1982

Fifth Biennial Cheese Industry Conference

Various Authors

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CHEESE CONFERENCE SCHEDULE

Tuesday Morning, August 31, 1982
9:00-10:00 Registration Eccles Conference Center, Registration Booth
All conference sessions will be in ECC Auditorium 216 except where indicated otherwise.

THEME: The Cheese Industry Today
Chairman: David Thomas

10:00-10:15 We are glad you are here ................. Doyle J. Matthews
10:15-10:55 Acquisition and disposal of dairy products under Federal programs ................. Jim Schlottman
10:55-11:30 Here we are. Where will we be tomorrow? ................. Harry Palmiter
11:30-12:00 California's interest in standards for raw milk cheese ................. Jethren Phillips
12:00-1:30 Lunch, Carousel Square, University Center

Afternoon Session
Chairman: Mathew Chappell

1:30-2:10 Commercial application of a defined strain starter system for cheese making ........ Randy Thunell
2:10-2:50 Proteinase negative cultures for cheese making ................. G. H. Richardson
2:50-3:10 Snacks and conversation
3:10-3:50 Preparation of cheese at elevated temperatures ........ J. F. Flannigan
3:50-4:30 Need for standards for culture tanks and culture control equipment ................. G. H. Richardson
6:00 Steak Fry, Malibu Site, Logan Canyon
Bus departs motels at 5:50 PM

Wednesday, September 1, 1982

THEME: Improving cheese yields
Chairman: Keith Geilman

8:30-9:10 Effect of starter media on cheese yields ................. Clair Hicks
9:10-9:50 Cheese making procedures that effect yield ................. N. F. Olson
9:50-10:05 Snacks and conversation
10:05-10:45 Effect of milk clotting enzymes on cheese yield ................. Robert Sellars
10:45-11:20 Progress toward use of ultrafiltered milk for increasing yields of curd for processing ................. Paul Savello
11:20-12:00 My experience in improving and accounting for cheese yields ................. Joe Heaps

THEME: New approaches to old problems
Chairman: Rulon Mayberry

1:30-2:15 Advances in ultrafiltration for production of process cheese base, and Mozzarella and Feta cheese ................. Pål Gjerve
2:15-3:00 Direct casein analysis of milk for use in cheese yield milk pricing ................. Bjarne Nicolaisen
3:00-3:15 Snacks and conversation
3:15-4:00 A new approach to dairy plant waste water treatment ................. R. J. Brown
4:00-5:30 Demonstration of waste water treatment ................. Norman Robinson
6:00-10:00 Cache Valley and Bear Lake tour (Meet front of University Residence Center).
Thursday, September 2, 1982

THEME: More new ideas to increase efficiency  Chairman: Dallas Ward

8:30-9:10  A rapid farm test for penicillin in milk  Dr. Swan

9:10-9:50  Low cost recovery of solids from whey and whey permeate  Norman Robinson

9:50-10:10  Snacks and conversation

10:20-12:00  Production demonstrations (choose the one of greatest interest)

A.  Solids recovery from whey. (Behind Conference Building)  Norman Robinson

B.  Production of curd from ultrafiltered milk and its manufacture into process cheese. (Room 208, Nutrition and Food Science Building)  Paul Savello and C. A. Ernstrom
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September 7, 1982

Attention: Biennial Cheese Industry Conference Participants

Dear Conference Participant,

Having just completed the 5th Biennial Cheese Industry Conference here at Utah State University, we wish to thank you for your attendance and participation.

We feel that the information given and the interactions achieved were most advantageous to the Cheese Industry, it's progress, and it's continued success and wish you the very best in your efforts in the industry.

Sincerely,

Frank Stewart
Program Specialist
I have been asked to speak today about California's interest in the proper labeling and defining of raw milk cheese. Before I cover this subject matter, I would first like to talk a little about the segment of the marketplace in which my company and I specialize—natural or nutritional foods.

During my ten years in the natural foods industry, I have been privileged to participate in and therefore observe first hand the literal explosion of demand for basic and whole unadulterated foods into every sector of the consuming public. Everyday the media is chalked full of stories telling us of the ill effects of improper eating. All diseases related to poor nutrition are increasing at alarming rates. It is no wonder the public demands more nutrition for their dollars spent.

A recent survey conducted by Woman's Day magazine reports that 34% of the United States population is interested in natural and nutritional products and that 15% would purchase such products exclusively if they were readily available. Additionally, the percentage of those interested in natural products is proliferating at an extraordinary rate. As far as a growth market, few offer better opportunities.

Recent market studies done by the highly regarded Business Trend Analysts of Commack, New York show the following. Annual sales of the natural foods category were approximately $170 Million in 1970. In 1975 sales had more than tripled to over $590 million. Just six years later revenue for 1981 had quadrupled to a hefty $2.5 Billion and best estimates for sales in 1985 are for a doubling to $5.3 billion and a more than doubling again to approximately $12.3 Billion in 1990. Now I don't know about you, but that's what I call growth!

By 1990 half of this projected $12 plus billion market will be sold through the supermarkets and the other half through the many other outlets selling natural foods such as natural and health food stores, co-ops, and the like.

SPECTRUM MARKETING, INC.
1120 Baird Rd. Santa Rosa, Cal. 95405 (707) 538-3868
For the past several years Spectrum Marketing and Spectrum Brokerage have been actively involved in the procurement, marketing, sales, and/or brokerage of natural cheeses with the majority of emphasis being in the area of raw milk cheeses; or should I say what I had been taught was an acceptable definition for raw milk cheese. It is this last statement that brings me to my real purpose for being here today and it is a story that I hope you will find both interesting and important.

I am not here today to point fingers nor to debate the nutritional considerations of whether or not raw milk cheese is better tasting or more nutritionally sound than heat treated or pasteurized cheese. I am here however, to promote TRUTH IN LABELING, because without it in the long run everyone loses.

Improper labeling is bad business; bad for the consumer, bad for the producer, and bad for all parties involved in any distribution chain be it cheese or not. It would be tough, if not impossible, to compete in the marketplace if the consumer could be easily misled into buying imitation for real cheese. The emergence of the "REAL" seal is a totally invaluable and necessary tool in helping the public choose between apples and apples and not between apples and oranges.

Likewise, it is abundantly clear that consumers willing to pay the higher prices required for the purchase of raw milk cheese expect and demand that cheese labeled as raw or being made from raw milk be just that—cheese made from 100% pure raw milk and not from heat treated, underpasteurized, or pasteurized milk.

Now, I am not a cheesemaker. I have a reasonable understanding of what is involved in making cheese, but that's as far as it goes. My limited understanding allowed me to accept as normal procedure and absolute necessity the heat treating of milk in order to make so called raw milk cheese. This position went unchallenged by me until the early fall of 1981, when I discovered through phosphatase testing that not only was 99% of the cheese labeled as raw made from highly heat treated milk, but additionally a very high percentage of cheese in fact was made from fully pasteurized milk. Well, I decided enough was enough. I decided to find out first hand if cheese could be mass produced from pure raw milk, and so I embarked on an extensive research program to find plants willing or able to produce legitimate raw milk cheese. My phone calls and travels took me all over the U.S., and I found out first hand that it is not only possible but quite economically feasible to produce the "real McCoy".
In talking to these very few plants that produce real raw milk cheese, I discovered a common fact. The ONLY way that a real raw milk cheese could be effectively produced was to use high quality Grade "A" milk. Anything else meant inconsistent, off flavored, or just outright poor product.

Between the obvious need for consumer and plant protection alike, contacts were made with prominent California legislators. Every plant that I spoke with that produces real raw milk cheese felt at a great disadvantage in trying to compete in the marketplace with heat treated or pasteurized product being labeled as raw due to the premium price they pay for Grade "A" milk. So, between the obvious fact that consumers believe that cheese labeled as raw should be just that and plants producing legitimate raw milk cheese wanting and needing the public to be able to compare like product with like product, legislation has been introduced to more clearly define raw milk cheese. This is an important and necessary first step, but there are still a few details which need to be worked out before the soon to become law is encompassing enough to really do the job.

Currently, existing law on both the federal and state levels only define pasteurized milk and therefore pasteurized cheese. In order to label cheese as being made from pasteurized milk, CFR Title 21, Section 133.113 (c) (2) requires that milk be held at a temperature of not less than 161°F for fifteen seconds or 143°F for not less than 30 minutes or for a time and temperature equivalent thereto in phosphatase destruction. If 0.25 gram shows a phenol equivalent of 3 micrograms or less than the milk is deemed to have been pasteurized.

Due to an unclear or lack of definition for raw milk cheese, it has been common practice that if the cheese is technically not fully pasteurized, it can therefore be labeled as raw. In other words, one supposes the other.

However, every responsible person that I have spoken to in the cheese industry, understands that underpasteurized or heat treated cheese is not the same as raw milk cheese. I quote from some very well known and respected sources within the industry.

In a letter written to me from Mr. Al Bauer of Land O Lakes on information requested by me he wrote: I checked our files on what work we had done on the differential of cheese labeled "raw milk" and "made from unpasteurized milk". In June of 1976, our production manager consulted with Mr. Robert Anderson, executive director of the National Cheese

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Institute in Chicago and I will quote directly from the note he made as a result of their conversation:

"Bob Anderson, N.C.I. Executive Director, has given the following opinion regarding labeling, "raw milk" cheese, "unpasteurized milk" cheese, and "pasteurized milk" cheese.

1. Cheese shall be deemed to have been made from pasteurized milk, if it passed the A.O.D.C. test described in C.F.R.

2. Cheese is deemed as unpasteurized, if 0.25 gm shows a phenol equivalent of more than 3 micrograms when tested by A.O.D.C. method.

Heat treated milk is not raw milk.

Cheese made from "heat treated milk" should be labeled "unpasteurized milk cheese", or "cheese made from unpasteurized milk".

I have not given the option of labeling the above as "aged over 60 days" because by inference at the last few Research Committee Meetings, Food and Drug will eventually abrogate that opinion.

Raw milk, by Mr. Anderson's definition is milk that has not been treated in any way.

I should also point out that Mr. Anderson confers with Federal Food & Drug officials when asked to clarify issues on labeling.

Signed, very truly yours, Al Bauer, Operations Manager.

In a memo written by Leland H. Lockhart, Chief, of the California Bureau of Milk and Dairy Foods Control dated January 25, 1982, he wrote: "Much cheese is made from milk that has been heated to less than a pasteurization equivalent. This cheese when sold is labeled as being "aged or cured 60 days or more". If cheese is advertised as being made from raw milk, then this milk should not be heated beyond the temperature needed to separate cream effectively (around 100°F.) Otherwise, I believe section 32914 could be used as an enforcement tool. However, it would be better for industry to introduce legislation to prohibit heated milk if the cheese is to be featured as being made from raw milk".

In the bill analysis of March 31, 1982 written by Mary Dignan for Assembly Committee Chairman on Agriculture John Thurman of California
the following is written: Staff Comments:

Existing law specifically establishes labeling requirements and standards for cheese, but does not specifically prescribe labeling requirements for cheese made from raw milk. State Department of Food and Agriculture officials have discovered cheese marketed and labeled as having been made from raw milk but actually made from pasteurized milk, or from milk that has been heated almost but not quite to the point of pasteurization. Staff notes that existing law does not define "raw milk" although "pasteurized milk" is defined in both state and federal law. In order to effectively assure consumers that cheese labeled as having been made from raw milk is actually raw milk cheese (and not cheese made from pasteurized milk or milk that has been heated), staff recommends that this bill be amended to define "raw milk".

In a article in the Sacramento Union, dated in late February of 1982, the following was written.

"Several brands of cheese sold in Sacramento natural food stores labeled as being made from raw milk are actually made from pasteurized milk according to a spokesman for the California Bureau of Milk and Dairy Foods Control.

We tested some raw milk cheese to see if it was actually raw milk, said bureau chief Leland Lockhart. Some of it was being sold as raw that was made from pasteurized milk, according to our tests.

Lockhart said the bureau has taken no legal action against the cheese manufacturers.

We want the industry to have a chance to clean their own house first, he said. "We've been notifying the companies who sell the cheese and telling them to check with their suppliers".

The new California law, when enacted, takes a great step forward in defining raw milk cheese and thus insuring proper labeling. However, the legislation, which I was fortunate enough to be a party in help drafting, is still somewhat limited in weeding out heat treated cheese from real milk cheese due to the limitations of the current testing procedures, which can only detect levels of postive 5 units of phosphatase. Hopefully, however, this limitation will be short lived.

Dr. C.A. Ernstrom, Dept of Nutrition and Food Science, Utah St. University, has graciously consented to head up a collaborative study, which we hope will once and for all establish definitive testing procedures by variety of cheese for identifying the high levels of phosphatase as would be found in raw milk.

**READ DR. ERNSTROM'S LETTER.**

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HERE WE ARE. WHERE WILL WE BE TOMORROW

by Harry Palmiter

Prepared for presentation at Utah State University 5th Biennial CHEESE INDUSTRY CONFERENCE
August 31-September 2, 1982
Here We Are. Where Will We Be Tomorrow?

It is a pleasure to be with you today because it provides an opportunity where industry, research and technology can come together to report and discuss what is happening in both areas.

When Dr. Ernstrom asked me to speak and to give him a title, I thought of all the many aspects of the cheese industry, the many different pathways to the single point of a successful cheese industry, plus the fact that between that date and today's date a myriad of happenings could take place. So, I settled on the title of: Here we are. Where will we be tomorrow?

What I want to do is provide you with a brief summary of where the cheese industry is today in several areas, then discuss some suggestions about where I think the industry should be heading, what it should be doing to get there, and what it should find when it arrives ... tomorrow.

It is no secret that the cheese industry of the US has a surplus on its hands and is continuing to add to that surplus. That's not only true of the US, really, it is basically true of the whole cheese world.

Looking at industry reports, the Australian and New Zealand industry, the European industry both the Economic Community and other European producers, we find that all are working with an abundance of cheese stocks and looking for a place to market them.

In spite of the abundance of cheese to be marketed, milk production is being improved and thus increased in most producing areas. This translates into more product looking for a market, even though in a couple of instances it is milk that may be limited in domestic utilization because of the greater economic potential of marketing that milk through export sales.

There has been in the United States a growing separation
between the cheese industry and the research laboratories and teaching facilities of the sites of higher learning and education for the past several decades, which has --- unfortunately --- developed a fairly wide chasm today as we have seen many former dairy schools become food science oriented or so labeled. No criticism is meant by this statement, it is simply a fact which the industry and dairy scientists are aware of, readily acknowledge, and are concerned about where it has meant a reduced dairy science program.

Where there used to be many cheese factories scattered across the nation, today those numbers have dwindled to a total of something around 400. An indication of the size of this change is readily evident when we look at the fact that there were about 3,000 cheese factories in the State of Wisconsin alone in the 1920's, today there are about 300 in operation.

Most of the cheese factories today are for the most part considerably larger than anything imagined in the 1920's, and while it is apparent that there are new factories appearing today, we can reasonably assume that they are not appearing as rapidly as some of the smaller factories are disappearing.

The size of the remaining factories has grown in most cases, through technology and development, with corresponding increases in amounts and products produced from growing volumes of milk from similarly expanding herds and production facilities.

The growth of technology and research has not only been applied to known products, such as cheese, however, and we've seen the development of and growth in recent years of a new industry, that of food imitations which include cheese-like products or analogs. Depending on where your position is in the dairy industry, the food field, research or marketing will determine your evaluation and opinion on it.

A recent article in Supermarket News said the field of cheese imitations is said to now account for "5 to 10% of retail cheese sales..."
today ..." and "will capture a 30 to 40% share by 1990." The source of this information said that the potential for cheese substitutes in the 1980s is similar to the potential for margarine years ago. "Cheese substitutes will be the margarine of the '80s and '90s as consumers look more and more for value. ... As the quality of substitutes increases, the market penetration for those products will grow. And competition will force quality up and prices down," the speaker was further quoted as stating.

On this subject, I'm sure we are all aware that the Federal Food and Drug Administration made an attempt a couple of years ago to permit the term imitation to apply to any product made to resemble cheese and, if the item was nutritionally equivalent to the real product in major vitamin and mineral content it could be named a substitute of whatever cheese variety it was made to imitate. This effort has been shelved for the time being, but the cheese industry has no way of knowing when it might be brought out again and again be suggested as the law of the land.

To our knowledge the State of Wisconsin is the only state which has fought the selling of imitation cheese, and it has fought the sale of imitation dairy products for the past 60 years. But, as it was recently noted, for various reasons the sale of margarine, coffee whiteners and imitation pizza cheese are now exceptions in the state. However, now legislation is being developed to provide for acceptable labeling of cheese imitations so they can be sold in the state.

Another point I want to mention in reviewing the present situation is that of whey protein solids. In recent years there has been a considerable amount of development in whey processing. I think there is little doubt that much of the credit for the work done in the Midwest, at least, and in the US for that matter, goes to Frank Thomas, Thomas Technical Services, Greenwood, WI. Frank isn't just a talker, he's a doer, and he's brought the several ends of whey protein production together to develop
a considerable volume of business and source of utilization of whey solids from cheese making operations.

Just about a year ago Express Foods of Ireland formally opened its whey solids operations in Vermont. That organization incorporates a more extensive method of condensing in the production of whey protein solids than has been utilized in the US, this work having come from research in Ireland.

These and other whey solids operations are now taking away the waste problem of a considerable amount of the whey from cheese factories but much remains still to be utilized.

And with that we'll stop looking at highlights of where we are today. Now, where will we be tomorrow????

I like the statement made by Thomas Jefferson, that illustrious member of our early history and a real man of vision, who said: "I like the dreams of the future better than the history of the past."

Or we can look at today in other way, this in the words of writer Bertold Brecht, who said, "Today, nourished by yesterday and proceeding into tomorrow."

In our own words, today we must look at the past for guidance and understanding, that's what experience is all about, but the real challenge are still ahead of us. How we deal with them is where we'll be tomorrow.

Now let's go back to some of the points I've touched on and see what we can line up to work on for tomorrow.

When I mentioned surplus cheese stocks I stated a fact we are all aware of in that in order to support the price of farm milk the government has purchased cheese that has not moved into consumer utilization as rapidly as it has been produced.

There is considerable argument by some who say that this is not surplus cheese, it is misplaced cheese because there are literally millions of hungry and undernourished in the world who should have it available to them before they perish or grow up maimed by malnutrition. While
there is much truth in this argument and we all wish there was a way the transposition could take place, this is not the purpose of our discussion here.

The marketing fact that we must deal with is that in most of the US the per capita consumption of cheese is about 17 to 18 pounds annually. This does not consume cheese produced as rapidly as it is being produced, and not at a price which would maintain the support price for milk.

Last week I sat in a marketing seminar, put on by the Wisconsin Cheese Makers' Assn. to inform and educate some 30 cheese makers, processors, and marketers. Two speakers, the director of the deli/bakery merchandising and the director of cheese stores for The Kroger Co., stated emphatically that they are gearing their future cheese operations to the obvious opportunities for growth of per capita consumption, and just as emphatically said they were confident that we in the US could increase the per capita consumption of cheese to 30 pounds per person by 1990.

Their story is a simple marketing one, they've watched closely for what the consumers were telling them about how they want to buy cheese, want to try new varieties, and would repeat purchases of new offerings properly introduced and merchandised.

The Kroger representatives presentation followed a full morning session on basic cost accounting for marketing. The well-known session leader, Dr. Lawrence L. Steinmetz, repeatedly informed the group that one of the biggest problems marketers have is that they are afraid to price products high enough to return costs and a profit, a price high enough to say to the potential consumer that it was a product worthy of consideration and appreciation, and that -- above all -- when product did not move in the market place at the set price one of the quickest ways to counter defeat and bankruptcy was to start dropping price.

Dropping price not only puts the seller in a bad financial position, it indicates to consumers that the product was probably overpriced at the start, that it is not worth that price and that it is probably still
overpriced and will go lower if the consumer is patient.

To this, Steinmetz told the group, you have a product that has quality, it is produced under high standards and is worthy of pricing at a quality level and sticking to that price. The industry has got to go into the market and develop its competitive edge that the product has, so the consumer knows why the product is worth the marked price.

That means that the industry has to develop its marketing plans before going to the retailer, provide a plan which the retailer can use and will be useful in offering the product to the consumer at a price at which all will profit.

How many times have we all heard speakers tell us that profit is not a dirty word? It is a very necessary part of successful marketing if the marketer expects to stay in business and be successful. Why are so many so afraid of it?

Is there a surplus? Or is it simply a supply of product that the industry has not successfully marketed to the potential consuming public?

Preparing for increased per capita consumption means that there will also be a need for growth in cheese making technology and varieties. That's where the dairy scientists and the industry have challenges to work on for tomorrow's successful industry.

I've mentioned the declining number of dairy schools and the concern about them in the future. There are still excellent dairy courses available, we are in one right here, one of many that are doing outstanding work for the dairy and cheese industry. Are they going to be here tomorrow, is the question that concerns them and the industry.

The industry must look at this problem, for it is the industry that will either suffer or profit if these resources of technology are not encouraged and supported.

The growth of the cheese industry in the last several decades caused the industry to be less and less closely associated with the dairy schools and their research capabilities.
In time, school administrations found that they needed to respond to other food makers and processors, to respond to where the communities and industries they served were making more use of the facilities and the instruction than the dairy industry was. The result was that some of the dairy schools curtailed teaching and research efforts for the dairy industry specifically, for one reason or another, and we are not in a good position today with education facilities for technologists in industry or research facilities to answer some of the tough questions necessary for future development and growth of the industry.

We are fortunate the industry today is realizing the situation and is responding. One response has been the development of the Walter V. Price Cheese Research Institute at the University of Wisconsin, other responses are increased communication and support to other dairy schools and research facilities.

This does not mean that there has not been excellent research work carried out in past years, there has been and a great deal is being done now. Much of this is being supported by industry groups who have placed research funding on specialized projects and questions with these institutions. To hear about these and others is why we are here.

Last year, in The Cheese Reporter's Special Convention Issue, we highlighted in capsule form research projects pertaining to cheese and the cheese industry. We tried to get hold of every listing of research then being carried out. There was a considerable amount then, and we know that we did not find out about many research projects underway, for we've heard reports on some outstanding work that has been and is being done.

One of the problems some of these research facilities have had, however, would appear to be that in lieu of industry inspired projects they have had more and more to devote their time to very basic research not of specific or direct need by the industry.

In no way do we want to imply belittling or downgrading of this work. It's problem is only that some of it has no direct application to
the industry in the near future or its marketing problems.

I know I've very casually covered this area, but I think we all realize that what is needed is more communication and a closer working relationship between these schools and the cheese industry. Not only does the industry need to keep in close touch with what schools and research are doing, it needs to see that the research facilities have available the equipment developed by industry and industry suppliers so that research can be carried on in modern and continually updated equipment that parallels the industry's facilities.

This is a costly and vital concern of many of the dairy schools. One which cannot always be taken care of by school budgets, and it puts a considerable hindrance in the way of teaching and research potentials. Consider for a moment the position of a school where a new student comes in after having worked in industry, to find the school using equipment for teaching which he may have seen discarded and rusting behind the plant that inspired him to study the subject more deeply.

What I am saying to the industry is that it must -- even though it may not have a question that needs an answer today -- keep in close contact with the teaching and research people today and help them solve their problems, so they can better solve the industry's problems.

The cheese industry recognizes that we are in a technology area which is rapidly expanding on all fronts of the food field. And, it recognizes that the technology of its field must not be neglected, either in research to improve its own technology or in the area of developing new products and variations of products for the consuming public. This awareness may seem be a little slow in coming, but it is coming.

This is the area where imitations of cheese products have surged ahead on their own, simply because the technology of combining elements have made it possible to imitate other products.

Let's not get bogged down in what the imitation field is today and find ourselves in the situation that the butter industry did with oleo-
margarine. Let's suffice it to say that the butter industry probably spent more time and money on defending its market and fighting the sale of oleomargarine than it would have taken to further solidify its market position through researching the nutrition of butter and marketing it properly, to a point where it would probably have maintained its original marketing position.

Let us recognize too, that in marketing, "New products are not foisted on consumers. They are offered to consumers -- usually tentative at first (in test situations), and usually only after months of research that suggests a demand for them exists. How these substitute foods will survive depends to a great extent upon how they respond to the realities of the market place. To survive, they will first have to be accepted into an increasingly crowded and competitive, and critical grocery environment -- and against some tough odds. Then, once more, they will have to continually justify their right to be there by satisfying both the retailer and the consumer.

"New substitute foods, or new substitutes for established substitute foods are part of this stream of products moving into and out of supermarkets. They are...a very small part currently. Whether they become larger or smaller in the future will depend first on consumer wants and needs, and second in the imagination, skill and technology of the grocery manufacturer."

This information also indicated that in grocery stores only, total new item introduction in 1974 numbered 6,525 items; in 1975 - 6,686; reached a low point in 1978 with only 4,754; then recovered to 1981 with 6,114 items.

The cheese industry is not the only food industry facing competition from new products and imitations. But each new product within a food field must also survive the same market introduction and dangers.

Let us recognize that old saying, which sometimes seems of little satisfaction, "Imitation is the greatest form of flattery, or admiration. That does not mean we can get puffed up about it, instead it means that
we've got to just work harder to maintain our place in the market.

The cheese industry will accomplish far greater success in competition if it will research fully its nutritional pluses, know its market position and consumer preferences, then market its products with all the skill necessary to provide continuing successful consumer satisfaction and supply, and maintain the position that is justified and deserved.

There will be new products which the cheese industry will and can develop within itself and its research facilities. One of these areas is that of new varieties and flavors. The reason we must acknowledge and accept this is the fact that new flavors and varieties are being imported into the domestic market place and are being accepted readily by consumers.

These have been accepted by grocery, deli and specialty food shops as new items they can offer consumers, for consumers are always looking for something new and different.

