

# DAIRY PIPELINE

## Exposing the perfidy of biofilms

After decades of research, we have learned a great deal about the microbial environment of a cheese vat. For example, we know that nonstarter lactobacilli (NSLAB), present initially in pasteurized milk at less than 1 per ml., will become the dominant bacteria in cheese. We also know that this isn't necessarily a bad thing; nonstarter bacteria contribute to the development of desirable cheese flavor. However, NSLAB can be the culprits behind some costly cheese defects, including off flavors, gas formation and that pesky (though aside from its effect on sales; harmless) problem of calcium lactate crystal formation.

How do NSLAB contaminate a vat of cheese to cause problems? A recent study published in the *Journal of Dairy Science* (84:1926-1936) supports the author's hypothesis regarding a possible source—biofilms. Amy Wong and Eileen Somers, Food Research Institute, worked with Mark Johnson, CDR, to investigate the ability of NSLAB's to form biofilms that can dislodge during cheesemaking and contaminate cheese.

### Biofilms are the sessile form of bacteria

Although scientists have been aware of biofilms since they had microscopes to see them, most of our focus on bacteria has been on individual cells, or planktonic bacteria. Only in the last few decades have we begun to understand the role of biofilms, the sessile form, in bacterial growth and colonization. (See side bar) In the medical world, biofilms have been implicated in gum disease, childhood ear infections and infections in knee and hip replacements. In the dairy industry, we know that biofilm formation allows bacteria, including pathogens, a better chance to survive both clean in place (CIP) systems and sanitizers.

Can NSLAB form biofilms, too? That was one of the research questions Wong's group asked. In addition, they wondered if they could demonstrate

that a preformed biofilm could contaminate a vat of cheese. The scientists used two different NSLAB, *Lactobacillus curvatus* JBL2126 and *Lactobacillus fermentum* AWL4001 in their study. The effects of contamination by these bacteria become obvious as the cheese ages; *Lactobacillus fermentum* can produce a gassy defect, which causes cracks and blown packages. Cheese contaminated with *Lactobacillus curvatus* develops the white haze of calcium lactate due to high levels of D(-) lactic acid. (See *Curd Clinic* for a thorough review.) In addition, the researchers used pulsed-field gel electrophoresis (PFGE), a technique based on genetic analysis, to accurately identify bacterial strains.

To assess the ability of NSLAB to form biofilms, these researchers inoculated pasteurized milk with *Lactobacillus curvatus*, made cheese and then cleaned and sanitized the vat before making another vat of cheese without adding *Lactobacillus curvatus*. The result: at six months the numbers of *Lactobacillus curvatus* in the second batch of cheese were comparable to the numbers in the inoculated batch. Both had heavy growth of calcium lactate crystals.

### NSLAB biofilms

In the second set of experiments, the researchers placed stainless steel chips coated with biofilms on the bottom of the vat before adding milk for cheesemaking. These chips were prepared in advance by the researchers who had cultivated the growth of biofilms of *Lactobacillus curvatus* and *Lactobacillus fermentum*. The result: contamination of the cheese with the biofilm NSLAB.

In another set of experiments, sterilized chips were placed in the vats before milk addition. Some chips were removed after cheesemaking, some were removed after cleaning, some were removed after sanitizing and the rest were removed after sanitizing but left out overnight to mimic overnight storage of the cleaned equipment. After removal

*continued on page 4*

### What's Inside:

Exposing the perfidy of biofilms .....	1
To Pasteurize or Not To Pasteurize .....	2
News from CDR .....	8
Skimming the Shelf .....	9
Curd Clinic .....	10

# To Pasteurize or Not To Pasteurize (Cheese Milk) —That is the Question

*Rusty Bishop, Ph.D., Director, Wisconsin Center for Dairy Research*

The cheese industry continues to be faced with the decision of how to treat their cheese milk prior to manufacture. Do I make cheese from raw milk, heat-treated milk, or pasteurized milk? What are my considerations? How will this affect the flavor, texture, functionality, safety, and/or quality of my cheese? Does this decision depend on the type of cheese being manufactured? What do my buyers prefer? What do my consumers prefer? How will this influence my marketing? How will this influence product liability? What is the ultimate “image” of my product?

