Mysteries of Conching Revealed

Conching plays an imperative role in the flavor development of chocolate and is crucial to the success of a smooth, well-balanced end product.

Carly Meck
Blommer Chocolate Company

From the discovery of the cocoa bean thousands of years ago to the irreplaceable treat the world knows today, chocolate has been an integral part of our lives. To better understand the transformation of chocolate over the years, it is important to explore an important step in the chocolate making process called conching. During conching, refined ingredients are kneaded under immense force to create a smooth, well-balanced end product. Conching has been shrouded in some mystery over the years. Looking at what takes place during this step sheds some light on this important process.

Conching has a long and accidental history with chocolate. Until the mid-1800s, chocolate was mostly consumed in beverage form while a few pioneers introduced it into baked goods. Solid chocolate was not a popular treat due to its coarse texture and undesirable sour and bitter flavor. Rudolphe Lindt changed this in 1879 by inventing the conche in Switzerland. There is no clear story on how his invention came to be, but it allegedly happened by accident while leaving a mixer on over a long weekend. The resulting chocolate had a smooth texture, mild flavor and improved viscosity. This led to more development on a machine known as a longitudinal conche (Figure 1). This machine, shaped somewhat like its namesake shell, consisted of a heavy roller repeatedly moving through a basin filled with liquid chocolate. By adding a small amount of cocoa butter to the thick chocolate mass, the roller is able to glide easily through the basin and create a uniform product. While years of technological advancements have since improved the process, this breakthrough was a game changer for the chocolate industry.

CONCHING STYLES

All conches are not created equal. Functionality differences exist between styles along with differences in price, cycle time and floor space requirements. Essentially all systems perform the same task of kneading chocolate; however, each uses a different method of doing so. The principle conching methods or styles are illustrated in Figure 2.

Longitudinal Conche

As shown in Figure 1 and 2A, the longitu- ➤

Carly Meck is senior R&D scientist — product development at Blommer Chocolate Co. In this role, she develops new chocolate and cocoa formulas, creates process improvements, provides training and executes technical studies. She has been with the company since 2010.

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Longitudinal Conche

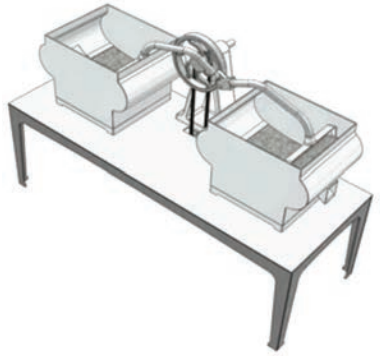


Figure 1 Brooklyncacao.com

dinal conche was where it all began. These conches create improved flavor development and texture of the chocolate, but cycle times can be restrictive, often taking days to conche a mass. Limitations of this conche method include difficulty in filling and emptying and in temperature control. Formulation can also be a challenge. Compared to other styles, paste fat is very high in this machine type, therefore chocolate is conched in a liquid phase. A higher fat content in the conche equates to less cocoa butter savings at the end of the process. Several chocolate makers still use this style of conche today, but it is not as common as other methods.

