Wisconsin Center for Dairy Research

Dairy Pipeline

25 YEARS 1989-2014 DAIRY PIPELINE

Volume 27 Number 4, 2015

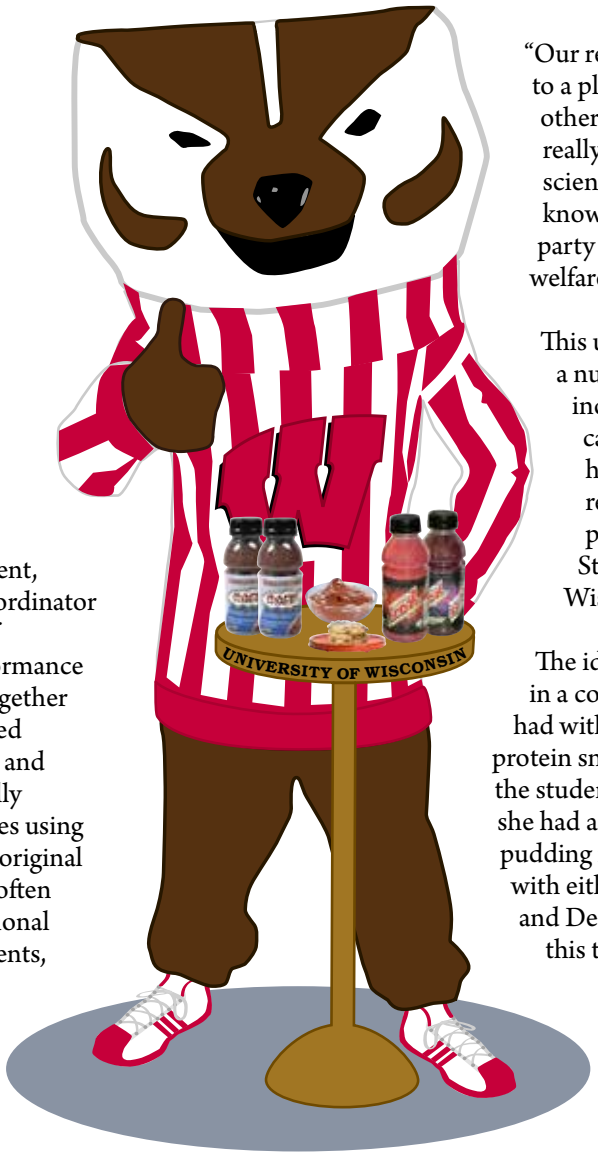
A Technical Resource for Dairy Manufacturers

IF YOU WANT TO FEED A BADGER

FROM FOOD SCIENCE TO THE FIELD

The Center for Dairy Research is proud to contribute to the Wisconsin Idea, which seeks to improve people's lives through cutting-edge research and outreach. CDR staff strive to bring such product research and practical applications to the state's dairy industry by collaborating with companies all over the United States. The work is always rewarding, but it's particularly special when outreach efforts benefit fellow Badgers.

An excellent example of the Wisconsin Idea at work is the relationship between the UW Athletic Department and CDR. For the last five years, CDR Dairy Ingredient, Cultured Products and Beverages Coordinator K.J. Burrington and the University of Wisconsin-Madison Director of Performance John Dettmann have been working together to develop safe, wholesome dairy-based products that benefit student-athletes and the public. These products are generally manufactured by Wisconsin companies using Wisconsin ingredients and, while the original intent of the product development is often to supply student-athletes with nutritional products that fit the NCAA requirements, these products are often made available to the public as well, benefiting Badgers around the United States.



"Our relationship with CDR has evolved to a place where we really consider each other a resource," said Dettmann. "K.J. really helps me filter all the targeted science and if I want to vet an idea I know I can contact her as a neutral party that understands student-athlete welfare."

This unique relationship has resulted in a number of successful collaborations including Rapid Whey® (once called Red Whey), BadgerMax®, high protein cookies and, most recently, a high protein chocolate pudding manufactured by Silver Star Nutrition in New Lisbon, Wisconsin.

The idea of a pudding came about in a conversation that Burrington had with Dettmann about new higher protein snack ideas that could be made for the student-athletes. Burrington knew she had an instant chocolate or vanilla pudding formula that could be made with either whey protein or milk protein and Dettmann was interested in adding this to the snack offerings. Becky Kalscheuer, a food scientist at CDR, began working with Burrington and Dettmann on

the reformulation of the pudding. Kalscheuer was given the task of revising the pudding from a formula that Burrington's group had developed for a nutritional research study in 2008. When Burrington showed the pudding to Dettman and his staff they loved it. Dettman decided he wanted to add it to the available snack options and contacted Silver Star Nutrition's Brian Slater to see if they could possibly produce the mix for the Athletic Department.

"Student-athletes get sick of eating the same thing every day," said Dettmann. "It's no different than you or I, so it's important that we provide them with a wide variety of nutritional options."

Becky Kalscheuer weighing MPC.

Each snack or meal provided by the school must meet rigorous NCAA standards. As such, Dettmann worked with Burrington, Kalscheuer and Slater to develop a pudding that would satisfy the palate and also provide the correct amount of protein, omega-fatty acids and other nutrients student-athletes need to succeed. Burrington's basic recipe worked well, but there were some challenges for Kalscheuer to work out. The formula from 2008 contained whey protein isolate (WPI) with the hydrocolloids sodium alginate and xanthan gum and also modified food starch to help thicken it when mixed with water. Dettman was interested in a clean label product that would contain fewer ingredients so Kalscheuer had some work to do.

