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ESSENTIAL PRINCIPLES OF CHEESEMAKING (PART 2): MEASURING AND CONTROLLING ACIDITY AND MOISTURE

In the last issue of the Dairy Pipeline, we covered how to establish and maintain a starter culture program. In this article, we're discussing how to measure and control acidity and moisture during the cheesemaking process. This article is part two of a two-part article that takes a deep dive into some essential principles that cheesemakers of all levels should know in order to make consistent, quality cheese.

Part 1: Establishing and Maintaining a Starter Culture Program (last issue)
Part 2: Measuring and Controlling Acidity and Moisture During the Cheesemaking Process

Why Measure Acidity and Moisture?

"All cheesemakers should be monitoring acidity and moisture because they drive how the cheese is going to turn out," explains Andy Johnson, outreach specialist/assistant coordinator, CDR Cheese Industry and Applications group.

Dean Sommer, CDR cheese and food technologist, agrees, "Controlling acidity and moisture content—those are two of the really big keys to successful cheesemaking. A lot of cheese defects are from improper moisture content and improper rate and extent of acid development."

Cheesemaking is ultimately a concentration process that involves monitoring and controlling multiple factors and reactions. "We're reducing the moisture content, we're concentrating fat, we're concentrating protein, and we're using up a large majority of the lactose retained in the curd to develop a significant amount of lactic acid, which drops the pH," Sommer said.

Milk has a pH of about 6.6-6.7, but during cheesemaking acid is developed and the pH drops, i.e. Cheddar has a pH of about 5.1. The cheesemaking process also reduces the moisture content—milk typically has a moisture content of about 87% whereas Cheddar has a moisture content of about 38%.

Andy Johnson, CDR, measuring pH during the cheesmaking process.

However, cheesemaking isn't just about reaching a final moisture level or pH, it's about controlling the loss of moisture and the rate and extent of acid development. As cheesemakers say, "The journey matters." Therefore, it's important to measure and control acid development and the process of moisture reduction during cheese manufacture. Acid and moisture impact the flavor, microbiological content, and structure/texture/body of the cheese.

What's Inside:

Why Keep Records?

A good cheesemaker is also a good record keeper. This is especially true when it comes to measuring and recording acidity during cheesemaking.

"If you have a defect or run into a problem with your cheese, it's almost impossible to figure out what happened if you don't have a record of the pH development," Johnson said.

Cheesemakers need to be able to go back and look at their records to see the "journey" that their cheese took during the cheesemaking process. Johnson recommends that cheesemakers detail all observations (not just pH), especially if something is abnormal like odor or the color. Record the milk quality measurements, heat-treatment (time/temperature) and starter growth conditions. Keep detailed records during manufacture of the pH, temperature, time, and curd firmness. Ideally, all batches of cheese would be tested for composition and microbiological quality

Issues with Improper Acid development

Again, a lot of common defects seen in cheese are related to an improper rate and extent of acid development (too little, too much, too fast, too slow). Here are some of the characteristics associated with excessive or inadequate acidity.

Excessive acidity (low pH) characteristics of cheese: Short/brittle body in dry hard cheese. Pasty body in soft cheeses. Grainy texture and acid (bitter) flavor. Cheese loses serum, which results in sweating. The cheese is more prone to developing calcium lactate crystals and microorganisms at the surface of the cheese (rind rot if packaged). A common underlying cause of these issues is excessive starter activity.

Inadequate acidity (high pH) characteristics of cheese: There is a food safety concern (pH>5.6). The curds may not knit very well. A short, crumbly cheese body and a tough, curdy texture. Can result in poor functionality/melt/stretch. Underlying cause: excess calcium remaining bound to the casein (more on this later).

Curdy Parmesan (inadequate acid development).

Measuring and Recording Acidity

What is pH exactly? pH is a measurement of the concentration of hydrogen ions. A neutral pH is 7.0 (water). A low pH, like 3.0, is very acidic (orange juice). A high pH, like 12, is very basic (caustic soda). As mentioned, milk typically has a pH of 6.6-6.7.

One important aspect of the pH scale is that it is logarithmic. For example, a pH of 5.0 is 10 times more acidic than 6.0. "What this means to a cheesemaker is that if you're shooting for a 5.2 pH and you get a 5.4—that's a big deal," Johnson said. "And if you're shooting for a 5.2 and get a 5.5 or 5.6 that's a huge deal. You've basically made a different cheese. Tenths of a pH unit make a difference in cheesemaking."

Most cheesemakers measure pH by using a pH meter (Potentiometric Method). A pH meter is composed of a pH electrode (probe) connected to a voltmeter (pH meter). How does a pH meter work? Two electrodes (housed in one probe) form a circuit and measure the voltage output from the hydrogen ions. Then the pH meter translates the voltage output into a pH value.

The pros of pH meters are that they are highly accurate if calibrated correctly and easy to operate. They also compensate for temperature, which can impact pH accuracy. The cons of a pH meter are that pH probes do require regular cleaning and calibration otherwise readings will be inaccurate. Also, good meters and probes are expensive, and any needed repairs or replacement parts will also be costly (probes are typically a few hundred dollars). There are less expensive models that cheesemakers can successfully use but these are not ideal to work with and will need to be replaced every year or so. When purchasing a pH meter, you also need to keep in mind that separate probes are needed for milk or whey and cheese.

