THE EFFECTS OF CENTRIFUGAL AND FACTORY OPERATION IN COLOUR INCLUDED AND OCCLUDED IN PLANTATION WHITE SUGAR CRYSTALS FOR FIVE FACTORIES OF CENTRAL AMERICA

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Abstract

COLOUR is the most widely accepted and possibly the most important quality parameter of white sugar. It is necessary to know what happens in the various stages of the factory operations to determine the colour inside the crystal (included colour) and colour on the crystal surface (occluded colour). Only surface colour is eliminated by wash water in the centrifugals. This study considers the effects of wash water time on the reduction in colour and the loss through dissolution of the sugar crystals in the batch centrifugals, and the analysis of the occluded (surface layer) and included (inside the crystal) colour for different process conditions such as changing the purities of the C and B magma, using different process cationic flocculants and using different washing times in the centrifugals in five sugar factories of Central America. Experimental equations for crystal loss against washing time are studied in three of the factories. Results indicated the impact of using cationic flocculants, syrup clarification and improving boiling purity for strikes for the five factories. The results indicate that crystal colours of 85 to 135 ICUMSA can be obtained when best practice processes are adopted, However, crystal losses of at least 15% can be expected when wash times of more than 20 seconds with 480 kPag water at 85°C to 95°C is used.

Introduction

Colour and impurities

Colour is the most widely accepted and possibly the most important quality parameter of white sugar. It is necessary to know what happens in the various stages of the factory operations to determine the colour inside the crystal (included colour) and colour on the crystal surface (occluded colour). Only surface colour is eliminated by wash water in the centrifugals and that is why, above a certain level, further increase in the amount of wash water does not result in an improvement of the quality of the sugar (Van der Poel *et al.,* 1987).

Colour in white sugar massecuites comes from colour in raw juice, colour formation in heaters, evaporators and clarifiers, colour formation in tanks and pans, type of factory operations and colour recycling from B and C magma.

In crystallisation operations, impurities have a dramatic effect on the habit and crystal size distribution due to the influence on the kinetics of growth and nucleation. Some examples of the impurities in the sugar crystal are (Genck, 1997) colour molecules, inorganic ash compounds, mother liquor located at the surface of the crystal, air and gas bubbles, mother liquor droplets included in the growing crystal lattice, and polysaccharides and oligosaccharides.

A high supersaturation of the mother liquor during boiling promotes fast growth but it also promotes inclusion of impurities within the crystal lattice. Impurities adsorb onto crystal surfaces and influence interfacial tension. Also, impurities are incorporated more easily into large crystals and at high concentrations like at the end of a strike.

Centrifugal process performance

When considering centrifugal performance, it is possible after several assumptions to idealise the flow of the mother liquor (A, B or C molasses) through a sugar cake by considering the flow down a thin pipe. Grimwood (1996) shows that the small gaps which exist between the individual crystals of sugar in the centrifugal basket are proportional to the average size of the crystals or mean aperture (MA). It is possible to write this expression as follows:

$$\text{Centrifuge performance} = (MA)^2 * G * \Delta t / (\text{Mother liquor viscosity} * L) \quad (1)$$

Where:

MA = Mean aperture of sugar (average size of sugar crystals), µm.

G = force pushing syrup through the sugar cake. Ft/s^2.

Δt = Spin time, s.

L= Sugar cake thickness, ft.

During acceleration a water wash is normally applied to the sugar. Washes are applied for 5 to 20 seconds depending on the grade of sugar being produced, wash jets and other operational parameters. The application of wash water has two main beneficial effects, first to increase the purity of the sugar and, secondly, to reduce its final moisture.

As the wash water flows through the cake, it becomes saturated with sugar after the first 50–75 mm and this saturated solution displaces the massecuite mother liquor (Grimwood, 1996). However, washing has the unwanted effect of melting (dissolving) a proportion of the sugar.

According to Grimwood (1996), there are three washing mechanisms that take place in the centrifuge: displacement, diffusion and dissolution.

In displacement wash, the mother liquor filling the gaps between the crystals is displaced by wash liquor; in diffusion wash, dissolved material in the remaining mother liquor adhering to the crystals is transferred (diffuses) into the wash liquor, and in dissolution wash, the surface layers of the crystals are dissolved by the wash liquor.

