Chocolate-Tempering Equipment and Techniques

The advantages and disadvantages of the four major styles of tempering equipment.

Joe Sofia
Cargill Cocoa & Chocolate

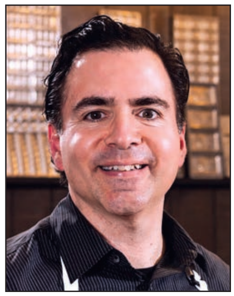
There are various types of equipment and techniques used for tempering chocolate. Advantages and disadvantages of the four major styles of tempering equipment, used for both large-scale and small-scale confectionery applications, are discussed here. Tempering equipment design must take into account three important variables crucial to the tempering process—agitation, temperature and time. In order to choose the appropriate tempering machine, users must have a basic understanding of tempering and how these variables affect the process. Criteria for evaluating tempering equipment include ease of changeover and cleanout, production capacity and operational complexity.

DEFINITION OF TEMPERING

Temper can be defined as "the induced partial pre-crystallization of cocoa butter." However, it is not just any cocoa butter crystal we seek; for optimal final results the stable Form V crystal, also known as β crystal, is the goal. In addition to quality cocoa butter crystals, the correct quantity is also important. We need roughly 2 to 4 percent of the cocoa butter crystallized while the other 96 to 98 percent remains in the liquid phase. These crystals must be well distributed throughout the liquid chocolate.

To produce the right number and size of stable Form V crystals, agitation is one important variable. As a result, some means of mixing or agitation must be part of any tempering machine. We teach budding chocolatiers to temper with a very simple method: stirring chocolate chunks into a bowl of untempered chocolate with a spatula. The best results are achieved by the students who diligently scrape the bowl and keep the chunks moving throughout the liquid chocolate. Another factor related to agitation is shear. In a tempering machine, shear takes place where there is scraping against the cooling surface. More shearing will help create more crystals, while excess shearing creates too many. Mae West said "too much of a good thing can be wonderful," but in the case of tempering, too many crystals can create problems down the line.

Over time, the small, newly formed cocoa ➤



Joe Sofia is Cargill Cocoa & Chocolate's chocolate specialist and an instructor for Cargill's Chocolatier's Workshop. He worked for Nestlé USA and Peter's Chocolate prior to his current role.

By choosing the appropriate temperatures throughout the tempering process, we can induce crystal formation, maintain a constant crystal population or melt away undesirable crystals.

butter crystals will grow larger and more resistant to melting or, in other words, they mature. This makes time another meaningful variable of tempering. The crystal transformations of cocoa butter do not happen instantaneously—they also take time.

Temperature is perhaps the most critical variable of tempering. By choosing the appropriate temperatures throughout the tempering process, we can induce crystal formation, maintain a constant crystal population or melt away undesirable crystals. Quite simply, a tempering machine is a heat exchanger. The temperature control must be precise, and the temperature readings must be accurate in tempering equipment.

Tempered chocolate, therefore, can be defined as approximately 3 percent Form V cocoa butter crystals that are well distributed in liquid chocolate, held at the correct temperature and appropriately mixed to maintain the desired quantity of crystals.

CRYSTAL FORMATION

There are many ways to temper chocolate and many different types of equipment to achieve this goal. However, all of these options can be divided into two groups: those that internally create the Form V cocoa butter crystals, referred to as the *mush method*, and those that rely on an external source of Form V cocoa butter crystals, referred to as the *seed method*. Most tempering equipment is designed to operate by one means or the other, but some can be used both ways.