"One of the first things we did was to use milk protein concentrate instead of whey protein isolate to get more water binding ability and thickening from the protein ingredient," said Kalscheuer. "MPC binds well and creates the instant pudding texture we need with the use of fewer additives such as, sodium alginate and xanthan gum. We also removed the dextrose, maltodextrin sucralose and replaced them with granulated sugar."

Once the functionality was in place, Burrington handed the product over to Slater for further development. Slater and Dettmann have continued working together on the project which has been evolving over the past few months.

"Without K.J. it's hard to say if these products would be possible, "said Dettmann. "She really opens doors for us and provides access to people who can help us to source the right ingredients. She is an expert and knowing her expertise in the subject inspires me to be on my game when I bring her a new idea."

Brian Slater, KJ Burrington, John Dettmann

As products like the new pudding, Rapid Whey®, Badger Max® and others continue to evolve, Dettmann and Burrington are already discussing new projects that will benefit student-athletes, the public and the Wisconsin dairy industry.

"When you look at the things we offer our student-athletes it's all about Wisconsin agriculture feeding Wisconsin student-athletes," said Dettmann. A prime example of the Wisconsin Idea at work.

CDR NEWS

Welcome Jeff Henslin

As a Senior Financial Specialist, Jeff assures that all financial and purchasing aspects of CDR are running smoothly. With more than eight years of experience on campus and more than 20 years in industry, Jeff is well-versed in the many aspects of accounting and finance. In addition to providing accounting services, Jeff also greets CDR clients at the front desk and helps with events and other special activities. He enjoys the opportunity to work with CDR clients and particularly enjoys the challenges and opportunities that his role presents. When he's not working Jeff can be found cheering on the Packers, cooking, or running his own landscaping business.

Congratulations, Gina!

Please join CDR in congratulating Gina Mode on becoming President of the Wisconsin Association of Food Protection (WAFP). The Wisconsin Association for Food Protection is a non-profit association that provides leadership in food safety training and education for Wisconsin food processors.

WAFP
Wisconsin Association for Food Protection

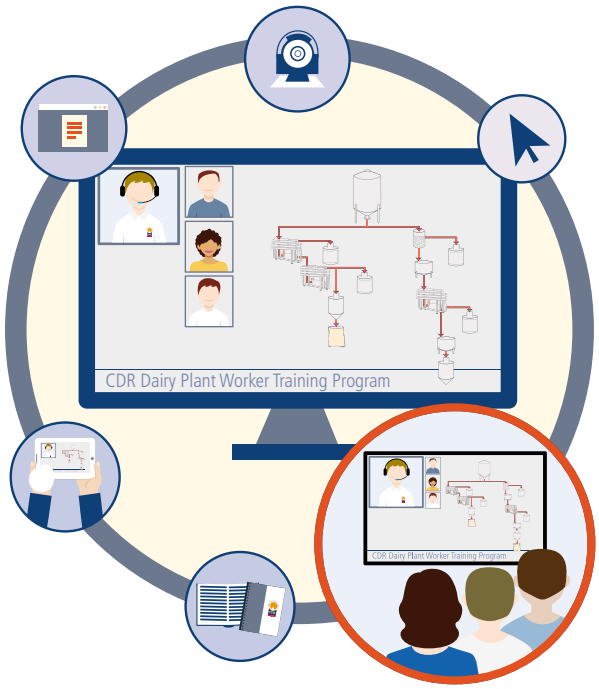
CDR WELCOMES DON OTTER AND PREPARES TO LAUNCH THE NEW DAIRY PLANT WORKER TRAINING PROGRAM

The Center for Dairy Research recently welcomed Don Otter, Ph.D. as a senior outreach specialist and coordinator of the new online Dairy Plant Worker Training Program at CDR.

With more than 30 years of experience in the dairy industry, Don has worked in both academic and industry settings. Originally from New Zealand, Don holds a Master's of Science in Biochemistry and a Ph.D. in Chemical Engineering. After graduating, Don spent a combined 11 years working for a government research lab in his home country studying processing technologies for plant, animal and microbial products. He also consulted with the dairy industry regarding the processing of sheep, goat and deer milk. For 16 years, Don worked on various properties of whey proteins at the New Zealand Dairy Research Institute and Fonterra Research Center. Finally, for the past five years, Don has been lecturing at the University of Auckland in the Food Science program, working with 15 Ph.D. and Master candidates. Don is passionate about education and is looking forward to sharing his many years of experience with dairy processing employees.

Don Otter, CDR

The inaugural Dairy Plant Worker Training class will begin in May 2016, with open registration to start in April after the official announcement at the International Cheese Technology Exposition (ICTE) in Milwaukee, Wisconsin. Plant workers in Wisconsin and/or company members of the Wisconsin Cheese Makers Association (who are supporting this initiative) will have priority registration. During the first year, Otter hopes to see three classes of 30 students go through the program with one beginning in May, the next in August and the final group beginning in late fall. Each group



will start the 10 week training program with an orientation meeting at CDR. The course will then continue with live lectures online and a new module or lesson being posted each Wednesday and exams for each module every Sunday. Throughout each ten week session, Otter will travel around Wisconsin meeting with students at various plants and to provide assistance. At the end of the ten week session students will take an extensive open-book test, in addition to completing a hands-on test with their supervisor or mentor. Students who pass the program will receive a Certificate of Dairy Processing from CDR. Please note that at this time, the program will be taught in English but in future the program may be translated to other languages.

For more information, please attend the program unveiling at the ICTE meeting April 12-14 in Milwaukee, Wisconsin or contact Don Otter at dotter@cdr.wisc.edu.

The Dairy Plant Certification online course will be composed of 10 modules each covering an important aspect of dairy product manufacturing.

