Centrifugal control and the quality of white sugar: Results from G.T.S. still of topical interest*

Zentrifugenarbeit und Weißzuckerqualität: Ergebnisse des Groupement Technique de Sucreries noch immer zeitgemäß

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Centrifugation plays an important part in determining the quality of sugar. This unit operation takes place after crystallization and cannot repair defects such as inclusion of mother liquor or crystal size distribution. However, it happens often in the sugar factories that wash water feed rate or the position of washers are not controlled. Sometimes, the centrifugal cycle is not optimized. Some 30 years ago G.T.S. (Groupement Technique de Sucreries) researchers have set up tests to optimize the running of centrifugals.
Likewise, some studies were made at CSM Sugar in the Netherlands. G.T.S and CSM Sugar results agree on the fact that ash is located at the surface of crystals. However concerning the color, the Dutch team does not believe in mother liquor droplets inclusion whereas G.T.S. workers think that each of the three colorants (caramel, HADP, melanoidins) behaves differently.

Key words: centrifugal control, white sugar quality

Die Zentrifugenarbeit hat maßgeblichen Einfluss auf die Zuckerqualität, kann allerdings keine der bei der Kristallisation entstandenen Mängel wie Sirupeinschlüsse in den Kristallen oder unbefriedigende Kristallgrößenverteilung beseitigen. Indes kommt es in Zuckerfabriken immer wieder vor, dass die Deckwassermenge oder die Deckwasserdüsen nicht richtig eingestellt sind; mitunter wird der Chargenablauf nicht optimiert. Bereits vor über 30 Jahren haben Mitarbeiter der G.T.S. (Groupement Technique de Sucreries) Tests durchgeführt, um die Zentrifugenarbeit zu optimieren. Ähnliche Untersuchungen wurden bei der CSM Suiker, Niederlande, angestellt. Die Ergebnisse der G.T.S. und der CSM Suiker stimmen darin überein, dass sich Asche auf der Kristalloberfläche befindet. Hinsichtlich der Farbe glauben die Niederländer nicht an Einschlüsse von Muttersiruptröpfchen; die G.T.S.-Forscher nehmen an, dass sich jeder der drei Farbstoffe (Karamell, alkalische Zuckerabbauprodukte, Melanoidine) dabei anders verhält.

Stichwörter: Zentrifugensteuerung, Weißzuckerqualität

1 Introduction

Centrifugation of massecuites takes place after crystallization as the final step of purification to remove nonsucrose from the surface of sugar crystals and only leaves traces of water which are evaporated during the drying process. However, this ultimate stage of removal of nonsucrose cannot remedy defects occurring in earlier stages. The quality of white sugar depends on all the steps of beet sugar processing before boiling (storage of beet, extraction, purification, concentration) and also, particularly on crystallization which is preponderant for the determination of crystal size distribution and the repartition of the nonsugars in the crystals.
The importance of the quality of crystals on the stability of white sugar as regards caking was shown recently [1]. Hence, the adsorption of water vapor greatly depends on crystal size distribution and on the nonsucrose on the surface of crystals, especially for sugars imperfectly washed at the centrifugals as well as twins and conglomerates which retain nonsucrose between crystals.
To standardize the conditions of control of industrial centrifugation, a laboratory test has been applied at the G.T.S. (Groupement Technique de Sucreries) since the 1970s. This test consists in applying ideal conditions of washing using a double magmatizing procedure with a saturated pure sucrose solution. Analysis of quality criteria (EU points ash and color) for sugar before and after

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the test made possible the detection of the defects in the running of industrial centrifugals.
Repartition of the nonsucrose between the crystal and the mother liquor surrounding it was also studied by G.T.S. [2] as well as by *Verhaart* et al. [3]. Analysis of the results which go back almost 40 years shows the importance of controlling the cycle of the centrifugal when it is desired to eliminate the film of mother liquor surrounding the crystals. Moreover, the G.T.S. has prepared a chart for running both the batch centrifugals and the continuous ones. In this paper the recommendations made by G.T.S. are summarized and the repartition of the nonsucrose and their washability are analyzed.

