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WHY THE GYRATING MARKETS AND PRICES FOR DAIRY PRODUCTS?

by

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Logan, Utah

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THE 1990 FARM BILL: STATUS AND ISSUES

by

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Presented at the
9th Biennial Cheese Industry Conference
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Logan, Utah

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THE 1990 FARM BILL: STATUS AND ISSUES

Congressional action to pass new farm legislation has moved faster than most people expected. Both the House and the Senate have passed versions of the 1990 Farm Bill, and in both cases, the vote was lopsided in favor of passage--70 to 21 in the Senate and 327-91 in the House. Differences between the House and Senate bills are to be resolved by a Conference Committee this fall after Congress returns from its August recess.

The leadership of both Congressional Agriculture Committees have expressed general satisfaction with the Farm Bill outcome so far. Contending interests have been balanced in classical political fashion. Yet, the President and the Secretary of Agriculture have raised the threat of a possible veto if budgetary and policy problems in the bills are not improved in the Conference.

The budget problem is that the bills ignore the necessity to bring down Federal spending. Both would cost more than current law. The most important policy problems are moves away from market orientation in the dairy program, the new soybean marketing loan program, and the loan rate provisions for the grains.

From the viewpoint of both the Executive Branch and Congress, the budget deficit is a dark cloud hanging over the Conference. Unless the budget summiteers reach an agreement large, across-the-board cuts in Federal spending will follow under the Gramm-Rudman-Hollings (GRH) Balanced Budget Act. The size of the GRH reductions could be around 30 percent in FY 1991, and farm programs would be subject to these cuts.

Efforts to reach a budget agreement will be intense after the August recess, and most people expect an agreement in order to avoid the large cuts under GRH. At this writing, no one knows the size of the reductions that agriculture might face, but it is not unreasonable to think that the budget-cutting agreement could reduce government spending on farm price and income support programs by $1-$1 1/2 billion in FY 1991 and by $10 to $20 billion over the life of the new Farm bill. Obviously, a rewrite of the current Congressional versions of the 1990 bill would be required to meet the revised spending targets.

Because deficiency payments account for such a large share of CCC outlays, efforts to cut spending will likely focus on reductions in target prices and payment bases.

The differences between the Senate and House versions of a 1990 Farm bill are matters of detail, but some of these details are important. Some have said that neither bill departs significantly from current law, the Food Security Act of 1985. In many instances this is true; for example, the price support programs for sugar, peanuts, cotton, and rice are essentially
unchanged. But, in other cases--target prices, the dairy programs, grain loan rates, and the soybean loan program--there are significant changes not only in the provisions themselves but in the intent of the legislation as well.

It is not surprising that the Administration in presenting its 1990 Farm bill proposals (the Green Book) and the House and Senate in passing their bills all claim to be building on the 1985 Act. The 1985 Act broke new ground as it was written in an atmosphere of crisis in U.S. agriculture--many farmers were facing financial stress, U.S. export market share was eroding at a rapid rate, grain and cotton stocks were accumulating and government spending on farm programs was escalating.

Farm economic conditions have turned around under the 1985 Act. The 1985 Act is of course not fully responsible for the rebound in U.S. export market share and farm income, but it helped. And government spending on farm programs is expected to be less than $7 billion in the current fiscal year, far below the record-high $26 billion in FY 1986 and $22 billion in FY 1987.

The 1985 Act staked out a clear path toward a more market-oriented U.S. agriculture. In the midst of a farm crisis, Congress voted to lower loan rates rather than raise them and to schedule reductions in future target prices rather than freeze them at 1985 levels. Those decisions, unconventional as they were in terms of how farm policy is usually made, turned out to be the right ones.
By nearly all measures, American agriculture is much stronger today than it was at the time the 1985 Act was being written. And virtually no one disputes the fact that the 1985 Act has been immensely helpful in this turnaround. Therefore, wouldn't it make sense for the new Farm Bill to enhance the movement toward market orientation initiated by the 1985 Act? Wrong! The bills passed so overwhelmingly by the House and Senate in some cases signal a clear reversal in policy; in other cases, they continue programs that are decidedly not market oriented; and, Congress missed an opportunity to write a bill that encourages U.S. producers to respond fully to market price signals in making their crop planting decisions.

Now, let's turn to some specific issues that have surfaced from the Senate and House bills.

Grain Loan Rates: The House bill limits the size of the so-called "Findley" reductions in loan rates and ties them to stocks-to-use ratios. The Senate offers two choices: Plan A--mandatory marketing loan with no provision for a Findley reduction, and loan rates no lower than 1990 basic loan rates; Plan B--mandatory marketing loans with Findley reductions, but each 1-cent reduction in the loan rate requires advance payments to increase 0.75 cent.

The House bill would give the Secretary authority to set the 1991 corn loan rate at $1.66 per bushel and the wheat loan rate at $2.20 per bushel at currently expected stocks/use ratios. Current law would have permitted $1.49 and $1.88, respectively.
The Senate bill's Plan A provides loan levels that are higher than current law because there is no Findley reduction. Marketing loans are intended to alleviate market interference but are inefficient and costly. The irony is that under current law the probability of market interference is extremely low. So what's the point of the Senate action?

Senate Plan B permits loan rates as low as in current law, but this provision may be unusable because of the difficulty of collecting likely excess advance deficiency payments. During the past 3 years (including 1990), USDA has had to collect overpayments when the advance was only 40 percent. What would happen if the advance was 75-80 percent of the total deficiency payment as it is quite likely to be under Plan B?

Dairy: Current law permits the Secretary to adjust the support price as necessary to keep surplus dairy products from accumulating. Both the House and Senate establish $10.10 per cwt, the current support level, as a minimum support price for milk. CCC removals would be calculated on a total solids basis rather than on a butterfat basis as in current law. Support prices may be raised when removals are below 3.5 billion pounds and lowered when removals are above 5.0 billion (but in no case may support be reduced below $10.10). At CCC removals of 7 billion pounds (Senate) or 6 billion pounds (House), total solids basis, the House triggers a 2-price plan and the Senate triggers supply controls.
Under continuation of current law, dairy product purchases are projected to trigger additional reductions in the support price. The support price is expected to fall to $8.60 by January 1, 1993. However, milk prices remain well above support price due to relatively low purchase levels. The decline in the support price is expected to reduce dairy product purchases from about 6.0 billion pounds, milkfat, in 1991/92 to 3.4 billion pounds in 1994/95.

Not being able to reduce support below $10.10 has two effects. It means a more costly dairy program. It also means the virtual certainty of supply controls with detrimental effects on efficiency and structure of production. Under our current expectation, dairy product CCC purchases are expected to trigger a two-price plan in the House and supply controls in the Senate for the 1991/93, 1993/94 and 1994/95 marketing years. The net cost of the dairy program is expected to increase by $1-$2 billion over FY 1991-95 under either the House or the Senate bill.

For some time, the dairy industry and USDA have questioned whether the formula for valuing butterfat in the pricing of milk overstates the value of butterfat in the marketplace. Consumer demand has shifted from whole milk and other high-fat dairy products to lower fat products. To combat the tendency toward milkfat surpluses, the CCC purchase price for butter has been reduced by more than 30 cents a pound over the past year. The
1990 Farm bill provides for further reductions in the butter support price.

USDA held a public hearing in Alexandria, Virginia, on July 31 to consider proposed changes in the formula for determining the value of butterfat in the pricing of milk in all Federal milk marketing orders. Proponents of change contend the current formula overstates the value of butterfat. Seven proposals to change the formula were aired at the meeting. Of those, two are currently being studied.

More fundamentally, some dairy producers, particularly in the traditional producing areas of the upper Midwest, have criticized the marketing order system as it currently operates. The structure of minimum Class I prices, basing points, and regulation of reconstituted milk have been said to encourage overproduction of milk in other regions and reduced the market for manufacturing milk from the upper Midwest. Interest groups outside the industry have also been critical of dairy marketing orders for many years on the grounds that they amount to a price discrimination scheme that overprices fluid as compared to manufactured milk products.

On March 29th, USDA announced it will hold hearings on possible changes in the pricing provisions of federal milk marketing orders. The public hearing will include proposals on Class I differentials, multiple basing points, Class II price differentials, the pricing of reconstituted milk and other milk order issues. The hearings are tentatively scheduled to begin in
early September. The hearing process, announcement of final
decision, producers voting on amended orders, etc., could take us
well into 1992.