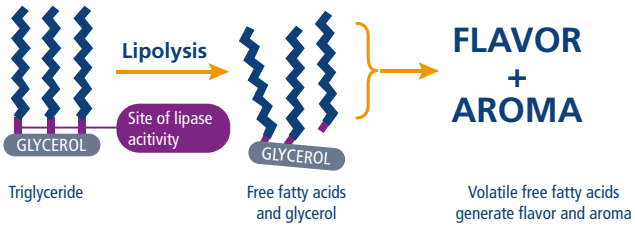
Module 1	Understanding Milk	Module 2	Milk Quality from Farm to Plant	Module 3	Processing Equipment 101	Module 4	Ingredients Used in Dairy Products	Module 5	Production of Dairy Products
Module 6	Production of Cheese	Module 7	Converting, Packaging, Ripening	Module 8	Production/ Handling of Whey	Module 9	Food Safety	Module 10	Sanitation

THE USE OF LIPASE ENZYMES IN CHEESEMAKING

Contributed by Dean Sommer, CDR

Lipase is a word that invokes dramatically different reactions from cheesemakers. To an old school aged Cheddar maker, lipase brings thoughts of horror as there are few things worse than the flavor of rancid aged Cheddar. To a hard Italian cheesemaker, lipase is a necessary ingredient in the manufacture as it is essential to obtaining the desired flavor.

To be clear, lipases are enzymes, or protein catalysts, that accelerate chemical reactions by attacking certain substrates. Enzymes act on very specific compounds and in the case of lipases, they act on fats. Lipases are not destroyed by the reactions in cheesemaking, however, and they are available to go on and catalyze more chemical reactions. In particular, they cleave fatty acids from the triglyceride molecule which can be seen in the diagram below.

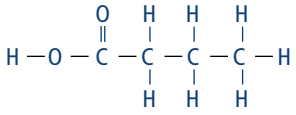


The fatty acids that are liberated from the triglyceride molecule are now called free fatty acids. The significance of this reaction in cheesemaking is that free fatty acids can have intense flavor character.

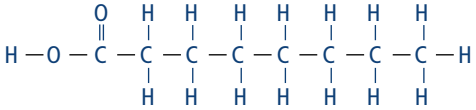
The type of flavor is linked to the length of the fatty acid chain. Technically speaking, there are many different fatty acids naturally attached to glycerol to make triglyceride molecules in milk fat. The different fatty acids are identified by their chain length or how many carbon atoms make up their backbone.

Shorter length fatty acids, such as C4 butyric acid, give cheeses sweet, piquant, baby's breath flavor notes. Medium length fatty acids, such as C9 methylated octanoic fatty acids, tend to give cheeses goaty and sheepy flavor notes. Fatty acids of longer chain length will give cheeses undesirable soapy flavor notes.

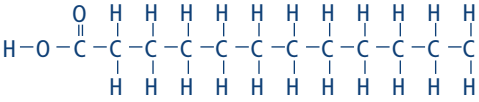
Short: Butyric Acid (C4)



Medium: Caprylic Acid (C8)



Large: Lauric Acid (C12)



In addition to a basic understanding of free fatty acids, it's also important to note that there are several different types of lipases that affect the cheese flavor differently. Native lipoprotein lipase (LPL) is the lipase naturally present in the milk that cleaves triglycerides to produce the small chain free fatty acids. LPL is easily inactivated by pasteurization and it can also be impacted by physical agitation, like over agitation of raw milk during slow cooling, or by using high speed pumps to load or unload tankers of raw milk. This agitation can break the protective membrane layer surrounding the fat globule. Once this layer is broken the lipase has access to the triglyceride. The result is the formation of free fatty acids which give the milk and the cheese made from the milk undesirable rancid flavors. These flavors generated by this process are typically harsh, unbalanced and offensive. Note that in sheep and goat milk the lipase enzyme is located on the membrane itself. This makes these milks very susceptible to the development of rancid flavors if the milk is abused. In cows milk the enzyme is found in the serum and on the casein which offers a bit more protection. There are also other forms of lipase including non-indigenous lipases, which come from microorganisms and are very thermoresitant. Consider that lipases from molds can still be active at -40 degree Celsius. There are also lipases added on purpose to give flavors to cheese.

So how does this affect cheesemaking?

Decades ago many aged Cheddar manufacturers learned the hard way that agitation causes major flavor issues. When farmers switched from can milk to bulk tank milk and initially high speed pumps were used to load and unload bulk trucks, the result was damage to the protective fat globule membrane and the onset of dramatic rancid flavors in aged Cheddar cheese. Pasteurization destroys much of the activity of native lipases in raw milk, but in the case above the damage to the fat in the raw milk had already been done.

For certain cheese varieties, such as cow's milk romano, asiago, provolone and feta, some of these picante, rancid flavors in the cheese are desirable. In such cases cheesemakers today

Feta cheese

intentionally add lipase to the milk in the vat in order to generate flavor from the release of free fatty acids. Traditionally the added lipases were generated from an animal source such as a calf, kid goat or lamb. Lipases from these three species give different flavor profiles. Calf is the mildest, giving a buttery, sweet, milky, mild picante flavor. Kid goat gives a peppery, goaty, sharp picante flavor, while lamb gives a sharp, lingering sheepy flavor. In commercial use blends of these lipases from animal sources are often used to customize the flavor in the resulting cheese. Note that historically these animal lipases were not considered Kosher. This can be problematic if the cheese manufacturer needs to produce kosher cheese or whey product, so today limited amounts of kosher animal lipases are commercially available. As one would expect the cost of these products is high.


