Wisconsin Center for Dairy Research

Dairy Pipeline

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A Technical Resource for Dairy Manufacturers

CHEESE RIPENING

The ripening of cheese, or the process of a complex series of biological and chemical events that occur during cheese aging, can be a wonderful thing. This ripening process has the potential to create unique, desirable flavors, ideal texture and great machinability and melt. Unfortunately, inappropriate ripening can cause poor flavor, poor machinability and poor melt as well as a number of undesirable textural attributes. Therefore, ripening is a balancing act, but luckily, that balance can be achieved by applying sound science and the art of cheesemaking.

A Good Cheese Starts with Good Milk

The first step in creating a perfectly ripened cheese is selecting quality milk that does not contain microbes that will negatively impact your cheese down the road. Poor sanitation on the farm or in the plant can introduce unwanted microbes into the cheese milk which will create challenges during the ripening process. Keeping your equipment free of biofilms and having high standards for your incoming raw milk microbial quality will both be key to successful ripening.

It's also essential that the correct cultures, adjuncts and enzymes are added in the appropriate amounts to the milk to aid in the development of flavor and texture. Keep in mind that the breakdown of milk proteins, fats and lactose is primarily done by enzymes and microorganisms in the cheese. Some of these enzymes are naturally occurring in your raw milk supply while others are produced by microbes contained in the milk. In many cases enzymes may also come from the starter cultures and adjuncts that you add to your milk at the beginning of the cheesemaking process, or from the coagulant/rennet or even the added lipase enzymes. Still, more than likely in aged cheeses many of these enzymes will come from natural microbial contaminants, often called non-starter lactic acid bacteria, which reside in your cheese plant and inoculate your cheese in low numbers during the cheesemaking process. Overall, these multiple enzymes from various sources work in concert to help determine your cheese's finished textural and flavor characteristics. Therefore, your selection of microorganisms and enzymes will play a critical role in the entire process. Additionally, the temperature of the aging room as well as the acidity, the moisture level and the salt level of the cheese must also be monitored. Keep in mind that aging takes place at a faster rate at warmer temperatures while salt hinders bacterial growth, including the work of adjuncts used to develop flavor. As such, it's essential that these levels are monitored to allow for proper microbiological activity as the higher the aging temperature, and the lower the salt, the more active the enzymes and microbes are in the cheese.

The Ripening Process

There are three main steps in the ripening process:

A) Fermentation, or the conversion of milk sugar lactose to lactic acid

B) Proteolysis, or the breakdown of protein structure

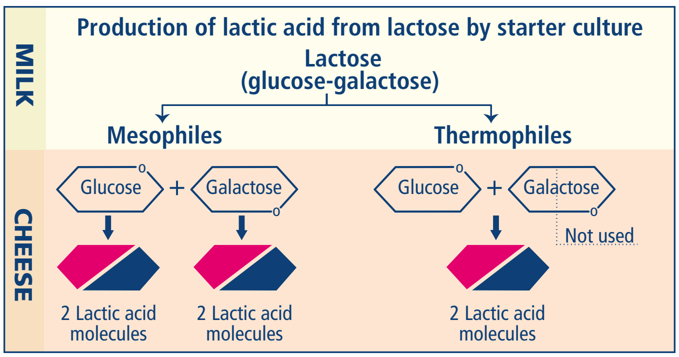
C) Lipolysis, or the breakdown of milkfat.

While each process is different, each of them is aided by the enzymes that are either added or naturally present in the cheese. Sources of these enzymes are:

- The milk itself
- Coagulant
- Starter
- Microbial Contaminants
- Lipase, added for flavor or specific ripening needs

Fermentation

Fermentation, or the conversion of lactose to lactic acid, is one of the first aging related reactions to occur in the cheese. This essential step can sometimes be difficult to understand but essentially, lactose is converted to lactic acid thanks to the work of the lactose fermenting lactic acid bacteria which are either added to the milk in the form of starters or naturally present in the raw milk. These lactic acid bacteria produce the enzyme lactase, a type of beta-galactosidase enzyme, which splits the lactose molecule into two sugars chemically, glucose and galactose, which can then be fermented into lactic acid by these cultures.



Lactose fermenting bacteria consume the lactose in order to gain energy. When using a mesophilic culture, which likes temperatures from 85-100 °F, the microbes will ferment both the glucose and galactose molecules into lactic acid. Conversely, if using a themophillic culture, which is used in most Italian style cheeses, then remember that these cultures prefer temperatures from 100-115 °F and struggle to ferment the galactose half of the lactose molecule. This leads to elevated levels of galactose in these Italian style cheeses and the whey from these cheeses.

Given the rate at which lactic acid increases during fermentation, it's not surprising that the pH of the cheese will begin to decrease. This drop in pH and the rise in lactic acid causes unique flavor changes that tend to add a tanginess to the cheese. Lactic acid can also be used to change the calcium phosphate balance in the cheese which aids in functionality such as melt and stretch. This occurs due to the partial dissolving of some calcium bonds that cross link protein molecules. This is the part that many cheesemakers struggle with as too much or too little acid at the wrong time can lead to poor functionality. Often a cheese with insufficient acidity will be too curdy or have poor stretch due to excessive remaining calcium cross linking in the cheese curd. The best way to remedy this is to really monitor the rate and extent of acid development at each cheesemaking step. Also keep in mind that there are some yeasts and molds that can consume lactic acid and therefore cause the pH to become more basic. It is common to see this in blue veined cheeses and white molded cheeses as well as those cheeses smeared with a rub that contains yeast. Additionally, in the case of Swiss cheese, a unique lactic acid consuming bacteria called Propionibacterium is added in order to create the eyes.

