Wisconsin Center for Dairy Research 2004

annual report

Wisconsin

Center for Dairy Research

annual report 2004

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CDR

CDR Annual Report

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Our annual report is a technical overview of CDR funded research and other Center activities during fiscal year 2004. This document was prepared for organizations funding CDR and for fellow dairy researchers. Although it describes projects in progress and interpretations of data gathered to date, it is not a peer-reviewed publication.

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Our Mission Statement

The Wisconsin Center for Dairy Research will serve as a national leader in strategic research to improve the competitive position of the dairy industry by linking Center/ University faculty, staff, students and the dairy/food industries to address key issues resulting in transfer of technology and communication of information.

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Chapter One

Interim reports

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Mechanisms for intensifying and modulating cheese flavor: A global approach

Personnel
Steele, James L.

Funding
Dairy Management, Inc.

Dates
1/1/2001 to 12/31/2003

Objectives
The overall objective of this project is to assemble a comprehensive database on the metabolic potential of *Lactobacillus helveticus* CNRZ32, an important cheese flavor-enhancing bacterium, for modulating and intensifying cheese flavor development. Based on our previous experience in cheese flavor research, it is our hypothesis that genome sequence analysis of CNRZ32 is the most expedient method to identify many of this bacterium's genes encoding enzymes involved in cheese flavor development. Because of their similarities, it is also our hypothesis that this knowledge can be applied to other important lactic acid bacteria.

Specific objectives:
1. Determine the nucleotide sequence of the *Lactobacillus helveticus* CNRZ32 genome

2. Assemble a comprehensive database of CNRZ32 genes likely to be involved in modulating or intensifying cheese flavor.

Cheese structure/function manipulations to improve shreddability

Personnel
Chen, Carol; Jaeggi, John

Funding
Dairy Management, Inc.

Dates
1/1/2004 to 12/31/2005

Objectives
1. Understanding chemistry, structure/function, acid development for enhancement and/or control of cheese performance

2. Develop new and novel functionality characteristics

Identification of physical/chemical changes in shredded cheese over time

Personnel
Chen, Carol

Funding
Dairy Management, Inc.

Dates
3/16/2000 to 12/31/2002

Objectives
1. To characterize physical/chemical/sensory characteristics over time of shredded cheese in consumer-sized packages.

2. To determine the effect of flow agents on the physical/chemical/sensory projects of shredded cheese.

Develop nonfat mozzarella for use in the school lunch program

Personnel
Johnson, Mark

Funding
Dairy Management, Inc.

Dates
1/1/2004 to 12/31/2004

Objectives
Research completed at the Wisconsin Center for Dairy has shown that the judicious use of condensed buttermilk (buttermilk condensed via evaporation of membrane processing) for the manufacture of pizza cheese does not compromise cheese quality or functional characteristics. Our proposal is to use buttermilk in the manufacture of nonfat mozzarella for use in the School Lunch Program with the intent that it will produce a nutritious, totally dairy based cheese with desirable sensory attributes.

Technical and economic development of a milk refinery

Personnel
Etzel, Mark

Funding
Dairy Management, Inc.

Dates
3/16/2000 to 12/31/2002

Objectives
1. Determine the technical capabilities of various MF systems from different suppliers for the separation of casein from milk serum proteins (i.e., how complete and clean is the separation) and the efficiency of subsequent UF concentration of the serum proteins.

2. Determine the throughput, yield, and recovery of the ion exchange chromatography step as a function of feed stream properties and target protein fractions.

3. Determine the technical properties and opportunities for use of casein concentrates (liquid or dry), and casein and milk serum protein fractions as dairy ingredients in non-cheese applications.

4. Determine the costs (capital, fixed, variable, operational, etc.) for the MF/UF and ion exchange chromatography aspects of fractionation and concentration of the milk protein streams.

5. Determine the potential market and utilization of milk refinery products (i.e., opportunities).

Understanding and controlling the calcium equilibrium in cheese

Personnel
Lucey, John A, Johnson, Mark E.

Funding
Dairy Management Inc.

Dates
July 2002 to June 2004

Objectives
1. To determine the impact of changes in the Ca equilibrium on the textural and rheological properties of these cheeses.

2. To identify changes in the proportions of bound and soluble Ca in cheese during ripening.

Relating rheological properties to cheese functional performances

Personnel

Lucey, John; Foegeding, Allen; Gunasekaran, S.; Johnson, Mark E.; McMahon, Donald

Funding

Dairy Management Inc.

Dates

January 2002 to December 2004

Objectives

1. To develop molecular-based mechanisms and models to explain the functional performances involved in meltability.

2. To develop molecular-based mechanisms and models to explain the functinal performances involved in machinability of cheese.

3. To develop an information piece (short booklet or workshop) that provides detailed descriptions of a range of cheese functional properties in terms that both industry and researchers could understand.

Production of intensely flavored cheddar-type cheeses by adjunct cultures

Personnel

Steele, Jim

Funding

Dairy Management, Inc.

Dates

3/16/2000 to 12/31/2002

Objectives

1. Construct strains of *Lactobacillus casei* which produce elevated levels of diacetyl.

2. Construct strains of *Lactobacillus casei* which over-express a bacterial lipase known to enhance cheese flavor.

3. Manufacture processed cheese from cheddar cheeses having significantly elevated levels of free fatty acids or furanones and pyrazines.

Developing pH-sensitive biodegradable smart hydrogels using whey protein concentrate

Personnel
Sundaram Gunasekaran

Funding
Dairy Management, Inc.

Dates
7/1/2001 to 6/30/2003

Objectives
The overall objective is to develop new biodegradable smart hydrogels using whey protein concentrate (WPC).
Hypothesis: Whey protein-based hydrogels exhibit a pH-sensitive swelling behavior. Therefore, they can be used as carrier matrices for pH-sensitive controlled delivery applications.

1. To develop new pH-sensitive hydrogels using whey protein concentrate and characterize their swelling behavior as a function of swelling medium and gel preparation conditions.

2. To determine the release kinetics of some model biologically active substances from whey protein-based hydrogels in various pH media.

Control of annatto cheese colors in whey products

Personnel
Wendorff, Bill; Lindsay, R. C.

Funding
Dairy Management, Inc.

Dates
1/1/2001 to 12/31/2002

Objectives
Hypothesis: The annatto-based off-colors in dry whey products are caused by the adsorption of annatto colorants onto protein or protein-lipid particles, and these off-colors can be minimized by oxidative bleaching and/or processing to disrupt and remove the adsorptive complexes.

1. Determine the quantitative binding capability of commercially-important forms (native, denatured, and delipidated) of whey proteins for annatto cheese colorants.

2. Devise commercially-applicable methods to minimize or eliminate annatto off-colors in dry whey products.

Improving lactose refining technology by controlling crystallization

Personnel
Hartel, R.W.

Funding
Dairy Management Inc.

Dates
July 2002 to June 2005

Objectives
1. To provide a better understanding of the mechanisms and kinetics of lactose nucleation (both primary and secondary).

2. To define the important compositional and operating parameters that influence lactose nucleation in commercial whey products.

3. To determine the importance of growth rate dispersion on commercial lactose refining operations and develop methods for minimizing these effects.

4. To provide economically viable operating parameters for commercial lactose refining operations that enhance the quality (color, purity, and particle size) and consistency (on a day to day basis) of lactose crystals produced.

Characterization of pigments and conditions responsible for browning in whey powders

Personnel
Rankin, Scott

Funding
Dairy Management, Inc.

Dates
4/1/2003 to 12/31/2003

Objective
Using compositional data and LC technologies, the nature of these browning pigments will be determined and the chemistry of their formation will be determined.

Development of parmesan cheese flavor using selected bacteria

Personnel

Johnson, Mark; Steele, James; Lindsay,Robert

Funding

Dairy Management, Inc.

Dates

7/1/2001 to 12/31/2003

Objectives

1. Define and verify the chemistry of flavors produced in parmesan cheese made with specifically selected adjunct lactic acid bacteria that provide flavor notes known to characterize high quality, aged parmesan cheese. Hypothesis: By correlating chemical and sensory data from experimental parmesan cheese, we will be able to identify and establish commercially viable starters and adjunct lactic acid bacteria and cheese manufacturing methods to produce parmesan cheese with intensified flavors.

2. Construct derivatives of *Lactobacillus helveticus* CNRZ32 that overexpress specific esterase activity. Hypothesis:We believe that esterase activity, i.e. production of specific esters, provides specific desirable flavor notes in parmesan cheese. The lactobacilli used as starters for parmesan cheese lack sufficient esterase activity to adequately develop full, aged parmesan flavor.

Develop a process for adhering meat products (pepperoni) to cheese for one-step pizza topping application

Personnel

Johnson, Mark

Funding

Dairy Management, Inc.

Dates

1/1/2004 to 12/31/2004

Objective

Manufacturers of meat products for use as toppings on pizza have approached us to test the feasibility of developing a process by which their products could be directly applied to cheese prior to the manufacture of the pizza. In this manner the cheese and pizza topping would be applied in a prefabricated form directly to the pizza.

Develop nonfat mozzarella for use in the school lunch program

Personnel
Johnson, Mark

Funding
Dairy Management, Inc.

Dates
1/1/2004 to 12/31/2004

Objectives
Research completed at the Wisconsin Center for Dairy has shown that the judicious use of condensed buttermilk (buttermilk condensed via evaporation of membrane processing) for the manufacture of pizza cheese does not compromise cheese quality or functional characteristics. Our proposal is to use buttermilk in the manufacture of nonfat mozzarella for use in the School Lunch Program with the intent that it will produce a nutritious, totally dairy based cheese with desirable sensory attributes.

A chemistry-based approach to understanding process cheese functionality

Personnel
Lucey, John

Funding
Dairy Management, Inc.

Dates
1/1/2004 to 12/31/2006

Objectives
1. To measure efficiency of the chelating properties of emulsification salts (ES) and the potential to promote cross-linking between ingredients

2. To control the performance of process cheese used in specific applications by understanding the interactions between raw materials (cheese), emulsification salts, and processing steps (temperature, time, shear.

Effects of cheese solids on *Clostridium botulinum* in process cheese products

Personnel
Norback, John; Johnson, Eric

Funding
Dairy Management, Inc.

Dates
9/1/2001 to 8/31/2005

Objectives
1. To determine the effect of substituting cheese solids with other dairy ingredients (whey, whey protein concentrate, nonfat dry milk) on botulinal toxin production in pasteurized process cheese products. Hypothesis: The percentage of cheese solids (provided fat levels are standardized) used will not affect the safety of process cheese products.

2. To determine if "percentage of cheese solids" can be used as a parameter in an improved predictive model to cover formulation-safe, non-standard of identity process cheese products/sauce.

3. To compare the effect of condiment types on botulinal toxin production in process cheese products. Hypothesis: Acidified or brined condiments will not negatively affect the safety of formulation-safe process cheese products.

4. To develop a computer program to adjust formulations of nonstandard-of-identity process cheese products with <50% cheese.

Feasibility study for development of shelf-stable cheeses

Personnel
Sommer, Dean

Funding
Dairy Management, Inc.

Dates
1/1/2004 to 12/31/2004

Objective
Develop high quality cheeses for availability in unrefrigerated snack packs.

Identifying genes involved in cheese flavor development

Personnel
Steele, Jim

Funding
Dairy Management, Inc.

Dates
7/1/2002 to 12/31/2004

Objectives
1. Develop microarrays that contain *Lb. helveticus* CNRZ32 genes encoding enzymes thought to be responsible for flavor development in bacterial-ripened cheeses.

2. Determine the effect of cheese ripening conditions on expression of these genes.

3. Construct isogenic mutants of *Lb. helveticus* CNRZ32 that differ in metabolic activities found to be expressed under cheese ripening conditions and believed to impact cheese flavor development.

4. Establish the role of these metabolic activities in cheese flavor development by analysis of isogenic pairs in a system that models ripening cheese environments.

Nutraceutical protein recovery from acid whey

Personnel
Etzel, Mark

Funding
Dairy Management, Inc.

Dates
1/1/2003 to 12/31/2004

Objectives
1. Develop and evaluate new process chemistries to capture and fractionate proteins from acid whey using process chromatography.

2. Measure the throughput, yield, and recovery as a function of the feed stream properties and target protein fractions.

3. Scale up and manufacture each protein fraction in amounts sufficient for functional and preliminary nutritional evaluation.

4. Estimate the costs of installation and operation of a commercial-scale process.

Phase/state transitions that affect drying of whey products

Personnel
R.W. Hartel

Funding
Dairy Management, Inc.

Dates
1/1/2003 to 12/31/2004

Objectives
1. Investigate the effects of various components (minerals, galactose, lactic acid, etc.) in whey products on the glass transition behavior of lactose, the primary component that leads to glass formation.

2. Assess the effects of holding conditions on drying of whey products, since it may be during holding of the whey products that negative effects are induced.

3. Investigate potential additives (i.e., maltodextrins, proteins) that might aid in drying.

Understanding structure/function relationship in cream cheese responsible for its performance

Personnel
Govindasamy-Lucey, Rani

Funding
Dairy Management, Inc.

Dates
7/1/2003 to 12/31/2003

Objectives
1. To identify how manufacturing conditions influence the functionality/textural properties of cream cheese products. Hypothesis: The initial gel formation and processing conditions used during the manufacture of cream cheese greatly affect the texture and other physical properties of the cream cheese.

2. To investigate the utilization of the cream cheese as an ingredient or its incorporation into other food ingredients. Hypothesis: Modification of cream cheese texture by the use of different processing conditions will result in alterations in its end-use functionality (e.g. in baking, and reworking/mixing with other food materials). Understanding the relationship between cream cheese manufacturing conditions and its end use functional properties will allow manipulation of the functional characteristics for a particular end-use.

Identification and control of off-flavors in commercially produced GMP products

Personnel
Rankin, Scott

Funding
Dairy Management, Inc.

Dates
4/1/2003 to 12/31/2003

Objective
Using modern mass spectral capabilities, identify the compounds responsible for the off-flavor present in commercially produced glysomacropeptide (GMP) product.

Review and comparison of nutritional and functional properties of dairy proteins relative to other market protein sources

Personnel
Rankin, Scott

Funding
Dairy Management, Inc.

Dates
4/1/2003 to 12/31/2003

Objective
Utilizing available abstracting resources, an extensive literature review will be conducted as the basis for a review paper to be published in an appropriate journal.

Develop innovative solutions for the "Cold Melt" of cheese when partnered with another food ingredient (i.e. meat)

Personnel
Wendorff, Bill

Funding
Dairy Management, Inc.

Dates
7/1/2003 to 12/31/2003

Objectives
1. To determine parameters influencing the migration of moisture to cheese pieces in process meat products.

2. To develop processing aids or manufacturing procedures for production of natural cheese products that eliminate or retard the migrations of moisture to the cheese pieces.

Manufacture of a no-sugar frozen desert

Personnel
Bradley, Robert

Funding
Dairy Management, Inc.

Dates
4/1/2003 to 12/31/2003

Objective
To produce a finished frozen dessert with excellent flavor and no carbohydrates to meet the demands of lactose mal-digesters and Atkins diet followers.

Production of sialyllactose from lactose using a bioreactor

Personnel
Romero, Juan

Funding
Dairy Management, Inc.

Dates
4/1/2003 to 12/31/2003

Objective
Feasibility study to evaluate the use of a bioreactor to produce sialyllactose from lactose as a value added ingredient for infant formula manufacturers and as a probiotic.

Improving WPI functionality for beverage applications

Personnel
Etzel, Mark

Funding
Dairy Management, Inc.

Dates
1/1/2004 to 12/31/2005

Objectives
1. Understand the causes of sediment formation and increased turbidity in current WPI products made using membrane processes and ion exchange.

2. Determine the operating parameters and equipment requirements needed to avoid damage to the enhanced WPI during downstream processing by membrane concentration and spray drying.

3. Develop and test prototype 'high protein' beverage formulations of different pH for lack of sediment formation and turbidity after low heat and high heat treatments.

4. Identify the individual proteins in the enhanced WPI that contribute most to sediment formation and turbidity and in prototype high-protein beverage formulations.

5. Adapt the processing conditions and explore food-grad additives to decrease sediment and turbidity and in prototype high-protein beverage formulations.

Analytical survey of the composition milk protein concentrates (MPC) available on the United States market

Personnel
Romero, Juan

Funding
Dairy Management, Inc.

Dates
2/1/2005 - 1/31/2006

Objective
To determine the physical, chemical and microbiological characteristics of Milk Protein Concentrate (MPC) that are currently avalable for purchase in the United States so as to answer industry questions when selecting alternative domestic ingredients.

Cheese serum component's role in inhibition of calcium lactate crystallization

Personnel
Mark Johnson

Funding
Dairy Management, Inc.

Dates
1/1/05 – 12/31/06

Objectives
1. To determine the impact of changes in the concentrations of soluble Ca and lactic acid as the cheese ages on the development of L-calcium crystals,

2. To determine the impact of impurities on the formation of calcium lactate crystals,

3. To determine the impact of the addition of NDM and condensed skim milk on the development of calcium lactate crystals in the interior of Cheddar cheese,

4. To deliver the results from this study to the cheese industry.

Increasing the whiteness of sweet whey powder

Personnel

Scott Rankin

Funding

Dairy Management, Inc.

Dates

1/1/05 – 12/31/06

Objective

Develop and/or provide knowledge to dairy processors and cooperatives to enhance the accessibility of dairy foods and ingredients to alternative distribution channels by expanding/extending their useful life.

Chapter Two

Final reports

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Crystallization Kinetics of Calcium Lactate

Personnel

Richard W. Hartel

Funding

Dairy Management, Inc

Dates

June 2001 to December 2002

Objectives

The primary objective of this project is to investigate the factors that influence crystallization kinetics of calcium lactate. Crystallization kinetics in model solutions and in expressed cheese serum will be studied. The effects of various storage conditions (temperature), chemical compositions (calcium and lactate content, pH, other salts, etc.) will be evaluated.

Summary

Formation of crystalline calcium lactate on cheese surface during storage has been a long-standing problem for the dairy industry and, although numerous studies have been conducted to understand its causes and occurrences, our ability to control crystal formation is still limited. Cheese is a complex, multi-phase system consisting of a para-casein gel in which fat, a salty serum phase, enzymes and bacteria are held. Salts, mainly calcium lactate, can crystallize out from this aqueous serum.

Ultimately, the problem associated with calcium lactate formation on cheese is related to the solubility limit at storage temperature. If the calcium and lactate concentration exceed the solubility product at storage temperature, a thermodynamic driving force for crystallization exists and there is the possibility that crystallization will occur. Due to the physico-chemical complexity of cheese serum, many factors including seasonal fluctuations, process variables and aging conditions may affect the calcium and lactate ion concentrations. However, even if a thermodynamic driving force exists, it is not mandatory that crystallization take place since there may be kinetic constraints. Certain components present in cheese serum may significantly inhibit the onset of crystal formation. In addition to calcium lactate concentration, temperature, other composition, and pH may also influence the crystallization rate of calcium lactate.

As an initial phase, nucleation plays the most important role in crystallization. For nucleation to occur in salt solutions, sufficient numbers of ions must come together so the cluster has sufficient energy to overcome the interfacial energy requirement. A high supersaturation level is necessary for nucleation to occur. However, nucleation may not happen for a long period of time even though a supersaturated solution exists. Supersaturated solutions may remain in a metastable state for a very long time. The kinetics of nucleation may be slow, or inhibited, so that crystals don't form even over an extended period of time. Development of crystals is result of crystal growth following the nucleation, thus the eventual formation of crystalline materials (appearance and amount) on the surface of cheese will depend on the behavior and kinetics of crystal growth. It is important to understand the behavior

and kinetics of both nucleation and crystal growth of calcium lactate to reveal the mechanism of formation of calcium lactate, determine the characteristics of crystallization of calcium lactate and develop a way to prevent or reduce the occurrence of 'cheese bloom'. Despite previous work in this area, our understanding of calcium lactate formation on cheese surface is still very limited.

In this work, the factors that influence crystallization kinetics of calcium lactate were investigated for model systems, as well as cheese serum. The effects of various parameters (calcium lactate concentration, temperature, pH, impurity level, etc.) were evaluated.

Calcium lactate used for preparation of supersaturated solutions was a product called PURACAL in pentahydrate form with purity higher than 99.0% from PURAC America, Inc. (Lincolnshire, IL). Serum of 3-week-old cheddar cheese (Land O'Lakes, Inc., Arden Hills, MN, USA) was extracted by hydraulic pressure method (Morris, H.A., et al., Journal of Dairy Research, 55, 255-268, 1988). Sodium chloride and chemicals for analysis of calcium were bought from Sigma Chemical Co. (St. Louis, MO, USA).

An EDTA titration method based on the AOAC Official Methods of Analysis 968.31 (AOAC Official Methods of Analysis, 155-156, 1990) was used to analyze the content of calcium ion in the solution and hence, the concentration of calcium lactate in solution was calculated.

The solubility of calcium lactate was obtained from previous phase behavior studies (Kubantseva et al., J. Dairy Sci., 87(4), 863-867, 2004) and is given in Table 1. The pH (6.5 – 6.6) of the solutions had very little effect on calcium lactate solubility under these conditions.

Table 1. Solubility (g/100g water)* of calcium lactate in water at different temperatures

Temperature (°C)	24.0	10.0	4.0
Solubility			
CaL_2 + water	6.41	4.03	3.38
CaL_2 + water + 3%NaCl	6.36	4.24	3.66
CaL_2 + water + 4%NaCl	-	-	3.65
CaL_2 + water + 5%NaCl	-	-	3.63
CaL_2 + water + 6%NaCl	6.42	4.15	3.56
* in anhydrous form			

Preparation of supersaturated solution

200 grams of solution was prepared by dissolving a suitable amount of calcium lactate in deionized water depending on the concentration desired. Calcium lactate, other required chemicals and deionized water were placed in a glass bottle with a magnetic stirring bar inside and sealed with a rubber stopper. The sample was heated to 60ºC on a hot plate with a stirrer and maintained at the temperature until the salt was completely dissolved. After cooling to room temperature, solutions were vacuum-filtered by use of Whatman #1 filter paper to

remove any remaining solid particles. The prepared solutions in sealed bottles were stored in a temperature-controlled oven at about 60ºC until use. Solutions with different supersaturation, salt and pH levels were prepared in the same way. For cheese serum, additional calcium lactate was added. The solutions were supersaturated at lower temperatures (24ºC or lower). The major parameters of these solutions are summarized in Table 2.

Table 2. CaL_2 concentration and supersaturation (g/100g-H_2O) of solutions

Solution ID	pH	Concentration (mass%)	(g/100g-H_2O)	Supersaturation at 4ºC	at 10ºC	at 24ºC	Preparation Remark
15N	6.87	16.1	19.2	15.8	15.1	12.8	CaL_2+H_2O
12N	6.98	13.0	15.0	11.6	10.9	8.6	CaL_2+H_2O
10N	6.95	10.5	11.7	8.3	7.7	5.3	CaL_2+H_2O
10P	4.80	10.5	11.7	8.1	7.5	5.2	CaL_2+H_2O+HCl
10S	6.85	10.0	11.7	8.2	7.6	5.3	CaL_2+H_2O+NaCl
10C	4.80	9.96	11.70	8.01	7.44	5.45	CaL_2+H_2O+HCl+NaCl
10J	4.65	10.1	11.7	*	*	*	cheese serum+CaL_2
8N	6.91	7.7	8.4	5.0	4.3	2.0	CaL_2+H_2O
6N	6.85	6.2	6.6	3.3	2.6	0.2	CaL_2+H_2O

* not available due to unknown solubility

Spectrophotometry for nucleation kinetics

Crystallization of calcium lactate on the cheese surface occurs in a static environment; therefore, nucleation studies were performed under static conditions. The characteristics of calcium lactate crystallization, where growth of calcium lactate crystals proceeded rapidly after only a limited number of nuclei were generated and formed a highly-associated branched crystals instead of many individual crystals influenced our study of the nucleation kinetics. We used induction time of formation of initial nuclei, instead of number of nuclei per unit volume and unit time in our work.

A turbidity method was used to determine induction time of formation of initial nuclei. Some (0.50ml) of the supersaturated solution was placed in a semi-micro spectrophotometer cuvette and sealed with Parafilm. The sample was then placed in the holder of a Genesys 5 spectrophotometer (Thermo Electron, Madison, WI) and absorbance of the solution was monitored and recorded every 5 min. The wavelength used was 490nm that was suitable for the calcium lactate solution based on wavelength scan tests performed prior to the sample tests. The machine had a temperature controller and a constant temperature of 24ºC was maintained throughout. A typical profile of absorbance versus time is shown in Fig. 1. Before nuclei appeared, for clear, transparent solutions, the absorbance was at a base line level with a value of about 0, because there was no solid particle in the solution. Once initial nuclei were formed, the turbidity, and hence, the absorbance reading increased. As more nuclei were generated and the crystals grew, turbidity increased gradually and until a maximum value was reached. The slope of the linear increase represented a characteristic growth rate of calcium lactate crystals. In this work, the onset time (i.e., the induction time) was found from the intersection of the base line and the extended line of the linear portion as shown in Fig. 1.