Romano cheese


Asiago cheese

Lipases from animal sources can be in short supply, however, so microbial (non-animal) sources are often used today. These microbial lipases are produced using specialized fermentation processes so they are not in short supply and tend to be cost effective. Also, because they are not derived from animal sources, microbial lipases are Kosher and Halal. Unfortunately, many microbial lipases can result in poor flavor profiles in the cheese. These microbial lipases tend to target longer chain fatty acids on the triglyceride molecule. These longer fatty acids also tend to be soapy flavored so great care must be taken when using microbial lipases to preclude the formation of such flavors in these cheeses.

Additionally, a very traditional source of lipase no longer in common use today is rennet paste. As the name implies, this product combines two enzymes into one product, rennet to coagulate the milk and lipase to form flavor compounds. This was a less purified, non-standardized product made by extracting enzymes from the tongue and the stomachs of young calves, goats and lambs. Today, rennet paste is still available but made by blending rennet and lipase together in a paste form.

The activity of lipase is influenced by the composition of the cheese as well as the conditions under which the cheese is aged. Lipase activity increases with higher fat and moisture content in the cheese. Also, the more lipase you add to the milk and the higher the temperature, the more intense flavor you will generate. Additionally, as expected the longer you age the cheese, the more time the lipase has to generate flavor compounds, thereby generating an increasingly intense flavor. All these factors must be carefully monitored and controlled, however, or the lipase activity can get out of control and result in an unbalanced flavor in the cheese.

RESEARCH UPDATE

A New Method for Analyzing Sodium in Cheese

Staff at the Wisconsin Center for Dairy Research (CDR) recently validated X-ray fluorescence (XRF) spectrometry as a new method for analyzing sodium in cheese, providing manufacturers with the first quick and accurate method for directly measuring sodium in the presence of salt replacers. The XRF technology, which is commonplace in the mining industry, had not previously been considered as a means for measuring sodium in cheese, but thanks to funding from the Innovation Center for U.S. Dairy, CDR staff were able to successfully develop and validate a method for both natural and processed cheeses. This work was recently published in the Journal of Dairy Science August edition, Volume 98, Issue 8, Pages 5040–5051, titled, "Evaluation of X-ray fluorescence spectroscopy as a method for the rapid and direct determination of sodium in cheese".

Raw Milk

The debate surrounding raw milk sales and consumption continues to be a point of contention. As such, the scientific journal Nutrition Today recently invited Wisconsin Center for Dairy Research director and UW-Madison Food Science professor, John Lucey, Ph.D. to review some of the popularly suggested health benefits that are being made by members of the public and media regarding the benefits of raw milk consumption.

In this peer-reviewed article, published in the July/August edition of Nutrition Today, Dr. Lucey found that there is no convincing evidence to suggest that the consumption of raw milk provides any health benefits related to improved nutrition, lactose intolerance or better digestion. Dr. Lucey reviewed more than 50 scientific articles related to this topic, and also read various websites from groups that advocate for raw milk consumption. The article, "Raw Milk Consumption: Risks and Benefits" can be viewed via open access at http://journals.lww.com/nutritiontodayonline/.

Editor's Choice

The article, "Low-sodium Cheddar cheese: Effect of fortification of cheese milk with ultrafiltration retentate and high-hydrostatic pressure treatment of cheese" by M. Ozturk, S. Govindasamy-Lucey, J.J. Jaeggi, M.E. Johnson, J.A. Lucey, published in the October issue of the Journal of Dairy Science was recently selected as the Editor's Choice. This honor allows the article to be featured on the homepage of the Journal's website and the article can be accessed for free. You can view it here:
www.journalofdairyscience.org/content/edchoice

UNDERSTANDING AND AVOIDING UNDESIRABLE CHANGES IN WHEY

Technical Contributor: Karen Smith, Ph.D., CDR

When prepared and stored under optimal conditions whey powder can remain in excellent condition for more than two years. Unfortunately, exposure to a number of adverse conditions during shipment and storage can lead to color change, changes in pH, loss of solubility and other defects in whey. Understanding the factors that influence product quality is a positive step in avoiding undesirable changes in your whey. As such, this article serves as a guide to identifying and eliminating defects in whey products that minimize shelf-life. Additionally, the end of this article contains a number of suggestions for limiting these undesirable changes in whey powders.

Development of Brown Color

Brown color development in whey is certainly the most to clarify, noticeable undesirable change in whey powders during storage. There are generally three types of browning in food products: caramelization, Maillard browning and oxidative. Caramelization is the decomposition of sugars from heat. Amino acids and proteins are not involved. Brown color development due to caramelization is not common in food products. Maillard browning, on the other hand, is the interaction between amino acids, peptides or proteins and a reducing sugar, this is very common in food products. Oxidative browning requires oxygen and is typically seen with browning of fruit. Oxidative browning is not a concern with dairy products.

The Maillard Reaction

Browning caused by the Maillard Reaction is one of the most significant causes of whey powder quality loss that occurs during storage. The Maillard reaction, also known as nonenzymatic browning, is a very complex series of reactions that can result in the formation of dark brown compounds known as melanoidins. Once started the reaction is autocatalytic, that is, products of the Maillard reaction are the catalysts for continued reactions. Oxygen is not required for the reaction.

While there are many factors that contribute to the Maillard reaction, temperature, pH history of the product and moisture content of the powder are among the most critical.

Color change as a result of the Maillard reaction in whey

The Maillard reaction is an exothermic reaction, meaning that it generates its own heat. Heat is, of course, the enemy when it comes to whey powder storage because it speeds up chemical reactions that result in whey quality defects. As such the Maillard reaction is a considerable problem when combined with elevated processing or storage temperatures. For example, a dryer discharge temperature of around 120 degrees Fahrenheit can accelerate the reaction and the browning of the powder, conversely storing powder at 40 degrees Fahrenheit decreases the rate of the Maillard reaction.