Proteolysis

For many cheeses, proteolysis is the most important step in flavor development but it can also be the most detrimental in terms of product quality loss if allowed to occur unchecked. Proteolysis is essentially the breakdown of large strings of amino acids called proteins into smaller groups of amino acids called peptides. Proteins, while beneficial in other ways, do not contribute directly to the flavor because they are too large for the microbes to consume. Luckily, the rennet, starter cultures and other bacteria that may be added to or naturally present in cheese aid in the breakdown of proteins into shorter units. The peptides are small enough for the microorganisms to consume and the by-product of that consumption process is an array of smaller peptides and eventually amino acids. Each is broken down into distinctly different flavors, which is what allows us to have so many unique cheese varieties. Consider, for example, the addition of blue mold to make a blue cheese. Without this adjunct, the blue cheese would essentially be Feta. Along that same vein, limburger would essentially be brick cheese without that unique blend of microorganisms that contribute to proteolysis.

In addition to its impact on flavor, proteolysis also contributes to the texture and functionality of cheese. For example, if the moisture in a cheese is higher than 39 percent, the cheese may become soft and pasty as proteolysis occurs. This is often seen in cheeses like Monterey Jack or Muenster if proteolysis proceeds too far because the cheese gets too old. In the case of a lower moisture cheese, too much proteolysis may cause the cheese to become crumbly and allow moisture seepage from an old cheese. This is sometimes seen in aged Cheddar. In either case too much proteolysis can also decrease machinability as the cheese becomes too soft and sticky.

Lipolysis

Lipolysis, or the release of the fatty acids attached to the backbone of the fat molecule gylcerol, is also essential to flavor development. Lipolysis occurs when fat molecules such as triglycerides are broken apart by lipase. While naturally present in milk, lipase is often made inactive during pasteurization. Therefore, many cheesemakers add lipase enzymes back into the milk following pasteurization to help create the unique

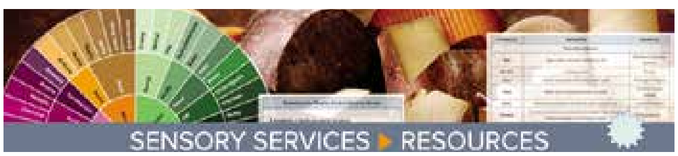
Dr. Mark Johnson, CDR & Gary Grossen, UW Food Science, Master Cheesemaker flavors typically associated with varieties such as Romano, Provolone, Asiago, Feta and Blue.

Let's imagine that we've encountered a triglyceride (fat molecule) which is made up of glycerol with three fatty acids attached to it. During the cheese ripening process the lipase will come along and begin to remove the fatty acids from the glycerol molecule. The cleaved fatty acids are now known as free fatty acids. These free fatty acids, such as butyric, caproic and stearic, are the source of intense flavors, which are determined by the length of the carbon chain. For example, a short chain fatty acid such as butyric (four carbons) contributes a desirable Provolone or piquant like flavor, while a medium chain fatty acid such as caproic (six carbons) gives off a goaty cheese-like flavor which may or may not be desirable depending on the cheese variety. On the other hand, a large chain fatty acid such as a steric acid (18 carbons) will contribute an undesirable soapy flavor. Again, the flavor produced can be predetermined by selecting the correct type of lipase. Keep in mind that although lipase is naturally present in raw milk, it is not at the levels that are needed to produce a strong flavor. For example, without added lipase Provolone would taste very much like a Mozzarella and Romano would taste a lot like a Parmesan. Therefore, for those cheese varieties where the typical lipase flavor is desirable, it's essential that cheesemakers determine their preferred flavor and then select the proper lipase enzymes that will allow this flavor profile to develop.

Conclusion

Cheese ripening is a complex process. A lot of things have to go right and work in unison in order to create the perfect cheese. From the quality of the milk to the cleanliness of the cheese plant, and from the selection of starter cultures, adjuncts and enzymes to the monitoring of moisture, pH and salt, the process of transforming liquid milk into solid cheese must be carefully guided by the cheesemaker. Additionally, the aging conditions of temperature, humidity and time must be carefully monitored and controlled by the cheese affineur during the disregarded ripening process, the name we give to the person who carefully ages the cheese. When all of these things come together, the science and art of cheesemaking combine to produce a cheese that will delight the taste buds of the consumer.

Technical Contributors: Mark Johnson, Ph.D., Dean Sommer, CDR



Sensory Resources are now Available Online

In addition to a list of services and a description of screenings, the sensory portion of the CDR website now contains three new cheese sensory resources: **A)** cheese basic flavor and texture training materials, **B)** sensory for quality assurance, **C)** cheese flavor wheel

A) The section on cheese basic flavor and texture training contains a searchable list of cheese flavors and textures including an example and definition for each, allowing users to find their desired attribute quickly and easily. As an added benefit CDR sensory staff have also made a sensory placemat available for download. This document, which is used during CDR trainings and short course sensory sessions can now be used as a learning tool for your company.

B) The second section, sensory for quality assurance, includes a quality control ballot developed by CDR as well as a list of guidelines for quality assurance sensory panels.

C) The final section contains a cheese flavor wheel developed by CDR sensory staff, which offers users an aesthetically pleasing way to learn the most common flavors found in cheese.

For questions or more information please contact sensory@cdr.wisc.edu

CHEESE CURDS: A WISCONSIN ICON

Technical Contributors: Mark Johnson, Ph.D., Pat Polowsky, CDR

There are few things as quintessentially Wisconsin as enjoying a fresh, squeaky cheese curd. Given the popularity of this delicious snack, it's not surprising that many consumers around the country are interested in experiencing this squeaky treat. Unfortunately, due to the short window in which cheese curds stay fresh and squeaky, many individuals living outside of Wisconsin cannot enjoy this unique delight. Thanks to consumer requests and feedback from the industry, however, CDR staff are now studying cheese curds in order to find a way to extend the squeak.

So what is a cheese curd and how is it made?