Mush Method

I can still remember the first time I was taught to temper chocolate, using the mush method of cooling untempered chocolate on a chilled, stainless steel table. I was instructed to manipulate the chocolate around the table with a metal scraper in one hand and a flat metal spatula in the other. When the milk chocolate became a thick mush at approximately 78°F, I quickly removed it from the chilled table and transferred it into a bowl, and added enough warm chocolate to bring it up to 84° to 85°F. Through trial and error, I learned that letting the mush get too cold on the table would result in a solidified mass that I could not work with. Once I perfected that part of the process, I also learned that adding too much warm chocolate to the mush would bring the temperature up higher than 85°F, which resulted in poorly tempered chocolate. Over time, I found that I achieved better results and finished faster when I cleanly and swiftly scraped the table and mixed the chocolate. With enough practice I was able to consistently duplicate the procedure and temper chocolate whenever it was required. But I did not understand the principles of tempering: the difference between stable and unstable cocoa butter crystals, the importance of agitation and shearing, and the distinction between undertempered versus overtempered chocolate.

As it turns out, the mush method is a fast and efficient way to temper a small batch of chocolate. It is also one of the techniques that creates the Form V crystals.

Tempering techniques and machines that create the Form V cocoa butter crystals have to utilize temperatures cold enough to grow the unstable crystal forms first, which then transform into the stable Form V crystals. A warming step to a temperature above the melting point of these unstable crystals finishes the job. That is, the remaining unstable crystals either melt out or transform to Form V. It is this approach, organically creating the Form V crystals, that most stacked plate-type and scraped-surface, screw-type tempering machines use.

➤

One advantage to this approach is less likelihood of creating overtempered chocolate. Overtempered chocolate can become extremely viscous, creating potential problems including difficulty pumping the chocolate, heavy weight of enrobed finished pieces and air bubbles in moulded pieces. This method is less likely to overtemper chocolate because there is typically not a long residence time. As Beckett notes, "When they are newly formed the crystals are small and easily melted." Over a long residence time these stable crystals will grow, become more stable and have a higher melting point, especially if the temperature remains constant. Chocolate viscosity increases when chocolate is tempered. As a general rule the viscosity increases by a factor of two from the incoming chocolate to that leaving the temperer. This factor will be higher when the chocolate is overtempered.

Seed Method

The second group of tempering techniques and equipment relies on an external source of Form V cocoa butter crystals. These sources can include large chunks of chocolate, small chocolate wafers or chunks, powdered chocolate or powdered cocoa butter. We typically refer to these sources as seed. These sources must be well tempered and show no signs of temperature abuse or bloom. The tempering process I mentioned earlier, stirring chocolate chunks into a bowl of untempered chocolate with a spatula, is an example of this approach. With this method, a target chocolate temperature of 88°F is suitable for tempering milk chocolate, and 1° to 2°F higher for dark or bittersweet chocolate. This is well above the formation temperature of crystal forms I to IV, so these are not formed in significant quantity. The Form V crystals from the seed are transferred to the untempered liquid chocolate, resulting in our desired endpoint. Scraped-surface, rotating bowl-type tempering machines utilize this approach. Some older-style enrobers were designed to be operated using powdered chocolate for seed to start the tempering process within the enrobing tank. Also, this seed-tempering approach can be applied to tempering chocolate in a bulk tank. Excellent, repeatable results are achieved when the correct quantity and quality of seed is used.

SCRAPED-SURFACE, ROTATING BOWL-TYPE TEMPERING MACHINES

Scraped-surface, rotating bowl-type tempering machines are characterized by a rotating bowl that is divided by a baffle. A temperature control system either turns on a cooling fan or a heater to achieve the desired chocolate temperature. A temperature probe immersed in the chocolate near the bottom of the bowl measures the chocolate temperature. The rotating bowl provides gentle and effective mixing and agitation of the chocolate. The heat exchange occurs through the surface of the bowl. Chocolate seed, usually in the form of large chocolate chunks or wafers, is placed behind the baffle. With the bowl rotating clockwise, scrapers installed on the baffle at the 9 o'clock position scrape against the bowl, providing cleaning and shearing action, and help incorporate the Form V crystals back into the chocolate. Examples of this type of machine are shown in Figures 1 and 2.