Melanger

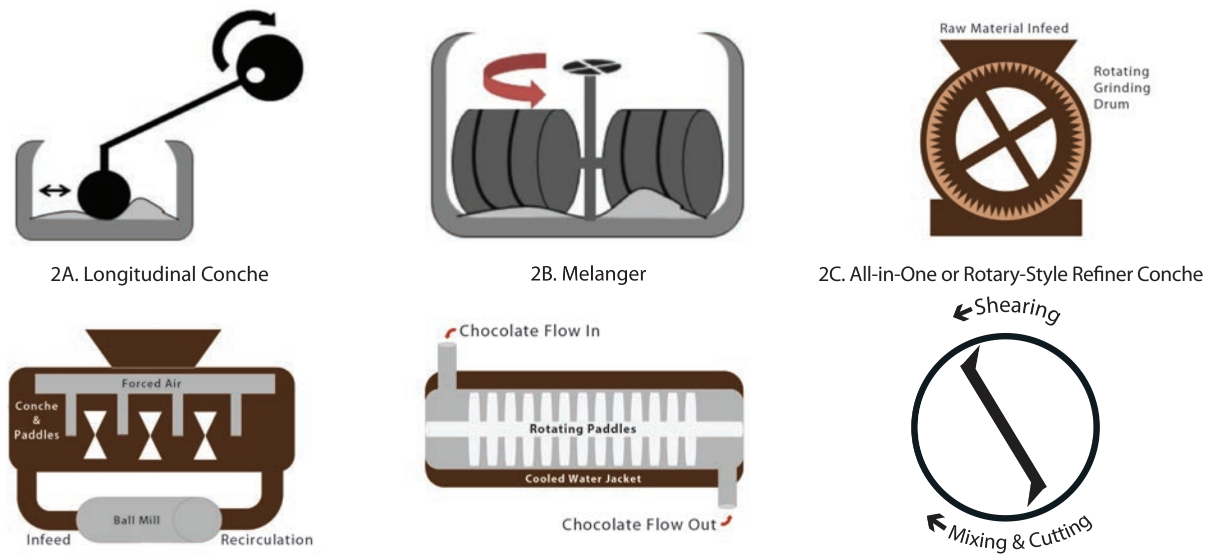
The concept behind the melanger is based on the centuries-old mortar and pestle. It can be used for several different functions including grinding nibs into liquor and making nut butters.

For the purposes of chocolate making, it is a refiner conch. The melanger uses rotating stone wheels which grind the mass against a stone-bottomed bowl reducing particle size of the raw materials while simultaneously conching (Figure 2B).

All of the ingredients are added at the beginning of the process resulting in high fat content while grinding over several hours. Significant particle size reduction can be achieved (down to 25 microns); however, cycle times can exceed 24 hours.

As with the longitudinal conche, paste fat is quite high so the ability to eliminate volatiles or moisture is minimal. Melangers are ideal for smaller confectioners; initial cost is low, and the machine footprint is

Conching Styles



2A. Longitudinal Conche

2B. Melanger

2C. All-in-One or Rotary-Style Refiner Conche

2D. Ball Mill Refiner Conche

2E. Continuous Conche

2F. High-Shear Conche

Figure 2

small. Furthermore, a significant productivity advantage for confectioners is that melangers are able to complete several conching steps at once.

All-in-One Conche or Refiner Conche

All-in-one conches, or refiner conches, have gained popularity over the years. A more sophisticated version of the melanger, the refiner conche reduces particle size and conches within the same machine. Forced air can help drive off volatiles, reduce cycle time and improve the flavor of the finished product. The principal theory behind this machine is based off high fat, or liquid conching. That being said, there are several styles of this equipment type.

The traditional style of refiner conche consists of a water-jacketed horizontal tank. Ingredients are added and a series of angled metal knives scrape the ingredients against a grooved metal inner wall while rotating around a center axis (Figure 2C). Variable pressure can be applied to achieve the desired particle size. These conches take up minimal floor space and consume less energy than other types and the cost is reasonable for the throughput. Drawbacks to refiner conches include long process times and the potential for using more cocoa butter for the desired final viscosity due to super fine particles formed while grinding.

Ball Mill Refiner Conche

A newer style of refiner conche consists of a conche trough attached to a ball mill. The ingredients are conched first, sometimes using forced hot air in the temperature-controlled trough. After conching, product is recirculated through a ball mill (Figure 2D) to achieve the desired particle size. Extra cocoa butter or emulsifiers are added during this step as the chocolate thickens and particle size is reduced. This all-in-one unit is another cost-effective option and has a smaller size footprint. As with the other styles of refiner conches, cycle times and throughput can be a challenge along with the higher amount of cocoa butter needed to standardize viscosity.

Continuous Conche

Continuous conches use a different mechanism to treat chocolate than the aforementioned styles. With this style, refined chocolate is fed through the machine which applies intense mixing for a short period of time through a jacketed rotor/stator (Figure 2E). Shearing and mixing are applied to the chocolate in one step while pushing the mass through a temperature-controlled cylinder. In some systems, ingredients such as cocoa butter or lecithin can be dosed as the chocolate advances through the system. Benefits to this style of machine are fast cycle times and homogenized product in a matter of minutes. Disadvantages are lack of volatile removal and fat release. A few systems pair the continuous conche with other machinery which aids in the removal of volatiles and moisture before the chocolate is conched.