Make sure to follow the manufacturer's instructions for probe care and maintenance (proper storage will extend the life of your probe and maximize its performance). One tip is to never store the probe in distilled or deionized water—this will cause ions to leach out of the glass bulb of the electrode and will eventually ruin it. CDR recommends that the probe be stored in a solution of 4M KCl (never store the probe dry).

Taking a pH Reading

The process of taking the pH of milk/whey or curd is relatively simple although it is important to do it correctly. To take a pH reading of a liquid sample (milk or whey), first take the probe out of the storage solution and rinse it with distilled water, blot it dry (with a laboratory wipe like Kimwipes or similar), immerse the probe in the milk or whey and gently stir the milk/whey with the probe and keep agitating it with the probe until the meter reaches a stable reading. Then take the probe out of the milk, rinse the probe and return it to the storage solution.

Taking a pH reading of a curd sample is similar. First you take the probe, (a spear tip probe for solids) out of the storage solution, rinse it and blot it dry. Then get your curd sample and squeeze it to get as much whey out of it as possible. Insert the probe into the cheese and hold the probe in the cheese until the reading stabilizes. Once you have a reading, remove the probe, rinse it, blot it dry and return it to the storage solution. For more details on taking accurate pH reading, you can refer to the book "Standard Methods for the Examination of Dairy Products" Wehr and Frank, 2004.

One issue cheesemakers face is the question of whether to record pH for both whey and curd. Some cheesemakers measure the pH of the whey, some do the curd, and some, like CDR, record both.

"You probably do not need to measure both whey and curd, but one thing to keep in mind is that you need to be consistent in which you measure because they are different," Johnson said. "Typically, the curd pH is .1 to .2 lower than the whey." If a cheesemaker adds water or rinses the curd, pH measurement of the curd is desired.

The curd is usually lower in pH because the curd is where the starter bacteria are creating the acid and releasing it into the whey. One advantage of measuring both curd and whey is that you can get a good indication of how fast your acidification is going based on the how far apart the pH is of the whey and curd.

Titratable Acidity

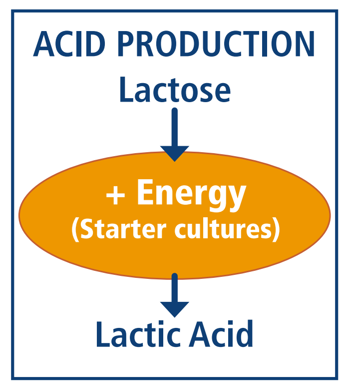
Before pH meters, cheesemakers used a titrator or acidometer to measure titratable acidity (TA) of milk or whey. Titratable acidity is related to pH in that the more acid developed, the higher the TA. TA is also a measurement of the buffer capacity of the milk or whey. Of interest to cheesemakers is the calcium phosphates, which have a direct effect on the buffering capacity of the milk. The more casein in milk, the more calcium phosphate. Since the calcium phosphate is the main buffer in milk and TA measures buffer capacity, a higher TA sometimes is not associated with more acid. It is the change in TA over time (more starter culture activity) that the cheesemaker needs to monitor.

Additionally, if you have a seasonal milk source, casein and calcium phosphate will change throughout the season so TA is a good way to monitor these changes in the milk. The actual process of taking a TA reading is more complicated than taking a pH reading.

As a cheesemaker, if you have to pick one (pH or TA) it is recommended that you use pH because pH will give a more consistent reading between cheesemakers and a pH meter is able to measure the pH of liquids (milk/whey) and solids (curd). Some cheesemakers who use high solids milk will use both because TA will indicate starter activity sooner than pH. Milks high in calcium phosphate may show little change in pH but a large change in TA.

Role of Acidification in Cheesemaking

As discussed in the last issue of the Dairy Pipeline ("Part 1: Essential Principles of Cheesemaking: Starter Cultures") acid development drives the cheesemaking process. Acid development occurs because the starter bacteria ferment the lactose in the milk and produce lactic acid, which drives the necessary reactions for cheesemaking. One of those reactions is that the lactic acid solubilizes colloidal calcium phosphate and thus helps determine the level of calcium in the cheese curd and the ratio of soluble to colloidal calcium. These factors, in turn, greatly influence cheese texture and functionality. Acidity also impacts the activity of the coagulant during manufacture and ripening. Acidity promotes syneresis (expulsion of moisture from the cheese curd) and therefore has a large impact on cheese composition, particularly the moisture content of the cheese. The lactic acid also influences the activity of enzymes during ripening and, hence, affects cheese flavor and quality. Finally, acidity helps control or prevent the growth of spoilage or pathogenic microorganisms.



Acid takes time to develop during the cheesemaking process—the starter cultures need time to ferment or consume the lactose. So, at the beginning the pH is higher but it drops during cheesemaking. As mentioned, lactose is the fuel for acid development—the more lactose, the more lactic acid that can be produced. Fortifying the cheese milk with extra lactose containing solids (condensed skim, NDM) will add more lactose to the system, allowing for more lactic acid to be produced, resulting in a lower pH cheese. Conversely, cheesemakers can remove some lactose from the milk by using ultrafiltration (UF) and adding back water into the UF milk. This will help remove some lactose from the system, resulting in less of a pH drop in the cheese. CDR has been promoting this method as a strategy to avoid making "acid cheese." ➡

"One of the single biggest cheese defects we're seeing is acid cheese," Sommer said. "We're doing a lot of work using ultrafiltered cheese milk and diluting it with water. This brings down the ratio of lactose to protein. So, there's less lactose in the system and you don't develop acidy cheese."