Methods

Crystal loss

The real amount of crystal sugar that is dissolved in the wash water and ends up in the syrup can be determined by measuring the sugar cake thickness for different wash times, including no washing as the base case for a specific batch centrifuge, strike and factory. Different amounts of wash water were applied for a specific centrifuge in two factories.

For zero or low wash times, the measurements can be taken before the centrifugal is returned to the normal cycle to achieve the desired sugar quality. The temperature and pressure of the wash water was also recorded.

Included colour

It was decided to limit wash water use to a maximum of 25 s because available data show that additional wash water did not improve the quality of the sugar. Further improvement in quality could be achieved with changes to other process conditions such as changing the purity of C magma and B magma, seeding for A strikes, using different process cationic flocculants or colour precipitants, syrup clarification and improving the boiling purity for A strikes for different sugar factories.

Qemitreat SEP (from Qemi International Inc.) decolourant usage was set at 40 ppm on solids. The polymer was diluted 1:1 with water and added to the clear juice tank.

Colour elimination

The colour remaining in the sugar crystal at the end of the cycle can be determined as a function of wash time. For no washing or low washing times, a sample of sugar was taken before the normal cycle was resumed to obtain the desired sugar quality.

Results and discussion

Trials were conducted at five factories to measure the effects on the sugar product from the application of different process conditions, with and without syrup clarification and with and without the use of colour precipitant. The centrifugals used during the trials are listed in Table 1.

Table 1—Details of the centrifugals used during the trials.

Factory	Centrifugal brand	Basket size (in mm)	Wash water supply	
			Pressure (kPag)	Temperature (°C)
B	Western States	54 x 40 (1370 x 1016)	480	85–95
C	Western States	48 x 36 (1219 x 914)	550	80–90
D	Western States	48 x 30 (1219 x 762)	550	80–95

Figure 1 illustrates the degree of crystal loss as a function of wash water usage for the Western States centrifugals at factories B, C and D. The centrifugal used at factory B was working at 1020 G. The collected data for factory B represent the averages of 87 separate measurements. The data show a crystal loss of 11.8% when wash water was applied for 20 seconds.

For factory C, the collected data correspond to the averages of 90 measurements. A crystal loss of 15.5% is reported when 20 s of wash water is applied. Factory D has the smallest centrifugal of the three units tested. The collected data correspond to the average of 50 measurements and show a crystal loss above 20% at 20 s of wash water application.

These three trends in Figure 1 show just how much sugar is dissolved when excessive quantities of wash water are used in the centrifugals to achieve low colour sugar.