I think I can probably best illustrate this last fact by asking how many men here, whenever possible, browse through a hardware store or the hardware section of department stores, the sporting, fishing or hunting departments? You probably don't buy much at any one browse, unless you have something special in mind or find something new. Chances are you'll spend the most time if you do find something new, or different than you've seen or bought before. You examine it and consider whether it might not fit into your tool box, your tackle box or in with your sports equipment.

The food shopper is the same. They browse while looking for some specific item on their list, and they are interested in things new and different they may be able to use. In this case it is some new flavor of food that will give one or more of the family a special pleasure. Or it may be a product that can be used in a favorite recipe to give it new twist, a new tang, a new something that will break the old routine.

In this area of thought, I tell you that I heard our famous and
favorite varieties of cheese referred to as "commodity" varieties the other day, as a speaker said the consumer wants new experiences, new thrills and new products in the foods they buy.

Shocking isn't it? But with exporters like France who recently noted they would introduce more than 100 new varieties of cheese into the US in coming months; or Denmark which is also preparing new exports for the specialty food houses and deli counters of the US, this opens a vast and virtually unchallenged opportunity. And these are opportunities which they can take to the retailers as new ways to keep old customers coming back and draw new customers.

It means, my friends, that we must look to our domestic marketing. We must not only continually make our production of the favorite varieties and specialties the best that can be made, we must also make every effort to make every consumer more conscious of, more knowledgeable about and more loyal to those varieties and products that form the basis of our cheese industry.

One more word about the imported new varieties. They are not on the import quota lists, they are not limited to quantity, except by the reception and purchasing by the American consumer. The exporters realize this fully, and in many cases the countries involved work with their exporters in developing a whole national campaign for their cheese varieties played before the American public. That's called enterprise, and they are taking full advantage of appealing to the same consumer which we look to to buy and use the cheeses we are making.

Let's take a closer look at the new product mentioned earlier. That's our whey protein product. Those now producing and marketing them say that the market is growing rapidly enough so that they cannot make too much of the products.

But what is down the road for those products? We know that they are by no means yet approaching the processing of all available cheese
whey in the United States, and before the problem of whey to be disposed of is over there will be a considerably larger utilization and market potential needed to make whey protein solids a continuing and profitable market item. Then we must be alert to the possibility of being imitated.

I am delighted to see these products utilizing the whey that is so full of many nutrients that need to be made available to consumers, but I am concerned about whether there is a growing development of product utilization that will parallel the increased whey protein solids production.

I am concerned about whether we will be building another surplus product before we reach the point of profitable utilization of raw whey.

I am concerned about whether we are building a profitable demand and return for these products that will help to give the industry a combined operation that is profitable for its future.

This may be one of the most important areas of research need we currently have, along with new varieties and flavors. Are we working at it? Yes, I know we are, but will it be adequate to keep ahead of the need?

These areas I have merely touched on are some of the things I view down the road to tomorrow. And tomorrow we need to have solved many of these problems or we may again face such adversity as we felt when in 1973 the Flannigan Report suggested that much of the needs for dairy products in the US could be satisfied by imports from other countries whose dairy industries were growing, and that this could help the US to improve its balance of trade position, make for friends of those exporting countries, and save supporting the price of milk in the US.

As a summary and for your thought, I'd like to refer to an article in the current issue of Reader's Digest, entitled The Seven Secrets of Peak Performance. I'd like to give these seven points my own ideas for them to lead us into a successful tomorrow for the cheese industry.
Point one: **Lead a well-rounded life.** To the industry and those of us in it, it would mean to be mindful of all the industry, not just our own little corner, and to work and cooperate for the industry's future success.

Point two: **Select a career you care about.** In this case most of us have done that, but we can select a specific goal in a part of that career which we'd like to challenge and work full speed for it.

Point three: **Rehearse each challenging task.** Plan well what you are going to do to accomplish point two, think it out carefully before you embark on accomplishing the task you choose.

Point four: **Seek results, not perfection.** The point being that you must not get bogged down in some of the little details that may allow the large opportunities to slip away while you're still snagged on the minor point. Most little points can be worked on as the bigger objective is pursued, or can be improved later as new and added features.

Point five: **Be willing to risk.** I think that should be clear. With all the potentials available and all the possible ways to advance, we should be willing to make a decision and pursue it confidently.

Point six: **Don't underestimate your potential.** Don't even consider giving up before you start. Take a good look at all the opportunities and be confident that you can prepare for and accomplish the goals you seek.

Point seven: **Compete with yourself, not others.** Keep your eyes on the objectives you've selected. Let's also keep our eyes on the objective of a successful cheese industry for tomorrow. Let's do the best we can with our own products, our own marketing potentials, and let no obstacles turn us from the path of making our products the consumer's choice. When we've achieved the greatest possible potential our product has, then you will know that you've done the best that you can and the results will be your success to enjoy.

Thank you for your attention.
INTRODUCTION. No matter what sophisticated techniques are used in the isolation and selection of lactic cultures for Cheddar cheese manufacture, we have relied upon one test to confirm our interest in keeping a culture; whether or not the strain can coagulate milk in 24 hours at 22°C. If it can then we will make trial vats and put it to work. If it fails we discard it. The ability to coagulate milk in 24 hours is dependent upon the ability of the organism to break down casein to produce soluble compounds for the protein building needs of the organism during growth. Normal milk has insufficient soluble nitrogenous compounds to allow organisms to grow beyond about 20% of their capability. Thus the organisms that dissolve casein are traditionally kept. Those that cannot are discarded. The successful strains have a proteinase enzyme associated with the cell wall and are referred to as proteinase positive (Prt+) and those lacking this activity as proteinase negative (Prt−). Upon initial isolation and propagation of a clone the organisms are essentially all Prt+.

If we carry a culture by daily transfers for a long time there will be a build up of Prt− variants. These are produced as cells divide and loose the DNA plasmid associated with the cell wall proteolytic activity. About 1 to 2% of the daughter cells are Prt− depending upon strain characteristics. Therefore, a strain at any one time will be an unknown
mixture of Prt+ and Prt- cells depending upon the number of transfers from original isolation and upon the strain.

The Prt- variants build up until their demands for protein building blocks exceed what the Prt+ cells can provide by breaking down casein.

When this occurs the culture slows down, we either discard it or return it to the laboratory where we reisolate a Prt+ clone and start all over again.

If we have very high numbers of Prt+ cells at milling we can expect more problems with bitter flavored cheese. For this reason much of our culture management has been associated with encouraging Prt- cells and discouraging the Prt+ from surviving and growing at cheese cooking temperatures. Mills and Thomas (New Zealand J. Dairy Sci. Technol. 15:131, 1980) confirmed that better quality cheese can be manufactured with high proportions of Prt- cells but they would not advocate exclusive use because the organisms prolonged the make times. The New Zealand industry also uses milk substrate for cultures and the Prt- cells would not grow to high numbers without the Prt+ cells to provide the essential end products of proteolysis. As we carry a culture we are thus not sure if it has a ratio of

or

as long as it produces acid normally. We actually have a variable mixture of cell types, even in a so called "single strain" culture. The cells produce acid at comparable rates until Prt+ numbers drop too low.
There are evidences that we tend to favor the Prt- variants in our cultures; we can use strains that would not be useable if pH control was not involved, we use higher volumes of bulk inoculum in our vats than expected considering the numbers of viable cells available, yields from milk solids are better and we have fewer problems with acid control and bacteriophage (phage). We especially encourage Prt- growth when we use stimulatory media which include yeast and protein hydrolyzates. Such media contain sufficient available nitrogenous compounds to allow these variants to grow without waiting for the Prt+ to dissolve the casein.

GROWTH AND ACID PRODUCTION. By increasing the nutrients in a pH controlled bulk culture medium we can obtain Prt- cell masses equal to those in a normal culture. Thanks to Jago and associates in Australia we can get a rapid estimate of cell mass in milk and turbid media using a spectrophotometer (Australian J. Dairy Technol. p. 142, 1975). We can easily convert the cell mass turbidity readings to colony forming units per milliliter (cfu/ml). The normal cell numbers in a pH controlled culture exceed ten billion or $1 \times 10^{10}$ cfu/ml. A shorter way to express this number is to use the term "log 10". I will use this approach throughout my discussions. With the proper medium we can exceed log 10 cfu/ml in the bulk culture of either Prt+ or Prt- cells. With this capability we can therefore use Prt- cells exclusively without adverse affect upon cheesemaking time. This is because we can grow more in the culture tank and use more cells in the cheese vat. The use of more cells discourages growth in the cheese vat, which has significant advantages. In Table 1 we have included data on the ability of cells to grow in reconstituted nonfat dry milk when present in high concentrations.
Table 1. Growth rates of Prt+ and Prt- UC171 cells in milk during 5h at 38C. Bulk inocula were prepared in pH controlled whey-based medium.

<table>
<thead>
<tr>
<th>Inoculum (%)</th>
<th>Doublings in 5 hours: Prt+</th>
<th>Prt-</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>5.0</td>
<td>2.7</td>
</tr>
<tr>
<td>1</td>
<td>4.1</td>
<td>2.3</td>
</tr>
<tr>
<td>2</td>
<td>3.2</td>
<td>2.1</td>
</tr>
<tr>
<td>5</td>
<td>2.1</td>
<td>1.7</td>
</tr>
<tr>
<td>9</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Both types of cells grow poorly when high concentrations are present. Strain UC171 prt- variant grew about half as much as the prt+ strain at low concentrations. At low inoculum levels there is sufficient nutrient for Prt- to initiate growth. If we used this organism to produce acid in Cheddar manufacture the Prt+ would need to be used at about 1% inoculum where 4 generations occur. The Prt- cells would be used at 4% inoculum levels where only 1.7 generations would occur. Cell crowding is involved in retarding multiplication. Growth of Prt- in the vat is further discouraged due to lack of available nitrogenous material. Thus we can effectively separate Prt- growth and acid production so that growth occurs in the culture tank and acid production in the cheese vat.

Let us consider for a minute the numbers of cells required for cheese manufacture. If we start with fresh curd and take a microbial count we find that Cheddar cheese at milling contains from log 9 to log 9.6 (1 to 4 x 10^9) lactic cells per gram. If we assume a tenfold mechanical concentration to take place during conversion to cheese,
then milk in an activity test along side the vat would have approximately log 8 to log 8.6 cfu/ml. We can now work backwards to determine the amount of culture needed in the vat initially. Let us first consider traditional cheese manufacture. If a non-pH controlled culture containing log 9 cfu/ml is used at 1% inoculation into the milk we would probably need a ripening period before rennet addition. The initial cell numbers would be log 7 (log 9-log 2 = log 7) and the cells would need to divide or generate 5.3 times (Generations = G = log 8.6 - log 7 / .301) from inoculation to milling. If we use 2% of the same culture we would start with log 7.3 eliminate the ripening period and reduce the generations required to 4.3 (G = log 8.6 - log 7.3 / .301).

We could use an inoculum level of only .24% of a pH controlled culture containing log 10 cfu/ml (though we use more cells than theoretically possible because of our predominate use of Prt- cells as explained earlier). In all these examples of conventional cheese manufacture, we expect the lactic cells to be actively growing in addition to producing acid. Conversely, if we add more cells they become crowded and don't grow as well but, and more importantly, they continue to produce acid. We don't want to use Prt+ cells because their high numbers at milling is associated with bitter flavor development. They would also adversely affect cheese yield.

If we use Prt- cells it is possible to select strains that can only generate once or twice during cheese making. If we use such with only one generation then the initial count must be log 8.3 cfu/ml (G = 1 = log 8.6 - log 8.3 / .301) and the inoculum volume would be 2% which is within normal percentage usage levels. Such numbers would produce acid at normal rates if not faster. Therefore, only growth not rate of acid
production is affected during cheese making. If normal mixed Prt+/- or Prt+ cultures are involved then the changes during making are log 7 to log 8.6 compared to Prt- where the changes are log 8.3 to log 8.6 from vat inoculation to milling. The same final numbers are available and are involved in cheese ripening. As they lyse internal proteolytic enzymes are released from both types of cells to age the cheese.

With this approach we have effectively separated cell growth from acid production; growth is emphasized in the culture tank and acid production in the vat. Less casein is solubilized both in the culture tank and in the cheese vat. The chances for bitter flavor production are reduced.

BACTERIOPHAGE. With high numbers of Prt- organisms that are not growing, there are no potential problems with bacteriophage (phage)! We compared both types of cells by inoculating them into milk along with homologous phage filtrates and evaluating what happened to culture activity during a cheese making temperature cycle. The log of numbers of phage inoculated is expressed as log of plaque forming units per milliliter (log pfu/ml). We used 2% Prt+ compared to 8% Prt- inoculum to get comparable acid production rates. The activity during five hours incubation was compared to the culture without added phage. Table 2 summarizes the means of six strains of both types of cells.
Table 2. Percent activity of Prt+ and Prt- lactic cells in milk after 5h incubation at cheese making temperatures. Homologous phage filtrates were added with the lactic strains. The data represent means of six strains.

<table>
<thead>
<tr>
<th>Phage Inoculum (log pfu/ml)</th>
<th>Activity Prt+</th>
<th>Activity Prt-</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62</td>
<td>99</td>
</tr>
<tr>
<td>5</td>
<td>52</td>
<td>97</td>
</tr>
<tr>
<td>7</td>
<td>23</td>
<td>88</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>78</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>58</td>
</tr>
</tbody>
</table>

Note that insignificant losses in acid production rates occur when Prt- cells are challenged with log 5 pfu/ml while the Prt+ cells have lost 50% of their activity. This is partially because we have required them to grow and they also "grow" phage particles when the infective DNA is present. It would not be possible for log 5 phage particles to be in the incoming milk supply thus phage activity would be insignificant with Prt- cells.

The Heap and Lawrence test (New Zealand J. Dairy Sci. Technol. 11:16, 1976) was applied to three pairs of Prt+ and Prt- types. In this test phage filtrate of the previous day is added to the culture to allow time for maximum phage build up and adverse effect upon the cultures. The test can predict when a culture will become unuseable due to phage activity before cheese plants can detect a problem. The activity of the two types of culture were compared and the data are listed in Table 3.
Table 3. Percent activity of Prt+ and Prt- lactic cells in milk after successive cycles of the Heap-Lawrence Test. Culture was added at 2% and 1% phage stock concentrate and 1% whey filtrate from the previous cycle were added simultaneously. The data represent means of three strains.

<table>
<thead>
<tr>
<th>H-L Test Cycle (day)</th>
<th>Activity Prt+ (%)</th>
<th>Activity Prt- (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>68</td>
<td>84</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>86</td>
</tr>
<tr>
<td>3</td>
<td>NT*</td>
<td>86</td>
</tr>
<tr>
<td>4</td>
<td>NT</td>
<td>92</td>
</tr>
<tr>
<td>5</td>
<td>NT</td>
<td>97</td>
</tr>
<tr>
<td>6</td>
<td>NT</td>
<td>96</td>
</tr>
<tr>
<td>7</td>
<td>NT</td>
<td>94</td>
</tr>
</tbody>
</table>

*NT = Not tested due to low activity.

Note that Prt+ cells were not useable after two days because the activity was only 32%. The Prt- cells retained activity which increased up to 97% probably because unreplicating phage was diluted out. These data also reflect the observation that phage activity reduces as defined strains are continually used without rotation. With such activity phage problems would not occur.

ANTIBIOTICS. If organisms are not growing antibiotic problems are reduced. We don't want to imply that cheese should be made from milk containing antibiotics, but if such were present we could make cheese rather than dumping milk down the drain. Making cheese from antibiotic milk appears possible after studying the effects of antibiotics on lactic acid production by Prt+ and Prt- cells. Different
concentrations of penicillin, erythromycin and or dihydrostreptomycin were added to milk containing 2% Prt+ and 8% Prt- inocula. The milk was incubated through a cheese temperature cycle and the mean pH change was .18 for the Prt+ and .89 for the Prt- when contaminated with equal levels of antibiotics. The Prt- organisms produced acid though not growing.

COOKING TEMPERATURE AND MAKE TIMES. All lactic organisms produce acid faster at slightly elevated temperatures. However, Prt- cells produce more acid at higher temperatures because there are more present and they are not growing. Their acid production rate is more constant over a wider range of temperature. For example both types of cells from strain UC171 produced Cheddar make times as shown in Table 4.

Table 4. Comparative Cheddar cheese make times calculated from acid production rates of 2% Prt+ and 8% Prt- UC171 cultures in milk incubated 5 hours at different temperatures.

<table>
<thead>
<tr>
<th>Cooking Temp. (°C)</th>
<th>Make Time Prt+</th>
<th>Make Time Prt-</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>1.9</td>
<td>3.2</td>
</tr>
<tr>
<td>38</td>
<td>2.5</td>
<td>3.3</td>
</tr>
<tr>
<td>40</td>
<td>4.8</td>
<td>3.7</td>
</tr>
<tr>
<td>42</td>
<td>13.1</td>
<td>6.4</td>
</tr>
<tr>
<td>44</td>
<td>43.0</td>
<td>23.2</td>
</tr>
</tbody>
</table>

In this example strain UC171 Prt- was slower than the Prt+ strain but much more uniform only varying from 3.2 to 3.7 while the Prt+ varied from 1.9 to 4.8 hours. The make time could be shortened through addition of more cells. There would be advantages with these organisms where overcooking might occur. It is obvious that make time could be
shortened through using higher cooking temperatures and not sacrificing acid production. It may be necessary to use higher temperatures to stop acid production. If whey expulsion rates can be meshed then manufacturing can be significantly accelerated.

Strain UC 73 was used in simulated cottage cheese manufacture and the data summarized in Table 5.

Table 5. Comparative cottage cheese make times calculated from acid production rates of 2% Prt+ and 8% Prt- UC73 cultures in milk incubated 5 hours at different temperatures.

<table>
<thead>
<tr>
<th>Incubation Temp. (°C)</th>
<th>Make Time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prt+</td>
</tr>
<tr>
<td>32</td>
<td>4.0</td>
</tr>
<tr>
<td>34</td>
<td>5.0</td>
</tr>
<tr>
<td>36</td>
<td>7.0</td>
</tr>
<tr>
<td>38</td>
<td>7.9</td>
</tr>
<tr>
<td>40</td>
<td>18.3</td>
</tr>
<tr>
<td>42</td>
<td>42.3</td>
</tr>
<tr>
<td>44</td>
<td>550.0</td>
</tr>
</tbody>
</table>

Acid production rates were much more uniform for the Prt- cells over a wide range of temperatures. Since we do not need to wait for cells to grow as in conventional cottage cheese manufacture we could use more, cells, cook at higher temperatures and significantly shorten the process without worry about phage or antibiotic problems. Proper conditions need to be established to assure quality product.

CHEESE YIELD. Proteinase activity can only mean conversion of casein to a soluble form since milk soluble proteins are not attacked by these enzymes. Soluble casein would go out in the whey and would be
lost as cheese. Significant yield increases from milk solids have been reported in cottage cheese when external pH controlled cultures are used. This is probably partially due to the encouragement of Prt- cells in such medium through the use of available nitrogenous compounds. Geilman (MS Thesis, Utah State Univ., 1981) found that the highest milk solids yields were in direct acid cottage cheese, the poorest were when milk cultures were used and pH controlled whey-based cultures were in between. Milk culture was poorest because it necessarily produced high levels of Prt+ cells which dissolved casein both in the bulk culture and in the cheese milk. Ogden (J. Dairy Sci. Suppl. 1 64:53, 198) obtained a 2.8% greater yield of the milk solids in commercially manufactured cottage cheese with pH controlled whey-based culture than when milk culture was used.

If all the cells used in such cheese were Prt- then casein losses would have been minimized. The same would hold for Cheddar cheese. This might explain the claimed yield increases associated with the use of direct-to-the-vat set cultures. These cultures are grown under conditions which encourage Prt- cells. If a sufficient number of these are added to a cheese vat so that growth is discouraged, then no losses would be associated with bulk culture medium (since it is not used) and there would be less solubilization of casein in the cheese vat.

Dr. Kalab, this year's recipient of the American Dairy Science Association Pfizer Award in Cheese Research has demonstrated the effect of lactic proteinase activity in yogurt cultures. Large clear zones appear around both Streptococcus thermophilus and Lactobacillus bulgaricus indicating casein solution. If yogurt is made with heat inactivated lactobacilli then the growing streptococci demonstrate the normal clearing zone while the inactive lactobacilli are trapped in
undissolved casein gel. We are now evaluating the use of Prt- variants of these strains for use in Swiss and Italian cheese manufacture. Around *S. cremoris* cells used in cottage cheese manufacture such zones are evident. Yield improvement by using Prt- cells should be measureable and have economic impact.

CONCLUSION. There is building evidence to suggest advantages to the exclusive use of Prt- cultures in cheese manufacture instead of discarding them as we have in the past. They are now useable because we can produce higher numbers of cells in bulk tanks with pH control systems. Advantages for their use include: no problems with bacteriophage or antibiotics, more rapid cheese production through the use of higher cooking temperatures, greater yields of product because of less casein solubilization by the cultures, more uniform and controllable make conditions, less bitter flavor defects, and the potential for reconsidering the use of other organisms such as *S. durans*.

There are several studies underway to evaluate in depth the applications suggested. There has been several tons of normal Cheddar made commercially with these organisms. The cheese was not aged and current priorities include the collection of data on yields, curing and quality.

ACKNOWLEDGMENTS. We greatfully acknowledge the work of graduate assistants, Aly Gamay, Steve Wright, Ron Malouf, Jin-Moon Kim, Steve Winkel and post graduates Dr. Mohamed Shelaih and Dr. Raga Hafez. We also appreciate the financial support of the USU Dairy Research Advisory Board members and Dairy Research, Inc.
PREPARATION OF CHEESE AT ELEVATED TEMPERATURES

J. F. Flanagan

Eastern Regional Research Center
U.S. Department of Agriculture
Philadelphia, Pennsylvania 19118

Fifth Biennial Cheese Industry Conference
August 31 - September 1982
Logan, Utah
GROWTH AND ACID PRODUCTION OF *S. CREMORIS* ATCC 14365 AFTER HEAT TREATMENT
TEMPERATURE EFFECT ON MULTI-STRAIN STARTER CULTURE

![Graph showing the effect of temperature on Log\(10\) count and pH over time. The graph on the left shows an increase in Log\(10\) count with time at both 88°F and 100°F. The graph on the right shows a decrease in pH with time at both temperatures.](image-url)
INITIAL CELL COUNT AND PERFORMANCE OF STREPTOCOCCUS LACTIS

Log10 COUNT

TIME, HOURS

pH

TIME, HOURS

88°F

100°F

7.0

8.0

9.0

7.5

8.5

9.0

0 1 2 3 4 5

0 1 2 3 4 5

100°F

88°F
### Protocol of Cheese Preparation

<table>
<thead>
<tr>
<th>TIME (H)</th>
<th>STEP</th>
<th>TIME (H)</th>
<th>STEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1. CULTURE ADDITION</td>
<td>0</td>
<td>1. CULTURE ADDITION</td>
</tr>
<tr>
<td>1</td>
<td>2. RENNETING</td>
<td>0</td>
<td>2. RENNETING</td>
</tr>
<tr>
<td>1-1/2</td>
<td>3. CUTTING</td>
<td>1/2</td>
<td>3. CUTTING</td>
</tr>
<tr>
<td>2-1/2</td>
<td>4. COOKING AND HOLDING</td>
<td>1-1/2</td>
<td>4. HOLDING</td>
</tr>
<tr>
<td>2-3/4</td>
<td>5. PACKING</td>
<td>1-3/4</td>
<td>5. PACKING</td>
</tr>
<tr>
<td>3-1/4</td>
<td>6. PACKING + 30 MINUTES</td>
<td>2-1/4</td>
<td>6. PACKING + 30 MINUTES</td>
</tr>
<tr>
<td>5</td>
<td>7. MILLING</td>
<td>4</td>
<td>7. MILLING</td>
</tr>
</tbody>
</table>
EFFECT OF INITIAL COUNT AND TEMPERATURE ON STREPTOCOCCUS LACTIS

Graphs showing the effect of different temperatures (100°F and 88°F) on the log of the count and pH over time (0 to 6 hours).
## COMPOSITION OF CHEESES
### SIX TRIALS

<table>
<thead>
<tr>
<th>ANALYSIS (%)</th>
<th>CONTROL</th>
<th>EXPERIMENTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAT</td>
<td>33.6</td>
<td>33.1</td>
</tr>
<tr>
<td>FOB*</td>
<td>53.7</td>
<td>53.2</td>
</tr>
<tr>
<td>YIELD</td>
<td>9.2</td>
<td>9.2</td>
</tr>
<tr>
<td>MOISTURE</td>
<td>37.4</td>
<td>37.8</td>
</tr>
<tr>
<td>SALT</td>
<td>1.83</td>
<td>1.78</td>
</tr>
<tr>
<td>pH AT MILLING</td>
<td>5.56</td>
<td>5.58</td>
</tr>
<tr>
<td>pH AT 24 HR.</td>
<td>5.32</td>
<td>5.27</td>
</tr>
</tbody>
</table>

* FAT ON THE DRY BASIS.
OVERALL BODY SCORES FOR
6 TRIALS (ADSA SCORING SYSTEM)

<table>
<thead>
<tr>
<th>STORAGE TIME (MONTHS)</th>
<th>CONTROL</th>
<th>EXPERIMENTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>28.40</td>
<td>28.53</td>
</tr>
<tr>
<td>6</td>
<td>28.39</td>
<td>28.43</td>
</tr>
<tr>
<td>12</td>
<td>28.35</td>
<td>28.40</td>
</tr>
</tbody>
</table>
CURDY

CURDY MEAN SCALE

3 MONTHS 6 MONTHS 12 MONTHS

- - CONTROL - - EXPERIMENTAL
OVERALL FLAVOR SCORES FOR
6 TRIALS (ADSA SCORING SYSTEM)

<table>
<thead>
<tr>
<th>STORAGE TIME (MONTHS)</th>
<th>CONTROL</th>
<th>EXPERIMENTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>38.29</td>
<td>38.38</td>
</tr>
<tr>
<td>6</td>
<td>38.35</td>
<td>38.23</td>
</tr>
<tr>
<td>12</td>
<td>37.78</td>
<td>38.13</td>
</tr>
</tbody>
</table>
INITIAL CELL COUNT AND PERFORMANCE OF STREPTOCOCCUS CREMORIS DURING CHEESE MAKING

![Graph showing the initial cell count and performance of Streptococcus cremoris during cheese making. The graph includes plots for different temperatures (88°F, 100°F) and pH levels, illustrating the cell count over time.](image-url)
COMPARISON OF TEMPERATURE ON CFU AND pH IN HIGH TEMPERATURE CHEESE MAKING

- Log CFU Count vs. Time (hours)
- pH vs. Time (hours)

- Temperature: 100°F (38°C)
- Temperature: 102°F (39°C)
NEED FOR STANDARDS FOR CULTURE TANKS AND CULTURE CONTROL EQUIPMENT

Gary H. Richardson

Fifth Biennial Cheese Industry Conference  
Utah State University  
31 August 1892
Lactic cultures used to inoculate milk for the production of fermented dairy products are universally produced in steel processing tanks with capacities up to around 1,000 gallons. Cheese plants using pH controlled production of lactic culture can use fewer and smaller tanks. The tanks provide an environment where lactic cultures can grow to high numbers without inhibition or contamination. Fermentation technology has developed so that such protection can be assured. However, in our industry the principles are not consistently applied to bulk culture tanks. We see millions of dollars spent to protect culture rooms instead of tanks, we see large holes in tank tops, no filtration of air entering as a tank is cooled, lack of uniformity in the use of head space heating equipment and inoculation fittings that are not used or are not useable. No information is available on the relative merits of steam rings, fire rings or chlorine fogging treatments during inoculation of bulk tanks and some have concluded these steps are not needed. In spite of the progress in fermentation equipment, it is still possible, and relatively easy, to get one bacteriophage (phage) particle into a lactic bulk culture—and that is all it takes with some homologous cultures!