Acid Development During Cheesemaking

Now, let's get into acid development during the cheesemaking process. Again, it is critical to measure and record the acidity during the cheesemaking process (including during aging and of the final cheese). This is where a good make sheet with a lot of data points is crucial. For example, at a minimum, cheesemakers should be recording pH of the initial milk, before adding the coagulant, at cut, during milling/salting and hooping/brining. We also need to continue recording the pH during ripening /aging at day 1 and so on.

It's important to measure the pH of the initial milk because you want to know the "starting point" of the cheese. The pH of the initial milk will give an indication of the quality of the milk. For instance, if the pH reading of the milk is high (more than 6.8) this is likely a sign of mastitis. If this is the case, you will want to monitor the somatic cell count of the milk. Recording the pH of the initial milk is helpful in other ways as well. For instance, pasteurization slightly lowers the pH, also the stage of lactation will impact pH and the type of milk (seasonal milk, sheep or goat milk) will also impact pH. In general, if the pH of the initial milk is off, you will want to investigate why.

Creating Wet Acid

The next point in the cheesemaking process when it is important to know (and record) pH is before adding the coagulant. This is when the cheesemaker is creating "wet acid." It's called "wet acid" because you are creating acid before draining the whey. Monitoring acid at this point is important because wet acid development has the greatest impact on calcium solubilization. A lower pH before coagulant addition will allow more calcium to be solubilized (removed) from the casein (this also results in a higher moisture cheese). For example, we can have two cheeses that both have a final pH of 5.2. Even though they have the same final pH, one has a curdy texture and the other has a nicer, less curdy body that allows for an easier shred. The difference is that the curdy cheese had a pH of 6.5 at coagulant addition compared to the nicer cheese, which had a pH of 6.35 at coagulant addition. "That's the power of creating wet acid where you're solubilizing calcium," Johnson says. This also illustrates how a "small" variation in pH (6.5 compared to 6.35) can have a big impact on the final cheese.

Measuring Acidity During Cheesemaking before Coagulant Addition

	Cheese A	Cheese B
pH at Coagulant Addition	6.50	6.35
pH at Draining	6.35	6.10
Final pH	5.20	5.20
Cheese Performance	Curdy	Less curdy, better shred

Note: More acid development before coagulant addition = greater demineralization and lower buffering capacity.

This also brings up an important point regarding the development of "wet" versus "dry" acid. As mentioned, wet acid is developed early in the cheesemaking process and up to the point that the whey is drained. Dry acid is developed after the whey has been drained and the cheese is moved to hoops or forms (the acid is developed when the cheese is "dry"). The wet and dry acid dynamic is an important concept for cheesemakers to understand. For instance, let's say we are making Cheddar. Sommer says he wants the pH to be 5.4 when the Cheddar is going into the hoop because a lower pH reading at this point shows that he has created wet acid (pH has lowered) before the whey was drained. However, Sommer said that a lot of cheesemakers rely on dry acid and will hoop their Cheddar when it has a pH between 5.8-6.0. "I'd run screaming out of the door if I saw that," Sommer said. Why? Because, if a cheesemaker develops acid in the milk or curd/whey (wet acid) then a lot of the lactic acid will go in the whey and will be removed when the whey is drained. Conversely, if acid is developed in the hoop (dry acid) where will that lactic acid go? It will stay in the cheese. This results in an acid Cheddar that is more likely to develop a bitter taste, whey taint flavors, and defects like calcium lactate crystals.

Cheesemakers next need to record pH when draining the vat. As described previously, this pH reading will let the cheesemaker see if they have developed the right amount of acid, depending on whether they were trying to develop wet acid or if they are relying on more dry acid development. When draining the vat, we are taking lactose away from the bacteria, which will slow down acid development.

If making a milled or stirred curd cheese, you will want to measure pH before milling and before salt addition, respectively. Knowing acid development before adding salt will allow you to better target final pHs in your cheese as some cultures are inhibited by salt.

For a brined cheese, whether you're pumping the curd into a pre-press or taking it right out of the vat to hoops, you want to measure an acidification point at hooping because at this step you're basically switching from ➡

forming wet to dry acid formation. It's important to get this acid reading for eyed cheeses as typically you want a lot of unsolubilized calcium in the curd with these styles of cheese.

Buffering—Loss of Insoluble Calcium

Tracking and recording pH doesn't stop when the cheese is out of the vat. It's very important to record the pH history during post-manufacture because you want to find the lowest terminal pH that the cheese reaches. "That [lowest terminal pH] is going to determine a lot of the final characteristics of your cheese," Johnson said. It's also important to record the cheese pH after manufacture because this is when the cheese pH is going to "buffer." In other words, this is when the pH will reach its lowest point and then buffer back up until it reaches its final pH.

Buffering occurs because, as cheese ripens or ages, the hydrogen ions in the cheese displace the calcium ions and "disappear" or are absorbed into the cheese matrix. This causes there to be less free hydrogen ions in the cheese and therefore raises the pH. To track the cheese's buffering and pH history post-manufacture, typically the pH is taken at 4 hours, 1 day, 1 week, 2 weeks, 4 weeks, and 3 months. Of course, there is a lot of variation considering the type of cheese being made. The cheese pH history post manufacture will help indicate if anything is going wrong with the cheese. For example, if making a Blue cheese, the lowest terminal pH will be around 4.8 and then buffer up to a pH of about 6.0. If the lowest terminal pH drops to 5.0, it's going to be a different cheese in terms of flavor and texture. It will ripen faster.