Manufacturers of this style machine offer various sizes with tempering capacities up to approximately 600 pounds per day, suitable for smaller-scale applications. These machines are designed for very easy cleaning and changeover from one type of chocolate to another. If an allergen or ➤

The second group of tempering techniques and equipment relies on an external source of Form V cocoa butter crystals. We typically refer to these sources as seed.

A higher continuous capacity can be achieved by slowly feeding in untempered liquid chocolate that is very close in temperature to the well-tempered chocolate in the machine.

other thorough cleanout is required, these are uncomplicated to disassemble and clean thoroughly.

It is recommended that the smaller-sized machines of this style are operated as batch machines. Once the chocolate in front of the baffle is well tempered, the remaining solid chocolate seed is removed from behind the baffle. The tempered chocolate is used until the machine is nearly empty.

The larger sizes are typically run continuously when an enrober is mounted onto them. Chocolate can be fed to the machine by keeping the area behind the baffle full of solid chocolate. A higher continuous capacity can be achieved by slowly feeding in untempered liquid chocolate that is very close in temperature to the well-tempered chocolate in the machine.

Scraped-Surface Tabletop Machine

Approximately 30 pounds of holding capacity.

Figure 1 © 2013 Cargill

Scraped-Surface Tempering Machine

Capacity of 600 pounds per day.

Figure 2 © 2013 Cargill

Continuous Screw-Type Temperer

Continuous capacity of 200 pounds per hour.

Figure 3 © 2013 Cargill

Feeding tempered chocolate from another source to match the rate of chocolate being used by the enrober is yet another option that can increase capacity.

These machines are best operated in a room temperature range of 65° to 75°F. Since these machines cool using the air from the room, air temperatures warmer than 75°F will not properly cool the chocolate. And in rooms cooler than 65°F, tempered chocolate will quickly solidify on the surfaces of the machine, increasing the possibility for overtempered chocolate. Also, these machines are best operated at or near full capacity. As the chocolate level empties, the temperature control is less dependable because more temperature fluctuation can occur.

CONTINUOUS SCREW-TYPE TEMPERING MACHINE

This style of tempering machine commonly used in confectionery production utilizes a screw or worm to continuously move chocolate through a tube-shaped heat exchanger. A refrigerated liquid cools the inner surface of the tube. The heat exchanger has different temperature zones, because this type of machine uses the mush method of tempering. The chocolate must be cooled enough to begin crystal formation, which by nature starts with unstable cocoa butter crystals. Further along the heat exchanger, the chocolate is warmed enough to melt the unstable crystals and allow the Form V crystals to remain. Simply stated, warm, untempered chocolate goes in one end of the heat exchanger and tempered chocolate emerges from the exit.

Figure 3 shows a style of machine that has continuous capacities ranging from 120 to 440 pounds per hour. The stirred basin maintains a pool of untempered chocolate. The chocolate is pumped upward through a screwpump and is tempered as it moves ➤

vertically through the different temperature zones. The action of the screwpump scrapes the chocolate against the cooled metal outer tube and mixes it together. The chocolate that comes out of the top spout is tempered and ready for use. The chocolate that is not used falls back into the basin where it is reheated and detempered, readying it for another trip back through the heat exchanger. During continuous operation, chocolate must be added to the basin to replace the chocolate being used for moulding or enrobing. This particular style of machine contains a foot pedal that will temporarily stop the flow of tempered chocolate to allow a mould to be inserted under the chocolate flow. Traditionally, these machines were not convenient to disassemble for an allergen or other thorough cleanout. The chocolate manufacturer would have one of each machine for each distinct allergen or chocolate type. However, more modern versions of these machines are designed to be more easily cleaned. The screwpump is easily removable and a thorough cleanout can occur.