High-Shear Conche

High-shear conches are a specific category of equipment based on the theory of low-fat conching. Low-fat conching results in the maximum efficacy of moisture and volatile reduction, particle rounding due to shear, fat release and flavor enhancement. Unlike the other conche styles, these machines run in conjunction with a roll-refining line. In this process, refined flake is conveyed into the conche. A small amount of cocoa butter is added to create a thick paste. Target fat percentage of the refined flake is 22 to 25 percent while the target fat percentage of the conche is 27 to 30 percent. The conches are able to use a specialized paddle design to kneed the chocolate more efficiently. A wedge- ➤

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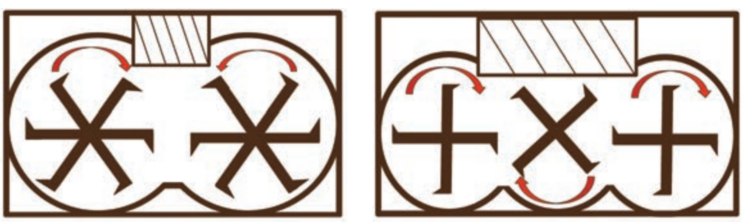
shaped blade at the end of the paddle moving in one direction allows the blade to cut into the chocolate mass and thoroughly mix the product (Figure 2F). This step occurs first during conching at high rpm. Next, the conche paddles switch direction creating intense shear at high rpm scraping the mass between the wedge-shaped paddle and the conche wall.

During the entire conching process, temperatures are closely controlled through chilled water flow in the jacket. Milk chocolates typically reach temperatures between 55° C and 65° C. This allows for flavor development without risking the creation of scorched flavors. Dark chocolates can reach temperatures ranging from 70° C to 90° C depending on product and cycle time.

Different styles of machines exist within the high-shear conche realm (Figure 3). Two-shaft conches are typically designed to hold the dry phase longer than other styles. The paddle design of the two-shaft conche allows for independent movement around the machine with more paddles driving sheering action against the walls. Louvres at the top of the machine can be opened or closed. Opening allows for moisture and volatiles to be eliminated while closing during liquefying contains splatter. Capacity of these machines is typically quite large, as are the footprint and energy requirement. As with any model of high-shear conche, cost can be prohibitive. However, full automation of these machines makes them a user-friendly option.

Two-Shaft versus Three-Shaft High-Shear Conches



Two-Shaft High-Shear Conche — Three-Shaft High-Shear Conche

Figure 3

Three-shaft high-shear conches have intense mixing capabilities that tend to bring the product into a plastic or pasty phase quite quickly. Three interlocked paddles move the mass from one end of the unit to the other while continuously exposing the product to air to help eliminate volatiles and moisture. About halfway through the cycle, the paddles automatically change direction facilitating further shearing action. Cost, power consumption and footprint make three-shaft systems a restrictive option, however this may be outweighed by their ability to produce a premium chocolate product.

THREE STAGES OF CONCHING TRANSFORM CHOCOLATE

Conching occurs in the middle of the chocolate-making process. While the conche does wonders to transform chocolate in various ways, the upstream and downstream processes can also have an effect on the final product. After dried cocoa beans arrive at a processing facility, shells are removed and the nibs are roasted to develop a deep chocolate flavor and to ensure a reduction in their microbiological load. The nibs are next milled into liquid chocolate liquor then sugar, cocoa butter and, potentially, milk powder are mixed together to form a thick paste as seen in the conching steps in Figure 4. This paste is sent through a pre-refiner and subsequent five-roll refiners to reduce particle size to a desired specification and produce a dry flake. Other forms of particle size reduction could be used as well. The flake is added to a conche with a small amount of cocoa butter to create a thick paste to be kneaded. After conching, the product is liquefied with an emulsifier and stabilized to a specific viscosity using cocoa butter. The product can then be tempered and deposited into its desired form. ➤

Conching Stages

Chocolate is transformed during three distinct stages of the conching cycle (Figure 5). The dry phase, plastic/pasty phase and liquid phase are common terms associated with these chocolate conching steps. This section will specifically apply to high-shear conches which are quite common in chocolate manufacturing.