Before discussing the secret of the squeak, it's important to understand what constitutes a cheese curd and how a cheese curd is made. From a tradition standpoint, most cheese curd purists believe that cheese curds are the result of the cheddaring process. The cheddaring process essentially follows the basic steps of adding culture, color and rennet to warm milk and then allowing the curds to settle into a mass. The cheese mass is then cut into "loaves" and stacked and turned by hand. These loaves are then placed into a mill when the cheese pH reaches about 5.4. The mill cuts the cheese loaf down into pieces that are about 1.5 to 2 inch cheese curds. This warm milled curd is then salted and can be enjoyed right away, but the squeak will only last for a few days. Also, note that there are less traditional cheese curds that can be made out of brick, such as Muenster and Monterrey Jack but these also have similar issues with maintaining their squeak.

Frozen curd freshly thawed

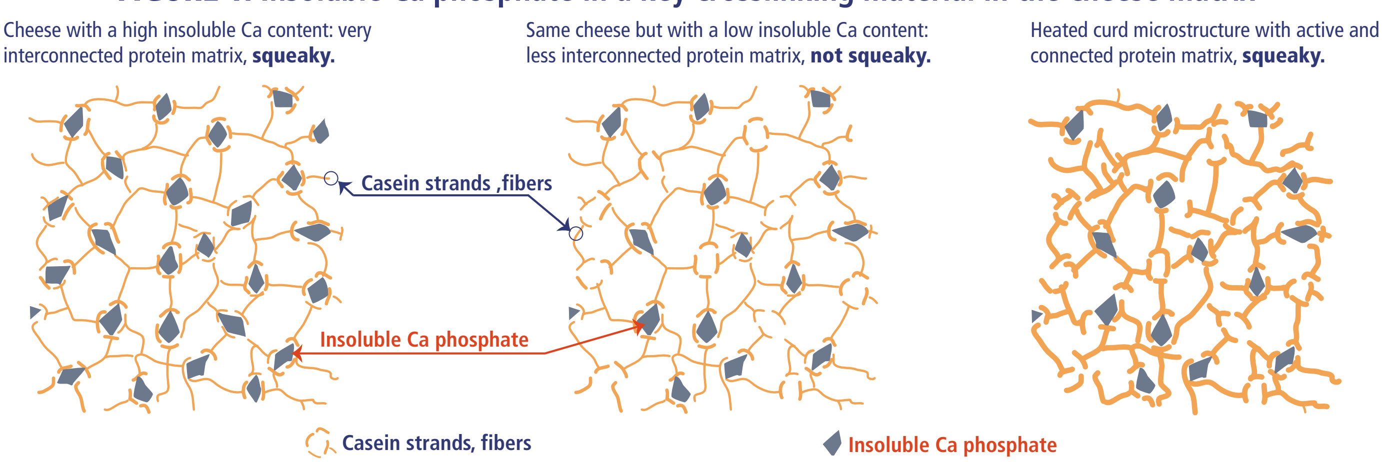
In terms of standards, Cheddar curds are subjected to a standard of identity, but in general there is not a standard of identity for cheese curds. There are, however, some attributes that are used to judge cheese curds in a contest. Essentially, a good curd will be fresh, meaning that is has retained its squeak and has a good shape. Additionally, the cheese should have a fresh, milky and salty flavor and be void of any flavor or physical defects. Generally, in competition the curds must have been made within the last day or two. While they will be refrigerated, the curds must be tempered to room temperature before consumption as the warmth is needed to create the squeak. While we will discuss the use of microwaves in tempering a cheese curd from refrigeration, most competitions do not currently allow curds to be microwaved prior to judging.

The story of the squeak

So where does this squeak come from? In the simplest terms, the squeak in cheese curds is created when our teeth compress the protein network in the cheese and it resists but then rebounds as our teeth pass through it. The rebound is what generates vibrations and causes the squeak.

The more complicated version of that answer involves the attributes of casein, the protein in cheese, and its ability to bind with calcium. To clarify, casein molecules are often called the building blocks of cheese because they form its physical structure. In cheese, these molecules of casein are held together by calcium phosphate. In a fresh cheese curd, the casein is very tightly knit, connected by a high number of these calcium phosphate molecules, allowing the protein network in the cheese to resist our teeth and rebound in order to create the squeak. Time, however, is not on the side of the curd manufacturer as the acid in the cheese from the cheesemaking process will slowly break down the calcium phosphate bonds. This weakens the micelles and causes the curd to lose its ability to squeak. In other words, when cheesemakers add bacteria to ferment lactose into lactic acid, the resulting lactic acid will dissolve some of the calcium phosphate bonds, eventually resulting in a network of protein that is softer. Keep in mind that it may take a few days for enough calcium phosphate to be dissolved by the acid but once this occurs, the squeak is lost and may not be restored even if the cheese is warmed.

FIGURE 1: Insoluble Ca phosphate in a key crosslinking material in the cheese matrix



Microwaved but not squeaky due to too much proteolytic activity.

Microwaved and squeaky thanks to minimal proteolytic activity.

Squeaky curds stretched after two weeks in refrigeration.

Speaking of which, cold temperatures are also the enemy of the cheesemaker as cooling the cheese will cause a change in the sturcture which will in turn cause the sqeak to disappear. CDR studies show, however, that warming the cheese forces the protein molecules to interact more closely, enhancing their ability to resist and then rebound recreating the curd's ability to squeak. It is important to note, however, that excessive heating (4 oz. of cheese at > 20 seconds in a 1,100 watt microwave) will alter the protein network so that the squeak may not return.

The final enemy of the squeaky curd manufacturer is the process of proteolysis, or the breakdown of the protein in the cheese. To make cheese curds, cheesemakers add a milk clotting enzyme called rennet to the milk, which causes proteolysis to occur. If proteolysis is too extensive the squeak is lost. While it will likely take a couple of weeks for this to occur, it is irreversible.

