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An Experiment of Chocolate Softness Measurements Using a New Machine Design

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Abstract

In principle, the study is based on the objective of upgrading chocolate softness and homogeneity by designing a new machine that would be alternative to the costly current one. The eventual target is to elevate the present level of chocolate delicacy to match with that in the developed countries.

The findings of the study are satisfactory; the mixing period in the factory machines has been reduced from 24 to 12 hours in the newly designed machine, while chocolate softness is lowered from 55 to 25 micron. Hence the chocolate conformity and cohesion.

Coarse sugar, which was used in chocolate mix in this experiment, is now substituted by powdered sugar. Eventual results demonstrate ample saving in energy consumption and reduce the cost production due to the reduced mixing time, in addition to improving the quality product.

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Keywords: Chocolate softness; Primary mixer; Weiner; Grinding; Marble; Mixing time; Viscosity

1. Introduction

Chocolate is, in fact, a matrix of discrete solid particles (sugar, cocoa and milk) set in a continuous fat medium. This fat makes up about a third of the weight of the chocolate, but because it has a lower density, it occupies almost half the volume. When the fat is solid, the chocolate is harder to bite through, although at higher temperatures it becomes softer and eventually turns into a liquid. This is what happens when chocolate is eaten, as the melting temperature of the fat is below that of the mouth [1,2].

The fat in milk chocolate is a mixture of cocoa butter (derived from cocoa beans) and milk fat. The geographical origin of cocoa beans affects the hardness of the chocolate produced and the rate at which it melts, with the fat from beans grown nearer the equator being harder and slower to melt than those grown further from the equator [3-5].

Chocolate is highly affected by temperature, a factor that has to be reckoned with before and during manufacturing, and in stockpiling and distribution as well.

Chocolate manufacturing greatly depends on how well its components of cocoa mass, cocoa butter, sugar and milk are mixed [6]. At the Philadelphia factories, this process takes about 24 hours daily, and carried out in two 500kg mixers (primary mixers) (Fig.1). The temperature generated by this process should not exceed 45°C. Otherwise, the control unit would stop off the mixer and thus save the chocolate mass.

The chocolate would then be carried by double jacket pipes, at 45°C, to two storage tanks, the capacity of each is 1000 kg. These latter two are also double jacket tanks with 40-45°C though preferably to be at 42°C. After that, chocolate would be carried to the Tempering Unit, where its temperature drops to 29°C, then to the Depositing Unit, which is connected with the control unit, with a view to determining the quantities required for poured in the molds. By that time, those molds would have been exposed to preheating. Indeed, the temperature of the mold should be very close to that of the chocolate so that chocolate breaking would be avoided when being poured in molds. Then the molds would be carried mechanically to the Vibration Unit, where chocolate is conformed inside the molds. After that, it would be carried to the three-phase Refrigeration unit, then for packing, and finally to the refrigerated stores.

2. Advanced Mixers (Five-Roll Refiner)

The five-roll refiner (Figure2) has five barrel-shaped rollers, which are normally between 800 and 2500 mm wide and are approximately 400 mm in diameter. These rolls become parallel under the pressure of operation. The particles are broken by the shearing action between the two counter-rotating rolls. The gap between them becomes narrower until the top gap is the same size as the largest particles within the chocolate, i.e. less than 30µm (micron).

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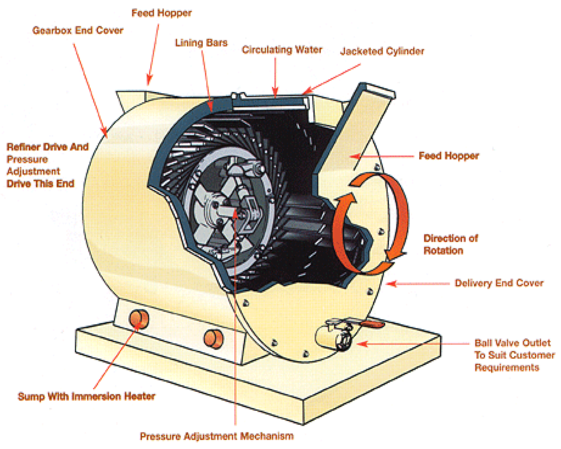

Figure 1: Shows the Primary Mixer (Pre-mixer) [7].

The material, with a maximum particle size of around 150µm, is fed in between the two lower rollers and is transferred up the 'stack' due to the increased speed of the next roller. The film of material becomes thinner by a factor related to the speed difference. The ratio of roll speeds in fact is one of the ways of controlling the particle size of the machine. This is normally between 1.5 and 1.7 with the roll speeds varying from less than 50 r/min to greater than 400 r/min. In some five-roll refiners the rolls have set speeds and in this case the maximum particle size is manipulated by adjusting the feed gap between the first two rolls. The greater this feed gap, the larger will be the particles between the top two rolls. The pressure between the rolls does not control the particle size but is just used to ensure a uniform coating of the rollers by the chocolate. The Bühler Company [8] in Switzerland has produced an automated feedback system, in which a thickness-measuring device on the final roll gives a measurement which adjusts the relative speeds of the first two rollers. The viscosity of the chocolate is critical, however, and, if there is insufficient fat to bind the solid particles into a film, the material may be thrown from the rollers. On the other hand, if the feed material is very thin, because too much fat is present, some of the sugar and milk particles will segregate out in the hopper, resulting in uneven grinding. Temperature has a very large effect upon the flow properties of this fat and so accurate cooling and heating of the rolls is required to obtain an optimum particle size distribution within the chocolate [1].