The dry phase begins while the conche is being filled with chocolate flake and is crucial to help reduce some of the excess moisture. By continuously mixing the flake at a controlled temperature and exposing it to air near the louvres, moisture and unwanted volatiles are removed. This removal is easier to accomplish earlier while particles are not fully bound in fat.

The second plastic/pasty phase begins once the conche is filled and additional cocoa butter has been added to help form a thick paste. The goal of this step is to hold the chocolate in this thick paste for as long as possible. By holding the paste in this phase, the intense shear and heat begin to release any bound fat and coat the other particles in the matrix. Just as in the dry phase, unwanted volatile molecules are driven off. The plastic/pasty phase is also responsible for additional flavor enhancement by means of flavor transfer between molecules which will be explained later.

The last phase of the conche cycle is the liquid phase. In order to properly evacuate the chocolate from the conche it must be liquefied. This is accomplished using an emulsifier, cocoa butter or a combination of the two. Cocoa butter can then be dosed in order to achieve the desired viscosity for the application. After the chocolate is liquefied, limited further flavor enhancement and volatile removal occurs.

These three steps occur at different times during the conching cycle and no two recipes are typically the same. Milk chocolate conche cycles can last anywhere from 6 to 16 hours while dark chocolate can exceed 20 hours, depending on the system. Dark chocolate cycle times are typically longer due to the increased chocolate liquor portion of the formula. Unless the liquor has been pretreated, a longer cycle time will help eliminate unwanted volatile molecules and produce a less bitter and sour chocolate.

CONCHING BENEFITS

Reducing Volatiles

Several studies over the years have shown that volatile organic compounds (VOCs) are reduced over time during conching. The majority of volatiles being driven off are acetic acid which is inherent in chocolate from the fermentation process. One study shows that 30 percent of the concentration of acetic acid can be driven off by conching while another study indicates that 57 percent of overall volatiles can be

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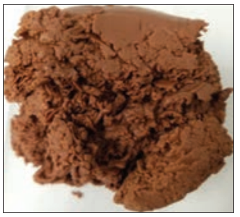
Steps in making chocolate



Refiner Paste

Dry Flake

Conche Paste

Figure 4

Conching Stages

Dry Phase

Plastic/Pasty Phase

Liquid Phase

Figure 5

The majority of volatiles are released during the filling and dry conching phase when the mass is thick, the temperature is elevated and the energy input is high.

decreased. Simply from the acrid odor observed through open louvres while a conche is running, it is evident that volatiles are driven off during the conching process.

To demonstrate and quantify the timing of volatiles exiting the conche, the author conducted a study of headspace volatiles during conching. A photoionization detector (PID) was used to measure the total VOCs exiting the conche. Various recipes of dark and milk chocolate were tested hourly in a production setting while a dark chocolate made in a tabletop melanger was also studied. An average of the results is shown in Figure 6.

As expected, the majority of volatiles are released during the filling and dry conching phase when the mass is thick, the temperature is elevated and the energy input is high. Dark chocolate had a higher volatile output due to the increased chocolate liquor portion of the formula. Even though a dark chocolate formula was made in the melanger, hardly any volatiles were driven off during the cycle.

Reducing Moisture

Moisture is driven off in small amounts during conching, particularly during filling and dry conching. Interestingly, this happens at temperatures below the boiling point of water. Water removal occurs as the chocolate mass is continually mixed and exposed to the surrounding air. Ensuring proper filling rate enables the moisture to be driven off in adequate time. Filling the conche too quickly can lead to grit or agglomeration if the moisture is not removed. Having any louvres or ventilation open on the conche during this process aids in moisture removal.

Chocolate is fundamentally a low moisture food. Since chocolate and water are not miscible, any reduction in moisture content will yield a better finished product. Beckett suggests that moisture can be reduced by 30 percent during conching. This reduction in moisture causes the product to have an improved rheology as well. In addition to the release of free fat, the moisture reduction helps thin the chocolate.