These are definitely considerations every cheesemaker must take into account when such a decision is made. There have been numerous articles, and a few testimonials (some paid for), regarding the virtues of raw milk cheese. There are just as many articles supporting a heat treatment of some sort, whether it be a non-specified heat-treatment, a specified timed and sealed heat-treatment, or a certified pasteurization treatment. The utmost consideration must be the health and safety of consumers. It is crucial that the information used to make these decisions be science-based, but also take into account present industry practices.

The consideration of present industry practices must be based on true numbers and properly defined treatments. At least 95% of U.S. cheese is manufactured from pasteurized milk. Certain advocates would have you believe the other 5% of cheese is made from raw milk. Legally, this is a true statement, but, technically, this statement is incorrect. Of the remaining 5%, 4.9% is heat-treated and less than 0.1% of U.S. cheeses are made from untreated raw milk.

## **Code of Federal Regulation**

Presently, the CFR mandates, “If the dairy ingredients used are not pasteurized, the cheese is cured at a temperature of not less than 35°F for at least 60 days.” Therefore, this 60-day aging requirement includes heat-treated and true raw milk cheeses. We must also investigate the reasons for each of the treatments or non-treatments of milk for cheesemaking. Raw cheese milk and heat-treated milk cheese proponents argue that this milk is necessary for proper flavor development and texture. Others state they have conclusive evidence, especially with hard, ripened cheeses, that this can be accomplished with the use of starter adjuncts and other technologies available to the industry. (This may not be true for a small, select group of mold-ripened, soft cheeses.) Mandated pasteurization is viewed by a large portion of the manufacturers as necessary to insure the health and safety of the food. There is also the portion of “non-standardized” cheeses that are manufactured that are not specifically covered by the CFR 133 regulations. These products, however, are covered by the CFR in 1240.61, which states, “Mandatory pasteurization for all milk and milk products in final package form intended for direct human consumption.”

Where do we as an industry turn? What technologies are available to insure targeted product quality and attributes, and safety parameters (as determined by regulatory agencies, manufacturers, and the consuming public)? There has been much work undertaken in Europe and the U.S. on

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“ The consideration of present industry practices must be based on true numbers and properly defined treatments.”

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“alternate technologies” which could replace pasteurization or minimize the severity of necessary heat treatments. These include bacteriophage, high pressure, irradiation, microfiltration, pulsed electric field, ultrasonication, and hurdle technology (a combination of treatments with and without heat). It is likely that each of these would be used in combination with a specified heat treatment to assure all product attributes and safety parameters required.

Ongoing work within the Codex Committee on Food Hygiene is attempting to define crucial terms such as, “Appropriate Level of Public Health Protection” and “Food Safety Objectives.” These will become the basis for international trade of food and will ultimately be defined by the country of manufacture and the country of sale. These may be defined as “equivalent to pasteurization” by some countries, and “causing an ‘acceptable’ number of illnesses” by others. What are our Food Safety Objectives and what do we define as the Appropriate Level of Public Health Protection?

Each of the three possibilities for cheese milk (raw, heat-treated, and pasteurized) may fit this situation, with certain critical accompanying considerations. If raw milk cheese is manufactured, how do we assure the consuming public the milk utilized was of the highest quality and safety that would present zero risk? A signed affidavit from a producer stating assurance of certain practices is definitely NOT adequate. If it were, we would no longer need any regulatory oversight of industry as they could all just sign a piece of paper and be done with it. France has a raw milk and farm quality program (“Happy Cow”) to provide these assurances, but the reported cases of food-borne illnesses for raw milk cheeses in that country would lead one to believe that it is not working. Maybe the issue comes down to a “truth in labeling” issue of making the consumer aware they are consuming a cheese made from raw milk or heat-treated milk or pasteurized milk, and potential risks involved with each. As mandated for unpasteurized juices, “WARNING: This product has not been pasteurized and, therefore, may contain harmful bacteria that can cause serious illness in children, the elderly, and persons with weakened immune systems.”

### Hurdle technology

This route also demands a definition for “heat-treated” milk used for cheesemaking. This would require a specific time/temperature combination delivered within a timed and sealed system. For each sub-pasteurization treatment, there would also be an aging requirement as part of the “hurdle technology” approach. Each step in the process (farm to consumer) would be responsible for reducing the potential pathogen load in a product to an acceptable level (zero in the U.S.) for consumption.