Strategies to Influence Moisture Content

Like acid, cheesemakers need to monitor and control the moisture content of the cheese. Moisture content impacts the quality and safety of the cheese and even a small change (± 1%) can have a negative impact on the final cheese.

Typically, cheese with too much moisture will have a weak body and pasty texture. There may also be food safety concerns because more moisture results in a higher water activity (a_w), which results in more microbial growth (bad) and an increase in proteolysis (good depending on cheese type).

Cheese with lower moisture levels can result in a hard, firm, corky body and texture. These cheeses have lower a_w and higher salt-in-the-moisture-phase resulting in decreased microbial growth (good) but also less proteolytic activity (bad depending on cheese type).

Depending on the milk composition, you may need to adjust the moisture content. "As your milk changes, other parameters change; you're going to have to change your moisture content to match that," Johnson says. For example, if you have higher levels of fat, you will need to adjust moisture level down to compensate for that otherwise you might get pasty, weak bodied cheese.

Of course, different cheeses require different moisture contents. The make for an aged Cheddar is different than a young Cheddar. For an aged Cheddar, the moisture content needs to be 35-37% (depending on how long the cheese will be aged) to give the cheese the best chance to develop the correct body, texture and flavor. See page 8 for some strategies to influence moisture content.

Continued on page 8 ➡

Strategies to Control Acid Development
Culture: Increasing the amount of culture used during the cheese make will increase the rate of acidification and help develop more wet acid.
Prolong stirring: The cheesemaker can develop more wet acid by prolonging the stirring of the curd after cooking, which will give the starter cultures more time to ferment lactose and develop more lactic acid and firm the curd body. This will produce a lower pH cheese. However, it will also lower the moisture content.
Replace some whey with water: Cheesemakers can produce a cheese with less acid (higher pH) by removing some of the whey prior to cooking and replacing the whey with water, which removes some of the lactose (which drives acid development).
Increase cooking temperature: This will slow down acid development by shutting down mesophilic cultures (don't grow in high temperatures) and less acid will be produced. It will increase acid development by thermophilic cultures.
Cool down curd: Lowering the temperature of the curd with cool water will slow down the starter cultures and remove some of the lactose, which will result in a higher pH cheese. This also allows for a more open body cheese (i.e. Colby).
Salt: In addition to promoting moisture loss and controlling microbial growth, salt acts as a "brake" on starter culture activity/acid production. Salt is especially effective at slowing down *Streptococcus thermophilus.*

TRICKS OF THE TRADE: FORMULATING DAIRY PROTEIN BEVERAGES

Technical reviewer: KJ Burrington, CDR

Dairy protein beverages are an exciting area for the dairy industry. Innovative new products are hitting the shelves and consumers are beginning to appreciate the nutritional value of beverages made with dairy proteins. Additionally, there is room in the market for more dairy beverage products.

However, when developing these beverages, it is important to have a good understanding of the functionality of different dairy protein ingredients. For more than 20 years, the Center for Dairy Research's Beverage Applications Program has been a leader in helping companies and entrepreneurs develop dairy protein beverages. Staff are well versed in using milk and whey protein ingredients, as well as non-protein dairy ingredients such as permeate.

High Acid or Low Acid?

In the beverage world, there are two categories—low acid and high acid. A low acid beverage is typically anything above pH 4.6. A high acid beverage is anything below pH 4.6. According to KJ Burrington, CDR's Dairy Ingredients, Beverages & Cultured Products Coordinator, when a company or entrepreneur works with CDR on a beverage, her first question is what's the pH?

Selecting a pH is especially important when developing a beverage using dairy proteins. Generally speaking, whey protein ingredients work best in high acid beverages and milk protein ingredients have better functionality in low acid beverages. Depending on the pH, stabilizers might be needed to add stability to the dairy protein. For instance, a whey protein isolate can be used to develop a clear high acid beverage. However, if the beverage has a "mid-range" pH (between 3.5 and 4.5), a stabilizer like pectin might be needed because the whey proteins are closer to their isoelectric point and a stabilizer like pectin will help prevent aggregation of the whey proteins during the heat process. The level of acidity plays a big role in the development of a beverage.

Processing Conditions

In addition to dictating what dairy protein ingredient to use, the pH of a beverage will also dictate the processing conditions. For instance, low acid beverages that are shelf stable essentially have two processing options— retort and ultra high temperature (UHT). Retort is a very high temperature treatment (250-300°F) for a long amount of time (20-40 minutes). Retort products are shelf stable and are typically in bottles or cans. UHT processing is a high temperature (above 275°F) treatment but for a very short time (2 to 5 seconds). UHT is also shelf stable if it is aseptically packaged in cartons or bottles. There is also one "in between" processing option for low acid beverages: extended shelf life (ESL). These products undergo the UHT process but are not packaged aseptically. ESL is currently used for some low acid filtered milk products and coffee drinks and require refrigeration.

For shelf stable high acid beverages, the typical processing option is hot fill. During the hot fill process, the beverage is heated >18^{0}F for up to 2 minutes, filled hot into the bottle and then cooled. Of course, high acid beverages pose less pathogen risk than low acid beverages. Even if a pathogen is present in a high acid beverage it will die off very quickly because of the low pH. Another processing option for high acid beverages is basic pasteurization. Some smoothie products are pasteurized. However, these products require refrigeration.

Which Ingredient to Use?

Once the pH and the processing conditions are determined, then it's time to select a dairy protein ingredient.