Tank construction in other cheese making countries around the world frequently provides superior protection yet they do not have uniformity either. I desire to explore this with you and discuss some of the possibilities for use of improved tanks and culture inoculation techniques.

For over twenty years our industry has emphasized development of numerous phage-inhibitory-media over improving bulk culture equipment
and handling techniques. Stimulatory media provides a logical improvement in culture tank efficiency and produces maximum cell mass in the tank. This provides a definite advantage over much of the world's industry that still uses higher inoculation levels and less efficient cell mass production. But, the addition of phosphates or citrates in the levels required is counter productive to culture growth, counteracts the calcium chloride additions in milk and requires shipment and storage of large amounts of dry media. In fact, they are useless except as phage inhibitors in modern pH control systems. What is more astounding, their use presupposes one or more of the following problems:

1. Phage is present in mother culture.
2. Phage contamination from the environment will occur during inoculation of the tank.
3. Phage can get into the tank during cooling and incubation.

I desire to discuss the status of each of these concerns:

1. Defined strain culture technology, as advocated by Oregon State University researchers and described by Dr. Thunell earlier, eliminates the phage-in-mother culture problem. The defined strain culture program at Utah State similarly controls the first problem and uses only two strains in one pair. Over 3,000 consecutive vats of Cheddar and Monterey cheese have been made in two cheese plants during the past three months with no rotation and no acid control problems. The same economies mentioned by Dr. Thunell have been observed with the simpler two-strain program. The New Zealand culture industry. They recently applied paired strain technology for over 40 years. They applied one
pair program at the Table Cape plant in Tasmania, Australia two years ago. This plant converts 700,000 lbs into cheese daily and has operated with strains 584 and 134 for two years "without a hiccup" (Personal Communication, Howard Heap, 2 August 1982). Two of the largest New Zealand plants, with over 1.2 millions lbs of milk per day, have produced the highest percentages of finest grade cheese to date. Most plants will be on this program next year. Australian industry leaders confirm that it is now possible to avoid phage in the culture inoculum by using single strains or triplets.

2. Contamination by phage or unwanted bacteria during bulk tank inoculation has been prevented in various ways. We generally chlorinate an easy-open container, our hands, the environment and then transfer a partially thawed plug of bulk inoculum through an environment of unknown contamination. Steam or fire rings are on some tanks but are not conducive to such handling techniques. One manufacturer of aseptic transfer equipment likened our techniques to, "Making our doctor's examination areas into 'clean' rooms and then chlorine fogging the entire rooms, patient and doctor before administering a penicillin shot!" When the patient is "closed" only an antiseptic wash and sterile needle/syringe system is needed. It is only in operating rooms where patients are "open" that we need face masks, sterile gloves, clothing and clean room conditions. Too often our tanks are "open" thus creating the need for extreme sanitation measures. These measures are not unique to our country. Walker, Mullan and Muir in a review of culture handling techniques in the United Kingdom (J. Soc. Dairy Technol. 34:78, 1981) recently concluded, "...in spite of the technological advances in the
design of bulk starter vessels and the improvement in inoculation techniques there is a serious omission in facilities for inoculating frozen concentrated cultures. Of the 52% of factories using frozen concentrates, the majority relied upon hypochlorite aerosol fogging, while some protected the inoculation port with cloths soaked in hypochlorite; some added the concentrate through the open lid and some took no precautions at all." Some protective steps were combined and one plant used formaldehyde generation for protection!

A double needle Astell system has been in use for many years in Great Britain and Ireland. Sterile needles are attached to a small stainless steel valve. One needle punctures a rubber septum into the inoculum bottle and the second needle punctures a septum into the intermediate or bulk tank. The culture is then "milked" from the polyethylene inoculating bottle into the awaiting substrate.

In Ireland one to three gallons of intermediate culture are prepared in stainless steel tanks with long one-inch diameter necks. The top of the neck is covered with a rubber septum. An inoculation port on the tank top is fitted with a puncturing device and chlorine cup. Ripened culture is transferred by inverting the intermediate tank, rupturing the septum over the puncturing device and allowing culture to flow through into the bulk tank.

At the recent ADSA Meetings in Pennsylvania, Dr. Stadhouders from the Netherlands Institute for Dairy Research was awarded the Miles/Marschall International Award. In his invitational lecture he described the inoculation techniques that assure contaminant-free lactic cultures and he provided me the diagram describing inoculation port
design. A specially fabricated chamber is mounted atop the bulk tank and steamed before each inoculation. Culture containers, resembling yogurt cups, are placed upside down in the chamber. When the frozen culture is adequately thawed the handle at the top is pushed, the containers are punctured to allow drainage into the vat and a separate puncture allows air to replace the draining inoculum.

In New Zealand all bulk inocula are propagated in pH controlled medium at the Dairy Research Institute. No mechanical concentration is necessary. Howard Heap and colleagues have been provided a separate laboratory with adequate facilities to prepare 20 liter batches of each strain. After propagation the cultures are blended, packaged in 75 ml containers for 300 gallon tanks and in 150 ml containers for 600 gallon tanks. The cultures are frozen and stored at -40C. Special dry-ice packed containers are used to ship cultures to all plants. Each plant is provided an economical -40C freezer. The specially designed culture containers have shoulders that exactly fit over the inoculation port on the culture tank. The containers are chlorinated rapidly, clasped by special tongs, opened with a special opener and inverted over the inoculation port through a steam or fire ring. When in position the tongs are released and the frozen plug of culture is released into the tank. The tank is agitated until complete melting of the plug is assured. Since pH control of the bulk culture is not practiced, agitation is then ceased.

These are several techniques used in the critical step of bulk culture inoculation. I am sure you can see their advantages. There are excellent principles here to assure contaminant-free inoculation.
A representative of Becton-Dickinson suggested that a better approach would be to use an aseptic disposable needle/syringe system. My first reaction was that they would not be big enough. However, where pH controlled cultures allow more efficient growth of lactic cultures, and where we don't need to "turn over" a tank every 16 to 18 hours, this becomes an attractive possibility. If a small disposable rubber septum were installed through a small hole in the inoculation cap of the bulk tank, culture could be injected through a sterile needle from a sterile syringe and there would be no need for hazardous chlorine washes, sprays or steam ring rituals. If a sleeved septum was used a small cup for chlorine treatment would provide adequate protection. It would be better than sprinkling powders or pouring thawing concentrates through contaminated air and would give culture suppliers better protection for their seed cultures.

I would like to divert here to discuss briefly the numbers of lactic cells needed to produce a normal bulk culture. If you recall my previous paper discussion let us assume that we need a bulk culture with log 10 colony forming units per milliliter (cfu/ml). This would be a normal pH controlled culture. If you wanted this number in a certain time after inoculating a 600 gallon tank of substrate, we could determine the size of inoculum required if we knew the generation time of the strains. The pair we now use has a generation time of 1.1 hours. If we need the culture after 18 hours of incubation then a log 5 cfu/ml would be required initially. This could be provided by only 22.7 ml of unconcentrated log 10 culture! This suggests that we are overinoculating in most cases and not allowing bulk culture tanks to be
used at maximum efficiency. For example, we traditionally add 70 ml frozen concentrate into 300 gallon tanks. If these are ten fold concentrates (log 11) then we only have 9.1 generations and the culture is ready in 10 hours. If they are 100 fold concentrates (log 12) then only 5.8 generations are involved and the culture is ready 6.3 hours. The use of low inoculum levels are consistent with those used in New Zealand where 150 mls of unconcentrated culture inoculate 600 gallons of milk culture. Only 10 generations are required there. In the 22.7 ml example I cited we would have 16.7 generations in 18.3 hours and also have more cells per milliliter. Even if the bulk inocula were thawed out or provided as fresh cultures and severe losses occurred, manageable increases in incubation times would be required. For example, if 90% of the cells were inactive upon inoculation, the culture would be ready in 21.9 hours and if 99% were inactive, the culture would be ready in 25.6 hours.

We feel that the syringe approach to inoculation is overdue and that even smaller units can be used where tanks do not have to be ready in the traditional 18 hour incubation period. These approaches suggest methods to solve problem number two, that of infection during inoculation or handling of mother and intermediate cultures.

3. The third source of phage related to the contamination associated with the design and operation of the bulk tanks.

I requested that the 3A Sanitary Standards committee consider establishing standards for bulk culture tanks. There are good fabrication standards for dairy process tanks however, they are
inadequate to cover the types of problems indicated at the beginning of this talk. For example, the standard for the agitator opening in batch processors for milk products dated 1964 reads, "...will provide a 1-inch minimum annular cleaning space between the agitator shaft and the inside surface of the flanged opening on processors...A shield that can be raised or dismantled, to permit the cleaning of all its surfaces, shall be provided to protect against the entrance of dust, oil, insects and other contaminants into the processor through the annular space around the agitator shaft." Phage is not on that list and we must do more than protect against; we need to refuse admittance.

Interest has been shown by one tank manufacturer for consideration of such standards. Another expressed that he was aware that we and Dr. Sandine at Oregon State University were developing suggested standards for such vessels and looked forward to our recommendations! A third respondent to our recent survey indicated our suggestions would be considered in fabrication of future bulk tanks.

Earlier this year I wrote to seventeen manufacturers in the USA that were listed for fabrication of bulk culture tanks. Ten did not fabricate dairy processors, two only designed what they were asked into a culture tank and five provided bulk culture tank designs and features. It was of concern that cheese makers must specify their needs to some fabricators since most of us cannot be expected to know the types of protection that are best nor can all processor salesmen. For example, when we ordered a processor we specified that it was to be for lactic culture and requested a "culture kit". The tank was equipped well and included a space heater, pH control port, sealed manhole and steam
inoculation ring. However, with a large hole in the top around the agitator shaft in an atmospheric processor, all of those protective features were of moot value. The probability of phage contamination must be reduced to the absolute minimum by using only pressure/vacuum processors. Tanks in the Netherlands are equipped with filtered sterile air pressure to assure that any contamination would be from the inside out. We have many tanks equipped with such systems in this country however many are turned off or disconnected!

In New Zealand tanks are provided with water seals and positive air pressure that can be easily monitored because the floating lids of the culture tanks are proof that the 2-3 psi system is operational. The lids drop when the rubber bung is removed and the tank is inoculated. The outrush of air prevents contamination. The air is filtered through cotton and passes through a steam heated chamber before passage into the tank. Positive pressure is maintained throughout incubation. Contamination does not occur even when tanks are installed right next to whey separators!

Dr. Sandine and coworkers (Appl. Microbiol. 14:497, 1966) conducted laboratory studies to confirm the ability of a small fiber glass filter chamber and air pressure system to significantly reduce the phage in an air supply. Use of such protection is warranted because from one to five cubic feet of air is sucked into a culture tank during cooling.

Effective filters are available. There does not need to be a positive pressure system involved. For example, if a tank can be properly sealed so that any air sucked in during cooling would be required to pass through a micropore filter, the filter would remain
effective longer since only a few cubic feet would pass through it daily instead of a continual flow of air. These units can have pore sizes down to 0.2 microns and are autoclavable. They can be attached to the tank through a diaphram valve. If the valve is closed and the tank is vented during filling and heat treatment there is minimal filter back flow. The valve can then be opened as the tank starts to cool and all incoming air would be contaminant free.

To solve the problems associated with the third source of phage we suggest that bulk culture tanks be standardized to include the following protective measures in addition to those currently specified for dairy processors:

1. Assure that only pressure-vacuum processors are used for lactic culture production and constructed to force any incoming air through a satisfactory filter system. (Pressure vacuum processors are presently offered by all manufacturers)

2. Augment or replace inoculation port steam rings with simple rubber septum ports of such construction that proper heat treatment is assured during tank heat treatment. This would allow sterile needle/syringe inoculation with better protection during inoculation. (A septum inoculation port is presently offered by one manufacturer)

3. Install a micropore (.22 micron) filter into the tank headspace through which all incoming air must pass. (This feature is presently offered by three manufacturers).

For optimum protection these options, or their equivalents, must become standards whenever lactic cultures are produced. If such protection can be provided, and problems 1 and 2 are also solved, we can
get rid of phage-inhibitory-medium buffering agents and confidently place bulk tanks in any environment—even next to cheese vats or whey centrifuges. Savings in physical plant design and construction of culture rooms would be significant. Additionally a 500,000 lb per day plant would save from $18,500 to $74,000 annually on the cost of buffers and media tonnage to the plant and storage would be reduced from 3 to 18 tons per year. These savings would rapidly offset the added cost of the suggested tank modifications.

Tank pH and temperature controls are very reliable. Economical external pH control systems are available that can be paid for in a few weeks with the savings generated over other culture systems. Data from pH and temperature controllers can be used in microprocessors to establish times that bulk cultures are ready to use, automatically initiate cooling of the tank and pinpoint inoculum levels for cheese vats. Wells for pH and temperature sensors can be installed by manufacturers or added to existing tanks.

I wish to thank all who responded to our requests but particularly representatives of Cherry-Burrell, CREPACO, Inc., Dairy Service and Manufacturing, Inc., Damrow Company and DCI, Inc. for providing specifications and designs on current culture tanks.
Effect of culture media on cheese yield.\(^1\)

by C. L. Hicks, F. Marks, J. O'Leary and B. E. Langlois

The question of whether culture media affects cheese yield has often been asked. Since the cheese industry has many culture systems to choose from, the answer to this question would help management make decisions in selecting the best culture systems for an individual plant. To answer this question, data must determine the amount of solids from the culture media that ends up in the cheese mass and the effect that media buffers, heating and starter bacteria enzymes may have on milk protein solubility and the amount of milk solids that end up in the cheese mass. If yield differences exist between culture media, cheese plant managers would be able to choose a cost effective system of low risk for their operation.

**Media systems analyzed.**

Cheese yield from four culture media were compared to yields from direct to the vat set culture. Media examined were skim milk, enriched ammoniated whey, citrate base and phosphate base powdered premix. The citrate and phosphate medias contained approximately 11.5% sodium caseinate. Bulk cultures were prepared from each media and used to inoculate 6.8 kg of milk at a rate of 0.5, 1.0, 5.0 and 10.0 percent. Direct to the vat set cultures were added at a rate to equal the number of organisms present in skim milk bulk cultures. The use of several different inoculation concentrations allowed a comparison of yields between different media types.

\(^1\) The above paper was presented by Dr. C. L. Hicks, Associate Professor of Animal Science, Department of Animal Sciences, University of Kentucky, Lexington, Kentucky 40546, at the 1982 biennial Cheese Industry Conference at Utah State University, Logan, Sept. 1-2.
and the effects produced by bacterial enzymes and media buffers on protein solubility.

Cheese yield.

Direct to the vat set and enriched ammoniated whey base cultures were observed to produce greater yield than skimmilk or citrate base medias as shown in Table 1.

Table 1. Difference between media type at the 1% concentration of bulk culture added to the cheese vat.

<table>
<thead>
<tr>
<th>Media Type</th>
<th>Treatment (TRT) (Dry Matter)</th>
<th>Yield Kg/100 Kg Milk</th>
<th>Probility&gt;T,LS mean (I)=LS mean(J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skimmilk</td>
<td>TRT 1</td>
<td>6.53</td>
<td>-0.105, 0.509, 0.315, 0.004</td>
</tr>
<tr>
<td>Whey Base</td>
<td>TRT 2</td>
<td>6.63</td>
<td>0.488, -0.034, 0.538, 0.318</td>
</tr>
<tr>
<td>Citrate Base</td>
<td>TRT 3</td>
<td>6.50</td>
<td>0.469, -0.095, 0.004</td>
</tr>
<tr>
<td>Phosphate Base</td>
<td>TRT 4</td>
<td>6.59</td>
<td>0.482, -0.132</td>
</tr>
<tr>
<td>Direct to the vat set</td>
<td>TRT 5</td>
<td>6.71</td>
<td>1.100%</td>
</tr>
</tbody>
</table>

Penn State University workers (2) also recently suggested that direct to the vat cultures produce greater yields than phosphate bulk cultures. Data from Table I supports the Penn State observation although our data only indicated this difference as a trend. Cheese yield from direct to the vat sets showed no decrease in yield when the inoculum concentration was increased suggesting that maximum cheese solids were derived from the milk by this procedure.

Enriched ammoniated whey base culture was not significantly different in yield from direct to the vat set culture. However, at the higher inoculation levels (5.0 and 10.0%) tested, a decrease in cheese yield was observed suggesting a possible dilution effect on the milk solids by the low solids whey bulk culture.
Citrate and phosphate base media are both low buffered media which cause an increasing yield loss as higher concentrations are used. Although these media contain sodium caseinates, little if any is incorporated into the cheese mass. Apparently the polyvalent anions (citrate and phosphate) cause an increase in milk protein solubility causing the decrease in cheese yield. These data may indicate that the industry should be concerned about the cheese yields resulting from highly buffered media.

As skim milk bulk culture concentration increased, a trend for lower cheese yield was observed, suggesting that some protein degradation occurred in the skim milk during the incubation of the bulk culture. Calculations suggest that approximately 68% of the cheese solids in the skim milk bulk culture are lost in the whey. These results are comparable with those observed by Formost Foods (1) who suggested that 50 to 70% of the cheese solids are lost from skim milk bulk culture and those from Kansas State University (3).

Probable yield losses.

A range for cheese yield losses for each media type are presented in Table II.

Table II. Cost differential from yield due to media type at 1% bulk culture added to a 40,000 lb (18143 kg) set compared to direct to the vat set and enriched ammoniated whey base media.

<table>
<thead>
<tr>
<th>Media type</th>
<th>Yield/CWT lost (lbs)</th>
<th>Amt of curd (lbs) lost at 39% moisture from 40,000 lbs milk</th>
<th>Possible cost differential at $1.40/lb of cheese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skimmilk</td>
<td>.10-.18</td>
<td>66-118 lbs</td>
<td>$92-165</td>
</tr>
<tr>
<td>Whey base</td>
<td>0-.08</td>
<td>0-52</td>
<td>0-73</td>
</tr>
<tr>
<td>Citrate base</td>
<td>.13-.21</td>
<td>85-138</td>
<td>119-193</td>
</tr>
<tr>
<td>Phosphate base</td>
<td>.05-.13</td>
<td>32-85</td>
<td>45-119</td>
</tr>
</tbody>
</table>
These yield losses are calculated from mean differences between media types and direct to the vat and enriched ammoniated whey base cheese yields. The costs shown would be for the amount of yield lost at 39% moisture from 40,000 lbs (18143 kg) of milk, with cheese wholesaling for $1.40 per pound. Cheese plant cost for each media type, excluding labor, is shown in Table III.

Table III. Probable cost of culture systems including yield and culture cost to inoculate 40,000 lbs of milk.

<table>
<thead>
<tr>
<th>Media type</th>
<th>Cost due to yield differences (from Table II)</th>
<th>Cost of Media</th>
<th>Cost of Culture</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skimmilk</td>
<td>$92-165</td>
<td>$29^1</td>
<td>$5^3</td>
<td>$126-199</td>
</tr>
<tr>
<td>Whey base</td>
<td>0-73</td>
<td>8^1</td>
<td>3^3</td>
<td>11-84</td>
</tr>
<tr>
<td>Citrate base</td>
<td>119-193</td>
<td>40^2</td>
<td>5^3</td>
<td>164-238</td>
</tr>
<tr>
<td>Phosphate base</td>
<td>45-119</td>
<td>42^2</td>
<td>5^3</td>
<td>92-166</td>
</tr>
<tr>
<td>Direct to the vat set</td>
<td>0</td>
<td>0</td>
<td>52^3</td>
<td>52</td>
</tr>
</tbody>
</table>

^1Foremost Foods, Dublin, Ca.
^2Pfizer Inc., Milwaukee, Wi.
^3Marshall Div. of Miles, Madison, Wi.

Note that the figures are based on more than one make per day and are rounded off to the nearest dollar. Media costs were from current industrial figures. Although the cost figures are representative of the culture systems used in this experiment, they are not necessarily the most economical system available to industry. However, of the culture systems evaluated, the enriched ammoniated whey base and the direct to the vat set starters were the most economical systems for setting cheese milk and citrate base cultures the most costly.

Conclusion.

Enriched ammoniated whey base cultures and direct to the vat set cultures
were the most economical starter systems tested and produced cheese yields that were greater than those observed for citrate and skim milk media. Both citrate and phosphate media produced decreasing cheese yields per cwt. of milk as bulk starter concentration increased, suggesting that buffering anions cause lower yields. The data further suggests that highly buffered media may produce even lower cheese yields and that additional research is needed to analyze those types of media. The data also confirms the results of Foremost Foods (1) and Kansas State (3) suggesting that 68% of the cheese solids contained in skim milk bulk culture is lost in the whey.
References


Cheesemaking Procedures that Affect Yield

By

Norman F. Olson
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At the

Fifth Biennial Cheese Conference
Utah State University
Logan, Utah

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Yield of cheese is affected by a multitude of factors including milk composition, season of year, mastitis, feeding and herd management practices, and cheesemaking procedures. It is well-recognized that obvious abusive practices in handling curd reduces yields. Most cheesemakers remember, with dismay, the first and hopefully only time that they forgot to stop the agitator after adding the milk-clotting enzyme.

Less apparent variations in cheesemaking also can affect cheese yields. These became apparent to us in a research project in which we were evaluating an instrument to monitor curd firmness (27). Substantial differences were observed between curd firmness at the point of cutting in different cheese plants. Firmness levels in some plants were twice those measured in other plants. Some of the differences were intentional with cheesemakers claiming better yield with firm curd whereas others had the opposite viewpoint. Some of the variation was unintentional and resulted from milk temperature variations, inaccurate measuring of milk-clotting enzyme, and uneven distribution of enzyme in the vat. Close examination of milk during clotting indicated that substantial milk movement was still evident in some cases. This probably caused disruption of the milk gel and loss of yield.

The previous observations and the perceived need for standardizing the firmness of curd at cutting prompted the evaluation of a curd firmness measuring device designed by Vanderheiden in Australia (27). The device was used to evaluate the effects of curd firmness at cutting on cheese yield.

The strength of a milk gel at the time that it is cut during cheesemaking is considered to be important for maximum recovery of milk components in cheese. Electron micrographs of curd at cutting reveal that casein micelles aggregate to form a sponge-like network of cross-linked casein that trap fat globules and bacteria (21, 25). Undoubtedly, any milk constituent not contained in the casein network would probably be lost in whey and not included in yield of cheese. J.G. Davis (15) listed milk gel formation as one of the most crucial steps in cheesemaking since few measures during subsequent cheese manufacturing would rectify the consequences of incomplete milk coagulation.

Conventionally, many cheesemakers cut curd 30 min after adding the milk-clotting enzyme to conform to time requirements of factory schedules (28). This practice is questionable since many factors affecting curd firmness are not constant. Refrigerated storage significantly decreased curd-forming properties of milk to an extent that cutting had to be delayed to obtain normal curd strength (11, 37, 38). Breed of cow (41), method of standardization (8, 10), acidity (36), and heat treatment (16) influenced curd firmness. Seasonal variability in milk constituents such as calcium (2), casein (47), and inorganic salts (24) and ratio of fat to solids-not-fat (8) had a definite impact on gel strength of milk. Dilution of rennet with chlorinated tap water partially inactivated milk-clotting enzymes and caused variable curd firmness at cutting if available chlorine exceeded 1 ppm (30).