2 Test for the control of washing efficiency

This test is designed to control the quality of sugar after centrifugation. It is aimed to improve the conditions of work in white sugar centrifugals. It was initiated by the crystallization team of G.T.S. in 1970. It consists in comparing the quality of white sugar crystals discharged from batch industrial centrifugals to the same sugar (from the same massecuite) treated in the laboratory. The test consists of two successive magma preparations at normal temperature with a saturated sucrose solution. The conditions are: 100 g of sugar per 100 g of saturated solution. The mixture is stirred in a beaker for 15 min. Each of the 2 magmatizing procedures is followed by a centrifugation in laboratory centrifugal. The obtained sugar is then washed with isopropanol (30 mL) and dried. A first test using a 3 magma procedure was abandoned because only 2 are necessary. About 90% of the nonsucrose (ash, color) are eliminated at the first washing and 10% at the second; the third did not bring any improvement.
The G.T.S test gives results by default. Indeed, the sample of sugar leaving the centrifugal which should be controlled is composed of crystals more or less surrounded by a film of mother liquor and other crystals which are over-washed (partially dissolved). If the test shows an important defect, it is necessary to take different samples at the discharge of centrifugal and make the test again. This can reveal heterogeneities often originating from the machine or a defective setting of the washing device. The results of a G.T.S. test performed in 1975 are reported in Table 1. In this Table ash content and color (EU points) are given before and after magma preparation.
Figure 1 gives a comparison between ash and color values determined before and after the centrifugal test. As a general rule, ash is much easier to remove from crystal surface than colorants. Some discrepancies are observed between samples from different factories. This is likely to come from differences in adjustment of the washing devices.

Fig. 1: Comparison between color and ash content determined before and after the centrifugal test

3 Localization of nonsucrose

3.1 Results from G.T.S.

Nonsucrose controlled are ash and color. Ash found in white sugar is mainly made up of potassium and sodium from the beet. A large fraction (30–50%) of the ash is located on the surface of crystals. It is eliminated by the washing test. The difference between total ash and surface ash represents the fraction included which might originate from centrifugation or more likely crystallization. Standard liquor purity influences the ash content in white sugar. The higher the purity, the more the difference between surface ash before and after G.T.S. magma test is low (Fig. 2).

Fig. 2: Effect of massecuite purity on surface ash content of white sugar

It was found that an additional 300 color units/100 g dry substance for standard liquor leads to a difference of 0.5 units EU point on sugar color. Colorants are localized at the surface or inside the crystal depending on their nature and the size of colorant molecules. A study of the nature of colorants [4] showed that caramels are the most noxious and their localization is both at the surface and inside the crystal. Other colorants such as HADP (hexose alkaline degradation products) or melanoidins are situated at the surface of crystal.

3.2 **Results from CSM**

Verhaart et al. [3] added Na^+ and K^+ ions before crystallization and also in mother liquor before centrifugation. Crystallization and centrifugation were performed in the laboratory using standardized conditions. After washing the crystals and analyzing the ash content, the authors concluded that ions are localized at the surface of crystals and that both methods of adding ions i.e. before crystallization and before centrifugation, led to the same results as concerns sugar ash.
On the other hand, *Verhaart* et al. [3] thought that the concept of inclusion of droplets of mother liquor inside the crystals was not verified if crystals obtained at the laboratory were washed with 100, than 200, 300 or 400 mL of water. Meanwhile, the adsorption of some colorants and surface active molecules such as saponins was demonstrated. Another logical conclusion was drawn, namely the increase in adsorption when crystal size is decreased.
Nonsucrose transfer during centrifugation from crystal surface to wash water is due to 2 mechanisms: mass transfer which is limited because of the short contact time, and mechanical transfer of runoffs surrounding the crystals to washing water which is also limited by viscosity, thickness and permeability of the crystal layer in the centrifugal. Finally, equilibrium between centrifugal forces (which pushes the washing water to the outlet) and centripetal forces (which cause a segregation thick-to-thin layer) constitute another factor of perturbation of centrifugal efficacy.