This discussion leads us to a possible solution which has 3 possibilities of milk treatment, or not, for cheesemaking:

### Pasteurized milk

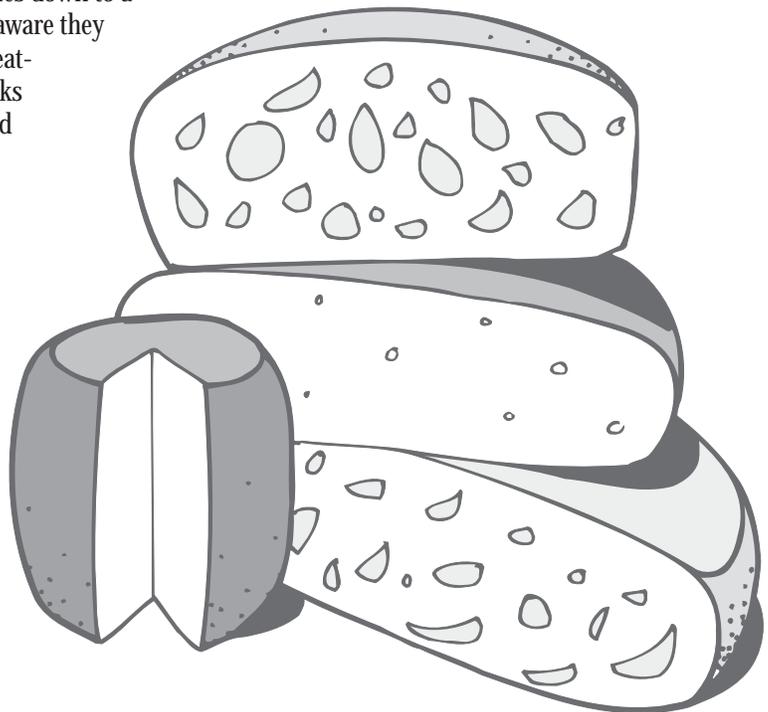
timed and sealed system  
no aging requirement (other than specified cheeses)

### Heat-treated milk

≥148°F, 16 seconds, but less than pasteurization  
timed and sealed system  
60-day aging requirement

### Raw milk

heat-treatment less than “heat-treated”  
no system requirements relative to timing/sealing  
60-day aging requirement  
labeling requirement similar to that for unpasteurized juices (stated earlier)



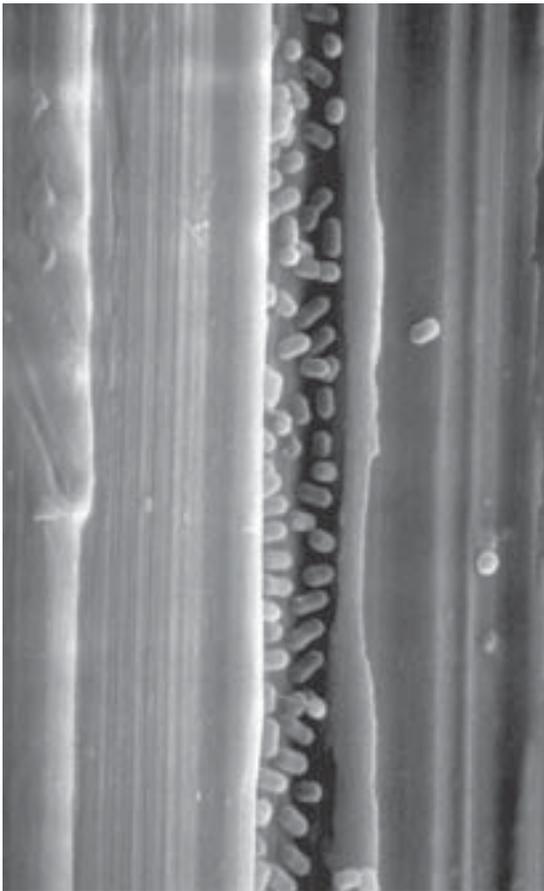
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*Stainless steel harboring an early stage biofilm of Listeria monocytogenes*

from the vat, the researchers attempted to harvest and grow bacteria from all the chips—looking for evidence of living bacteria. The result: total lactic acid bacteria numbers, mostly starter culture, decreased after each cleaning step, with the biggest decrease after scrubbing. However, the starter culture and the two experimental strains all showed some tolerance for chlorine and heat.