The Experiments

To obtain the above information, CDR staff conducted a number of experiments with cheese curds. In particular, researchers were interested in prolonging the freshness and squeak of the curd. Refrigerating the curds and then reheating them in the microwave was one of the first methods tested. Researchers decided to store fresh cheese curds at 45^{0} F for three weeks and then test them for mouthfeel and squeakiness. By testing the curds at various points during the three week study, researchers were able to analyze the point at which the squeak disappeared. What they discovered was that by microwaving 4 oz. of the curd for 15 seconds, the squeak could be recovered for up to two weeks. The cheese curds could also still be stretched when hot. After two weeks of refrigerated storage, however, the curds did not recover the squeak, even after they were microwaved. The curds also started to flow or melt by that time due to proteolysis and loss of calcium phosphate.

Curd Experiment Findings

Curd condition	15 sec. microwave heating
Refrigerated fresh curd	Squeak returns in curd up to 2 wks old
Frozen fresh curds, thawed, then held under refrigeration	After being frozen for up to three months and refrigerated for up to an additional two weeks the squeak returned.
Juustoleipa cheese	Squeak returns even after several months at refrigeration

The second experiment involved freezing the cheese curds. This time, the researchers checked for squeak at one, two and three months. Before testing, the curds were thawed in the refrigerator and then held in refrigeration for up to three weeks. Again, researchers discovered that after being frozen for one, two or three months and then refrigerated for up to two weeks, the thawed/refrigerated curds were able to regain their squeak after 4 oz. were heated for 15 seconds in a 1,100 watt microwave. Regardless of the time the curds were frozen, researchers could not regain the squeak in curds that were held in refrigeration for more than two weeks.

How to Prolong the Squeak

What this study shows is that storing cheese curds at refrigerator or freezer temperatures can help to extend shelf-life from a few days to about three and a half months. This is likely the case because the cold temperatures reduce the proteolytic activity. Additionally, researchers also believe that minimizing rennet additions and lowering acid production during manufacture can also improve the squeak shelf-life of fresh curds.

A Final Note

One interesting observation that was made during the cheese curd study is that warmed Juustolepia cheese does not lose its squeak, even after months of refrigeration. This is true because the manufacture of this cheese requires the use of rennet only and there is no acidification of the milk or cheese. The curds are pressed together into a block, cut into slabs, and then the slabs are baked in an oven. If properly baked, the rennet is destroyed preventing further proteolysis. Basically, because there is no acidification, there is no loss of calcium phosphate and with no proteolysis the squeak is maintained almost indefinitely in refrigerated Juustolepia. This observation confirms the researchers' belief that it is the loss of calcium and eventual proteolysis that is contributing to the loss of squeak in cheese curds. Keep in mind, however, that Juustolepia cheese will also lose its squeak if the baking process is insufficient and does not destroy the rennet.

Conclusion

The take-home message is that cheesemakers can freeze cheese curds immediately after they are made, ship them all over the country, and thaw them as needed. This might including selling the curds on the same day to consumers, or even selling the curds to consumers frozen and allowing the consumers to thaw the curd. Either way, as long as the curds follow the timing outlined here and are allowed to thaw, the squeak should remain as fresh as a curd from the vat.

PLANT INSPECTIONS: MAKING A GOOD FIRST IMPRESSION

Technical Contributor: Marianne Smukowski, CDR

There's an old saying that, "you'll never get a second chance to make a first impression," a statement that is invariably true when it comes to a customer's or auditor's impression of your plant. Those first few moments of a walkthrough can be a determining factor in the outcome of the visit so it's important to maintain a well-kept plant that is prepared for a visitor at any time. It's also important to note that there are certain red-flags that auditors will be looking for in your plant including issues with the three main areas, **environment, ingredients and employees**. As such, this article outlines audit and visitor preparation best practices.

The Exterior

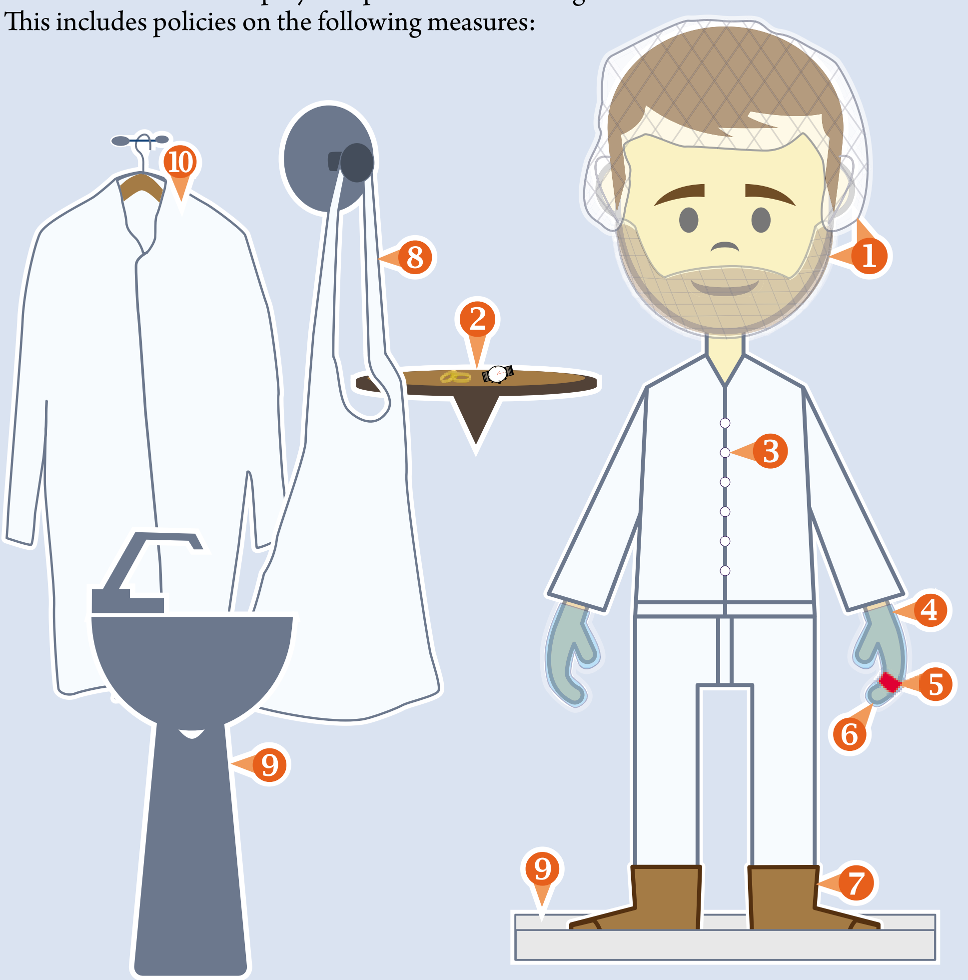
Before a visitor enters your plant they will be taking notice of the exterior, including security measures and pest management. Chipped paint, broken doors and an unsafe walkway are all things that should be taken care of as soon as they become a problem. Quick fixes or patches should be just that and should never become a permanent fixture of the plant.