Average Results of Hourly PID Readings of Volatiles Exiting a Conche

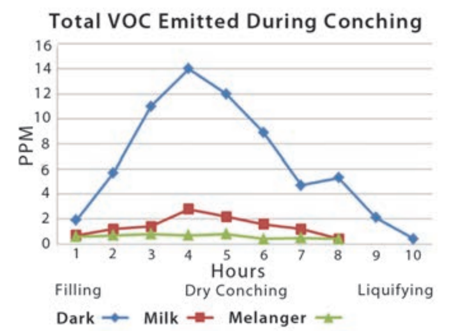


Figure 6

Improving Texture and Mouthfeel

Although particle size is not reduced in traditional conches (excluding refiner conches or melangers), sharp edges are rounded off creating the illusion of finer particles and a superior mouthfeel. A recent study analyzing particle shape and size through the use of an environmental scanning electron microscope showed conched chocolate particles to be more round in shape and less densely packed into their crystalline network compared to samples taken early in the chocolate making process. This is shown in Figure 7.

Another aspect of texture improvement from conching is in fat distribution within the chocolate matrix. By releasing the fat bound in refining, particles will contain an even fat distribution which helps them to better glide across a consumer's palate.

Particle Shape and Size

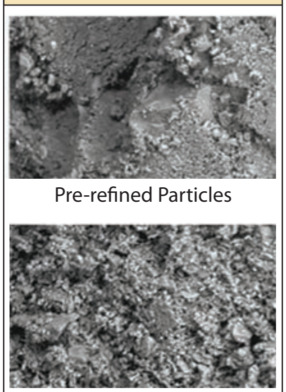


Figure 7

Improving Flow Characteristics

Conching has the ability to release fat that has been encapsulated during the refining process. A properly conched mass will yield a thinner chocolate once stabilized. To demonstrate the effect that conching has on viscosity reduction, the author con- ➤

ducted an experiment using a 400 lb, high-shear conche to make milk and dark chocolate. Samples were taken at 2-hour intervals and stabilized to a targeted viscosity. Figure 8 indicates the amount of added cocoa butter needed to stabilize samples to the specification. While this is only a small study to quantify viscosity reduction, released fat is a proven characteristic of a well-conched chocolate. This viscosity improvement ultimately leads to cost savings in end product since less cocoa butter is needed to standardize the chocolate. This study also demonstrates that there is a plateau in viscosity improvement.

Enhancing Flavors

Flavor enhancement is another benefit of conching, but it seems to be the least understood. Numerous scientific studies over the years have attempted to identify the mechanism behind flavor improvement occurring during conching, and some of the results contradict one another. To observe how flavor improves over time, the author conducted an experiment in a 400 lb, high-shear conche. Samples of milk and dark chocolate were taken at 2-hour intervals during a 10-hour conche cycle and standardized to the same viscosity. The samples were then evaluated by a trained chocolate sensory panel. While some preferences differed, the majority felt that the flavor of the milk chocolate stopped improving after 6 hours while the flavor of the dark chocolate stopped improving at 8 hours.

This small-sample experiment demonstrated that a longer conche cycle does not necessarily mean a superior product. It should be noted that these are shortened cycle times compared to production machines and the data is not directly translatable. Chocolate formulation, conche style and processing constraints should also be taken into account when determining a cycle time for optimum flavor enhancement. Figure 9 displays a spider graph of an unconched dark chocolate verses a dark chocolate in a 22-hour conche cycle evaluated by a trained sensory panel.

Another factor of flavor enhancement is the redistribution of those flavors over various molecules. By collecting cocoa butter from the mass using a centrifuge before and after conching, a gas-chromatography and mass spectrometry analysis was carried out to determine overall volatile compound content. It was discovered that a significant portion of the flavor volatiles surrounding the fat and cocoa molecules

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Flavor Change on Unconched versus Conched Dark Chocolate

