in solution" value is automatically calculated by reference to a calibration function, and is presented to the operator. The computer has digital outputs for alarms. The results are also transferred via an analogue output (4 to 20 mA) to the refinery's central process control system.

On the computer's display, the measurements are presented along with information on the discharge of each centrifugal. If colour variations occur, it is immediately clear which centrifugal has caused the change.

Figure 1 is a photograph of the actual installation in the refinery.

INDIRECT METHOD OF MEASUREMENT

The in-line method is an indirect method:

> The instrument is calibrated using samples taken from the production stream, while the instrument takes and stores corresponding measurements. The colour in solution values of the samples are determined in the laboratory. From the laboratory values and the stored measurements, Neltec calculates a calibration curve. After the calibration has been registered in the instrument, the measurements are presented in units of ICUMSA colour in solution (ICU).
>
> The accuracy of the instrument is normally checked in the same way, i.e. using test samples. Their colours are determined in the laboratory and compared to the instrument's readings at the time the samples were taken. The instrument's Standard Error of Prediction (SEP) is calculated by:

$$SEP = \sqrt{\left[\sum_{i=1}^{N}\left(LaboratoryColour - NeltecColour\right)^2\right] / N}$$

> where N is the number of samples in the test.

It is evident that any errors in the laboratory measurements are included in the calculation of the SEP of the calibrated instrument, so the calibrated instrument can never have an error smaller than the laboratory method. Thus, for evaluating the accuracy of an instrument giving readings based on calibration measurements, it is very important to compare the SEP with the error of the method used for the calibration.

Calibration Considerations and Procedure

For good calibration, the sample set must include as much as possible of the range of the product quality and process parameters.

From the sample set of laboratory determinations and the corresponding reflection data stored in the instrument to be calibrated, it is possible to make a mathematical model (a calibration function) correlating raw reflectance measurements with laboratory findings. After this has been calculated and installed in its computer, the instrument will display readings corresponding to the values determined in the laboratory.

During the first months of operation, the sampling set was gradually enlarged to cover larger colour variations and fluctuations in the raw sugar quality. In all, more than 100 duplicate samples were taken for the calibration. The accuracy of the measurements improved along with the extension of the range and sample numbers.

Since July 1998, no changes have been made to the calibration.

ANALYSIS OF THE ACCURACY OF THE TWO METHODS

Analysis of the accuracy of the laboratory measurements

Saint Louis Sucre has carefully evaluated the errors in the laboratory method, based on the errors of the single steps/instruments used in the procedure. No extra error has been added to account for operator interference. Saint Louis Sucre has estimated the error to be 0.45 EEC points, corresponding to 3.4 ICU.

Analysis of the accuracy of the in-line instrument

For practical reasons the following method was applied:

> The in-line instrument calculated an average value over 4 hours. This average was compared to the laboratory-determined colour of dry sugar sampled by an automatic sampling system over approximately the same period.

This adds at least three sources of error:

> The in-line instrument measures wet sugar, while the laboratory measures dried sugar.
>
> The amount of sugar may vary over the sampling period. When this happens, the sugar may be weighted differently by the two methods in the averaging.
>
> The four-hour measurement period for the in-line instrument may be shifted relative to the interval for the collection of the dry sugar sample.

The advantage of the method was that laboratory measurements taken on a routine basis could be utilised. Thus, it was easy to get a large number of laboratory values.

Ninety samples were taken over four weeks. The resulting SEP was calculated to be 0.47 EEC points, corresponding to 3.5 ICU. The measured values can be seen graphically in Figure 2.

Conclusion about accuracy

The major inference from this analysis is that the ColourQ 800 does not introduce any further errors compared to the laboratory method.

USE OF THE INSTRUMENT

The operators' attitude to the instrument

Immediately after installation of the colorimeter, the operators were sceptical about the measurements, because the instrument and its precision were unknown (another in-line instrument had been tested previously, unsuccessfully). After a few months their attitude changed. The operators now use the instrument and appreciate the measurements for allowing fast and qualified decisions about process adjustments.

Immediate comparison between centrifugals

One of the very first charges measured showed a variation of colour within the charge of more than 25 ICU (measured with both methods). This was unexpected, but the in-line instrument recorded that one of the centrifugals consistently produced sugar with this level – or sometimes even greater – variation. Soon it was clear that the three centrifugals in this line performed differently. However, after mechanical adjustments to the centrifugals, their performance became more uniform.

Immediate detection of error conditions

The in-line measurements are very important for process control. All irregularities are detected at an early stage, so serious consequences are avoided or minimised. If a centrifugal develops faults, it can immediately be stopped and repaired. The risk of producing sugar with high colour for hours has been eliminated.