Figures 4 and 5 show the outside and inside of a large-capacity, continuous screw-type tempering machine. This style of machine allows for high capacities, ranging from 1,100 to 5,500 pounds per hour. This unit contains a heated, stirred chocolate hopper that feeds the multi-temperature-zoned heat exchanger. The machine works in a similar manner to the one in Figure 3, except the worm screw is horizontal and much larger in diameter. The various temperature zones are set accordingly to achieve the proper chocolate temperatures along the heat exchanger to cool the chocolate, form cocoa butter crystals and melt excess and unstable cocoa butter crystals. The action of the worm screw scrapes the chocolate against the cooled heat exchange surface, and also mixes it back into the chocolate within the worm tracks. This type of tempering machine will accommodate inclusions such as nuts, dried fruits or cereals mixed into the chocolate being tempered.

One caution that must be taken with all continuous screw-type tempering machines is to avoid cooling-fluid temperatures that are too cold and freeze up chocolate onto the inside cooling surfaces.

STACKED-PLATE HEAT EXCHANGERS

Another very popular style of machine for continuous tempering is the design that uses stacked heat exchange plates. Cooling or heating liquid is pumped through the inte-

One caution that must be taken with all continuous screw-type tempering machines is to avoid cooling-fluid temperatures that are too cold and freeze up chocolate onto the inside cooling surfaces.

Large-Capacity, Continuous Screw-Type Temperer — Outside

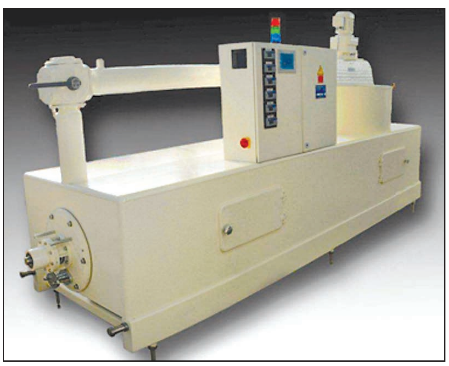


Figure 4 © 2013 Cargill

Large-Capacity, Continuous Screw-Type Temperer — Inside

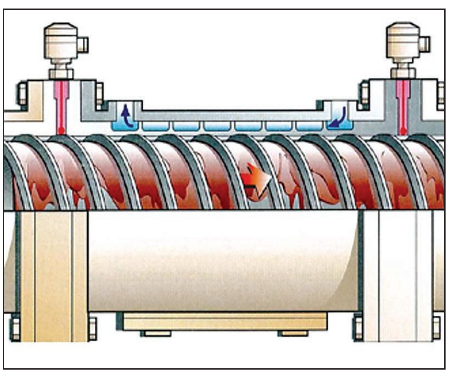


Figure 5 © 2013 Cargill

A temperature-controlled agitated tank can be used to temper chocolate. Typically, this is done in a vertical tank with a hollow jacket surrounding the full tank circumference.

rior of these hollow plates for heat exchange. Multiple plates are stacked one on top of the other, and the chambers created between the plates become the heat exchange surfaces that the chocolate flows through. These areas are mixed and scraped to provide efficient shear and heat exchange. More plates on the stack create a higher-capacity tempering machine. The plates are grouped into temperature control zones, each with an individual temperature control system for the cooling and heating fluid. As with the screw-type temperers, this style uses the mush method of tempering. Most of the crystal growth takes place in the coldest zone, and the next zone provides reheat to melt the unstable crystals. Chocolate is pumped from the bottom to the top of the plate stack.

This is a very efficient design for continuously tempering chocolate, with a wide variety of capacities available up to 40,000 pounds per hour. Similar to the continuous screw type, the cooling-liquid temperature must be well controlled for precise chocolate temperature control. If the cooling liquid becomes too cold and the chocolate in the unit freezes up, these machines typically have a pressure relief switch which stops the chocolate pump and changes the machine to quick heating. This prevents damage to the internals of the tempering unit due to excess pressure. Figure 6 shows an example of this type of tempering machine, and Figure 7 shows a schematic of the stacked plates.