Both the Senate and House bills prohibit a state from using
a cost of manufacturing or make allowance greater than that
provided for in Federal programs. Currently, the California make
allowances exceed the Federal make allowances. Despite the heat
that this issue has generated, our analysts think that requiring
California to adopt the Federal make allowance will have little
or no impact on the California or national dairy industry.

USDA is currently reviewing alternatives to the Minnesota-
Wisconsin (M-W) price for Grade B milk which is currently used to
establish minimum prices in all Federal milk marketing orders.
The continuing decline in Grade B milk production is making the
M-W price less and less useful as a base price. Results of the
USDA study will be presented at a hearing which will be held at
some date after the national hearing on all Federal milk orders,
tentatively set for this September.

Both the House and Senate extend the Dairy Export Incentive
Program through 1995. As far as mandated export sales of dairy
products are concerned, the Senate bill extends the current
mandate through 1995. The House bill mandates export sales of
not less than 150,000 metric tons of dairy products (not less
than 100,000 MT of butter and not less than 20,000 MT of cheese)
if it will not disrupt commercial trade. However, the House bill
mandates export sales of at least 184 million pounds of butter in
FY 1991 without regard to the effect of such sales on market price and commercial trade.

Soybeans: The House requires marketing loans with the loan rate initially set at $5.25 a bushel while the Senate requires marketing loans with $5.50 as the base marketing loan rate. Both bills allow loan rates to change based on stocks-to-use ratios, but in order to lower the loan rates, the ratio triggers are set so high that they are unlikely to be triggered. Marketing loans are also required for sunflowers, rapeseed, safflower, flaxseed, and mustard seed.

The soybean marketing loan program combined with the programs for several minor oilseeds will prove an administrative nightmare that will cause market distortions.

Increased outlays are likely, and after the first year of large marketing loan payments, there will be budget pressure to reduce oilseed program spending. Needed spending cuts would come from other program co-ops and generate support for soybean supply restrictions which would hurt competitiveness, the supposed objective of the marketing loan.

Barley and oats: The House excludes the malting barley price from the barley deficiency payment rate calculation. The Senate limits the use of malting barley price by allowing a spread between malting and feed barley prices no greater than $0.22 a bushel. The Senate raises the oats target price from $1.45 to $1.85 a bushel over the life of the bill.
We don't think that malting barley prices should be excluded from determining barley payments when malting barley is eligible for the price and income support program. Other commodities, e.g., wheat, cotton, and rice, also have different quality varieties commanding premium prices and could make the same argument.

The oat target price increase is motivated by the desire to increase production and stop imports. Why should consumers and taxpayers pay for self-sufficiency in oats? Rather than raising the target price, our farm program should encourage producers to make decisions based on market prices. That's the way to get more oats produced when oat supplies are tight and prices are high.

**High ARP bonus and high price bonus:** The House has a "high ARP bonus" which raises target prices for wheat and feed grains if ARP levels are increased above certain levels. The Senate has a "high price bonus" which rebates deficiency payments to the producer when actual prices are higher than projected prices.

The high ARP bonus may bias policy choice toward lower ARPs to avoid the target price increase. This may result in higher outlays due to excessive production and stock accumulation.

The high price bonus compensates farmers for high prices, just the opposite of the program objective of compensation for low prices. After all, what does the word "deficiency" mean?

**Sugar:** Both bills continue the loan rate for cane sugar at 18 cents per pound, above the world price and costly to
consumers. The Senate basically extends the current program, but extends the loan term to 9 months; the House changes the method for determining the beet sugar loan rate in relation to the cane sugar loan rate; sets an annual minimum import level of 1.25 million tons maintained with mandatory marketing controls on domestic sugar and crystalline fructose. The minimum import quota and increased production incentives would likely violate the objective of no cost to the Government.

**Peanuts:** Both the Senate and House voted to keep the current peanut program intact. As a result, U.S. consumers will continue to pay more for peanut butter and other peanut products than they would under a market-oriented program.

**Cotton and Rice:** The statutory minimum loan rates for upland cotton (50 cents a pound) and for rice ($6.50 cwt) are continued. Loan rates that are inflexible downward hurt U.S. competitiveness and have spawned costly and administratively complex marketing loan programs. These problems are the principal reason for our opposition to relying on marketing loans to achieve competitiveness in grains, as the Senate's Plan A would require.

**Planting Flexibility:** True planting flexibility comes from farm programs that allow producers to make decisions according to market returns and/or crop rotation needs. Both bills contain flexibility provisions, but they are not likely to have much effect on planting decisions. The bills essentially allow 25 percent of program crop base acres to be flexed. Base history
would be protected on a crop-by-crop basis, but deficiency payments would be foregone on the flexed acres. Thus, as under current law, producers will consider farm program payments each time they decide which crops to plant and how many acres of each.

Technological and political changes suggest that the 1990's could feature a return to surpluses in farm commodities, unless farm policies move toward market orientation in the United States and other countries. The House and Senate bills are a move back to increased government involvement in U.S. agriculture and greater protectionism, compared with the 1985 Act and even more so the Administration proposal for the 1990 Farm bill.

We currently estimate that the Senate bill's commodity provisions will cost U.S. taxpayers nearly $1.0 billion beyond that of current programs during FY 1991-95. In addition, both the House and Senate bills will add several more billions to the cost of export, conservation, forestry, rural development, nutrition, and science and education programs. New forestry initiatives in the Senate bill are expected to add $1.1 billion as are new and expanded rural development programs. The nutrition title will increase spending by another one-half billion and the science and education title will increase federal spending by $1.7 billion over FY 1991-95. In total, the House and Senate bills would raise spending by $4-$5 billion over FY 1991-95.

What the House and Senate bills have given us is a set of proposals that break no new ground on flexibility, do not reduce
spending, raise loan rates, create a variety of new and complex programs in the areas of conservation and acreage reduction, and create the potential for supply controls on milk and soybeans. This may have been the best outcome given the contending political pressures that the Agriculture Committees faced, but fallbacks from the 1985 Act programs as substantial as these must be vigorously opposed.
WHAT MUST THE CHEESE INDUSTRY DO TO STAY HEALTHY

by

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What must the Cheese Industry do to stay Healthy?
by James Tillison, Morgan&Myers, Jefferson, Wisconsin

I was honored when Tony Emstrum invited me to speak at this important meeting. When he told me my topic, "What must the cheese industry do to stay healthy," I wondered about his choice. After all, during the nine years I was executive director of the Wisconsin Cheese Makers Association, the number of cheese plants in Wisconsin went from 336 down to just under 200.

To answer the question, "What must the cheese industry do to stay healthy," we need to define healthy. To me, a healthy cheese industry is one that has numerous plants of various sizes, producing a wide variety of products profitably while paying a fair price to producers for milk.

I first became involved in the cheese industry in 1975. I bought an insurance agency that specialized in providing fire and liability insurance to cheese plants in Wisconsin. Frankly, it didn't take me very long to realize I had become involved in a very unusual industry.

It appeared that the cheesemakers little control over what they paid farmers for milk, how much milk they received and what they got for their cheese. If anything was left, it was all theirs.

In 1975, most plants I contacted were making an American cheese and selling it to one buyer. Those were the good old days when big companies like bought all of a plant's production and paid for it promptly. All pricing was National Cheese Exchange based.

How things have changed. Fifteen days after I became executive director of the cheesemakers association, a major company announced it was no longer buying from plants on an exclusive basis. Some 30 plants had thirty days to find a new home for their cheese. Other steady buyers soon followed suit. Before too long only the very largest plants remained under exclusive supply agreements with a few buyers.

Today, we have two cheese industries -- the huge automated plants producing bulk cheddar or Italian cheese and the smaller plants making specialty cheeses. All plants are more involved in product marketing than ever before and generally waiting for their money longer. New technology is being adopted to varying degrees.

Technology widened the gap between plants, forcing smaller plants to either
grow or toward producing non-commodity cheeses. Today we have plants running as much as two million pounds of milk a day with one cheesemaker in the make room. We have enclosed automated vats, cheddaring machines, block forming towers that bag the cheese that is then boxed and palletized automatically. Such automation requires volume. Smaller volume plants just can’t compete.

As more than one cheesemaker has told me in the last few years, it’s not fun anymore. I attribute this attitude to the extra work involved in managing a cheese operation and the lack of return on investment and effort.

There are several basic factor that affect profit -- raw materials, production and overhead costs, and selling price. The biggest cost factor is the basic raw material, farm milk and it has become a lot more expensive over the last ten years.