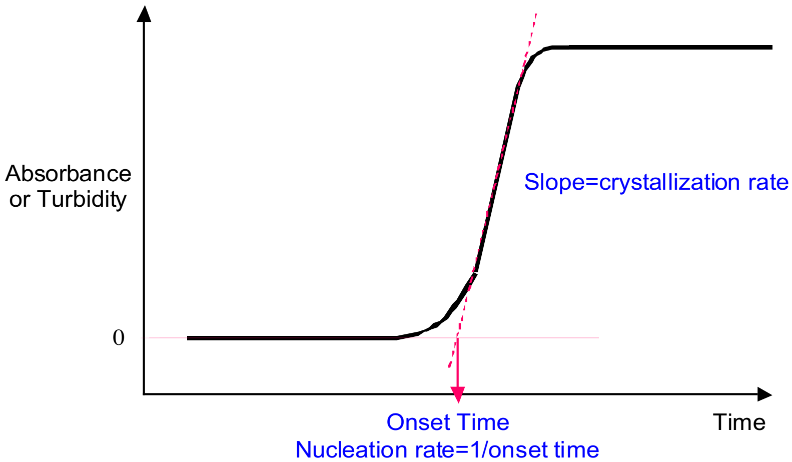


Figure 1. Typical simple kinetic profile by spectrophotometry.

Because the temperature could only be controlled between 15 and 50ºC for the Genesys 5 spectrophotometer, for temperatures of 10ºC and 4ºC, sample solutions in cuvette were placed in constant temperature (10ºC or 4ºC) chambers and monitored periodically for formation of initial crystals. Solutions were also examined by spectrophotometer to measure any turbidity increase. The time at which absorbance readings reached a level of 0.1-0.2, where a few visible crystals appeared, was taken as induction time for these lower temperatures.

Microscopy and image analysis for growth kinetics

In addition to the growth kinetics data obtained from the linear portion of the plot of absorbance versus time by spectrophotometry, a microscopic method was used to study the growth kinetics at different temperatures (24, 10 and 4ºC). A temperature-controlled glove box equipped with a microscope and digital camera was used to provide a constant temperature environment for crystal growth. A home-made microscope cell was filled with supersaturated solution, seed crystals were added into the sample solution and then covered by using a microscope cover glass. In the glove-box, the sample was place on the microscope stage and certain seed crystals were focused for image acquisition as they grew. The digital camera was controlled by image analysis software (Optimas 6.1) and sequence image acquisition was performed with a preset time interval. Typical images of calcium lactate crystals during growth in supersaturated solutions are shown in Fig. 2.

To study growth kinetics, images of calcium lactate crystals during growth in supersaturated solutions were analyzed to obtain data for crystal size increase as they grew. Because morphology of calcium lactate crystals were varied and the obtained images were only 2-dimensional, an average apparent equivalent diameter (AAED) based on the projective crystal image area was used to represent the characteristic crystal size. The procedures of image analysis are illustrated in Fig. 3.

Optimas 6.1 software was used to perform the image analysis. Original image of calcium crystals was treated by adjusting brightness and contrast, if it is necessary, to make crystals easier identified. After inverting the black and white based on gray scale, crystals were identified from the solution (background) according to the set threshold limits (lower and upper gray scales). Area of each projective area for individual crystals was then found out by the Auto-Find-Area function of the software and further interpreted into equivalent diameter for a sphere crystal with same projective area.

Figure 2. Characteristic growth of calcium lactate seed crystals in the photomicroscope cell.

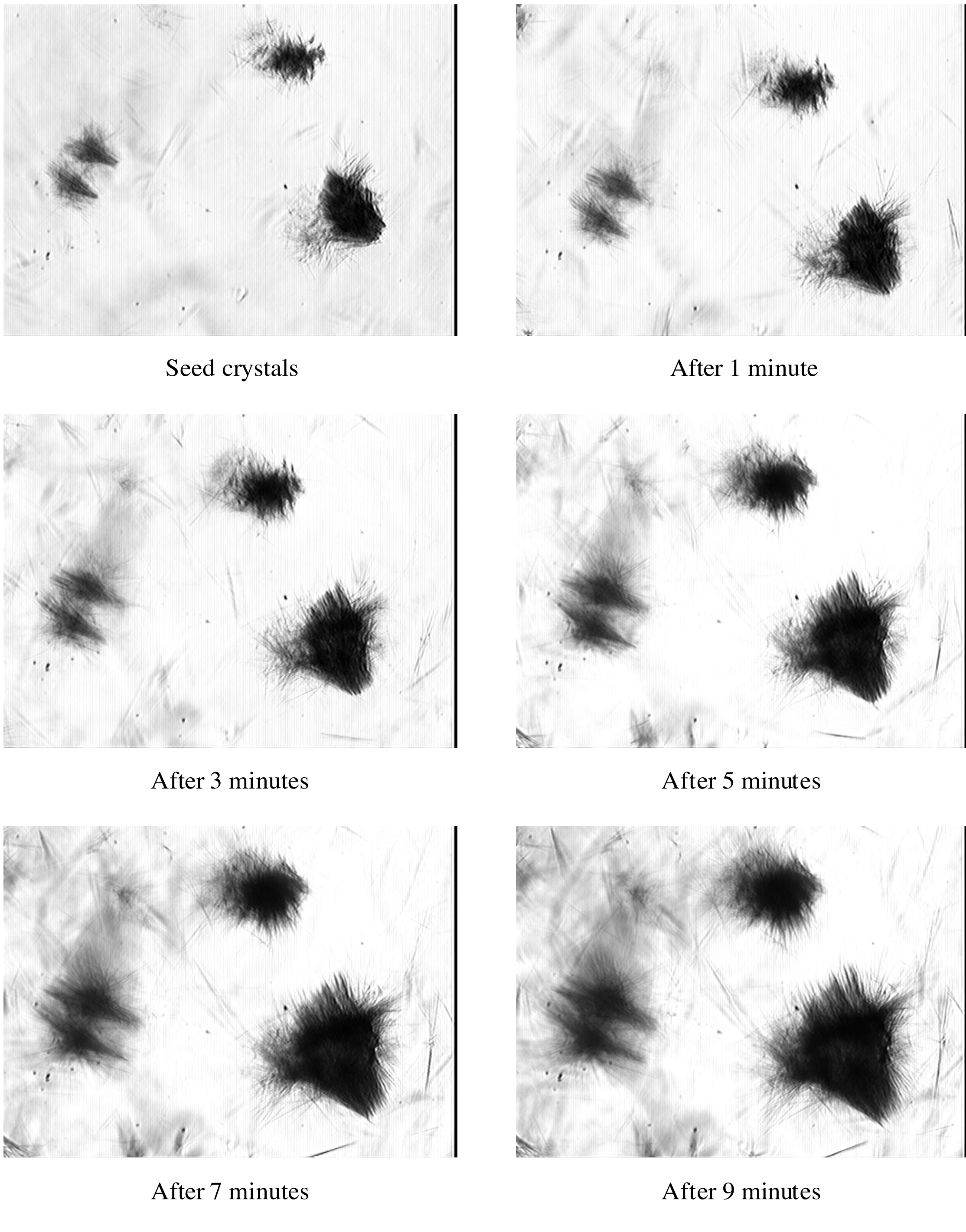
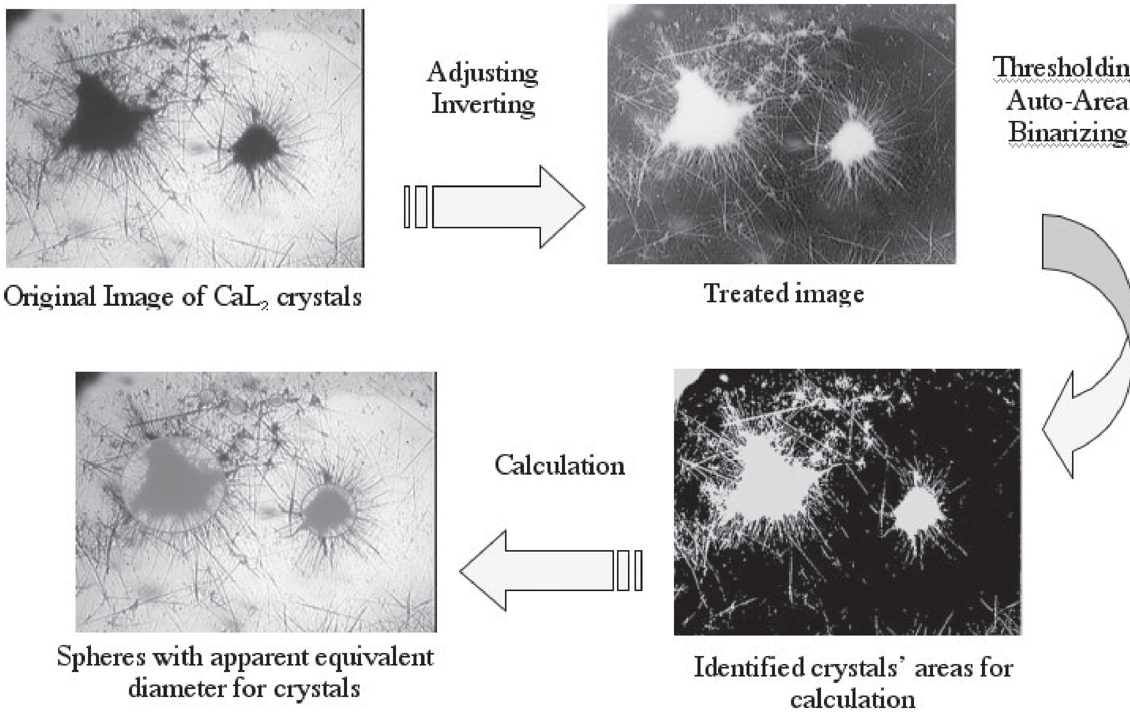
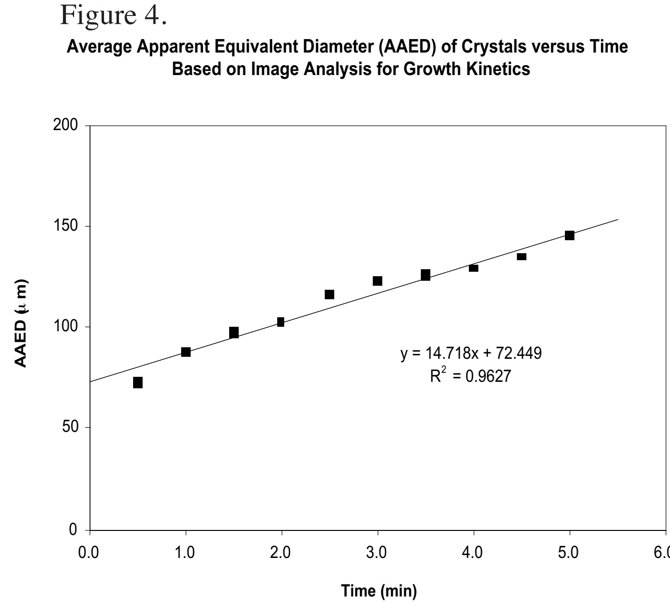


Figure 3. Image analysis sequence for characterizing crystal size.



The obtained apparent equivalent diameter data was output to MS Excel for further treatment giving average apparent equivalent diameter and other statistical data. After analyzing all images obtained from sequence acquisition in a growth kinetics run, average apparent equivalent diameter versus time lapse in the course of crystal growth was plotted. Fig. 4 is a typical plot showing there is a linear relationship between crystal size and time. Therefore, linear growth rate (i.e. the slope) was obtained by linear regression of the data points.

Figure 4.



Crystallization behavior

Crystallization behavior of calcium lactate was observed by both spectrophotometry and microscopy. Calcium lactate crystallized from supersaturated solutions in the form of pentahydrate and had various morphologies. The elementary crystals of calcium lactate have needle shape. However, the needle-shaped crystals may be combined together at certain contact points leading to larger crystals, or they may overlap to each other forming net-like structure. Packing of elementary crystals of calcium lactate was not dense so that there were spaces among crystal units. This resulted in various morphologies for calcium lactate crystals.

Images in Fig. 5 show some typical morphologies obtained in this work: the needle-shaped elementary crystals (1); needle-shaped crystals grew in all directions forming a sphere/egg-like crystal with needles around (2); needle-shaped crystals grow on existing crystal seeds (3); thick, large crystals formed by combination of grown individual crystals (4); developed dendrite/branch shaped crystals with overlapping and network (5 and 6). Instead of smooth surfaces, the developed crystals have needle-

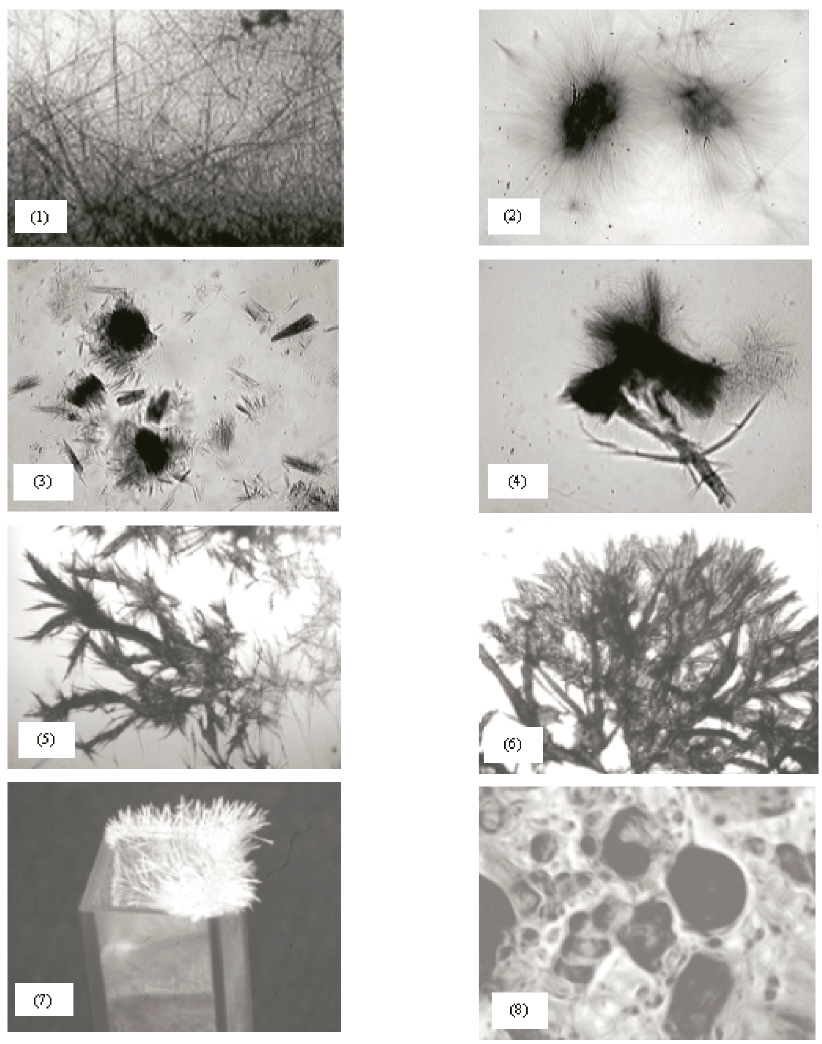


Figure 5. Typical images of calcium lactate crystals grown in this study.

shaped small crystals shooting outwards so that they have much large surface area per unit mass beneficial for molecule incorporation, and hence the growth, compared to those with smooth surfaces.

We observed that needle/dendrite-shaped crystals might shoot into air away from the solution when they grow (Image 7 in Fig. 5 and Fig. 6). Photos in Fig. 6 are examples of this phenomenon. The level of original solution was below the mid of cuvette, but the grown crystals were shooting up into the air, even beyond the top edge of the cuvette. On the surface of supersaturated solution, it was much easier to form nuclei and to grow for crystals because evaporation made supersaturation increased. Once crystals were formed on the surface of solution, as discussed above, there were a lot of spaces among individual crystals due to loose crystal packing. Thus, capillaries were formed inside the crystal structure and the solution could migrate upwards along those capillaries supplying materials for growth on the tips of existing crystals making them grow into air. This phenomenon indicated that migration of calcium lactate solution played an important role in crystallization.

Image 8 of Fig. 5 shows crystal aggregates of calcium lactate pentahydrate formed in 3-week-old cheese serum by static spontaneous crystallization. Their granular shape was significantly different from those formed in model systems indicating impurities (other components in serum) had remarkable effect on morphology of calcium lactate.

It was also observed that supersaturated calcium lactate solution, particularly those with lower supersaturation level, could exist in metastable state for quite a long time. However, compared to this slow nucleation kinetics, growth of calcium lactate was relatively fast. As long as there was enough number of nuclei, growth of calcium lactate was completed in relatively short period of time depending on the supersaturation level. For 3-week-old cheese serum without addition of calcium lactate, it seemed that it was unsaturated since there was no onset of crystallization observed as the serum stayed at 4ºC for almost two months.

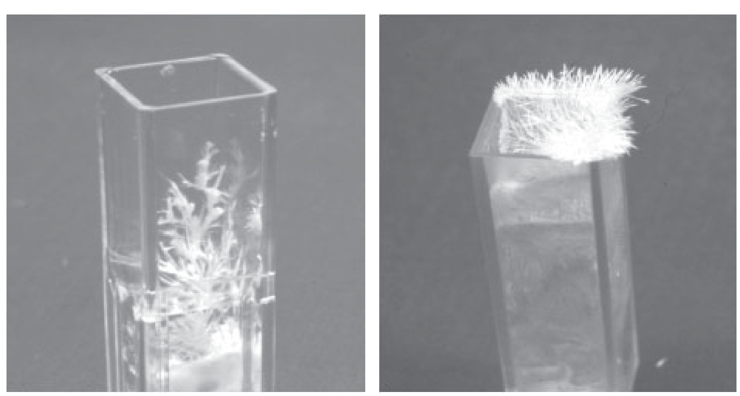


Figure 6. Calcium lactate crystals growing out of the sample cuvette.

Nucleation kinetics

Fig. 7 shows typical examples of absorbance versus time profile from the simple kinetics test by spectrophotometry for calcium lactate solutions with different supersaturations at 24ºC. Induction time obtained from kinetic studies by spectrophotometry for solutions with different concentration/supersaturation at different temperatures are shown in Fig. 8. It can be seen from both figures that induction time varied from as short as a few hours to as long as a thousand hours depending on the supersaturation of solution. As we combine factors concentration and temperature into one – supersaturation, the relationship between induction time (or nucleation rate, the inverse of induction time to represent nucleation kinetics,) and supersaturation (i.e. difference between concentration C and solubility C_S) can be seen in Fig. 9.

In Figure 9, a semi-log trend is found, which indicates the existence of an exponential relationship between induction time and supersaturation:

$$T_i = 1222.4 \exp(-0.506\,(C - C_s)) \qquad (1)$$

where T_i induction time (hr)
C concentration of calcium lactate solution (g/100g water)
C_s solubility of calcium lactate (g/100g water).

Higher concentrations and lower temperatures, which meant higher supersaturation, led to shorter induction time and higher nucleation rate. Thus, at lower concentration (e.g., 6.6 g/100g water) it was difficult for nuclei formation of calcium lactate, even at lower temperatures. However, with higher concentration (e.g.,19.2g/100g water), onset of calcium lactate crystallization could occur within one hour.

Figure 7.

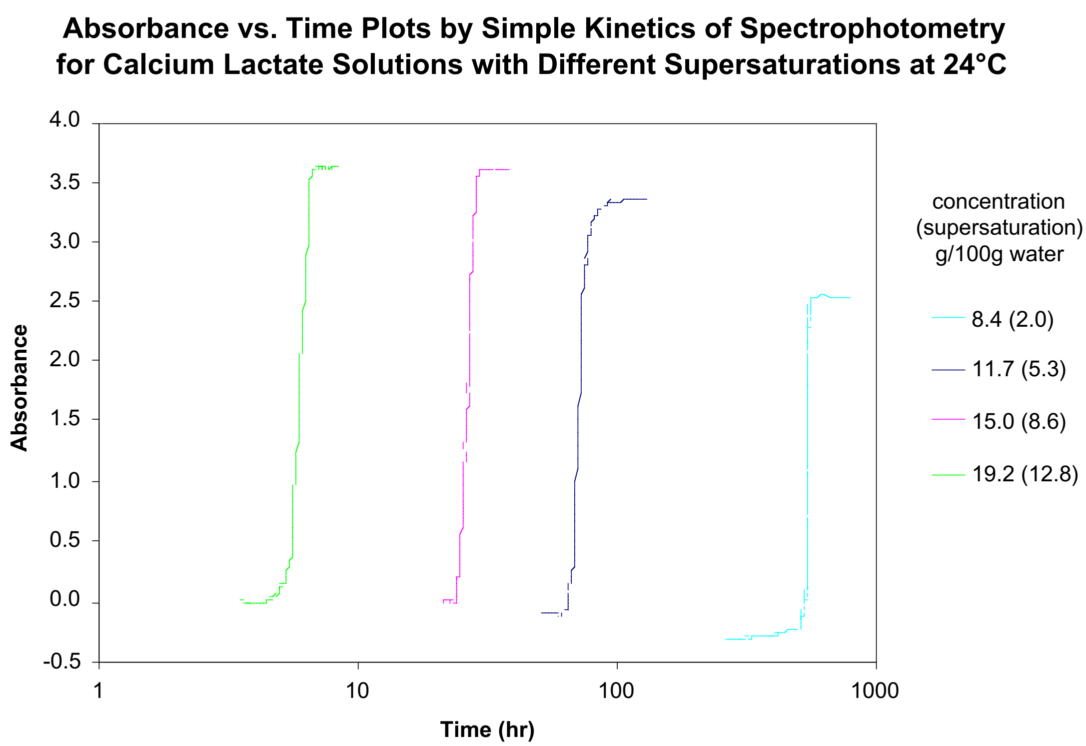


Figure 8.

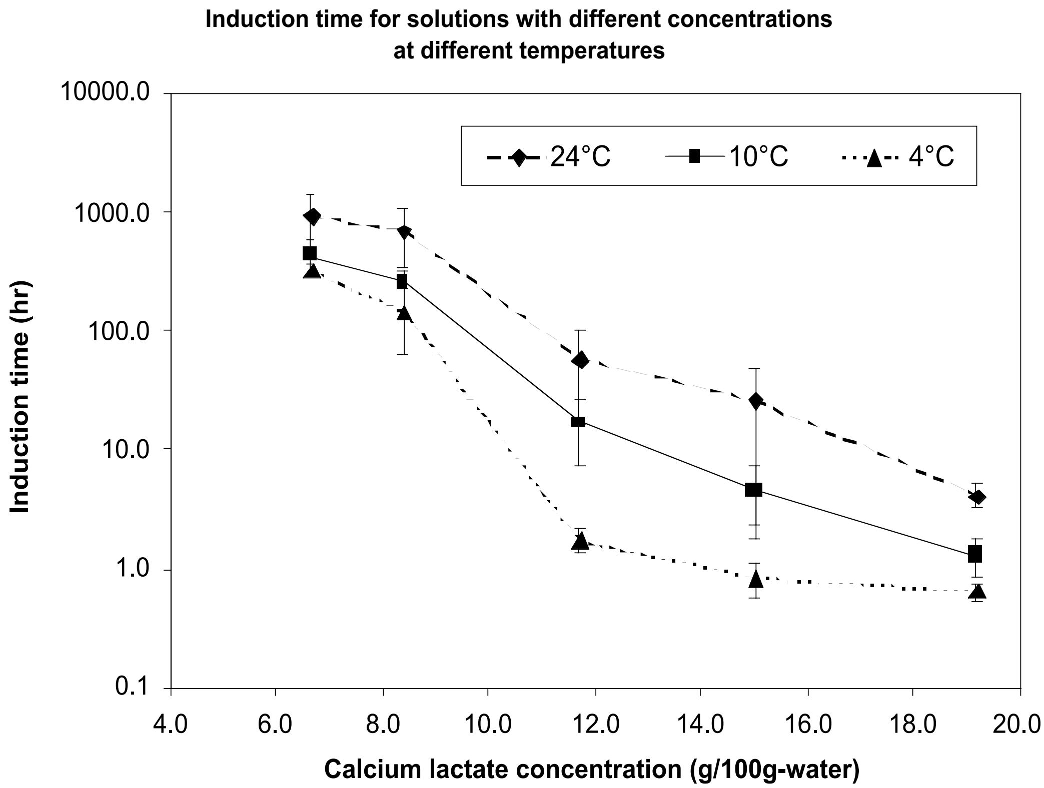
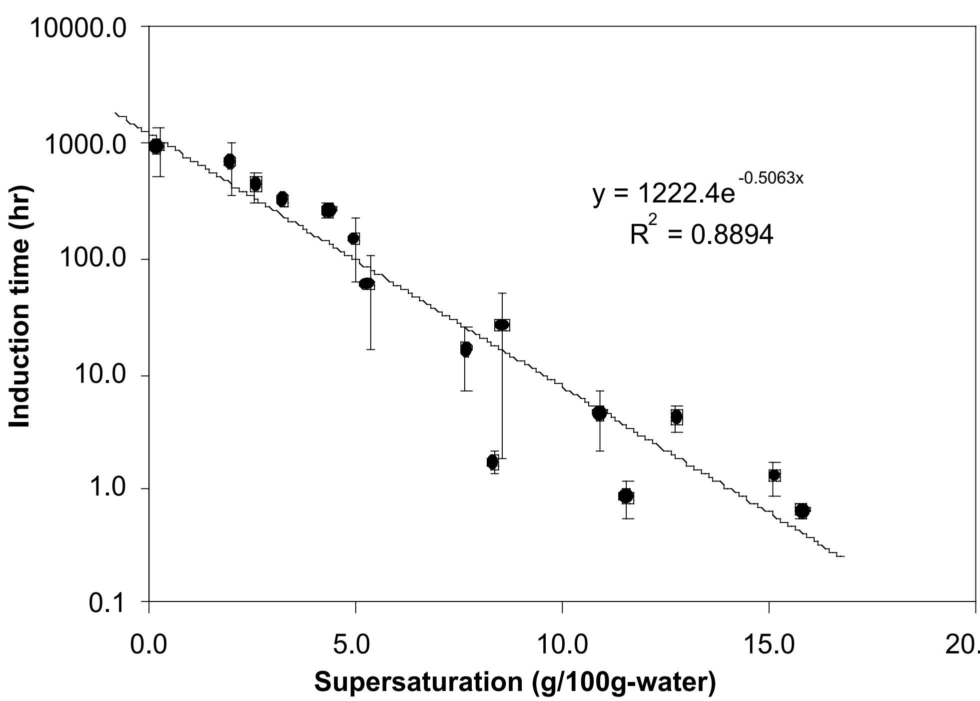


Figure 9. Kinetics of lactose nucleation plotted against supersaturation.