After analyzing the data here's what they concluded: NSLAB, common contaminants of cheese, can live in biofilms that survive the cleaning process to dislodge and contaminate cheese. One of the most surprising findings was the small number of microorganisms that can grow enough to contaminate cheese. Stainless steel chips were prepared with *Lactobacillus curvatus* biofilms of varying bacterial levels and placed in the vat before cheesemaking. The lowest counts, ( $7.2 \log_{10}$  cfu total), assuming all bacteria were dislodged, produced a concentration of  $2 \log_{10}$  cfu/ml in the cheesemilk. This was enough to assure growth of calcium lactate crystals in four month old Cheddar cheese.

### **A single inoculated square contaminates the vat**

Although they did not include this finding in their study (they hadn't repeated it yet), Wong and her collaborators were surprised to find that a single inoculated square placed in the vat was able to contribute a contaminant. Thus, fewer than 30 cells per ml of milk, a very low load, could eventually compete with the starter culture and show up in the cheese. Think of it this way, an area of biofilm roughly comparable to the size of a handprint could potentially contaminate an entire double-o cheese vat.

Dr. Wong emphasizes that, "These nonstarter bacteria are everywhere in the plant environment. We found some on equipment surfaces and later found the same strain in the cheese." She suggests a holistic approach to the problem that would include more frequent and thorough cleaning. Right now, the best way to handle biofilms is to work at preventing their formation. According to Wong, "Biofilms are an insidious problem because they are mostly invisible. But if you can see it, then it is *really* a problem."

Scientists are actively working on methods to control biofilm attachment. One approach is to develop something that is able to coat a surface and disrupt attachment. Bower et al have suggested that applying antimicrobial proteins to surfaces might inhibit attachment, particularly if enzymes designed to retain activity could be developed. A group of researchers from New Zealand (Flint et al) found that "Proteolytic enzymes removed more biofilm cells of thermo-resistant streptococci than cleaning chemicals routinely used in dairy manufacturing plants."



# The benefits behind the communal nature of biofilms

From ants to prairie dogs to humans, individuals interacting and working together as a community present a familiar concept we know and understand. Now it turns out that is a common scenario in the bacterial world, too.

For decades bacteria have been labeled primitive; seen only as unicellular organisms struggling to survive on their own. This idea is now evolving to a concept of a bacterial life that includes a community able to communicate, coordinate growth and even remove waste products. Scientists suspect that these bacterial shelters, or biofilms, offer a protective environment because the bacteria are embedded in a polysaccharide matrix, essentially a sugary slimy structure that they produce. If you've been to Yellowstone National Park then you have seen biofilms in the natural world; the colorful biofilm scum in the geyser pools may have been growing for hundreds of years. Other evidence of long established biofilm communities can be found in marshes and swamps. Indeed, biofilms, also known as the sessile form of bacterial life, may be a more common mode of existence than the single, or planktonic, form.

## Organized communities

Because these large groupings of bacteria are easily seen with the naked eye, we have been aware of biofilms since the first primitive microscopes. But it has only been in the last few decades that scientists have realized biofilms are a major component in bacterial life, and in fact, a very organized one. Mittleman describes a three-stage process of biofilm formation that begins when an organic conditioning film quickly coats a surface. In a dairy processing plant, milk proteins and minerals can easily provide an organic film. During the second stage, single bacterial cells serve as primary colonizers by attaching to the film and forming a community, the third stage, which is held together by a self-produced polymeric matrix. The structures that form in a mature biofilm include channels for circulating nutrients and regions that exhibit different patterns of gene expression. Some researchers suggest that critical cell densities lead to an increase in chemical signals able to then trigger expression of genes directing the architecture of biofilm formation.