For one thing, when the most milk is produced is not when the most milk is needed. As a result, plants find themselves with more cheese than demand in the spring and more demand than cheese in the fall. Their desire to have as much milk as possible in the fall only exacerbates the losses extra cheese to sell causes in the spring. The axiom in cheesemaking used to be, and may still be, lose money in the spring and make it up in the fall. That has been happening lately.

Farmers are also getting more for their milk because plants are getting more out of it. It used to be make cheese, spread whey. Today it’s make cheese, dry and sell whey, or RO or UF whey, dry whey protein and sell it and the lactose. The more plants get for whey, the more they can pay for milk. Plants are paying for high quality milk too because it allows them to get more cheese from the milk.

There is a significant cost in procuring and handling producer milk. I would estimate that the average plant issues 6 checks per month per producer in Wisconsin. A cheesemaker and I once estimated that the total cost per hundredweight of having your own milk producers was at least $1.20 considering adminstration, testing, field staff, hauling, and so on. The total cost of milk doesn’t leave much for production costs, overhead, or profit.

Increased competition, labor, changing regulatory requirements, and environmental issues are all adding to the cost of production. A flow diversion valve requirement adopted in Wisconsin closed several small plants. Getting something for your whey requires an investment, but it is an investment that now is necessary.

Environmental issues also will become a bigger and bigger factor. Even in water
rich states like Wisconsin, are tightening rules on what a plant can do with its waste water. Several large operations have put in sewage treatment plants to handle their water problems. More will be required to do so.

The final factor affecting profit is the price plants get for their product. Most cheese sold today is still priced off the National Cheese Exchange price. Because the production and demand cycles, yields, composition, and quantities for cheddar and other cheeses are dissimilar, this makes little sense.

Many buyers don’t realize that all that is traded on the Exchange is cheddar blocks and barrels in carload lots. There are probably more buyers who think all types cheese are traded on the Exchange than we might suspect. Using Exchange based pricing buyers don’t have to be knowledgeable, they just let the Exchange set their prices.

Product marketing has changed dramatically. Almost every cheese manufacturer has marketing expenses they didn’t have before. Their time and involvement is greater. Move have consultants, brokers, or in house sales people to pay. More direct marketing meets additional investment in cutting and packaging and inventory carrying and waiting to get paid.

The preceding are some of the major factors that can affect the industry's health, the following are some of the solutions.

Regarding the area of milk my suggestions on what should the industry do to stay or get healthy are pay what milk is worth, look at where you get milk, and communicate with producers.

Pay for milk based on what it produces. I have always felt that the only right way to buy milk is product yield pricing. Whether you are getting milk from farmers or buying loads, it should be paid for based on what it will produce.

Numerous plants are buying milk this way. They are very satisfied with the results they have gotten. Yes, it is scary when a plant first goes to product yield pricing because some farmers will leave. But, if a plant analyzes its milk supply and plans the best time to make the change to product pricing, producer losses can be anticipated and minimized.

Still, the concern about volume dies hard. I was visiting a cheesemaker and his wife who had been on product pricing about a year. The cheesemaker was anxious to cut our meeting short so he could go out and solicit additional milk from farmers. His
wife couldn't understand why he felt this was necessary, "We made more money in the last year running one third less milk then we ever did before. Why do we want more milk?"

Medium to small cheese plants need to decide whether their best return is investing time and money in procuring milk or marketing cheese. It's difficult to do both.

If I had a plant that ran less than 250,000 pounds of milk a day, I would not have my own producers. Unless you have enough milk to justify a full time fieldman, having you own producers takes you away from where you make money -- selling product. I'd buy this milk on a product yield basis.

Plants need to tell with producers about their milk needs. Plants need to tell each producer how much milk they produced by month and in total for the previous year. The plant needs to explain to the farmer the ebb and flow of demand for milk at the plant. The plant needs to share with each farmer what his ideal milk production would be by month. For example, why not tell the farmer that it would be best if he maintained milk production at last year's level in May, but sales projection show your plant would like him to increase production 3 percent in the fall.

In the production area, all plants need to get as much out of their milk as possible. This starts with projecting yields regularly and comparing them with actual numbers. One cheesemaker we know did this and determined he had an equipment problem. The change in equipment paid for itself in a year with increased yield. An investment in whey equipment usually pays for itself very quickly.

Getting the biggest return for what is in the milk is enhanced by standardizing the milk. With butterfat values so low, you are better off producing more cheese than selling cream. Standardize accordingly to keep the butterfat in cheese. As Utah State has suggested, why not produce cheddar cheese with 52 percent butter if there is no sacrifice in taste and performance.

From a marketing standpoint, plants should take the time to find out what the producer funded promotion organizations are doing and have available. National and state dairy promotion organizations have all sorts of campaigns and promotions going on that plants can tie into. There are also a wealth of materials available that can help even the smallest manufacturer's effort look very professional and sell more cheese. Remember, each year producers are anteing up over $200 million dollars. They are
spending a large part of this is on cheese promotion. Plants need to take advantage of what they are doing.

Moving to pricing, unless you are selling carload lots of cheddar cheese and getting paid in ten days, there is no reason to follow National Cheese Exchange pricing. What buyers like about the Exchange is that it gives them a guidepost. They think it tells them whether they are paying for product competitively.

Because of this, breaking away from the Exchange is difficult, but it can be done. One plant that has been successful in doing this developed their own "index." Their buyer understood all the facts, that their type cheese didn't follow the same demand cycle as cheddar, that quantity and payment terms were different, and all the special production costs, but the buyer wanted independent justification for the plants price adjustments. This plant developed an index mover based what the M-W did. The buyer could read in an independent publication that the cost of milk did change. This allowed him to justify the plant's price changes to himself and his boss.

Besides price, purchasing agents need to be educated that cheese is not like meat. I've read that many cheese buyers are or were meat buyers. Parts is parts and cheese is cheese so buy on price. I can't tell you how many plants have told me buyers don't even want a sample, they just want the price. This needs to be changed through education.

Finally, a healthy cheese industry depends on the quality of the product. A big threat to cheese, the whole dairy industry, is animal treatment residues in milk. The July 30, 1990 edition of Food Chemical News talked about the FDA meeting with consumer groups to discuss this concern. Consumers Union said they will be watching milk and testing milk. Dr. Gerald Guest of the Center for Veterinary Medicine stated that government can't test their way out of this problem. He said we need to get vets and producers involved. He's right. Plants are offering to test milk from treated cows for producers and producers are running tests on milk from treated cows themselves. This is the only real way to be sure residue milk doesn't get in the milk. I've got to believe that testing a cow's milk is more cost effective than dumping a farm tank or bulk truck full of milk.

A healthy cheese industry must be profitable. The first step is to decide you are going to be profitable. Then consider the preceding suggestions and decide which ones will help you achieve business health.
COMPONENT PRICING: BACKGROUND AND WHERE IT IS LEADING US

by

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August 21-23, 1990
Of the pioneer dairy scientists in our industry, we probably owe as much to Dr. Steven Moulton Babcock as to any of the researchers. When Dr. Babcock arrived at the University of Wisconsin in 1887, the dairy industry was in a genuine turmoil.

Without an effective test to determine the fat content of milk, cheese factories and creameries were able to buy milk by the pound, paying the same price for it whether it was skimmed or watered as for whole milk. The worst victim was the consumer. Consumers could never be sure of the quality of the dairy products that they purchased. With a sincere interest in the dairy industry, always typical of the State of Wisconsin, the Dean of Agriculture said, "The creamery business all over the country is going to pot". He told Dr. Babcock, "The honest men aren't taking their milk to the creameries anymore". About two years later, Babcock announced his discovery of the butterfat test which still carries his name. As all of you know, this test frees up the fat globules by dissolving the casein in sulfuric acid. The milk is then run through a centrifuge and the fat column is read directly giving the test of the incoming milk. One remarkable characteristic of Dr. Babcock, for which he should long be remembered, is that he refused to patent it and insisted that it be "given to the public".

This first effort at paying for milk on the basis of its components, led many thinkers within the industry to measure other components and pay for them according to their value. In November, 1961, Professor H.A. Bendixen, Professor Emeritus at Washington State University authored an article entitled
"It's Time for a Change in Milk Pricing". Even before that, in 1958 a Dutch cooperative was paying its members on the basis of fat and protein.

