A Study of Sugar Drying and Conditioning

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ABSTRACT

A laboratory investigation of the mechanism of sugar drying was conducted. The effects of drying time, air temperature, and agglomerates on drying rate and the final moisture content of sugar crystals were examined. Because of the complicated nature of this study on a factory scale, a bench model granulator was constructed.

The study indicated that the drying temperature has considerable effect on the quality of the finished product. High temperature drying tends to encourage the formation of small sugar particles which can in part contribute to the dust problem.

INTRODUCTION

In the sugar industry, it is necessary to store a significant portion of the production for a considerable length of time. Caking and dust formation are usually encountered during sugar handling and storage. The final product should, however, reach the consumer in first class condition. Krautmann (2) claimed that most of the unfavorable phenomena such as caking and dust formation result from the supersaturated film on the crystal surface and are caused by conditions encountered during the drying process. Powers (4) indicated that the major cause of dust formation is the rapid drying of the thin films of syrup left on sugar after spinning. Accordingly, drying in the granulator may be considered as a continuation of the crystallization process. Others (1) demonstrated that wet sugar

samples washed with alcohol prior to drying dried with a brilliant shine, a negligible amount of dust, and very little tendency toward caking.

This investigation was undertaken in order to determine the effects of various drying conditions on the physical characteristics of sugar crystals.

MATERIALS AND METHODS

Equipment: A bench batch dryer (granulator) with an approximate capacity of 12 quarts per hour was constructed at our laboratory. It consisted of a cylinder 18" long and 12" in diameter, with eight evenly spaced flights inside to give a more efficient agitation of the sugar. The granulator was supplied with a small fan and heating unit to provide a stream of forced hot air, and was rotated at a constant speed of ten revolutions per minute. The granulator was capable of drying a two liter sample of sugar to .05% moisture content in approximately the same time as that required by the factory granulators.

A conditioning bin model was also constructed. It consisted of an 18" long by 5" diameter glass chromatograph tube with a fritted glass disc in the bottom. Air was blown up through the disc and distributed through a layer of sugar placed over it. The air supply was laboratory compressed air that had passed through a silica gel dryer and a rotameter to measure the volume of air used.

Moisture was determined on the samples by a standard method for the determination of moisture in sugar. Samples were dried in glass-stoppered weighing bottles for a period of three hours in a 105°C oven, then cooled and reweighed to determine weight loss. Dust levels were determined by using the method developed at the U and I Research Laboratory. (1)

Procedure: A two-liter sample of wet sugar was found to be
the optimum amount for the operation of the bench granulator. Prior to drying a sample, the granulator was preheated to the desired temperature for a period of 10 to 15 minutes, then the sample of wet sugar was added. Drying temperatures were varied from 25° to 145°C. The granulator was started with samples collected at pre-determined intervals in bottles which were stoppered and allowed to cool. Approximately 10 grams of the sample was taken, quickly and accurately weighed, then dried in an oven for three hours at 105°C.

The sample was then cooled in a dessicator, reweighed, and the percent moisture calculated. The dried sugar was conditioned and examined under the microscope. Finally, the sample was tumbled in a plastic bottle for 30 minutes in order to simulate the effect of physical movement, and dust levels determined.

Further tests were conducted in order to examine the drying pattern of sugar crystals as compared to the drying characteristics of both wet sand and sodium chloride, and additional tests compared the drying rate of conglomerate sugar to that of clean, uniform grain.

RESULTS AND DISCUSSION
The average results for varying air temperatures (25, 70, 100 and 145°C) are illustrated in Figure 1. It should be noted that in all cases the initial moisture content was considered to be unity, and all moisture contents were adjusted accordingly.

From these curves, it can be seen that sugar drying is not a smooth, continuous process. Each curve can be divided into a warming up period followed by a constant rate period which appears on the graph as a straight line. The third period of drying is typified by a continuously changing rate until the entire surface is supersaturated. This marks the start of a portion of the drying cycle in which the rate
Figure 1. Sugar drying at various temperatures.

of internal moisture movement and crystallization from the syrup controls the drying rate. (3)

Figure 2. Air temperature versus drying time (constant time curves) - Moisture indicated as percent.
Figure 2 shows the length of time required to reach percent moistures from 0.8 to 0.04 at various air temperatures. Note, for example, that with air at 140°C, it takes 1.25 minutes to dry sugar to 0.06% moisture. If the same sugar were dried with air at 100°C, it requires only two minutes. A drop of 40°C in air temperature lengthens the drying time to the .06% moisture level by only three-quarters of a minute. On the other hand, there is a much larger difference in the time required to reduce the moisture level from .06 to .04% at temperatures below 100°C. At these moisture levels, the low temperatures do not appear to provide the driving force required to force the moisture out of the saturated sugar solution surrounding the crystals.