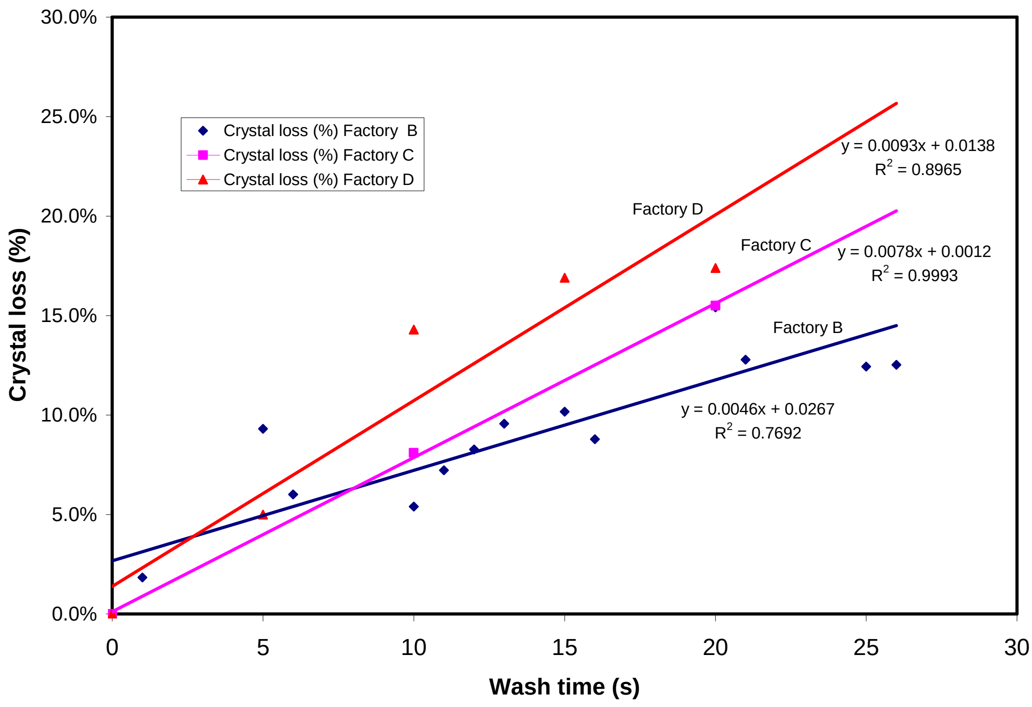

Fig. 1—Crystal loss as a function of wash time for three factories.

Figure 2 illustrates how much colour is removed as a function of wash water usage for the same Factory B centrifugal and conditions of Figure 1. It can be seen that, after about 20 s, further increases in the amount of wash water do not result in any improvement in the quality of sugar in terms of colour. A colour ratio can be defined and represents the colour remaining in the sugar as a ratio of the original colour before any wash water is applied. Thus, after 20 s of wash, the colour remaining is about 16.6% and, after 25 s of wash, the remaining colour is about 10.6% of the original colour. However, the extra 5 s of wash dissolved another 2.3% of the crystal according to the data in Figure 1.

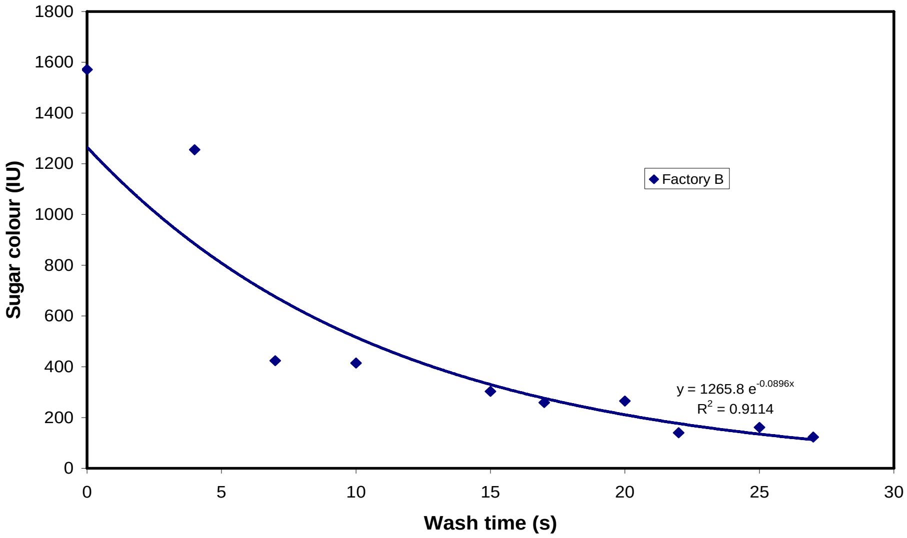

Fig. 2—Final sugar colour as a function of wash water time for factory B. (Western States centrifugal, 54 x 40, 480 kPag, 85–95°C).

For factory C, the colour elimination curves as a function of water and cationic flocculant (at 40 ppm on solids) usage are shown in Figure 3 and Table 2. When using cationic flocculant, the sugar colour was about 28% lower than the sugar colour produced without the use of the cationic flocculant. This means that less wash water is required to achieve a certain sugar colour if cationic flocculant is used. For example, if 20 s of wash is required to achieve the required colour without flocculant, then the same colour can be achieved with only 17 s of wash if cationic flocculant had been used in the process and 3% less crystal would have been dissolved in the centrifugals.