"For high acid beverages, we almost always recommend whey proteins because they have better solubility and heat stability at that pH [below 4.6]," Burrington said. "Most low acid beverages are in the pH range of 6-7, so we will always recommend milk proteins over whey because milk proteins are going to have the best solubility and heat stability in that pH range."

Examples of whey proteins include whey protein concentrates (WPC), whey protein isolates (WPI), and milk-derived whey. Milk proteins include milk protein concentrates (MPC), milk protein isolates (MPI), and micellar casein.

Isolates and concentrates have their pros and cons. A concentrate is going to cost less but it will also have more lactose and minerals, which will contribute to the overall sugar content. Concentrates will also have some fat, which is going to produce a more cloudy, milky product. In addition, the mineral content of concentrates can also create some instability depending on the pH. So, even though isolates cost more, some manufacturers opt for isolates because, among other factors, they can produce a beverage with a lower sugar content and the best clarity, which is important for protein waters

One of the newer milk protein ingredients is micellar casein. This ingredient is different than an isolate or concentrate because it is processed by microfiltration (MF) while concentrates and isolates are most commonly made by ultrafiltration (UF). MF separates the casein from the whey protein. So micellar casein will have the same protein level as a concentrate or an isolate, but the protein composition has changed to be predominantly casein. There are about four companies making micellar casein in the U.S. and they will typically produce it in the range of 90-95 percent casein (compared to MPC, which is about 80 percent casein). Micellar casein could have a couple of advantages. It should be more heat stable because it has less whey proteins. Micellar caseins also tend to develop less sulfur aroma during UHT or retort processing, due to the lower whey protein content.

There is also a new whey ingredient called milk derived whey. "This ingredient is different than cheese derived whey because the milk derived whey has never gone through a cheesemaking process," Burrington said. "The flavor of milk derived whey is going to be very clean—it doesn't have any of the flavors that the cultures have created or from the extra heat processing that has happened as the whey is further processed. It has a clean, milky flavor that a lot of people like."

In addition, milk derived whey contains no fat (in the MF process, the fat is separated from the whey protein stream). Since it has no fat, milk derived whey is very clear like a WPI, which makes it a good option for clear beverages like protein waters.

CDR's KJ Burrington, Hong Jiang & Ben Oldenburg, developing a new dairy beverage in the CDR pilot plant.

Hydration is Essential for Dry Dairy Proteins

Some of the solubility and heat stability issues that are seen with dairy protein beverages can be avoided by properly hydrating the dairy proteins before they are added to the beverage formulation.

Milk proteins are especially important to hydrate properly. Burrington says milk proteins need to be hydrated for about an hour at 50°C (120°F minimum). "We always recommend warmer temperatures for milk proteins because they are very slow to hydrate and warmer temperatures help optimize their hydration conditions," Burrington said.

On whey protein side, it takes less time—about 20 to 30 minutes at no higher than 130°F. It is important not to exceed 130°F because you want to avoid denaturing the whey proteins.

Hydrating dairy proteins is important, especially as drinks are being produced with higher levels of protein. Poorly hydrated MPC or MPI ingredients will lead to defects like a grainy texture or protein settling in the finished beverage. Properly hydrating the proteins will help avoid these issues and improve the quality of the beverage.

Processing Aids

There are a couple of special considerations when developing beverages, especially low acid beverages, in order to help the dairy proteins go through the heating process without getting damaged. For instance, often in low acid beverages, a stabilizer will need to be added (like carrageenan or gellan gum). These will help protect the protein and also prevent it from interacting with itself.

The other consideration is that in a high heat process (like UHT), the Maillard reaction occurs. This reaction will drop the pH of the beverage, which can create protein instability. One way to help stabilize the pH is by adding buffer salts (usually mono-, di-, or polyphosphates). These buffers help hold the pH up and some will also chelate calcium (sometimes calcium will also cause protein instability). The buffer salts are not perceived as clean label by some consumers but they really help make the beverage more stable.

Custom Dairy Ingredients

A couple of U.S. companies produce an MPC with a reduced calcium content as a way to avoid the use of buffers and to achieve a clean label. These special MPCs with reduced calcium are more heat stable and are a nice option for low acid dairy protein beverages.

One consideration when producing a beverage with whey proteins is to use a pre-acidified whey protein isolate. One issue that manufacturers face when making beverages with whey protein isolates is that the pH of the beverage formulation needs to be decreased sometimes as low as pH 3.0 with the addition of an acid like phosphoric, citric or malic acid. Depending on the level of protein in the beverage, the amount of acid added could be very high. Several companies in the U.S. have developed a pre-acidified whey protein isolate that makes it much easier for the processor and also makes a whey protein ingredient that will be less astringent in the finished beverage.

Hong Jiang, CDR, bottling a dairy beveage in the CDR Pilot Plant.

As mentioned at the beginning of this article, dairy protein beverages are a still emerging and developing area of the dairy industry. Most dairy protein beverages are focused on muscle health, whether it be focused on sports (muscle recovery), weight management (lean muscle) or healthy aging (maintaining muscle). Burrington said that there is room in the market for more products, "The one area that I think we're really short on is the healthy aging category. There are very few products in the market. That's one area that in which I've been really encouraging companies to develop products."

CDR is also working to increase its ability to support companies and entrepreneurs develop new beverages. Babcock Hall, which houses CDR, is undergoing a building project. As part of that project and with support from the Wisconsin Economic Development Corporation, CDR will be able to offer small-scale aseptic processing equipment. More information will be made available when the equipment is ready for use.