In the early 1970's, our members began asking at District Meetings why we were not paying for protein or solids in the milk. In an attempt to be responsive to these grassroots requests, I began to study the situation to see if it would be feasible. One thing that we knew early on is that any payment system must be economically sound. Unless it is economically sound, it will not last in our competitive economy.

Another realization that surfaced is that payment for milk on a component basis was not a breed issue. If you want to get a hot discussion going among dairy farmers, just make a remark about how one breed is superior over another. This really perks their interest and starts some extremely interesting discussion. Consequently, we began viewing it simply as a more equitable way to pay for milk.

In June of 1973, I attended the American Dairy Science Annual Meeting at Washington State University in Pullman. Dr. Gary Richardson of Utah State University spoke on "Instrumental Capabilities". During his discussion, he mentioned that protein testing of the dye binding system was quite accurate and he also said that there were two other systems that were good. He further explained that France was doing a lot of testing for protein and that there is poor correlation between the fat and protein on individual farms. At that same seminar, Dr. Allen Luke, then Market Administrator for the Denver Market, told of his experience with protein testing. He suggested that protein testing could be an excellent means of running shrinkage balances on plants. He also said that the value for protein was there and that should be paid for.
For some time we had noted that the percentage of butterfat in Class I utilization was going down each year in the Upper Midwest Orders. This signaled a voluntary preference by consumers for lower fat products. In looking further into the values placed on butter and non-fat dry milk, which represent the butterfat and solids not fat side of milk, we noted that in 1950 butter was priced at about 62 cents a pound and non-fat dry milk at about 12 1/4 cents. This meant that non-fat dry milk was about 20 percent of the value of a pound of butter. In looking at the 1973 numbers, we noticed that butter was about the same at 61 1/2 cents a pound but that non-fat dry milk was up to over 45 cents a pound making it about 73 1/2 percent the value per pound of butter. There appeared to be a very strong trend toward more value on the solids not fat side of milk. In looking ahead, we remembered the old admonition "If you want to know about the future, look at what is happening around us now".

Our initial goals on pricing were as follows:

1. Improve equity among members
2. Try to signal market needs
3. Follow trends in component values

A few weeks following the ADSA Meeting, I presented a proposal to our Board that we commence paying a protein premium to our members including each and every member of our organization. After reviewing the situation thoroughly, our Board agreed to commence such a payment on October 1 of 1973. We started with a Grade A premium of 3 cents on each one-tenth percent over a 3.3 percent protein base. For manufacturing milk, since almost all of it went into cheese or non-fat dry milk, we began paying a 6 cent premium on the same
basis. In 1976, seeing the success of the program, our Board approved moving the base from 3.3 percent down to 3.2 percent and increasing the premium on A milk to 4 cents per point and on manufacturing milk up to 9 cents per point. At about that time, we began to get some reactions from industry. Higher testing herds for protein began coming over to us and, naturally, those organizations or companies losing those producers were upset about it. As a result a number of them began calling protein pricing a "Gimmick". In some states, some went so far as to sic the state officials onto us indicating that it wasn’t legal to test and pay for protein.

We had a number of members in Wisconsin, including our Vice President. We were called in by the Wisconsin State Department of Agriculture and told that we were not legal in making such payments. They wanted us to go through a long period of testing, including ceasing to pay for protein immediately. We heard them out in their request, and our then Vice President indicated that he could see nothing wrong with the program since it was being paid to all of our members and that he felt the testing was accurate. Further debate continued and he finally indicated to the state officials that perhaps Wisconsin needed a proposition 13 (similar to California) if the people in the department did not have enough to do. We eventually convinced the department that our testing was accurate and with the adoption of protein payments by others in the state, they wisely allowed its continuance.

In Minnesota, we were not so fortunate. Some large organizations opposed us and pushed the Department of Agriculture into taking us to court. As repugnant as it was to him, the Judge had to order a temporary injunction to restrain us from paying our Minnesota members for protein for over a year.
This is the only time in our history that our members in Minnesota, Wisconsin, Iowa, Illinois, and Missouri have not been paid on the same basis for protein and other premiums. In other words, we were forced to not pay them at that time in Minnesota, but after a series of hearings during the winter the state finally came out with a ruling that it was legal to pay for protein or solids not fat in addition to butterfat in pricing milk.

Our program continued to evolve. In 1978, we put a neutral zone of 2.9 to 3.2 percent on protein and not only added 5 cents per point above 3.2 percent but also made a deduct in the same amount for Grade A milk. For manufacturing milk, we used the same base and set the premium at 10 cents per point both up and down. About 3 years ago, we shrunk our base from 3.0 to 3.2 percent, raised the Grade A bonus to 10 cents a point and manufacturing to 13 cents a point. This same base is still in effect but we are now paying 13 cents a point for Grade A and 15 cents a point for manufacturing milk protein. If cheese prices break, I'm sure that we will see lower protein premiums because these are the very maximum that can be justified at the high levels of cheese pricing that we have today.

Since 1973, we have paid competitive prices to our members for their milk and, in addition, have paid them over $10 million dollars in protein premiums. Over that period of time, I believe that our members have gotten a signal, weak as it may be, that there is a value in the solids not fat portion milk. Quite a few of them have observed this and implemented it into their breeding programs as well as their feeding programs. We are sometimes asked "Where do you get the money for your protein premiums"? Our answer to that is that there would have been additional earnings for the co-op if we hadn't paid
it out in a form of premiums. However, I don’t believe that we would have had all of that money if we had not been paying for extra solids or protein. The higher protein has given us added efficiencies and higher yields in cottage cheese and other cheese production which has flowed to the bottom line of our organization.

During all of the turmoil in the industry regarding component pricing, we want to recognize Dr. Truman Graf, University of Wisconsin as one professor who stood by his guns. Even though he was under tremendous pressure, Dr. Graf recognized that the economics of component pricing worked and that it was right. Also the people at Utah State University have been extremely supportive and progressive toward this system of payment. The sad thing is that we have lost more than 20 years in the industry as far as an upgrading in milk quality is concerned. It takes many years to make changes in breeding and also it takes some time for farmers to adapt to new methods of feeding which might make a change in components.

During all of the turmoil in component pricing, numerous professors in economic departments had various theories on component pricing. Having heard a number of these theories at meetings and following some ivory tower talk, I finally concluded that "it might not work in theory, but we were sure that it works in practice, because it has for us".

Where should we go from here? First of all, I think that we need to get component pricing into all the Federal Milk Marketing Orders. At the present time there is a wide variety of pay prices out there for Grade A milk as far as components are concerned. Some operations are not getting the money back from their plants with the present pricing systems. If we can implement
pricing systems in Federal Orders comparable to those in the Great Basin Order, it would appear that the industry would be better off over the long run. From all indications that we hear the Great Basin Order is working well. Secondly, everyone here knows that we are awash in butterfat. The Wisconsin Milk Marketing Board and the National Dairy Board are doing a lot of research on the utilization of butterfat. However, that is going to be a while in coming about so we need to get signals to dairy farmers to reduce the amount of fat and increase the amount of solids not fat if it can be economically done. In 1968, I visited New Zealand and they were paying on fat and protein. Several years later they went away from paying for protein. During a visit there in 1987, the cooperative managers indicated that they were going to fat and protein again. He said that they must give the farmers the signal that fat is less valuable and less desirable in today’s society.

For over 30 years, pork producers have been breeding their stock for less fat and more leanness. The same is true of beef producers. It is time that we caught on to doing something more in the dairy industry. The market has been telling us for many years what is desired by consumers. We simply haven’t passed it on in a meaningful way that farmers can adjust to the market changes that are out there and so obvious to us.

For those of us in the cheese business, we have many reasons to support component pricing. When we look at the cost of hauling the water from the farms to market, this is a real incentive. Then, we get milk into our plants and have to evaporate that additional water out that we have hauled in to our operations. With increasing energy costs we sure don’t need anymore evaporation costs than is absolutely necessary.
Also, we need to think about the flavor of products that we produce, particularly in the fluid milk industry. Most of us eat and drink foods because they taste good. Consumer tests have showed time and again that 9 1/2 to 10 percent solids not fat is a preferred product, particularly in lower fat and no fat milks. We can add solids to reconstitution, but this is not always done and we wind up selling an inferior product as far as flavor is concerned.

In summary, let’s look at what has happened in component values. Going from 1950 to today, butter prices are up 158%, and non-fat dry milk is up 100%.