4 **Chart for discontinuous centrifugals**

In spite of the progress achieved in the construction of modern centrifugals, there is a need to recall some principles. This chart summarizes the important points for optimal running of centrifugals.

4.1 **Centrifugal cycle**

A typical cycle is shown in Figure 3. During the phase of basket rotary speed increase, the cycle consists of sequences of loading, prewashing and washing. At constant speed, a plateau of centrifugal separation is programmed. During the speed decrease, unloading takes place. After the end of cycle, basket washing is performed under moderate centrifugal force.

Fig. 3: Typical centrifugal cycle

4.2 Loading

Optimization of all the sequences of the cycle depends on the loading regularity especially with regard to obtaining of an even wall thickness. Loading should take place at constant speed and constant feed rate. The massecuite distributor makes it possible to obtain of a regular layer of sugar for a given quality of massecuite. It is obvious that a constant quality of massecuite is essential for the optimization of loading.

4.3 Pre-washing

The role of pre-washing consists in "pushing" the run-offs and lowering the viscosity of the last fractions of mother liquor to make its removal easier. Pre-washing duration and the speed at which it starts are to be determined for each centrifugal and the quality of sugar targeted. For a better efficiency, pre-washing should not start too early in the cycle. From practical experience, it seems that the optimal moment corresponds to the color change from "brown to yellow" at a rotary speed of 350 min^{-1}. At this stage, if the pre-washing occurs too early, it is possible to observe the driving back of the water with the appearance of a brown color. Table 2 summarizes the effect of pre-washing on sugar color. For a given cycle duration, pre-washing improves sugar color as compared to simply washing.

Table 2

4.4 Housing rinse

This sequence, when correctly programmed in the cycle considerably improves the quality of the run-offs. It should occur between the sequences of pre-washing and washing (Fig. 4). The effect of this sequence on the quality of the run-offs is reported in Figure 5 where comparison is made between run-offs with and without bowl washing. This washing improves the purity and decreases the color. However, it is needed to optimize the time of this sequence.

Fig. 4: Position in cycle of housing rinse
Fig. 5: Washing of bowl wall and its consequences on the quality of run-offs

4.5 Washing

The **volume of water** used for washing depends on the quality of the massecuite (viscosity, crystal size distribution). Conversely to the generally accepted idea, the volume of wash water is not proportional to the quantity of centrifuged sugar. It is necessary not to confuse between a centrifugal and a "washing machine". An excess of water leads to a loss of sugar (approximately 1 kg of sugar per kg of water in excess).
For a given water volume, the quality of washed sugar may vary depending on the washing **position in cycle**. It is necessary to establish the optimal conditions for each type of centrifugal (see Fig. 6 and Table 3).
A **spray washer** (sward or multi-nozzle) should provide a homogeneous repartition of wash water. However, the limiting step remains the thickness of the sugar layer in the centrifugal basket.

The distributor should ensure an even layer during the loading of massecuite, whereas the detector of wall thickness adapts the washing duration to the quantity of sugar in the basket.

Fig. 6: Optimal speed for centrifugals
Table 3

3.6 Unloading and basket washing

Unloading is very often not satisfactory because an important quantity of sugar remains in the basket and is not dissolved after basket washing. The discharge plough should be controlled regularly.
It is sometimes difficult to correctly **wash the** lower part of **basket**. It happens that sugar is accumulated at the bottom and prevents the evacuation of run-offs. Such a defect may be visually observed when traces of yellow color are present on white sugar at the end of unloading. This shows that good basket washing is necessary.

5 Continuous centrifugals

Continuous centrifugal separation considerably improves working conditions in the sugar end. Unfortunately, this method is hardly applicable to obtaining good quality white sugar.

5.1 Massecuite quality

Ideally crystal size should be above 300 mm and no fine particles (<50 mm) should be found in a good quality massecuite. A regular crystal size distribution improves the fluidity. An increase in the proportion of fine crystals gives a high purity molasses. Figure 7 reports the effect of fine crystals on molasses purity. With 2% of particles at 60 mm, there is almost 1 point of purity in excess as compared to purity of molasses when 2% of fine crystals at 70 mm are present in the massecuite.