Monitoring the quality of the sugar in real-time means that poorly crystallised products cannot pass undetected through the centrifugals. Furthermore, the continuous measurements are a good tool for quickly re-establishing process control after a stoppage.

Centrifugal optimisation

When some centrifugals deliver sugar with a higher colour than others, the average colour is increased. This increase represents wastage, because better sugar could have been produced with the same amount of washing, or the same quality could have been produced with less washing. Thus, optimisation of the centrifugals is critical for the cost-effectiveness of the process.

Centrifugal optimisation requires several measurements from each centrifugal charge at each chosen combination of process parameters, requiring a large amount of measurements. Thus, centrifugal optimisation is very costly, if conventional colour determination in the laboratory is used. Consequently, centrifugals are seldom fully optimised. With the ColourQ 800, the measurements are made continuously without any manual effort.

Previously, at Saint Louis Sucre, the sugar was washed in three steps during a centrifugal cycle. Step one was a pre-wash (W1) just after the acceleration started. Step two was a wash (W2) just before the basket reached full velocity. Step three was a steam-wash (SW) while the centrifugal was spinning at full velocity.

After installation of the in-line instrument, the refinery comprehensively investigated the centrifugals' performance. During the investigation, the following parameters were varied in many different combinations: duration of W1, duration of W2, duration of SW, and massecuite quality. The influence of each of these factors was determined on sugar colour, ash, temperature, purity of the syrup, and the amount of saccharose in the syrup.

The following results from this investigation are particularly noteworthy:

> SW (the steam wash) had no influence on colour, ash, temperature, or other significant properties. This wash has now been abolished.
>
> W1 has some influence on colour and ash. The results indicate that W1 dilutes the syrup without melting much of the crystal mass.
>
> W2 has a major influence on colour and ash. One second of variation in W2 changes the colour by 4.5 ICU.

The colour variations associated with changes in W1 and W2 are shown in Table 1.

Dynamic sugar colour optimisation

Saint Louis Sucre has produced an (unpublished) investigation of the correlation between ash, colour type, and colour in solution. The investigation was based on more than 5,000 samples, and showed no correlations between ash, colour in solution, and colour type. However, this investigation, combined with the analysis of the accuracy of the in-line instrument, led to the following interesting result:

> When the colour measured by the in-line instrument is below 5.5 EEC-points (41.25 ICU), then the risk of producing sugar with non-conforming colour is less than 5%, and the risk of producing sugar with non-conforming ash, colour type, or total EEC-points is less than 0.6%.

Previously, the refinery worked with a larger safety margin than it does now. The average colour was below 5 EEC points (37.5 ICU), and sometimes considerably below this level. After installation of the in-line instrument, the refinery expects average colour to be over 5.1 EEC points (38.25 ICU).

As a result of the dynamic adjustment of the washing, the refinery estimates that at least 250 tons of good sugar is being saved annually since it is no longer being unnecessarily remelted in the centrifugals.

CONCLUSIONS

The in-line instrument does not add further measurement error to the errors of the laboratory measurements.

The measurements are performed in real-time, enabling the operators to make fast and qualified decisions about process adjustments.

The consequences of any adjustment in the process are fed back to the operators immediately, giving new and better insight into the process.

The operators get an alarm automatically when the quality of the sugar declines, or an error arises in a centrifugal.

Any systematical malfunction in a centrifugal is displayed immediately.

The instrument displays low colour readings immediately. Thus, it is safe to reduce the washing in the centrifugals, when appropriate, and avoid melting good sugar.

The centrifugals may be optimised as often as wished. The colour measurements are made continuously and automatically without any manual effort.

The investment may be paid back in weeks, not years.