Induction time for different solutions with same calcium lactate concentration (11.7 g/100g water) at different temperatures is compared in Table 3. Compared to pure model system (CaL2+H_2O), induction time in the solution with lower pH (10P) was much longer, but in the solution with NaCl (10S) was shorter. For cheese serum, it much longer than for the pure system, this might be attributed from its lower pH and higher solubility of calcium lactate in cheese serum that was not available at this point. Thus, higher concentration of calcium lactate in cheese serum would be a necessity to have earlier and easier formation of 'bloom' on cheese surface.

We noticed that some standard deviations of induction time, particularly for solutions with lower concentration, were large indicating that induction time could have a wide range under the same crystallization conditions. Thus, there may have been other unpredictable factors (e.g., disturbance) causing variation.

Table 3 Comparison of induction time (hr) for different solutions

T(K)	10N		10S		10P		10C		10J	
	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std
277	1.7	0.4	0.9	0.4	2.7	1.6	1.4	0.4	3.1	0.7
283	16.8	9.4	5.8	5.3	66.4	19.7	19.9	5.7	37.5	7.3
297	59.2	42.8	20.8	5.6	356.6	154.6	90.8	35.5	203.5	43.5

* Avg.– average; Std.– standard deviation.
See Table 2 for definition of sample conditions

Crystal growth kinetics

The results of growth kinetics for calcium lactate crystallization in solutions at 24ºC studied by spectrophotometry are shown in Fig. 10, in which growth rate is expressed as turbidity (1/m) increase per unit time (hr). As expected, higher concentration lead to higher growth rate. The relationship followed an exponential model:

$$R_t = 13.3 \exp(0.307 (C - C_s))(2)$$

where R_t growth rate in terms of turbidity increase per unit time (1/m-hr).

The growth kinetics in terms of apparent linear growth rate of calcium lactate in supersaturated solutions with different concentration and at different temperatures are shown in Fig. 11. As expected, growth rate increased as the concentration increased at each temperature. However, it is interesting that for a solution with a certain concentration, growth rate at 10ºC had higher value than those at 4ºC or 24ºC. This is shown more clearly in Fig. 12. If the supersaturation ratio (C/Cs) is used to express the driving force, plots of apparent linear growth rate versus supersaturation ration are obtained as shown in Fig. 13. Over a wide range (supersaturation ratio larger than about 1.8), growth rate was higher as temperature increased at a certain supersaturation level. This is more clearly shown in Fig. 14, in which growth rate at different supersaturation ratios was calculated based the trendlines for each curve in Fig. 13.

Our results indicate that concentration and temperature had a complex influence on growth kinetics. Supersaturation is directly related to con-

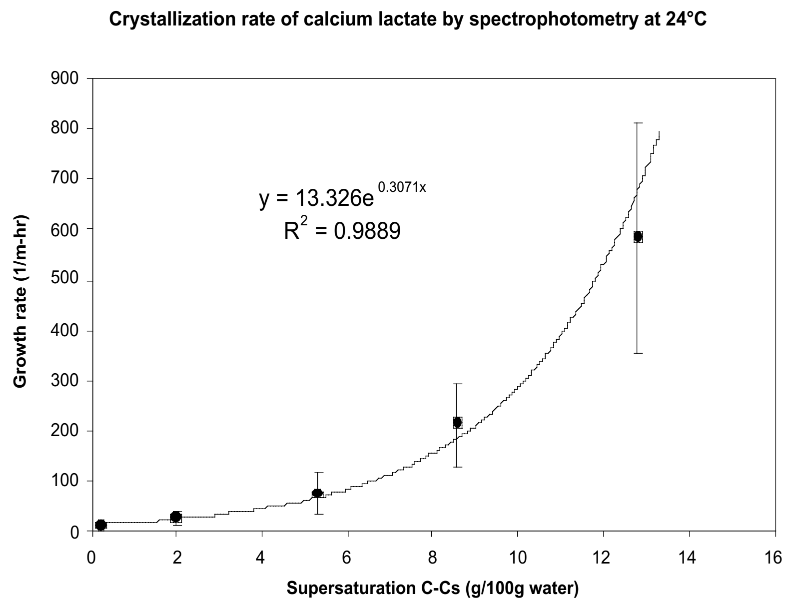


Figure 10.

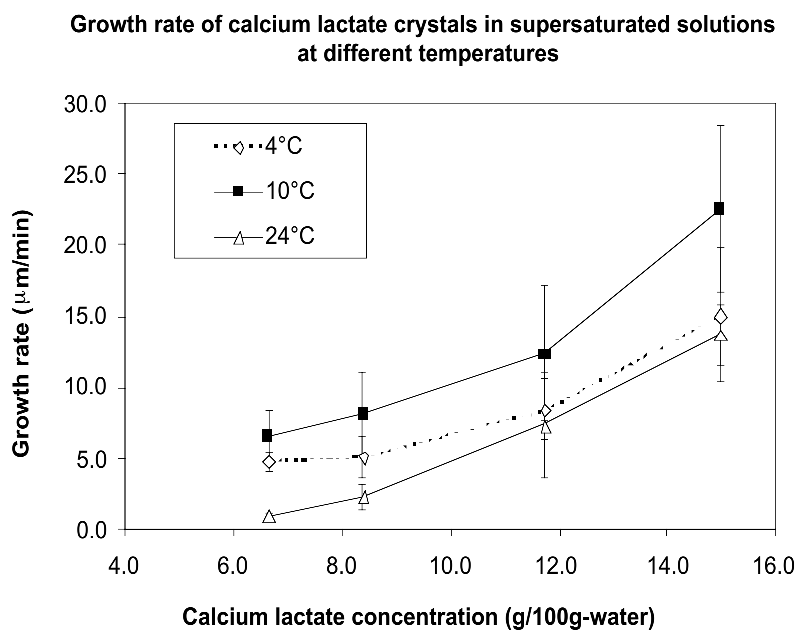


Figure 11.

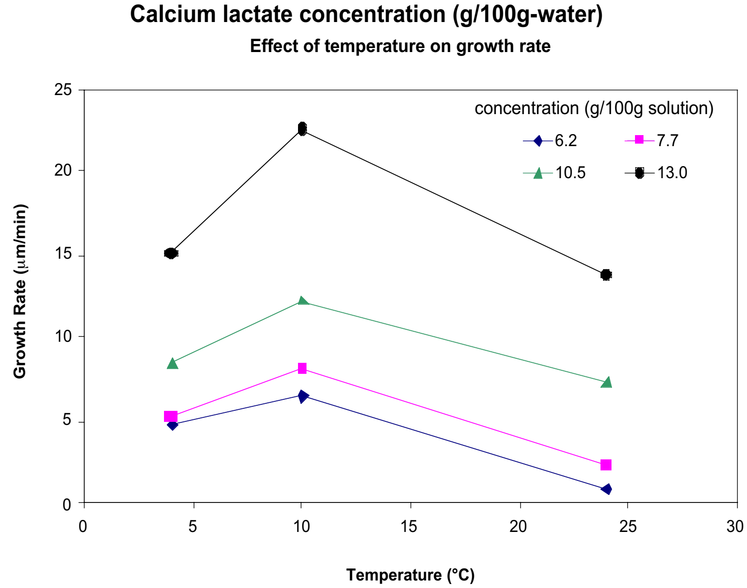


Figure 12.

centration, as well as temperature via solubility. The viscosity of solutions is temperature-dependent and also affected by concentration. Higher temperature led to lower viscosity, which would be beneficial to diffusion of calcium lactate molecules from bulk to crystal surfaces, hence promote growth kinetics. However, on the other hand, higher temperature increased solubility and reduced the supersaturation level of a solution with a certain concentration. Thus, effect of temperature on growth kinetics should be analyzed based on the balance of those two aspects. Generally, the temperature of 4ºC was too low to allow calcium lactate molecules to move efficiently; hence, higher growth kinetics were found as temperature increased, even though this led to a lower solubility. The temperature of 24ºC , however, was too high to have sufficient supersaturation level for solutions with a relatively lower concentration, but it was beneficial to molecule diffusion and could result in very high growth kinetics if the supersaturation level was high enough. Summing up, for solutions with concentration in a certain range, the temperature of 10ºC might provide the most suitable environment for crystal growth of calcium lactate. It must be pointed out this is only a preliminary result based on the work at only 3 temperatures.

A plot of growth rate versus supersaturation level based on all runs is shown in Fig. 15, regardless of the solution concentration and crystallization temperature. A clear trend that growth rate increases as the supersaturation increases is observed, although data points in the higher supersaturation range are scattered. A linear regression was performed

$$R_g = 1.53\ (C^{\dagger} - C_s) \qquad (3)$$

where R_g apparent linear growth rate (µmm/min).

The linear growth rate for calcium lactate could reach a level as high as 25 µmm/min in a stagnant environment. Compared to nucleation kinetics, growth rates are much faster. Therefore, once nuclei are formed, cheese 'bloom' will develop quite quickly as long as there is sufficient source of calcium lactate solution. Growth rate for different solutions with same calcium lactate concentration (11.7 g/100g-H_2O) at 10ºC is compared in Table 4. The growth rate of calcium lactate in cheese serum was much lower than those in model systems that had similar growth kinetics implying other components in cheese serum had significant effect on the kinetics.

Similar to the character for nucleation kinetics, standard deviations of linear growth rate, particularly for solutions with higher concentration, were relatively large indicating that the growth kinetics was influenced by other unpredictable factors (e.g. disturbance, etc.) in addition to concentration and temperature.

Mechanism of formation of cheese 'bloom'

According to the results drawn form this work, nucleation of calcium lactate is slow whereas growth is relatively fast. Since nucleation is the first phase for crystallization, it must be the key issue for formation of cheese 'bloom'. Nucleation of calcium lactate may occur from the cheese serum (solutions with CaL_2) on the surface of cheese, but it takes a long time if the concentration of calcium lactate is not high enough. However, if moisture is lost from the cheese serum due to any reason (e.g., evaporation), the concentration of calcium lactate will be increased, nucleation

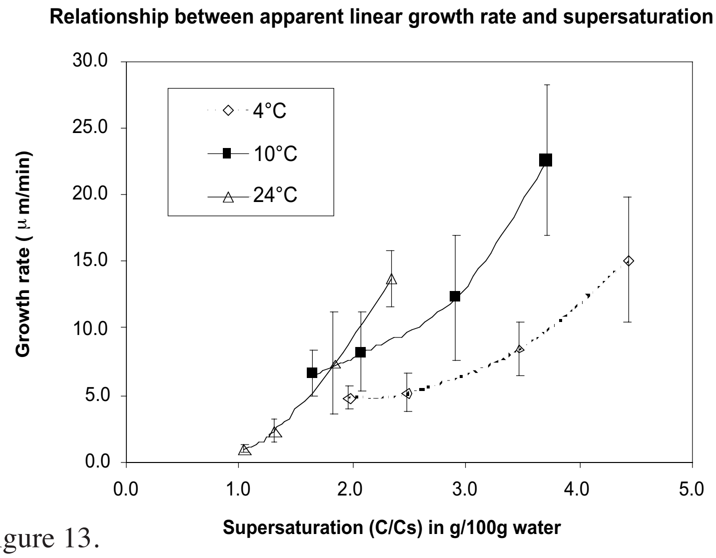


Figure 13.

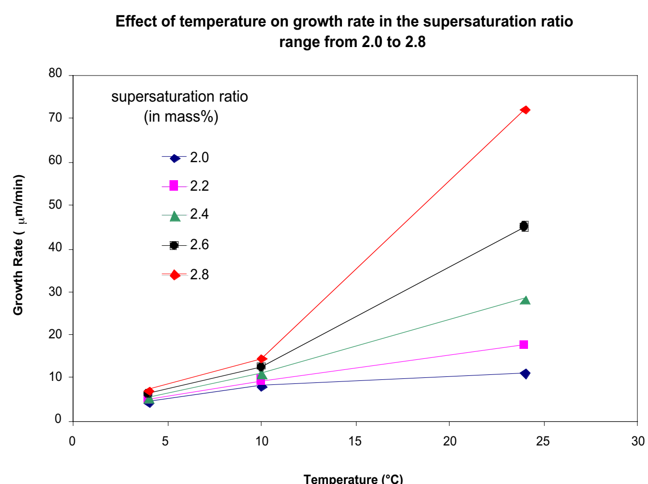


Figure 14.

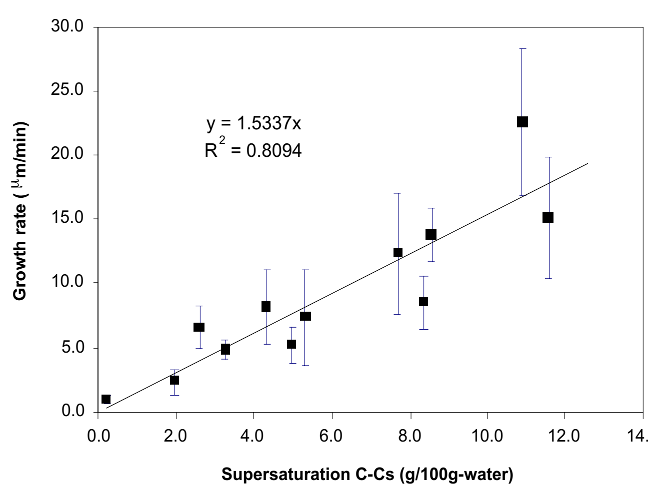


Figure 15. Growth rate plotted against supersaturation for all experimental conditions.

kinetics will be promoted and nucleation will be initiated. Cheese serum may migrate from inside to the surface, particularly if there is a capillary structure existing inside cheese or in the formed crystal network. This provides a CaL_2 source for crystal growth, which is usually fast, especially at 10ºC or higher temperatures, and leads to 'bloom' development.

To prevent development of 'bloom' during storage, it is most important to avoid nucleation. Sites for nucleation may be small cracks or crevices in the cheese structure or perhaps sites where dust particles have landed during processing. Further work on quantifying the nature of surface active sites for calcium lactate nucleation would be useful provide directions for preventing cheese bloom by preventing the initiation of CaL_2 crystals. Drying out of the cheese surface will also promote onset of crystal formation as the supersaturation is increased.

Summary

Spectrophotometry and photomicroscopy can be successfully used for studies of nucleation and crystal growth kinetics, respectively.

Nucleation kinetics of calcium lactate is relatively slow with induction time from several hours to hundreds of hours. Higher concentration and lower temperature will result in higher nucleation rate (or shorter induction time)

Compared to nucleation, growth of calcium lactate crystals is relatively fast. Effect of combination of temperature and concentration on growth kinetics is complex with maximum growth rate occurs at about 10∞C.

The model systems studied crystallized much more readily than the cheese serum extracted from young cheese. Apparently, either the calcium lactate concentration in the serum is lower than in our model systems or there is another minor component with very strong effect on calcium lactate crystallization.

Future work on controlling cheese bloom should focus on (1) reducing the calcium lactate serum concentration, (2) understanding what crystallization inhibitors are present in serum, and (3) understanding the active surface sites for nucleation.

Publication/Presentation

A paper, 'Solubility and crystallization kinetics of calcium lactate in aqueous systems', was presented at the ICEF9 – International Conference Engineering and Food (2004). This work is published in the proceedings of that conference. Additional publications are being considered.

Table 4 Apparent linear growth rate (mm/min) for different solutions at 10ºC

Solution	10N		10S		10P		10C		10J	
	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.
Rate	12.3	4.7	13.5	6.3	10.2	4.4	12.0	5.7	3.6	1.3

* Avg.– average; Std.– standard deviation.
See Table 2 for definition of crystallization conditions

Determination of the minimum levels of galactose in whey

Personnel

Richard W. Hartel

Funding

Dairy Management, Inc.

Dates

June 2001 to December 2002

Objectives

To determine the minimum level of galactose and lactic acid that lead to stickiness during drying of whey permeate. Model systems of lactose, galactose and lactic acid were prepared to simulate whey permeate (minus the salts). Glass transition temperature was measured along with mechanical stickiness.

Summary

Materials

Analytical grade α-lactose (monohydrate), lactic acid and galactose used for studies of glass transition and stickiness of lactose glasses were obtained from Sigma Chemical Co. (St. Lois, MO). Distilled water was used for all preparations.

Preparation of glassy samples

Extra water (2-3 times of target) was added into 20 gm mixture of components according to a predetermined formulation in a 200-ml high-style beaker with a vapor duct on the top. Gradual evaporation was conducted by controlled heating until predetermined moisture content, which was monitored by gravimetry at an accuracy of 0.01gram, was reached. Finished mixtures were then cooled immediately in ice water to form the glassy samples.

Measurement of Tg

Samples were taken from the glassy material just before the DSC (differential scanning calorimetry) analysis. For samples in hard solid state, they were broken into small pieces first. For samples in soft semi-solid state, a small part of a sample was chosen randomly by use of a spatula. Heating scan was performed at 5ºC/min in a range of temperatures covering the glass transition point. 6-9 replicates were done for each sample.

Texture analysis

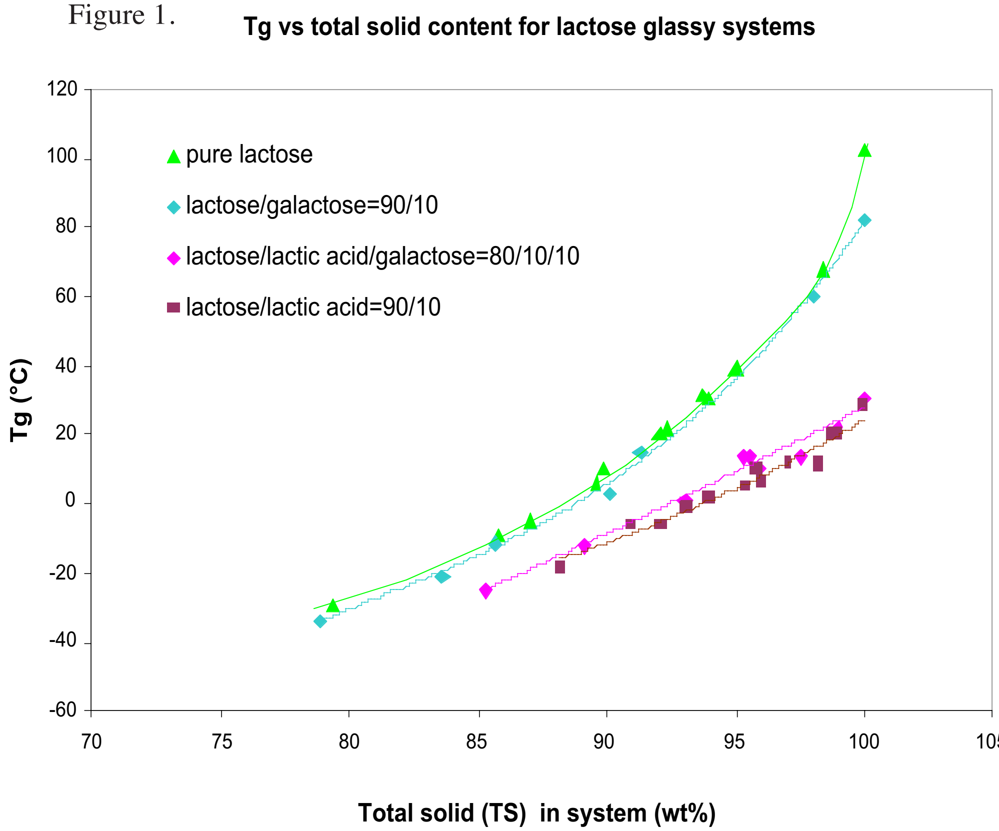
Samples for texture analysis were taken at the end of cooking for preparation of lactose glasses. An aluminum mold with 8 cylinder shapes (10mm in diameter and 10mm deep) was used. Initially, the molds were overfilled for solidification, but then the extra material was cut off to provide a flat surface for analysis. The samples were covered with Parafilm to prevent any moisture loss. Samples were analyzed with a TA-XT2 texture analyzer for stickiness once the sample was cooled (in about 1 hour). A standard program (method) for stickiness by compression test with a stainless steel cylinder probe (5mm in diameter) was used. Once a preset force of 0.5N was established and kept for 60 seconds, the probe was moved to the initial position. Force versus time was recorded and the maximum force generated at the moment of upward movement of the probe after the 60-second force (0.5N) equilibration was taken as a measure of stickiness (s)

Results and discussion

The effects of galactose and lactic acid in lactose glassy systems on phase/state transition in terms of glass transition temperature (Tg) can be analyzed from the DSC results.

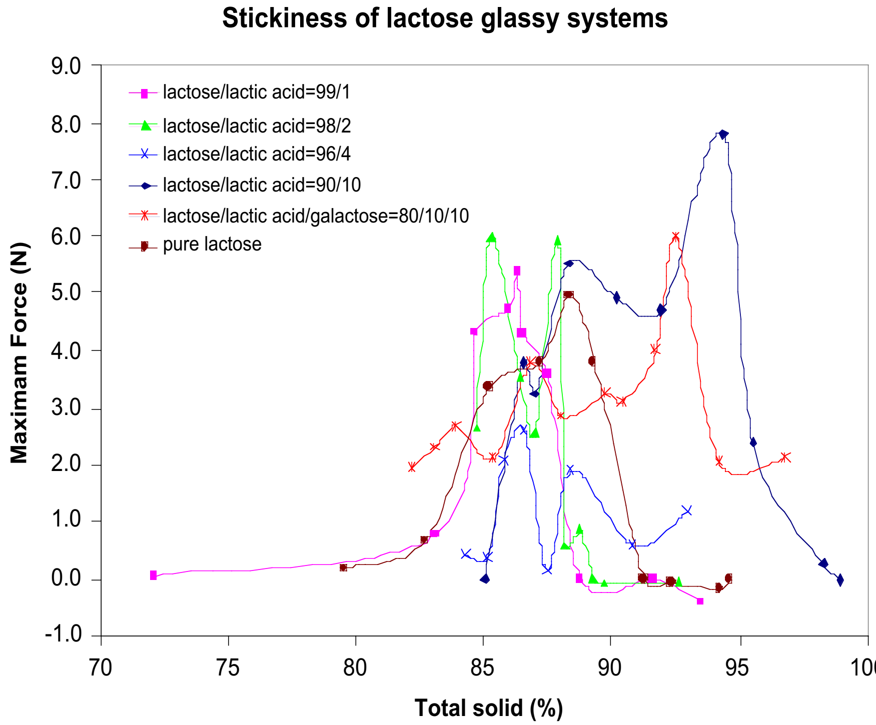
Fig. 1 shows the Tg of lactose glassy systems containing lactic acid and/or galactose at 10% (dry basis) level. The profile curve for systems with lactic acid is far under that for pure lactose systems indicating lactic acid had significant effect on Tg. It can be seen that unlike lactic acid, galactose had much less effect on Tg. The curve for systems with galactose is very close to that for pure lactose systems. The curve for systems with both lactic acid and galactose is located very close to that for systems with lactic acid, further documenting that galactose had little effect on Tg of lactose glassy systems.

Figure 1.



Profiles of stickiness versus moisture content for the lactose glassy systems with different formulations are shown in Fig. 2 from preliminary experiments on texture analysis. Since the lactose glass was very hygroscopic, it easily absorbed moisture and changed its property of stickiness; thus, texture tests had to be done with fresh samples by cutting off the extra part (of the over-filled mold). Even when the tests were carefully performed, variation of the results was still relatively large. Further work is underway to improve the accuracy of these results. Stickiness was found to be at a maximum for a certain water content, but that was dependent on the ingredient composition. Further details of these curves is provided below.