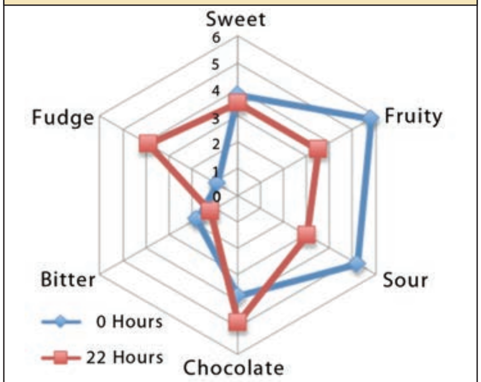

Figure 9

Amount of Added Cocoa Butter Needed to Stabilize Milk and Dark Chocolate

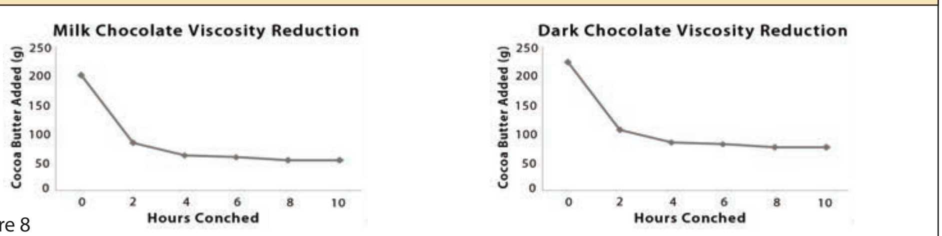

Figure 8

There is no perfect way to conche chocolate. Every method has positives and negatives associated with it, be it from a cost, energy, cycle time or flavor perspective.

transferred to the sugar molecules during the course of the conche cycle. All molecules present in the mass then contained similar flavor levels which lead to a well-rounded chocolate flavor profile with a decreased sweetness perception as indicated in Figure 10.

Malliard reaction may be responsible for some of the flavor development in milk chocolate but research on this is limited. The temperatures in milk chocolate conching would likely be too low to deliver much flavor change. However, if any flavor development or browning did occur from the Malliard reaction, it would be between the reducing sugars, i.e., lactose and free amino acid groups.

Harnessing Chocolate Supplier Knowledge to Fit Application

As mentioned earlier, there is an optimum cycle time for viscosity reduction as well as for flavor development. It is up to the time-tested expertise of the chocolate manufacturer to find the ideal cycle time for flavor delivery while maximizing the available free fat for each individual formulation. This would not only save on energy usage to produce the product, but on cycle time as well since many varieties of conches are batch processes.

Certain recipes may require a longer cycle time and will likely cost more due to ingredient requirements such as a high cocoa mass dark chocolate. On the other hand, some may be quite short, such as a milk chocolate with a low developed milk flavor profile. Work with your chocolate supplier to select a chocolate that is right for your product line, customer base and price range.

CONCLUSION

There is no perfect way to conche chocolate. Every method has positives and negatives associated with it, be it from a cost, energy, cycle time or flavor perspective.

Flavor Distribution Before and After Conching

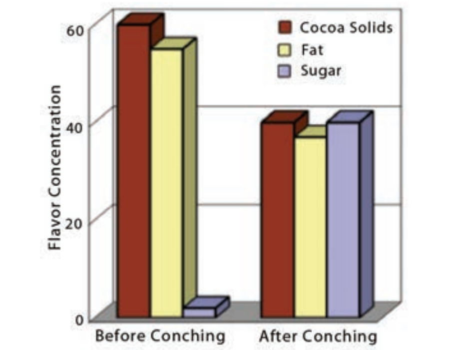

Figure 10

That being said, chocolate transforms in a unique way inside a conche. Moisture is reduced, volatiles are removed, flavor is enhanced, viscosity is lowered and mouthfeel is improved—all within one machine. There is still much to learn about the aspects of conching and the mechanisms by which it alters chocolate. □

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Questions and Answers

Q: Can the volatiles *be recycled and used for chocolate flavors and how?*

A: Theoretically they could but I don't know of anyone who is doing this in practice. There are over 400 flavor molecules in chocolate, many of which are undesirable (i.e., acetic acid). To select, segregate, and bottle a few individual flavor molecules would likely cost more than it would be worth.

Q: Can you briefly discuss conche optimization techniques?

A: There are a few things you could do. If we are talking about high-shear conches, which are very common in the chocolate manufacturing industry, it is important to have the proper target fat percentages at the different stages of the process. If the flake contains too much fat when entering the conche, then little shearing action will occur. Additionally, if the fat is too low, then the proper flavor development will not occur. Other steps can be taken like increasing the temperatures slightly which could help reduce the cycle time. Many styles of conches have the ability to report out data during the conching process in the form of a graph which contains valuable information such as temperature and amps. This is a tool you can use to make sure the conche is running efficiency for each individual formulation.