Recapping our thoughts for our industry today we suggest the following:

1. Incorporate component pricing in all orders
2. Increase minimum solids in fluid milk
3. Support equitable pricing for producers and processors.

We will hear more today from some leading scientist as to whether we can change the composition of milk by genetics, feeding, or genetic engineering of the cow. We have a very interesting future ahead of us. We have an excellent industry that has been built up over many years. Our greatest need is to work together and do all that we can to maintain and develop the dairy industry to its greatest potential.

We believe that it is important to give dairy farmers a strong financial signal to produce for the market place.

By: Carl E. Zurborg
DEALING WITH MILKFAT -- GENETICALLY

by

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Presented at the
9th Biennial Cheese Industry Conference
Utah State University
Logan, Utah

August 21-23, 1990
Dealing with Milkfat--Genetically

R. W. Everett
Department of Animal Science
Cornell University
Ithaca, NY 14853

Milkfat production in the dairy industry has become a major issue. Diets of consumers have changed with increased emphasis on protein and reduced fat intake. These education or public health issues, like fat, have reduced fat consumption and accelerated consumer trend towards products with lower fat. This paper presents the concept of reducing fat production in dairy cows by using selection in the dairy genetic program.

The biological processes of the dairy cow have been modelled by researchers in many ways. Nutritionists model the rumen and its many interactions in an attempt to predict the consequences of a change in diet on production of milk, fat, and protein. Reproduction specialists model the reproductive system to determine the optimum strategy to impregnate cows. Animal breeders use models to estimate the genetic value of animals for milk, fat, and protein. Can strategies be developed to manipulate the composition of milk quickly to meet changing market demand?

Background

In the United States, milk is purchased from dairy farms using a basic formula:

\[ X \text{ cwt milk} \pm Y \text{ pt fat above or below 3.5} \]
\[ + Z \text{ pt of protein above or below 3.2} \]

In addition, farmers may receive incentive payments for quality (SCC or bacterial counts) or quantity (shipping costs).
Farmers trying to maximize net income are keenly aware of the milk price and input costs of production.

However, many farmers believe they are paid for milk components on a percentage basis rather than on pounds sold. The confusion arises as follows. Farmer A is quoted a milk price of:

$13.50/cwt ± $.11/pt of fat ± $.07/pt of protein

and, therefore, believes there is payment on percent fat. In fact, the above milk price actually pays the farmer as follows:

\[
\begin{align*}
\text{Milk} & = \$0.0741/\text{lb} = (13.50 - 35 \times 0.11 - 32 \times 0.07) / 100 \\
\text{Fat} & = \$1.10/\text{lb} = 0.11 \times 10 \\
\text{Protein} & = \$0.70/\text{lb} = 0.07 \times 10
\end{align*}
\]

Therefore, farmer A receives $1.10/lb of fat sold from the farm and $.70/lb of protein sold. The farmers must be reminded continually that a milk sample is taken from the bulk tank to determine the percent fat in the bulk tank so that the pounds of fat purchased can be calculated. Farmers must be educated to feed and manage for pounds of fat and protein produced and not percentages. This alone would be a giant step toward solving the fat production problem.

**The biology of dairy genetics**

From the prospective of an animal breeder, the biology or mathematics of production is very simple:

Production = genetics + environment

The genetics and environment are additive, which means that two herds with genetically identical cows could have very different herd averages because the environments of the herds could be very
different. For example, a herd averaging 20,000 lb per cow in Utah may produce only 5,000 lb per cow when moved to Pakistan.

Specifically, an animal breeder would say:

$$ P = G + E \quad (I) $$

<table>
<thead>
<tr>
<th>Production</th>
<th>Genetics</th>
<th>Additive</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td></td>
<td></td>
<td>Feeding</td>
</tr>
<tr>
<td>FAT</td>
<td></td>
<td></td>
<td>Mastitis</td>
</tr>
<tr>
<td>Protein</td>
<td></td>
<td></td>
<td>Milk system</td>
</tr>
<tr>
<td>Somatic cells</td>
<td></td>
<td></td>
<td>Temperature</td>
</tr>
<tr>
<td>Calves</td>
<td></td>
<td></td>
<td>Humidity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Age</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage of lactation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Days pregnant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Housing</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Barnyard</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bedding</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flies</td>
</tr>
</tbody>
</table>

Production is output or yield that is sold. Production is changed and hopefully improved by selection (genetics) and management of the environment.

Feeding, which is manipulated and hopefully improved by farmers, tends to dominate the environmental component of production. If production drops, managers instinctively study and evaluate the ration fed to correct the situation and improve production.
The goal of every dairy farmer is to increase production and profit per cow. Utilizing equation I and Northeast production records, the improvement in P, G, and E can be calculated. Figures 1 through 4 document increases in production per cow since 1960 for Holsteins. First lactation, 305-day mature equivalent milk production has increased 8,000 lb, from 13,500 to 21,500 lb. The increase due to genetics is 2,600 lb, and improvement in environment resulted in 5,400 lb of progress. As seen in Figure 1, approximately 2/3 of the improvement in production is the result of modifications or improvements in the environment. Listed under equation I are some of the areas of management that have changed. The specific improvement due to each area of management such as nutrition, barns, etc., is impossible to separate; therefore, only total environmental improvement can be estimated.

Genetic improvement represents 1/3 of the total improvement and, in general, this is consistent over years.

Figures 2, 3, and 4 document the genetic improvement in milk, fat, and protein since 1957. The genetic merit of Holstein cows is below that of their AI sires. Progress in the 1960s was very slow and has increased in recent years as AI studs have selected better bulls and the bulls are pulling the cows along at a faster rate. These results are consistent with the improvement of the breeding programs of the AI industry.

A comparison of Figures 2, 3, and 4 indicate very consistent and nearly identical trends in the genetic progress of milk, fat, and protein. This suggests there may be a positive relationship
among the genes for milk, fat, and protein or equal selection emphasis was placed on all three traits.

In fact, Table 1 shows strong relationships exist among milk, fat, and protein. The phenotypic correlations are the relationships observed by farmers from their records. Farmers have observed for many years that the highest milk-producing cows also produce the most fat and protein. These relationships can result from two sources, the genetic correlations and environmental correlations which can be derived from the phenotypic correlations using equation I.

The genetic correlations are shown in Table 2. These relationships are very high, .72 to .87, indicating the genes producing high milk yield have a strong tendency to produce high fat and protein yields. This presents the real issue of concern: is it possible to select for high milk and protein production while decreasing the fat production?

To answer the question, one can utilize proven genetic theory to estimate the change in milk, fat, and protein production under different selection programs. Theory says,

\[ b_i = P^{-1}Ga \]  

\[ I = b_m X_m + b_f X_f + b_p X_p \]

where \( P \) is the phenotypic variance-covariance matrix among milk, fat, and protein, \( G \) is the genetic variance-covariance matrix, and \( a \) is a vector of economic weights. The economic weights are the value in dollars to the farmer of each of the components. For example, it was shown that farmer A had economic weights of
$.0741/lb of milk, $1.10/lb of fat, and $.70/lb of protein. These values change as the milk price changes from month to month, so let's observe what happens to the selection response as the price of the components change. In fact, we could ask what would happen if there were a negative price on fat? That is, the farmer would be charged for every pound of fat sold to the processing plant.

The results are in Table 3. The economic values are on the left of the table and the responses to selection are on the right. In the first row, milk is priced at $.13/lb, and the other components are worthless. A selection program based only on improving milk will increase milk 200 lb per year, but fat also increases 5.59 lb per year and protein 4.43 lb per year. Fat and protein improve because of the genetic correlated response, i.e., the genes for milk also increase fat and protein. Also observe that selecting for fat or protein alone increases all the components. Other milk prices are given in Table 3, including negative weights for fat production. Charging the farmer for fat produced still results in 4+ lb of fat due to the genetic correlation.

The problem is clear. The underlying biology of production in the cows is determined by the genes of the cow. For production traits, the genes are highly correlated. They are so highly correlated that even a penalty on fat production will not greatly retard fat production when one selects for other components.
Conclusions

In conclusion, research has clearly demonstrated the following points.

1. Genetic correlations among production traits are high and positive.
   A. It is impossible to reduce fat production genetically while increasing milk and protein.
   B. It is possible to reduce the rate of fat increase.