The pH of the whey can effect several steps of the Maillard reaction. A lower pH favors the initial steps of the reaction. The compounds formed are colorless or white. A subsequent increase in pH favors later steps in the reaction which produce the brown color compounds typically associated with the Maillard reaction.

Put into practical terms, the drop in pH for milk and subsequent whey during cheese manufacture starts the Maillard reaction with the formation of colorless or white compounds that eventually can become brown color compounds. Processing conditions that increase the pH of the whey, such as neutralization of the whey, will increase the rate and intensity of brown color development.

Water or moisture also plays an important role in color development. Too little water and the compounds cannot move about enough to interact while too much water will dilute the compounds and limit color formation. Studies show that the Maillard reaction rate increases greatly when a sealed packaging is used. This is because water that is released during the initial phases of the reaction is retained in the sealed package. The released water increases the water activity (a_w) of the powder and in turn, speeds up the Maillard reaction.

Composition of whey is also a factor. For example, the ratio of lactose to protein affects the rate at which the initial Maillard reaction compounds are produced in whey products. Studies have shown that reactions proceeded faster in WPC35 and WPC50 than WPC60, WPC75 and WPC80. It was postulated that the lactose molecules needed for interactions are more limited in the higher protein products thereby reducing the reaction rate. Reaction rates for WPC35 and skim milk powder, which have comparable protein content, were similar. It's also worth noting that the higher concentrations of reducing sugars as well as certain salts and buffers will accelerate the Maillard reaction. Whey with increased mineral contents can develop brown color from the Maillard reaction at an increased rate as compared to similar products with a lower mineral content. Some researchers have postulated that phosphate salts are important in increasing the rate of the Maillard reactions.

Problems caused by the Maillard reaction are not limited to formation of color compounds. The reaction can also cause

defects in flavor physical properties. In fact, a study evaluating whey powders stored for 19 months found significant differences between the flavor and odor of the powder after 1 month of storage and 19 months. However, the flavor and aroma that developed initially did not increase as the brown color from the Maillard reaction developed. The authors concluded that whey powders have significant changes in flowability and dispersibility before changes in flavor and aroma are evident.

There are some differences in the compounds formed by the Maillard reaction in whey versus milk. Maillard browning of whey powder under conditions designed to accelerate color development resulted in the formation of 55 compounds of which 12 compounds were not present in skim milk powder subject to similar treatment. The most common volatile compounds in the browned whey powder were maltol, 2-acetyl furan, furfuryl alcohol, acetic acid and dimethylsulfone. The main differences between brown compound formed in the whey and skim milk powder were the absence alkylpyrazines in the whey and the large amount of β-hydroxy-γ-butyrolactone in the skim milk powder.

Caramelization is another form of browning that occurs during the decomposition of sugars and polysaccharides. Reaction products from caramelization resemble those formed through the Maillard reactions. Water and carbon dioxide are released, compounds having a noticeable odor are formed and pH decreases. Oxygen has only a slight effect on color production while sulfur inhibits the reaction. An increase in pH will increase the brown color.
Here is a simple table that describes the various conditions that can occur due to browning or color change in whey:

Volatile compounds affect the flavor of a product undergoing nonenzymatic browning. Approximately 3,500 volatile compounds have been associated with the reaction. Pyrazines are among the more important compounds affecting flavor.
Water activity (a_w) may change because of the release of water by the Maillard reaction. More important is the affect of a_w on reaction rate. Maximum reaction rate is at intermediate a_w. When the a_w is higher the reaction will be hindered in part because of dilution of the compounds that need to interact. A lower a_w will reduce the mobility of these same compounds thereby limiting interactions. Whey has a maximum Maillard reaction rate at an a_w of 0.44.
pH changes and loss of carbon dioxide occur during the Maillard reaction. Acids are produced and amines are converted into other nitrogen compounds through the Maillard reaction thereby resulting in a decrease in pH and loss of carbon dioxide.
Reducing power or antioxidant activity increases as sugars are converted to glycosylamines by the nonenzymatic browning.
Loss of solubility accompanies the Maillard reaction. Melanoidin formation, increase in molecular weight and a decrease in solubility are possible with nonenzymatic browning.
Loss of vitamin C occurs during the Maillard reaction thereby decreasing the nutritive value of the milk. Vitamin C is reactant in Maillard browning.
Loss of biological value occurs when lysine is lost through involvement in nonenzymatic browning. Because lysine is an essential amino acid the loss of lysine will decrease the nutritive value of the milk.

Water Uptake

Result of moisture uptake by whey powder.

Whey powder is hygroscopic, meaning that it holds water from its environment. The result is that moisture in the air during storage can cause the powder to cake, lactose to crystallize or lipids to oxidize.

Flavor Issues

Browning, water uptake and other such changes can lead to off-flavor development during storage of whey powder. Studies show that volatile compounds such as maltol, 2-acetyl furan, acetic acid and others are common in whey that has developed brown color due to the Maillard reaction. These compounds can cause off-flavors that are detectable by trained panelists. It's also worth noting that studies suggest that consumers are more likely to detect flavor issues in beverages made out of agglomerated or instantized WPC80 where an additional heat treatment has been used. As such, experts recommend a shelf-life of 8-12 months for agglomerated WPC80 and WPI vs. 12-15 months for regular WPC80 and WPI.

Limiting Undesirable Changes During Storage of Whey Powders

Although it is not possible to prevent all undesirable changes in whey powder quality over time there are several things that can be done to limit problems.