Stacked-plate tempering units are not readily disassembled for cleaning. Changeover to a different type of chocolate is usually accomplished by a purge, and some mixed chocolate rework is created during the changeover. This design of tempering unit does not lend itself to an allergen or other thorough cleanout, so typically separate machines are used for allergen and nonallergen applications.

Stacked-Plate Tempering Unit

Figure 6 © 2013 Cargill

Stacked-Plate Temperer Schematic

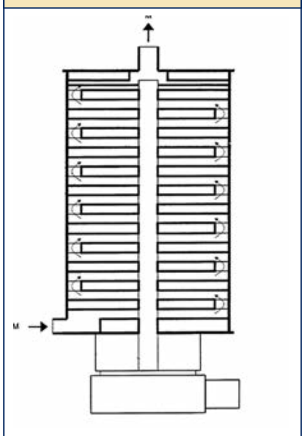


Figure 7 © 2013 Cargill

BULK TANK

A temperature-controlled agitated tank can be used to temper chocolate. Typically, this is done in a vertical tank with a hollow jacket surrounding the full tank circumference. Heating and/or cooling liquid circulating through the jacket provides the necessary heat transfer for tempering. The tank must be agitated to keep the chocolate temperature consistent throughout the tank, as well as evenly distributing the cocoa butter crystals once the chocolate is tempered. Both a seed-tempering and a mush method approach can be taken to temper in a tank.

Using the seed method, a tank full of melted milk chocolate held at approximately 100° to 110°F can be tempered by one of the following procedures:

- Add 10 lb blocks of well-tempered chocolate into the tank and turn on the agitator. If possible, place the blocks directly against the agitator arm so the rotation moves the blocks around the tank. Be ➤

sure to add enough chocolate blocks so that when the temperature reaches 88° to 90°F, some chunks remain. Water jacket cooling can be applied here to speed up the cooling process. Once the chocolate temperature falls below approximately 93° to 95°F, some of the Form V crystals from the seed chocolate remain unmelted in the liquid chocolate, and as the chocolate continues to cool the population of Form V crystals grows. Somewhere in the range 88° to 90°F, the chocolate in the tank will be well tempered, and the remaining blocks should be removed to avoid overtempering.

- Cool the milk chocolate to the range of 91° to 93°F using the water jacket cooling. Add 3 percent by weight powdered, well-tempered chocolate or 1 percent by weight powdered, well-tempered cocoa butter to the chocolate tank. Allow the tank to mix, distribute and incorporate the powdered seed throughout the tank. Allow 15 to 20 minutes for the seed to melt and mature in the liquid chocolate.

Once the milk chocolate is tempered, use the water jacket system to maintain 89° to 91°F to keep the chocolate in perfect temper. The specific formulation of your chocolate will determine your exact target temperature. The more milk fat (or other vegetable fats) mixed in with the cocoa butter in your formulation, the lower your target temperature must be. If your chocolate becomes too warm, the Form V crystals will melt out and the chocolate will be undertempered and eventually untempered. If the chocolate is held too cool, it will become overtempered and too viscous. I like to refer to the correct temperature as the *temper equilibrium temperature.*

A bulk tank can also temper chocolate using the mush method. Figure 8 shows an example of a temperature-controlled agitated tank designed for this purpose. Since the mush method will require temperatures cold enough to develop crystals on the inside wall of the tank, the agitator must scrape the surface of the tank to shear off the crystals as they form and mix them back into the tank. The inside wall of the tank is not only the heat exchange surface, but also the nucleation site where the crystals are created. Figure 9 shows the scrapers inside the tank wall.