Figure 2.



A typical profile of stickiness versus moisture content (or total solid content) for a glassy system with a certain formulation is shown in Fig. 3. When moisture content was very low, the glassy system was not sticky (s=0). When moisture content was increased and exceeded a certain level (critical point where s>0), its stickiness increased. When moisture content was higher than a certain level and the system was in solution state or close to a solution state, the sample again was not sticky. Thus, the profile had a peak in stickiness at a certain moisture content. During drying of a liquid mixture, stickiness will be changed from left to right along the profile curve. The critical points (moisture content for a certain formulation) for both pre-sticky and post-sticky, can be found from the profile where s s=0. Since the pre-sticky point is usually out of the range of drying, the post sticky critical point is more important for drying.

Profiles of stickiness versus moisture content for the lactose glassy systems with lactic acid or galactose at 10% (dry basis) level compared to pure lactose system are shown in Fig. 4. It can be seen that systems with lactic acid had a profile peak at lower moisture than for the pure lactose systems. The critical point occurred at very low level of moisture content indicating lactic acid increased the stickiness property very much. In contrast, the stickiness peak of systems with galactose was about the same as that for pure lactose systems. Stickiness only increased a little when moisture content was less than 9% making its critical point at about 7.8% moisture. This implied galactose had limited effect on stickiness, and certainly not to the same extent as lactic acid.

Figure 3.

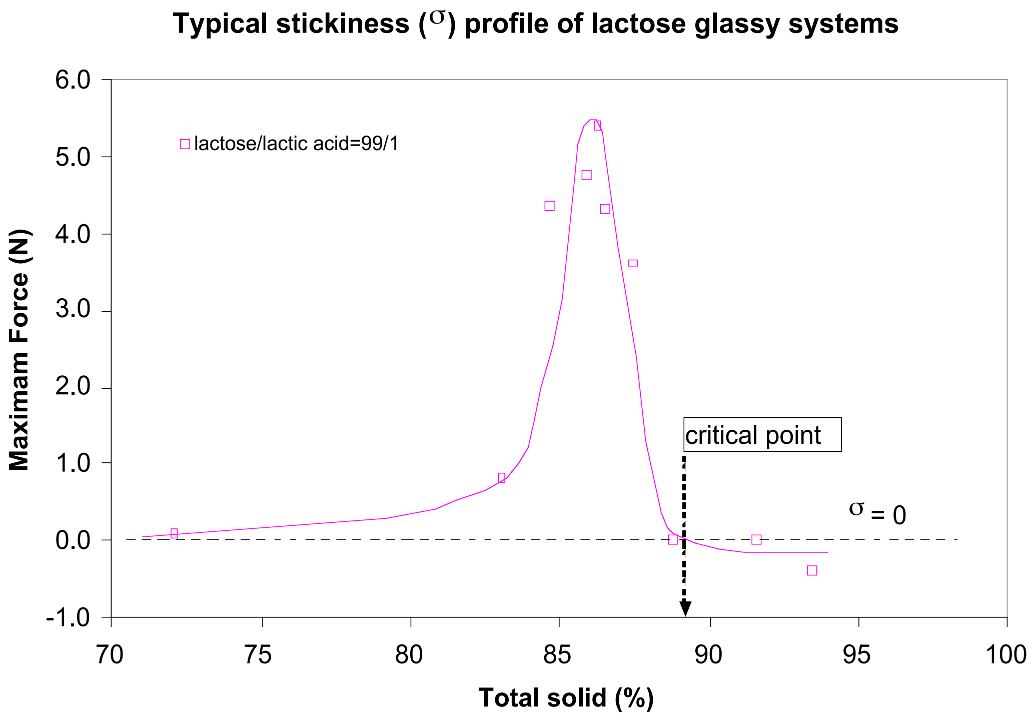
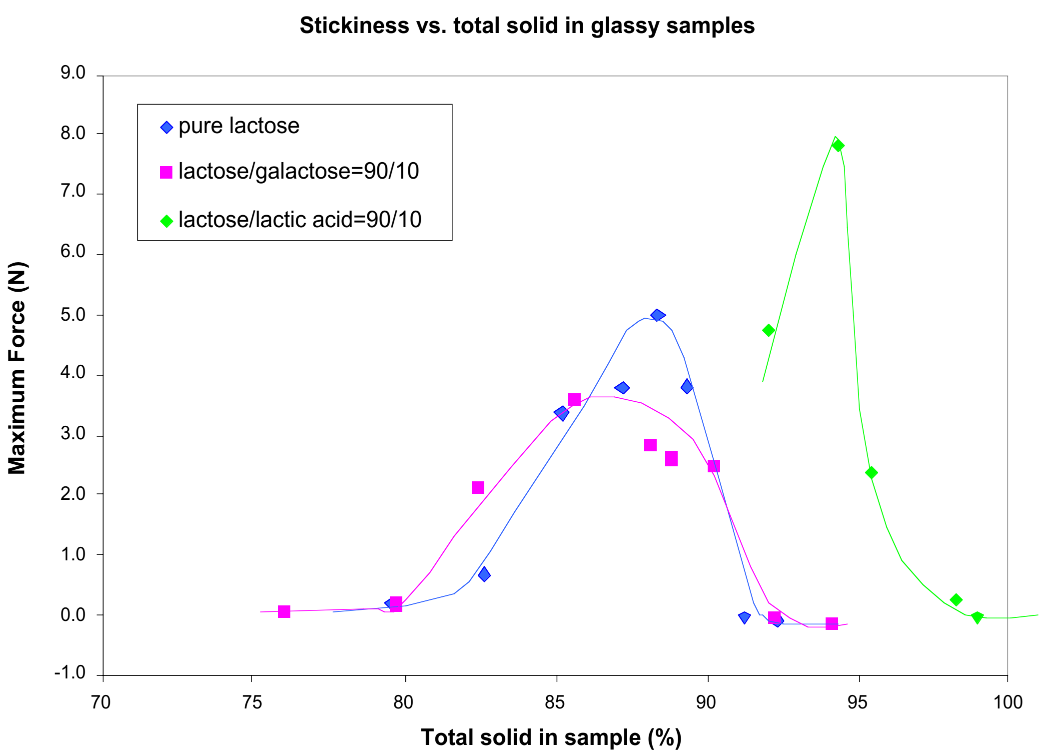


Figure 4.



From the critical point data, a sticky zone map can be generated as shown in Fig. 5 (note: data still preliminary). The sticky zone shown in Fig. 5 represents the peak part of the stickiness profile in Fig. 2 for each different formulation. The area above the sticky zone, at higher moisture content, represents the region with solution state for systems. Here, the material is fluid and does not exhibit a sticky characteristics. The area below the sticky zone, at low moisture content, represents the region of non-sticky glassy state for these systems. Drying of a system with a certain formulation may be represented by a downward procedure as shown, for example, by the dashed arrow line in Fig. 5 for lactic acid/ lactose=1.7/98.3 (dry basis). Clearly, higher levels of lactic acid mixed with lactose result in a much wider sticky zone, especially at lower moisture contents.

The relationship between moisture content and lactic acid/galactose content based on the post-sticky critical point was established, as shown in Fig. 6, from which sticky zone and non-sticky zone can be distinguished. As lactic acid or galactose content increased, the critical moisture content for stickiness decreased; however, systems with galactose were not as affected as systems with lactic acid. This implied again that the effect of galactose on stickiness was quite limited. Systems (with a certain moisture and lactic acid content) with galactose would have much larger area located in the lower left zone and would be non-sticky. The minimum lactic acid or galactose level that lead to stickiness for a target moisture content in drying can be found from the corresponding curve.

Figure 5.

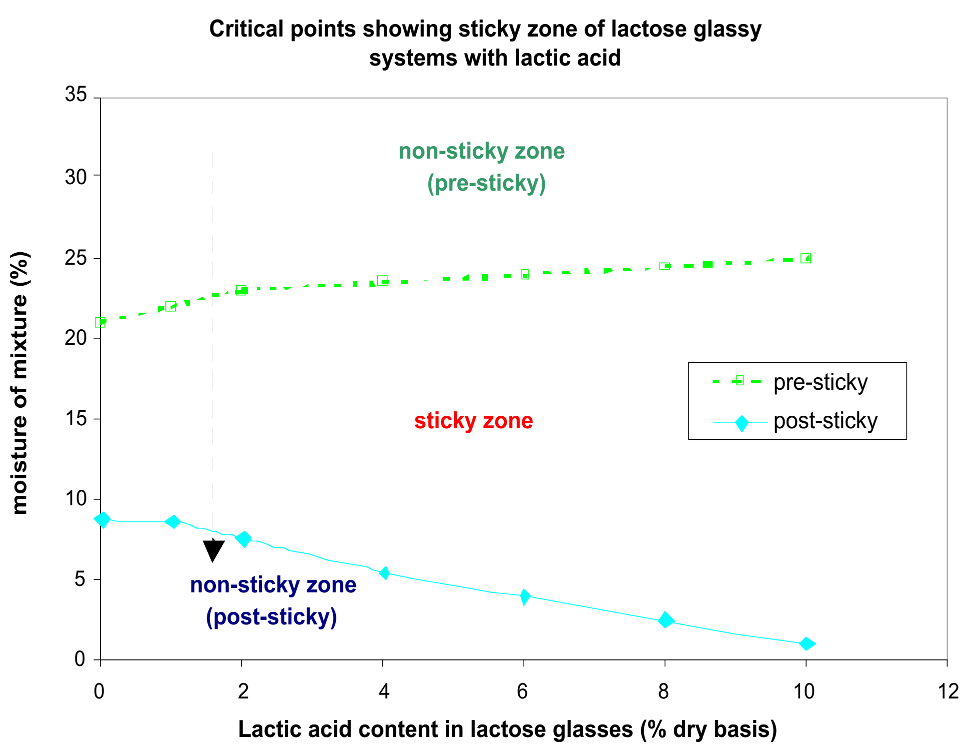
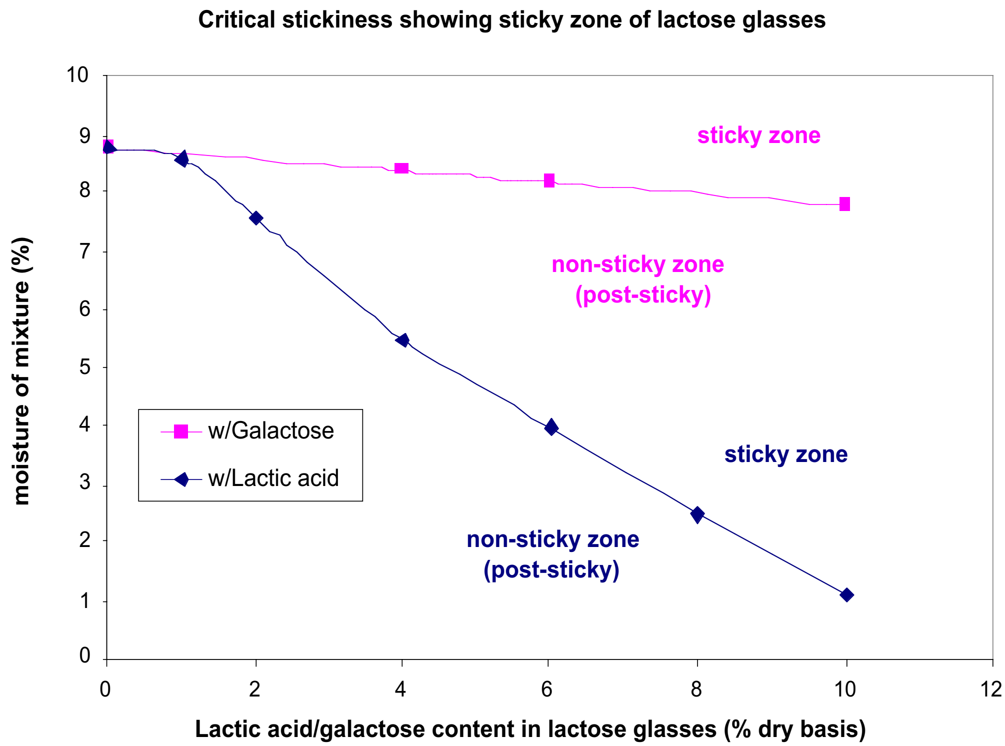


Figure 6.



The presence of lactic acid had significant effect on the glass transition temperature of lactose, particularly in the lower level of lactic acid..

Unlike lactic acid, galactose and salt (calcium lactate) had little impact on Tg of lactose glassy systems.

Stickiness for lactose systems appears in a moisture range from a pre-sticky critical point to a post-sticky critical point and for pure lactose systems, this range of moisture content is from 8.8% to 21%.

The presence of lactic acid significantly affected stickiness of lactose systems in terms of the range of moisture content for stickiness and the magnitude of stickiness. In contrast, the effect of galactose on the stickiness nature was very limited, as expected from the limited Tg effect.

A relationship between moisture content and lactic acid content based on the critical sticky point was established, from which sticky zone and non-sticky zone can be identified. These results will help provide guidance for developing protocols for drying.

Relationship between cheese melt profiles and chemical/textural/sensory properties

Personnel

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Funding

Dairy Management, Inc

Dates

March 2000 to December 2002

Objectives

1. To characterize the effect of selected manufacturing protocols on cheese melt profiles.

2. To correlate cheese melt profile characteristics to chemical/textural/sensory properties.

3. To develop strategies based on correlations that enable cheesemakers to design manufacturing practices which result in specific melt/flow characteristics for food application systems.

Summary

To gain a better understanding of relationships between cheese melt profile characteristics and chemical/textural/sensory properties data was collected from a variety of cheese types, compositions and ages (See Table 1). Cheeses were procured from concurrent research projects and local cheese manufacturers. Melt profile analysis, a modified squeeze flow method for assessing cheese meltability, simultaneously measures the decrease in cheese height and increase in cheese temperature over time when a disc of cheese is placed in an oven. This method characterizes the time, temperature and rate of heating on cheese as it softens, flows and ceases to flow. The eight traits measured by melt profile analysis are: softening rate, softening temperature, softening time, flow rate, complete melt rate, complete melt temperature, complete melt time and extent of flow. Chemical data collected included moisture, protein, fat, salt, pH and TCA soluble N (measures the degree of casein hydrolysis). Trained descriptive panelists, using IFT guidelines for Quantitative Descriptive Analysis evaluated cheese texture (cubes at 40ºF), and melted cheese stretch, surface and texture attributes. Cheese texture attributes were as follows: firmness, deformabilty, hardness, fracturability, adhesiveness and cohesiveness. Observations made on melted stretch and surface characteristics were strand length, thickness and cohesiveness, force to stretch, cheese tenting (amount of cheese pulled off crust when pulling a strand of cheese with a fork), blister quantity and color, free oil release and degree of skinning. Melted cheese texture attributes were as follows: liquid release during chewing, cohesiveness of mass, roughness of mass, chewiness and hardness. For data analysis we used Stepwise Regression Analysis, a multiple regression model that simultaneously

Table 1. Melt Profile Project summary of cheese types, composition, ages and number of samples analyzed.

Type of Cheese	Description	% Moisture	% FDM	Ages of Cheese (wk)	Lots Analyzed
American – Type					
Brick	Mesophilic cultures, washed curd	Range: 41.1 - 42.1 Mean: 41.6	Range: 54.4 - 53.8 Mean: 54.1	1 to 10	Lots: 2 Total: 8
Cheddar	Milled curd, no curd washing	Range: 36.8 - 37.9 Mean: 37.5	Range: 52.0 - 52.6 Mean: 52.3	1 to 26	Lots: 4 Total: 18
Cheddar	Stirred Curd, no curd washing	Range: 36.1 - 37.5 Mean: 36.7	Range: 51.8 - 53.7 Mean: 53.0	1 to 26	Lots: 4 Total: 18
Cheddar	50% Reduced-fat, no curd washing	Range: 47.1 - 48.9 Mean: 48.2	Range: 25.8 - 29.2 Mean: 27.2	1 to 15	Lots: 3 Total: 15
Colby and Monterey Jack	Mesophilic cultures, washed curd	Range: 37.6 - 43.7 Mean: 41.5	Range: 52.2 - 54.1 Mean: 53.4	1 to 20	Lots: 8 Total: 38
Muenster	Thermophilic cultures, no curd washing	Range: 45.4 - 52.1 Mean: 47.0	Range: 44.3 - 52.1 Mean: 47.9	1 to 10	Lots: 3 Total: 13
LMPS Mozzarella					
Pasta filata	Typical make, Higher than normal milk pasteurization temperatures, WPC addition)	Range: 43.0 - 51.2 Mean: 46.4	Range: 38.2 - 44.0 Mean: 42.4	1 to 10	Lots: 15 Total: 67
Stirred Curd Non Pasta filata	Typical make (CDR stirred curd Mozzarella, direct salted), higher than normal milk pasteurization temperatures, WPC addition)	Range: 44.6 - 48.0 Mean: 46.4	Range: 41.1 – 48.5 Mean: 43.8	1 to 15	Lots: 12 Total: 45

assesses all explanatory variables. The model searches for the one variable, which gives the best explanation of the dependent variable (highest R^2 of all possible simple regressions). Next the model searches for a second explanatory variable and chooses the one that gives the maximum increase in R^2 to the value of R^2 from the first step. This search continues until remaining variables have insignificant contributions to the dependent variable.

Understanding the correlation between the melt profile analysis characteristics and melted cheese properties will enable cheese end users to more accurately and reliably manipulate and control cheese melt properties for a specific ingredient application system. Melted cheese properties were split into three groups: stretch properties, melted cheese surface characteristics, and melted cheese texture/mouthfeel. Stepwise regression analysis was completed using the each of the three cheese melt properties group as the dependent variables and melt profile analysis characteristics (softening rate, softening temperature, softening time, flow rate, complete melt rate, complete melt temperature, complete melt time and extent of flow) as the independent variable. Table 2 summarizes the top explanatory variable for the melted cheese attributes for all the cheeses.

Stretch properties

The stretch properties of strand length, strand thickness, strand cohesiveness, force to stretch and cheese tenting were assessed by expert panelists. There were no strong correlations between the melt profile attributes and descriptors for stretched cheese strands (length, thickness and cohesiveness). These stretch properties are strongly influence by cheese pH and degree of proteolysis. Correlations existed between cheese flow and descriptors relating to the stiffness of the melted cheese during stretching. Melt profile analysis 'flow rate' correlated well to the force to stretch for Cheddar cheeses (50%RF $R^2 = 0.81$; Milled $R^2 = 0.67$, Stirred $R^2 = 0.55$) during the first 8 weeks of aging. Melt profile analysis 'softening temperature' also correlated well to 'force to stretch' (cheddar stirred $R^2 = 0.73$, colby/jack $R^2 = 0.68$, mozz pasta $R^2 = 0.64$). The 'softening time' correlated well to cheese tenting (cheddar 50% RF $R^2 = 0.75$, colbyjack $R^2 = 0.61$). In general, the slower the 'flow rate' or the greater the 'softening temperature/time', the stiffer the cheese. Stiffer cheeses required a greater force to stretch or exhibited more cheese tenting.

Surface characteristics

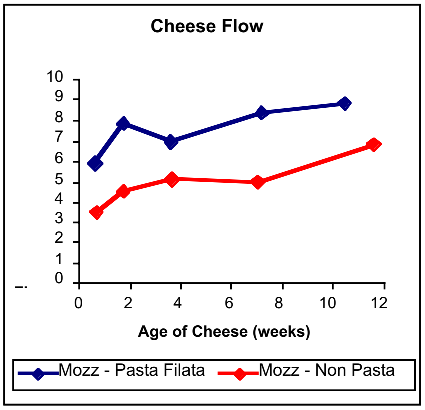
The following melted cheese surface characteristics of blister quantity, blister color, flow off crust, free oil release and degree of skinning were assessed by expert panelists. Melt profile attribute 'flow rate' correlated well to cheese flow off crust and free oil release for many of the cheeses tested (cheddar 50% RF, cheddar milled, cheddar stirred, mozzarella pasta filata). The faster a cheese flows, the more likely it is to release free oil and flow off a crust in a cooking application. Cheese flow rate and free oil release are related. We need to take a closer look at this relationship. Is the progression of melt, the milk fat becoming liquid, then cheese flowing or is cheese flowing then allowing free oil to be released? Milk fat solid is completed changed from a solid to a liquid at 37ºC. So in theory, the cheese should start to flow at the same temperature. Does the amount to milkfat influence flow rate? Statistical analysis on this data set shows no correlation between percentage of cheese fat or fat in the dry matter and flow rate. The event of milkfat changing from a solid to liquid state within the cheese matrix does not affect the rate at which cheese flows.

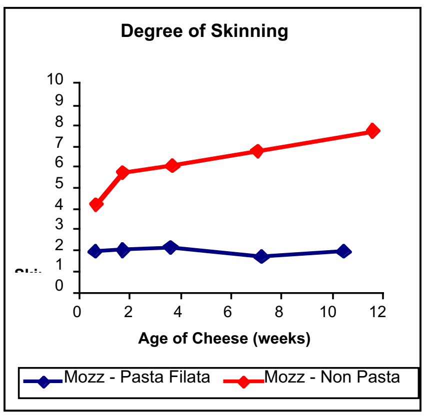
Table 2 Significant Variables from Stepwise Regression Analysis for all the cheeses

Dependent Variable	Stretch Properties	R^2	Surface Characteristics	R^2	Texture and Mouthfeel	R^2
Cheddar, 50%RF						
Flow Rate	Force to Stretch	0.81	Blister Color Free Oil Release Skinning	0.74	Chewiness Cohesiveness	0.91
Cmelt Rate					Roughness	0.74
Soft Temp			Free Oil Release Blister Color	0.56	Chewiness	0.54
CMelt Temp			Free Oil Release Blister Color	0.67	Chewiness	0.55
Softening Time	Cheese Tenting Strand Thickness Strand Cohesive	0.75				
CMelt Time	Force to Stretch	0.51	Free Oil Release Blister Color	0.62	Chewiness Cohesiveness	0.75
Extent of Flow					Chewiness	0.53
Cheddar, Milled						
Flow Rate	Force to stretch	0.67	Flow off Crust	0.62	Hardness	0.64
CMelt Rate					Roughness	0.74
Softening Temperature			Free Oil Release	0.64		
CMelt Temp					Hardness	0.51
Softening Time			Blister Quantity Blister Color	0.76		
CMelt Time			Flow off Crust Blister Quantity	0.60		
Extent of Flow	Force to Stretch	0.52				
Cheddar, Stirred						
Flow Rate	Force to stretch	0.55	Flow off Crust Free Oil Release	0.85	Hardness Cohesiveness	0.86
Cmelt Rate	Cheese Tenting	0.50				
Soft Temp	Force to stretch	0.73	Free Oil Release Blister Color	0.75	Chewiness	0.85
CMelt Temp	Force to stretch	0.67	Flow off Crust Free Oil Release	0.77	Hardness	0.71
CMelt Time			Flow off Crust Blister Quantity	0.69	Hardness Cohesiveness	0.69
Extent of Flow	Cheese Tenting	0.59	Free Oil Release Flow off Crust	0.84	Hardness	0.74

Colby Jack						
Flow Rate			Flow off crust	0.50		
Complete Melt Rate			Free oil release	0.50	Hardness Cohesiveness Roughness	0.60
Soft Temp	Force to stretch	0.68	Flow off crust Blister quantity	0.52	Hardness	0.83
Softening Time	Cheese tenting	0.61				
CMelt Time	Cheese tenting	0.61				
Extent of Flow			Flow off Crust Free Oil Release	0.65		
LMPS Mozzarella, Pasta Filata						
Softening Rate			Blister Color Skinning Free Oil Release Flow off Crust	0.62		
Flow Rate			Flow off Crust Free Oil Release	0.64	Chewiness	0.61
Soft Temp	Force to Stretch Strand Length Cheese Tenting	0.64	Skinning Flow off Crust Blister Quantity	0.59	Cohesiveness Hardness	0.85
CMelt Temp	Force to Stretch Strand Cohesive	0.63	Flow off Crust Skinning Free Oil Release	0.67	Hardness	0.61
Softening Time			Skinning Flow off Crust Blister Color	0.56		
CMelt Time			Flow off Crust Skinning	0.66		
Extent of Flow			Flow off Crust	0.59	Chewiness	0.52
LMPS Mozzarella, Non Pasta Filata or Stirred Curd						
Flow Rate			Flow off Crust Blister Quantity	0.66	Chewiness Hardness	0.78
Softening Temp			Flow off Crust	0.61	Hardness	0.71
Cmelt Temp			Free Oil Release Flow off Crust Skinning	0.58	Chewiness Cohesiveness	0.66
Softening Time			Free Oil Release Flow off Crust	0.59	Hardness Liquid Release	0.50
Cmelt Time			Flow off Crust	0.58	Hardness	0.60
Extent of Flow			Free Oil Release Flow off Crust Blister Color Skinning	0.63	Chewiness	0.61

Figure 1. Changes over time in cheese 'Flow off crust' and''Skinning' scores for mozzarella cheeses after baking in a forced air ovens.





