Savings to be made in the chocolate production process through close fineness monitoring

David Pugh
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Provided By:
Microtrac, Inc.
Particle Size Measuring Instrumentation
**Introduction**

One of the key ingredient in many foods is chocolate. It adds the extra taste appeal in your favorite cereals, biscuits, drinks and most importantly, chocolate bars. Chocolate is a product that requires complex procedures to produce. The process of creating chocolate starts with the harvest of coca, refining the coca to cocoa beans which are then cleaned, roasted, ground and pressed, blended and refined, conched, tempered and molded. The cocoa beans are exported from countries which lie within 20 degrees of the equator, such as Mexico, Ivory Coast, Ghana and Indonesia.

The coca is first harvested manually from tropical Cocoa trees, which grow in the wet lowland tropics of the Americas, West Africa and Southeast Asia. The cocoa pods are hacked down by machete from the trunk and branches of the cocoa tree. They are split open and up to 50 cocoa beans are removed and either placed in heated trays, covered with banana leaves or heated by the sun for fermentation to take place. When the beans turn brown, this signals the end of the fermentation process. They are then dried for a week before they can be being sacked and exported.

Once the cocoa beans reach the chocolate factories, they are refined by roasting and winnowing. The outer shell of the beans is removed after becoming brittle from the heating process. The inner cocoa bean is broken into small pieces called cocoa nibs. Chocolate manufacturers prefer to roast the beans before shellling them, while cocoa processors favor roasting the shelled nib as it retains more cocoa butter since cocoa butter can’t migrate from the bean into the shell during the roasting process.

There are usually two stages of grinding in the manufacture of fine chocolate. In the first stage, the nibs are ground into a thick paste called the chocolate liquor. The size of the particles in the chocolate mass is now about 100 microns. To avoid a grainy taste in the finished chocolate, another grinding takes place to reduce the particle size to about 18 microns as the tongue can sense grains of 18 microns or larger. If cocoa powder is being made, the chocolate liquor is further processed into pressed cake, and cocoa butter. The chocolate liquor or mass is put into hydraulic presses under extremely high pressure to drain off the clear, golden liquid cocoa butter. The press cake that is left is cooled, pulverized and sifted into cocoa powder. At this stage the chocolate liquor and other ingredients are kneaded together according to the kind and quality of the chocolate being made. The cocoa liquor is mixed with cocoa butter and sugar and this is further refined by reducing the particle size of the added milk powder solids and sugar down to the desired fineness. The Cocoa powder or ‘mass’ is blended back with the cocoa butter (added to promote better mouth feel and reduce the viscosity) and liquor in varying quantities to make different types of chocolate. Lecithin, an emulsifier, which is much cheaper than cocoa butter $2577/ton (£1,577/ton) is also used to reduce the viscosity of chocolate and so reduces the amount of extra cocoa butter that must be added.

The ingredients can be churned together for hours. The resulting mixture is then dried to form a crumb which is ground with more cocoa butter in the next phase to make the thick chocolate crumb into a silky chocolate. This step reduces the particle size of the cocoa mass to 25 to 30 microns. The smoother the chocolate desired, the more rolling milling required. In 1879, Rudolph Lindt invented the conche machine to produce chocolate with superior aroma and melting characteristics. Before conching was invented, solid chocolate was gritty and not very popular. The conche is a surface scraping mixer and agitator that evenly distributes cocoa butter within chocolate, and acts as a ‘polisher’ of the particles. The conching machine kneads the paste for anytime from a few hours to a few days. The conches have heavy rollers that can produce different degrees of agitation and aeration. This process strongly affects the final flavor and texture of the chocolate. When ingredients are mixed in this way, sometimes for up to 78
hours, chocolate can be produced with a mild, rich taste. Lower quality chocolate is conched for
as little as six hours. The conching process redistributes into the fat phase the substances from
the dry cocoa that creates the flavor. The temperature of the conche is controlled and varies for
different types of chocolate. Generally higher temperature leads to a shorter required processing
time. Temperature varies from around 49 °C for milk chocolate to up to 82 °C for dark chocolate.

The final critical step for the chocolate is that it must be tempered to deter large crystals from
forming. The chocolate would have a gritty texture and a dull appearance and/or the cocoa butter
would separate from the mixture without tempering taking place. This is a delicate process that
involves slowly heating and cooling the chocolate repeatedly to temperatures between 41°C and
29°C. This stabilizes the product and achieves the smooth, shiny texture, pleasant mouth feel
and stops the chocolate becoming crumbly as it hardens.