2. Scientists currently cannot change the underlying biology--genetic correlation--of production traits.

3. The greatest opportunities exist in changing the environment, i.e., feeding.

4. Currently, milk price is the culprit because farmers receive 38% of gross income from fat, and many are purposely selecting for fat % because they believe they are paid on fat %.
Figure 1

Holstein Genetic Trends
Northeast Data (Milk)

- Cows  --- AI Sires  ■■■ Phenotype

Milk (lb) - Genetic

Milk (lb) - Phenotypic

Year

0  60  64  68  72  76  80  84  88

-2600 -1000 0  600 1200 1800 2400 3000 3600 4200 4800 5400

64 68 72 76 80 84 88

13.50 15.10 16.70 18.30 19.90 21.50
Figure 2

Holstein Genetic Trends
Northeast Data (Milk)

--- Cows --- AI Sires

Year

Milk (lb)

1200
-1200

-1080

-1840

-2600

56 60 64 68 72 76 80 84 88
Figure 3

Holstein Genetic Trends
Northeast Data (Fat)

--- Cows
--- AI Sires

Year

Fat (lb)
Figure 4

Holstein Genetic Trends
Northeast Data (Protein)

--- Cows --- Al Sires ---
Table 1

Phenotypic Correlations

<table>
<thead>
<tr>
<th></th>
<th>Milk</th>
<th>Fat</th>
<th>Prot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>1.00</td>
<td>.83</td>
<td>.76</td>
</tr>
<tr>
<td>Fat</td>
<td></td>
<td>1.00</td>
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</tr>
<tr>
<td>Prot</td>
<td>.31</td>
<td>.28</td>
<td>1.00</td>
</tr>
<tr>
<td>Herit</td>
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Table 2

Genetic Correlations

<table>
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<tr>
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<th>Milk</th>
<th>Fat</th>
<th>Prot</th>
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<tbody>
<tr>
<td>Milk</td>
<td>1.00</td>
<td>.81</td>
<td>.87</td>
</tr>
<tr>
<td>Fat</td>
<td></td>
<td>1.00</td>
<td>.72</td>
</tr>
<tr>
<td>Prot</td>
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<td></td>
<td>1.00</td>
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### Table 3

<table>
<thead>
<tr>
<th>Economic Weights</th>
<th>Genetic Response</th>
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<tr>
<td><strong>Milk</strong></td>
<td><strong>Fat</strong></td>
</tr>
<tr>
<td>0.13</td>
<td>3.71</td>
</tr>
<tr>
<td>0.0428</td>
<td>1.40</td>
</tr>
<tr>
<td>0.0928</td>
<td>1.20</td>
</tr>
<tr>
<td>0.0810</td>
<td>1.40</td>
</tr>
<tr>
<td>0.1243</td>
<td>-0.90</td>
</tr>
<tr>
<td>0.0871</td>
<td>-0.90</td>
</tr>
<tr>
<td></td>
<td></td>
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</tbody>
</table>
WHAT IS THE POTENTIAL FOR CHANGING COMPOSITION OF MILK THROUGH FEEDING?

by

Dr. Larry D. Satter
and
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Presented at the
9th Biennial Cheese Industry Conference
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Logan, Utah

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WHAT IS THE POTENTIAL FOR CHANGING COMPOSITION OF MILK THROUGH FEEDING?

Larry D. Satter¹ and Ric Grummer²

Introduction

The composition of milk has been surprisingly stable over the years despite a reduction in the number of high-testing colored cattle and major changes in feeding programs. That does not preclude changing milk composition through diet manipulation. This presentation will indicate the potential for changing milk composition through feeding of the lactating cow.

²Dairy Science Department, University of Wisconsin, Madison.
Milk Production, Milk Fat Content and Grain Consumption of Cows in Wisconsin (1950-1988)

<table>
<thead>
<tr>
<th>Year</th>
<th>Milk Production per Cow (lbs/yr)</th>
<th>Milk Fat (%)</th>
<th>DHI Milk Protein (%)</th>
<th>Grain Fed Per Cow (lbs/yr)</th>
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<tbody>
<tr>
<td>1950</td>
<td>6,850</td>
<td>3.69</td>
<td>-</td>
<td>1,770</td>
</tr>
<tr>
<td>1955</td>
<td>7,160</td>
<td>3.63</td>
<td>-</td>
<td>1,790</td>
</tr>
<tr>
<td>1960</td>
<td>8,270</td>
<td>3.67</td>
<td>-</td>
<td>2,410</td>
</tr>
<tr>
<td>1965</td>
<td>9,080</td>
<td>3.68</td>
<td>-</td>
<td>3,040</td>
</tr>
<tr>
<td>1970</td>
<td>10,163</td>
<td>3.68</td>
<td>-</td>
<td>3,970</td>
</tr>
<tr>
<td>1975</td>
<td>10,430</td>
<td>3.75</td>
<td>-</td>
<td>3,860</td>
</tr>
<tr>
<td>1980</td>
<td>12,331</td>
<td>3.73</td>
<td>-</td>
<td>4,930</td>
</tr>
<tr>
<td>1985</td>
<td>13,166</td>
<td>3.71</td>
<td>3.27</td>
<td>5,000</td>
</tr>
<tr>
<td>1988</td>
<td>14,407</td>
<td>3.71</td>
<td>3.20</td>
<td>5,330</td>
</tr>
</tbody>
</table>

Wisconsin Department of Agriculture, 1989.

Slide 1  Milkfat content has remained constant in Wisconsin (and the U.S.) despite a doubling of milk production and a tripling of grain consumption. Very preliminary evidence of a slight decrease in milk protein content.

Slide 2  A number of dietary factors can influence the percent of milkfat and milk protein. The two most important are the forage:concentrate ratio, and consumption of fats and oils. Lactose content of milk is not significantly affected by diet.
Slide 3  Grain additives up to 50% of the diet dry matter tend to reduce milkfat only slightly. Once grain makes up more than 50% of the diet, milkfat decreases rather sharply. Very high grain diets can cause health problems for cows.

TABLE 5. Percent of different feed ingredients fed for each dietary treatment when averaged over the entire 305 d lactation.

<table>
<thead>
<tr>
<th>TRT</th>
<th>ALFALFA</th>
<th>DICAL &amp;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SILAGE</td>
<td>HMEC</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>MULTIPAROUS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>53.1</td>
<td>34.8</td>
</tr>
<tr>
<td>2</td>
<td>63.5</td>
<td>26.9</td>
</tr>
<tr>
<td>3</td>
<td>72.7</td>
<td>19.7</td>
</tr>
<tr>
<td>4</td>
<td>86.7</td>
<td>8.3</td>
</tr>
<tr>
<td>5</td>
<td>98.2</td>
<td>---</td>
</tr>
<tr>
<td>PRIMIPAROUS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>53.9</td>
<td>34.4</td>
</tr>
<tr>
<td>2</td>
<td>63.6</td>
<td>26.9</td>
</tr>
<tr>
<td>3</td>
<td>74.0</td>
<td>18.9</td>
</tr>
<tr>
<td>4</td>
<td>86.9</td>
<td>8.2</td>
</tr>
<tr>
<td>5</td>
<td>98.2</td>
<td>---</td>
</tr>
</tbody>
</table>

Slide 4  Average composition of diets (throughout lactation) fed to cows whose performance information is in the next slide.
TABLE 6. Summary of lactational measurements for multiparous cows.

<table>
<thead>
<tr>
<th>MULTIPAROUS</th>
<th>TREATMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>COWS, n</td>
<td>8</td>
</tr>
<tr>
<td>305 d Milk, kg</td>
<td>8641&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>305 d 3.5% FCM, kg&lt;sup&gt;1&lt;/sup&gt;</td>
<td>8295&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>305 d Cheese Yield, kg&lt;sup&gt;2&lt;/sup&gt;</td>
<td>826&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk fat, %</td>
<td>3.37&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk protein, %</td>
<td>3.20&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>21.6&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Gross efficiency, kg FCM/kg DMI&lt;sup&gt;3&lt;/sup&gt;</td>
<td>1.26&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Body weight, kg</td>
<td></td>
</tr>
<tr>
<td>Week 44-Ave. of weeks 2 &amp; 3</td>
<td>87.7</td>
</tr>
<tr>
<td>Final body condition score</td>
<td>3.7±1.0</td>
</tr>
</tbody>
</table>

<sup>a,b,c,d</sup> Means in the same row with different superscripts differ (p<0.05).

<sup>1</sup> 3.5% FCM = [.432 * (kg milk)] + [16.2 * (kg fat)].