Fig. 7: Effect of fine crystals on molasses purity

5.2 Rate of repartition of massecuite

If the quality of massecuite is poor, it is necessary to limit the feed rate. Repartition of massecuite should be the most regular possible (uniform thickness along centrifugal wall). This is necessary to obtain a good quality sugar and an efficient washing on the one hand and from the safety point of view, to avoid vibrations on the other hand.

5.3 Water rate and washing conditions

As a general rule, wash water should not exceed 3 to 4% of massecuite feed rate. The washing method especially as concerns radial or co-axial repartition of water should be adapted to the quality of sugar and the purity of molasses requested.
Very often, only co-axial washing is used because radial washing yields an increased purity of molasses. However, only a suitably adjusted radial washing gives the required purity of low grade sugar, using a lower water rate than co-axial. It should also be remembered that a high rate of wash water in the co-axial washing method also increases the purity of molasses. Table 4 gives a com-

parison between co-axial and radial washing methods.

Table 4

5.4 **Utilization of vapor**

In order to reduce massecuite viscosity, vapor is used for washing. However, the difference of temperature between massecuite and vapor should not exceed 10 K. Above this value, enrichment of molasses with sugar becomes important (Table 5).

Table 5

5.5 **Quality of screen**

Pushing the sugar crystals on screen provokes their erosion. This damage of crystals is greater, if the screen is worn and wrinkled. Table 6 summarizes the abrasion of sugar crystals especially as concerns the amount of fine particles, in the centrifugal. Raw sugar may contain 10 times more fine particles than are present in the massecuite.
As a general rule, it is recommended to change screens after 2 months of work. From experience, it is known that the beginning of a campaign is more harmful to screens because of the particles of scale, metal or rust in massecuites. It is usual to utilize second-hand screens for the first days of a campaign.

Table 6

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Table 1: Color and ash content (EU points) before and after magma preparation [2]

Factories	Ash (EU points)		Color (EU points)	
	Before	After	Before	After
A	4.6	1.8	1.6	0.9
B	3	2.1	1.8	1.3
C	4.1	2.8	2.6	1.8
D	5.5	3.9	2.7	2
E	6.6	4	3.6	2.9
F	8.8	4	4.5	3.6
G	9.6	6.3	5.1	3.7

Table 2: Effect of pre-washing (duration) on sugar color

Pre-washing time (min)	Washing Time (min)	Color
0	9	36
0	7	45
3	5	30
3	7	27

Table 3: Evolution of EU points (color and ash) of sugar as a function of the centrifugal speed

Speed (min^{-1})	EU points		
	Color	Ash content	Total
1150	4.6	8.6	13.2
1100	3.9	7.0	10.9
1030	3.8	6.0	9.8
980 (optimum)	3.6	5.5	9.1
910	4.1	5.8	9.9
850	3.8	5.9	9.7

Table 4: Comparison between co-axial and radial washing methods

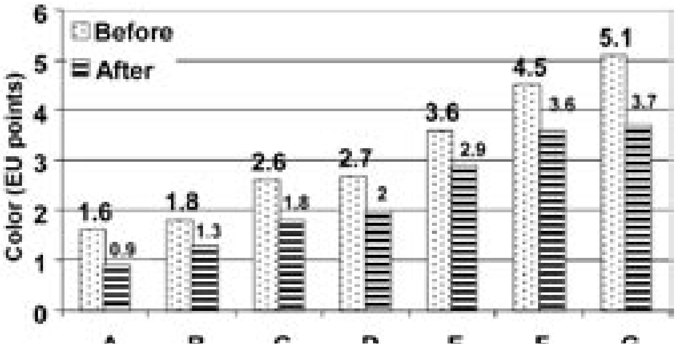
Experiments	Washing (L/h)		Purity	
	Coaxial	Radial	Molasses	Sugar
A	180	0	60.9	90.4
B	140	40	60.7	94.2