Figure 3 includes constant-time curves which illustrate the relationship of moisture to temperature; both high temperature and long drying time are required in order to effect moisture reduction below the 0.1 level.

Figure 4 includes the drying curves for equal volumes of sugar, sand, and sodium chloride dried at 100°C. In the case of drying sand, the phenomenon illustrated is merely
Figure 4. Comparison between drying curves, Sugar-sand-salt.

the evaporation of water from the surface. In the case of sugar, the wet sugar loses moisture first by evaporation from a syrup film on the surface of the crystal down to a moisture content of approximately .05%, followed in turn by a period of evaporation of a supersaturated surface which is gradually increasing in saturation until such a point that crystallization starts to take place. It is at this point that, in theory, the dust is formed. Sodium chloride is similar to sugar in that it is a soluble solid. It does not, however, form an appreciable glaze or surface layer upon drying as sugar does. This layer seems to cause an increase in the drying time of sugar crystals. It should be pointed out that both sand and sodium chloride have higher specific gravity and higher specific heat than sugar.
Table 1 is a typical example of the effect of the quality of sugar boiling on sugar end operation.

**TABLE 1 COMPARISON OF TWO SAMPLES OF SUGAR**

<table>
<thead>
<tr>
<th>Drying Time ($\text{seconds}$)</th>
<th>Percent Moisture</th>
<th>Sample 1</th>
<th>Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>1.380</td>
<td>.998</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>.900</td>
<td>.350</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>.480</td>
<td>.092</td>
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<td>90</td>
<td></td>
<td>.210</td>
<td>.047</td>
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<td>120</td>
<td></td>
<td>.086</td>
<td>.033</td>
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<tr>
<td>180</td>
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<td>.066</td>
<td>.033</td>
</tr>
<tr>
<td>240</td>
<td></td>
<td>.053</td>
<td>.021</td>
</tr>
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<td>300</td>
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<td>.037</td>
<td>.022</td>
</tr>
<tr>
<td>600</td>
<td></td>
<td>.037</td>
<td>.019</td>
</tr>
</tbody>
</table>

Sample 1 was a strike of sugar that had a large percentage of conglomerates, while Sample 2 had a very clean, uniform grain. As can be seen from the table, Sample 1 had a higher initial moisture content than did Sample 2. The latter had half the moisture content of Sample 1 after they both had been dried for a 10-minute period. This is due almost entirely to the fact that a conglomerate sugar has more syrup trapped on the surface, than does a well formed crystal. On a number of samples tested, there was a large variation in the moisture content of the sugar being introduced to the granulator. It has been shown that the initial moisture content has a very important bearing on the efficiency of the granulator operation.

A further study of dust formation at various air temperatures was as follows:

Wet sugar samples were taken from the spinners, then dried for ten minutes in the laboratory bench granulator at 70, 100, and 145°C, respectively. The samples were further treated for four hours in a conditioning bin model using dry air in an attempt to remove all moisture present in sugar in excess of the equilibrium quantity. Samples were
then tumbled in plastic bottles for 30 minutes. Percentages of dust were determined at 0.043, 0.058, and 0.083, respectively.

Microscopic examination of different samples indicated that crystals dried at higher temperature (145°C) were clear and sparkling as they came from the granulator. After conditioning, the sugar became dull and the slightest movement could produce very fine dust. On the other hand, sugar dried at lower temperature does not change appreciably in appearance after it has been conditioned. In general, there was a tendency for sugars dried at higher temperature to form dust more readily than sugars dried at lower temperatures. Figures 5 and 6 illustrate the effect of drying temperature on dust formation. It can be seen that the coating surrounding the crystals dried at 145°C looks almost amorphous. The submicroscopic crystals covering the mother crystal can be seen easily through the microscope at a high magnification (325x). It should be pointed out, however, that samples dried at high temperature (120-145°C) had less caking and required longer time for setting-up to take place.
Figure 7. Sugar crystal dried at 145°C at 325x.

It is important to emphasize that the drying rate and the final moisture content of sugar are also influenced by other factors besides time, temperature, and conglomeration. These factors include particle size, initial moisture content, and the humidity of the surrounding air.

**CONCLUSION**

This study indicates that the drying temperature has considerable effect on the nature of the finished sugar. High temperature drying tends to encourage the formation of small sugar particles loosely bound to the surface of the sugar crystal, giving it a dull, opaque appearance. During handling these particles are rubbed off quite easily and contribute at least in part to the dust problem.

Furthermore, any means of producing a wet sugar product at a reduced and uniform moisture content would be of great advantage. In this light, it can be seen that the centrifugals act as separators and physically remove the moisture. This is a relatively simple process which requires a relatively small amount of energy. On the other hand, granulators remove the water by a phase change or evaporation.
Which, from an engineering standpoint, requires a much greater amount of energy.

LITERATURE CITED