If curd firmness is assessed in commercial operations, it usually is done subjectively. Several objective methods and devices have been developed or adapted to measure curd firmness and detect the readiness of milk coagula for cutting (14, 42). These studies indicated that curd firmness affected properties of cheese. From results of a 3-year investigation, English researchers concluded that milk gel rigidity at cutting, firmness of Cheddar cheese and the percentage of moisture in nonfat portion of cheese were related (9). Experiments by Polish researchers demonstrated that more uniform cheese (Tilsit and Edam) composition was obtained when curd was cut at a constant, instrumentally-determined firmness as compared to cutting curd cut at...
rigidities determined subjectively (6, 18). Budny (7) reported a definite relationship between curd firmness at cutting and moisture content of Edam-type cheese. German workers used a thrombelastograph or lactodynamograph to establish optimum curd strength levels in manufacturing Edam and Camembert cheese (32, 42). Even when cheese milk composition was intentionally varied by addition of calcium chloride and caseinate, suitable cheese was obtained if the instrumentally-determined curd firmness was used as the indicator for cutting time (33). Baron measured curd rigidity with a plastic bowl apparatus and reported that gel strength at cutting produced Cheddar cheese of higher elasticity. This may have been related to moisture content of cheese since it was also observed that a firmer curd at cutting yielded a higher moisture level in cheese (4).

The present investigation was undertaken to determine the relationship between curd firmness at cutting and Cheddar cheese yield and recovery of fat and proteins of milk in cheese. Stirred-curd Cheddar cheese was made in the University of Wisconsin Dairy Plant and in a commercial pilot plant. Curd strengths at cutting evaluated in this study fell within a range of those used commercially and would have little or no effect on procedures and time schedules used in cheesemaking.

MATERIALS AND METHODS

Curd Firmness Measurement

Curd strength at cutting was determined with the curd firmness tester, designed by Vanderheiden, described by Kowalchyk and Olson (27). The instrument had a sensor component comprised of two capsules with flexible diaphragms that faced one another. One diaphragm oscillated to create pulses or slight compression waves that caused increased undulatory pressure changes in the pulse-receiving diaphragm as rigidity of the milk coagulum developed. A pressure transducer and recorder transformed the pressure changes into an electrical signal and a recorder trace that characterized coagulation of milk in the cheese vat. The sensor component of the apparatus was suspended in the center of the cheese vat so that the tops of the capsules were 4.75 inches below the milk surface (Figure 1). This allowed continuous firmness measurement without effects of surface cooling of milk or a cream layer that may accumulate on the surface of whole milk before cutting.

During cheesemaking trials, lactic acid bacteria were added and milk was ripened for approximately 1 hour before a milk-clotting enzyme was added uniformly to milk over the length of the vat followed by stirring for 5 min. Movement of milk was virtually stopped before the curd firmness sensor was placed in the milk. In the UW Dairy Plant study, curd was cut when the amplitude of the curd firmness trace was 44 units to represent a typical firmness (Treatment A) and at 60 units to assess effects of increased curd firmness (Treatment B). It normally required 30 min after enzyme addition to attain the 44 unit firmness and 45-47 min for 60 unit firmness. Since the milk supply used in the pilot plant study had less total protein, casein, and other constituents than found in the milk used in the UW study, the typical firmness (Treatment A) at cutting time was lower, 30 unit firmness, in the pilot-scale study. The higher curd firmness level (Treatment B) was maintained at 60 units since it required an average of 28.5 min to reach 30 unit firmness and 47 min to reach 60 units in the pilot plant study.

Cheesemaking

Whole milk was obtained from the mixed herd supply of the UW Dairy Plant for cheese manufacturing. The final weight of milk in the cheese vat was calculated from the volume and specific gravity as determined by milkfat content (43). Stirred-curd Cheddar cheese was made at various times from...
April to December, 1979, in a 5000 lb cheese vat. The cheese milk was pasteurized at 145°F for 30 min and held at 38°F overnight before manufacturing. The cheese manufacturing procedure was essentially as described by Price et al. (35) except that frozen lactic-culture-concentrate was added directly to milk in the vat and the desired point to cut the coagulum was determined by the curd firmness tester and not by an arbitrary time period. After pressing the cheese curd overnight at 15 psi, the 20 lb rectangular blocks of cheese were sampled and weighed.

Whole milk was standardized to 3.5% milkfat and pasteurized (161°F for 16 s) in a commercial pilot plant. Cheese vats of 1000 lb capacity were fitted on load cells which enabled direct measurement of the weight of milk and starter. The order of the treatment variable, two levels of curd firmness, was assigned by use of a random number table. Stirred-curd Cheddar cheese was made by essentially the procedure of Kosikowski (26). Lactic starter was added to the milk 1 hour before milk-clotting enzyme was introduced. Cheeses were made in four lots for 3 days over a week period in late May with the same starter strains. Some variation in the starter inoculum (0.7 - 1.5%) and the extent of time from cooking to draining of whey were necessary to keep moisture levels within normal limits. Salted curd was hooped to form 40 lb rectangular blocks that were pressed initially for 15 min under a 220 lb weight on each hoop, followed by pressing in a horizontal hydraulic press at 20 psi for 15 min and at 20 psi for approximately 15 hours. The cheese was weighed and sampled before wrapping.

**Sampling**

Milk was sampled, frozen and stored at -20°F until blended and analyzed (17, 29).

Procedures were used to obtain samples of cheese for analysis that were representative of the entire lot (39). In the UW Dairy Plant study, each 5000 lb lot or vat of milk yielded approximately twenty-five 20 lb blocks of Cheddar cheese that were pressed in a hydraulic horizontal press. Since moisture and other components were thought to be dependent upon the position of the cheese in the press, blocks numbered 1, 5, 10, 15, and 20 from the piston of the press were sampled before wrapping. Four plugs were drawn from each of the blocks. All cheese blocks from each lot were sampled after pressing in the pilot plant study.

**Compositional Analysis**

Cheese and milk were analyzed for fat by the Monjonnier modification of the Roese-Gottlieb method (19). Moisture of cheese was determined by drying 2-3 g of cheese in aluminum dishes in a forced-draft oven at 110°C for 16 h (34). Total nitrogen (TN), noncasein nitrogen (NCN), and nonprotein nitrogen (NPN) or 12% tricholoracetic acid (TCA) soluble nitrogen fractions were obtained from milk samples (1). Whey protein nitrogen was calculated as the difference between NCN and NPN; casein nitrogen (CN) was estimated as the difference between TN and NCN of milk. Total protein nitrogen (TPN) was estimated as the difference between TN and NPN of milk. Cheese samples were prepared and fractionated by the procedure of Vakaleris and Price (44) for subsequent analysis of total nitrogen, pH 4.4 soluble nitrogen (NCN), and 12% TCA soluble nitrogen (NPN). The automated, semi-micro Kjeldahl procedure using the Technicon Auto Analyzer II as described by Schafer and Olson (40) was used to determine concentrations of nitrogen in fractions of milk and cheese. Differences in composition and cheese yields were analyzed statistically (5).
RESULTS AND DISCUSSION

Composition of Cheese Milk

Average concentrations of milkfat and various nitrogenous components are shown in Table 1. There were no statistically significant differences in milk composition between treatments in both UW Dairy and commercial pilot plant studies. Seasonal variations in milkfat and casein nitrogen (CN) of milk used over the 9-month UW Dairy study exhibit the typical minimum concentrations during June to September. The trends for these two components generally correspond to patterns reported for milk analyzed in South Dakota in 1975 by Yee and Spurgeon (48). Calculating percentages (wt/wt) of casein by multiplying CN by the factor 6.51 (13), yielded estimated values of casein ranging between 2.60 to 2.89%. If the factor 6.38, was used casein concentrations ranged from 2.55 to 2.83%. Either calculation indicated that milk used in UW study contained slightly more casein than the reported mean values of 2.27% for New York milk in 1959-61 (22) and 2.31% for South Dakota milk (48). Seasonal trends in whey protein nitrogen and total protein generally approximated seasonal patterns reported for South Dakota milk (48). Whey protein concentrations increased gradually from April to December and total protein reflected the changes in casein concentration. The range of values of nonprotein nitrogen (NPN), expressed as percent of total nitrogen (TN), was 5.57 to 6.72% which was below previously reported values for control milks from this same milk supply (12) and suggested that little or no proteolysis of milk protein by psychrotrophic bacteria occurred before cheesemaking. Casein (CN x 6.51) to fat ratios ranged between .70 to .86 with the mean and standard deviation for all milks in the UW study being .76 ± .04 which was higher than ratios reported in the South Dakota study (48). One milk sample, used to form curd of increased rigidity, had a low fat content and an abnormally high casein to fat ratio of .86. Eliminating this sample narrowed the range to .70 to .78. The ratios were generally higher for samples cut at higher rigidities but the mean ratios were not significantly different. Average percent CN of TPN (excluding NPN) for all milk was 82.42 ± .89%. The proportion of casein was slightly lower during the summer months.

Milkfat content of milk used in pilot plant trials ranged from 3.15 to 3.58%. The ratio of CN to TPN (excluding NPN) was 79.72 ± 2.06% (mean ± S.D.) and the casein (CN x 6.51) content of milk ranged from 2.16 to 2.55% with an average of 2.39 ± 0.20. These values are more similar to casein concentrations found in milk supplies of South Dakota (48) and of New York (22). Ratios of casein to fat ranged from .62 to .73 with an average of .69 ± .06. Average NPN content of milk, expressed as percent of TN was 6.61 which indicated that the cheese milk was of good quality.

Concentrations of milkfat, CN and TPN and the casein/fat ratios, were significantly higher in milk used in the UW study than milk used in pilot plant trials. These could be attributed to the milk used in the pilot-scale study being standardized to 3.5% milkfat (Babcock) and being produced in late May when these milk constituents were generally at a seasonal low. Also, the differences could be ascribed to regional differences such as specific breeds of dairy cattle in herds, soil, pasture, and various types of dairying practices used in each of the two areas.

Cheese Composition

Compositions of fresh Cheddar cheeses produced in both UW and pilot-scale studies are compared in Table 2. There were no statistically significant differences among the mean concentrations of cheese constituents between treatments (curd firmness) in either study. Moisture in the non-fat portion
(MNFP) was greater in lots of cheeses made at UW than the suggested optimum range of 52-54% for Cheddar cheese (31). The percentages of fat, moisture, FDM, and MNFP in cheese made in the UW Dairy were virtually identical for the two treatments except for higher fat contents of two lots cut at the higher curd rigidity. As expected, the moisture contents of these two cheeses were lower. Percentages of moisture and MNFP were lower in all cheeses made during the summer. This could not be attributed to lower protein concentrations in cheese since FDM was lower and total protein in cheese was the same or slightly higher during this period. Moisture content and MNFP were not affected by differences in curd rigidity at cutting. Apparently subsequent treatments of curd during manufacturing offset any effects of curd rigidity.

Recovery of Milk Constituents and Yield of Cheddar Cheese

Efficiency of transforming milk into cheese is dependent largely upon recovery of milkfat and casein in cheese. Comparisons of means of cheese yield per pound of fat and per 100 pounds of milk, and recovery of various milk constituents between treatment levels are made in Table 3. Milkfat recovery in stirred-curd Cheddar cheese made in the UW Dairy was less in lots of cheese made with typical curd firmness (Treatment A) than in cheeses made with increased gel strength at time of cutting (Treatment B). The difference was statistically significant and was consistent throughout the study as shown in Figure 2. The observed ranges of milkfat recovery in cheese generally correspond to reported ranges of 86.49 to 94.32% reported by Van Slyke and Price (46) and 83.8 to 87.2% found by Barbano and Sherbon (3). There was a statistically significant increase in recovery of milk CN in Cheddar cheese when cheese was made with increased firmness at cutting as shown in Table 3. Recovery of casein was greater throughout the season for cheese made with greater curd rigidity with the exception of lots made in March (Figure 3). Recovery of TPN was lower but still within the range of 73.7 to 80.8% reported by Van Slyke and Price (46).

Yields were standardized for variations in moisture content of cheese by adjustment of cheese weights for a mean moisture content of 37.33%. When yield was gauged by amount of cheese produced per unit of milkfat, a statistically significant difference was found between treatments (Table 3, Figure 4). Seasonal trends of cheese yield per 100 pounds of milk shown in Figure 4 closely approximated seasonal patterns of cheese yield found in two South Dakota cheese plants (48). Lots of cheese made with Treatment B had a slightly greater mean yield of cheese per 100 pounds milk than cheeses made with Treatment A as indicated in Table 3 but the difference was not statistically significant. The discrepancy between this lack of difference and the statistically significant difference when yield was based on fat recovery probably resulted from the slightly greater milkfat content of milk used in Treatment A milk throughout the year which compensated for the greater fat losses with Treatment A.

Mean values for recovery of milkfat in cheese in pilot plant trials were close to that found in New York cheese plants where milkfat recovery averaged 83.8 to 87.2 (3). Yield figures were adjusted for the mean moisture content of 35.84%, which along with lower milkfat and casein concentrations, resulted in lower yield of cheese per 100 pounds of milk as compared to the UW study. There were almost identical cheese yields per unit of milkfat and yield of cheese per 100 pounds of milk for both treatments in the pilot plant study and there were no significant differences in recovery of milk constituents between treatments.

It is difficult to explain the significantly higher yield of cheese per unit of milkfat and recovery of milkfat and casein in cheese made with greater...
curd firmness in the UW study whereas no differences were observed in the pilot-scale study. Milk used in the UW study contained more casein, milkfat and TPN than milk used in pilot trials. The pilot plant study was conducted in May which has been classified by Irvine as the least efficient period to produce Cheddar cheese because of low fat and casein contents of milk (23). Also this traditionally has been a period of reduced cheese yield as reported in South Dakota plants (48). It is likely that conducting the pilot trials in May, associated with depressed yields, created factors that masked any potential influence of curd firmness at cutting on yield and recovery of milk constituents. Different cheesemaking procedures were used in UW trials than those used in the pilot-scale study but these would not seem to affect yields.

Results of the present study agree with those in some previous reports but differ from others. Van Slyke (45) concluded that curd strength at cutting time had no effect on yield or composition of Cheddar cheese. That study must be interpreted cautiously since curd firmness at cutting was not held constant throughout the study but allowed to fluctuate widely. Fisk (20) evaluated extreme differences in curd strength at cutting and reported that cutting soft curd resulted in greater loss of fat in whey, reduced yield of cheese per unit of milk, and decreased moisture content in the finished cheese as compared to cutting curd that was hard. He did not correct yields for moisture content and when the yields were corrected to a mean moisture level of 35.6% the difference in yield was minimal. Data from the present study do not support a correlation between curd firmness at cutting time and moisture in Cheddar cheese but differences in curd firmness were smaller in our trials than used in some of the previous work.

Results of this study have demonstrated that variation in curd firmness at cutting may result in greater losses of milk components and reduced cheese yield. The magnitude of differences in curd firmness evaluated was not great and could occur within a single cheese plant. Much greater differences in curd firmness at cutting have been observed by Kowalchyk and Olson (unpublished results, 1978) between different plants making the same variety of cheese. This suggests that monitoring curd firmness offers the potential for reducing losses of cheese yield. It should be emphasized that the correlation between a firmer curd at cutting and greater yield may not be true under all conditions and with different mechanical cutting systems. Undoubtedly a consistent firmness is critical for optimum cheese manufacturing.

ACKNOWLEDGEMENTS

Research was supported by the College of Agricultural and Life Sciences, University of Wisconsin-Madison and by funds from the Marschall Division, Miles Laboratories, Madison, Wisconsin and the Walter V. Price Cheese Research Institute.
REFERENCES


Table 1. Concentrations of constituents in milk (mean and standard deviations).

<table>
<thead>
<tr>
<th>Study</th>
<th>Constituents</th>
<th>Typical firmness</th>
<th>Increased firmness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(Treatment A)</td>
<td>(Treatment B)</td>
</tr>
<tr>
<td>UW Dairy Plant</td>
<td>Milkfat (wt/wt %)</td>
<td>3.75 ± 0.10</td>
<td>3.61 ± 0.21</td>
</tr>
<tr>
<td></td>
<td>Total protein nitrogen (mg/ml)</td>
<td>5.33 ± 0.13</td>
<td>5.38 ± 0.22</td>
</tr>
<tr>
<td></td>
<td>Casein nitrogen (mg/ml)</td>
<td>4.42 ± 0.14</td>
<td>4.41 ± 0.19</td>
</tr>
<tr>
<td></td>
<td>Whey protein nitrogen (mg/ml)</td>
<td>0.91 ± 0.05</td>
<td>0.96 ± 0.06</td>
</tr>
<tr>
<td>Pilot-scale</td>
<td>Milkfat (wt/wt %)</td>
<td>3.46 ± 0.07</td>
<td>3.34 ± 0.15</td>
</tr>
<tr>
<td></td>
<td>Total protein nitrogen (mg/ml)</td>
<td>4.76 ± 0.29</td>
<td>4.67 ± 0.31</td>
</tr>
<tr>
<td></td>
<td>Casein nitrogen (mg/ml)</td>
<td>3.80 ± 0.29</td>
<td>3.72 ± 0.35</td>
</tr>
<tr>
<td></td>
<td>Whey protein nitrogen (mg/ml)</td>
<td>0.96 ± 0.05</td>
<td>0.95 ± 0.05</td>
</tr>
</tbody>
</table>

aFor UW Dairy study, 44 unit firmness was typical firmness and for pilot study, 30 unit firmness was typical.
b60 unit firmness was the increased firmness level for both studies.
cFor UW Dairy study, means of five trials are shown and for pilot study, means of six trials are shown.
dMeans of six trials are shown for both studies.
eExcludes nonprotein nitrogen.
Table 2. Concentrations of constituents in fresh Cheddar cheese (means and standard deviations).

<table>
<thead>
<tr>
<th>Study</th>
<th>Constituents</th>
<th>Typical firmness&lt;sup&gt;ac&lt;/sup&gt; (Treatment A)</th>
<th>Increased firmness&lt;sup&gt;bd&lt;/sup&gt; (Treatment B)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UW Dairy Plant</strong></td>
<td>Fat (wt/wt %)</td>
<td>32.98 ± 0.83</td>
<td>33.45 ± 1.05</td>
</tr>
<tr>
<td></td>
<td>Moisture (wt/wt %)</td>
<td>37.45 ± 1.22</td>
<td>37.24 ± 1.16</td>
</tr>
<tr>
<td></td>
<td>Fat-in-the-dry matter (wt/wt %)</td>
<td>52.72 ± 0.85</td>
<td>53.30 ± 1.17</td>
</tr>
<tr>
<td></td>
<td>Moisture-in-nonfat substance (wt/wt %)</td>
<td>55.87 ± 1.37</td>
<td>55.95 ± 1.25</td>
</tr>
<tr>
<td></td>
<td>Total protein nitrogen (mg/g)&lt;sup&gt;e&lt;/sup&gt;</td>
<td>38.11 ± 0.88</td>
<td>39.20 ± 2.07</td>
</tr>
<tr>
<td></td>
<td>pH 4.4 soluble nitrogen (mg/g)</td>
<td>2.57 ± 0.29</td>
<td>2.81 ± 0.36</td>
</tr>
<tr>
<td></td>
<td>12% trichloroacetic acid soluble nitrogen (mg/g)</td>
<td>1.57 ± 0.17</td>
<td>1.67 ± 0.27</td>
</tr>
<tr>
<td><strong>Pilot-scale</strong></td>
<td>Fat (wt/wt %)</td>
<td>33.50 ± 0.80</td>
<td>33.41 ± 0.64</td>
</tr>
<tr>
<td></td>
<td>Moisture (wt/wt %)</td>
<td>35.92 ± 0.83</td>
<td>35.76 ± 1.07</td>
</tr>
<tr>
<td></td>
<td>Fat-in-the-dry matter (wt/wt %)</td>
<td>52.28 ± 1.35</td>
<td>52.10 ± 1.15</td>
</tr>
<tr>
<td></td>
<td>Moisture-in-nonfat substance (wt/wt %)</td>
<td>54.02 ± 1.34</td>
<td>53.72 ± 1.47</td>
</tr>
<tr>
<td></td>
<td>Total protein nitrogen (mg/g)&lt;sup&gt;e&lt;/sup&gt;</td>
<td>40.02 ± 0.40</td>
<td>38.66 ± 3.58</td>
</tr>
<tr>
<td></td>
<td>pH 4.4 soluble nitrogen (mg/g)</td>
<td>2.92 ± 0.27</td>
<td>2.86 ± 0.25</td>
</tr>
<tr>
<td></td>
<td>12% trichloroacetic acid soluble nitrogen (mg/g)</td>
<td>1.47 ± 0.10</td>
<td>1.53 ± 0.05</td>
</tr>
</tbody>
</table>

<sup>a</sup>For the UW study, 44 unit firmness was typical firmness and for pilot study, 30 unit firmness was typical.

<sup>b</sup>60 unit firmness was the increased firmness level for both studies.

<sup>c</sup>For UW study, means of five trials are shown and for pilot study, means of six trials are shown.

<sup>d</sup>Means of six trials are shown for both studies.

<sup>e</sup>Excludes nonprotein nitrogen.
Table 3. Yield and recovery of milk components in Cheddar cheese.

<table>
<thead>
<tr>
<th>Study</th>
<th>Yield or Recovery</th>
<th>Typical firmness (^a) (Treatment A)</th>
<th>Increased firmness (^a) (Treatment B)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UW Dairy Plant</strong></td>
<td>Cheese yield lb/100 lb milk(^b)</td>
<td>9.94 ± 0.35</td>
<td>9.97 ± 0.39</td>
</tr>
<tr>
<td></td>
<td>Cheese yield lb/lb milkfat(^b)</td>
<td>*2.64 ± 0.05</td>
<td>*2.77 ± 0.06</td>
</tr>
<tr>
<td></td>
<td>Milkfat recovery (wt/wt %)(^d)</td>
<td>*87.49 ± 2.70</td>
<td>*92.40 ± 1.24</td>
</tr>
<tr>
<td></td>
<td>Casein N recovery (wt/wt %)(^e)</td>
<td>*88.62 ± 2.34</td>
<td>*91.34 ± 1.19</td>
</tr>
<tr>
<td></td>
<td>Total protein N recovery (wt/wt %)(^f)</td>
<td>73.41 ± 2.65</td>
<td>74.96 ± 0.82</td>
</tr>
<tr>
<td><strong>Pilot-scale</strong></td>
<td>Cheese yield lb/100 lb milk(^c)</td>
<td>9.07 ± 0.06</td>
<td>8.98 ± 0.27</td>
</tr>
<tr>
<td></td>
<td>Cheese yield lb/lb milkfat(^c)</td>
<td>2.62 ± 0.06</td>
<td>2.62 ± 0.09</td>
</tr>
<tr>
<td></td>
<td>Milkfat recovery (wt/wt %)(^d)</td>
<td>87.92 ± 4.01</td>
<td>87.54 ± 2.92</td>
</tr>
<tr>
<td></td>
<td>Casein N recovery (wt/wt %)(^e)</td>
<td>98.59 ± 9.58</td>
<td>96.26 ± 13.54</td>
</tr>
<tr>
<td></td>
<td>Total protein N recovery (wt/wt %)(^f)</td>
<td>78.62 ± 6.09</td>
<td>76.26 ± 8.28</td>
</tr>
</tbody>
</table>

*Statistically significant (P < 0.05) difference between treatments.

\(^a\)Level of curd firmness at cutting time and number of trials are the same as those in Tables 1 and 2.

\(^b\)Adjusted for the mean of moisture values for all cheese in UW study (37.33 ± 1.13%).

\(^c\)Adjusted for the mean of moisture values for all cheese in pilot study (35.84 ± 0.92%).

\(^d\)Total lb of fat in cheese/total lb of milkfat.

\(^e\)lb total protein nitrogen (excludes NPN) in cheese/lb casein nitrogen in milk.

\(^f\)lb total protein nitrogen (excludes NPN) in cheese/lb total protein nitrogen (excludes NPN) in milk.
FIGURE LEGEND

Figure 1. Position of curd firmness sensor in the vat adjacent to stirrer paddle to simulate depth of immersion in milk.

Figure 2. Seasonal changes of milkfat recovery in cheese, kg fat in cheese/kg milkfat in milk, in 11 lots of cheese manufactured in UW Dairy.
Legend: ● = Treatment A, cheese made with typical curd firmness at cutting.
△ = Treatment B, cheese made with increased curd firmness at cutting.

Figure 3. Seasonal variation in percentage recovery of milk casein in cheese, kg cheese total protein nitrogen/kg milk casein nitrogen, in 11 lots of cheese produced in UW Dairy.
Legend: ● = Treatment A, cheese made with typical curd firmness at cutting.
△ = Treatment B, cheese made with increased curd firmness at cutting.

Figure 4. Seasonal variation of yield of cheese expressed as kg/kg milkfat and kg/100 kg milk in 11 lots of cheese manufactured in UW Dairy.
Legend: ● = Treatment A, cheese made with typical curd firmness at cutting.
△ = Treatment B, cheese made with increased curd firmness at cutting.
FIGURE 2

% MILKFAT RECOVERY IN CHEESE

JULIAN CALENDAR

20 60 100 140 180 220 260 300 340 365

FEB  APR  JUN  AUG  OCT  DEC
"EFFECT OF MILK CLOTTING ENZYMES ON CHEESE YIELD"

Presented at:
CHEESE INDUSTRY CONFERENCE
UTAH STATE UNIVERSITY
LOGAN, UTAH

September 1, 1982

by
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MILWAUKEE, WISCONSIN
"EFFECT OF MILK CLOTTING ENZYMES ON CHEESE YIELD"

Robert L. Sellars, Ph.D
Chr. Hansen's Laboratory, Inc.

INTRODUCTION

Accurate measurement and analytical/statistical evaluation of results obtained in a study of "cheese yield" is difficult regardless of the amount of milk/cheese involved, or the type and size of equipment, and/or the type of cheese manufactured. On one hand, weights and measures may be more accurate when the study involves small volumes and equipment, etc., while on the other hand, the ability to see differences of significance at the second and third decimals is not possible because of the minute interactions occurring in the manufacture of a piece of cheese. Only with sufficient volumes of milk set and manufactured into the cheese of choice will one be able to determine, with some degree of accuracy, the comparative effect of a specific ingredient, such as a "milk clotting enzyme"; or, a significant change in equipment or make procedure.