GMPs: Good Manufacturing Practices

Should the visitor be conducting an audit, one of the first things he or she will be looking for is documentation regarding the plant GMPs. All plants must have GMPs for any area that includes products or ingredients, product packaging, or food equipment/utensils. Included in proper practices should also be a visitor policy which requires a sign in and sign out sheet as well as name tags for all visitors. Clearly marked controlled access points should also be noted as well as which visitors and employees will be allowed into such areas. In addition to visitor policies, it is best practice to create a traffic flow map that illustrates the need for all traffic to begin at the production end and conclude at the intake area. This flow is essential and will be noted by an auditor as any other pattern will allow dirt and microbes from the intake to travel through to your clean production areas.

Dress Code and Employee Policies

In addition to this basic documentation, auditors will also be looking for a clear outline of employee expectations including dress code. This includes policies on the following measures:



1. Hairnets must be worn over the ears and cannot be covered by a hat. The use of beard snoods is also required.
2. No jewelry is allowed in the plant
3. Snap closures are required for lab coats or plant uniforms and there should be no top pockets
4. A policy regarding the use of gloves, including when and how often to change them
5. A policy regarding the proper covering of bandages and injuries
6. Nail polish is not allowed in the plant but should someone be wearing nail polish, gloves must be worn
7. Footwear must be reserved solely for the plant and a plan should be in place for visitor footwear
8. A policy regarding the use of aprons including when to dispose of them or get them cleaned
9. Employees must wash their hands and use foot sanitizer upon entering the plant
10. Lab coats that are worn in the plant should not be taken into bathroom or break areas

The Plant

Auditors will also make note of the cleanliness and general appearance of the plant itself. In particular auditors will be looking at the following areas:

- Plant floor, watch out for poorly taken care of grout or floating tiles as these will be a sticking point for auditors. There should also be a policy in place for cleaning and sanitizing drains.
- Pest control, if you are utilizing an outside provider ensure that they have insurance and a license. Also, be sure that you have a map on file that indicates the location of the traps. Plants utilizing bug zappers should also have a written plan regarding how often to change the tray. Remember a zapper should not be too close to product.
- If the plant has windows that open and close, be sure they have screens.
- Keep everything secure, i.e. don't keep overhead doors open and don't prop doors open.
- Knives for bags or boxes should be cleaned regularly and there should be a system for disposing of the track piece of the knife.
- Hoses and nozzles should not rest on the floor and should not be frayed or damaged.
- Scoops for ingredients should be checked for cracks and cleaned regularly.
- Note the water supply and how often it is tested
- Clean cart, trolley and hand truck wheels regularly as these are listeria hotspots.
- Proper ingredients storage is also essential. Be sure you know how they are stored, where they are stored and where they are used.
- Be sure to color code cleaning equipment per Chart 1.

Chart 1

COLOR CODING POLICY

(FOR BRUSHES & BUCKETS)

WHITE	➡ (PRODUCT CONTACT SURFACES ONLY)
YELLOW	➡ (NON-PRODUCT CONTACT SURFACES ONLY)
BROWN	➡ (BOOTS OR FLOORS ONLY)
BLACK	➡ (DRAINS ONLY)
RED	➡ (RAW AREAS ONLY)
GREEN	➡ (SANITIZERS ONLY)
ORANGE	➡ (BROKEN GLASS OR BRITTLE PLASTIC)

While the plant floor and production areas are generally the focus of plant audits, the ceiling can cause just as many issues. A leaking roof or condensation from pipes that drip into cheese vats are huge issues. Light fixtures are also an area of concern. As you prepare for an audit be sure to consider the following areas:

- Light fixtures should have a cover or shield of some sort to avoid potential glass breakage in the area.
- Be concerned about condensation dripping from above a product line. Insulate the lines and keep the room humidity in check. Inside of a cooler, be sure to keep drip pans on the condensing unit and note how often you clean this and where the condensation is piped. Note that auditors will be looking for the condensation to be piped outside of the building.
- Check the air filters; note when they are changed as part of a regular maintenance program.

Other areas of Concern

In addition to the items outlined here, plants should also consider what sanitation practices should be followed when items are being repaired. Dedicated tools are a must for raw and pasteurized areas. Also, consider cleaning tool belts between uses and be sure that all repair professionals are dressed appropriately for the plant. In regards to repairs, it's also worth reiterating the fact that all temporary repairs should never become permanent. Duct tape, binder twine, bungee cords or other quick fixes should be properly repaired as soon as possible.

It's also worth noting that a positive employee environment is key to maintaining a clean and well-run plant. Employees who are well-trained, understand the rules, conduct themselves in a good manner and feel comfortable talking with supervisors about issues are the cornerstone of a great plant. Auditors will also be pleased to see a positive environment where learning and communication are encouraged.