As shown above, mixing chocolate components is the important section of the production processes as a whole. Chocolate quality depends a lot on the mixing process which takes quite a long time.

Good chocolate is distinguished by taste. Like cream, it should melt in the mouth [9]. Hence to get a better chocolate taste with an elevated delicacy, the mixing process should be developed. In order to obtain the correct flavor and texture, solid particles must be ground to a size smaller than about 30 mm, which use a highly specialized and costly machine for that purpose [9,10]. However, the mass production of these machines is not fit to the needs of the local market, to say nothing about their costly maintenance that is only compatible to developed countries. In these machines, chocolate components are mixed by a group of moving rolls with very high level of softness. So the developing process we seek to achieve is to design an alterative machine at a low cost.

Figure 2: Shows an Advance Machine, Five-Roll Refine [1].

3. The Newly Designed Machine (Wiener):

The study is based on milling the chocolate components while being passed and revolved on chrome marbles. These components would be softened by the movement of the weighty marbles which are operated by on electric motor that is tied to a gearbox. The design incorporates the manufacture of a double jacket tin made up of a stainless steel material with an inner wall thickness no less than 6mm and 5mm for the outer wall, whereas the space between the two walls will be about 8cm, and the capacity of the machine will be bout 250kg of chocolate. Argon gas will be used in the welding so that chocolate would not the affected by any oxidization.

In the middle of the tinplate, an internally moving bar of stainless steel will be fixed, with 24 stainless brushes to do the mixing. The bar and brushes will be operated by the above mentioned electric motor and the gearbox, which will be fixed on a special-made basis above the upper lid of the tinplate.

At the bottom of the tinplate, chrome marbles of different or same diameter (pending availability in the marketplace) weighing to help in the mixing and milling process. However, the marbles weight should gradually be increased to reach the proper level of chocolate mixing and softness.

As the chocolate mix is well prepared, and its conformity achieved in the primary mixers of 500kg weight, a special pump at the lower part of the mixer will pump it to the upper part of the wiener (Fig.3). Meanwhile, the chocolate mix at the lower part of the wiener will also be drawn by a special pump and pumped to the upper part of the primary mixer. Thus a continued revolving of the mix will run between the primary mixer and the wiener to realize the chocolate's required delicacy.

A special control plate will run the chocolate stirring and pumping, and the cooling of the manufactured system will be done by a special cooling tower.

Figure 3: Shows the Newly Designed Machine (Wiener).

4. Means of Measurement

When chocolate conformity is realized (which usually takes one hour in this factory), we start measuring its softness once every half hour by a gauge device (Figure 4). A chocolate sample will be taken by a small-spoon. The grading surface device will be varnished by this sample. The grading device involves a straight line apertures, the highest grade of which is 185 micron and the lowest is 1 micron. So if the sample is immersed in an aperture, then it is the indication that the sample's grading is identical to that of the aperture. But if the sample is larger than 185 micron, then the chocolate softness can by no means be read. In other words, this softness is out of the grading reach.

As the factory used the coarse sugar in making chocolate, a comparison has been made on the primary mixer using two separate batches with coarse sugar and powder sugar. Figure (5) explains the curves of softening the chocolate by the coarse sugar and the powder sugar. From the curve of the coarse sugar, it is noted that the mix began gradation after 5.5 hours, and reached the highest delicacy level after 24 hours of mixing, while it has recorded 55 micron only, whereas the powder sugar curve showed that the mix began gradation after 2.5 hours, and the maximum chocolate delicacy was realized after 13 hour mixing. This shows a time saving of 11 mixing hours, with a 40 micron delicacy after 22 hour mixing; an apparently better delicacy level achieved by the powder sugar than that by the coarse sugar.

That is a primary indication for dispensing with coarse sugar. To make sure of that, an experiment was carried on the wiener with powder sugar after having added 210 kg of chrome marbles with a view to facilitating the mixing and milling process.

(Figure 6), which includes the curve mentioned in (Figure5), i.e. the powder sugar curve used in the primary mixer and the other curve pertaining to the wiener. Hence, it can be noted that the wiener performance by using powder sugar was better than of the primary mixer when using the same sugar. In fact, the required softness, i.e. 25 micron has been achieved after 24 hours of mixing 250 kg of raw chocolate material by the wiener. Given that, and to obtain better results, the mixing method in the factory has been changed. Coarse sugar has been replaced by powder sugar on the one hand, and the primary mixer and the wiener have been connected together so that the softening process will be realized between them by circulation on the other.