In today's business of manufacturing a product such as cheese, the maximum recovery or retention of the total solids used in the beginning versus the total solids remaining is so critical and most important to profitability. Decimal differences in the percent yield when accurately measured become more meaningful when large volumes of milk are processed.

There are a number of factors which influence the "recovery of solids" in the manufacture of cheese. One of the more influential factors is the "milk clotting enzyme" (coagulant) used and how it is used in the process.

Today, I will discuss the various types of "coagulants", their source, their overall function and factors which affect their optimal results, followed with the results of a large commercial study conducted under the most ideal conditions in order to obtain the highest degree of accuracy in the results.

Since most of you are primarily engaged or associated professionally in the manufacture of cheeses, I have chosen to discuss the "milk clotting enzymes" (coagulants) and their effect on cheese yield from the standpoint of their inclusion in various "coagulant preparations". I also want to discuss their total effect on yield, rather than to present the "pure chemical" approach such as their specific chemical or biochemical reaction on casein. This latter approach would involve some discussion of complex chemical reactions and their interrelationships on yield. References to some of these reactions will be made, however, since some of them are important in understanding why and how different coagulants (milk clotting enzymes) cause differences in the percent yield by maximization of solids retained.

MILK CLOTTING ENZYMES

WHAT ARE THEY?

Many biological reactions are not possible without the aid of specific biochemical reactions involving specific enzymes. Enzymes are proteins, put together in different sizes, shapes and are called catalysts. A catalyst is something that enters into or causes a reaction without being
altered in any way. It is neither transformed, changed or consumed in
these reactions. It simply remains as is -- available to continue its
activity so long as there is sufficient substrate or molecules in a
specific form (confirmation) for the enzymes to react with or on.

The commercial coagulants used for "setting" cheese milk contain a
variety of enzymes with special desirable properties and qualities that
is needed to manufacture quality cheese with reasonable economics. How­
ever, these coagulants, with their individualistic "milk clotting enzymes",
behave and react differently; enough so on a micro-scale that even when
compared under uniform/standardized conditions cause reactions that result
in differences in measurable and recoverable solids in the final product.
Why? How is this possible? And, how can one control the myriad of
conditions in order to effect the maximum retention of the initial
total solids with which we start?

SOURCE/CLASSIFICATION

Before answering the preceding questions, let us examine the classes,
types and composition of the commercial coagulants in general use throughout
the industry today. There are two basic classes of commercial cheese co­
agulants. One is derived from animal and the other is from microbial
sources. Generally, they are classified by the origin from which they
are extracted or prepared. Within the animal class we have three basic
types -- calf, bovine and porcine. The animal milk clotting proteinase
enzymes are technically called chymosin, bovine pepsins A and B, and
porcine pepsin.

Animal Extracts

The extract from calf stomachs contains predominantly chymosin.
However, this preparation will also contain various levels of
bovine pepsins A and B.

The extract from pig stomach linings contains pig or porcine
pepsin. This enzyme is rarely used by itself to manufacture
cheese even though under specific conditions and parameters it
can produce quality cheese. This enzyme as well as chymosin
and bovine pepsin is used for preparing specific coagulants
with various blends of these enzymes.

Microbial Extracts

Microbial coagulants are preparations containing their specific
"milk clotting enzyme-proteinase" which are derived from microbial
fermentations -- either from: Mucor pusillus var. lindt, Mucor
miehei or Endothea parasitica. Various brand names are used by
commercial manufacturers for these types. Their source or organism
from which it was prepared is identified on the label.

COMMERCIAL COAGULANTS

While commercial manufacturers have different brand names for their various
coagulants containing the various "milk clotting enzyme proteinases", all
have their own standards and specifications as to the percent composition of each enzyme and as to their percent strength. The percent strength is equivalent to the total enzyme active units in one ounce of material. While the percent composition and percent strength of the particular enzyme may vary for similar products between manufacturers, generally they are within the same basic range.

Animal Types

For example, Calf Rennet will be predominantly chymosin (85-95%). The remaining enzyme activity comes from the bovine pepsin fractions (5-15%). A blend of calf and porcine pepsin may contain chymosin (40-45%), bovine pepsin (5-10%) and porcine pepsin (50%). Bovine rennet may contain predominantly bovine pepsin (55-60%). The remainder is chymosin (40-45%). Mixtures of bovine pepsin and porcine pepsin are available. Their composition will vary depending upon its intended use. However, a typical composition may be 20-25% chymosin, 40-45% bovine pepsin and 30-40% porcine pepsin.

Microbial Types

Microbial coagulants, regardless of their source/origin, contain 100% of the native milk clotting proteinase enzyme. While mixtures of animal and microbial enzymes are possible, they are not widely used.

FACTORS WHICH AFFECT THE PERFORMANCE OF MILK CLOTTING ENZYMES (COAGULANTS)

As most of you are aware, there are factors other than the (milk clotting enzymes) coagulants which affect the recovery of milk solids (yield). I want to discuss a few of the more important ones as they directly affect the coagulant activity.

RAW MILK

The maximization of recovery obviously can be no better than the overall quality of the milk which we use. If the native casein has been sufficiently altered/degraded, none of the enzymes will work effectively. Yield and quality will suffer. Presence of other microbial proteinases can inhibit or antagonize the milk clotting process by inhibiting effective catalytic activity. Masking of reactive sites on the casein molecule is possible. Inactivation of the milk clotting enzymes by psychrotrophic proteinases have been recorded. Weak sets and incomplete gel formation results in less solids being trapped in the curd particles.

Another important factor affecting overall yields, which years ago was recognized but forgotten for awhile, and is now resurfacing more strongly than ever, is the total casein content of the initial cheese milk. With the advent of protein pricing of milk rather than on a percent butterfat and weight, as shown and documented by Dr. Ernstrom and his staff at Utah State University, the overall percent of cheese yields industry-wide will show noticeable improvement in future years.
With more native casein in milks, effective use of coagulants will become much more profitable. However, the microbial quality of raw milk will become much more critical. Milk free of deleterious proteinases generated by psychrotrophs will be essential in yield maximization. Heat treatment and/or the inoculation of the milk with appropriate/approved and beneficial organisms or enzymes will become effective in controlling an undesirable microflora.

**STANDARDIZATION - C/F RATIO**

If the raw milk meets acceptable quality as discussed above, the next most important factor that influences the percent yield or retained total solids is prestandardization of the cheese milk to a casein-to-fat ratio of 0.68 to 0.72% (avge. 0.70). This is important and directly interrelates with the activity of the clotting enzymes for maximum utilization of the specific and total enzyme units added to the milk. The ideal efficiency and utilization of catalytic activity is to add the minimum level of activity units to effect the desired gel (coagulum) in the desired time at the ideal temperature and pH. To obtain a firm "set" in 25 minutes at 86°F, a minimum number of activity units is required. More than this is not necessary nor is it an efficient use of catalytic energy -- so far as coagulation is concerned. The pH and/or temperature changes the minimum amount of animal enzyme that is required. The amount of animal type will vary depending upon the percent of enzyme composition of the coagulant. For example, less ounces of calf rennet with 90% chymosin is required to "set a vat" than a 50/50 or with a bovine type product. This is due to the specific catalytic activity and reaction of each enzyme on the casein. pH and temperature can noticeably affect their activity. So, with the proper ratio of casein-to-fat, enzyme activity is more efficiently utilized to gel the casein while incorporating the maximum amount of fat between the casein micelles. Thus, resulting in less unseparated "whey fat" in the whey, more fat in the cheese, better moisture control, etc. -- all translated into higher yields regardless of the type of coagulant enzymes used.

**pH AND TEMPERATURE AT TIME OF SET**

**pH**

All enzymes have minimum, optimum, and maximum pH's at which they react. The optimum pH of milk clotting proteinases is not the usual pH's of cheese milk (6.5-6.7). It is much lower. Porcine pepsin is the most sensitive to pH's above 6.6. Bovine pepsin, while more sensitive to pH's above 6.6 than chymosin (Calf), continues to react at pH's of 6.7. However, its rate of activity is reduced noticeably. Coagulants containing appreciable quantity of bovine pepsin are usually standardized higher in strength (total activity units) than products containing calf chymosin to compensate for the slower rate of activity when encountering cheese milk pH's above 6.6. Chymosin will react very well in "sweeter milk" (pH's above 6.7); but not quite as well as the
microbial proteinases which are the least affected by pH's at the time of "setting" commonly observed in most vats today.

The pH of cheese milk at "setting" plays a very important role in the clotting and coagulation process. Since pH influences the rate and type of activity of these proteinases, the optimum pH for the specific enzyme(s) used is critical, more for the initial clotting phase than for the complete coagulum phase. The clotting phase is where the proper set and alignment of the casein micelles take place for the gel formation to occur. Disturbance during this phase can be most damaging to firm sets, and consequently, yields. Therefore, when the milk has the proper casein-to-fat ratio (C/F), within the optimum/operable pH range and temperature, the yield will be different based upon the differences in proteolytic activity providing all other manufacturing parameters are the same. Extreme variations in pH will significantly affect yields.

**Temperature**

Milk clotting enzymes (coagulants) are not as sensitive to temperature as to pH during the normal cheese manufacturing process. Fluctuations of 2-4 degrees will, to be sure, speed up or slow down the whole coagulation process. However, slight fluctuations will not negatively influence the yield/recovery providing one uses caution and makes proper adjustments as necessary. For example, a vat set at 90°F versus 86°F with the same amount of coagulant per 1,000 lbs. and at the same pH's will generally be ready to cut 2-3 minutes faster. One wants neither too slow or too fast "a set". Twenty-five to thirty minute sets are ideal. Adjustment can be made appropriately in temperature, or the amount of enzyme used to give this time when 86-88°F sets are used.

**SUFFICIENT CALCIUM**

The efficiency of milk clotting enzymes in setting cheese milk is influenced by the amount of available free calcium ions. The clotting phase will be retarded and the strength (firmness) of the coagulum (gel) will be weak if insufficient calcium ions are not available. Therefore, the addition of calcium is preferred, particularly in low solids casein milks. Over addition may increase firmness but body and flavor defects may result. One should vary the amount depending upon the condition of the milk, set times and body of the curds. Dilution and addition to the cheese milk in the same manner as for the coagulant is best. To insure uniform distribution add it well in advance of setting the vat. Fill times and the type of equipment usually dictates this addition step.

**DIFFERENCES IN ACTIVITY OF MILK CLOTTING ENZYMES**

**pH/TEMPERATURE**

**pH: Animal Types**

Milk clotting enzymes do differ in their behavior to pH. The animal types (chymosin, bovine pepsins and porcine pepsin) exhibited similar
pH optima but vary significantly in activity and stability at pH's higher than 6.6. Calf chymosin functions reasonably well up to 6.8. Above this level, its activity is retarded noticeably.

The bovine pepsin fractions A and B exhibit slight differences between the two types; however, their optima appear nearly the same. But, their activity and action in cheese milk above pH 6.6 is about 10% lower than calf chymosin or the microbials. Therefore, more total activity units (percent strength) must be increased appropriately 10% in order to compensate for this difference. Generally, these types of commercial products are standardized to a higher strength so that they will function satisfactorily in cheese milk with pH's in the range of 6.6 to 6.75. Cheese milk pH's at setting higher than 6.75 will cause slow and weak sets when using bovine enzymes. Abnormally high percent unseparated whey fats will most likely result. Thus, the percent cheese yield will be significantly affected.

Porcine pepsin is very sensitive to pH's above 6.6. Activity and action is dramatically reduced under these conditions. When using blends containing porcine pepsin, one should monitor the cheese milk pH's carefully and make the necessary adjustments to obtain maximum activity. The percent cheese yield most likely will be lower when these products are used in cheese milk with pH's above 6.6.

All of the animal type enzymes display optimum activity at pH 5.0-5.6. This is ideal, since most of our American type cheeses fall within this pH range when finished for curing. Therefore, continued efficient activity can be expected during curing for developing the body and flavor desired.

**pH: Microbial Types**

The microbial milk clotting proteinases have greater activity and stability in cheese milk with pH's above 6.6 than do the animal types, bovine pepsin and porcine pepsin. Unless the cheese milk pH is in the 6.75-6.8 range, one does not see too much differences in activity of microbials and calf chymosin. In abnormally high cheese milk pH's the differences in activity, as a function of usage and "set times", will, however, be noted when comparing chymosin and the microbials.

The optimal pH range for microbial types is broader than it is for animal types. And, since microbials are least affected by high pH's, they do have some practical advantage in that they can be diluted in high pH, chlorinated water with more hardness for a longer period of time without any appreciable degradation than any of the animal types. However, regardless of the conditions of the water, for good GMP's (Good Manufacturing Practices) one should not make up the diluted coagulant for extended periods prior to addition to the vats. (More about this later).

Because of the differences in the rate of enzymatic activity between the different milk clotting enzymes as a function of pH, one should examine and evaluate their choice of coagulant (enzyme) before deciding which best fits their goals and objectives.
Other factors in the cheese making process contribute to the overall enzymatic activity of these enzymes in the finished packaged cheese. Even though their differences do not appear to have any significant effect upon the percent yield, these differences do exert noticeable changes in flavor and body development during curing.

For example: Most of you are aware that to hold a piece of cheese manufactured with certain microbials for an extended time, the drier the cheese the better the chance of not developing bitter flavor notes at 5.0-5.2 pH's. Also, you are equally aware that the rate of body breakdown and flavor development is faster in cheeses with higher moistures and/or when aged at higher temperatures. These phenomena are somewhat controllable but under more rigid supervision. These observations are explained simply by the fact that the water (moisture) does affect enzymatic rate by allowing more solubility and mobility of the enzyme throughout the curd mass. Coupled with the water/enzyme concentration and the mobility factor is the effect of pH. Thus, activity is moderated by the concentration effect of the enzyme associated with and in the aqueous portion of the curd mass regardless of which enzyme is present. Each one appears to be moderately to significantly different as measured by the organoleptic results obtained during maturation. Complete elucidation of these biochemical factors is very difficult to measure accurately. However, empirical observations have strongly indicated that these factors and phenomena do exert measurable effects under controlled conditions. The percent moisture in the finished cheese obviously dictates the percent wet weight yield. Any differences between the enzymes in uniform moisture control does impact profitability.

Temperature

All enzyme catalysts are moderated in activity by temperature. Temperature is seen as the governor of enzymatic rates. The milk clotting enzymes are no different in this respect when all other things are equal.

Where temperature at "setting" can influence the percent cheese yield is in its effect on the proteolytic activity phase of the individual enzyme. Some limited data shows that proteolysis is more affected by temperature than the catalytic (clot-coagulation) phase for each enzyme as seen by differences in the level of non-protein nitrogen values in whey studied under controlled conditions. The higher the temperatures the higher the value. Whereas the increase, percentage-wise, may be small on a per unit basis, i.e., mg/100 ml of whey, this translates into significant percent yield differences when calculated for large volumes of milk. As comparisons are made under controlled conditions using the same temperature at setting, then percent differences are attributable to the differences in proteolytic activity of the separate milk clotting enzyme factions.

While we see slight changes in "set times" by adjusting temperatures up or down; and when using the same amount of enzyme, the differences are not dramatic from a practical point of view, because most cheese milk temperatures at the time of "set" is between 86°F and 90°F
(30°C-32.2°C). One might observe a noticeable difference if one were to accurately cut at the same end point, i.e., same coagulum firmness. But, this is most difficult to measure accurately.

**PROTEOLYTIC ACTIVITY**

Each type of enzyme has its own chemical and physical characteristics. Their action on and reaction with casein in the clotting/coagulation process is significantly different in behavior. These differences have been accurately measured and reported by a number of investigators. Some of these differences have been shown to be significant and help to prove why differences in the percent yield may occur in cheese manufacture when comparing one class or type versus another. Other publications have detailed the specific biochemical reaction of these enzymes on casein; and, interrelate their activity and action to cheese yield and quality. (Ernstrom, Emmons, Olson).

Proteolysis during cheese manufacture is difficult to measure accurately. However, some investigators (A. Reps, et al) found that microbial milk clotting enzymes produced significantly higher amounts of non-protein nitrogen, peptide nitrogen, and amino-nitrogen in cheese whey after cutting than animal (calf) type enzymes. *Mucor pusillus* extracts produced 22% more non-protein nitrogen in the whey after cutting than calf chymosin. *Mucor miehei* types showed an increase of 17.8% more non-protein nitrogen in the whey versus chymosin. The increase in peptide nitrogen ranged from 26 to 33% and the amino-nitrogen from 17% to 22% when microbials were compared to chymosin. To further confirm the differences in proteolytic activity, the whey was stored at 20°C and re-examined for the nitrogenous components. In all cases the microbials continued to show higher proteolytic activity than the calf (chymosin) rennet. This more recent study confirmed previously reported results by Ernstrom and Emmons.

The proteinase produced from *E. parasitica* has been reported to have a higher degree of proteolysis than the enzymes from the *Mucor* species (*pusillus* and *miehei*) which were noted to be approximately the same. Whereas the animal types (chymosin, bovine pepsin and porcine pepsin) were significantly lower.

Calf chymosin is the least proteolytic while porcine pepsin is the highest in the animal classes. Bovine pepsin fractions were found to be in between. The degree of proteolysis by the individual milk clotting enzymes very definitely has a measurable and significant effect upon the degree of retained solids in the cheese curd. This factor coupled with the parameters of cheese manufacture will determine the overall percent yield.

**STABILITY/LABILITY**

The question of stability/lability of milk clotting enzymes as to the direct relationship of this characteristic to cheese yields has not been adequately clarified and proven, in my opinion. Some evidence does exist that, when specific microbial proteinases have been sufficiently modified to be less stable, their proteolytic enzymatic activity has also
been moderated accordingly. Measurable differences in cheese yields between non-modified and modified microbial types may be demonstrated in future trials. It is chemically conceivable that alteration of the protein/enzyme molecules could be achieved sufficiently to effectively reduce the magnitude of proteolytic differences which have shown to exist between non-modified types and the animal types. Reports have documented, however, that each clotting enzyme type does have its own individual stability profile. However, at the present time the stability/lability question primarily is associated with and is of some concern to the processing procedures employed in manufacturing WPC (Whey Protein Concentrates).

PERCENT SALT AND PERCENT MOISTURE

The percent salt and percent moisture do influence the percent solids recovered in cheese as measured in samples taken at 10 days of age. The salt and moisture levels exert their own influence on enzymatic activity. The animal type enzymes are moderated more effectively by higher salt levels than the microbials. The level of moisture dictates the concentration of salt in the aqueous portion/phase of the cheese particles and the enzymatic activity is moderated to different degrees depending upon the tolerance level of each individual enzyme. The rate at which salt penetrates completely the curd particles, therefore, influences proteolytic activity. (Note: The methods of application are important here). Since microbial type coagulants are more salt tolerant, their activity continues on a micro-scale and more "solids" will be expelled than with animal type enzymes. Therefore, the percent salt coupled with the moisture levels can affect the percent recovery of solids regardless of the enzyme. However, under uniform conditions for controlling salt and moisture levels, true differences in yield can be measured as a function of the differences in chemical proteolysis which is individualistic for each enzyme. And, the percent differences in yield are measurable when large enough volumes of cheese milk is examined.

OTHER FACTORS

DILUTION AND ADDITION TO CHEESE MILK

Diluting the enzymes in sufficient volumes (20 to 30x) of potable, low chlorinated (5 ppm) water at a pH of 6.5 is ideal for maintaining optimum activity. If this type of water is not available, then diluting out the total amount of coagulant a minimum of 20x and no longer than 5 minutes before the addition to the cheese milk is the next best procedure. Hard water and an alkaline pH (> 7.0) can inactivate the enzymes, particularly the animal types. The rate of inactivation is directly proportional to the degree of hardness, pH and time. Any significant inactivation will influence the rate of enzyme activity in the cheese milk. Slow sets usually result in weak sets, therefore lower yields.

Abnormal variations from vat to vat in set times, uniformity and firmness of sets when the milk is from the same silo/tank may be due to improper addition and mixing in the vat. This procedure directly influences the activity/action of the enzymes. It is desirable to achieve maximum
dispersibility of the coagulant both by adequate dilution and uniform dispersement to allow maximum efficiency of the enzymes. A uniform rate of catalysis will improve and insure maximum clotting and gel formation, thus maximizing yields. Catalytic energy is lost when the enzyme molecules are heavily concentrated and localized through the vat. This situation is compounded when the pH of the milk may retard activity. In horizontal/open vats, addition of equal quantity of diluted coagulant starting from each end of the vat and just ahead of the agitator will insure the best/uniform dispersement. In double O's/closed vats, injection in line with the last volume of milk is preferable. A change in agitator(s) speed may be advisable in order to get even distribution. Over-agitation is not recommended. Any way the agitators can be positioned to slow down milk movement is advisable.

OTHERS

There are other factors which affect recovery of cheese milk solids, i.e., type of equipment, handling methods of curd, and the final pH's, percent salt, and percent moisture in the final cheese. However, the previously discussed factors directly relate to and have influence upon the "milk clotting enzymes" as they affect cheese yields. An understanding of these factors, their influence and effect and how they should be handled to improve efficiency is important to insure maximum recovery of milk solids (percent yields) which translates into greater profits and ROI. As we progress into the decade ahead, we may see cheese manufactured without the use of these milk clotting enzymes. But, until this happens, I hope we can continue to utilize all the available technology and technics effectively to better insure continued success in the industry.

This concludes the technical/technological aspects and presentation on the "Effect of Milk Clotting Enzymes on Cheese Yield".

Reference:

Over the past ten years or so we have been asked on occasion why the percent cheese yields have been less than they used to be. How, why, what are the causes/reasons for changes in the percent recovery of solids in cheese? Is it the milk supply? Is there less casein in our cheese milk today than 15-20 years ago, which has caused an appreciable shift in the casein-to-fat ratio, thereby reducing the yield? Is the total microbiological flora of our milk today that much different to have had a negative effect? Has the revolutionary changes in the starter-culture system been a major factor? Has the milk clotting enzymes (commercial coagulants) profile, composition, strength, and predominant usage been changed appreciably to have caused noticeable reductions in yield? Have the changes in equipment and make procedure had a major impact in this regard? Is it any one factor or a combination of two or more which has caused a significant percentage shift? Perhaps you can suggest other reasons for this downward trend?

For whatever the reason(s), this shift has had an economic impact upon profits. The answer to most of these questions is "Yes". Most likely they all have had and still do have some impact upon the cheese yield.

In evaluating this question of cheese yield, the results of a commercial study you are about to see involved an evaluation of the "effect of commercial coagulants (CHL's) containing different types of animal and non-modified microbial enzymes at various compositions, all standardized to the same relative strength. We wanted to see if there were statistically measurable differences between the various types of coagulants as determined by the percent cheese yield, both wet weight and on a dry solids basis. And, try to resolve this question of differences between coagulants as they affect yield.

I want to point out and emphasize that this study was conducted before modified microbial enzymes were commercially available. I also want to point out that the results are related to this study only. A different comparable study and evaluation may show different magnitudes and relationships. However, it is my firm belief that coagulants containing minimal levels of chymosin or its molecular equivalent will continue to produce the highest percent yield when compared under controlled conditions.

To prove that the percent of cheese yields are influenced and affected by the type of coagulant containing these milk clotting enzymes used in the manufacture of 36% moisture American type cheese, we were privileged to coordinate and work with a staff of professionals to obtain results when comparing coagulant types as to their effect upon cheese yields under actual day-to-day, large-volume, commercial manufacturing operations.
I. THE STUDY — CHEESE YIELD

Before we begin the slide presentation, a few remarks specifically about this study are in order.

Validity and reliability of this type of data is always under suspect. Questions are raised as to: 1) Experimental design; 2) Administration of details; 3) Collection of satisfactory and accurate samples for analysis; 4) Technological competence of the individuals involved; and, the type of equipment and its operation — all of which can have individually and/or collectively some influence upon the data.

I assure you the individuals involved in and at all phases of this project were technologically experienced in design, implementation and operation of manufacturing operations. They were trained in the art and science of cheese manufacture. Also, the manufacturing facility and the process equipment were designed originally to eliminate as many influential variables in "solids recovery" in order to maximize efficiency in cheese yields.

Even though this data was collected in a highly automated, well controlled operation, the yield of cheese obtained in less controlled or automated operations may vary in actuality from the results you are about to see. We believe the percent magnitude of relative differences between the various types of coagulants will be nearly the same — when the same controls in specific steps of the manufacturing are the same — such as the same firmness of the "Set" before cutting, agitation, etc. The primary reason for this statement is because the composition of the coagulant — be it chymosin, bovine pepsin, porcine pepsin or the microbial proteases — will exert significant impact on the yield because of their inherent differences in proteolytic/enzymatic activity on casein. The higher the proteolytic activity, generally the greater the loss. Moderation of this factor is possible in certain operations for different types of cheeses.

II. SUMMARY/CONCLUSIONS

1. The percent recovery of total solids from milk during cheese manufacture was affected/influenced by the type of cheese coagulant used to "set" the milk.

2. Animal type coagulants ("Calf Rennet", "Bovin", "50/50") produced higher yields when compared to "Hannilase" (microbial — unmodified M. miehei) type coagulant when results from 11 vats are included.

3. When the statistically noted abnormal vats were excluded, "Calf Rennet" produced the highest wet weight yields (9.947%) followed by "Bovin" (9.909%); "50/50" (9.907%); "Hannilase" (9.848%) and "BP" (9.838%).

4. When abnormal vats were excluded, "Calf Rennet" gave the highest yield (6.320%) in recovery of dry solids, followed by "50/50" (6.318%); "Hannilase" (6.294%); and "Bovin" (6.263%). "BP" (6.261%) was the lowest.