For more information or for technical support regarding dairy protein beverages, contact CDR's Beverage Applications Program Coordinator KJ Burrington at 608-265-9297 or burrington@cdr.wisc.edu.

Additional Resources:

Dairy Protein Beverage Applications Short Course – September 15-16, 2020 www.cdr.wisc.edu/shortcourses

U.S. Dairy Ingredients in Ready-to-Drink Beverages (U.S. Dairy Export Council) – www.thinkusadairy.org *Search for "Ready-to-Drink Beverages."*

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Strategies to Influence Moisture Content

Pasteurization: Influencing moisture content can start way back at pasteurization. For instance, pasteurization at <166°F will not significantly denature whey proteins and will produce a lower moisture cheese. However, pasteurization at >166°F will begin to denature whey proteins, which will bind or retain water and produce a higher moisture cheese.

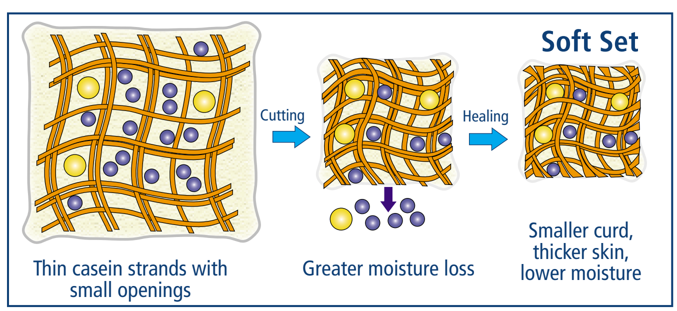
Culture Selection: Different cultures will also influence the final moisture of the cheese. Culture types and even strains within the same genus and species differ in their ability to retain or drive out moisture. For example, Sommer said when he worked in a dairy plant, he knew that certain cultures would produce cheese with a higher moisture content. So, he'd use cultures that retain more water for higher moisture cheeses like Monterey Jack and cultures that drive out more moisture for lower moisture cheeses like Cheddar.

Add Water: Another strategy to make a higher moisture cheese is to add water to the milk in the vat. This will reduce whey expulsion, resulting in a higher moisture cheese. This strategy is more common in Europe, but if you're a small artisan producer who is not concerned about whey quality, this might be a good option.

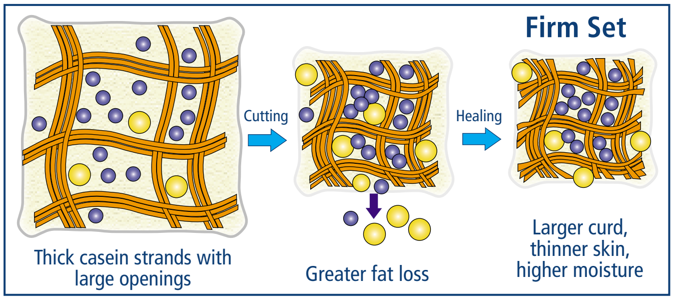
Add Calcium Chloride: The addition of calcium chloride to the milk in the vat will improve whey syneresis (moisture expulsion) and result in a lower moisture cheese. However, this is not a good option if making aged Cheddar or Parmesan because if you add calcium chloride, you add less rennet and rennet is important in aged cheese because it contributes to the proteolytic activity that is crucial to the cheese aging process and flavor development. Adding calcium chloride is a better option for higher moisture cheeses like Colby and Monterey Jack because then less rennet is needed and you don't want excessive amounts of proteolysis in thoes varieties.

Cutting the Vat

The firmness of the curd when the vat is cut influences moisture content as well as fat loss. "Not all cheese varieties should be cut at the same curd coagulant firmness," Sommer says. "This is part of the art and skill of cheesemaking."



The firmer the coagulated milk is at cut, the higher moisture of the final cheese. Conversely, the softer it is at cut, the lower moisture content. For example, when making a high moisture cheese, like Feta, the curd is cut when it is very firm. “The curd is so hard you can walk across the vat,” Sommer said. “It is like concrete. Why? Because they want to retain that moisture in the curd.” Low moisture cheeses, like Parmesan or aged Cheddar, are cut when the coagulant is very soft because the cheesemaker wants to lose moisture but retain more milkfat in the curd.



Why is this? When coagulated milk is soft, the opening or pores in the curd are very small. Since, the pores in the curd are small, they don’t hold much moisture. And, when the curd is harder, the pores are much larger and hold more moisture.

In addition to impacting moisture, the firmness at cut also impacts fat loss. Cutting the curd when it is firmer, results in more fat loss. This occurs because the structure of the casein is more rigid when the curd is firm so it takes longer for the curd to “heal” after being cut. It can’t close the gap and trap the remaining fat, so some of the fat will leak out into the whey, as compared to softer curd, where the casein is thinner and less rigid, and therefore takes less time to heal so it traps the fat in the cheese.

Other Tips to Influence Moisture Content
Cooking: Cooking the curd at a lower temperature will retain more moisture and higher temperatures will help expel more moisture.
Water: Cooling the curd with cool water will help retain more moisture and warming it with warm water will lose more moisture (this is often used with Muenster cheese when it is in the hoops).
Reducing make time after cook: This is another strategy to retain more moisture in the cheese. Once all the whey is drained after cooking, the longer the curd stirs, the more moisture will be lost. So, if you are making a higher moisture cheese, you might want to reduce the make time after cooking the curd by shortening up the time that the cheese is placed in the hoop after cooking.
Salt: Salt sucks water out of the curd, so the more salt you add, (i.e. Cheddar, Colby) the more water that is going to be removed, resulting in a cheese with a lower, final moisture content.
Reduce curd temperature at pressing: This will reduce whey expulsion, and, therefore, increase the cheese’s moisture content. The cooler the curd is at pressing, the less whey expulsion. However, if the curd gets too cold, the curd won’t get a nice tight knit.