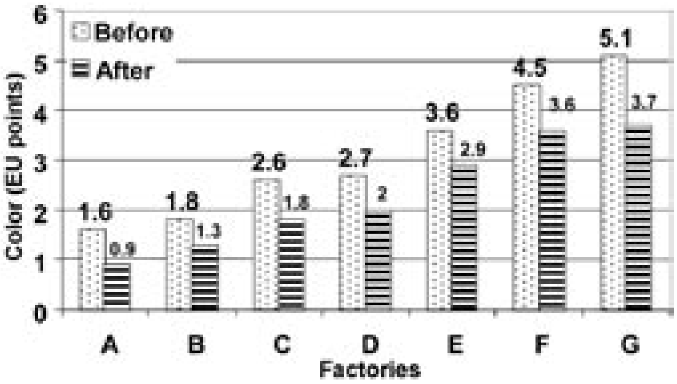
Table 5: Enrichment of molasses with sugar as a function of the difference of temperature between massecuite and vapor

ΔT (K)	Δ Purity
0	0.4
5	0.4
10	0.6
15	0.8
20	1.0

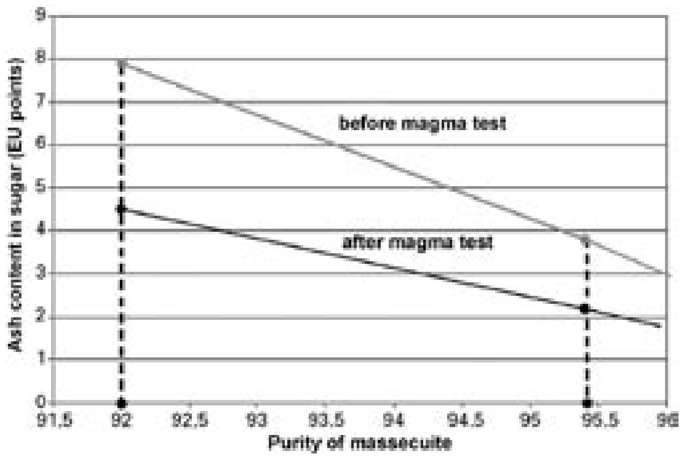
Table 6: Abrasion of sugar crystals in the centrifugal (change in mean aperture and % of fine crystals)

Massecuite			Raw sugar		
Mean aperture	% crystals		Mean aperture	% crystals	
	<60 mm	<70 mm		<60 mm	<70 mm
292	0.5	1.3	226	5.6	5.6
322	0.2	0.5	302	6.2	6.2

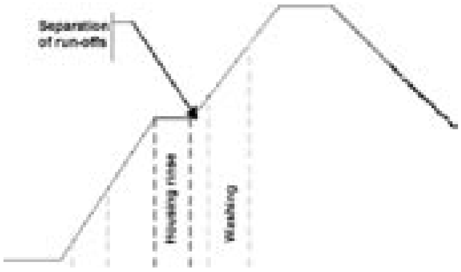

Before
After
Color (EU points)
6
5
4
3
2
1
0
1.6
0.9
1.8
1.3
2.6
1.8
2.7
2
3.6
2.9
4.5
3.6
5.1
3.7


Before
After
Color (EU points)
6
5
4
3
2
1
0
1.6
0.9
1.8
1.3
2.6
1.8
2.7
2
3.6
2.9
4.5
3.6
5.1
3.7
A
B
C
D
E
F
G
Factories