5. Sufficient volume of milk was required to accurately determine differences in percent recovery.
6. Prestandardization of commingled milk before pasteurization will maximize recovery of total milk solids and minimize the percent fat losses in unseparated whey. This procedure effectively reduces extreme variations from day to day and season to season. Also, this provides greater consistency and uniformity year round which maximizes profits.

7. Throughout this study potential factors which could influence yield recovery were rigidly controlled.

8. Analysis of the data did not reveal any significant effect of starter-culture, final pH's and percent moistures upon percent recovery of solids in relation to the coagulant used. Differences in "yields" were concluded to be the result of differences in enzymatic activity of the individual coagulants on casein.

9. An evaluation and computations using the percent wet weight cheese yield results obtained in this study showed that an appreciable quantity of "extra pounds of cheese" would have been produced had Calf Rennet been used throughout the study instead of the other coagulants. If these percent yield figures were the annualized averages for each coagulant and by applying them to a plant processing 500,000 lbs. of milk into cheese per day for 6 days per week and 52 weeks per year, 154,440 pounds more cheese would be produced with "Calf" than "Micro"; 62,400 more lbs. than "50/50"; and, 59,280 more lbs. than "Bovin". "Bovin" would yield 3,120 lbs. more cheese than "50/50"; but, 95,160 lbs. more than "Micro". "50/50" would yield less cheese than "Bovin" but 92,040 lbs. more than "Micro". (Note: The "Micro" here refers to the unmodified type from M. miehei.

10. Price/value relationships should be satisfactorily evaluated/established to insure maximum profitability.

Note: Conference Participants

A copy of the full report including much of the raw data is available upon request.

We hope this presentation has answered some questions as well as stimulated some other provocative and challenging ideas. If you can utilize some of the foregoing ideas and suggestions in your operations, hopefully your rewards will be not only financial but personal in having better utilized the technology available in manufacturing one of our most complex foods that has uniqueness and nutritive value of high quality.
PROGRESS TOWARD USE OF ULTRAFILTERED MILK FOR
INCREASING YIELDS OF CURD FOR PROCESSING

by Paul A. Savello, Utah State University

INTRODUCTION

The use of ultrafiltration (UF) processes has earned a place in the dairy foods industry. Ultrafiltration membranes have been successfully used for a long time in the preparation of whey and whey products with the "springing up" of entire industries utilizing UF procedures to produce commercial products. Following these years of success in using membranes to concentrate whey it has only been natural to use UF techniques to concentrate milk in the preparation of various types of cheeses from such milk concentrates.

UF FUNDAMENTALS

Ultrafiltration is a process in which an aqueous food product (such as milk) can be concentrated, purified, dewatered and/or demineralized. The procedure involves low-pressure membrane separation of low molecular weight materials (such as water, sugars and salts) from macromolecules or colloidal particles (such as, protein and fat). Thus, size and shape of the foodstuff molecular constituents determine the separation or filtering that will take place.

Ultrafiltration requires low operating pressures to effect the separation of the foodstuff components. The pressures needed range from 20-120 psi. A closely related operation, reverse osmosis, is used to separate low molecular weight components (sugars and salts, for example) from their solvent (water). This latter process requires very high
operating pressures, usually ranging from several hundred to more than a thousand psi.

The concentration of milk using UF techniques is a much-investigated procedure. In this process the milk is usually heated during the UF operation. The heating of milk to 120-135 F, along with the pressure applied, speeds up the concentration.

As concentration proceeds, the permeation rate (that is, the rate of removal of water, salts and sugars) decreases. This decrease in filtering rate is due to the increased concentration and thickening of the retentate.

**WHY USE UF?**

There are two main reasons why UF technology has a place in the future of dairy products (particularly cheese) manufacture. These include: 1) overall decreased energy usage and 2) increased product yield.

A decrease in energy usage through UF technology occurs in many ways:

a) mechanical energy by pumping is the main energy requirement rather than more costly heating with thermal energy;

b) large volumes of cooling water are not needed as milk concentration occurs at moderate temperatures.

c) decreased labor costs as UF techniques can be made more continuous than conventional cheese manufacture.

Product yield is a major concern of any dairy products manufacturer. The use of UF technology in producing various cheese products has generally indicated that the same or greater yield can be achieved. Researchers in England (Chapman et al., 1974) reported that no loss of yield occurred in producing Cheddar or Cheshire cheeses when UF concentrated milk was used. An increase in yield occurred when UF concentrated milk was used to
manufacture a medium fat, soft cheese.

As recent as December 1981 Sutherland and Jameson at CSIRO in Australia reported a significant yield increase in Cheddar cheese prepared from ultrafiltered whole milk that was concentrated 4.8 times. The reported yield increase was approximately 14% over the expected yield from conventionally-made Cheddar cheese.

Ernstrom, Sutherland and Jameson (1980) reported a 16-18% yield increase in cheese base prepared from UF concentrated whole milk. The cheese base was used for processing. This dramatic increase in yield was due mainly to incorporation of the whey proteins and all of the milk fat in the final product.

The use of cheese base as a substitute for natural cheese in process cheese manufacture has been investigated. Sood and Kosikowski (1979) found that process cheese made with 40% retentate solids was more acceptable than a commercial process cheese used as a comparison. They also used enzyme-treated retentate as a substitute for natural cheese in processing. Process cheese with up to 60% enzyme-treated retentate solids had better quality than the commercial process cheese.

Ernstrom and colleagues (1980) substituted 80% cheese base for natural cheese in preparing process cheese and process cheese food. The mix behaved normally in the kettle and had good flavor; however, the body of the product was brittle.

Research here at Utah State University has investigated the meltability and textural properties of process cheese prepared from cheese base. In particular, the research has attempted to define the cause or causes of the melt defect found when cheese base is used exclusively to manufacture process cheese.
CHEESE BASE PREPARATION

SLIDE 1

Retentate Production

The first slide shows the scheme used to ultrafilter whole milk to produce a retentate with 38-40% solids. One hundred pounds of whole milk is used in this example.

1. The milk is pasteurized at 145°F for 30 minutes and then cooled to 122°F prior to ultrafiltration;

2. Ultrafiltration of the whole milk proceeds using a single-stage Abcor membrane until 60# of permeate (60% of the original milk weight) is removed;

3. Diafiltration, or addition of deionized water to the partially concentrated milk in the feed tank, proceeds at the same rate that permeate is removed. This procedure does not increase the volume of liquid in the feed tank and allows more efficient separation of lactose from the concentrate. Approximately 40# (40% of the original milk weight) of diafiltration water is used in this step;

4. Following diafiltration, the retentate is further concentrated until approximately 20# more permeate is removed.

5. From the original 100# of milk approximately 20# of whole milk retentate is obtained. This retentate contains approximately 38-40% solids with over 99% of the original protein and fat of the milk present in the retentate.

Fermentation of Retentate

Fermentation of the retentate occurs by adding approximately 1% of a lactic starter culture and incubating the retentate for 16-18 hours. At the end of this incubation period the retentate has a pH of 5.1-5.2. During


this fermentation period proteolytic or lipolytic enzymes can be added to the retentate to cause some protein and fat breakdown.

Cheese Base Production

Following fermentation and enzyme treatment the retentate is ready to be made into cheese base. The retentate is placed in a scraped-surface, vacuum pan evaporator and water is removed under reduced pressure until the retentate takes on the appearance of cheese curd. The temperature of the product during this procedure does not go higher than 120 F. The resulting product, cheese base, has a moisture level of 36-38% and a pH range of 5.0-5.2.

The composition of cheese base is similar to conventionally-prepared cheese curd with the exceptions that the whey proteins and a higher quantity of the milk calcium are present in the cheese base.

SLIDE 2

The slide shows a pan of freshly prepared cheese base. Cheese base resembles freshly prepared curd in some ways but has its own characteristics - large chunks, less than smooth surface texture.

PROCESS CHEESE MANUFACTURE WITH CHEESE BASE

Process cheese prepared from unaged, fermented cheese base exhibits a serious melt defect subsequent to cooking. The cheese base, together with added sodium chloride, emulsifying salt and water (if necessary) cooks well in a batch-type process kettle. However, following cool storage for two days or more, the product does not display normal melt characteristics in objective cheese melt tests.

Research at this university has investigated the treatment of UF retentate with proteolytic enzymes to cause protein breakdown to different
levels. Following the enzyme treatment of retentate, cheese base was prepared and used to manufacture process cheese. The process cheeses contained sodium chloride at the level of 4.5% in-the-moisture of the cheese, emulsifying salt at 2.5% level, 39-40% moisture in the final product and 51-52% fat-in-dry-matter. The cheeses were cooked to 180°F in 6-8 minutes batch-wise and held at that final cook temperature for 1 minute. The products were packaged, cooled and stored.

Extent of protein breakdown was determined by precipitating the remaining protein in the retentate with 12% TCA and measuring soluble nitrogen in the filtrate. Soluble nitrogen levels ranging from 10-66% were obtained indicating a wide range of protein breakdown in the retentate.

All process cheeses prepared with the enzyme-treated retentates and cheese bases showed a serious melt defect. It was concluded from these trials that protein breakdown caused by enzyme treatments of the retentate did not overcome the lack of meltability of the process cheeses.

MODEL RETENTATE AND PROCESS CHEESE STUDIES

Model retentate and process cheese systems were designed to study the cause(s) of the melt defect when cheese base is used in preparing process cheese. The major difference between cheese base prepared from UF whole milk retentate and conventionally-made cheddar cheese is that the former has included in its composition all the whey proteins. A 1976 patent by Schultz entitled "Melt Resistant Process Cheese" explained in detail that with addition of various albumins (for example, milk, blood or egg albumins) to a process cheese formulation the resulting product will be melt resistant in objective melt tests. The obvious question "Could the whey proteins in the cheese base be the major cause of the melt defect noted?" was asked and
investigated.

Strict guidelines were determined and followed in the preparation of all model process cheeses. The formulations were to adhere to the standard of identity for such a product: the cook times and conditions of all samples were to be the same; the pH of the final cheese samples were to fall within a narrow range of 5.6-5.75.

The ingredients used in the preparation of the model process cheeses included: casein, butterfat, salt, water, and an emulsifying salt. When rennet casein was used as the casein source, the resulting process cheese melted well. However, when acid casein was used in the same model cheese system the process cheese did not melt. A method was designed in which the acid casein in the formulation could be treated in the cooker with a strong base in order to make the casein more soluble. The effect of the base was neutralized by the addition of sufficient lactic acid prior to final cook of the mix in the cooker. This procedure resulted in a model process cheese using acid casein which displayed an adequate melt property. Thus, we were able to produce model process cheeses using either rennet or acid casein as the main protein in the formulations.

In the production of cheese base from UF whole milk retentate the casein of the original milk closely resembles acid casein rather than rennet casein. Therefore, our attention was closely directed to the acid casein model cheese system. However, retentate can be rennet-treated prior to preparing cheese base resulting in a retentate with casein closely resembling rennet casein.

Model Process Cheeses With Added Whey Proteins

Whey protein powder with approximately 75% whey protein was prepared from 38% modified whey protein. The high percentage whey protein powder was
added to the model process cheese formulations in increasing amounts. Cheese base has approximately 4.0-4.1% whey protein concentration. Thus, whey protein was added up to a 4.5% level in both acid and rennet casein model process cheeses.

SLIDE 3

The slide indicates that as the whey protein (as native whey protein powder) concentration increases in both model cheese systems, the melt decreases.

SLIDE 4

The slide indicates that as the whey protein (as heat-denatured whey protein powder) concentration increases in both model cheese system, the melt decreases.

What Does It Mean?

The main advantage in using (UF) techniques in preparing a cheese base for processing is that this procedure incorporates the whey proteins in the final product. This results in the increased yield advantage that was previously discussed. However, the incorporation of the whey proteins into the final product causes the melt defect that is a disadvantage to the process cheese industry in this country. Closely allied work has shown that the enzymes normally used in the natural cheese industry (rennet, microbial rennets, etc.) do not break down the whey protein fractions significantly regardless of whether the whey proteins have been left in their native state or have been heat-denatured.

In order for cheese base to be used as a sole source of cheese for processing; it will be necessary to deal with the whey protein problem such that these proteins do not interfere with the melt defect noted.
What About Federal Regulations?

At present the regulations do not allow cheese base to be used exclusively as a base for preparing pasteurized process cheese. However, considering the increased nutritional quality of cheese base (with the incorporated whey proteins) it is evident that cheese base can be judged at least equal and possibly superior to natural cheese. Colleagues have stated that there exist two avenues that can be taken to initiate the use of cheese base in process cheese production. These avenues include: 1) petitioning the FDA for a change in the regulation regarding the use of cheese base in processing, and 2) initiating production of process cheese from cheese base (when a viable product has been achieved) and force the issue back to the regulatory agency. This latter approach may prove the more expedient of the two avenues.
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MY EXPERIENCE IN IMPROVING AND ACCOUNTING FOR CHEESE YIELDS

William Joe Heap

An address prepared for the 5th Biennial Cheese Industry Conference at Utah State University

August 1982

Our factory is located on highway 191 at Gallatin Gateway, Montana. We have been in business as a privately owned company since January of 1953 when the plant was first started by my father, Clarence J. Heap. Our plant is quite small by today's standards with daily production of cheese under 5,000 lbs. Our milk comes from our own producers plus a limited supply of diversion milk from local fluid plants.

During the past few years our company experienced a gradual decline in its ability to generate a profit. If not corrected this would have meant going broke. The first indication of our condition came in our quarterly statements which showed our deteriorating profitability.

Faced with this problem, I undertook an in plant study to see if I could locate the cause of our problems and instigate procedures to solve the problems. The following comments will show many of the trials our company underwent that finally led to our current profitable situation.

I first centered my attention on milk supply. I felt fairly confident that I was getting the tonage that I was paying for, but I wasn't certain. I installed a metering device at the receiving station and compared meter results with producer invoices to determine if I was receiving all the milk I was paying for.

Next, I had my cheese vat calibrated so milk volumes could be determined in the vat and compared with milk received. Using an analysis pad I recorded loads of milk received as to time, date, place of origin and storage tank the milk was placed in. Due to the nature of
this type of activity, it becomes quite easy to see wolves behind every rock, and clear objectivity can suffer.

The meter volumes almost never compared satisfactorily with the invoice volume of milk, showing repeated deviations of $\pm 2\%$ with extreme deviations as high as $\pm 6\%$. Our meter was checked weekly by weighing full trucks, unloading and reweighing empty. After repeated use, confidence was lost in our metering system as a method of accurately determining milk volumes at the level of repeatability that I wanted (ie. $\pm 1\%$). It is my feeling that a properly operating truck scale at receiving or a silo resting on load cells could guarantee invoice pounds of milk within acceptable limits.

Transfer of milk from storage tanks to vats as a secondary step in the determination of milk loss showed that the same deviations I was experiencing at receiving were now occurring at the vat. Pounds of milk in the vat did not correspond with pounds of milk received.

By using the inventory sheet I found deviations in invoice amounts, meter amounts, scale amounts and vat amounts that did not compare to my satisfaction on a daily basis, but averaged out relatively well over a 15 day procurement period. On too many occasions volume fluctuations greater than $\pm 5\%$ occurred between receiving and vat.

A better standard had to be found because monitoring of milk volumes showed that the irregularities found could not account for our losses. By attempting to follow our volumes to see if losses could have occurred, not all was lost because it exposed to us the many possible ways that milk volumes in a plant can be affected plus the development of analysis records helped us to expand our research into the following areas.
Knowing that volume did not account for our losses, it appeared that some milk components were responsible. Fat accounting in our plant began with the addition of a few more columns to the analysis record. The experience that we gained in following milk volumes through our system now became valuable because our people were already trained and familiar with the problems inherent in such a procedure. It should be pointed out that even in a small plant such as ours production, the systematic control, labeling identification and preservation of samples and data can become confusing. At this time, a lab record was developed to record information which could be entered at a later time on our analysis sheets. With this information, we first wanted to determine if samples were being brought to us which accurately reflected the total load of milk received.

With these procedures established, plus the proper work sheets, we attempted to follow fat usage from farm to vat to see if fat losses were occurring along the way and at what point.

Accounting of butterfat from farm to truck over a two year period showed that fat could be following quite accurately. On a majority of the loads, (approx. 95%), deviations were repeatably under ± .05%, which I accepted as being within the accuracy of fat testing. The error on the other 5% of the loads ranged from .1% to an extreme of .3%.

Following milkfat from truck to storage showed repeated differences of ± .1% with extremes as high as .3%. Deviations in fat tests in storage tanks very seldomly agreed with those shown from truck accounting. The causes for these deviations have never been answered to my satisfaction.
Following milk from storage tanks to vats showed the same phenomenon as truck accounting and storage accounting, except our deviations were at an average of .15% with extremes as high as .3%, once again revealing the frustration found previously.

Fat accounting failed to show conclusively why fat losses or gains occurred. On reflection, I feel we established as accurate a procedure as was possible for us to maintain. There are many possibilities for error in fat accounting and as some of you know, the list can go on forever.

Fat accounting on this level did not expose the reasons for the losses our company was experiencing, even though the approximately 5% of milk deliveries which showed abnormal fat losses did blend down the overall margins our plant needed. We also found total loads of milk (25,000 lbs. to 50,000 lbs.) which had fat ranges equal to the ranges found at the producer level. One would normally assume that a load of 50,000 lbs. of milk made up of 15 to 20 producers would average out to a fairly constant fat test from load to load. We found that this assumed average did not occur and that fat levels and total lbs. changed daily, but more significantly we found loads of milk with the same fat tests which varied by as much as .5 lbs. of cheese yield per cwt of milk.

We determined that it was necessary to treat each load of milk individually for payment price because values per cwt after manufacture varied extremely. We could no longer assume that our loads of milk would always yield constant, repeatable values based on the levels of butterfat in the milk.

By following and accounting for fat, we found that % butterfat in milk did not establish the value that 1 cwt of milk would be worth in finished cheese sold at the market level.
Once again we expanded our production sheets to reflect the flow of protein in the milk from the farm to the cheese vat. By purchasing one of the existing protein testing systems (dye binding method from Udy Instruments, Boulder, CO) we added the appropriate columns to our production records and began our research.

The same phenomenon that was found in fat accounting was found with protein accounting, only at half the error of fat. It is easier to maintain, store and handle milk samples for protein because of its tendency to stay suspended in the milk sample and not undergo the changes fat does, due to temp., churning of sample, etc.

Protein accounting did not reveal the cause of losses in conversion of 1 cwt of milk to finished cheese. Fat and protein retentions in cheese were not consistent with the rise and fall of fat and protein levels in milk. At this point I contacted Dr. C.A. Ernstrom to enlist his help in finding a procedure that would place proper values on incoming milk relative to the milk's value in cheese after manufacturing.

The result of this contact was that we incorporated a new pricing system into our operation beginning April 1, 1980. By knowing the levels of fat and protein in incoming milk we could predict cheese yields and therefore milk value. This new system necessitated that we buy a small computer to run the pricing programs which had been developed at USU.

Fat testing alone is not an accurate method of pricing milk. It became apparent to me that I could no longer assume that accounting for milk components would assure that margins per cwt of milk would be maintained. In short, I found that almost all of the traditional
assumptions I had learned to accept were not realities. It was obvious that my thinking had to be retrained and updated to the problems in the industry today, which could not be treated by industry standards of earlier years.

In a nutshell, I had placed too much confidence in too many accepted, traditional standards and supported them by too many traditional, accepted, safe answers. I think it proper to list some of the new questions that started to arise, as a spin off of our new pricing method. These questions and their answers started to expose the many ways I had fallen short in management, which had helped to bring about our economic problems.

I began asking myself questions such as:

1. How much milk have you purchased this year to date?

2. How much cheese do you get from 1 cwt of milk?

3. Are you getting the "right" amount of cheese per cwt of milk?

4. What is the "right" amount of cheese you should get from 1 cwt of milk?

5. Do milk tests always reflect changes in cheese yield?
   A. If so, why?  B. If not, why?

6. What is 1 cwt of milk worth in finished cheese?

7. What does it cost to convert 1 cwt of milk to finished cheese?

8. What price can I afford to pay for milk?

9. What is my net return on 1 cwt of milk?

10. What is my net loss on 1 cwt of milk?

11. If a loss, where is it?

12. Does our current milk pricing method reflect accurate values for milk?
   A. If so, why?  B. If not, why?
13. Can I maintain moisture levels in cheese at a given %?
14. How does moisture affect cheese yield?
15. Can I maintain accurate margins per cwt of milk?
   A. If so, why?  B. If not, why?
16. Is a moisture premium allowance a necessity for marketing cheese?
17. Does your quarterly financial statements answer the above questions?
   If so, how soon?  One month, six months, one year?
   Is this information current enough to make proper management decisions?
   If not, can I answer why?
   Is it possible to make statements current enough?

By becoming more aware of the many factors involved I also became aware that each one could influence our ability to maintain consistent margins. I had to develop a workable, consistent, honest and dependable system which would solve the problems at our plant.

The method used was very simple. When we received the laboratory results on the milk and cheese, we extended them to their $ equivalents by using our milk pricing model and our current cheese market values.

1. Cheese lbs x cheese price = $ value of cheese
2. Milk lbs x milk price = $ value of milk
3. $ value of cheese - $ value of milk = $ value of margins
4. $ value of margins / cwt of milk = margins per cwt

By using this method, we could determine on a vat by vat basis, the margins per cwt of milk in relation to fat, protein, moisture and type of cheese being manufactured. (We made some Monterey and Colby in small amounts for our cheese shop.) We could also follow margin changes occurring as these different variables changed.
The answers we received by this method began to show why our plant was in trouble. The problem was this simple: Margins varied from 30¢ per cwt to $1.70 per cwt from one load of milk to the next. It was amply demonstrated to me that margins per cwt of milk which I thought I was getting were wrong.

Our production analysis record was now expanded to show the lab results on cheese in moisture, fat and protein. I learned immediately that addition of these three components in cheese would not account for 100% of the cheese. There was a remainder present that fluctuated between 3.0% and 7.5%. It was determined from average cheese composition that 93.22% of cheese could be accounted for in moisture, fat and protein. The remaining 6.78% value was accepted by me as the value I would use to represent all other components in cheese.

Knowing the amount of cheese we were receiving from a given amount of milk, it was possible to determine what % of components in milk was being retained in cheese.

\[
\text{\% fat in cheese} \times \text{cheese lbs} = \text{lbs butterfat in cheese} \\
100.0\% - \% \text{moisture} - \% \text{fat} - 6.78 = \% \text{protein in cheese} \\
\text{\% protein in cheese} \times \text{cheese lbs} = \text{lbs protein in cheese}
\]

The lbs of fat and protein in cheese could be compared to the lbs of fat and protein in milk. Since our current milk pricing formula used % fat recovery and % protein recovery I determined to see what our recoveries were in fat, protein, moisture and trace components.

Fat recovery percentages ranged from a low of 84% to a high of 95% with the average at about 90.7%. Protein recovery ranged from a low of 72% to a high of 85% with the average at about 77.3%. Lactose, mineral,
ash and trace elements ranged from 3.0% to 7.5%, and cheese moistures ranged from 31.5% to 38.5% with the average at about 34.5%.

I found that margins change as a result of changes in fat, protein, moisture and trace components when a fixed, rigid pricing method is employed which doesn't adequately reflect these changes.

The following charts reflect economic conditions in relation to changing recoveries experienced on milk with changing components. The basis of these charts is milk priced on a fat differential formula using $12.80 per cwt on 3.5% fat levels and cheese values of $1.3825 per pound. Plant costs are $12.80 per cwt of milk. Cheese yield per cwt is determined at different recovery levels on the milk, incoming fat, protein, water and trace minerals by the following formula:

\[ y = \frac{\%RF \times F + \%RP \times P + RSNFP}{1 - W} \]

Where

- \( %RF \) = the percent fat in milk recovered in cheese
- \( %RP \) = the percent protein in milk recovered in cheese
- \( RSNFP \) = is a constant of 6.78%
- \( W \) = to the amount of water in cheese

Milk fat test is 3.5% and protein is 3.27%.

<table>
<thead>
<tr>
<th>Yield</th>
<th>%RF</th>
<th>%RP</th>
<th>%H₂O</th>
<th>Cheese Value ($)</th>
<th>Per Cwt Margin ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.825</td>
<td>.84</td>
<td>.773</td>
<td>.3800</td>
<td>13.583</td>
<td>4.783</td>
</tr>
<tr>
<td>10.203</td>
<td>.907</td>
<td>.773</td>
<td>.3800</td>
<td>14.106</td>
<td>1.306</td>
</tr>
<tr>
<td>10.277</td>
<td>.92</td>
<td>.773</td>
<td>.3800</td>
<td>14.207</td>
<td>1.408</td>
</tr>
</tbody>
</table>

Margins can fluctuate .625 cents per cwt on 8% fat recovery change.
PER CWT MARGINS AT DIFFERENT PROTEIN RECOVERIES

<table>
<thead>
<tr>
<th>Yield</th>
<th>%RF</th>
<th>%RP</th>
<th>%H₂O</th>
<th>Cheese Value ($)</th>
<th>Per Cwt Margin ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.930</td>
<td>90.7</td>
<td>.72</td>
<td>3800</td>
<td>13.728</td>
<td>.928</td>
</tr>
<tr>
<td>10.203</td>
<td>90.7</td>
<td>.773</td>
<td>3800</td>
<td>14.106</td>
<td>1.306</td>
</tr>
<tr>
<td>10.446</td>
<td>90.7</td>
<td>.82</td>
<td>3800</td>
<td>14.442</td>
<td>1.642</td>
</tr>
</tbody>
</table>

Margins can fluctuate .625 cents per cwt on 10% protein recovery change.