- Limit the development of acid in the liquid sweet whey. The greater the decrease in pH in the whey, the greater the formation of the initial compounds of the Maillard reaction. Because the Maillard reaction is autocatalytic these initial compounds can progress over time to very undesirable brown colors.
- Avoid neutralizing whey. Once the initial compounds of the Maillard reaction have been produced by the lower pH, a subsequent pH increase will accelerate the subsequent steps leading to a more rapid brown color development.
- Carefully control the moisture of the whey powder at discharge from the dryer. Excessive moisture removal can lead to browning of the powder while too much moisture can result in clumping and acceleration of the browning reaction over time.
- Discharge powder from the dryer and package at lower temperatures. Higher temperatures (for example greater than 110 degrees Fahrenheit) accelerate the brown color development.
- Store the powder under cooler conditions. Again, the higher the storage temperature the sooner brown color and off flavors may develop.
- Use bags with a greater moisture barrier. Absorption of moisture by the powder over time can result in clumping and provides the water needed to speed the Maillard reaction.

Given this information it's best to use water resistant packaging, maintain low storage temperatures and limit the length of storage if you wish to keep whey in ideal condition.

WHEY CLINIC: ULTRAFILTRATION PERFORMANCE EVALUATION FOR SWEET WHEY AND MILK, PART II

Clinic Doctors: Mike Molitor and Dean Sommer, CDR

Question: In the Dairy Pipeline Volume 25, Number 1 Whey Clinic you discussed the economic importance of routinely evaluating ultrafiltration (UF) membrane performance. Can you outline a comprehensive monitoring program and testing protocol to help me determine when I need to change my UF elements?

Answer: The goal of a comprehensive plan is to both quantify how much true protein we are losing into the UF permeate and pinpoint the specific vessels or even individual UF elements responsible for the true protein losses. Once we have the pounds of true protein lost in the UF permeate, we can use the current market value of protein products to calculate how much money we are losing over time. We can then compare the rate of lost income against the replacement cost of installing new elements to determine if we have reached the economic tipping point to justify the cost of the new UF elements.

Developing such a plan and making the logical calculations requires thorough knowledge of dairy processing and related testing methods. The following article aims to provide the necessary information to outline such a plan. Regardless of the routine you choose, the key is to have a plan in place and use it to make conscious decisions that support financial legitimacy for your business.

Protein Categories and Measurements
Crude Protein or some say the 'Total Nitrogen' Protein is all forms of nitrogen reported as protein.
Non-Protein Nitrogen (NPN) is a combination of various small molecules that contain nitrogen but are not proteins.
Crude Protein – NPN = True Proteins (Caseins & Whey Proteins) True Proteins - Caseins = Whey Proteins
Kjeldahl is the most common reference (or primary) method utilized to quantify Nitrogen.
Collectively the True Proteins (from milk) average 15.67% nitrogen, thus test samples for nitrogen using the Kjeldahl method and either divide the %Nitrogen by 0.1567 or multiply by 6.38 (because 6.38 = 1 /0.1567) to convert from %nitrogen to % protein.
When you want to know the quantity of one of the individual categories (casein or true protein or whey proteins) there's a specific wet chemistry procedures to segregate the category of interest away from the other types which is followed up by the Kjeldahl procedure and then multiply the nitrogen content by 6.38.
%Dry Basis meaning % of a component on a dry (no water) basis is the percentage by weight (Crude, True or NPN Protein) x 100/ % total solids. Example: If permeate is 0.20% crude protein and 5.50% total solids, then 0.20% x 100/ 5.50% = 3.7% Crude Protein Dry Basis
Mid Infrared Spectophotometry is a secondary (not reference) technique that can quickly (Less than a minute per sample) and precisely measures the true protein content after some calibration against Kjeldahl data (the reference or primary, but unfortunately slower and more costly method).

First Some Protein and UF terminology

The ultrafiltration process utilizes a consumable product referred to as an element. The UF membrane is simply the primary working component incorporated into the UF element. Therefore, we typically purchase and replace the complete element because the membrane contained within the element has a working life of roughly one to two years.

In milk and whey we have components that are very valuable including the butterfat and true proteins. There are several other less valuable components, including lactose, minerals and non-protein nitrogen. The fat and true protein molecules are relatively large in size while molecules of lactose, the soluble minerals and a group of nitrogen containing compounds termed non-protein nitrogen (NPN) are comparatively small in size.

The price paid for the butterfat and true protein is determined by multiplying the current pay price (a rate in $/lb. of a component like butterfat or true protein), times the fluid weight, times the component percent of the milk weight.

For raw milk, this calculation is done for both the butterfat and true protein. For fluid whey, the calculation is typically based on crude protein because whey products are typically based and priced on their crude protein content.

Fundamentally, the principle of ultrafiltration is that we choose a membrane pore size that's small or tight enough to retain (not pass through the membrane) the large components we want to concentrate, namely fat and true protein. When the correct membrane pore size is selected, the large molecules are retained by the membrane to generate the fraction termed retentate or the protein concentrate. The smaller and coincidentally less valuable compounds, such as lactose, soluble minerals, and NPN along with water, are able to pass through or permeate the membrane to become the product also referred to as the permeate. We use the word permeate as both a verb and a noun, thus; 'Part of the UF feed will permeate (used as a verb) the membrane and we call that fractionated stream, permeate (now used as a noun).