This would seem to indicate that the flowing of cheese provides an opportunity for melted cheese fat to rise to the surface. The melt profile analysis did not correlate well to other attributes that describe the surface of the melted cheese.

Melted cheese texture and mouthfeel

The melt profile attributes of flow rate, softening temperature and complete melt temperature in general correlated well to melted cheese chewiness and hardness (R^2 =0.54 to 0.91) for most of the cheeses tested. Complete melt temperature correlated well to melted cheese cohesiveness for cheddar 50% RF, cheddar stirred, and mozzarella stirred. Melted cheese chewiness and hardness are closely related. Melted cheese chewiness is described as the total energy expenditure required to masticate the sample to a state pending swallowing. The longer time required, the chewier the sample is. Chewiness is a product of cohesiveness, hardness and springiness. For American type cheeses, softening temperatures have slightly higher correlations to chewiness, while for mozzarella cheeses (pasta filata and stirred curd) flow rate measurements have slightly higher correlations to chewiness. Melted cheese hardness is defined as the force required to bite through the sample with molars. Melted cheese hardness as the opposite correlations. For American type cheeses flow rate have slightly higher correlations to melted cheese hardness, while for mozzarella cheese, softening temperatures have slightly higher correlations to melted cheese hardness. American cheeses overall have higher softening temperatures than mozzarella cheeses.

Controlling melted cheese functionality

Understanding the structure/function of melted cheese surface characteristics, stretch, and texture after baking can help to eliminate defects and allow the cheese manufacturer the ability to tailor make cheese for a specific food application system. Stepwise regression analysis was completed using the melted cheese surface characteristics, stretch and melted cheese texture as the independent variable and cheese composition, chemical factors (pH, TCA soluble N) and unmelted cheese texture as the dependent variables. Tables 3 & 4 summarize the top explanatory variable for the melted cheese attributes for pasta filata and stirred curd LMPS mozzarella cheeses.

Cheese manufacturers look to control mozzarella blister color, cheese flow and skinning on baked pizza pies. Blister color can be controlled through manipulation to residual sugar levels in mozzarella cheese. This topic was not in the realm of this project. Cheese flow and skinning are affected by cheese composition, structure, and manufacturing methods. Cheese flow is related to the melt profile characteristics and degree of skinning is primarily related to cheese structure. Figure 1 shows the differences in cheese flow and degree of skinning between pasta filata and non-pasta filata style mozzarella cheese through 12 weeks of aging. Refer to Table 2 & 3 for the summary of the top explanatory variables.

At all ages a pasta filata mozzarella more readily flows off crust of a pizza pie than a stirred curd mozzarella. For pasta filata mozzarella, the 'flow rate' as measured by the melt profile analysis correlates well to how much cheese will flow off a crust, $R^2 = 0.72$. Greater flow

Table 3. Top explanatory variable from Stepwise Regression Analysis for Mozzarella – Non Pasta Filata style.

	Top Explanatory Variable	R^2 value for Top Variable	Significant Explanatory Variables	R^2 value for Explanatory Variables
Strand length (cm)	Softening Time	$R^2 = 0.47$	TCA sol N Flow Rate pH	$R^2 = 0.72$
Force to Pull Strands of Melted Cheese	Adhesiveness	$R^2 = 0.53$	Adhesiveness % S/M Age of cheese Cohesiveness	$R^2 = 0.71$
Tenting	Adhesiveness	$R^2 = 0.51$	% Salt Age of cheese % Fat	$R^2 = 0.66$
Free Oil Release	C Melt Time	$R^2 = 0.56$	Softening Time % FDM Cohesiveness	$R^2 = 0.73$
Skinning	% Moisture	$R^2 = 0.73$	Adhesiveness % S/M % Protein Hardness Flow rate	$R^2 = 0.82$
Flow Off Crust	Flow Rate	$R^2 = 0.72$	% Salt Deformability pH	$R^2 = 0.83$
Melted cheese Cohesiveness	Softening Temp.	$R^2 = 0.67$	C Melt Time % S/M % Moisture Flow Rate Cohesiveness	$R^2 = 0.78$
Melted cheese Roughness	Fracturabilty	$R^2 = 0.69$	Softening temp Age of cheese Flow Rate	$R^2 = 0.78$
Melted Cheese Chewiness	Adhesiveness	$R^2 = 0.76$	Cohesiveness Flow Rate Fracturability Softening Time S/M	$R^2 = 0.89$
Melted Cheese Hardness	Softening Temperature	$R^2 = 0.78$	Adhesiveness % FDM Extent of Flow Hardness	$R^2 = 0.90$

Figure 2. Changes in cheese flow rate and softening temperature over time for mozzarella cheeses baked in a forced air oven.

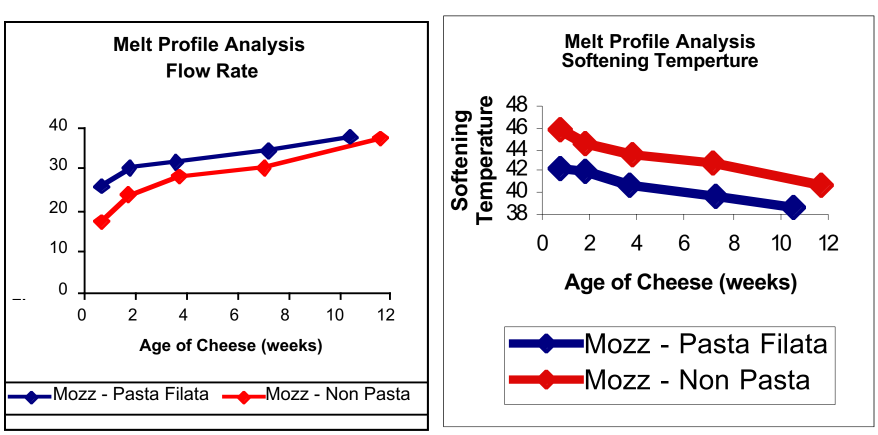


Table 4. Top explanatory variable from Stepwise Regression Analysis for LMPS mozzarella – non pasta filata or stirred curd style.

	Top Explanatory Variable	R^2 value for Top Variable	Significant Explanatory Variables	R^2 value for Explanatory Variables
Strand length (cm)	Age of Cheese	$R^2 = 0.55$	Flow Rate Deformability Extent of Flow Softening Time	$R^2 = 0.72$
Strand Thickness	Age of Cheese	$R^2 = 0.68$	Complete Melt Temp Deformability Fracturability Flow Rate	$R^2 = 0.76$
Strand Cohesiveness	Age of Cheese	$R^2 = 0.52$	Flow Rate Extent of Flow Cohesiveness Softening Time	$R^2 = 0.70$
Force to Pull Strands of Melted Cheese	Age of Cheese	$R^2 = 0.79$	% FDM % Salt Complete Melt Time Complete Melt Temp	$R^2 = 0.86$
Tenting	TCA soluble N	$R^2 = 0.72$	% Protein Firmness Deformability Fracturabilty	$R^2 = 0.77$
Free Oil Release	% Protein	$R^2 = 0.53$	% FDM Extent of Flow Fracturability Softening Temp	$R^2 = 0.77$
Skinning	% MNFS	$R^2 = 0.64$	Cohesiveness pH TCA soluble N % Protein	$R^2 = 0.84$
Flow Off Crust	Softening Temperature	$R^2 = 0.61$	Adhesiveness % FDM Flow Rate Complete Melt Temp.	$R^2 = 0.73$
Melted cheese Cohesiveness	TCA Soluble N	$R^2 = 0.54$	Complete Melt Temp. Extent of Flow Cohesiveness MNFS	$R^2 = 0.66$
Melted cheese Roughness	Deformability	$R^2 = 0.55$	Complete Melt Temp % Salt Softening Temp Extent of Flow	$R^2 = 0.70$
Melted Cheese Chewiness	TCA Soluble N	$R^2 = 0.80$	Flow Rate Age of Cheese % MNFS Complete Melt Time	$R^2 = 0.90$
Melted Cheese Hardness	Fracturability	$R^2 = 0.79$	TCA Soluble N % Protein Age of Cheese Cohesiveness	$R^2 = 0.92$

rates result in a higher degree of cheese flow off a crust. For successful mixing of pasta filata mozzarella curd, sufficient demineralization needs to have taken place prior to mixing. This higher degree of demineralization during the manufacturing process results in a more meltable cheese (cheese softens sooner and flows faster). Due to this manufacturing technique, controlling the cheese flow of a pasta filata mozzarella is limited. In a stirred curd mozzarella the 'softening temperature' has the highest correlation to cheese flow off a crust, $R^2 = 0.61$. The percentage of cheese FDM (Fat in the Dry Matter), flow rate, and complete melt temperature also contribute to cheese flow. In the manufacture of a stirred curd or non-pasta filata style mozzarella, cheese is stirred, direct salted, and pressed. The final cheese pH values are similar both manufacturing techniques. However, in stirred curd mozzarella milk clotting, separation of the curd from the whey and cheese block formation occurs at a higher pH. This implies that the stirred curd mozzarella will retain more minerals (calcium, phosphates) and have a higher buffer capacity. This may lead to higher energy requirements for the cheese to soften and flow. For a stirred curd mozzarella control of cheese flow can be done by manipulating the pH or degree of demineralization at renneting, draining, and hooping and through initial milk composition to alter the final percentage of FDM.

For a pasta filata style mozzarella, the degree of cheese skinning on the surface of a pizza pie is rated as very slight throughout aging. The degree of skinning for a stirred curd mozzarella increases from a very slight to slight – moderate during aging. Top explanatory variables for skinning in a stirred curd mozzarella are cheese MNFS, cheese cohesiveness, pH, protein, and level of TCA soluble nitrogen (indicator of cheese proteolysis), $R^2 = .84$. Due to the direct pressing (no heating step) in the manufacturing process of a stirred curd mozzarella, the protein matrix is more continuous, with smaller pockets of fat and moisture. This structure is better able to entrap fat at exposed cheese surfaces during melting, leading to less oiling off. The oiling off during the melting process protects proteins exposed to oven elements. Protein structure strongly influences the skinning. The degree of skinning is a function of cheese pH (degree of demineralization) and proteolysis. During the melting process, cheese flows when the proteins move past one another. The lower the pH and the greater the degree of proteolysis the more cheese proteins move past one another to flow. The more flow, the greater the amount of proteins being exposed to the heat. Thus the more pliable the melted cheese, the more protein is exposed to hot oven elements and the greater the degree of skinning. Controlling skinning in a stirred curd mozzarella involves manipulations to initial milk C:F ratios (to promote more protective oiling off), cheese pH and proteolysis levels.

Publications/Presentations

Correlation between melt profiles characteristics and sensory properties of pasta filata and non-pasta filata mozzarella cheeses. K. Muthukumarappan South Dakota State University, Brookings, SD and C. M. Chen, Wisconsin Center for Dairy Research, Madison, WI. Poster at the 2003 IFT Annual Meeting, Chicago, IL.

Models Relating Melting Profile Characteristics and Sensory Characteristics of Cheddar and Mozzarella cheeses. K. Muthukumarappan, C Chen, Raviraj Jhala, and C Shukla. Poster at the ASAE 2003 Annual International Meeting Las Vegas, Nevada.

Evaluation of sweet cream buttermilk for use as cheese ingredient

Personnel

Rani Govindasamy-Lucey, Mark Johnson and John Lucey

Funding

Dairy Management, Inc.

Dates

July 2001 to December 2003

Objectives

1. To characterize the composition of cream and sweet cream buttermilk derived from the same cream source and determine its effect on cheese functionality.

2, To evaluate whether the variation in sweet cream buttermilk is due to the specific processing steps rather than compositional differences.

3. To produce a phospholipid-rich fraction derived from buttermilk and to develop procedures to incorporate this fraction in the manufacture of cheese.

4. The effects of sweet cream buttermilk on the functionality and sensory characteristics of the cheese will be evaluated.

Summary

Sweet cream buttermilk (SCB), is obtained as a liquid by-product during buttermaking. It can be dried and used as a food ingredient. SCB is mostly used as an ingredient in baking applications but has relatively limited usage in the dairy industry. In order to increase the demand for sweet SCB, it was used as an ingredient to produce pizza-type cheeses, which is a non-standard of identity cheese, as there are no regulations preventing the addition of dairy ingredients to this cheese type. The pizza-type cheese used in this research was a stirred-curd, non-pasta filata cheese. The main objective of this study was to evaluate SCB as a value-added cheese ingredient. To achieve this objective, we investigated the (i) changes in SCB due to seasonal and processing variations; (ii) compositional, rheological, and sensory effects of addition of condensed SCB to partially skimmed milk to manufacture pizza cheese; and (iii) determined the influence of various types of concentrated SCB on the compositional, rheological, and sensory properties of pizza cheese.

Variation in sweet cream buttermilk

There were two main obstacles in using sweet cream buttermilk (SCB) as an ingredient in cheese making: variability in composition and inconsistent quality of the finished product due to processing conditions. To investigate compositional changes in SCB, raw and pasteurized cream and fresh SCB were collected over a one year period. The composition of these samples was analyzed and shown in Table 1. In our case, "raw cream" refers to the cream that the butter making plant receives before butter making. The extent of heat treatment of this "raw cream" before arriving at the butter making plant is not clear (it may have been heat

Table 1. Composition of raw cream, pasteurized cream and sweet cream buttermilk obtained from a local dairy over a one-year period

Composition[1]	Sample	January	March	July	September	October	December
Total Solids (%)	Raw Cream	47.25	43.68	46.31	43.10	46.98	48.38
	Past. Cream[3]	44.39	42.49	43.69	42.29	45.45	47.94
	SCB[4]	7.93	8.78	7.50	6.51	8.45	8.38
Fat (%)	Raw Cream	41.53	38.78	41.52	37.90	41.85	43.13
	Past. Cream	41.70	37.60	-	37.40	40.80	42.70
	SCB	0.69	0.88	0.64	0.62	0.65	0.72
Total Protein (%)	Raw Cream	1.71	1.89	1.91	1.64	1.69	1.84
	Past. Cream	2.00	1.82	2.10	1.55	1.73	1.82
	SCB	2.54	2.76	2.59	2.08	2.79	2.70
True Protein[2] (%)	Raw Cream	1.50	1.76	1.85	1.49	1.57	1.72
	Past. Cream	1.88	1.70	2.04	1.41	1.62	1.70
	SCB	2.35	2.60	2.41	1.93	2.62	2.54
Casein (%)	Raw Cream	1.36	1.49	1.66	1.15	1.33	1.45
	Past. Cream	1.76	1.49	1.86	1.27	1.51	1.56
	SCB	2.10	2.29	2.21	1.69	2.39	2.24
Total Phospholipid (mg/g sample)	Raw Cream	1.52	2.05	1.62	1.56	1.45	1.77
	Past. Cream	1.38	1.86	1.49	1.35	1.32	1.57
	SCB	1.25	1.26	1.43	1.29	1.13	1.53

1At each time point, one sample of raw cream, pasteurized cream and SCB was collected from a local dairy and analyzed. Results reported here were averages of triplicate analyses.
2True Protein represents the fraction that does not contain non-protein nitrogen.
3Past. Cream was cream pasteurized at 187ºF (average) or 86.1ºC for 18 seconds (average, the min. time used was 15 seconds).
4SCB was the sweet cream buttermilk remaining after the churning of the pasteurized cream.

Table 2. Whey protein denaturation in pasteurized cream obtained from a local dairy over a year.

Analysis Dates	Whey Protein Denaturation* (%)
September 2002	58.8
October 2002	56.5
December 2002	46.4
January 2003	18.2
March 2003	21.0
July 2003	5.3
December 2003	52.7

*Whey protein denaturation was calculated as described by Guinee et al. (1995)

treated several times either as milk or cream). The fat and solids content of cream were lower in March and September samples compared to other months. SCB composition followed the same trends as the seasonal variation in cream composition. Denatured whey proteins were found in SCB as a result of the pasteurization of cream (Table 2). The % denatured whey proteins in pasteurized cream varied throughout the year. In the September, October and December samples, the % denatured whey proteins were higher than other months of the year. Total phospholipid (PL) composition in cream was also measured. Pasteurization of cream appeared to degrade some PLs, especially phosphatidylethanolamine species. To assess how processing conditions of cream affected SCB quality, butter was made with cream that was pasteurized at 86, 89 and 92ºC for 15 seconds. PL composition of cream and SCB were measured. Results indicated that the extent of heat treatment of cream had only a slight effect on the PL composition of SCB.

A variation in the composition of cream affected the composition of SCB. No definitive conclusions were made as to whether this variation was due to sample variation or some specific seasonality effect; this would require further study over several seasons/years. The temperature at which cream was pasteurized did not affect the PL composition of SCB, but did affect the % denatured whey proteins found in SCB. In order to obtain similar SCB composition, it is important to keep the butter making procedure similar, the composition of cream constant, and control the total heat load applied to cream (i.e. to maintain a similar level of whey protein denaturation of the cream).

Addition of different levels

Four concentrations of condensed SCB (~35% total solids) were added to cheese milk used for pizza cheese manfacture (Chen & Johnson, 2001): 0 (control), 2, 4 and 6% (w/w). Pizza cheeses were allowed to ripen for four weeks. At the 1, 2, and 4 weeks time point, composition, rheology and sensory analyses were done. The addition of condensed SCB to milk increased the moisture content of cheeses (Table 3); the moisture difference between the control and cheeses with 6% SCB added was ~5%.

In order to evaluate SCB as a cheese ingredient, the moisture content of cheese was made similar by altering the cheese making conditions (by increasing the set temperature, cook temperature and wash temperature for the SCB cheeses) to limit the variations in rheological and compositional properties that could take place. After modifying the manufacturing procedure, all cheeses had similar compositions (Table 4).

Cheese yield significantly increased for cheeses made with addition of condensed SCB, e.g. the moisture-adjusted yield for control and 6% SCB cheeses were 7.90 and 8.89 %, respectively. The % total phospholipid (PL) recovery in cheese ranged between 40% for control cheese and 31% for cheeses made with 6% SCB addition (Fig. 1). The majority of phospholipids in cheese milk were found in the drained whey because most of the phospholipids had already partitioned into a different “phase” in milk and buttermilk. When the serum phases of milk and buttermilk were separated by ultra-centrifugation, it was found that most of the phospholipids resided in the supernatant. In cheese making, phospholipids that resided in the supernatant would probably end up in the whey, which explained why most of the phospholipids were lost in whey.

Table 3. Cheese composition (% w/w) results for SCB trials where pizza cheeses had different moisture contents: addition of 0 (Control), 2, 4, and 6% condensed SCB to cheese milk to manufacture pizza cheese (n=3).

	Control	2% SCB	4% SCB	6% SCB
Moisture, %	45.43[c]	48.29[b]	48.61[b]	51.00[a]
Fat, %	23.44[a]	21.87[ba]	21.75[ba]	20.44[b]
Total Protein, %	25.81[a]	24.37[ba]	24.43[ba]	23.48[b]
Salt, %	1.35	1.50	1.48	1.63
MNFS[1], %	59.33[b]	61.80[ba]	62.11[ba]	64.11[a]
FDM[2], %	42.93	42.30	42.31	41.72
SM[3], %	2.98	3.10	3.04	3.21
Lactose (1 wk), %	0.037[a]	0.003[b]	0.030[a]	0.081[a]
pH at 1 week	5.05[a]	5.00[a]	4.93[b]	4.92[b]
Calcium (mg Ca/g protein)	25.56	24.25	24.23	24.59

[a,b,c]Means within the same row without a common superscript differ ($P < 0.05$).
[1]Moisture in the nonfat substance of the cheese
[2]Fat content on a dry weight basis
[3]Salt in the moisture phase of the cheese

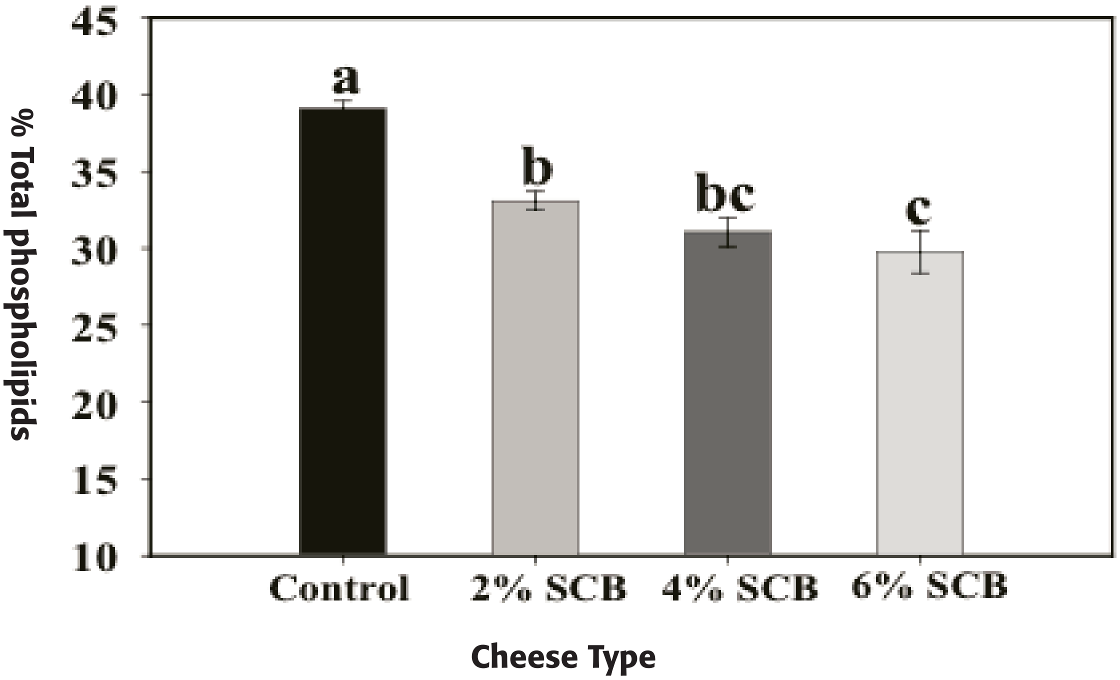
Table 4. Pizza cheese composition results where manufacturing protocol was modified so as to adjust for the moisture content of the cheeses; addition of 0 (Control), 2, 4 and 6% condensed SCB to cheesemilk to manufacture pizza cheese (n=3).

	Control	2% SCB	4% SCB	6% SCB
Moisture, %	47.09	46.14	46.68	47.13
Fat, %	23.22	23.24	23.04	22.50
Total Protein, %	24.88	25.29	25.26	24.97
Salt, %	1.44	1.46	1.55	1.51
MNFS[1], %	61.33	60.10	60.64	60.80
FDM[2], %	43.89	43.14	43.19	42.54
SM[3], %	3.07	3.17	3.32	3.22
Lactose (1 wk), %	0.060	0.090	0.030	0.080
pH at 1 week	5.16	5.14	5.12	5.08
Calcium (mg Ca/g protein)	23.19	21.39	23.84	23.25

[a,b,c]Means within the same row without a common superscript differ ($P < 0.05$).

[1]Moisture in the nonfat substance of the cheese
[2]Fat content on a dry weight basis
[3]Salt in the moisture phase of the cheese

Fig. 1. Amount of total phospholipids recovered in the cheeses during pizza cheese manufacture. Vertical bars indicate standard deviations and the bars with different letters are significantly different ($P<0.05$).



The meltability of cheeses was assessed by the parameter "extent of flow", which measured the change in cheese height when cheese was heated to 60ºC in the UW Melt Profiler. For cheeses with significantly different moisture contents, the meltability was higher for cheeses made with addition of SCB. On the other hand, when the moisture contents of these cheeses were made to be similar, the meltability of control cheese was significantly higher (Fig. 2).

At 5ºC, the storage modulus, loss modulus, and loss tangent values (obtained from rheological tests) of the four cheeses were similar, which suggested that these cheeses had similar rheological properties at this temperature. Using small amplitude oscillatory rheometry (SAOR) tests, loss tangent (ratio of viscous to elastic component) values increased with increasing temperature, which indicated that the cheeses had become more viscous. The maximum loss tangent values were used to determine how meltable the cheeses were (Fig. 3). The higher the maximum loss tangent value, the more meltable the cheese is likely to be. Control cheese had higher maximum loss tangent values than cheeses made with addition of SCB. This suggested that control cheese melted more than cheeses from SCB treatments. Unmelted and melted sensory attributes of all the cheeses were similar; however, the stretchability of control cheeses was significantly better than cheeses made with addition of SCB.