PER CWT MARGINS AT DIFFERENT % MOISTURE RECOVERIES

<table>
<thead>
<tr>
<th>Yield</th>
<th>%RF</th>
<th>%RP</th>
<th>%H₂O</th>
<th>Cheese Value ($)</th>
<th>Per Cwt Margin ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.235</td>
<td>90.7</td>
<td>77.3</td>
<td>31.5</td>
<td>12.767</td>
<td>-.330</td>
</tr>
<tr>
<td>9.962</td>
<td>90.7</td>
<td>77.3</td>
<td>36.5</td>
<td>13.772</td>
<td>-.972</td>
</tr>
<tr>
<td>10.286</td>
<td>90.7</td>
<td>77.3</td>
<td>38.5</td>
<td>14.220</td>
<td>1.420</td>
</tr>
</tbody>
</table>

Margins can fluctuate 1.750 cents per cwt on 7% moisture recovery change.

PER CWT MARGINS AT DIFFERENT % RECOVERY ON FAT, PROTEIN AND MOISTURE

<table>
<thead>
<tr>
<th>Yield</th>
<th>%RF</th>
<th>%RP</th>
<th>%H₂O</th>
<th>Cheese Value ($)</th>
<th>Per Cwt Margin ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.645</td>
<td>.84</td>
<td>.72</td>
<td>.315</td>
<td>11.952</td>
<td>-.848</td>
</tr>
<tr>
<td>10.122</td>
<td>.907</td>
<td>.773</td>
<td>.375</td>
<td>13.994</td>
<td>1.194</td>
</tr>
<tr>
<td>10.605</td>
<td>.92</td>
<td>.82</td>
<td>.385</td>
<td>14.661</td>
<td>1.861</td>
</tr>
</tbody>
</table>

Margins can fluctuate 2.709 cents per cwt when all recoveries go simultaneously from high to low.

By placing the majority of our research on milk procurement only our economic problems were not solved. It did show, however, the many possible combinations that milk components can assume and that their ability to always, by a repeatable %, become cheese wasn't realized. It also showed that sampling and testing must be very
carefully monitored for accuracy. When any problem is observed all components must be considered simultaneously.

The following is our current method of milk pricing.

\[(\text{yield} \times \text{cheese value}) - \text{conversion cost} = \text{break even point of milk cost}\]

Where conversion cost = year to date manufacturer cost divided by year to date milk purchase

Break even milk price = Maximum values that could be placed on milk

My directions have changed in that I place more emphasis on what I have to sell, because it is values received which dictates what I can pay for milk.

By testing cheese for fat and moisture and milk for fat and protein, the following equations can be used.

Cheese is evaluated for its component parts by the following rationale:

<table>
<thead>
<tr>
<th>Cheese (lbs)</th>
<th>Moisture (%)</th>
<th>Fat (%)</th>
<th>SNFM (%)</th>
<th>SNFPW (%)</th>
<th>Protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>35.0</td>
<td>33.0</td>
<td>32.0</td>
<td>6.78</td>
<td>25.22</td>
</tr>
</tbody>
</table>

The components determined in milk

<table>
<thead>
<tr>
<th>Milk (lbs)</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>3.6</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Yield

\[10 \text{ lbs cheese} = 10.0 \text{ lbs Cheese per cwt Milk}\]

\[\frac{100 \text{ lbs milk}}{10 \text{ lbs cheese}}\]

Determination of Fat and Protein Recovery

\[\frac{\text{Fat lbs Cheese 3.3}}{\text{Fat lbs Milk 3.6}} = 91.67\% \text{ Fat Recovery}\]

\[\frac{\text{Protein lbs Cheese 2.522}}{\text{Protein lbs Milk 3.3}} = 76.42\% \text{ Protein Recovery}\]
Trace Components of Cheese

SNFPW = 6.78

Yield Formula

\[ Y = \frac{(\% R) \text{ Fat} + (\% R) \text{ Protein} + 6.78}{100.0 - \text{Cheese Moisture}} \times \text{Actual Cheese lbs} \]

\[ \text{Actual Milk lbs} \]

I am aware that using a constant of 6.78% trace material in cheese as a constant has potential for error. Since this type of research is outside the capabilities at our factory, I will leave the accuracy of these numbers to those people and institutions that are better able to make these determinations. Any developments that come I will welcome wholeheartedly and make them an integral part of our operations.

Determination of cwt of milk's value in finished cheese

yield \times \text{cheese price} = \text{cwt value of milk in finished cheese}

By using the formula:

\[ (100.0 - \text{actual moisture}) \times \text{actual yield} = \text{yield at 38.0% moisture} \]

\[ .62 \]

It became relatively easy to follow the changing values of 1 cwt of milk to finished cheese and know these value changes were not the result of yield differences due to varying moisture levels in cheese.

The methods of accounting we were using did not lend themselves to the type of information I needed to run my operations. They were helpful for tax planning, budgeting etc., but outside these areas the only help I received was to know where I had been economically over the past quarter. Many of the problems I faced needed answers sooner than statements could be provided, plus the fact that it was not the nature of our accounting system to address these types of problems. I found it more unnerving than helpful to be made aware I was going broke.
My approach to the problem was to expand significantly our chart of accounts in the general ledger and develop more refined methods of allocating costs and to make this information available much sooner. By purchasing a small business computer and the appropriate software these problems were solved, in that we could provide accurate and current information with which to work. For example, we now have available:

1. Total company expenses allotted to manufacturing
2. Total milk lbs purchased year to date

Expenses year to date = cwt cost to convert milk to cheese
Milk cwt year to date

With the above information, it is possible for me to determine very accurately the break even point on milk cost. Thereby we can accurately maintain margins at predetermined levels and be made constantly aware of production costs, yield changes etc. Almost all information is made available in current report form which is needed to intelligently direct the activities of our company.

Due to the production records that were developed, it is possible to determine the actual % recoveries on each load of milk we receive. Over a 15 day procurement period on our own producer routes, averages of recoveries are quite easy to determine and diversion loads of milk are treated independently.

Our production records could be simplified by simply calculating total recoveries on all milk purchased on a 15 day basis and placing these values in the yield formula to calculate milk payments. But since some of our milk supply was showing deviations too far outside our plant average, our by load production records are maintained to assure proper payment is made on all milk sources.
At the end of a 15 day procurement period, the samples of milk (composites) are tested for fat, protein, plus the moisture levels on cheese on that exact milk, on each diversion load and every individual producer. These values are placed inside the yield formula to project the pounds of cheese derived from 1 cwt of milk from each source.

Example:

\[
y = \frac{(% \text{ R} \times \text{ Fat test}) + (% \text{ R} \times \text{ Protein}) + 6.78}{100.0 - \text{ Cheese moisture}}
\]

<table>
<thead>
<tr>
<th>Lab Reports</th>
<th>Milk (By load, pay period or year to date)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer No.</td>
<td>lbs Milk</td>
</tr>
<tr>
<td>1</td>
<td>5,000</td>
</tr>
<tr>
<td>2</td>
<td>3,000</td>
</tr>
<tr>
<td>3</td>
<td>2,500</td>
</tr>
<tr>
<td>4</td>
<td>4,300</td>
</tr>
<tr>
<td>5</td>
<td>6,000</td>
</tr>
<tr>
<td>6</td>
<td>4,200</td>
</tr>
<tr>
<td></td>
<td>25,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lab Reports Cheese (By vat, pay period or year to date)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vat %</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

Receiving Invoice

<table>
<thead>
<tr>
<th>25,000 lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab results Milk</td>
</tr>
<tr>
<td>Lab results Cheese</td>
</tr>
</tbody>
</table>

Constant 6.78
% Recoveries

Fat 91.67  Protein 76.42

\[ y = \frac{91.67 \times 3.6 + 76.42 \times 3.3 + 6.78}{.65} \]

\[ y: = 9.999 \quad \text{actual yield} = 9.999 \]

Now 9.999 x 1.3825 Cheese Price = $13.82 value of 1 cwt milk in cheese

Assuming conversion cost of $1.20 per cwt

$13.82 cwt value - $1.20 conversion = $12.62 break even point

$12.62 Break even point = $1.2621 per cwt milk cheese as (cheese yield value)

Individual Producer yield x cheese yield value = cwt payment on milk

9.999 \times 1.2621 = \$12.62 per cwt

Pay Roll Report (By day, pay period or year to date)

<table>
<thead>
<tr>
<th>Prod No.</th>
<th>lbs milk</th>
<th>F test</th>
<th>P.test yield</th>
<th>cheese yield value</th>
<th>cwt val.</th>
<th>$ payment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5,000</td>
<td>3.7</td>
<td>3.4</td>
<td>10.260</td>
<td>1.2621</td>
<td>12.95</td>
</tr>
<tr>
<td>2</td>
<td>3,000</td>
<td>3.5</td>
<td>3.2</td>
<td>9.743</td>
<td>1.2621</td>
<td>12.30</td>
</tr>
<tr>
<td>3</td>
<td>2,500</td>
<td>4.15</td>
<td>3.85</td>
<td>11.424</td>
<td>1.2621</td>
<td>14.42</td>
</tr>
<tr>
<td>4</td>
<td>4,300</td>
<td>3.5</td>
<td>3.2</td>
<td>9.743</td>
<td>1.2621</td>
<td>12.30</td>
</tr>
<tr>
<td>5</td>
<td>6,000</td>
<td>3.4</td>
<td>3.1</td>
<td>9.484</td>
<td>1.2621</td>
<td>11.97</td>
</tr>
<tr>
<td>6</td>
<td>4,200</td>
<td>3.6</td>
<td>3.3</td>
<td>10.000</td>
<td>1.2621</td>
<td>12.62</td>
</tr>
<tr>
<td></td>
<td>25,000</td>
<td>3.6</td>
<td>3.3</td>
<td></td>
<td>12.62</td>
<td>3,154.14</td>
</tr>
</tbody>
</table>

Cheese 2,499.9 x $1.3825 = $3456.11

Milk 25,000/100 x $12.616 = $3154.14

Margin on Load $301.97

$301.97 Load Margin = $1.208 Margin per cwt Conversion cost $1.20

25,000 Milk lbs

Some Final Observations

1. Using cheese recovery as a necessary part of milk pricing has provided me with a 15 day report form that has proven helpful in
evaluating current manufacturing practices and seasonal trends, plus the ability to maintain plant margins.

2. Current values on milk were made available on a 15 day period showing the rise and fall of milk components and their direct effect on plant margins.

3. Calculating recoveries on milk purchases greatly reduced the errors that are possible in sampling and testing milk and cheese, making it possible to control plant margins more effectively.

4. The yield pricing formula made it possible to pay for milk more equitably for its contribution to our system and showed us which types of milk made the greatest contribution.

5. Determining the value of 1 cwt of milk in finished cheese showed us immediately when values began to rise and fall and by comparison to our other data it helped to show which individual producer, milk source, etc. appeared to be responsible.

6. The placing of more emphasis on manufacturing and maintaining this value as a constant costs helped greatly in evaluating decisions concerning investments, scheduling, interest, labor cost, budgeting, etc.

7. By knowing what 1 cwt of milk was worth at the market level, plus knowing what costs were incurred in getting it there, I knew $ amount I could pay for milk. Is it inherently more honest to assume that the income any pricing scheme generates will cover all costs and profit, thereby always being able to pay the maximum amount possible for milk? Eventually all costs and a profit must be paid for if operations are to continue.

A parting note from an old cheese manual of my father's:
"In spite of all scientific and technical advance, cheese making has remained essentially a matter of experience — an art. The practice of an art requires a flair for that art.

In the first place, the cheese maker must be possessed of sufficient general talent to enable him to grasp somewhat difficult matters and to absorb technical scientific instruction. In the second place, he must have the ability to **observe** well and to remember his observations accurately. Furthermore, a certain knack for his occupation is very profitable, this knack will, to a certain extent, enable him to pick the right way through knotty problems. But all his natural aptitudes will be of no avail apart from **great diligence**. The words of the poet Fontane apply to some extent to the occupation of cheese making: "Aptitudes, native to all; talents, a plaything for children. Earnestness only makes one a man, and diligence genius."

Many a cheese maker is lucky and gets into a set-up where the means for producing and delivering milk are well arranged and where high quality cheese can be produced according to a technique acquired by practice. This luck, however, is deceptive and remains relatively faithful, even in cheese making, only to the informed and diligent man. Very often luck turns aside and makes even the experienced and the diligent cheese maker realize that he has not learned everything yet and may not plume himself on his superior art too much.

If, in spite of all care and diligence, a cheese goes wrong, the cheese maker should not lose his head. He must search after the causes with a clear mind and sustained attentiveness and get advice and help from cheese makers and experts who are scientifically informed. He must also get the follow-up procedures clearly in mind and constantly observe
all the circumstances which can have an influence on his business of making cheese."

At this point I would like to thank publicly, Dr. Tony Ernstrom for exposing me to this method of pricing milk and to let you know that our small factory could very well be insolvent by now if this information had not been known. Even though I used it somewhat differently because the needs were uniquely different, our current solutions would not have been possible without his help and the help of Dr. Rodney Brown, in that they gave their sincere, applied efforts on all occasions, to help a small factory in Montana.
### GLACIER MOUNTAIN CHEESE CO.

**Instructions:**

<table>
<thead>
<tr>
<th>Prod No.</th>
<th>Storage Tank</th>
<th>Milk Pounds</th>
<th>B.F. Test</th>
<th>B.F. Hours</th>
<th>Cryo Test</th>
<th>Protein Test</th>
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<td>151.2</td>
<td></td>
<td>3.3</td>
<td>128.6</td>
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</table>

| 8        |              | 25,000      | 3.597     | 899.4      | 3.298     | 824.5        |                        |

| 9        |              |            |           |            |           |              |                        |
| 10       |              |            |           |            |           |              |                        |
| 11       |              |            |           |            |           |              |                        |
| 12       |              |            |           |            |           |              |                        |
| 13       |              |            |           |            |           |              |                        |
| 14       |              |            |           |            |           |              |                        |
| 15       |              |            |           |            |           |              |                        |
| 16       |              |            |           |            |           |              |                        |
| 17       |              |            |           |            |           |              |                        |
| 18       |              |            |           |            |           |              |                        |
| 19       |              |            |           |            |           |              |                        |

**Note 1**

- **Date:** 0-30-82

**Bottling Inc.**

### Table

|---------|---------------|------------------|-----------------|------------------|--------------------|-----------------|-----------------|------------------------|
APPENDIX

Column 1 is the identification number of the producer or surplus load of milk being received. Column 2 represents the storage tank the milk was transferred to. Column 3 lists the producer invoice pounds of milk purchased at the farm or surplus milk billing from the plant of origin. Column 4 contains the producer or load butterfat tests determined by the Babcock method from the samples of milk brought as representative of milk purchased.

The procedure we used in taking truck samples was such that the sample would accurately represent the co-mingled volume contained in the truck. The driver was instructed after completing his loading procedure at his last pick up to reverse his pump and transfer milk back into the farm tank (approx. 50-100 gallons) then repump back into the truck. When the farmer tank was empty, the process was repeated and the sample for the truck was taken from the milk repumped into the farm tank. Any other method we used at that time did not compare favorably with the above method. We are currently using (Pro-Rata Line Sampler from Liquid Sampling Systems, Inc.).

At least 15 minutes after unloading of the truck storage tank samples were taken and kept under constant agitation to be sure that the sample would represent the milk in storage.
ADVANCES IN UF FOR PRODUCTION OF CHEESE-BASE, MOZZARELLA AND FETA CHEESE

(Address for Presentation at the 5th Biennial Cheese Industry Conference, Utah State University, USA, September 1982)

by

P. Bjerre, PASILAC A/S, DK-8600 Silkeborg, Denmark
(General Dairy Equipment, Minneapolis, Division of PASILAC A/S)
The first scientific works with production of cheeses by means of UF-technique were made at the end of the 1960's. In 1969 an application was made in France for a procedure for the production of cheese based on UF-technique.

The so-called M.M.V. patent indicates that by use of ultrafiltration a retentate is produced which, as far as fat, protein and ashes are concerned, has a composition that is identical to what is wanted in the cheese. Further the lactose content of the retentate has to be adjusted according to the buffer capacity of the retentate so that the pH will be as desired after a bacteriological acidification. The retentate thus produced is called "fluid pre-cheese" as a consequence of the fact that only rennet has to be added to the product in order to be transformed into cheese.

The advantage by using this technique in cheese production is that theoretically approx. 20% more cheese can be produced of the same milk quantity as the contents of the milk of whey proteins are not lost in the whey like in traditional production, but are retained in the retentate, i.e. in the cheese.

An extra yield of 20% should mean that there is basis of a very fast change of the production technique from conventional technique to UF-technique. However, as now 10-15 years later, worldwide, only limited quantities of cheese are produced by UF-technique there are several reasons for this.

1. Legislation.
2. The quality of the UF-systems.
1. Legislation

The legislations of the single countries vary, but the legislation will not become an obstacle to the UF-technique.

2. The Quality of the UF-Systems

Since the early 1970's many changes of the quality of the UF-plants have taken place, both as regards chemical resistancy, and design, consumption of power and capacity. Today there is equipment of different manufacture suitable for production of fluid pre-cheese. The limitations of the plants lie in the fact that as a consequence of the increasing viscosity of the retentate with increasing total solids contents only skim milk retentate with 18-20% protein or whole milk retentate with 34-38% total solids can be produced. This had the consequence that the UF-technique could only be used for soft types of cheese like camembert and feta. If you want to produce cheeses with a higher content of total solids, you have to use a combination of UF-technique and evaporation. DDS-PASILAC have now developed and marketed an ultrafiltration module, the so-called module 37 which makes production of skim milk retentate with over 30% protein and whole milk retentate with 50% TS possible.

The development of this module means that it is now possible to produce cheeses with a high total solids content, mozzarella by means of UF-technique, e.g. Further this new module is suitable for ultrafiltration of acidified milk.

Traditional cheese production is based on experiences of centuries. Therefore it is not surprising that a new production technique cannot prolong the traditional technique completely or partly in a few years. During the latest years a lot of literature has been published concerning UF-curdling technique which has the consequence that more and more products can be produced with a satisfactory product quality.

The cheeses and cheese-like products which can be produced today by means of UF-technique are a.o.: Quark, Feta, Queso Fresco, Cheese Base, Mozzarella etc.

Quark

Quark is an unripened fresh cheese (17.5% total solids) which a.o.t. is very popular in Germany. Quark is produced by separating acidified skimmilk (pH 4.6) in whey and quark in a special quark separator. For many years it has been tried to produce this product by UF-technique, skimmilk was ultrafiltrated to the wanted total solids content, and after pasteurization the retentate was acidified bacteriologically. The result has always been negative as in a few days the product started to develop an off-flavour. The reason for this off-flavour has not been established with certainty, but it is probably due to the increased Ca-content of the product which appears by the milk being ultrafiltrated, i.e. concentrated in unacidified state.
By using DDS/PASILAC module 37 in which it is now possible to ultrafiltrate acidified milk it is now possible to produce quark with a quality which is fully up to the standards of traditionally produced quark.

The production is the following: Pasteurized skimmilk acidified bacteriologically with a mesofile starter, and the next day when this is acidified the coagulum is stirred, and after heating to 50 deg.C the acidified milk is ultrafiltrated. The retentate which contains 18% total solids is cooled and packed. If a fatty quark is to be produced the retentate is mixed with the necessary cream before cooling.

Feta Production

Feta is a so-called white cheese and traditionally produced from goat's milk. The cheese contains min. 43% total solids of which 3% is salt. The fat contents are normally 40% in total solids.

The cheese is packed in tins containing approx. 38 lbs cheese excl. the brine in which the cheeses are kept.

Since 1975 the Feta cheese has been produced on the basis on UF-technique, and in 1981 the Danish Feta production amounted to approx. 70,000 t. In the largest production units up to 120,000 gall. of milk are treated daily.

The course of production is like this: The whole milk is pasteurized and homogenized before the ultrafiltration (1:5) to approx. 38% to-
tal solids. The produced retentate is re-pasteurized and cooled to the acidification temperature which is approx. 25 deg.C. Lipase and starter are added, and after a pre-culturing of approx. 1 hour a mixture of rennet, brine and retentate are dosed in the sales packing, the previously mentioned tin. The tins are filled in 3 turns with an interval of 30 minutes. The reason is that hereby you will get 3 layers of individually coagulated retentate. By the following syneresis 3 separate layers of cheeses will be made. When the last retentate filled in has coagulated, 2 or 3 horizontal cuts are made perpendicularly to each other through the retentate. In this way the contents of the tin are divided in the wanted number of cheeses. After this dry salt is filled in which in connection with the whey made following syneresis makes the brine in which the cheese is to be kept. After salting the tin is closed and packed. After a short storing the cheese is ready for shipment.

The theoretical extra yield at this production method compared to traditional production is approx. 18%. However, in practice the extra yield is between 25 and 30%. The explanation is partly that the direct production losses are diminutive, and partly that exactly the quantity of retentate, i.e. the quantity of total solids required for 1 tin of cheese is measured.
The need for manual manpower is reduced to a minimum, namely:

1. Supervision of the UF-plant and the retentate treatment plant.
2. Measuring of retentate, rennet and mixing of this.
3. Cutting of coagulated retentate, salting and packing.

With manually operated plants 3-4 persons are sufficient, but in most cases measuring of retentate and rennet, mixing and the cutting of the coagulated retentate is automated. In that case the need for manpower is reduced to 2 persons.

The quality of the cheese thus produced is very high and homogeneous. The best proof of this is the increasing sales figures for this cheese.

Cheese-Base

In 1980, Ernstrom described a cheese-like product, cheese-base, and a suitable production method. This method has been improved upon at the developmental dairy in Nr. Vium in order to make the method practically applicable for the dairy industry with respect to product quality as well as the production method itself.

As cheese-base is to be used as a raw material in the production of processed cheese, the product must satisfy the requirements made for the cheese used in processed cheese production, that is, cheddar cheese:

- Fat in dry matter ................ min. 50%
- Water content ...................... max. 39%
- pH ..................................... 5.2
By using the UF-technique, 19% more cheese-base can be produced than cheddar cheese from the same amount of milk, provided that the fat content is correspondingly higher.

The initial milk is pasteurized, and standardized to 3.8% fat dependent on the milk's protein content in order to give the cheese-base the desired fat content. The pasteurization is carried out at 72°C for 15 seconds. After being cooled to 50°C, the milk is conveyed to the continuous UF-plant.

The ultrafiltration is carried out as a diafiltration, that is, the UF-plant is divided up into 3 zones with the following functions:

Zone 1: Preconcentration in common ultrafiltration to a dry matter content of 30%.

Zone 2: Continued ultrafiltration but with the simultaneous addition of water. This process is called diafiltration. It is meant to reduce the retentate's content of lactose by leaching in order to attain the correct balance between the retentate's buffer capacity and its content of lactose which guarantees that a subsequent bacteriological acidification will result in a final pH of 5.2.

Zone 3: Final concentration in common ultrafiltration to a dry matter content of 40%.
After repasteurization of the retentate at $72^\circ C$ for 15 seconds, it is cooled to the acidification temperature and 1% cheddar culture is added. After 1-2 hours preculturing the retentate is pumped to the evaporator. The evaporation is carried out on a swept surface evaporator. A Niro Atomizer evaporator is used in the experiments. The evaporation takes place in a 91% vacuum, that is, an evaporation temperature of $43^\circ C$, until a dry matter content of 60% TS is attained.

The cheese-base is pumped directly from the evaporator to the sales packaging. In our experiments this packaging has consisted of plastic buckets with a cubic content of 7 kg for practical reasons, but they could just as well have been 25 kg boxes or something else. As the culturing process of the cheese-base is to be finished in the sales packings, the product is stored for 2 days at room temperature before transfer to cooling room at 4-5°C.

Cheese-base has a pure, acidified taste without the typical cheese taste. An analysis of the product, the initial milk and the retentate shows the following:

<table>
<thead>
<tr>
<th></th>
<th>full-cream milk</th>
<th>retentate</th>
<th>cheese-base</th>
</tr>
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<tbody>
<tr>
<td>dry matter</td>
<td>12.56</td>
<td>39.9</td>
<td>60.1</td>
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<tr>
<td>fat</td>
<td>3.8</td>
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<td>30.1</td>
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<tr>
<td>protein</td>
<td>3.38</td>
<td>16.7</td>
<td>25.7</td>
</tr>
<tr>
<td>ash</td>
<td>0.79</td>
<td></td>
<td>3.9</td>
</tr>
</tbody>
</table>
From a bacteriological point of view, the product has met the requirements.

Based on different mixtures of cheese-base and stored cheddar, various types of processed cheese-spreads have been produced with good results.

Here below is a comparative economy for traditionally produced cheddar and cheese-base.

Standards for cheddar: min. 50% fat in dry matter – max. 39% water.

Per 100 lbs cheese/cheese base:
Dry matter .................. 61.5% = 61.5 lbs
    fat = 50.5% = 31.05 lbs
    salt = 1.5% = 1.50 -
    f.f.m.t. 28.95 -
    in all 61.50 lbs
Water ....................... 38.5% = 38.50 -
In all ....................... 100.00 lbs

Per 100 lbs skimmilk skimmilk cheddar cheese-base
Protein .................... 3.4 lbs 2.60 lbs 3.10 lbs
Lactose .................... 4.7 -
Mineral + acids .......... 1.0 - 0.50 - 0.60 -
f.f.m.t. .................... 9.1 lbs 3.10 lbs 3.70 lbs
Consumption per 100 lbs cheddar or cheddar-base incl. milk-fat

<table>
<thead>
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<th>cheese-base</th>
<th>saved/100 lbs</th>
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<tr>
<td>kg skim milk</td>
<td>933.90</td>
<td>782.40 lbs</td>
<td>151.50 lbs</td>
</tr>
<tr>
<td>kg butter-fat</td>
<td>31.55</td>
<td>31.05 -</td>
<td>0.50 -</td>
</tr>
<tr>
<td>kg full-cream milk</td>
<td>965.45 lbs</td>
<td>813.45 lbs</td>
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</tr>
</tbody>
</table>

% fat in full-cream milk 3.27% 3.82%

\*0.05% fat in separated whey.