A couple notes about coagulation. The rate of gel firming is:

- Increased by increasing concentration of casein,
- Increased by increasing amount of rennet used,
- Increased by adding $CaCl_2$ (maximum level 0.02%),
- Increased by increasing the temperature, and
- Increased by decreasing the pH at rennet addition.

The other important factor to keep in mind when cutting is determining the size of the cubes. This is pretty straight forward—cutting into larger cubes will retain more moisture in cheese and smaller cubes will lose more moisture. So, if making aged Cheddar, you would cut smaller cubes and if making Feta or fresh Mozzarella, you will cut larger cubes.

Measuring Moisture

Typically, when measuring moisture content, you want to have a consistent time point—1-2 weeks if possible, (depending on the style) and longer for brined cheeses because you want to have the cheese reach equilibrium before you sample it. To get accurate, consistent results, you need to take a representative sample and it’s best to sample the cheese when cooled. Also, if possible, it’s best to send a representative cut portion to the lab compared to a plug.

There are a couple different ways you can measure moisture. An inexpensive and easy option is to measure moisture using a forced draft oven (see "Standard Methods for the Examination of Dairy Products,"procedure 15.114). In this procedure, the first step is weighing the sample then placing it in an oven for several hours or overnight, and then weighing it again when it comes out of the oven to determine the moisture content. The loss of weight after heating is used to calculate moisture content of the sample.

In Summary

- Keeping the moisture content in the proper range is critical to achieve the correct cheese flavor and texture.
- Rate (speed) and extent (range) of acid development determines calcium retention and cheese body, texture and performance.
- Everything is connected—especially acidity and moisture. If you make an adjustment in one step, it will impact other areas and/or characteristics of the cheese.

“Cheesemaking is a holistic process—you change one parameter like moisture and you’re going to change another like acidity, which will result in changing the body,” says Sommer. “That’s where the artisanship of cheesemaking comes into play.” *Continued on page 12*

CDR ARTICLE ON LACTOSE STANDARDIZATION RECEIVES SPECIAL RECOGNITION

The Journal of Dairy Science, published by the American Dairy Science Association, recognized CDR's work on lactose standardization of cheesemilk. Paul Kononoff, editor-in-chief of the Journal of Dairy Science, selected CDR's paper, "Low- and reduced-fat milled curd, direct-salted Gouda cheese: Comparison of lactose standardization of cheesemilk and whey dilution techniques" as an editor's choice article for the February issue. The article is also being featured on the Journal of Dairy Science website (www.journalofdairyscience.org).

The paper's authors are: Rodrigo Ibanez, CDR Associate Scientist; Rani Govindasamy-Lucey, CDR Senior Scientist; John Jaeggi, CDR Cheese Industry and Applications Coordinator; Mark E. Johnson, CDR Associate Director and Distinguished Scientist; Paul McSweeney, Professor, School of Food and Nutritional Sciences, University College Cork, Ireland; and John Lucey, CDR director.

The findings in the article are from Rodrigo Ibanez's Ph.D. research work. This exciting research investigated an alternative method to control cheese acidity by altering the initial lactose content of the cheesemilk. Traditionally, in cheeses like Gouda, acidity is controlled by whey dilution, which involves partial removal of whey and its replacement with water. By standardizing lactose in the cheesemilk, cheesemakers may be able to produce a quality cheese while also reducing water usage.

"My Ph.D. thesis was focused on studying the factors that affected the quality of low fat cheeses," Ibanez said.

Rodrigo Ibanez, CDR, working in the lab.

"In general, this type of product develops excessive acidity due to a change in the balance of cheese components, such as a reduced fat content, but increased moisture content. We wanted to evaluate how lactose standardization controlled acid development in Gouda style cheeses with reduced fat levels, but we also wanted to contrast with traditional methods to control acidity, such as whey dilution."

The paper also drew upon the earlier work of Mark Johnson, CDR Assistant Director. Mark developed the idea of lactose standardization in the 1990s. It is part of an overall process of standardizing milk to the same composition to produce cheese with little variation in composition and pH. The functionality of the cheese can be more tightly controlled.

CDR is very proud to have talented scientists like Mark, Rodrigo and others working on innovative solutions that directly benefit the dairy industry. Rodrigo joined the CDR staff in the summer of 2019. As an associate scientist at CDR, Rodrigo is focusing on microbiological topics related to cheese and dairy products, along with writing research proposals and supporting research and outreach activities at CDR.

To view the paper, visit www.journalofdairyscience.org.