<sup>2</sup> Cheddar cheese yield = (((kg fat * .93) + (% casein - .1)) * 1.09) / .63 * (305 d milk cwt).

<sup>3</sup> All gross efficiency values were calculated on an individual cow basis, (kg 3.5% FCM / kg DMI).

*Slide 5* Treatment 1 (high grain diet) has a lowered milkfat test.
Treatment 5 (all forage diet) has a lowered protein content. Dietary forage:concentrate ratio can have a very significant effect on milk composition.

*Slide 6* The reduction in milk protein content as grain is removed from the diet can be very large. These data are with first lactation heifers.
Responses of milk yield and composition to various forms of lipid supplements, including lipids protected by formaldehyde-treated protein.

<table>
<thead>
<tr>
<th>Supplement</th>
<th>Percentage of diet</th>
<th>Milk yield (kg/d)</th>
<th>Milk Composition Percentage (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogenated tallow</td>
<td>2.7</td>
<td>+2.3</td>
<td>Fat: -.37, Protein: -.16, Lactose: -.01</td>
<td>(35)</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>2.7</td>
<td>+2.2</td>
<td>Fat: -.86, Protein: -.34, Lactose: +.06</td>
<td>(35)</td>
</tr>
<tr>
<td>Free fatty acids¹</td>
<td>3.4</td>
<td>+1.5</td>
<td>Fat: +.10, Protein: -.09, Lactose: +.04</td>
<td>(8)</td>
</tr>
<tr>
<td>Free triglycerides</td>
<td>3.4</td>
<td>+1.8</td>
<td>Fat: -.27, Protein: -.24, Lactose: +.02</td>
<td>(8)</td>
</tr>
<tr>
<td>Protected triglycerides</td>
<td>4.7</td>
<td>+1.7</td>
<td>Fat: -.40, Protein: -.24, Lactose: -.04</td>
<td>(8)</td>
</tr>
<tr>
<td>Protected tallow</td>
<td>12</td>
<td>-.7</td>
<td>Fat: +.71, Protein: -.33, Lactose: -.15</td>
<td>(17)</td>
</tr>
<tr>
<td>wk 1-6</td>
<td>19</td>
<td>+2.3</td>
<td>Fat: +.58, Protein: -.10, Lactose: -.04</td>
<td>(9)</td>
</tr>
<tr>
<td>wk 7-13</td>
<td>20</td>
<td>+1.9</td>
<td>Fat: +.48, Protein: -.36, Lactose: -.16</td>
<td>(9)</td>
</tr>
<tr>
<td>Protected tallow</td>
<td>18</td>
<td>-2.0</td>
<td>Fat: +.73, Protein: -.31, Lactose: -.19</td>
<td>(36)</td>
</tr>
</tbody>
</table>

¹ Dairy fat prills (BP Nutrition UK Ltd., Wincham, Northwich, UK). The fatty acids were more hydrogenated in the prills than in the triglycerides.

Slide 7 Feeding of fat or oils almost always stimulates total milk production. Milkfat may be either increased or decreased, but milk protein is almost always decreased.

WMMB 1988 MILK FAT ROUNDTABLE

Slide 8 The Wisconsin Milk Marketing Board suggested an "ideal milkfat"! The ideal milkfat would contain 10% polyunsaturated fatty acids, 83% monounsaturated fatty acids, and 8% saturated fatty acids. This differs considerably from typical milkfat.
DIETARY FATTY ACIDS AND PLASMA CHOLESTEROL

1. **C18:0 AND C4:0-C10:0 ARE HYPOCHOLESTEROLEMIC RELATIVE TO C16:0, C14:0, AND C12:0**

2. **C18:0 ~ C18:1 ~ PUFA**

3. **THEREFORE, IT MAY BE DESIRABLE TO INCREASE C18:0 AND C18:1, PARTICULARLY AT THE EXPENSE OF C16:0**

Slide 9 From a human health point of view it appears desirable to increase the relative amount of milk fatty acids containing 18 carbons, and to decrease the saturated fatty acids containing 16 carbons.

Slide 10 Supplemental dietary fat reduces the proportion of short chain fatty acids in milk (C4-C14:0).
Slide 11  Supplemental dietary fat reduces the proportion of C16:0 fatty acids. The exception may be when fat sources derived from palm oil are fed. Palm oil is rich in C16:0 (palmitic acid).

Slide 12  Supplemental dietary fat increases the proportion of C18:0 and C18:1 fatty acids in milk.
Influence of oil supplementation on milk fatty acid composition.

<table>
<thead>
<tr>
<th></th>
<th>Whole Raw Soybean</th>
<th>Crushed Rapeseed</th>
<th>High Oleic Sunflower Seed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Saturated FA (%)</td>
<td>65</td>
<td>54</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>54</td>
<td>71</td>
</tr>
<tr>
<td>Hypocholesterolemic (%) (C4-10 &amp; C18)</td>
<td>55</td>
<td>61</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>43</td>
<td>58</td>
<td>46</td>
</tr>
<tr>
<td>Hypercholesterolemic (%) (C16)</td>
<td>26</td>
<td>21</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>21</td>
<td>33</td>
</tr>
</tbody>
</table>

Murphy and McNeill, 1988
Middaugh, et al, 1988

Slide 13 Overall effect of oil supplementation on milk fatty acid composition. Feeding of oil and fat "moves" fatty composition in the right direction from a human health point of view.

EFFECTS OF ROUGHAGE LEVEL AND SUPPLEMENTAL LIPID ON MILK FATTY ACID COMPOSITION AND YIELDS

<table>
<thead>
<tr>
<th>YIELD (g/d)</th>
<th>HIGH ROUGHAGE</th>
<th>LOW ROUGHAGE</th>
<th>LOW ROUGHAGE + TALLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4:0-C14:0</td>
<td>178</td>
<td>76</td>
<td>79</td>
</tr>
<tr>
<td>C16:0</td>
<td>262</td>
<td>96</td>
<td>159</td>
</tr>
<tr>
<td>C18:0</td>
<td>61</td>
<td>22</td>
<td>43</td>
</tr>
<tr>
<td>C18:1</td>
<td>126</td>
<td>108</td>
<td>257</td>
</tr>
</tbody>
</table>

Storry et al., 1974

Slide 14 Diets low in forage content appear to have an altered milk fatty acid content. Addition of tallow to low forage diets may have a very dramatic effect on milk composition.
Slide 15  Fats and oils may be protected from being hydrogenated (saturated) in the rumen through an encapsulation procedure. This results in much more of the unsaturated fatty acid reaching the intestine where it can be absorbed into the blood.

Transfer Efficiency of C18:2 and C18:3 into Milk

<table>
<thead>
<tr>
<th></th>
<th>C18:2</th>
<th>C18:3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g Fed</td>
<td>g in Milk</td>
</tr>
<tr>
<td>Ext. full fat soy flour</td>
<td>380</td>
<td>6</td>
</tr>
<tr>
<td>Formaldehyde treated</td>
<td>380</td>
<td>136</td>
</tr>
</tbody>
</table>

(Bitman et al., 1975)

Slide 16  Milk from cows fed protected polyunsaturated fatty acids can be very high in polyunsaturated fatty acids. Butter made from such milk is spreadable right out of the refrigerator.
**Summary** Changing the dietary forage:grain ratio and feeding fats and oils can have important effects on milk fat, milk fatty acid and milk protein. Some movement in desired directions is possible. The growing popularity of feeding some form of fat or oil may be depressing milk protein content and cheese yield.
CHANGING COMPOSITION OF MILK BY GENETIC ENGINEERING OF THE DAIRY COW

by

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Presented at the
9th Biennial Cheese Industry Conference
Utah State University
Logan, Utah

August 21-23, 1990
Changing Composition of Milk by Genetic Engineering of the Dairy Cow

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In the future the composition of milk may be altered using genetic engineering techniques. Transgenic cattle have been produced which contain the added gene for growth hormone. It is likely that fat composition and content, lactose content and protein composition and content in the milk of dairy cows can be controlled in the not too distant future using genetic engineering technology.