Product milk saved in the production of cheese-base = 16.2%. Saved butter-fat 1.5%.

Introduction of a new production method also results in revised consumption values for electricity, steam, work hours and special consumption materials which in the case of ultrafiltration mean membranes.

The revised consumption values are per 1000 lbs produced cheese-base:

**Savings:**
1515 lbs milk
5 - butter-fat

**Extras:**
Electricity 160 kWh
Steam 500 lbs
Membranes etc. 12 US doll.

**Advantages:**
Constant chemical composition of the product.
Reduced product loss on floors.
Continuous product flow.
Mozzarella

Today this cheese can be produced by means of UF-technique, and with a quality that fulfills the demands for the stretching, structure, brown colouring and melting down properties by baking of pizzas. However, the right cheese, i.e. a cheese with the wanted total solids content could not be produced until after UF module 37 had been developed. The production method is like this: Pasteurized skimmilk is acidified chemically to pH 6.0 after which the milk is diafiltrated with NaCl solution. The purpose of this way of ultrafiltration is partly to give the retentate a salt content, but also to reduce the Ca-content of the retentate as an ion change of the Ca-content and the Na-content takes place. The retentate thus produced which has a protein content of approx. 34%, and a total solids content of 38% is after this mixed with pasteurized cream with a fat content of 70%. After this 1% starter is added to the pre-cheese. When pH has been lowered to 5.3, retentate and rennet are dosed and mixed. The mixture is coagulated in a number of small containers (approx. 25 lbs). Then the coagulated pre-cheese can go through the traditional mozzarella process.

In order to test both module 37 and the mozzarella process in practice we have built up a production plant in a Danish dairy with a production per hour of 1900 kg (4000 lbs) skimmilk. The test results at the plant have been satisfactory, but naturally it has been necessary to make certain adjustments, but we hope to be able to start
a daily production of mozzarella cheese very soon.

The theoretical extra yield is identical to the yield indicated for cheese-base.

Final Remarks

Today world-wide at many research stations research works are increasing the knowledge that is necessary to produce cheese and cheese products by means of UF-technique.

The knowledge thus created has the effect that the new production technique will spread widely in the years to come.

The prospect of the future cheese production shows that the UF-production technique will develop in 2 directions:

A. Total concentration by means of ultrafiltration and evaporation.
B. Pre-concentration.

A. Total Concentration

This procedure will be used for production of new products like cheese-base, e.g. Further the method will be used for the production of copies of well-known products. An example of this is the mentioned ultrafeta. This does not mean, that ultrafeta is inferior to the feta produced traditionally. Today there are countries in which the ultrafeta is appreciated more than the one produced traditionally. A contributory cause for this is a.o.t. that the
quality of the ultrafeta is better, more homogeneous in quality than cheese produced traditionally.

B. Preconcentration

The preconcentration most mentioned in literature deals with a 1:2 concentration of the milk before a traditional cheese making process. An indication of the obtained extra yield by such a production method varies from 0 to 4%. Production tests with cheddar that Pasilac has made in cooperation with a cheddar producer shows with certainty an extra yield of 3.5%. The quality of the produced test cheeses is fully satisfactory.

The production method which in my own opinion will be that of the future when you want to produce a cheese identical to the one which is produced traditionally will be the following:

The pasteurized and standardized whole milk as regards fat is ultrafiltrated and diafiltrated. The total solids content has to be so that out of 2 lbs retentate 1 lb of cheese and 1 lb of whey are produced. The produced retentate is mixed continuously with starter and rennet and is then led through a continuous coagulation system. When the coagulum leaves the coagulator this passes a cutting device which cuts the coagulum into cheese grains. These cheese grains then have to go through an aftertreatment after which they are transported to a traditional process, a cheddaring process, e.g.

This means that the future cheese factories for continuous production and for traditional cheeses will contain the following equipment:
UF-plant, plant for mixing of retentate, starter and rennet, an automatic coagulator, a cutting system for cheese curd, an after-treatment plant for cheese grains, and a traditional aftertreatment equipment.

The extra yield at such a production will be lower than by total concentration, namely between 10 and 15%.

Plants as described are today in operation in Denmark for production of structured feta cheese for areas in which a traditionally produced feta cheese was prefered.

Silkeborg, 19.08.82
334-P Bj/1h
Direct Casein Analysis of Milk for use in Cheese Yield Milk Pricing

Rodney J. Brown

Most of the U.S. cheese industry purchases milk on the basis of pricing formulas similar to those established by the Federal Milk Market Administration or by state departments of agriculture. These formulas recognize milk as having a value which is dependent on its fat content, or in some cases, its fat and total solids content. They do not reflect the value of milk as it is used in the cheese industry.

The situation has not always been as it is now. Originally milk was sold strictly by volume. Then, in the 1890's, it became possible to test producers' milk for fat and pay for it accordingly. During the early part of this century milk produced during the flush season was separated and the cream made into butter for sale during the rest of the year. Since the skim milk had little value, butter was able to stabilize the price of milk throughout the year.

Many people gradually became accustomed to margarine and milk fat lost its ability to absorb all of the value of milk. In an effort to shift part of the value of milk to the serum, pricing programs were instituted based on a standard value per cwt for milk testing 3.5% fat with a fat differential that was added or subtracted for each 0.1% above or below 3.5% (Bergman et al., 1949). Fraker and Hardin (1942) said, "Until some practical method is devised for independent measurement of the solids-not-fat or the casein content of milk when making purchases from individual producers, it is believed that the relationships with fat...will need to be used as a basis for payment." Fat Differential Pricing
seems to have served the fluid milk industry well since the public has not been willing to pay a premium for extra solids-not-fat in their milk. It has not served the manufacturing industry very well, and has created particular problems for the cheese industry.

Cheese makers recognize that yields are dependent on the casein in milk as well as the fat. When related to the amount of cheese which can be made from milk of different compositions, Fat Differential Pricing pays too little for milk with high cheese yielding capacity and too much for milk containing lower levels of cheese solids. It is not uncommon for cheese plants to pay more for low solids milk than the total value of the finished cheese made from that milk. This inequity is balanced by paying too little for high cheese yielding milk from another source.

Changes in the milk being produced indicate that dairy farmers have responded to the pricing system by producing larger volumes of lower solids milk. They will continue to do this unless a price incentive toward higher solids milk is provided. With nearly one-third of all milk produced now going into cheese, fluid milk cannot no longer be the sole dictator of milk value. Cheese production cannot remain profitable under a pricing system which unfairly penalizes those dairymen who produce milk which is best suited for cheese.

Numerous suggestions have been made for Component Pricing of milk based on fat, protein, solids-not-fat, etc. (Brog, 1969; Brog, 1979; Ladd and Dunn, 1979). These programs have had limited success because of the difficulty of establishing values for each component or group of components in milk. It is easy to say what one pound of
cheese or one gallon of milk is worth. It is worth what it can be sold for. It is very difficult to determine what fat, protein and solids-not-fat each contribute to the total value of the product.

Table 1 shows an example of what happens to prices based on a Fat Differential system when milk is diluted with water. In this example 10 pounds of water is worth $ .64 if added to milk. This is not intended to imply intentional addition of water to a tank of milk, but to show the bias of this pricing structure in favor of low solids milk. Notice that the cost of enough milk to make one pound of cheese increased from $1.25 to $1.32 as the % fat and % protein decreased by less than 10%. Under this pricing system all efforts by

| Lbs Milk | 100 | 100 |
| Lbs Water | 10 |
| Total Milk | 100 | 100 |
| % Fat | 3.5 | 3.18 |
| % Protein | 3.2 | 2.91 |
| Lbs Cheese / cwt Milk | 9.75 | Add 10 Lbs Water | 8.86 |
| Total Lbs Cheese | 9.75 | 9.75 |
| Price / cwt Milk$ | $12.19 | $11.67 |
| Total Price | $12.19 | $12.83 |
| Milk Price / Lb Cheese | $1.25 | $1.32 |

$12.19 base price, $ .15 differential
producers to increase fat or protein percentages in their milk are rewarded with lower prices.

One pricing program which is being successfully used was first suggested by Dr. Ernstrom (1980). Rather than trying to determine values for the individual components of milk, price is based on the cheese yielding ability of milk. The basis of this program is the well known Van Slyke and Price (1949) yield formula for Cheddar cheese:

$$Y_c = \frac{.93 F + C - .1}{1 - W} 1.09$$

where

- $Y$ = Pounds of cheese per cwt of milk
- $F$ = % fat in the milk
- $C$ = % casein in the milk
- $W$ = Pounds of water per pound of cheese

This formula assumes that 93% of the fat in milk is recovered as cheese and that all of the casein except 0.1% is recovered. Other solids including added salt equal 9% of the casein and fat in the cheese. Yield is also affected by cheese moisture which is included in the formula. By determining fat and casein percentages in milk and using this formula the cheese yielding value of milk can be determined on a constant moisture basis before cheese is made.

Many cheese plants report that their fat recoveries are closer to 90% than 93% (Barbano and Sherbon, 1980). A study we have just completed using a large number of careful measurements of cheese yield and moisture along with percentages of milk fat and protein shows that at least one cheese plant is making cheese with exactly 93% fat recovery. The formula can be adjusted to whatever the
recovery is in the plant.

A direct test for casein which is fast and reliable enough to use in pricing milk is not yet available. By calling 78% of the protein casein (Cerbulius and Farrell, 1975) we can adjust the formula and still predict cheese yield.

\[ Y = \left( 0.90F + 0.78P - 0.1 \right) \left( 1.09 \right) \]

where

\[ P = \% \text{ protein in the milk} \]

Casein, as a percentage of total protein, varies from cow to cow and from breed to breed (Blake et al., 1980). It is also recognized that mastitis and other factors can cause a change in casein content of milk in comparison with other milk proteins. It is remarkable how well the Van Slyke and Price formula works, even when modified to use an estimate for casein rather than direct measurement.

A direct test for casein that could be run on producer milk is badly needed. But before talking about direct testing for casein, we will look at how Cheese Yield Pricing works using protein testing and this modified formula. If a plant sells cheese for $1.37 per pound and it costs $0.12 per pound to run the plant, pay the workers, etc. and still make a profit the milk in each pound of cheese must be worth $1.25.

\[
\begin{align*}
$1.37 & \quad \text{Cheese Value} \\
-0.12 & \quad \text{Operating Costs} \\
$1.25 & \quad \text{Cheese Yield Value}
\end{align*}
\]

Milk with 3.5% fat and 3.2% protein would produce 9.75 pounds of 38% moisture cheese per cwt of milk. This milk would be worth $12.19 per cwt.
$ 1.15  Cheese Yield Value
x 9.75  Cheese Yield per cwt Milk
$12.19  Cheese Value per cwt of Milk

As long as the protein content of milk is high enough to allow utilization of the fat in cheese, the milk value is established strictly by the cheese yield formula. If the fat content of milk is too high compared to protein, a larger amount of fat is lost in the whey. A casein/fat ratio of .70 (approximately .90 protein/fat ratio) is near ideal for 50% fat in the dry matter Cheddar cheese. When the fat content exceeds the appropriate protein/fat ratio some of this excess fat is paid for at an excess fat price. For example, milk with 4.3% fat and 3.2% protein would be adjusted to 3.9% fat, leaving 0.4 pounds of excess fat per cwt of milk. At $1.40 per pound the excess fat is worth $ .56. The yield if 38% moisture cheese from 100 pounds of 3.9% fat and 3.2% protein milk would be 10.38 pounds. The value of this milk, at $1.25 cheese yield value, would be $12.98. The total milk value would be $ .56 plus $12.98 or $13.54.

<table>
<thead>
<tr>
<th>4.3%</th>
<th>Fat (in milk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 3.9%</td>
<td>Fat (adjusted to match protein)</td>
</tr>
<tr>
<td>.4%</td>
<td>Excess Fat</td>
</tr>
</tbody>
</table>

$ 1.40  Extra Fat Value
x .4    Pounds Excess Fat per cwt Milk
$ .56   Extra Fat Value per cwt Milk
$ 1.25 Cheese Yield Value
x10.38 Cheese Yield per cwt Milk
$12.98 Cheese Value per cwt Milk

$12.98 Cheese Value per cwt Milk
.56 Extra Fat Value per cwt Milk
$13.54 Total Value per cwt Milk

Under present market circumstances it is profitable to market as much fat as possible in cheese. Adjusting the fat to give a casein/fat ratio of .64 gives about 55 - 56% fat in the dry matter of cheese. It is probably not advisable to exceed this level unless you are making low moisture cheese. Each plant must decide the maximum percentage of fat in the dry matter they will allow.

Table 2. The effect of milk solids on Cheese Yield Pricing.

<table>
<thead>
<tr>
<th>Lbs Milk</th>
<th>100</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lbs Water</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Total Milk</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>% Fat</td>
<td>3.5</td>
<td>3.18</td>
</tr>
<tr>
<td>% Protein</td>
<td>3.2</td>
<td>2.91</td>
</tr>
<tr>
<td>Lbs Cheese / cwt Milk</td>
<td>9.75</td>
<td>Add 10 Lbs Water</td>
</tr>
<tr>
<td>Total Lbs Cheese</td>
<td>9.75</td>
<td></td>
</tr>
<tr>
<td>Price / cwt Milk&lt;sup&gt;1&lt;/sup&gt;</td>
<td>$12.19</td>
<td>$11.08</td>
</tr>
<tr>
<td>Total Price</td>
<td>$12.19</td>
<td>$12.19</td>
</tr>
<tr>
<td>Milk Price / Lb Cheese</td>
<td>$ 1.25</td>
<td>$ 1.25</td>
</tr>
</tbody>
</table>

<sup>1</sup>$1.25 Cheese Yield Value
The example shown in Table 1 can now be reevaluated using Cheese Yield Pricing. This is shown in Table 2. The 10 pounds of extra water which was worth $ .64 with Fat Differential Pricing is now worth nothing. Availability of water does not change the cost of enough milk to make a pound of cheese. Furthermore, any increase in fat or protein will now be rewarded with an increase in milk price.

We have recently used some computer techniques which were not available when the original formula for Cheddar cheese was developed to find equations for Swiss and Mozzarella cheese.

\[
Y_S = \frac{.77 F + .78 P - .2}{1 - W} \times 1.1
\]

\[
Y_M = \frac{.88 F + .78 P - .02}{1 - W} \times 1.12
\]

The Swiss formula was developed at a single plant from about 80 vats of cheese over a one year period. Several other forms of equations were tried, but none of them improved over the Van Slyke and Price type equation. The Mozzarella formula was developed at a different plant based on a larger number of samples, but over only a one month time period. These formulas have not been tested as extensively as the Cheddar formula, but we are confident that they give reliable estimates of yields.

All of the formulas mentioned here have one serious fault. We are saying that casein always represents 78% of the total protein in milk. The reason we say this, knowing all the time that it is not true, is that we cannot test for casein like we do for total milk protein. The largest contribution to errors in yield prediction is the estimation rather than measurement of casein.

We are now trying to develop a direct casein test which will
capable of operating with presently available milk testing instruments. The concept we are using is very simple. A column is filled with very small glass beads which are full of uniform diameter holes. The glass is chemically coated so that protein will not stick to it. As milk is passed through the column the small molecules, such as whey proteins, are slowed down by the holes. Larger molecules, such as casein micelles, pass through faster because they are too large to fit into the holes.

![Figure 1. Separation of casein from other milk components](image-url)
We have succeeded in selecting beads with pores of the proper diameter to separate casein from whey proteins. Figure 1 is an example of such a separation. The casein can be collected and measured as any protein would be on any of the instruments now being used in plants. We are optimistic about the prospects of merging this method into one or more of the instruments now in use for measuring protein.

Since the output of dairy processing plants includes many different products, each of which demands its own price in the market place, we have expanded Cheese Yield Pricing to include other products. With the analytical and computer technology now available values can be allotted to milk based on several different products at the same time. This whole pricing concept is called End Product Pricing, and such a system is now being used by many cheese factories and at least one butter-powder plant. It is a workable system which cannot be compared with previously proposed Component Pricing systems. Judging from the rate at which plants are adopting End Product Pricing, it will have a significant impact on milk pricing in the future. Addition of a useable casein test for cheese plants will make it even more attractive.
References


Liquipure Systems, Inc., has been totally involved during the last three years in the development of methods to manage liquid waste streams, liquid process streams and culinary water systems. Liquipure's approach is best characterized as application of the following:

1. Ozonation
2. Filtration
3. Chemical Flocculation

The key to Liquipure's success is centered around the unique understanding which has been gained of the remarkable effects of the proper application of ozone. Properly used in preparation for subsequent treatment, effects are obtained which heretofore have not been achieved.

Waste Water Neutralization

Each dairy operation is faced with the responsibility of disposing of relatively large amounts of waste water. Generally this is made up of:

1. CIP solutions
2. Wash-down water
3. Cooling water
4. Process water

In most installations this water is separated from the sanitary sewer within the plant. It is the source of probably 98% of the plant liquid discharge, with the exception of whey.

Traditionally the wastewater is disposed of in the following ways, with an indication of the problems encountered relative to each method.

1. Discharge to the public sanitary sewer system.
   a. Excessive surcharges based upon BOD$_5$, suspended solids, and/or hydraulic volume loading.
   b. Refusal to permit discharge to sewer because plant effluent loads sewer system beyond the capacity of the treatment facility.
   c. Assessment to the plant for capital cost of public sewer treatment facility with no guarantee that future circumstances may not result in sur-
2. Discharge to a public waterway (directly or indirectly)

   a. The advent of EPA regulations at the State and Federal level along with broad based public attention has made continuation of this practice very risky and tenuous as a long term solution. Heavy fines and plant closure are not unknown.

3. Discharge to a lagoon, treatment in the lagoon and subsequent disposal through land application, discharge to the sewer or public waterway.

   a. Management of the desired aerobic condition in the lagoon is often times elusive.

   b. Systems often are fitted with aeration pumps which are heavy energy users and expensive to operate.

   c. There is generally an offensive odor associated with the lagoons which is the cause of poor public relations and not infrequent lawsuits by aggravated neighbors.

   d. Continued application to the land of the water usually results in an undesirable effect characterized by blinding of the soil to the point on non-absorption and continually decreasing productivity of the land as it relates to crop production.

   e. Lagoons become filled with solids resulting in the need to use additional land and build more lagoons or dredge the existing lagoon.

   f. Often, the land dedicated to the lagoon is far too valuable for that application when considering the need for plant expansion or sale of the land for cash if a cost effective alternative was available.
4. Treatment by a plant owned and operated on-site conventional sewer treatment system and subsequent discharge of the treated effluent to the public sewer, public waterway or land application.

a. Experience clearly demonstrates that conventional sewer treatment systems involve initial capital costs significantly greater than a Liquipure system. Being passive in their nature compared to the dynamics of Liquipure's system, the physical requirements are much greater in conventional systems compared to Liquipure technology given the same rates of flow.

b. The Liquipure system is easily designed to meet the desired discharge requirement and is easily modified to increase the level of treatment if necessary to meet a more stringent discharge requirement.

The Liquipure System is proprietary and subject both to patents and patents pending.

Through the Liquipure technology, wastewater is received from the plant at typical loading factors of BOD$_5$ at 2000 and suspended solids of 600 measured in mg/L. Processed through the system, the discharge is a solids material of clay-like consistency and water of a clarity and purity up to and including potable water if such should be deemed necessary.

Each facility is uniquely designed and engineered for a particular plant. For the purpose of examining and considering the capital expenditure a plant might expect, the amount is affected by space available, whether a building is necessary, the quality of the raw effluent and the quality of the desired effluent ultimately discharged.
Whey Concentration and Drying:

Cheese plants desiring to process their whey to a dry powder have traditionally installed multiple effect evaporators and dryers. Historically this equipment has been very expensive both as to initial capital cost and post-installation operating costs. The equipment, approved for production of human food grade product, is stainless steel in construction and equipped to satisfy all State and Federal regulations pertaining thereto.

A review of the market reveals a relatively modest price differential existing between the price at which cheese processors are selling whey for human consumption and the price at which they could sell the product as an animal food.

Liquipure has developed a system for concentration and drying of animal food grade whey powder at an initial capital cost as low as 1/10 that of conventional systems. Moreover, operation of the system is usually expected to be at a cost of 1/2 conventional systems.

It is not at all unusual to compare pro-forma financial projections of a conventional system versus a Liquipure system at a plant and find it would require a payout of 15 years longer to return the investment on a conventional system over a Liquipure system.

Using a unique and proprietary application of ozone, a specially designed and manufactured cooling tower acts as the basic concentrating mechanism. Avoiding massive application of energy to effect the evaporation and concentration results in highly cost effective operation. Carried through drying, hammermilling, mixing with chemicals to maintain non-hygroscopic quality and bagging or delivery in bulk, a highly desirable and marketable product is produced.

Financial analysis reveals that a return of investment within three years is experienced in small operations and a return of two years and less is expected in larger operations. Financed as we might outline over a five year term results in a positive cash flow situation each year after service of debt.

Lactose Conversion

Some plants have chosen to fractionate their whey and are left with substantial lactose after separation of the protein concentrate.

Liquipure has developed systems for treatment of the lactose and production of a high protein product through bio-mass conversion. This product is expected to command a premium price on the market. Specific discussion concerning this application will be held with
plants having a sincere interest who are willing to devote the time and expense to engineer a system design particularly for them.

Cooling Tower Management

Traditional management of cooling towers has centered around chemical application to:

1. adjust pH
2. inhibit algae
3. destroy microbiologics
4. prevent plating and scaling
5. retard corrosion

Generally it may be said that comparatively few systems are well maintained and far too great a number are seriously compromised in their efficiency.

In many cases where the treatment results are highly ineffective, the reason is not application of too little chemical. It is very common to see flagrantly violated systems wherein the dollar expenditure in chemicals far exceeds that necessary.

Instances are also prevalent wherein too little or very irregular chemical application has compromised the system.

The proper design of a system to apply ozone to a cooling tower system results in the following when installed on a cooling tower:

1. Significantly reduced need for application of acid for adjustment of pH.
2. Elimination of the need for other chemical treatment.
   a. no chromates
   b. no algaecides
3. Dissolution of scale and plating in the system. Within 45 days after installation the cooling system should be essentially free of scale and plating.
5. Passivation of metal surfaces with a thin oxide protective coating inhibiting corrosion of the system.
6. Elimination of need for annual tear-down and cleaning of condensors.
7. Highly increased efficiency resulting in energy savings of as great as 35%.

Applications commonly show a return on investment of a year and less when cost savings in chemicals, man hours and energy are calculated.
A RAPID FARM TEST FOR PENICILLIN IN MILK

Melvin J. Swanson, Ph.D.

Bio-Metric Systems, Inc. is developing a test system in which a protein that specifically binds penicillin is attached to a solid phase and a penicillin derivative is coupled to an enzyme. The solid phase-binding protein is packed into small columns in bands or layers separated by layers of inert solid material. In use, the enzyme-bound penicillin is added to the milk sample which is then applied to the column. After it has flowed into the column, a color-generating solution is added and allowed to flow into the column.

Penicillin in the sample competes with enzyme-bound penicillin for binding sites in the bands of the column. When no penicillin is present in the milk, color develops in only the top band of the column. Penicillin in the sample causes color to develop in more than one band. The more penicillin present, the more bands become colored.

In its present form, this test takes about thirty minutes to perform. We anticipate achieving a ten to fifteen minute test with further optimization. Currently, this test has a sensitivity of about fifty parts per billion. We expect to increase the sensitivity by several fold with further optimization. Our goal is to have this test on the market in about a year. This technology is also applicable to other antibiotics. We expect to quickly follow a penicillin test with other antibiotic tests.
The use of Natamycin (Pimaricin) in controlling mold growth on cheese

by H. A. Morris, Professor
Food Science and Nutrition Department, University of Minnesota

OUTLINE

I. A good fungicide must satisfy the following requirements:

- it must be very active against all molds and yeasts that can cause deterioration.
- it must remain active long enough to keep the food products fungus-free when used under natural conditions.
- it must be safe for the consumer.
- it must not increase cost.
- it must not affect quality, appearance, smell, color and flavor.
- its use on food products will not lead to selection of resistant strains of microorganisms.

II. Comparison of Sorbic acid and Natamycin as Cheese Preservatives

<table>
<thead>
<tr>
<th></th>
<th>Sorbic Acid and its calcium, sodium and potassium salts.</th>
<th>Natamycin (Pimaricin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural occurrence:</td>
<td>Mountain ash berry</td>
<td>Streptomyces natalensis</td>
</tr>
<tr>
<td>Some insects</td>
<td>Penicillium species</td>
<td>Pseudomonas putida</td>
</tr>
<tr>
<td>Solubility: (g/100 g water)</td>
<td>Sorbic acid 0.16</td>
<td>Ca-sorbate 1.2</td>
</tr>
<tr>
<td></td>
<td>K-sorbate 35</td>
<td>Na-sorbate 58.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.005</td>
</tr>
<tr>
<td>Migration into the cheese:</td>
<td>&gt;5.5 cm</td>
<td>&lt;1 mm</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>pH range:</td>
<td>Below 3. Between 3 and 9 Up to 6.5. Activity increases (100% between 5 and 7)</td>
<td></td>
</tr>
<tr>
<td>Color, organoleptic deviations in cheese:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Active against:</td>
<td>Bacteria, Yeasts, Molds, Activity against molds somewhat greater than activity against bacteria. Only yeasts and molds</td>
<td></td>
</tr>
<tr>
<td>Minimum inhibition concentration - Values ug/ml:</td>
<td>ca 80-3000 (molds)</td>
<td>ca 0.1-100 (molds)</td>
</tr>
</tbody>
</table>

III. Use on Blue Cheese

IV. Use on Cheddar and Colby cheese

V. Use on Brick cheese

VI. Federal Food and Drug Administration approval