Type of concentrated sweet cream buttermilk

In order to examine the effect of different types of concentrated SCB on cheese functionality, fresh unconcentrated SCB was obtained from a local dairy and concentrated in-house at CDR using cold (<7ºC) ultrafiltration (UF), cold (~10ºC) reverse osmosis (RO), and evaporation (~64ºC) (EVAP). The composition of each of the differently concentrated SCB is

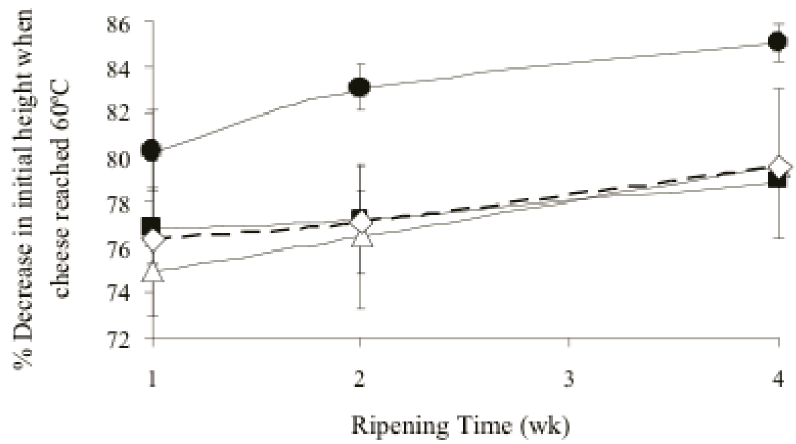


Fig. 2. Extent of flow or % change in the original height of the cheese at 60ºC during the 4 week ripening of the control, 2% SCB, 4% SCB and 6% SCB pizza cheeses during 4 wk ripening time at 7ºC. Vertical bars represent standard deviations.

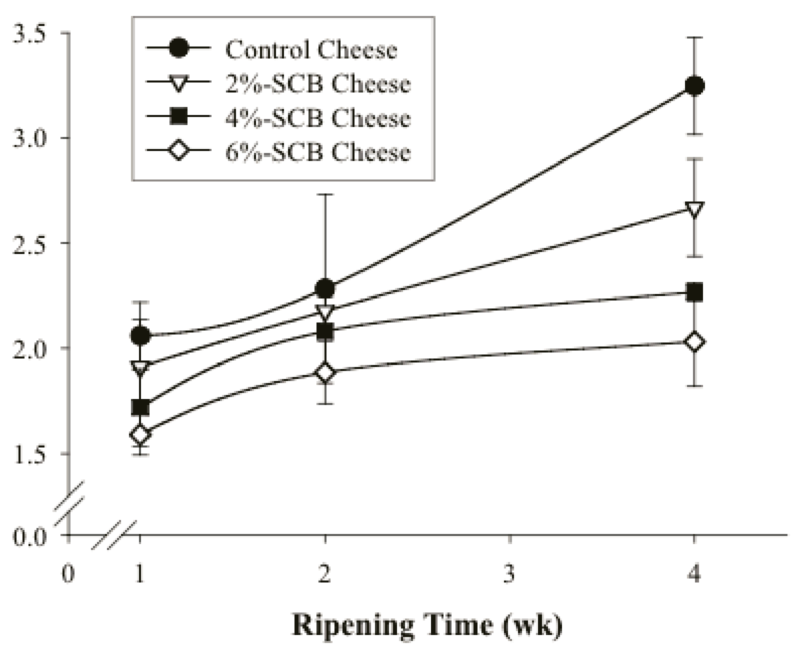


Fig. 3. Changes in the maximum loss tangent (determined from rheology tests) as a function of ripening time for the control, 2% SCB, 4% SCB, and 6% SCB) pizza cheeses during 4 wk ripening time at 7ºC

given in Table 5. The casein contents of both UF- and EVAP-SCB were higher than the RO-SCB. The lactose content of UF-SCB was lower than that of the RO- or EVAP-SCB (as expected).

Four types of standardized cheesemilks were prepared; control, UF-SCB, RO-SCB and EVAP-SCB cheesemilks by standardizing to a casein:fat ratio ~ 1. The casein content in each of the three experimental cheesemilks was brought to about 2.7%, based on our previous studies, where the quality of the cheeses were not compromised when this amount of casein was in the vat. The amount of UF-SCB, RO-SCB and COND-SCB added to each vat was different depending on the composition of the processed SCB. The amount of UF-SCB, RO-SCB, and EVAP-SCB added to the cheese milk was approximately 3.84%, 7.83% and 3.77% (weight basis, as a % of total weight), respectively.

Four vats of cheese were made without altering the manufacturing protocol: control cheese (without addition of SCB), cheeses with addition of UF-SCB, cheeses with addition of RO-SCB, and cheeses with addition of EVAP-SCB. These cheeses were ripened for four weeks and analyses were conducted at 1, 2 and 4 weeks of ripening. The moisture contents of the SCB cheeses were similar (UF-SCB = 51.67%, RO-SCB = 51.77%, EVAP-SCB = 52.42) but were higher than control cheeses (47.18%). All three SCB cheeses were found to be acidic, had a soft body and poor stretch. When the manufacturing protocol was modified by increasing the set temperature, cook temperature and wash temperature for the SCB cheeses, the moisture content of all three SCB cheeses were slightly lower than the control cheeses but within the range that is expected for this cheese type, ~ 46-47% (Table 6). All three SCB cheeses had higher fat and protein contents than the control cheeses (Table 6). Cheeses made with addition of SCB had higher moisture-adjusted cheese yield than control cheese regardless of how the SCB was processed (Table 6).

Fat recoveries in the SCB cheeses were slightly lower than the control cheeses but not significantly different (Fig. 4). Comparing the three SCB cheeses, the amount of fat recovered in the RO-SCB or EVAP-SCB cheeses were slightly lower than that of the UF-SCB cheeses. Although the amount of nitrogen recovered in all the cheeses were not significantly different, there was slightly higher nitrogen recovery in the UF-SCB than the other three cheeses.

Table 5. Composition of SCB processed by ultrafiltration (UF-SCB), reverse osmosis (RO-SCB) and evaporation (EVAP-SCB)

	Unconcentrated SCB	UF-SCB	RO-SCB	EVAP-SCB
Total Solids (%)	8.26 ± 0.46	19.89 ± 0.71	21.94 ± 0.43	36.59 ± 0.73
Fat (%)	0.75 ± 0.11	3.22 ± 0.33	2.02 ± 0.17	3.22 ± 0.28
Total Protein (%)	2.66 ± 0.11	11.19 ± 0.86	7.05 ± 0.18	11.27 ± 0.47
True Protein (%)	2.49 ± 0.13	11.00 ± 0.86	6.67 ± 0.19	10.51 ± 0.42
Casein (%)	2.22 ± 0.10	9.94 ± 0.82	6.05 ± 0.18	9.50 ± 0.36
Lactose (%)	Not determined	4.16 ± 0.23	10.87 ± 0.27	18.30 ± 0.25
Whey Protein (%)	0.28 ± 0.03	1.06 ± 0.06	0.63 ± 0.07	1.01 ± 0.10

Table 6. Composition of pizza cheese (after moisture adjustment) (n = 4).

	Control Cheese	UF-SCB Cheese	RO-SCB Cheese	EVAP-SCB Cheese
Moisture (%)	47.52[a]	46.15[b]	45.74[b]	45.66[b]
Fat (%)	22.48[b]	23.62[b]	23.10[ba]	23.32[a]
Protein (%)	24.80[b]	25.55[ba]	25.28[ba]	25.50[a]
MNFS (%)	61.30[a]	59.89[b]	60.00[b]	59.54[b]
FDM (%)	42.83	43.53	42.88	42.91
S/M (%)	3.48	3.97	3.98	4.19
pH at 1 day	5.18	5.12	5.12	5.11
Moisture-adjusted Cheese Yield to 46% (%)	7.90[b]	8.68[a]	8.46[a]	8.60[a]

[a,b,c]Means within the same row without a common superscript differ ($P < 0.05$).

Most of the PLs in the cheese milk were lost in the drained whey and the % total PL recovered in control cheese, cheeses made with addition of UF, RO, and COND SCB was ~ 41%, 37%, 36% and 33%, respectively (Fig. 5). The amount of total PL recovered in the SCB cheeses was lower than the control cheese. The PL recovery in the EVAP-SCB cheeses was less than the RO-SCB or UF-SCB cheeses. There was no difference in the formation of 12% TCA soluble nitrogen during the cheese ripening as the rennet:casein ratio was kept the same for both the control and the SCB cheesemilks during manufacturing (Fig. 6). As expected, the amount of 12% TCA soluble nitrogen increased with age.

Control cheese had a higher meltability, or extent of flow, than cheeses made with addition of SCB, regardless of how the SCB was processed. These results agreed with the findings from the SAOR tests, which also showed that control cheese melted more during heating than cheeses from SCB treatments (Fig. 7). There was no difference in the maximum loss tangent values for the SCB cheeses.

When the cheeses were shredded, the shreds were found to be similar. The sensory results showed that the flavor attributes of all cheeses were similar, especially when cheeses were baked. Slight oxidized flavors were detected in cheeses when they were baked in a forced-air oven or a conventional oven. Cheeses with the UF-SCB had the lowest amount of free oil observed on the surface on the baked pizza. Stretchability of cheeses with added SCB were lower than control cheese and tended to decrease during ripening. It appeared that all the sources of concentrated SCB performed reasonably in cheese applications.

Recommendations

The main objective of this study was to evaluate SCB as a cheese ingredient. The judicious use of condensed buttermilk (buttermilk condensed via evaporation or membrane processing) for the manufacture of pizza cheese does not compromise cheese quality or functional characteristics. In order to use SCB as an ingredient in pizza application, however, it is crucial to modify the cheese manufacturing

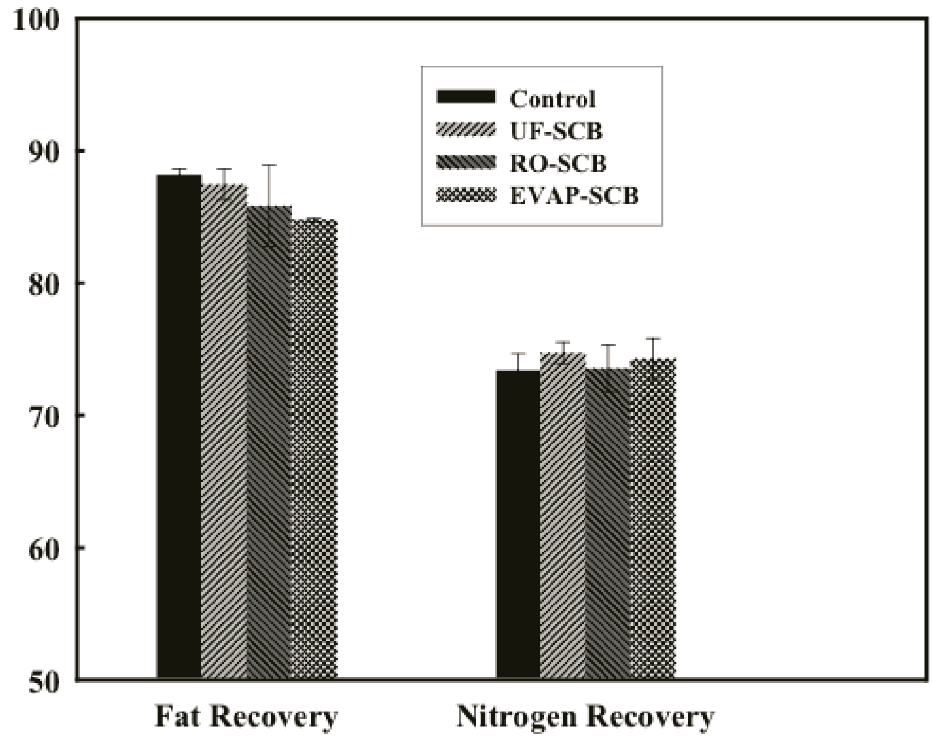


Fig. 4. Fat and nitrogen recovered in the control, UF-SCB, RO-SCB and EVAP-SCB cheeses during the manufacture of pizza cheeses. Vertical bars represent standard deviations.

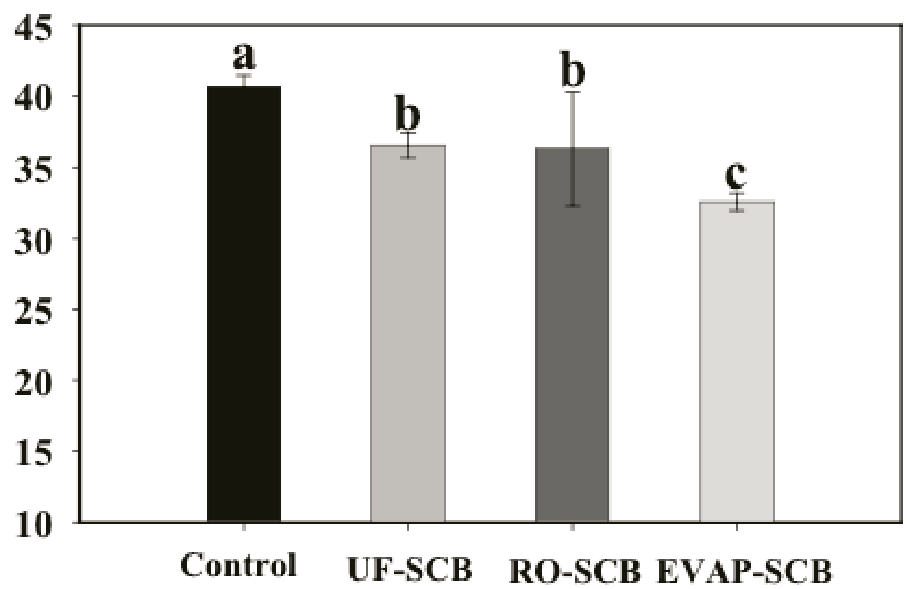


Fig. 5. Amount of total phospholipids recovered in the cheeses during pizza cheese manufacture. Vertical bars indicate standard deviations and the bars with different letters are significantly different ($P<0.05$).

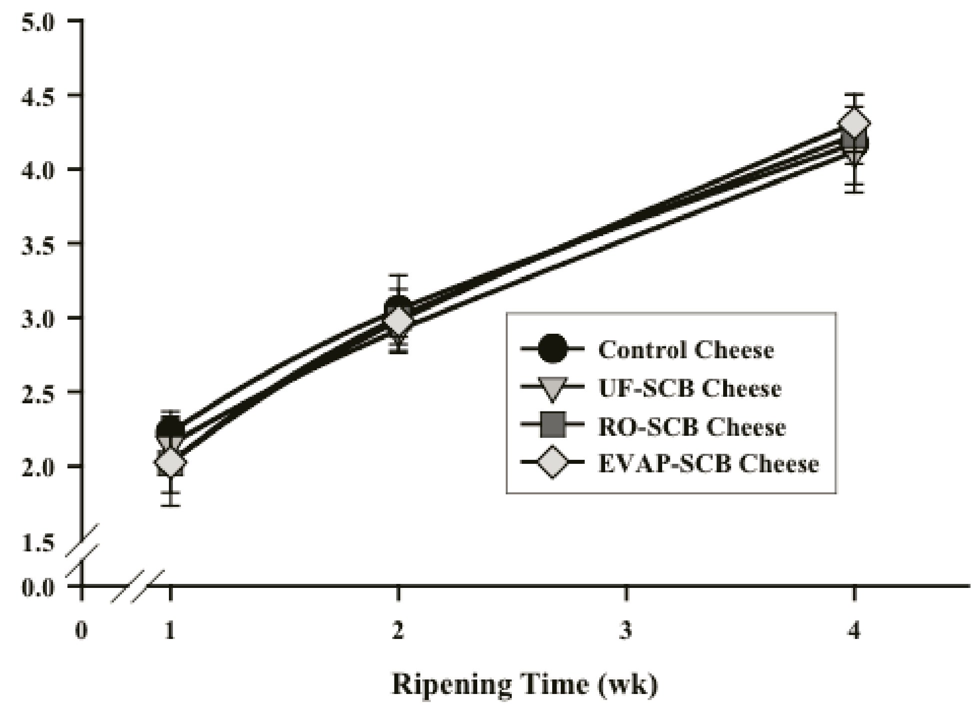


Fig. 6. Twelve percent TCA-soluble N as a percentage of total N for control, UF-SCB, RO-SCB and EVAP-SCB cheeses during the 4 week of ripening of pizza cheeses at 7ºC. Vertical bars represent standard deviations.

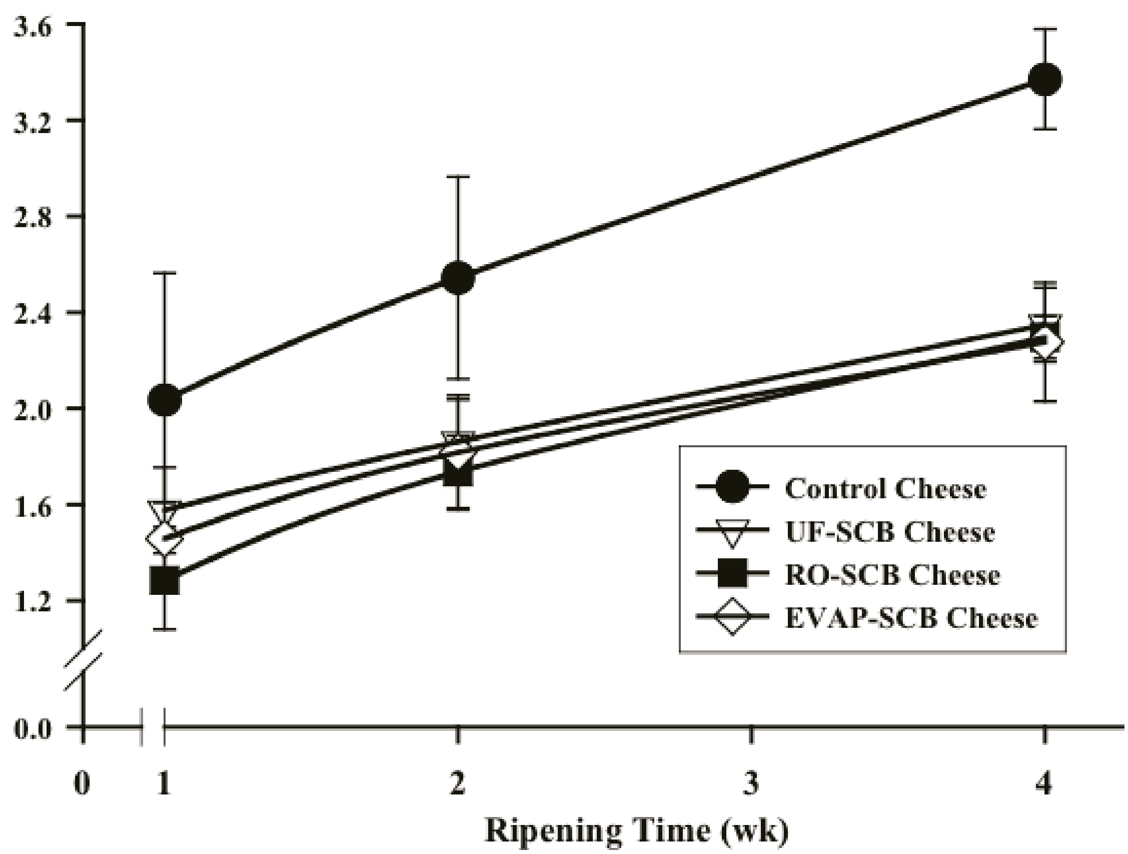


Fig. 7. Changes in the maximum loss tangent (determined from long rheology tests) as a function of ripening time for the control, UF-SCB, RO-SCBand EVAP) pizza cheeses during 4 wk ripening time at 7ºC. Vertical bands represent s andard deviations.

procedure to obtain a moisture content of ~47%. To obtain consistent quality and to control the concentration of denatured whey proteins of SCB, the extent of heat treatment the cream receives before butter making must be monitored. If we can obtain SCB that had consistent quality and composition, then using SCB as a cheese ingredient may be practical. For the future, SCB could also be used to introduce PLs species that had health-related benefits into the cheese matrix.

As a result of the heat-treatment given to cream used for butter manufacture and the buttermilk there is a substantial amount of serum protein denaturation (as high as 40 %). Subsequently, cheese made from milk supplemented with buttermilk will have higher moisture (denatured serum protein slows syneresis and increases water holding capacity of casein gels, i.e. cheese). So we have also carried out some internal work at the Wisconsin-CDR looking at the use of RO buttermilk to standardize cheesemilk used in the manufacture of high moisture cheeses (such as Ricotta cheeses) and we were successful in doing so without compromising the quality of these cheeses.

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Publications/presentations

Oral presentations were given at the 2003 and 2004 American Dairy Science Annual Meetings:

Lin, T., J. Lucey, S. Govindasamy-Lucey, M. Johnson and J. Jaeggi. 2003. The influence of sweet cream buttermilk on the compositional and rheological properties of a stirred-curd cheese. Journal of Dairy Science, Suppl. 1, 86: 9.

Lin, T., S. Govindasamy-Lucey, J. Jaeggi, C. Martinelli, M. Johnson and J. Lucey. 2004. Impact of type of concentrated sweet cream buttermilk on the manufacture and functionality of pizza cheese. Journal of Dairy Science, Suppl. 1, 87.

Lin, T. (2003). Investigation into the use of sweet cream buttermilk as an ingredient in cheese. M. S. Thesis, University of Wisconsin-Madison, Madison.

Manuscripts in Preparation to be submitted for Publication:

Lin, T., S. Govindasamy-Lucey, J. A. Lucey, M. Johnson and J. Jaeggi.. The influence of different concentrations of condensed sweet cream buttermilk on the yield, compositional and rheological properties of stirred-curd pizza cheese. Journal of Dairy Science.

Lin, T., S. Govindasamy-Lucey, J. Jaeggi, C. Martinelli, M. Johnson and J. A. Lucey. 2004. Impact of type of concentrated sweet cream buttermilk on the manufacture and functionality of pizza cheese. Journal of Dairy Science.

Manufacture of kid's flavored fun cheeses

Personnel

John Jaeggi, researcher, Lorraine Heins, research specialist, Bill Hoesly, research cheese maker, Catherine Landers, research specialist, Brian Leitzke, research cheese maker,
Kate Lim, sensory coordinator, Juan Romero, analytical coordinator, Dean Sommer, cheese and food technologist

Funding

Dairy Management, Inc.

Dates

January 2004 to December 2004

Objectives

To develop a manufacturing protocol and identify selected ingredients and commercially available colorants to make fun flavored cheeses that would appeal to younger children.

Work with plants that currently have equipment available and would be willing to work with us on this endeavor.

Summary

This project has taken a two-pronged approach to incorporate sweeteners, flavors, and ingredients into cheese. The primary focus has been on string cheese while the secondary approach has been manufacturing kid flavored fun processed cheese.

For string cheese we have conducted a total of 6 separate trials. Four of the six trial runs concentrated on manufacturing protocols as well as adding multiple ingredients to manufacture strawberry string cheese. A Wisconsin based manufacturer and a national marketer suggested strawberry-flavored string cheese as an area of interest. There were concerns about the pH ranges needed to achieve a full strawberry flavor in comparison to the pH range of string cheese. Another concern was the possibility of interaction between thermophilic starter culture and sweeteners, possibly causing late gas formation in the cheese package. We were also concerned about incorporation points and retaining different strawberry flavors and purees in the cheese matrix.

The four strawberry-flavored string cheese trials involved different methodologies to incorporate sweeteners and strawberry flavoring with the end goal to have a cheese that tasted similar to strawberry yogurt but string like a cheese. From those first four trials we were able to determine that the string cheese texture was better when standardizing milk to a similar casein:fat ratio as normal string cheese as opposed to using higher casein:fat milk ratios. Thermophilic cultures did not visually show any greater potential to produce gas in the packages than did the mesophilic cultures. We also determined that adding all ingredients to the stirred curd —at the time of salting and ingredient addition —before the molding step was the best way to incorporate into them into the cheese matrix. We were able to pinpoint level of sweetener addition (sugar) as well as artificial

sweetener addition (sucralose) to bring out flavor and sweetness in the string cheese. We were also able to verify that adding the emulsifying salt in addition to sodium chloride aided in incorporation of the sweetener and flavor into the string cheese as opposed to adding sodium chloride only.

Although many manufacturing questions were answered during these four strawberry-flavored trials, we were not able to successfully add multiple strawberry flavors, particulates, or purees. The general consensus was the pH range of string cheese (~5.10-5.30) was not favorable to bring out more strawberry flavor. When malic or citric acid was added, a threshold of strawberry flavor was noted as well as a nice aroma. However, these acids had a detrimental effect on final string cheese texture due to the lower pH. Final string cheese texture had little or no string and was generally regarded as pasty and "broken down." When no acid was added, the texture of the string cheese was good with nice string, however very little strawberry flavor was detected.

Applied research trials were then conducted manufacturing string cheese using flavors which are detectable at pH ranges similar to those of the string cheese. In one trial we used the manufacturing parameters developed for the strawberry flavored cheese and incorporated those parameters to manufacture cotton candy, bubble gum, green apple, and banana. Colors were added to the cheese milk to give vibrant colors. Although they had no effect on the cheese manufacturing process, the colors, as expected, had an effect on the whey color. The issue of color incorporation by adding directly to the cheese after mixing will be looked in future privately-funded trials. All cheese flavors, particularly the cotton candy and the bubble gum were easily identified by informal tasters.