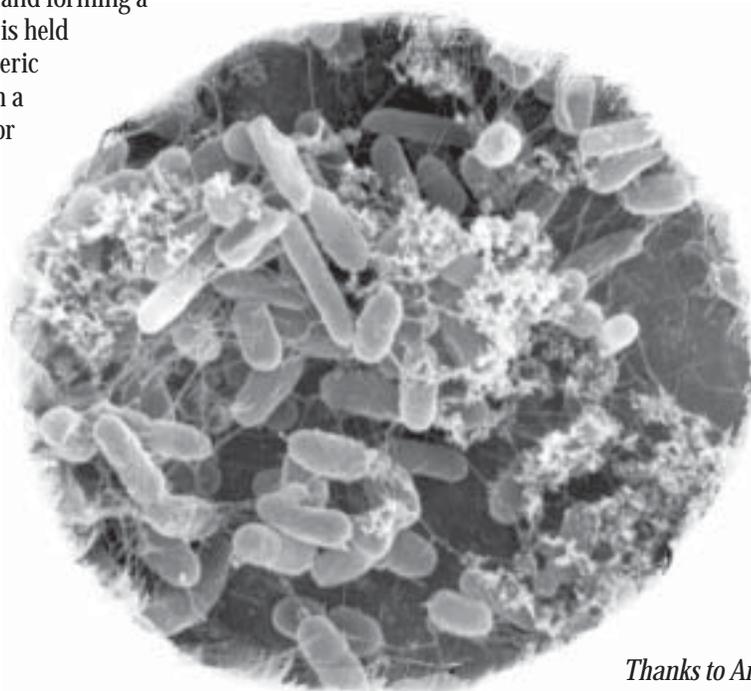
Scientists originally thought that it was the slimy structure around a biofilm that protected it from assault, resisting the effects of antibiotics, drugs and chemicals. But now they suspect several factors are at work and the communal nature of a biofilm is one that

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“Biofilms may be a more common mode of existence than the single form of organism life.”

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plays an active role in resistance. For example, bacteria produce an enzyme that can inactivate hydrogen peroxide. A lone cell can't produce enough to save itself, but a group might be able to pool resources by making enough to protect the community. Right now scientists are just trying to understand the biofilm phenomenon, learning how to control, disrupt, or perhaps harness them are tasks for the future. 🔄



*Thanks to Amy Wong, Ph.D. for the use of the biofilm photos.*

# Farmstead Focus

## Wisconsin Farm Center Awarded Grant

Norm Monsen, Wisconsin Farm Center at the Department of Agriculture, Trade, and Consumer Protection recently announced success in the grant application arena. The US Department of Agriculture awarded Wisconsin's Farm Center a grant from the Federal State Marketing

Improvement program to develop farmstead dairy systems. Successful farmstead dairy operators, farmers, DATCP employees, and interested UW Extension representatives will serve on the steering committee that will administer the grant. Expect to see a continuation of the Farmstead Dairy Field Days and some serious web site development in the future.

DATCP's Farm Center will be continuing to build on their successes—a series of Field Days generously hosted by people who have fared well in the farmstead dairy world. On September 11th Bob Wills of Cedar Grove Cheese in Plain, Wisconsin brought his cheese “partners” together to share their experience with a group interested in some aspect of a farmstead operation. Wills' five licensed cheesemakers, including one loyal employee who has worked there since 1956, make more than the cheese for Cedar Grove. They also are involved with producing cheese for a rabbi, a farmer who markets his own cheese, a group of farmers who graze their cows and have documented that the milk they use for cheese is high in CLA. (See the book review on page 8.)

In addition, Mike Gingrich, a newcomer to cheesemaking who took the Best of Show Award at the American Cheese Society this summer, makes cheese at the Cedar Grove plant on summer weekends.

If you are interested in learning more about Wisconsin's Farmstead Cheese movement, call Norm Monsen at the Wisconsin Farm Center, 1-800-942-2474



*Gathering information at the Farmstead Dairy Field Day at Cedar Grove Cheese*





*Mike Gingrich was awarded the top honor, Best of Show, at the American Cheese Society this summer. He makes his cheese at Cedar Grove Cheese Company.*

*Cedar Grove hosted the Farmstead Dairy Field Day on September 11, 2001*



## News from CDR

CDR welcomes two new food scientists to the fold; Alice Ping and Margaret Lubbers. After earning a Bachelor of Science in Food Engineering from South China University of Technology, Alice completed a Master of Science in Food Science from Pennsylvania State University. She brings both a strong interest and a broad background in sensory analysis and evaluation, timely skills for CDR research projects.

If you have been involved in any projects with CDR down in the pilot plant then you might have already met Margaret Lubbers. She works closely with John Jaeggi, coordinator of CDR's Cheese Applications program and Bill Hoesly, research cheesemaker. Margaret draws on her diverse dairy background; years of experience as technical service director of quality assurance/research and development for a dairy manufacturer and her education in Food Science at the University of Minnesota, and Masters in Business Administration from Eastern Illinois University.



*Margaret Lubbers*

## From the Department of Food Science

As of July 1, 2001, Professor Bill Wendorff took on the responsibility of Chair of the Department of Food Science. He follows the reign of Jim Steele, who is resuming his research and teaching program. Bill brings ample administrative experience; over the past 12 years he has developed and coordinated 11 different short courses for the dairy industry. In addition, Bill has conducted an applied research program focused on physical and sensory problems in cheese and regulatory and environmental issues in the dairy industry.