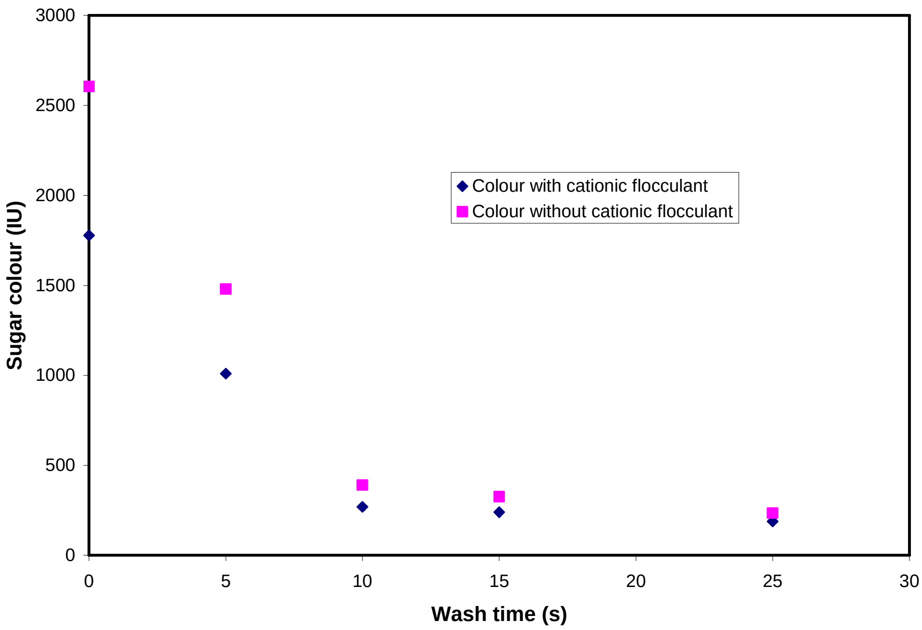

Fig. 3—Final sugar colour as a function of wash water time for factory C (Western States centrifugal, 48x36, 550 kPag, 80–90°C).

Table 2—Sugar colour results for factory C.

Wash time (s)	0	5	10	15	25
Sugar colour after using cationic flocculant	1778	1010	269	240	188
Sugar colour without using cationic flocculant	2605	1480	390	326	235
Colour ratio with cationic flocculant	100.0%	56.8%	15.1%	13.5%	10.6%
Colour ratio without cationic flocculant	100.0%	56.8%	15.0%	12.5%	9.0%
Colour reduction due to use of colour precipitant	31.7%	31.8%	31.0%	26.4%	20.0%
Average colour reduction	28.2%				

Table 3 shows the included colour data collected from five sugar mills and some variations of the processes involved. The best practice is to achieve low impurity concentrations in mother syrup to minimise the probability of including impurities in the growing crystal. This can be done by improving the B and C magma purities, using syrup clarification, using cationic flocculants or decolourants and seeding for A strikes. Factory E has produced a low colour sugar but with the disadvantage of the impact in sucrose recovery and the extra recirculation load in the boiling scheme. This factory sells its sugar to a market that pays a special price for the quality. The benefit of using cationic flocculants is that some colourants are removed from the syrup before going to the boiling house. The key variables for improving sugar quality after syrup clarification are the target purities of C and B magma, due to the colour impact on the A strikes. As seen in Table 3, the crystal sugar process which uses only the juice from the first mill results in a high quality sugar product. The double magma boiling scheme uses seeding for C strikes and uses C magma as a footing for B strikes and B magma as the footing for A strikes.

Table 3—Crystal (included) colour after 25 s of wash water at five mills with different process conditions.

Factory	Process	Syrup clarif.	Cationic loc.	Magma purity		Included colour (IU)
				B	C	
A	Strikes using syrup from first mill juice (crystal sugar process)	No	No	n.a.	n.a.	92
B	Double magma boiling scheme	Yes	No	n.a.	n.a.	183
C	Double magma boiling scheme	Yes	No	n.a.	n.a.	220
B	Double magma boiling scheme	Yes	Yes	n.a.	n.a.	123
C	Double magma boiling scheme	Yes	Yes	n.a.	n.a.	177
C	Double magma boiling scheme	Yes	Yes	97	93	135
C	Direct crystallisation, A strike seeding	Yes	Yes	97	93	125
D	Double magma boiling scheme	Yes	Yes	97	90	160
D	Double magma boiling scheme Strike of syrup with melted B magma	Yes	Yes	n.a.	n.a.	85
E	Double magma boiling scheme	Yes	Yes	98.5	95	90

n.a. = not available

Another process variation, where tanks and pans are available, is to process special strikes using melted B magma (for the best sugar quality), and melted C magma and syrup for the other commercial strikes.

Cane quality has a dramatic effect on sugar quality and included colour. The presence of vegetable and mineral trash, time delay, harvesting systems and cane deterioration, are key factors for a good crystallisation operation because impurities are incorporated more easily at high concentrations. Impurities like polysaccharides, oligosaccharides and other macromolecules that are related to cane quality influence sugar processing and have been implicated in the inclusion of colour in crystals. They also influence the mother liquor viscosity that also affects centrifugal performance.