2020 DAIRY SHORT COURSES

Continuing Education Opportunities for the Dairy Industry

- Ice Cream Makers Workshop ➡ February 12-14
- Wisconsin Process Cheese Seminar ➡ February 18-20
- Cheese Technology Short Course ➡ March 9-13
- World of Cheese ➡ April 27 – May 1
- CIP ➡ May 5
- Food Safety (HACCP) ➡ May 6
- Certificate in Dairy Processing ➡ May 7
- Applied Dairy Chemistry ➡ May 12-13
- Cheese Grading ➡ June 2-4
- Buttermakers Short Course ➡ June 16-17
- Buttermaker Apprenticeship Workshop ➡ June 22-26
- Milk Pasteurization ➡ August 4-5
- Certificate in Dairy Processing ➡ September 3
- Dairy Protein Beverage Applications ➡ September 15-16
- Master Artisian Course ➡ September 22-24
- Cheese Tech Short Course ➡ October 5-9
- Dairy Ingredient Manufacturing ➡ October 20-21
- Cheese Grading Short Course ➡ November 4-6
- Ice Cream ➡ December 1-3

For the most current short course schedule see our website.
www.cdr.wisc.edu/shortcourses

CHEESE EXPO

Global Technology for Dairy Processors

April 14 Special Events | April 15-16 Exhibits and Seminars
Milwaukee, Wisconsin | www.cheeseexpo.org

Join CDR staff at the Cheese Expo 2020. Nowhere else will you find the opportunity to network with 4000 of your colleagues and industry experts while accessing relevant educational sessions and the latest technology and services to support your business success at the trade show.

CDR is excited to again partner with the Wisconsin Cheese Makers Association in co-hosting the Expo. Staff have put together three technical sessions that will address topics you told us were important to you. Be sure to register today for Cheese Expo 2020 so you can learn and network with CDR staff and your colleagues.

Wednesday, April 15 | After the Make: Role of Brines and Curing in Quality Cheesemaking

Part I: Brines: Quality of brines, salt update in cheese varieties, brine cleaning technologies, and brine best practices and disposal. You'll also hear an update on the hydrogen peroxide study.

Part II: Mold Control during Aging: Practical approach to mold control, including a panel of experts addressing the challenges and solutions related to 640 production.

Thursday, April 16 | Where Efficiency Meets Excellence: Maintaining Quality in Modern Manufacture

Part I: Cheesemaking Efficiency: Mark Johnson and John Jaeggi will be sharing ideas for calculating and optimizing cheese yield, including how to reduce cheese fines, optimize yield and fat retention, and other important factors.

Part II: Ask the Experts Panel: Here's your chance to stump the CDR experts. We'll be discussing the Top 5 defects we've seen over the past five years related to cheese and whey, but also open the floor for your questions.

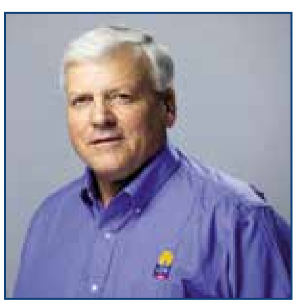
Artisan Track: Affinage -Creating the Ideal Aging Space
From surface flora to air handling, this session will address all of the important conditions needed to create that perfect artisan cheers. We'll discuss different conditions for different rinds, and you'll also hear from an Affineur on best practices. This session will conclude with Andy Johnson sharing CDR's plans for the various affinage caves we'll offer in the new CDR building.

Join us on April 14-16, 2020 in Milwaukee for Cheese Expo 2020. Register now at www.cheeseexpo.org

EXPERIENCED CHEESEMAKERS JOIN CDR

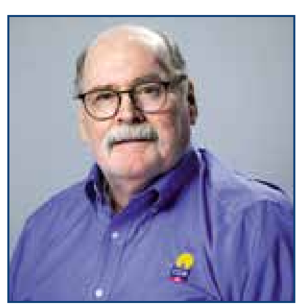
Gary Grossen, Research Cheesemaker

Gary is a Wisconsin Master Cheesemaker® (certified in Brick, Cheddar, Gouda, Havarti, Muenster) with more than 60 years of experience in the dairy industry. He worked in his family's cheese plant in Monroe, Wisconsin for more than 50 years, making Brick, Muenster, Colby, and 200-pound wheels of Swiss in traditional copper kettles. In 2005, Grossen came to the University of Wisconsin and worked in the Babcock Dairy Plant where he made award-winning cheeses. At CDR, Grossen helps with all aspects of cheesemaking from milk pasteurization to assisting with research and industry trials. His cheeses have won many awards at national and international competitions. Most recently, his Gouda was named Cheese and Butter Grand Champion at the 2019 World Dairy Expo.



Ben Oldenburg, Research Cheesemaker

Ben has worked for more than 25 years in dairy plants as a cheesemaker, supervisor and safety and loss control manager. Before CDR, Ben was a lead worker in the Babcock Hall Dairy Plant. Ben's many years of experience in the dairy industry give him valuable knowledge and perspective. At CDR, Ben helps pasteurize milk, assists with industry trials and helps ensure that CDR's research cheesemaking runs smoothly.



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Technical reviewers: Andy Johnson and Dean Sommer, CDR

Resources

- *Johnson, M. 2015. pH Control in Cheese. Dairy Pipeline: Volume 27, Number 1.*
- *Johnson, M., D. Sommer. 2013. Basic Techniques to Gain More Moisture in Cheese. Dairy Pipeline: Volume 25, Number 3.*
- *Johnson, M., D. Sommer. 2013. Importance of Acid Development on Cheese Milk Prior to Renneting. Dairy Pipeline: Volume 25, Number 3.*
- *Wehr, M., J. Frank. Standard Methods for the Examination of Dairy Products. American Public Health Association: 17th edition (June 1, 2004).*

Events

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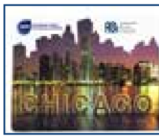

2020 ADPI/ABI Joint Annual Conference
American Dairy Products Institute
Sun, April 26 — Tue, April 28, 2020

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