Scott Rankin, assistant professor, is the newest member of the Department of Food Science. Scott established a major extension program at the University of Maryland before moving on to Madison to continue outreach to the dairy industry. His extension niche here includes fluid milk, ice cream and cultured products. Scott's research program will focus on the sensory properties of dairy products and frozen desserts.

Assistant professor John Lucey was awarded the 2001 Foundation Scholarship Award from the American Dairy Science Association in July, 2001. John is well known for his research on the rheology and gelation of milk proteins. He is currently investigating molecular interactions during the melting of cheese.

Achyuth Hassan, UW Food Science graduate student under Dr. Lucey, won the ADSA graduate student paper competition with his presentation "Development of two analytical methods to quantify the concentrations of insoluble and soluble calcium in Cheddar cheese". ☺



*Alice Ping*

# Skimming the Shelf—



## What's New in Print?

### The Omega Diet

by Artemis O. Simopoulos, M.D. and Jo Robinson

I'm always skeptical of diets that make enthusiastic claims to solve or improve chronic health problems and the Omega Diet makes its share of pronouncements that brought out the skeptic in me. However, this book helped me learn about types of essential fatty acids in the diet, and the differences between them.

For years we have all heard about Mediterranean diets that may protect against the cardiovascular diseases rampant in the United States. I knew fish oil was supposed to be good for me, and in the last few years the trans fatty acids in margarine spreads were supposed to be very bad. I wasn't sure why. After reading Simopoulos's book, I feel that I can at least formulate questions. (Then I'll go to the scientific literature and sort through the studies.)

It turns out that the "healthy" Mediterranean diet is best exemplified by the food habits of the people living on the Greek island of Crete. According to Simopoulos, in the 1960's a fifteen-year study revealed that "men from Crete were healthier than all the other 12,000 men surveyed in seven quite different countries—Greece, Italy, the Netherlands, Finland, Yugoslavia, Japan and the United States." The men from Crete really stood out; compared to Americans they had half the cancer deathrate and one-twentieth of the mortality from coronary artery disease.

Simopoulos grew up on the Greek island of Crete and went to college in the United States, so she experienced first hand the differences between the two cultures and the corresponding diets. She believes that the ratio of essential fatty acids (EFAs) in the Crete diet explain the beneficial effect on the cardiovascular system.

Omega 3 fatty acids are the stars of this approach, which include monosaturated oils like olive oil and canola oil and polyunsaturated oils like fish oil, flaxseed oil and walnut oil. But guess what, you don't have to give up butter! Simopoulos recommends mixing it with canola oil or olive oil to form a spread.

According to this book, it is the ratio of omega 6 fatty acids (like corn oil, peanut oil, safflower oil, cottonseed oil, etc.) to omega 3 fatty acids that is totally out of whack in the typical American diet. Simopoulos notes that, as we evolved during the Paleolithic era, the ratio of omega 6 to omega 3 EFAs was less than 4 to 1. Today, many of us have gone overboard, ingesting fourteen to twenty times more omega 6 than omega 3 fatty acids. We are upsetting the optimal balance of fatty acids developed in our formative evolutionary years.

What is really missing from this book is a chapter on conjugated linoleic acid, or CLA. Some researchers have been impressed by the anti-cancer benefits of this omega 6 fatty acid which is found in many dairy products. Grass fed cows produce milk with even higher levels of CLA, which do find their way into the cheese made from this milk.

Curious about the Omega diet? Simopoulos includes three weeks of menus, and the recipes you'll need to follow it. Enjoy. 🍴

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Guess what, you don't have to give up butter!

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# Curd Clinic

Curd clinic doctor for this issue is Mark Johnson, senior scientist, CDR

**Q.** Despite my best efforts, once in awhile I still have trouble with calcium lactate crystal formation on my cheese. What can you tell me about this issue?

**A.** You certainly aren't the only cheesemaker who wants to know more about calcium lactate crystals, it is a question that comes up often. Let's review what we know. During distribution and handling of Cheddar cheese, a white crystalline material sometimes forms on the surface of the cheese. Although this material—calcium lactate—is harmless, consumers avoid it.