The basic ingredients of milk chocolate are sugar, milk or milk powder, cocoa powder, cocoa
liquor, cocoa butter, lecithin and vanilla. White chocolate contains all of these ingredients except
cocoa powder and plain dark chocolate excludes the cocoa powder, sugar and milk powder. A

<table>
<thead>
<tr>
<th>Chocolate Type</th>
<th>Milk Chocolate</th>
<th>Dark Chocolate</th>
<th>White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa liquor %</td>
<td>18</td>
<td>35-80</td>
<td>0</td>
</tr>
<tr>
<td>Cocoa Butter %</td>
<td>25</td>
<td>5-50</td>
<td>20</td>
</tr>
<tr>
<td>Sugar %</td>
<td>38</td>
<td>0</td>
<td>55</td>
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<tr>
<td>Milk Fat %</td>
<td>4</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Non Fat Milk solids %</td>
<td>14</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Vanilla and Lecithin %</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

From an understanding of the chocolate production process, it is obvious that particle size
monitoring is required at many stages to ensure the final mouth feel of the chocolate product. As
the cost of cocoa butter has climbed so has the relationship between particle size and cocoa
butter usage been of increased interest also.

Dr. Walter Rostagno suggested that particles larger than 20 microns are the particles to which the palate
is most sensitive. Several chocolate equipment manufacturers have stated that the palate is
primarily sensitive to the smallest dimension of a particle because the particle will tend to orient
along its flattest axis in the mouth. In addition, as sugar tends to dissolve in the mouth, the size of
the sugar particles in chocolate can be slightly larger than cocoa particles without affecting the
mouth feel. For some uses of the cocoa powder, knowledge of the entire particle size distribution
would be very important. In chocolate milk, the color and suspendability are
dependent upon the size of all of the cocoa solids particles not only the large particles. If mouth
feel of a chocolate coating is of interest, the mouth feel of a coarse chocolate will correlate with
the size of the largest particles. However, for fine chocolate coatings, the mouth feel correlates
more with the entire particle size distribution than with only the large particles. Fat requirements
of chocolate coating also correlate with the particle size and distribution more closely than with the
large particles only.

Graph 1 shows the particle size distribution of a milk chocolate.
Graph 2 shows the distribution of a dark chocolate.

It is worthwhile noting some key differences between the two. Firstly, the milk chocolate particle size distribution has a Dv(50) of 14.43 microns compared to Dv(50) of 7.75 microns for the dark chocolate. This is easily explainable by the fact that there are sugars in the milk chocolate and not
in the dark. We have already stated that the sugar particles can be larger than the cocoa particles, because of its ability to dissolve quickly in the mouth.

In Graph 3 we can see a comparison of the 2 different types of chocolate.

![Comparison Plot](image)

It is worth noting the greater number of fines in the dark chocolate compared to the milk chocolate. Typically more fines will produce a greater surface area of the cocoa particles. The greater the surface area of cocoa particles, then the greater the volume of cocoa butter needed to coat them. In this particular instance, if we look at the surface area values (CS) in tables of Graphs 1 and 2 we can see that there is 33% more surface area in the dark chocolate than the milk. We have already seen that in the second grinding stage, the aim is to reduce the size of the cocoa particle mass down to 18 microns. If the particles are ground down to 19 microns, there will be a gritty mouth feel. If we overgrind (Insurance grinding), the size could be 17 microns and there will be up to an extra 5% of cocoa butter required to cover the increased surface area, in addition to the extra grinding costs. So for each ton of chocolate produced, an extra $129/ton (£79/ton) is required (cocoa butter costs $2577/ton or £1,577/ton) to coat the cocoa particles.

The shape of particles should be considered in particle size analysis. The particles in chocolate products are primarily cocoa solids, sugar, and possibly milk. Cocoa solids are not crystalline, and they can therefore be found in almost any shape. Sugar (sucrose) is a monoclinic crystal which means it usually will be found in a uniform shape but in differing dimensions and sizes. Milk solids particles may appear in a variety of shapes and sizes depending upon how it is processed. As part of the Microtrac system there is the possibility of adding a shape and image analyzer, which will provide both shape and size information to assist the chocolate formulation scientist.

**Conclusion**

The Microtrac S3500 is a rugged particle size analyzer which is usually situated in the laboratory, but the system can be placed in the production area for close monitoring of the size until it meets the ideal specifications. If a chocolate company is producing 1000 ton/year, up to $130,000 (£79,000) could be saved on cocoa butter alone by controlled grinding, this is in addition to milling costs and operator time, measuring with antiquated methods. The use of the Microtrac will result in a payback (ROI – Return On Investment) in as little as 3 months.