Q: Have you utilized pulling a partial vacuum on a conche to more precisely control volatile removal and reduce conching time?

A: I haven't specifically tried this, but in theory, it could be a good technique (and there might be some folks out there in the industry currently doing this). You do want to be careful not to remove too many volatiles or you will have a flavorless chocolate.

Q: At what point in the process is flavor added? Specifically, how is vanilla extract added (in regard to moisture)?

A: It depends on the conche system used but in the vast majority of cases, vanilla extract is added in stabilizing which is the very last step of the process. This is after the product is refined and conched. Since vanilla extract has such a high alcohol content, you would want to add it when the chocolate is thinned out and cooled down to avoid flashing off the flavor. Adding this before the conching step would result in driving off this flavoring in the form of volatiles,which would lead to very expensive waste.

Q: How many different conche times and processes is it feasible for a manufacturer to have?

A: The various conche times would be seemingly endless. If you have an automatic system, your programming would need to have enough space for the different recipes but that is essentially your only roadblock. Each individual chocolate formulation should have a separate conche recipe to maximize the available free fat and flavor development. Conche recipes and processes are not *one size fits all* and really depend on the flavor, throughput and cycle time you need to achieve.

Q: How do you determine optimal conching time? Trial and error? Are there ways to decrease conche time or increase throughput?

A: Trial and error is a good method to begin with when you are first starting up. Once you have several recipes established, then any new formulations can be offshoots of those existing recipes. Each type of conche would have a way to reduce cycle time. In a high-shear system, for instance, you could increase the temperature slightly to reduce the cycle time. This won't work with every recipe but some might have that flexibility. If you are working with a refiner conche, a step you could take would be to increase the forced hot air flow or widen the range of particle size target. As with any cycle time reduction, a trial should be conducted to ensure the change does not have any negative side effects to the final chocolate product.

Q: How does the addition of lecithin in paste mixing affect roll refining and conching?

A: In some cases, lecithin can aid in the refining of a product. Care should be taken to minimize any lecithin needed as this will affect conching. Adding lecithin too early in the process can do one of two things. 1) it could start to liquefy the chocolate before it has a chance to fully conche and 2) it could denature under the high heat and cause you to need more emulsifier or cocoa butter to standardize to viscosity.

Q: How does particle size and distribution affect fat release and viscosity reduction?

A: Particle size will always affect the viscosity of a product in terms of any additional cocoa butter needed to achieve a desired viscosity. A smaller particle size will need more cocoa butter to standardize to the same viscosity than a larger particle size.

Q: What causes grit if a conche is precharged with butter and bypasses the dry and plastic phases?

A: Grit, or agglomeration, will be caused by moisture in most cases with the exception of severely burnt/scorched product. When bypassing the dry and plastic phases, moisture does not have a chance to escape from the chocolate matrix before it is enveloped in fat.

Q: Can you describe the impact of increasing particle size on conching?
A: The larger the particle size, the less surface area. This correlates to less time needed to fully envelope the particles in fat from the matrix. This would lead to a shorter cycle time but you have to consider any negative sensory affects that coarse particles would have for a product.

Q: What leads to the release of cocoa butter during plastic phase?
A: During high-shear conching, heat and shear/friction lead to the release of fat. By controlling the fat percentages during refining and dry conching, you can maximize the ability of the machine to release all of that bound fat. If the incoming flake contains too high of a fat content, then the product will immediately start to liquefy in the conche and little release of any bound fat will be seen.

Q: Why isn't more moisture and organic acids driven off in roasting rather than doing this in a conche?
Moisture and organic acids are driven off in great numbers from cocoa beans or nibs in the roasting process. However, the resulting chocolate liquor still has a sour and bitter flavor. Some systems exist that can pretreat the chocolate liquor before conching by means of thin film evaporation. This would help to eliminate moisture as well as volatiles (with the added benefit of reducing conche cycle times).

The conching process helps to alleviate moisture from other adjacent processes. Milk powder, for instance, can contain 3 to 4 percent moisture so this must be removed from the chocolate as well.