One of the issues to be addressed with privately-funded work is to revaluate the mixing and molding process used to make the string. It seems water in the cooker can dilute the flavors and sweetness. We still need to look at the feasibility of adding ingredients after the mixing during the molding steps. Some companies add savory flavors during this phase. We are going to look at adding ingredients much the same and see if the ingredients are adequately dispersed during this step.

The second part of this project looked at incorporating these flavors in a processed cheese. Multiple small stove-top batches of flavored processed cheeses were made in an effort to identify the cheese base to use, flavor types, amounts and effect on flavor. As a result of the stove-top runs, we scaled up two trials in which we have successfully made strawberry, blue raspberry, and green apple processed cheese. Molten cheese was then poured into many different shapes and sizes which would be appealing to children.

Future privately-funded work will continue to look at other flavors and cheese manufacturing combinations.

Samples of the string cotton candy, bubble gum, banana, and green apple as well as the processed samples of blue raspberry, strawberry, and green apple were given out during the joint National Milk Producers Federation/DMI annual producers meeting in Reno, NV the last week of October of 2004. Plans are to show these products in 2005 at various WMMB, DMI, and at the Wisconsin Cheesemakers Association/Center for Dairy Research Annual Cheese Exposition.

Characterizing the effects of common manufacturing practices on the flavor and functionality of sweet whey powder

Personnel

D. S. Banavara and S. A. Rankin. Dept. of Food Science

Funding

Dairy Management Inc.

Dates

December 2001– June 2004

Objectives

1. Procure and/or manufacture sweet whey powders with attributes representative of typical manufacturing processes and process variation.

2. Characterize the distinct influences of whey processing parameters on the flavor and functional characteristics using sensory, chemical and physical assessments.

3.Continuation of 2; complete data analysis and report generation.

Summary

Sweet whey powder (SWP), a valuable byproduct of cheese industry is used in food industry for its functionality. High lactose in SWP contributes to browning while proteins participate in foaming, gelling and emulsifying. Results of previous studies demonstrated that foaming capacities varied greatly; this variation is hypothesized to be influenced by the availability of amphiphilic proteins and peptides. Our objective was to characterize the protein composition of SWP as related to foaming properties.

SWP samples with high, medium and low foaming capacities were selected. Protein composition was studied using SDS-PAGE. SWP samples (1%) were purified/enriched using centrifugal ultrafiltration (3KDa cut-off) and characterized for protein composition by both reducing and non-reducing SDS-PAGE using 4-20% Tris-HCl gels. The foams formed were drained separately and the draining liquid was further purified/enriched and electrophoresed. Polypeptides profiles of samples and foams were also studied using Tris-tricene gels. Similar experiments were performed on heat treated samples.

Non-reducing SDS-PAGE showed the presence of protein aggregates and ß-lactoglobulin (ß-lg) octamers (144KDa) in low foaming and medium foaming samples. High foaming samples did not show prominent bands of ß-lg octamer or protein aggregates. Densitometric study of gels revealed that high foaming samples were found to contain ß-lg and ∂-lactalbumin in higher proportions with negligible amounts of protein aggregates, ß-lg octamers and albumin. Heat treatments of low foaming samples improved foaming in some cases. However, the protein composi-

tion was not altered from native samples. There were no differences in the protein compositions of sample and respective foam.

The results suggest that degree of polymerization, proportion of ß-lg and protein-protein interactions may have a role in foaming properties of SWP. Understanding the concepts related to foaming will help in modifying the manufacturing process to obtain SWP of desired foaming character.

Presentations/Publications

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Institute of Food Technologists annual meeting, Chicago, IL.

D. S. Banavara and S. A. Rankin. 2004. Characterization of proteins in sweet whey powder foams.. Institute of Food Technologists annual meeting, Las Vegas, NV.

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Rankin, S.A. 2003. Factors affecting variation of commercial sweet whey powder flavor. Institute of Food Technologists Annual Conference, Dairy Flavor Chemistry Symposium, Chicago, IL. (Invited presentation).

Publications
D. S. Banavara, D. Anupama, and S. A. Rankin. 2003. Studies on Physicochemical and Functional Properties of Commercial Sweet Whey Powders. J. Dairy Sci. 86: 3866-3875.

D. S. Banavara, D. Anupama, and S. A. Rankin. 2004. Characterization of sensory and volatile profiles of sweet whey powder. J. Dairy Sci. In preparation.

Chapter Three

Applications reports

annual report 2004

Dairy Marketing and Economics Program

Personnel

Brian W. Gould , director, John Hackney, research assistant, Yuhe Chang, graduate research assistant, Badri Bhasker, graduate research assistant

Funding

Wisconsin Milk Marketing Board

Dates

January 2004 to December 2004

Objectives

1. Support cheese manufacturers through optimization of domestic dairy ingredients for specified cheese and whey performance, composition and yield

2. Enhance the demand for Wisconsin dairy products by increasing manufacturer knowledge and understanding of the determinants which influence the demand for traditional and value-added products

3. Provide timely dairy market information influencing Wisconsin dairy manufacturers, marketers and producers.

Summary

Our objective is to assist Wisconsin dairy farm operators and cheese manufacturers to understand the factors that influence cheese yield. We hope that a better understanding of the role that milk and cheese characteristics have in determining cheese yield will lead to a better relationship between receipts from the sale of farm milk and the value of that milk in cheese manufacture. A better understanding will also provide a framework by which component value-based payment systems can be implemented. The primary activity associated with this objective was providing technical support to Wisconsin cheesemakers in their use of the ***E**conomic **A**nalysis of **C**heese **Y**ield* (**EACY**™) software program which is supported by the DMEP. This software is available electronically by contacting the author, Dr. Brian W. Gould at the email address, gould@cdr.wisc.edu

We provided technical support to numerous cheese manufacturers, dairy product marketers and cheese purchasers using the EACY program to answer specific questions. Examples of issues addressed included: determination of the value of various ultrafiltered milk in cheese manufacture, the value of additional protein and fat in cheese manufacture and the economic implication of alternative cheese characteristics (moisture and fat content) of a particular cheese variety.

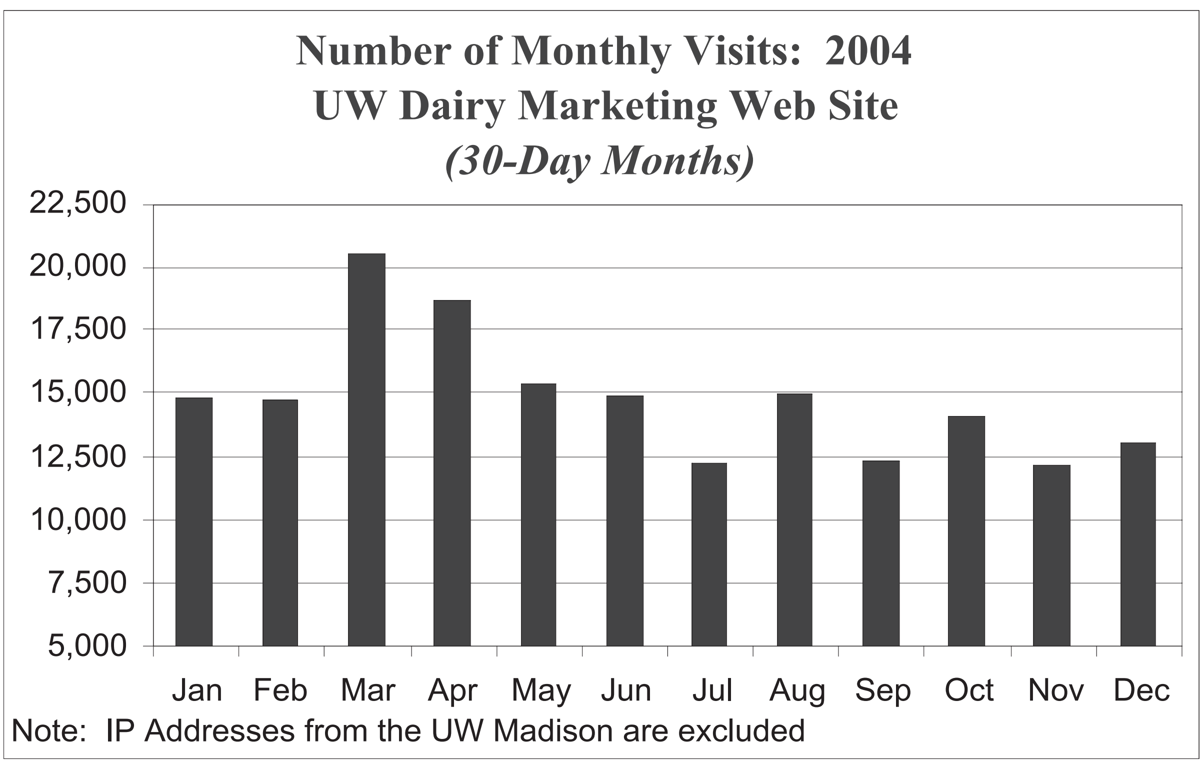
A number of activities were undertaken to provide the Wisconsin dairy industry with information regarding the national and international demand for dairy products and the implication of changes in these markets. Examples include the analysis of dairy product purchases in the NAFTA region (the U.S., Canada and Mexico) which has been undertaken with support of the University of Wisconsin Babcock Institute for International Dairy Development, analysis of the determinants of the demand for dairy products in China again supported by University of Wisconsin Babcock Institute for International Dairy Development the and the analysis of pricing in the retail fluid milk pricing which was funded via a grant from the U.S. Department of Agriculture. These analyses have used an extensive collection of household as well as market level data to develop and estimate a number of econometric (statistical) models.

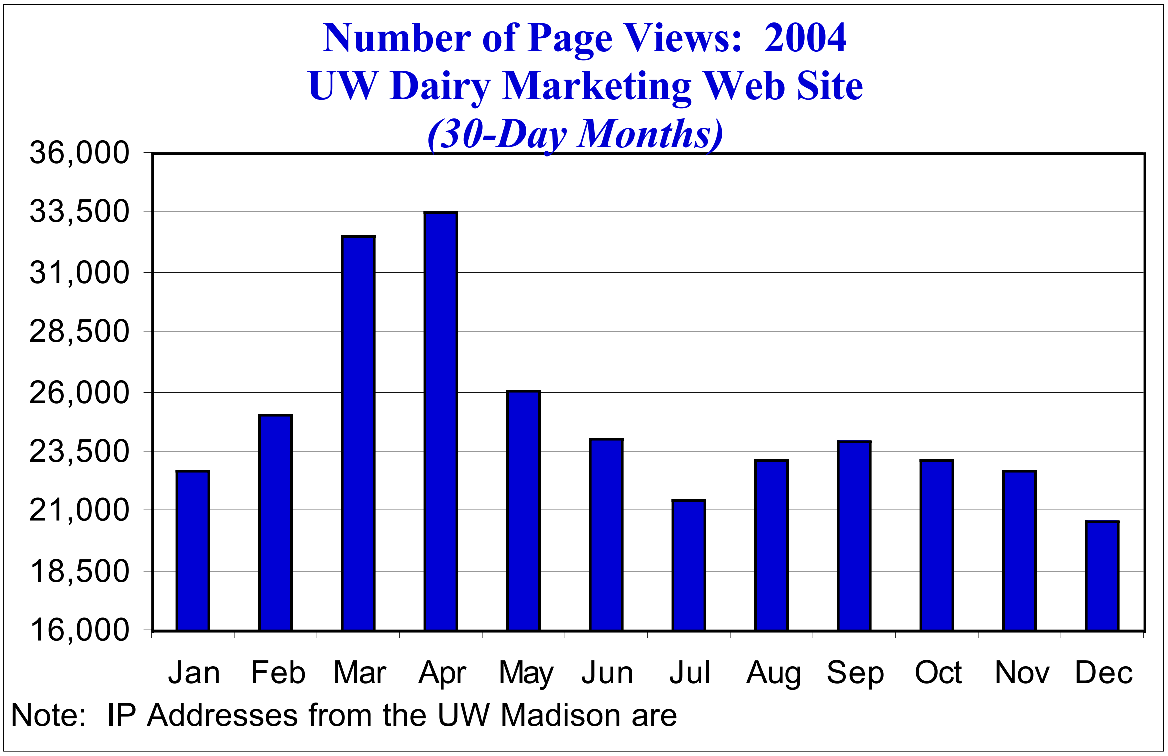
We maintained and extended the ***University of Wisconsin Dairy Marketing Website*** *(*www.aae.wisc.edu/future*)*. This website contains an extensive collection of current and historical state, national and international dairy market data. Examples of information contained in this website include retail and wholesale milk and dairy product prices, milk production, production of dairy products, dairy product stocks, imports/exports of dairy-based commodities, simulation models of the federal classified pricing system, an archive of dairy-related publications and a collection of decision tools related to participation in the MILC program.

As noted in the previous year's report we continue with our efforts to automate both the data collection process and graphical analyses of this data. Our long-term goal is to have approximately 80% of our data automatically updated soon after release. This automation will ensure the timely availability and accuracy of data.

To understand the degree to which the ***University of Wisconsin Dairy Marketing Web Site*** is used as a marketing resource by the U.S. dairy industry, Figure 1 provides a summary of this site over the January – December, 2004 period. We provide this overview from 2 perspectives, the number of monthly

Figure 1: Summary of the 2004 Utilization of the UW Dairy Marketing Web Site





Note: This website can be found at *www.aae.wisc.edu/future*.

site visits and the number of monthly page views. Given the different number of days per month, we convert these values to 30 day months for comparison purposes. Over 2004, the average monthly numbers of visits was 14,824 and the number of monthly page views was 24,935. Given the subject matter of this website and the size of the U.S dairy industry, we view these values as being significant. To place these values in perspective, in 2003, in the U.S. there were less than: 90,000 dairy farms, 400 cheese manufacturing plants and 400 fluid milk bottlers.

During 2004 we assessed the value placed by participants in the dairy industry of this web site. We obtain responses to our request for comments from a wide range of industry participants from within and outside the state of Wisconsin. Below are three examples of typical comments received:

Comment from milk procurement officer with a major dairy processor: This industry from a milk marketing standpoint is starving for information. It is hard to make solid decisions based on what the class III, cheese, or butter markets are doing on a given day. Information that you provide on your website help industry people as well as dairy producers understand how the system works.Your website provides a common place to acquire information to help individuals
with hard marketing decisions.

Comment from the owner of a Wisconsin commodity brokerage firm: We use your site for all types of training and research. We send all of our clients to the site too. Stopping the site would be a tremendous disservice to the entire dairy industry! Please keep it up!

Comment from a Midwestern university extension agent:
I believe your web site is an excellent source of information to many in the dairy industry. I visit your site at least 6-8 times per month as I research information about dairy markets and marketing. I have also used many of the education materials on the site in my marketing education efforts here in my state. Keep up the good work, we really need this information!

If you would like more information concerning these activities contact program coordinator, Dr. Brian W. Gould at the email address: gould@cdr.wisc.edu .

Safety/Quality Applications Program

Personnel
Marianne Smukowski

Funding
Wisconsin Milk Marketing Board

Dates
January 2004 to December 2004

Objectives
1. Provide technical assistance to Wisconsin companies in the areas of safety/quality audits, preparation for regulatory audits, sanitation program reviews and overall GMP reviews.

2. Assist in development of HACCP plans and programs.

3. Provide technical support for safety/quality problem solving.

4. Assist in executing the Wisconsin Cheese Food Safety Initiative Program

Summary
The Safety/Quality Applications Program assists WI cheese manufacturers in the following areas: safety/quality audits, third party audits, recall issues, GMP reviews, developing HACCP plans, assist the Wisconsin Master Cheesemaker Program® and provide technical support in regulatory matters.

I provide technical support through emails, phone calls, lectures, and plant visits on a regular basis. The company contacts consist of dairy manufacturers, regulatory staff (state and Federal), various universities; funding organizations (WMMB and DMI) and various trade associations (IDFA, WCMA, WDPA).

I assisted a small food company with grading/sensory analysis of milk, butter, and cheese to their employees. I presented to a large food company about Hot Spots in a Dairy Plant Environment. Kristen Houck assisted a cheese manufacturer with a shelf-life study. Assistance was also given to the Food Science Department with a study on cleanability of dairy equipment.

Some highlights of the Safety/Quality Applications Program are listed as follows.

The Committee for the Assurance of Wisconsin Dairy Product Safety continues to assist Wisconsin dairy facilities with their food safety system and to deal with numerous third party audit requests. The intent of this committee was for the Wisconsin dairy industry to buy-in to a uniform audit program. I served as a technical advisor for this committee. This committee created a Wisconsin Dairy Food Safety Manual, which includes sections on Good Manufacturing Practices, Prerequisite Programs, HACCP Program, Audit Program and references.

I was the head judge for the World Dairy Expo Championship Dairy Product Contest. This was the second year for this contest sponsored by Wisconsin Dairy Products Association. There were over 100 samples submitted for the evaluation of butter, ice cream, yogurt and cheese. There were 19 classes of product. Wisconsin companies won 10 of the 19 classes.

I continue to familiarize myself with biosecurity regulations that arise in this country. The security of our food supply continues to be an issue as well as having a crisis management program in place. Topics that would be included are product traceability, Radio frequency identification (RFID), awareness of intentional product contamination, and effective, strategic decision making skills during a crisis.

Publications and presentations

WI cheese grading short course, Italian cheese evaluation (twice a year)

Collegiate Dairy Products Evaluation Contest (Lead Butter Judge)

WI CIP Workshop, Plant Sanitation Audits, Kristen Houck presented Bioluminescence for Rapid Assessment

WI Dairy Products Assoc. Cheese and Butter Evaluation Clinic, Overview of butter grading

Dairy HACCP Workshop, Program coordinator, Kristen Houck presented Environmental Monitoring in Dairy Plants

WI Process Cheese Seminar, HACCP for Process Cheese

WI Cheese Technology Short Course, Cheese Handling-Plant to Retail (Twice a year), Kristen Houck presented Secondary Micro flora of Raw Milk

World Dairy Expo Championship Dairy Product Contest 2004 (Head Judge)

Cheese Packaging Short Course, Distribution of Packaged Cheese

Cheese Industry and Applications Program

Personnel

John Jaeggi, researcher, Amy Bostley, research specialist, Carol Chen, researcher, Rani Govindasamy-Lucey, associate scientist, Lorraine Heins, assistant program coordinator,Bill Hoesly, research cheese maker, Kristen Houck, research specialist, Mark Johnson, senior scientist, Catherine Landers, research specialist, Brian Leitzke, research cheese maker, Kate Lim, sensory coordinator, Cindy Martinelli, research specialist, Pam Payne, lab technician, Juan Romero, analytical coordinator, Dean Sommer, cheese and food technologist, William Tricomi, assistant researcher

Funding

Wisconsin Milk Marketing Board
Dairy Management, Inc.

Dates

January 2004 to December 2004

Objectives

1. Provide direct technical support for the use of commodity and specialty cheese, processed cheese, cold pack/club cheese and cream cheese in food application systems through consultations, pilot plant trials, application lab evaluations and plant visits.

2. Conduct industry directed cheese applications research - modifying manufacturing processes or ingredients during cheese making to produce a cheese with specific functional characteristics.

3. Direct contact with the cheese and dairy industry, DMI, WMMB, IFT, ADSA or other cheese industry related outlets to meet informational needs from manufacturers through end users.

4. Provide technical support on internal cheese trials and projects, funded by WMMB, DMI, CDR, CDR Cheese Industry Team, and/or other UW departments through consultations, pilot plant trials, and application lab evaluations.

5. Provide technical support to other CDR Application Program areas and to University of Wisconsin Food Science Department through consultations/lectures, pilot plant trials/ lab sessions, and application lab evaluations/demonstrations.

6. Participate in international efforts that affect standards of uniformity of import/export cheese opportunities.

7. Work with WMMB and DMI to develop and execute the state and national cheese research plan. Also continue the transfer of technology generated from past farmer-funded research.

Summary

This report includes Wisconsin cheese industry activities, national cheese industry activities, international cheese industry activities, and internal CDR and various UW interdepartmental cheese activities.

Our report does not account for the multiple contacts we have from different individuals from the same state, national, and international companies on a wide range of topics. Interactions continue to increase from milk producers/farmstead through end users and all facets in-between. The Center's continuing goal with all cheese work as it relates to manufacturing plants and end users is to execute the technology triangle. This technology triangle brings together CDR experts with the manufacturer and end user to achieve a common goal as it pertains to a specific project. Having the cheese technologist position for its first full year has allowed the Cheese Industry and Application Program even more opportunity to reach the full spectrum of cheese research and product development from manufacturing all the way through the end users. This has allowed us to work with more end users to maximize cheese performance and flavor that will increase cheese usage. This demonstrates the continued commitment of cheese research and cheese product development between the Wisconsin Milk Marketing Board, Dairy Management, Inc, Wisconsin Center for Dairy Research, the CDR Cheese Industry and Applications Program, and the cheese industry.

Support of the industry by our program is made via phone and e-mail consultations, short courses, CDR or on-site meetings, research trials, on-site scale up or troubleshooting, and working in conjunction with other CDR program areas such as Wisconsin Master Cheesemaker, Safety/Quality, Analytical, Economics, Whey and Whey Applications, Administration, and Communications.

These multiple contacts with the industry include (but are not limited to) topics such as cheese defects, cheese end use, regulatory, cheese functionality, cheese texture, sensory, cheese flavor development, manufacturing protocols for natural/processed (sauces/foods/spreads)/cold pack/cream cheese, cheese or milk microbiology, cheese milk standardization, cheese yield, labeling, ingredient addition, cheese/milk chemistry, plant sanitation, labeling/regulatory issues, organic cheese issues, kosher cheese issues, cheese equipment, cheese packaging, cheese ripening, cheese marketing, analytical equipment and protocol, data interpretation, geographic indication (GI), cheese nutrition, project updates, and general cheese technology.

One of the functions of our program is the manufacture of cheese on a contract basis. We work with ingredient/flavor suppliers, cheese manufacturers, equipment manufacturers, end users/distributors/marketers, consultants, and individual milk producers. Due to the proprietary nature of our contracted cheese trial work, the information supplied below is general, rather than specific.

We manufactured many vats/batches of natural and processed cheese and conducted follow-up research work on behalf of ingredient / flavor suppliers in 2004. These trials included evaluation of DVS starter cultures/adjuncts and effect on cheese flavor/texture/functionality, evaluation of different culture strains and effect on the rate of acid development, evaluation on elimination of calcium lactate crystals in cheese when using specific ingredient additions, addition of various enzymes and studying effect on cheese flavor, addition of contaminants to study effect of subsequent ingredient addition on extending shelf life in a fresh cheese product, addition of healthy fatty acids to processed and natural cheese, and addition of various stabilizers and/or emulsifying salts to processed cheeses and studying effect on physical characteristics.

We also worked on behalf of numerous Wisconsin and national cheese manufacturers and marketers through cheese manufacturing trials/data collection/follow-up, consultations, meetings, etc. Some of this work included developing standardization methodologies using different milk streams such as ultrafiltered (UF) (whole and skim) and microfiltered (MF) milk, non-fat dry milk (NDM), whey protein concentrate (WPC), and concentrated buttermilk to manufacture commodity, specialty/ethnic, and non-standard cheeses. The impacts on cheese manufacture, yield, composition, functionality, texture, microbiology, ripening, and sensory was in all or part studied. As part of working with alternative standardization methods utilizing dairy components, we continue to work with national companies and the US Food and Drug Administration to try to receive a variance allowing cheese manufacturers to standardize cheesemilk with addition of UF. We have assisted in the past with similar standardization methods for use in manufacturing cheddar, mozzarella, and cottage cheeses.

In addition, we continued to assist manufacturing plants with improving plant efficiencies. One method used to accomplish this was working with plants on adding whey protein concentrate (WPC) as secondary starter and studying the effects on the end product. We continued to work with manufacturers on increasing plant throughput by increasing milk solids levels through milk standardization.

As in the past five years, we continue working with individual farmstead producers and milk producer cooperatives looking at making a specialty cheese from their own milk at an existing cheese manufacturing facility or looking to build their own on-farm manufacturing facility.

We continued to work with cheese manufacturers and equipment suppliers to develop altered cheese manufacturing protocols to attain different flavor profiles, textural attributes, and/or functional characteristics. We have also worked on altering physical or functional characteristics through manufacture of many different processed specialty and ethnic cheeses.

We continue to develop specialty and ethnic cheeses by setting up manufacturing methods, carrying out successful trials, submitting all results, and working on-site scaling up at the manufacturing facility; all the while keeping in mind the goals of the product end-use. Many of these new cheeses developed by the Cheese Industry and Applications Program in conjunction with the cheese industry are now sold nationally to many different specialty and ethnic markets.

Nationally, in 2004 more pressure is being applied on the food industry to provide healthier alternatives for consumers. Along these lines we worked privately with ingredient suppliers as well as end users and manufacturers to work on natural, processed, and/or cream cheeses containing omega-3 fatty acids, lactose-free cheeses, and zero/low/reduced fat cheese.