This type of equipment can be programmed to cool and then subsequently warm the chocolate to the appropriate temperatures to achieve temper. When cooling, there are two important temperatures: the temperature of the chocolate and the temperature of the cooling liquid in the tank jacket. The cooling-liquid temperature must be cold enough to form the unstable cocoa butter crystals inside the tank wall, but not so cold that excessive solidified chocolate develops in the tank. Cooling liquid should be in the range of 55° to 65°F. The appropriate cooling time and chocolate target temperature will be determined by the chocolate recipe and the size of the tank. The larger the tank is, the lower the ratio of cooling surface area to chocolate volume will be, reducing the rate of heat trans-

The cooling-liquid temperature must be cold enough to form the unstable cocoa butter crystals inside the tank wall, but not so cold that excessive solidified chocolate develops in the tank.

Temperature-Controlled Agitated Bulk Tank

Figure 8 © 2013 Cargill

Scrapers Inside the Tank Wall

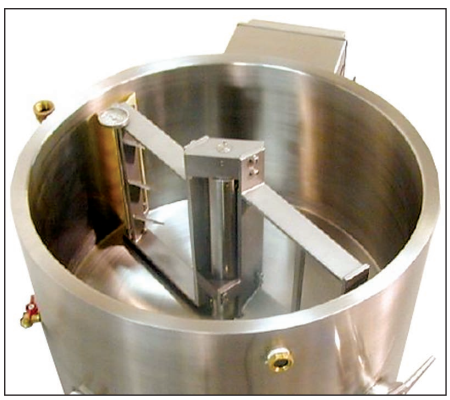


Figure 9 © 2013 Cargill

Once the principles of tempering are understood, and the operational needs are defined, the selection of the type of tempering machine is made easier.

fer in and out of the chocolate. A target cooling temperature for milk chocolate is 80° to 82°F.

After enough crystal formation has occurred, and to avoid too much crystal formation, warm liquid is run through the tank jacket. The chocolate is reheated to 85° to 87°F to melt away the unstable crystals and ensure transformation to stable Form V crystals. As previously discussed, the Form V crystals will mature and grow in the tank over time. If the tempered chocolate in the tank will be used over the course of a full production day, the milk chocolate temperature must be eventually warmed to 89° to 91°F to keep the chocolate in perfect temper. Same as with the seed method, the exact target temperature depends on the formulation of chocolate. Dark and bittersweet chocolates have a temper equilibrium temperature that is one or two degrees Fahrenheit higher.

In this way, confectioners can use a chocolate-melting tank for tempering, perhaps for a seasonal product requiring more tempered chocolate than their existing continuous machine can produce. Tempered chocolate can be stored at the equilibrium temperature, ready for use. However, the temperature control system for the tank must be capable of maintaining this temperature within a close range. An advantage of the bulk tank method is the ease of changeover and allergen cleanout. Also, chocolate with inclusions can be tempered in this manner. A disadvantage is the limited amount of chocolate that can be tempered at a time (the volume of your tank), which will limit the daily production. The production rate can be increased by slowly feeding untempered chocolate into the tank of tempered chocolate while it is being used.

SUMMARY

Tempering machines are used in different types of operations such as chocolate manufacturing, confectionery production and snack food manufacturing. There are many ways to temper chocolate but, drilling down to the basics, they can be grouped into the mush and seed methods. Two popular styles of continuous tempering machines, the screw type and stacked-plate type, utilize the mush method of tempering. These machines are the workhorses of high-capacity continuous tempering in our industry. Scraped-surface, rotating-bowl tempering machines use the seed method of tempering, and are very popular for small- to medium-capacity applications. Both the mush and seed methods can be applied to bulk tank tempering. Once the principles of tempering are understood, and the operational needs are defined, the selection of the type of tempering machine is made easier. □

REFERENCES

Beckett, S.T. *Industrial Chocolate Manufacture And Use.* Pg 156, pg 174. New York: Van Nostrand Reinhold, 1988.

Beckett S.T. *The Science of Chocolate, Royal Society of Chemistry, 2nd Edition.* Pg 107, 2008.

Presented at the AACT National Technical Conference