(Figure 7) shows the softness that has been achieved by this experiment of circulation, where the chrome marble maintained its weight, i.e. 210 kg, and the way of mixing was the only thing that has been changed. The figure also shows that the blend started to come into the grading scale only after 3-hours of mixing, and that the required softness, i.e. 25 micron has been achieved after 16.5 mixing hours. This means that the wiener works positively, and that the blend works positively, too.

Given all that, the marbles weight in the wiener by 10 kg each time up to 260kg as shown in Figure (8), where weights are 220, 230, 240, 250, 260 kg respectively. In all cases, gradation started on hour after the mixing process, excluding the case of 260kg when gradation began immediately.

Figure 4: Shows the Chocolate's Gage Device

It is noted that the curves of 240, 250, and 260 kg weights began coming closer to each other after 11 hour mixing. They registered 35, 34 , and 30 micron respectively, and that the required softness of the chocolate started to be achieved by the 12 hour of mixing time, with 28, 27, and 25 micron respectively. The curve also shows that 25 micron required delicacy took 16 hours for a 220kg weight, 14.5 hours for 230kg, 14 hours for 250 kg, and 12 hours for 260 kg weights. Eventually, it can be safety said that the required chocolate softness has been achieved in a 12 hour mixing period for 500 kg of chocolate revolved between the primary mixer and the wiener.

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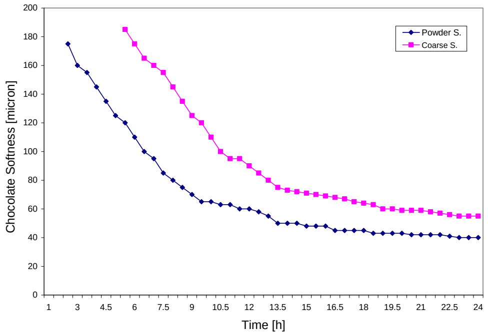

Figure 5: Shows the Chocolate's Softness by the Primary Mixer Using Coarse and Powder Sugar.

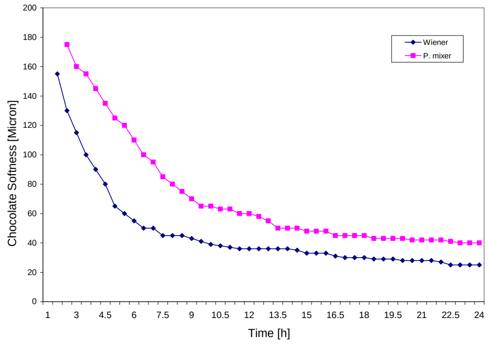

Figure 6: Shows the Chocolate's Softness by the Primary Mixer and the Wiener Using Powder Sugar.

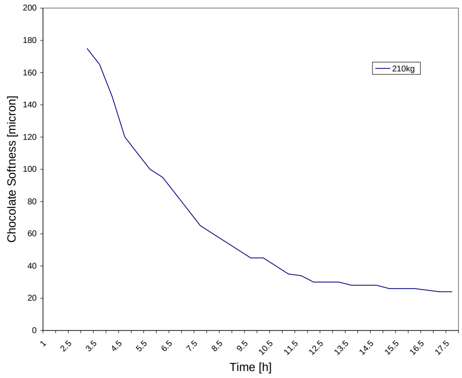

Figure 7: Shows the Chocolate's Softness by the Circulation Method between Primary Mixer and Wiener Using 210kg of Chromic Marbles.

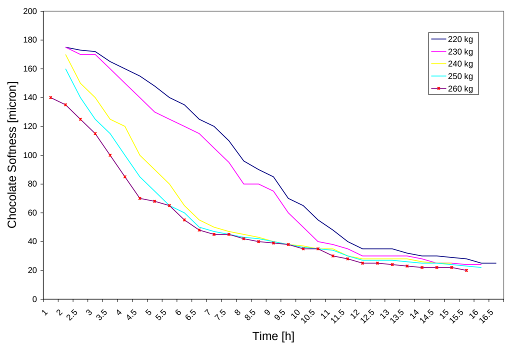

Figure 8: Shows the Chocolate's Softness by the Circulation Method Between Primary Mixer and Wiener Using (220-260) kg of Chromic Marbles.

5. Conclusions

The obtained results are summarized as follows:

- The results of the design and manufacture of the wiener machine, and the use of circulation method to have led the satisfactory results by reducing the chocolate softness from 55 to 25 microns thus, improving the quality of the product.
- The curves show that 25 micron required delicacy took 16 hours for a 220kg weight, 14.5 hours for 230kg, 14 hours for 250 kg, and 12 hours for 260 kg weights.
- The undertaken measurements show that the wiener has reduced the mixing time from 24 to 12 hours for 500kg chocolate (i.e. 50 percent of the time consumed by the primary mixer.
- The designing and manufacture of the wiener has lent coarse sugar dispensable and should be replaced by powdered sugar.
- The best softness that was realized by the primary mixer by using powder sugar was 40 micron after 22 hours of blending, whereas it was achieved after 9.5 hours by the wiener.
- The improved chocolate softness, has simultaneously improved the viscosity and homogeneity of the mixture, and accordingly the chocolate taste much better than before.

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