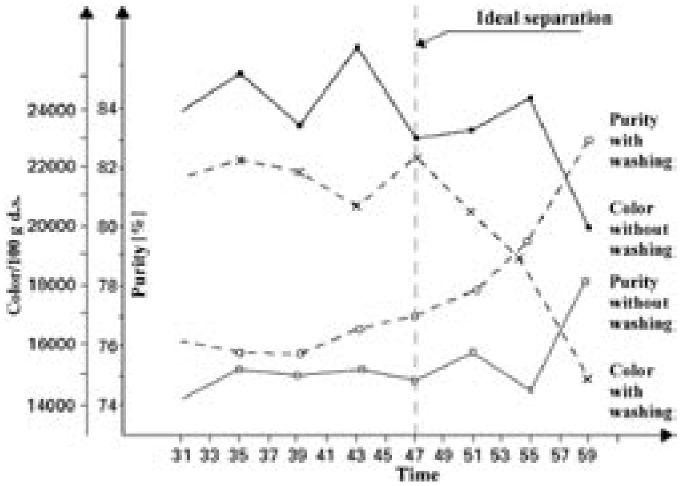
1


Ash content in sugar (EU points)
9
8
7
6
5
4
3
2
1
0
before magma test
after magma test
91,5
92
92,5
93
93,5
94
94,5
95
95,5
96
Purity of massecuite

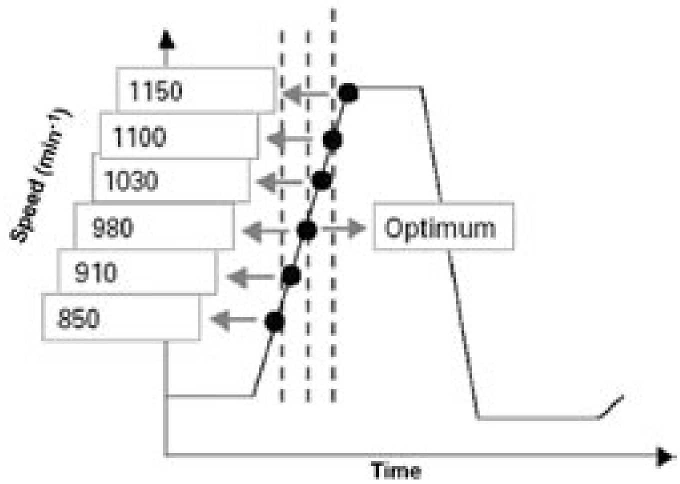
2


Separation of run-offs
Housing rinse
Washing

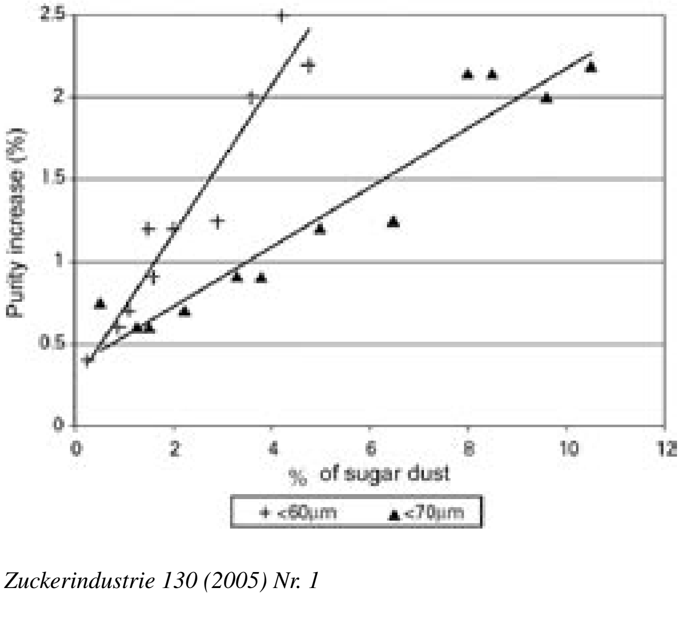
4


Ideal separation
Purity with washing
Color without washing
Purity without washing
Color with washing
Color/100 g d.s.
Purity [%]
Time
24000
22000
20000
18000
16000
14000
84
82
80
78
76
74
31 33 35 37 39 41 43 45 47 49 51 53 55 57 59

5


Speed (min⁻¹)
1150
1100
1030
980
910
850
Optimum
Time

6


Purity increase (%)
% of sugar dust
+ <60µm
▲ <70µm
0
0.5
1
1.5
2
2.5
0 2 4 6 8 10 12

7

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