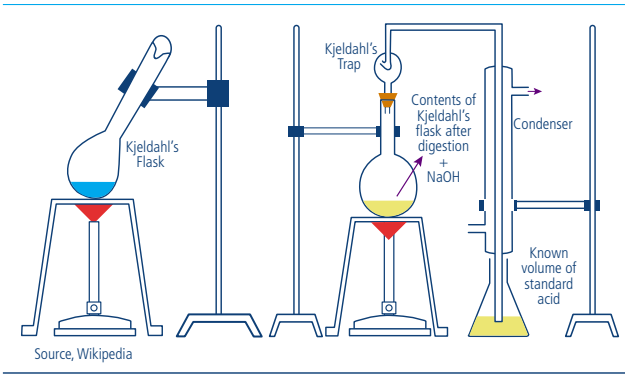
All is well as long as the membranes function properly and do not allow the true protein to permeate or 'leak' through the membrane into the UF permeate. The trouble is, it's very hard to know if and how much true protein is leaking unless you've instituted a comprehensive monitoring program that will show you trends of how much true protein was lost, which UF elements are responsible and which of your UF elements are losing true protein into the UF permeate. Quantifying UF element performance is a critical step to making financially sound decisions as to the proper timing to replace the UF elements.

So how do I create the monitoring program?

The monitoring program should specifically measure the amount of true protein that is being lost in the permeate stream at a reoccurring frequency you choose. Think of the two methods (Kjeldahl reference and mid-IR secondary) as being complimentary means to evaluate the UF performance in two steps.

The Kjeldahl Method

The Kjeldahl testing method literally quantifies the nitrogen content but it's a slow, laborious and costly method compared to mid-IR. Therefore use the Kjeldahl method to measure the total nitrogen content of just a few UF permeate composite samples to confidently determine the overall or average amount of crude protein in the UF permeate composite samples. Either a commercial lab or your in house analyst will provide this service for you.



Recall that milk and whey contain some small non-protein nitrogen containing compounds (NPN) such as urea and others but because the NPN components are small and easily pass through the UF membrane, the NPN accounts for the majority of the nitrogen in UF permeate. Fortunately, the quantity of NPN in commingled milk and thus also the sweet whey is quite uniform throughout the year, whereas the true proteins are the components known to have wide seasonal fluctuations. The uniformity of NPN allows us to keep the Kjeldahl testing program simple and less costly, meaning it's not necessary to generate the more costly Kjeldahl **true** protein results because Kjeldahl crude protein gets the job done.

Determining the Baseline or Cut off between NPN and True Protein in UF Permeate

It's also common scenario that sweet whey is diluted and/or concentrated as a result of wide ranging practices utilized for cheese makes. Thus the real trick is to convert the Kjeldahl crude protein results of the UF permeate samples into crude protein dry basis. By converting UF permeate crude protein results to dry basis, the impact of vat milk fortification, curd washing and even permeate concentration with reverse osmosis is simply erased. The dry basis number really boils down to a ratio of the small component categories, NPN and carbohydrate. Whey and UF permeate solids are primarily carbohydrates in which lactose is the most prevalent type.

With the explanations above, the baseline for accurately tested UF permeate (not containing true protein) is about 3.1 +/- 0.1% crude protein dry basis (%Cr.Pr.DB) due to the natural NPN content. So if a lab reports %Cr.Pr.DB < 3 percent, I would doubt the testing accuracy and seek further confirmation. And for UF permeate results greater than 3.1% Cr.Pr.DB, the amount above the 3.1, is true protein, the highly valuable component the UF is supposed to retain!

Now an example of how to calculate pounds of True Protein lost and then also it's $ Value

The daily composite sample representing 500,000 fluid pounds of UF permeate is accurately tested and determined to contain 4.5% Cr.Pr.DB and its 5.54% total solids (see table two February composite results). Also, assume the UF is making WPC34 and its current fluid value is $0.5/lb. of solids.

(4.5% actual Cr.Pr.DB - 3.1% NPN baseline) x 500,000 lb. x 5.54% = 388 lb. True Protein lost

And 388 lb. of true protein / 0.356 (WPC34 DB target) = 1090 lb. WPC34 solids NOT made

Finally 1090 lb. WPC34 solids X $0.5/lb. = $545.00 of WPC value NOT realized due to the UF

Mid-Infrared Analyzers, the Complimentary Technique Identifying the Problematic Elements

Luckily, all plants now have at their disposal (internally or via commercial testing labs) an economical technology to test for the true protein content of their fluid whey and especially UF permeate samples. This is made possible by the use of mid-infrared analyzers. mid-IR achieves specific analysis at a minimal cost per sample which is less than $5 each via commercial labs. It can be set up to measure butterfat, true protein, lactose and total solids. The beauty of this technology is that it's incredibly fast and the mid-IR (6.465 μm) wavelength of light only measures true proteins and does not detect NPN. Thus mid-IR measures only what we actually care about, the valuable components, true protein, that the UF membrane is supposed to retain. Once we have this equipment in place there are few limits as to how many samples we can test or conversely small plants should not feel guilty about submitting samples to a commercial lab because the sample testing cost is so low. The mid-IR test, however, is not a direct method like Kjeldahl. Thus by definition, mid-IR will not be as accurate as the primary method. Instead realize that mid-IR provides the economical means to detect true protein differences which make for an excellent relative comparison for all the UF vessels you choose to sample and evaluate.

These analyzers are secondary testing devices meaning they need to be calibrated if you want accurate protein results. Even without strict calibration these testing devices can give us a relative measurement that serves to inform us of significant differences between the protein content of the individual permeate samples. This testing protocol can be used on permeate from all vessels to generate rapid, inexpensive but precise results pointing out which elements are leaking how much valuable true protein.