While this list is not comprehensive, it is a great starting point for all plants. In addition to following this checklist, always be sure to stay up-to-date on regulations. If you need help, please feel free to reach out to CDR's dairy safety coordinator Marianne Smukowski | 608-265-6346 | email msmuk@cdr.wisc.edu

A short video highlighting a CDR third party audit is posted on the CDR website. www.cdr.wisc.edu/safety

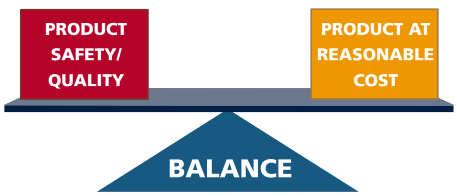
WHEY HANDLING IN WISCONSIN

Contributed by: Karen Smith, Ph.D., CDR

Over the last few years the food industry has made a number of changes to further ensure the safety of the food supply. Nowhere is this change more apparent than with the handling of raw whey, that is, whey immediately drawn from the vat that has not yet been pasteurized. As such, CDR has been partnering with Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) to investigate this issue and provide guidance and assistance to companies as these changes take place.

Some History

A full list of the regulations concerning whey handling and processing in Wisconsin are covered in Ag80. In general, the current regulatory focus in regards to whey handling has been on the safe transport of whey. At this time the requirement states that whey must either be



cooled to less than 45^0 F or heated to at least 140^0 F within four hours of draw from the vat. Heating and maintaining whey at a minimum of 140^0 F costs money and may result in damage to whey proteins and undesired color changes in the whey. Cooling whey to 45^0 F or less is preferred from a product quality standpoint but for many plants this requires the addition of extra cooling capacity.

The Center for Dairy Research and DATCP have been working together for several years to develop alternative options that ensure product safety for plants that cannot meet the four hour requirement and lack the ability to either cool or heat the whey. The final outcome for several plants has been a variance from DATCP that allows them to ship and process whey so long as the plants follow the steps and meet the requirements listed in the variance.

Another result of this partnership: DATCP is allowing the use of up to 100 ppm hydrogen peroxide as an antimicrobial agent in whey. However, there are a number of conditions that must be met for hydrogen peroxide use. One of the most important conditions is that the concentration of hydrogen peroxide may never exceed 100 ppm and should that occur, DATCP must be notified and the whey discarded. In addition, there can be no detectable hydrogen peroxide in the final whey products so any remaining hydrogen peroxide must be removed by either physical or chemical (enzymatic) means before final processing. Another critical component of the allowance of hydrogen peroxide use is that the four hour processing requirement remains in effect.

The Pathogens

All pathogens are important, however, the pathogen of greatest concern in warm whey produced from pasteurized milk is *Staphylococcus aureus*. The organism itself does not cause illness, rather it can produce a toxin that is heat stable and is not eliminated by further processing of whey. Since *S. aureus* is commonly found on people it can therefore be relatively easy to contaminate whey with the organism. *S. aureus* is a mesophile so it grows at the same temperature range as cheese cultures. This is important because warm whey is at the ideal temperature for the bacteria to grow, possibly allowing for the production of the toxin. Regulations therefore are designed with the prevention of this organism in mind.

Current Situation

Given that many small plants currently do not have the equipment or capacity to cool their whey within the four hour window, and the fact that it will take time to install such equipment, there has been a need to develop an interim process for handling warm whey. Therefore, DATCP and CDR worked together to develop an overall approach that would take into consideration, the cost of testing, ability of the testing to indicate possible problems and a way to gather data to support the safety of the final process. The final process is written into the form of a variance.

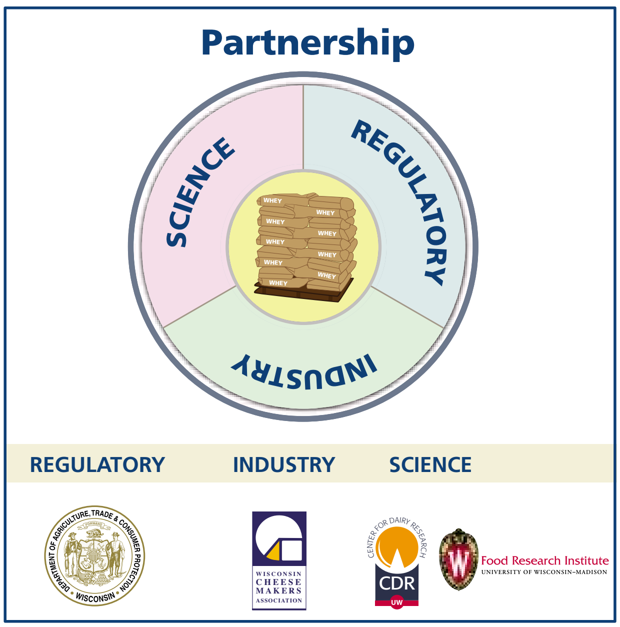
Although the exact process is different for each plant, the overall approach is the same. Testing for the organism *S. aureus* is possible, however, you are looking for a bacteria that is normally in very low numbers in a large volume of whey so the results are not very helpful for the day-to-day managing of the process. A far better and easier way to indicate product safety is the presence of coliforms. Large numbers of coliforms in whey from pasteurized milk indicate a problem. Coliforms are relatively intolerant to heat, sanitizers and the presence of other microorganisms such as starter bacteria. Therefore, so large numbers of coliforms indicate that the whey either has been exposed to a large number of coliforms or held under conditions such that small numbers of coliforms have been able to multiply. Because coliforms and *S. aureus* have similar growth conditions it follows that if coliforms could enter the whey and multiply, then it is possible that *S. aureus* also could have made its way into the product and multiplied. However, the presence of coliforms does not mean that *S. aureus* is present.