Conclusions

It is important to determine experimental relationships for crystal loss and sugar colour against wash time for a specific model of batch centrifugal and the material being processed at a factory. The crystal loss of the three factories and centrifugals discussed in this paper varies from 11% to more than 20% with 20 s of wash time.

For factory C, the results show that, by using the same wash time, sugar with 28% less colour is achieved when colour precipitant is used as part of the syrup clarification process.

The key variables after a good syrup clarification and cane quality for improving sugar quality are the target purities of C and B magma.

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LES EFFETS DES CENTRIFUGES ET DE L'OPÉRATION A L'USINE SUR LA COULEUR INCLUE ET OCCLUE EN CRISTAUX DE SUCRE PLANTATION POUR CINQ USINES D'AMÉRIQUE CENTRALE

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**MOTS-CLEFS : Couleur, Inclue, Occlue, Centrifuge,
Eau De Lavage, Ouverture Moyenne.**

Résumé

LA COULEUR est le paramètre de qualité le plus connu et le plus important pour le sucre blanc. Il est nécessaire de savoir ce qui se passe aux différentes étapes des opérations en usine pour déterminer la couleur à l'intérieur du cristal (couleur inclue) et la couleur sur la surface de cristal (couleur occlue). Seule la couleur de surface est éliminé par l'eau de lavage dans la centrifuge. Cette étude examine les effets du temps de lavage sur la réduction de couleur et la perte par dissolution des cristaux de sucre dans la centrifuge discontinue. On a détermine l'occlusion totale de couleur (surface) et la couleur inclue (à l'intérieur du cristal) pour des processus différents, tel que la modification des puretés du magma C et B, de l'utilisation de différents floculants cationiques et de l'utilisation de lavage a différents moments dans la centrifuge, dans cinq usines a sucre de l'Amérique Centrale. Des équations expérimentales pour la perte de cristal contre le temps de lavage sont étudiées dans trois des usines. Les résultats indiquent l'impact de l'utilisation de flocculants cationiques, de la clarification du sirop et de l'amélioration de la pureté des massecuites pour les cinq usines. Les résultats indiquent que des couleurs de 85 à 135 ICUMSA peuvent être obtenues lorsque les meilleures pratiques sont adoptées. Toutefois, on peut s'attendre a des pertes de cristaux d'au moins 15% quand le lavage s'étend a plus de 20 secondes avec 480 kPag d'eau à 85–95°C .

EFECTOS DE CENTRÍFUGAS Y LA OPERACIÓN FABRIL EN EL COLOR INCLUIDO Y OCLUIDO EN CRISTALES DE AZÚCAR BLANCO EN CINCO INGENIOS CENTROAMERICANOS

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PALABRAS CLAVE: Color, Incluido, Ocluido, Centrífuga, Agua de Lavado, Apertura Media.

Resumen

EL COLOR es el parámetro de calidad del azúcar blanco más aceptado universalmente y posiblemente el más importante. Se requiere conocer lo que sucede en las varias etapas operativas de la fábrica para determinar el color dentro del cristal (color incluido) y el color en la superficie del cristal (color ocluido). Solamente el color superficial es removido por el lavado en las centrífugas. Este estudio considera los efectos del tiempo de lavado en la reducción de color y la pérdida por disolución de cristales en las centrífugas de batch y el análisis de color incluido y ocluido para diferentes condiciones de proceso tales como purezas variables en magma C y B, uso de diferentes floculantes catiónicos y el uso de diferentes tiempos de lavado en las centrífugas de cinco ingenios centroamericanos. Se estudiaron las ecuaciones experimentales para la pérdida de cristales contra tiempo de lavado en tres de los ingenios. Los resultados muestran el impacto del uso de los floculantes catiónicos, la clarificación de meladura y el mejoramiento de la pureza de las templas para las cinco fábricas. Cuando las mejores prácticas se adoptan, pueden obtenerse colores de cristal de 85 a 135 ICUMSA; sin embargo, pueden esperarse pérdidas de cristal de al menos 15% cuando se emplean tiempos de lavado mayores a 20 s con agua a 480 kPag y 85°C a 95°C.