To routinely monitor the overall situation, composite samples of permeate can be occasionally analyzed by the more expensive Kjeldahl method to determine accurate crude protein concentrations in your permeate. You will also need to determine the total solids content of these samples. Ideally, samples can be taken from concentrated permeate streams if you use reverse osmosis (RO) on your permeate before shipment or evaporation. Concentrating the permeate solids obviously increases the NPN concentration which also helps test accuracy and thus more confidence in the data. This is because 'fluid' (not concentrated) permeate contains less than 0.03 percent nitrogen.

Tables one & two contain commercial plant reference and mid IR data respectively. Note that the February samples contain lots of true protein lost in the UF permeate. Many of the ill performing elements were replaced and thus the April overall composite sample contains dramatically less true protein compared to the February overall composite sample (4.5% & 3.2% respectively). But reflecting on the April mid IR data, some of the individual stage two (April) vessel samples still contain too much true protein for instance, see the table two stage two vessel four. As these were samples obtained from a commercial facility it's assumed that not all of the UF elements were changed before the April samples were taken.

Table 1. Reference Test Data (Kjeldahl Proteins & Total Solids)
The UF Permeate & Test Results are from Commercial Facilities

	Feb. Crude Protein	April Crude Protein	Feb Total Solids	April Total Solids	Feb. Cr. Protein Dry Basis	April Cr. Protein Dry Basis
Stage 1 Comp.		0.16		5.42		3.0%
Stage 2 Comp.		0.19		5.65		3.4%
Overall Comp.	0.26	0.18	5.73	5.54	4.5%	3.2%
RO Conc. UF Perm	0.77	0.56	17.27	17.29	4.5%	3.2%

Table 2. Mid Infrared True Protein Data the UF Permeate & Test Results are from Commercial facilities

	Feb., 2014	Apr., 2014
Stage 1, Vessel 1	0.11	0.03
Stage 1, Vessel 2	0.19	0.01
Stage 1, Vessel 3	0.14	0.03
Stage 1, Vessel 4	0.21	0.02
Stage 2, Vessel 1	0.06	0.07
Stage 2, Vessel 2	0.10	0.04
Stage 2, Vessel 3	0.12	0.07
Stage 2, Vessel 4	0.09	0.11

In the end, accurate, relevant information is required to manage process equipment. Having a logical understanding of product composition and analysis options is fundamental to establishing quality control routines that provide the plant management with sound performance data.

BUILDING UPDATE

These images are a part of the 35 percent design report submitted by Zimmerman Architectural Studios, Inc. The project is set to meet the goal of a summer 2016 groundbreaking with a 26 month construction period.

CDR TECHNOLOGY TRANSFER UPDATE

Beginning in January 2016, the CDR Technology Transfer, University Research and Business Opportunity program (TURBO) will be offering additional economic development assistance to dairy products companies in Wisconsin through its fee-for-service economic development assistance. CDR has long been a resource for companies looking for technical help to develop a product, but now CDR is available to guide companies through the next steps of their business growth.

A recent survey of small cheesemakers and board members of the Wisconsin Cheese Makers Association (WCMA) revealed that the industry is looking for information regarding appropriate economic development resources. More the 70 percent of the cheesemakers surveyed noted that they will be planning a plant expansion in the next three years. This is the perfect opportunity to investigate economic development opportunities that can provide grants and funding to help with such expansions.

Additionally, new product development and new equipment projects may also be supported through various economic development programs. As such, the CDR TURBO program is now available to help you connect with these opportunities. By facilitating these connections, the TURBO program is available to help companies find the right development service, fill out paperwork and understand the process. Specific information regarding the services being offered by the CDR TURBO program is listed below.

For more information or to receive help, please contact
TURBO Program Coordinator, Vic Grassman| vgrassman@cdr.wisc.edu | 608-512-6661

CDR TURBO

Economic Development Services

Site Selection

- Real estate identification and coordination
- Assistance in discussing potential economic development financing and incentives
- Identifying and coordinating access to potential workforce resources

Export

- Identifying & applying for grants to develop a program
- Promoting export development training opportunities

Capital Expenditures (i.e. Equipment)

- Identifing which economic development financing programs are applicable to their purchase scenario
- Assisting in the application and negotiation processes

Building Expansions

- Identify and negotiate relevant economic development financing programs
- Contacting WEDC for incentives
- Represent the company with local townships/ communities. Examples include: getting approval for permits, easements, negotiating zoning issues, infrastructure needs (water, sewer etc.)
- Accessing workforce resources

Workforce Issues

- Identifying and accessing workforce data
- Identifying training needs and potential resources
- Identifying other workforce issues and providing assistance in accessing them

Entrepreneurial Services

- Technology transfer
- "Lean" business planning, marketing plan development, etc.
- Identifying entrepreneurial resources available in Wisconsin
- Identifing "licensed" space, co-packers, etc.
- Assistance in finding financial resources

Center for Dairy Research
University of Wisconsin-Madison
1605 Linden Drive
Madison, Wisconsin 53706-1565

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Dairy Pipeline

Center for Dairy Research
1605 Linden Drive
Madison, WI 53706-1565

608-262-5970 *fax: 608-262-1578*

We welcome your questions and comments.
Send to: Bekah McBride, Editor
rmcbride@cdr.wisc.edu *608-262-8015*

Technical Reviewers:
Debra Wendorf Boyke, KJ Burrington, Vic Grassman, Mark Johnson, John Lucey, Mike Molitor, Don Otter, Juan Romero, Karen Smith, Dean Sommer, Tom Szalkucki

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Short Course Calendar:

- Milk Pasteurization, January 5–6
- Batch Freezer Workshop, January 12–14
- WI Dairy Field Reps, February 9–10
- WI Process Cheese, February 23–24
- Cheese Technology, March 14–18

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

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