Several years ago we investigated the development of calcium lactate crystals on the surface of Cheddar cheese. We designed our experiments to test manufacturing, packaging and storage conditions to determine what caused crystal growth, and what could effectively prevent it. This is what we found.

## Crystals are a mixture

The calcium lactate crystals were a mixture of two forms of lactic acid, L(+) and D(-). Each is produced by separate groups of bacteria. The *Lactococcus* sp. used as a starter for Cheddar cheese can only produce L(+) lactic acid while some non-starter lactobacilli can convert L(+) lactic acid to D(-) lactic acid. Although *Lactobacillus helveticus* adjunct bacteria, which is sometimes used to enhance the flavor of Cheddar cheese, can ferment lactose to both forms of lactic acid it is not very good at converting L(+) to D(-) lactic acid. The dominant lactobacilli found in Cheddar cheese are *Lb. casei* strains and they are very capable of "racemizing" the L(+) to D(-) lactic acid.

We found that calcium lactate crystal formation on the surface of Cheddar cheese is linked to the following factors: growth of *Lactobacillus* sp. (greater than 1 million per gram of cheese), total amount of lactic acid (usually greater than 1.4% but we have seen crystals in cheese with 1.2 % lactic acid), racemization of lactic acid (at least 20% but more commonly 40% or more of the total lactic acid in the cheese in the D(-) form. Indeed the correlation was so strong that we rarely saw a cheese with crystals that did not meet all three observations. However, not all cheeses that meet these criteria developed crystals.

We noticed that crystals were more likely to develop when the packaging material did not make a tight contact with the cheese surface. Indeed, crystals developed in wrinkled areas, at the sides or at the ends of the package. We observed vacuum-sealed cheeses that were high in lactic acid (1.65% total lactic acid, 50% in the D(-) form) that did not exhibit crystals while cheeses that were gas-flushed had a much greater tendency to develop crystals. If we pricked the vacuum-packaged cheeses with a needle to create an area where the packaging material did not fit tight to the cheese, crystals would develop in this area. Eventually they would spread across the surface of the cheese.

## Temperature fluctuations

Temperature fluctuations are common in retail cheese displays. When we tested the effect of fluctuating temperatures, we found they increased the propensity of the cheese to develop crystals. In many cases we also observed that the packaging material might pull away from the cheese, especially if the high temperature was above 48°F.

Light exposure per se did not cause calcium lactate crystals to develop. However, if the exposure to light caused the surface of the cheese to warm, cheese serum might accumulate at the surface, especially in areas where the packaging material was not tight, and crystals would develop. Microbial metabolism (increased with warmer temperatures) might result in CO<sub>2</sub> production, which would in turn "open" the package. Crystals would develop at a faster rate when the cheese was subsequently lowered to 40°F but storing cheese at lower temperature (40°F) without temperature fluctuation did not prevent crystal formation.

In the past three years a "new" variation of the crystal was brought to our attention that did not meet any of the three criteria except one, high lactic acid content (usually greater than 1.6 %). We have now found calcium lactate crystals that are almost pure L(+) lactic acid; very little (less than 5%) D(-) lactic acid is present in the cheese and we calculated less than 10,000 lactobacilli per gram of cheese. We can reproduce the crystal defect in cheese making experiments, producing crystals in less than 6 weeks.

## Preventing calcium lactate crystals

The two most successful methods to prevent the appearance of calcium lactate crystals are to lower the lactic acid content to below 1.4 % and to vacuum package the cheese. A continuing problem is that all cheese is not vacuum packaged, so the potential for crystal formation will remain.

Our initial approach was one of looking for correlations. This type of approach will not answer questions regarding the whys and wherefores behind the chemistry of calcium lactate crystallization—more details are necessary. DMI has recently approved a grant to Land o' Lakes (Arden Hills, MN) in collaboration with Dr. Rich Hartel (UW Food Science Department) to study the chemistry of calcium lactate crystallization. Results will give technologists the ammunition they need to develop manufacturing procedures that will lessen the likelihood of crystal formation in Cheddar cheese.