Since the time limit for cooling whey starts with draw from the vat and ends when the whey is either pasteurized or cooled to 45^0 F, the process for documenting how the whey has been handled involves both the producer and the processor of the whey. In some cheese plants, they are one and the same but in Wisconsin, often one plant produces the cheese/whey and another plant processes the whey. A variance in this case requires the involvement of both plants collecting data and samples.
A typical process for handling whey that is not cooled

or pasteurized within the four hour time limit involves documenting time, temperature, pH, any use of hydrogen peroxide and coliform levels throughout processing until it is cooled/pasteurized. Limits are set for time and coliform counts along with the outcomes for whey that do not meet conditions for time and coliform counts. The conditions and limits are listed in the variance.

Advancing Our Knowledge

When CDR and DATCP started working together several years ago, it quickly became apparent that we were lacking the knowledge about how *S. aureus* behaves in whey. This lack of information brings us back to the regulatory requirements of less than 45^0 F or greater than 140^0 F within four hours of production for storage of raw whey. When information is lacking you use the information available to you. Therefore, because it has been established that milk can safely be held under the above conditions, that information was used in developing regulations. What was not known was whether whey from pasteurized milk could be held safely at temperatures greater than 45^0 F which would allow for reduced cooling costs and capacity.



Earlier this year, DATCP, Wisconsin Cheese Makers Association (WCMA), Food Research Institute (FRI) and CDR worked together to develop a plan for finding answers to the questions about how *S. aureus* behaves in whey. The outcome of the meeting was a project that looked at *S. aureus* growth under several different conditions. Questions to be answered included:

- How does the presence of starter bacteria and acid production affect *S. aureus* growth?
- What is the effect of temperature on *S. aureus*?
- What is the effect of hydrogen peroxide on *S. aureus* growth?
- What are the Z- and D- values for *S. aureus* in whey?

With these questions in mind, a study was designed to look at the growth of *S. aureus* (a strain known to cause illness) in the presence of both mesophilic and thermophilic cheese cultures. Sweet whey was to be held at either 70^0 F or 90^0 F both with and without the addition of hydrogen peroxide at either 10 or 100 ppm.

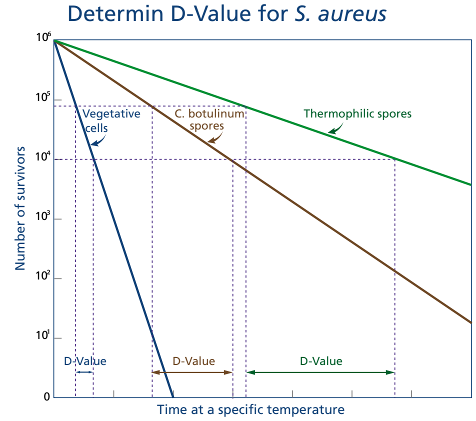
A hydrogen peroxide concentration of 10 ppm was chosen based on a provision in the CFR that permits the use of this low level of hydrogen peroxide in whey. The higher concentration was selected because it is the upper concentration permitted at this time by DATCP. The study looked at whey both with and without hydrogen peroxide because it is very possible that hydrogen peroxide use will be greatly limited in the future. End user requirements have been limiting the use of hydrogen peroxide and those restrictions are not expected to ease in the future. Applications such as infant formula typically do not allow the use of hydrogen peroxide in whey ingredients.

Microbial Exponential Death Rate (10-Fold Reduction)

Time (minutes)	Deaths per minute	Number of Survivors	Number Log
0	0	1,000,000	10^6
1	900,00	100,00	10^5
2	90,000	10,000	10^4
3	9,000	1,000	10^3
4	900	100	10^2
5	90	10	10^1
6	9	1	10^0

The determination of Z- and D- values is especially important. Decimal reduction values or D-values are the time in minutes needed to kill 90 percent of the bacteria. Said another way, it is the time in minutes needed to achieve a 10-fold reduction in the population of a specific bacteria or type of bacteria at a given temperature and solution conditions (pH, total solids, etc.). Typically vegetative cells, like cheese cultures and *S. aureus*, have a lower D-value as compared to bacterial spores. Once you know the D-value for a microorganism you can determine the Z-value. A Z-value tells you the time and temperature that kills 1 log of a specific bacteria. For example, it would tell you how long you would have to hold whey at 140^0 F to kill 1 log of *S. aureus*.

Determin D-Value for *S. aureus*



Once you know the Z-value for *S. aureus* in whey, you can design a heat treatment that would be an additional layer of safety for whey that is not cooled immediately to 45^0 F. An additional benefit of such a heat treatment would be a reduction in the number of cheese culture

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Dr. Mark Johnson and Marianne Smukowski Inducted into La Guilde Internationale des Fromagers

Please join CDR in congratulating CDR Assistant Director and Distinguished Scientist Mark Johnson, Ph.D., and CDR safety and quality coordinator Marianne Smukowski on their recent induction into La Guilde Internationale des Fromagers, which occurred during the American Cheese Society Annual Conference in Des Moines, held July 27-30, 2016. They now join the more than 6,000 Guilde members who have been selected over the years for their know-how and respect for tradition.

Marianne Smukowski Receives Above and Beyond Award

In addition to her induction into La Guilde Internationale des Fromagers, Smukowski also received the Above and Beyond Award from the American Cheese Society in recognition of her outstanding contributions to the cheese industry.

Marianne Smukowski & Mark Johnson with La Guilde medals.

Dr. John Lucey Receives KraftHeinz Teaching Award in Dairy Manufacturing

Please join CDR in congratulating Dr. John Lucey on being named the 2016 recipient of the Kraft Heinz Teaching Award in Dairy Manufacturing. This award recognizes "outstanding teaching of undergraduate students in dairy foods," and was presented to Dr. Lucey at the American Dairy Science Association® (ADSA®) Annual Meeting in Utah.