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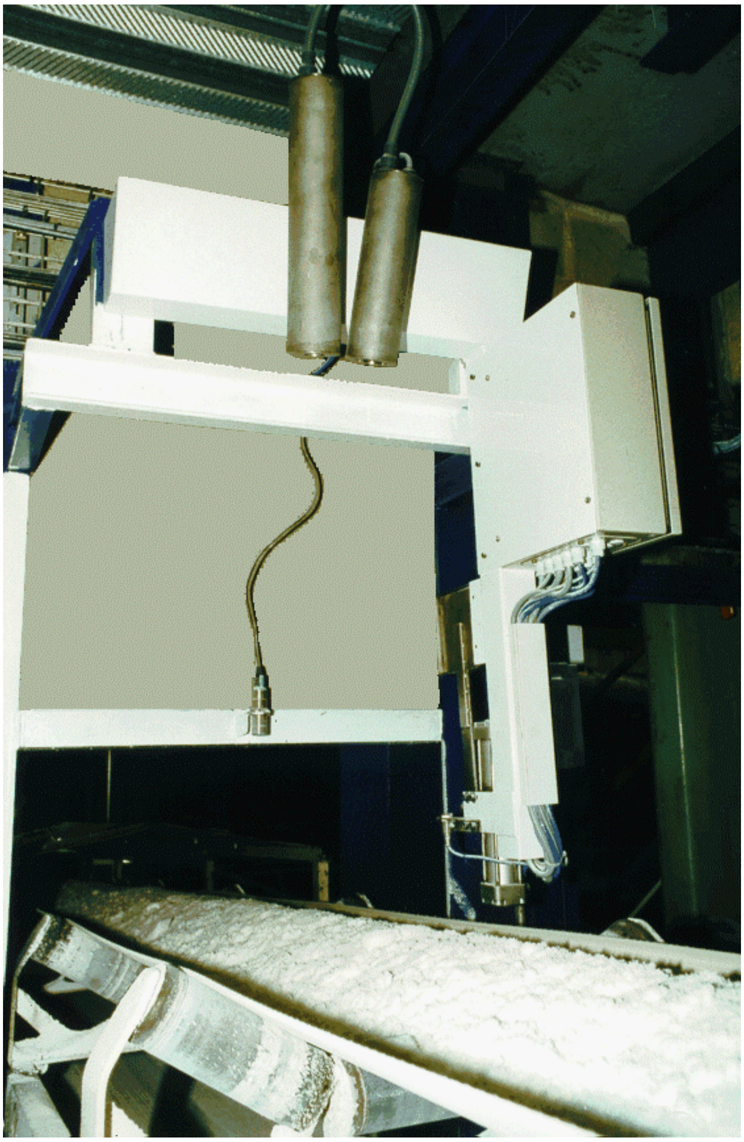

Figure 1

ColourQ 800 installed on a conveyor belt with wet crystals

		Variation of Wash 1			
	Time [sec]	0	±1	±2	±3
Variation of Wash 2	0	0	−+1,5	−+3,8	−+5,3
	±1	−+4,5	−+6,8	−+8,3	
	±2	−+9,0	−+11,3	−+12,8	
	±3	−+14,3			

Table 1

Colour variations in ICU associated with variations in Wash 1 and Wash 2

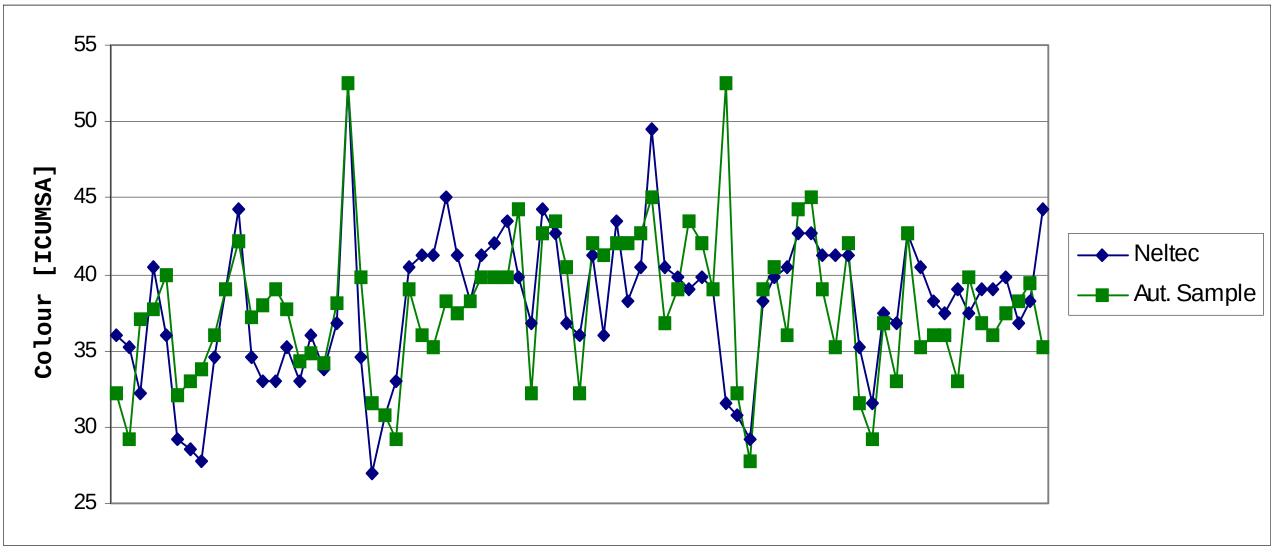

Figure 2

Comparison of the in-line method and

the automatic sampling determined in laboratory