Dybing (et al, JDS 1988) speculated that high ionic calcium in cheese would help promote crystal formation. Keep in mind that, after all, these crystals are calcium and lactic acid. We are exploring this avenue in more detail, especially in the context of calcium equilibrium in milk and cheese and the use of concentrated milks (RO, UF, NFDM). ☺

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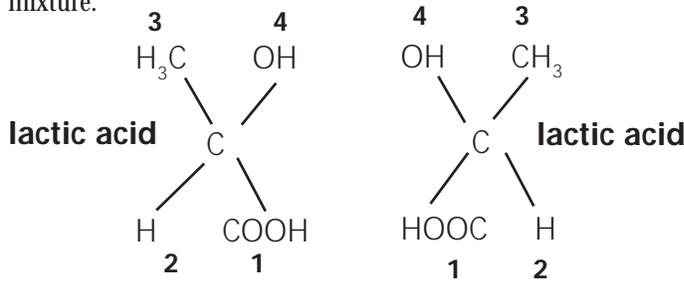
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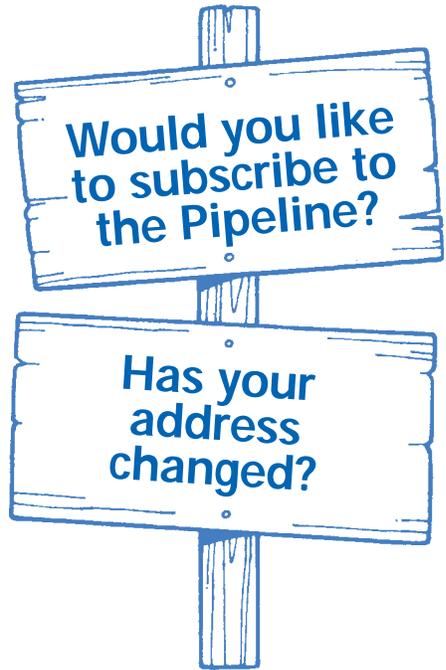
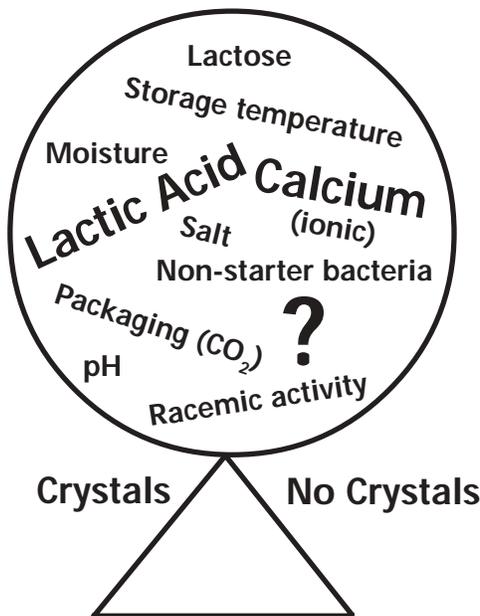
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**About lactic acid...**

Lactic acid exists in two forms, or isomers. Each form consists of a carbon atom surrounded by four different atoms, in this case a carboxyl group, hydrogen, a methyl group and a hydroxyl group. These two forms are mirror images, and they differ from each other in the way they reflect polarized light. The dextro-rotatory form, or d(-) lactic acid rotates light to clockwise while the levo-rotatory form, or l(+) lactic acid rotates light counter clockwise. A mixture of equal amounts of the d(-) and l(+) forms gives an inactive or racemic mixture.



Do these two forms differ in solubility? According to the Merck Index, the bible of chemists everywhere, both forms are extremely soluble, however the d(-) lactic acid may be slightly less soluble. But does that matter in the cheese world? We really don't know. So many variables (see diagram below) influence the development of lactic acid crystal formation in cheese; solubility of isomer forms is only one of them.



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You can also find the Dairy Pipeline on our website: [www.cdr.wisc.edu](http://www.cdr.wisc.edu)

## Calendar

**Jan. 8-10 Milk Pasteurization and Process Control School.** Madison, WI. Call Scott Rankin at (608) 263-2008 for information, or the CALS Outreach Services (608) 263-1672 to register.

**Feb. 19-20 Quality Milk Conference (WI Dairy Field Reps).** Madison, WI. Call Bill Wendorff at (608) 263-2015.

**Feb. 26-27 Wisconsin Process Cheese Short Course.** Madison, WI. Call Jim Path at (608) 262-2253 or Bill Wendorff at (608) 263-2015 for more details.

**Mar. 18-22 Wisconsin Cheese Technology Short Course,** Madison, WI Call Bill Wendorff at (608) 263-2015.

**Mar. 25-28 Premium Ice Cream Short Project,** Madison, WI. For information, call Scott Rankin at (608) 263-2008.



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