Rodrigo Ibáñez Alfaro, Luis A. Jiménez-Maroto, Dr. John Lucey, Jessica Stankey, Som Khanal

Dairy Ingredients Research Update

Two studies detailing the potential usage and functionality of whey protein phospholipid (WPPC) concentrate and delactosed permeate (DLP) were recently published in the Journal of Dairy Science, September 2016 edition. Both studies were conducted by UW-Madison graduate student Maddy Levin, CDR Dairy Ingredients, Cultured Products and Beverages Coordinator KJ Burrington and UW-Madison Food Science Professor Richard Hartel.

Journal of Dairy Science

"Composition and functionality of whey protein phospholipid concentrate and delactosed permeate" analyzed four WPPC samples and one DLP sample for chemical composition and functionality. According to the report analysis showed that WPPC composition was highly variable between suppliers and lots and that functionality of the WPPC varies depending on the supplier. Additionally, the study showed that WPPC has a high water-holding capacity, is relatively heat stable, has low foamability, and does not aid in emulsion stability. For more on this study visit: www.cdr.wisc.edu/ingredients/research

"Whey protein phospholipid concentrate and delactosed permeate: Applications in caramel, ice cream, and cake" investigated the potential applications of WPPC and DLP blends in foods. As the title suggests, the study looked at the application of these ingredients in caramel, ice cream and cake. In terms of the ice cream, WPPC was added as an emulsifier and it was discovered that WPPC decreased the amount of partially coalesced fat and increased the drip-through rate, making WPPC a viable and affordable alternative to synthetic emulsifiers. In terms of cake, WPPC and DLP were added as egg replacers and very little difference was seen in the end product making WPPC and DLP viable and affordable options for egg replacement. In terms of caramel, however, the use of WPPC and DLP caused cold flow to increase significantly, and hardness and stickiness to decrease leading the researchers to believe that WPPC and DLP do not work well as ingredients in chewy caramels but may be better suited for caramel sauces For more on this study visit: www.cdr.wisc.edu/ingredients/research

TRAINING THE NEXT GENERATION

Submitted by Debra Wendorf Boyke, CDR

A trained workforce is an ongoing concern for everyone in the dairy industry, from line employees to R&D staff. During last year's CDR Industry Team (CIT) Research Forum, companies discussed concerns about the significant reduction in the number of graduate students coming out of U.S. universities that are experienced in dairy. One of the major challenges is finding new dairy graduates to replace retiring, experienced staff. A major contributor to this problem is the significant reduction in basic research funding available to universities; funding which is used to hire and train graduate students.

A solution to this important issue will need to involve collaborative efforts between universities, industry and research funders. CDR is taking the first step by initiating collaboration with its own Industry Team to create a fund to support two research projects each year, and thus two graduate students. In addition, CDR Director, Dr. John Lucey encouraged individual companies to contact him if they are interested in working with CDR to recruit a student to work on a research topic related to an area of interest to that company. The Wisconsin Cheese Makers Association has already stepped forward to participate in this effort.

Last fall, CDR worked with its Industry Team to have them select two projects that will be CIT-funded beginning with the fall semester 2016; one related to cheese and one related to dairy ingredients. Those projects are:

- Cheese: Use of microfiltered milk in cheesemaking (e.g. for the manufacture of standardized cheeses)
- Dairy Ingredients: Use of microfiltration to generate customized milks, fermented dairy products or ingredients (e.g. beta casein) for specialized applications

We are thankful to our Industry Team for their willingness to collaborate with CDR to be part of the solution. It's a win-win situation. We're training more students to understand dairy foods while at the same time researching topics of interest to the dairy industry. This type of collaboration speaks volumes to the forward-thinking companies that make up CDR's Industry Team, and the advantage of working together on critical issues for our industry.

Please Join CDR in Welcoming Nils Irland

As the IT Systems Administrator, Nils maintains the computer systems used by staff at the Center for Dairy Research and assists with day-to-day technical support. Nils comes to CDR with more than a decade of experience in information technology but his passion for IT goes back to his early childhood. In fact, Nils built his first computer at the age of fifteen before going on to earn his B.S. in Computer Science at the University of Wisconsin–Madison. Since his graduation in 2006 Nils has had the opportunity to participate in a number of unique IT-related projects including one at the South Pole as a part of the University's IceCube project.

While his interests are diverse, Nils remains passionate about information technology. He particularly enjoys the fact that the field is always changing, which allows him to remain curious and continue learning on a daily basis. Please join us in welcoming Nils to CDR!

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bacteria that continue to produce acid in warm whey.

Given the input from DATCP, WCMA, FRI and CDR it was agreed that FRI would do a study to answer the above questions about *S. aureus* with WCMA providing funding for the study. DATCP and CDR would then be able to use the information to hopefully develop some alternatives for processing whey that did not require cooling to less than 45^0 F but would maintain both safety and quality of the whey.

All of this brings us to where we are today. The study is in its final stages with the final results to be published in peer reviewed journals. Some of the preliminary results have found that, as expected, *S. aureus* can grow in sweet whey held at either 70^0 F or 90^0 F, however, it grows much slower at 70^0 F. Hydrogen peroxide at 10 ppm slows the growth of *S. aureus* and at 100 ppm kills *S. aureus*.

The growth of cheese cultures and their subsequent production of acid did not kill *S. aureus*. Cheese cultures continued to produce acid at either temperature but pasteurization of the whey especially with subsequent holding at 70^0 F significantly slowed the decline in pH.

It is hoped that we will be wrapping up the study this fall with publication of the results to follow thereafter. It is important to note that this work was only made possible by the collaboration of DATP, CMA, FRI and CDR. By working together these four groups were able to construct a study that would reflect real life conditions in the cheese/whey industry with the end goal of ensuring cost effective methods for producing a safe, high quality product.

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Short Course Calendar:

- Cheese Grading, November 2–4
- Ice Cream, November 30–December 2
- Milk Pasteurization, January 3–4
- Batch Freezer Workshop, January 10–12
- Certificate in Dairy Processing, January 18– April 4
- WI Process Cheese, February 21–22

For detailed information on each CDR short course:
www.cdr.wisc.edu/shortcourses

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