Contact and follow up work has continued to increase drastically with end users the past couple of years. The new cheese technologist position and Program personnel continue to increase contacts with large state/national manufacturers, brokers, and end users making them aware of the effect of tailoring manufacture of cheddar, mozzarella, and specialty cheeses. This included uses in appetizers, snack foods, frozen entrees, baking applications, sauces, spreads, and pizza applications to name a few. Work also continues in conjunction with DMI staff contacting companies in the fast food industry to look at ways to increase the use of cheese.

We continue to work on cheese related projects funded by outside or internal sources, many reported in detail elsewhere in this report. The CDR-Cheese Industry Team (CDR-CIT) currently funds two such projects. One project, "Understanding and Controlling the Calcium Equilibrium in Cheese" involves the study of re-creation of calcium lactate crystal formation in Cheddar and Colby cheese so as to evaluate the type of crystals formed and how they differ from past years. This project is looking at many possible causes including manufacturing protocols and milk standardized by membrane concentration using reverse osmosis (RO), which is a common practice in industry.

The second project that is a continuation of earlier work in the area of use of ultrafiltrated (UF) milk used in milk standardization is use of microfiltered (MF) milk for use in milk standardization. Work in the area of UF is either in the process of being published or will be in the future. Results from this work are already being used in the industry having been relayed through various seminars, short courses, or general consultations with the industry.

We continue to work with other University of Wisconsin departments or CDR personnel on various cheese projects. "Relating Rheological Properties to Cheese Functional Performance" is an on going DMI-funded project the Cheese Industry and Applications Program was involved with in 2004. This is a joint project between the CDR, UW Food Science, and North Carolina State University. This project started with the manufacture of mozzarella with different fat in dry matter (FDM) targets.

Another on going DMI-funded CDR project the Program is involved with is "Cheese structure/function manipulations to improve shreddibility." This project has looked at manipulating lactose levels, enzyme levels, and manufacturing methods and the effect on cheese chemistry, texture, and functionality.

A CDR/UW Food Science DMI-funded project involving the manufacture of cream cheese titled, "Understanding structure/function relationships in cream cheese responsible for its performance" has begun looking at effect of milk standardization methods, homogenization pressures, and set temperatures. Work continues with future work planned.

In 2004 we began a new DMI-funded projects in which Program personnel were either private investigators (PI's) or were directly involved. One project, "A chemistry-based approach to understanding processed cheese functionality" has begun and involves manufacture of multiple batches of processed cheese looking at individual and combinations of emulsifying salts and hold times to gauge their effect on cheese chemistry and functionality.

A new 1-year DMI-funded applied research titled "Manufacture of kid's flavored fun cheeses" was completed in 2004. Exploratory work looked at the concept of manufacturing flavored string and processed cheeses which would appeal to children. The goal of this project was to provide product concepts for manufacturers and marketers. Several marketers and manufacturers have expressed interest in the work. Product was shown at the NMPF/UDIA/DMI Annual Meeting held in Reno, NV this past fall. Future work in conjunction with industry is planned.

A couple of previous DMI-funded projects that we are beginning to wrap up include "Development of Parmesan cheese flavor using selected bacteria" and "Evaluation of Sweet Cream Buttermilk for Use as a Cheese Ingredient." The Parmesan project has already generated information which has been relayed to an ingredient supplier while the Buttermilk project has resulted in further work with private industry exploring the use of buttermilk in different forms (RO, UF, condensed). Both projects either have papers or reports submitted with more scheduled for 2005 submission.

The Cheese Industry and Application Program is also involved in international issues. Program staff attended the Geographic Indications (GI) Conference held in Green Bay, WI. In 2004 staff assisted work with USDA in regards to GI-related issues with Manchego and Parmesan cheeses. Program staff also participated in various IDF Codex standards meetings over the course of the year. Program staff also worked with the United States Dairy Export Council (USDEC) and DMI personnel to look at potential areas of research and product development opportunities for export to potential worldwide markets.

Our group also continues to assist the Specialty Cheese/Master Cheesemaker Program area in regards to coordinating grading and sampling of Master Cheesemaker and Master Mark candidates' cheeses, grading final exams, and attending all Master Cheesemaker member and board meetings.

Cheese Industry and Application personnel played a key role through lectures, demonstrations, and cheese making labs in the various seminars and short courses offered by the CDR and the UW Food Science Department. These included: the Wisconsin Cheese Technology Short Course (March, October), the Wisconsin Process Cheese Seminar (February), Cultured Dairy Products Seminar (May), Cheese Packaging Seminar (May), the French Cheese Seminar (November), and the Wisconsin Cheese Graders Short Course (June/November). The Cultured Dairy Products Short Course and the Cheese Packaging Short Course were new additions in 2004. Due to high demand both courses will be repeated in 2005.

The Cheese Industry and Applications group generated samples for the Analytical Program to conduct chemical, microbiological, physical property, application, and sensory testing on various cheese samples that are related to applications research projects. A large percentage of the Analytical Program's laboratory work conducted is in conjunction with CDR pilot plant cheese making. This continues to show the cheese industry is placing an emphasis on understanding how the cheese composition/age affects the sensory and physical properties, and thus the functionality in the end application.

Program personnel attended and participated in many national and international dairy conferences in 2004. This included the International Pizza Show in Las Vegas, NV, IDF Cheese Ripening Symposium in Prague, Czech Republic, DMI Annual Dairy Forum in San Antonio, TX, International Cheese Technology Conference in Madison, WI, 4th International Symposium on Recombined Milks in Cancun, Mexico, International Food Technology Show in Las Vegas, NV, the American Dairy Scientist Association annual meeting in St. Louis, MO, AOCS Conference on Food Structure and Food Quality in Cork, Ireland. and the NMPF/UDIA/DMI annual meeting in Reno, NV.

In 2004 we hosted several industry groups to discuss the Cheese Industry and Application Program as well as past and current cheese research topics. Program personnel also conducted a two-day seminar for a large US CDR-CIT manufacturing member on the topics of basic cheese making and sanitation principles as it related to the specific company. Program personnel conducted a one-day seminar for a large CDR-CIT ingredient supplier member on the topic of Parmesan manufacture, sensory evaluation, and work the CDR has done in the area of Parmesan cheese. Program personnel also assisted with a one-day topical seminar for a large international CDR-CIT end user member on the topic of cheese nutrition. Members of the Cheese Industry and Applications Program team also lectured or worked trade show booths at several national and regional meetings or conferences across the country as well as internationally.

Throughout the year, Program staff assisted the CDR to provide tours and/or interviews for various media outlets (journalists/radio/TV), councils, academia, government agencies, and industry groups.

The Cheese Industry and Applications group continued to travel to cheese plants, distributors, food service, and end users not only in Wisconsin, but also nationally to provide one-on-one technical transfers of cheese making protocols, milk standardization, identifying problems for potential cheese defects, and other cheese technology and end use issues.

Publications and Presentations

The publications listed below either were authored and/or co-authored by Cheese Industry and Applications Program personnel, or were authored by others based on cheese making trial work carried out by Program personnel. The presentations listed below for 2004 were either presented by Cheese Industry and Applications Program personnel or were presented by others based on cheese making trial work carried out by Program personnel.

"The Road Ahead for Cheese Manufacturing" by Dean Sommer. "The NEW Lowfat Cheeses: How We're All Going to Get It Right This Time" by Dr. Mark John son. "What Moved My Cheese? Cheese Measurement, Performance and Controlling Functionality" by Dr. John Lucey. All presented at the annual DMI Dairy Research Forum, February 2004, San Antonio, TX.

"Practical Cheese Manufacturing Standardizing With UF Retentate, A Look at Trials Conducted at the Wisconsin Center for Dairy Research" by J. J. Jaeggi, and "Eliminating the calcium lactate defect" by M.E. Johnson at the WCMA/CDR joint International Cheese Technology Conference, April 2004 in Madison, WI. Dean Sommer also chaired the morning technical session.

"Standardization of milk using cold ultrafiltration retentates for the manufacture of Parmesan cheese". S. Govindasamey-Lucey, J.J. Jaeggi, A.L. Bostley, M.E. Johnson, and J.A. Lucey. J. Dairy Sci. 2004; 87 2789-2799.

"Milk composition and cheese yield from hard and soft cheese manufactured from sheep milk". J.J. Jaeggi, W.L. Wendorff, M.E. Johnson, J. Romero, and Y. Berger. 2004. Proc. of 10th Great Lakes Dairy Sheep Symposium, Nov. 4-6, 2004, Hudson, WI, pp. 132-142.

"Technology for production of hard cheeses using recombined milk". S. Govindasamey-Lucey, J.J. Jaeggi, A.L. Bostley, M.E. Johnson, and J.A. Lucey. 2004. Proc. Of 4th International Symposium on Recombined Milk and Milk Products, May 9-12, 2004, Cancun, Mexico, pp. 157-165.

"Use of cold ultrafiltered retentates for standardization of milks for pizza cheese: impact on yield and functionality". S. Govindasamey-Lucey, J.J. Jaeggi, T. Wang, M.E. Johnson, and J.A. Lucey. International Dairy Journal. (in press).

"Physical and chemical characteristics of sheep milk considering its subsequent processing". W.L. Wendorff, 2004. In Proc. of IDF Symp. on the Future of the Sheep and Goat Dairy Sectors, Oct. 28-30, 2004, Zaragoza, Spain (in press).

"Sheep milk and milk production: Processing and marketing. In Encyclopedia of Animal Science". W. L. Wendorff, 2005. W. Pond and A. Bell, eds., Marcel Dekker, Inc., New York, NY. pp. 794-796.

"Impact of seasonal changes in ovine milk on composition and yield of a hard pressed cheese. J.J. Jaeggi, W.L. Wendorff, J. Romero, Y.M. Berger, and M.E. Johnson. 2005. J. Dairy Sci. 88: (in press).

"Changes in the proportions of soluble and insoluble calcium during the ripening of Cheddar cheese". A., Hassan, M. E. Johnson and J. A. Lucey. 2004. Journal of Dairy Science 87:854-862

"Rheological and calcium equilibrium changes during ripening of Cheddar cheese". J. A. Lucey, R. Mishra, A. Hassan, and M.E. Johnson. 2004. International Dairy Journal (in press).

"Rheological properties of rennet-induced gels during the coagulation and cutting process: Impact of processing conditions". R. Mishra, J. A. Lucey, and S. Govindasamy-Lucey. 2004. Journal of Texture Studies.

"The use of Fourier transform mechanical spectroscopy to study the melting behavior of cheese". C. Udayarajan, J. A. Lucey and D. S. Horne. 2004. Journal of Texture Studies.

"Effect of insoluble calcium phosphate on cheese functionality". J. Choi, D. S. Horne, M. E. Johnson, and J. A. Lucey. 2004. Presented at 2004 ADSA annual meeting. Journal of Dairy Science 87: suppl. 1, 231

"Properties of Acid-Induced Gels made from High Fat Milk". S. Govindasamy-Lucey, C. Phadungath, T. Wang, J. Jaeggi, and J. A. Lucey. 2004. AOCS Conference on Food Structure and Food Quality, held in October 2004, Cork, Ireland.

"Use of reverse osmosis concentrated milk for the manufacture of Cheddar and Colby cheese: impact on Ca equilibrium and functional properties". M. R. Lee, J. A. Lucey, and M. E. Johnson. 2004. Presented at 2004 ADSA annual meeting. Journal of Dairy Science 87: suppl. 1, 285

"Impact of type of concentrated sweet cream buttermilk on the manufacture and functionality of pizza cheese". T. Lin, S. Govindasamy-Lucey, J. J. Jaeggi, C. J. Martinelli, M. E. Johnson, and J. A. Lucey. 2004. Presented at 2004 ADSA annual meeting. Journal of Dairy Science 87: suppl. 1, 288.

"Effect of emulsifying salts on texture of pasteurized process Cheddar cheese". N. Shirashoji, J. J. Jaeggi, and J. A. Lucey. 2004. Presented at 2004 ADSA annual meeting. Journal of Dairy Science 87: suppl. 1, 231

"Effect of fat content on rheological and melting properties of Mozzarella cheese". C. Udayarajan, T. and J. A. Lucey. 2004. Presented at 2004 ADSA annual meeting. Journal of Dairy Science 87: suppl. 1, 288

"Rheological and Calcium Equilibrium Changes during Ripening of Cheddar Cheese" by Dr. John Lucey at International Dairy Federation, Cheese Ripening and Technology Symposium. Prague, March 23, 2004.

"Use of cold ultrafiltered retentates for standardization of milks for pizza cheese: impact on yield and functionality" by S. Govindasamey-Lucey at International Dairy Federation, Cheese Ripening and Technology Symposium. Prague, March 25, 2004.

"Understanding and Controlling the Calcium Equilibrium in Cheese", "Relating Rheological Properties to Cheese Functional Performances", and "A Chemistry-Based Approach To Understanding Process Cheese Functionality" by J.A. Lucey at the Center for Dairy Research-Center Industry Team Project Update Meeting, December 2004 in Madison, WI.

"Understanding Structure/function Relationships in Cream Cheese Responsible for its Performance" by S. Govindasamey-Lucey at the Center for Dairy Research-Center Industry Team Project Update Meeting, December 2004 in Madison, WI.

"Cheese structure/function manipulations to improve shreddibility" by C.M. Chen at the Center for Dairy Research-Cheese Industry Team Project Update Meeting, December 2004 in Madison, WI.

"Manufacture of Kid Flavored Fun Cheeses" by J. J. Jaeggi at the Center for Dairy Research-Center Industry Team Project Update Meeting, December 2004 in Madison, WI.

Dairy Ingredient Applications Research Program

Personnel

Kimberlee J. Burrington, coordinator, Karen Smith, PhD, researcher, Kathy Nelson, research specialist

Funding

Wisconsin Milk Marketing Board, Dairy Management, Inc.

Dates

January 2004 to December 2004

Objectives

1. Enhance the value of milk and whey-derived ingredients by providing technical support to the milk and whey processing industry. Provide processing and applications support for whey, permeate, lactose, whey protein concentrate, whey protein isolate, and whey protein fractions as well as buttermilk, MPC, and NFDM.

2. Conduct industry directed dairy ingredient applications projects, which evaluate the functional attributes of specific dairy ingredients in finished food systems. Areas of food applications for dairy ingredients are dairy and bakery products, beverages, confections, soups, sauces, meats, nutraceuticals, and infant formula.

3. Initiate development of a pilot plant facility which provides the ability to conduct milk and whey processing projects with industry for the evaluation of existing and new processing conditions.

Summary

In 2004, the Dairy Ingredient Applications program was contacted by 30 Wisconsin-based companies and 100 national companies, consisting of whey processors, ingredient suppliers, end-users, equipment manufacturers, ingredient companies, associations, government organizations, universities, and the press.

Whey applications were developed and presented at the following events, seminars, and companies: Pepsico seminar, Atkins Seminar, Quaker Oats Table Top, Membrane Processing Short Course, Waisman Center, DMI Annual Meeting, and IFT. Applications development focused on ready to drink milk and whey-based beverages, low carb baked products and beverages, and more PKU foods. Glycomacropeptide is currently the only food protein that is free of phenylalanine, so it is the only suitable food protein that can be used in the PKU diet. GMP applications developed to date include fruit leather, vanilla pudding, bread, pancakes, and acidified strawberry pudding. Work will continue on this project in 2004. General whey processing, functionality, applications, and nutrition information were presented 24 times over the year.

Utilization of the pilot plant included whey processing, milk processing and whey applications projects for a total of 37 trials. Many of the needs of the whey processors and end-users have been informational needs. Typical requests are for standard methods for chemical and functional analysis, specifications, whey ingredient sources, literature searches, whey nutrition information, formulations for specific applications, and processing trouble-shooting questions. Membrane processing support is also provided to the CDR cheese group on all projects utilizing ultrafiltered milk, buttermilk, and whey-based fluids.

Presentations and Publications
Karen Smith, Ph.D.

Evaporation/Drying lab Chemistry and Technology of Dairy Products Course, March 5.

Turning Milk and Whey into Value Added Dairy Ingredients, SABIT group from former Soviet Union. March 8.

Drying Lab for Food Processing Course, March 9.

Manufacturer Applications for Whey and Milk Ingredients, DMI visit to CDR, March 11.

Membrane Lab for Chemistry and Technology of Dairy Products Course, April 9.

Membranes 101, 2004 International Cheese Technology Exposition , April 21.

Acid Whey Utilization, Cultured Dairy Products Short Course, May 5.

Filtration Facts #1, New Equipment and Processes, IDFA Plant Operations Conference, May 6.

Whey Processing for Sorrento-Lactalis seminar at CDR, May 14.

Enzymes 101, DSM Food Specialties onsite seminar, June 30.

Principles of Membrane Separation, Minor Whey Protein Fractionation, UF/MF/RO in the Dairy Plant, Membrane Short Course, October 19,20.

Changes in Galactose and Lactic Acid Content of Sweet Whey During Storage, Journal of Food Protection Vol 67, No. 2, 2004, Pages. 403-406.

K.J. Burrington

Whey Functionality, Applications and Nutrition, USDEC seminar at AIB, March 1.

Whey Applications Program, DMI visit to CDR, March 11

Dairy Ingredient Functionality Lab, Chemistry and Technology of Dairy Products Course, UW Food Science April 2.

Nutritional Properties of Whey Proteins, Kraft visit to CDR, April 6.

Whey Applications Program, Cheese Industry Team Meeting, April 20.

Cultured Beverages, Cultured Products Short Course, May 4-6

Whey Functionality, Dairy Chemistry Lab, UW Food Science, May 12.

Formulating Dairy-Based Beverages, G.C. Hahn Dairy Based Beverages Seminar, May 20.

Whey Applications Program, DMI Applications Meeting, May 15.

Nutritional Properties of Whey Proteins, ADSA Annual Meeting, July 27.

Dairy Ingredient Processing, Applications, and Nutrition, Seminar at Conagra, August 31.

Whey Protein Functionality and Applications in Meat, Prepared for Seminar at Tyson Foods, October 8.

Processing Parameters that Affect Whey Functionality, Membrane Processing Short Course, October 19-20.

Dairy Proteins and Weight Management, Seminar at EAS, November 8.

Dairy-Based Beverages, Seminar at Atkins Nutritionals, December 1.

Factors that Affect the Flavor and Functionality of Whey Ingredients, Dairy-Based Beverages, Seminar at Pepsico, December 2.

21^{st} Century ice Creams, Food Product Design, May 2004.

Building a Precise Pizza, Baking & Snack, July 2004

Topping It Off, Baking & Snack, June 2004.

Flax, Food Product Design, November 2004

CDR Communications Program

Personnel

Mary Thompson, coordinator; Joanne Gauthier, communications specialist; Tim Hogensen, graphic designer; and Karen Paulus, senior editor

Funding

Wisconsin Milk Marketing Board

Dates

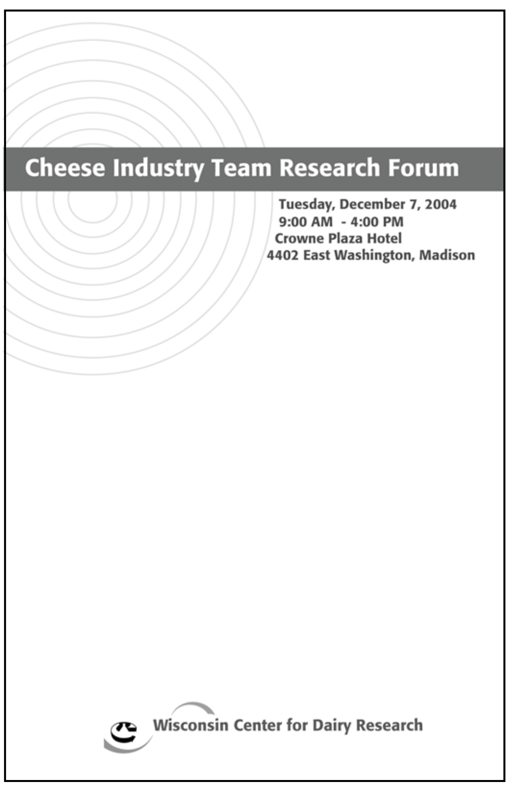
January to December 2004

Objectives

1. CDR Communications (CDRC) support the Center's research and associated applications programs to sustain the viability and enhance the economic position of the Wisconsin dairy industry. CDRC provides Wisconsin's dairy industry the information necessary to enhance or maintain their competitive advantage.

2. The CDRC team goal is to provide information to Wisconsin's dairy industry through the most effective and efficient channels. We use a variety of communication tools to deliver our message including technical conferences, forums, short courses, training programs, publications and our web site. The information that follows is a sampling of the work done by the CDRC team.

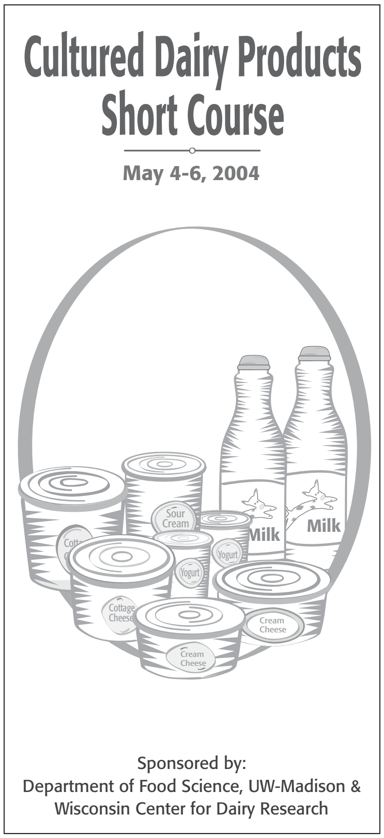
Design and coordinate technical conferences, forums, short courses, industry events



2004 International Cheese Technology Exposition
The International Cheese Technology Exposition (2004 ICTE) was held in Madison, WI April 21, 2004. Panel moderator Dean Sommer, CDR opened the technical session Use of Membrane-Filtered Milks in Cheesemaking – CDR Case Studies. Speakers addressing the topic follow: Membranes 101 – Karen Smith, Logistics of using membrane filtered milks – Bob Fassbender, MSS/TC Jacoby, and CDR Case studies – John Jaeggi, CDR.After a short recess, the next technical session, Control of Calcium Lactate Crystals in Cheese – The New Story was introduced by moderator Dean Sommer, CDR. Topics and speakers for the session include: Mark Johnson, CDR, and Peggy Swearingen, Land O Lakes.The CDR exhibit during the WCIC featured the 2004 Wisconsin Master Cheesemaker class and a list/description of short course offerings at UW/CDR and current research projects. CDRCcoordinates the WCIC technical program.

Forum

The fall 2004 Cheese Industry Team (CIT) Research Forum featured 16 principal investigators providing industry members updates and progress on their research. Industry attendance continues to increase. The Forum was held December 9, 2004 at the Crowne Plaza, Madison, Wisconsin.

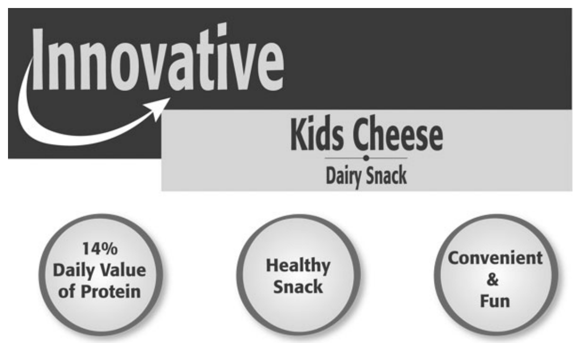


Short courses

CDRC is involved in 30+ short courses or tailor-designed training programs each year. CDRC was instrumental in the development of 3 new short course offerings for 2004, Cultured Dairy Products and Cheese Packaging and Cheeses of France.

Industry event

The "Tastes of Innovation – Dairy Check-off Works" booth at DMI, NMPF, UDIA and NDRPB national meeting featured new products in the marketplace and innovative product prototypes. Of the products displayed, CDR developed orange-mango-peach sport beverage (whey) and cheeses flavored for kids. Flavored string cheeses featured include bubble gum, cotton candy, green apple and strawberry. CDRC developed all the exhibit visuals and handled logistics for the booth. The event was held October 2004, Reno, Nevada.



Develop publications and other communication vehicles to deliver technical information

The quarterly newsletter, "CDR Pipeline" has 1800 subscribers. Lead articles for 2004 include Monitoring the Biological Safety of Dairy Plants, Part 2, Uncovering the cause of cheese defects, is it the retailer, the cheesemaker or the packaging? Monitoring the Biological Safety of Dairy Plants, Research Update - Reducing the risk of Listeria monocytogenes or Preventing listeriosis, Revisiting Calcium Lactate Crystals in Cheese and Specialty Cheese in the Southern Hemisphere.

Wisconsin Master Cheesemaker Recognition Ceremony, April 22, 2004

The Wisconsin Master Cheesemaker newsletter, "The Cheese Wedge" is mailed two times a year to graduate Wisconsin Master Cheesemakers. The newsletter's emphasis is on short courses, events and Master program information.

Manage the CDR Web site

The CDR web page www.cdr.wisc.edu includes technical newletters, world cheese exchange, pilot plant equipment and a calendar of short courses, meetings and events.