A number of bovine milk genes have been isolated and characterized. This is the first step in the modification of milk composition. The genes will be initially inserted into the genomes of receptor mice to examine the possibilities of expression of the genes in mammalian systems. In addition, transfection of bovine genes into bovine mammary epithelial cell lines may provide useful information on gene expression in bovine mammalian systems. Ultimately transgenic dairy cattle will be generated containing additional or modified bovine genes to alter the composition of milk in desirable ways. This could impact favorably on the development of new dairy products by the dairy industry.
BOVINE SOMATOTROPIN (BST): WHAT IT IS AND HOW IT WORKS

by

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Utah State University
Logan, Utah

August 21-23, 1990
BOVINE SOMATOTROPIN (BST): WHAT IT IS AND HOW IT WORKS

Dr. Robert C. Lamb
Animal, Dairy and Veterinary Sciences Department
Utah State University

WHAT IT IS

Bovine Somatotropin is a natural protein that is produced in the pituitary gland of all cattle. Like other proteins, it is composed of various amino acids. BST is also known as growth hormone because it helps coordinate how energy from feed is allocated to meet a cow’s physical needs such as growth in young animals, and milk production in mature cows. It is the latest in a long list of dairy technology advances: genetic improvement, nutrition, health care, housing, milking equipment and techniques, artificial insemination, embryo transfer and others.

WHAT IT DOES

Supplemental BST stimulates cows to produce more milk from a proportionately smaller increase in feed consumption. With supplemental BST, therefore, less feed is required to produce a pound of milk.

HOW IT WORKS

Bovine Somatotropin is generated in the pituitary and released into the bloodstream. Then it activates "BST Receptors" for specific body needs. For example, "Growth Receptors" in young animals direct food energy into normal growth; when the animal matures, the growth receptors shut down. In mature animals, "Mammary Receptors" are activated at calving. These receptors help direct food energy into milk production. Supplemental BST stimulates the cow to produce more milk, which prompts the cow to eat more to provide the necessary extra food energy. However, more of that energy is directed into milk production rather than body maintenance.

HOW IT IS MADE

BST can be produced in commercial quantities using recombinant DNA technology. The gene responsible for natural BST production in dairy cows has been isolated and can be transferred to ordinary bacteria cells. The bacteria are used to produce large quantities of BST through standard fermentation techniques. The bacteria are then killed, and the BST is separated, highly purified and formulated for use. Similar technology has been approved by the FDA and is now in commercial use to produce insulin and human growth hormone for human medical treatment.
CURRENT STATUS

Human and short-term animal safety data have been compiled and submitted to the FDA. Long-term animal safety and efficacy trials have been in progress for about four years at several universities, including Utah State University. Data from the first of these trials has been submitted to FDA to determine if BST causes any adverse health effects on treated cows or the calves they were carrying and to determine the effects of supplemental BST on milk production and efficiency.

MILK QUALITY

No difference has been detected in the milk from cows receiving supplemental BST and the milk from non-supplemented cows, or from the same cows before they received supplemental BST. Milk from BST treated cows cannot be distinguished from the milk cows have always produced and we have always consumed. Trace amounts of BST occur naturally in cows' milk, generally between two and ten parts per billion. No increase in BST levels in milk has been observed in cows receiving supplemental BST at expected use levels. The composition of milk (with respect to fat, protein and lactose composition) is not different in cows treated with BST and those not receiving supplemental BST.

HUMAN SAFETY

Bovine Somatotropin is a protein, and if consumed it is simply digested like any other protein. It has not been found to be active in humans or other primates. Even when medical researchers in the 1950's administered it to people by injection, attempting to treat dwarfism, BST had no effect. For these reasons, milk and meat from cows treated in BST trials has been authorized by the Food and Drug Administration as safe for human consumption.

EFFECTS ON COWS

Trials to date, many for a complete lactation and some for more than one lactation, indicate that supplemental BST increases milk production about 10 to 25 percent while it is administered. In most trials, BST administration has begun at 60 to 100 days after calving and continued for the remainder of the lactation. BST is given by injection. Some products are injected daily, others at 14 or 28-day intervals. Trials to date indicate that supplemental BST improves feed efficiency about 5 to 15 percent. No undesirable effects on health of cows or their calves have been observed. Calves from treated cows are the same size and grow the same as calves from non-treated cows. There is some evidence that calving interval is longer for cows treated with BST, but this appears to be an effect of higher milk production and not a reduction in fertility.
AN INDUSTRY PERSPECTIVE ON BST

by

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Presented at the
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Utah State University
Logan, Utah

August 21-23, 1990
It is a pleasure to be with you today, and to participate with this panel of speakers in a program that will broaden your understanding of both biotechnology and its very positive implications for the world of milk and milk products.

Most of us have some knowledge of biotechnology, --what it is, how it works, what some of the questions are in the areas of government regulation, consumer perception and so forth. Of course, the end goal of any technology applied to agriculture is improving the efficiency of food production, or the quality of our food.

I would like to outline for you how one of the first major biotechnology products being developed for the food business came into being, and how we expect that product to enhance the food industry. I also want to address some of the regulatory and consumer-perception implications of this product -- bovine somatotropin, or BST.

First, it is important to recognize that our understanding of the role of BST in milk production is not new. Our understanding of how to manage that role effectively is fairly new, and promises to be one of the first major success stories coming out of the biotechnology laboratory and onto the farm.

Scientists discovered in the 1930's that the pituitary extract, known today as BST, increased the volume of milk produced when injected into the cow. Unfortunately, the pituitaries of many cows were needed to yield enough BST to make 1 day's injection. And, so, there was no way to practically apply this knowledge until the advent of recombinant DNA technology during the 1970's.

Now, by taking from one dairy cow's pituitary gland the gene responsible for BST production, and splicing that gene into a non-pathogenic bacteria routinely used in pharmaceutical
fermentation systems, we can produce great quantities of BST -- enough BST to supplement thousands of cows. This same technology, by the way, is used at Eli Lilly to produce human insulin for diabetics and human somatropin to treat dwarfism. As you probably know, diabetics for many years had to rely on insulin derived from bovine and porcine pancreas -- a product which was both limited in supply and more difficult to purify than recombinant human insulin.

The implications of our ability to mass-produce a biological copy of BST are immense for the dairy industry. It gives the American farmer -- who has seen his feeding costs skyrocket -- an opportunity to produce the same amount of milk with fewer animals, thereby lowering his overhead. And, in times of milk shortage such as experienced during last year's drought over parts of the United States, BST could allow farmers in a region with adequate feedstuffs to boost their production and make up the shortfall being experienced elsewhere in the country.

On a global scale, BST will help us boost milk production in underdeveloped nations and help feed the under-nourished people of nations which are badly in need of protein to feed their people. As evidence of this potential, we have BST development projects underway in Eastern Europe, Pakistan, India and Mexico as well as other countries. Now let's take a look at the safety profile of BST. We can drink the milk from BST-supplemented cows with confidence because the milk we drink has always contained BST. Furthermore, the overall composition of milk is not altered due to BST supplementation in the dairy cow.

BST is one of over 20 proteins found naturally in milk, but in minute quantities compared to casein, lactalbumin and others. Whether or not the cow has received supplemental BST, BST levels in the milk remain normal. Medical science has known for many years that BST is inactive in humans. BST is a protein hormone. Protein hormones like BST are broken down in the digestive tract, so they have no effect when eaten as food. And BST -- even when it was injected into humans -- had no effect, because human cells simply do not have the capability to react to a cow's somatotropin. The structure of human somatropin is vastly different from bovine somatropin-BST.
This long-standing knowledge about the human safety of BST prompted the Food and Drug Administration to allow marketing of meat and milk from BST-treated cows early-on in the FDA approval process for BST. Approval for commercial use by the FDA is anticipated once the FDA completes its review of animal testing data to assure that BST can be used effectively and safely in dairy cows. At present, hundreds of scientific reports have been submitted to the FDA to support a decision by the FDA for the use of supplemental BST as a safe and effective management tool for use in dairy cows.

It also is important to understand that each of the four companies (Elanco, Monsanto, Upjohn and American Cyanimid) developing BST must submit the total package of data necessary to obtain FDA approval for their individual products. This approval process, which is being repeated by four separate companies, establishes BST as the most thoroughly tested and reviewed animal product to be developed for animal agriculture.

This unprecedented volume of data provides insight into the recent comment by Dr. Gerald Guest, Director of FDA's Center for Veterinary Medicine, and I quote "Milk from BST treated cows is safe for human consumption. This I can say unequivocally." End of quote.

Once these approvals for commercial use are received, Eli Lilly and three other companies will be prepared to market BST to dairy farmers. Let me reiterate, over 300 studies on over 22,000 dairy cows have been conducted to determine the safety and efficacy of BST. Additionally, the FDA has stated unequivocally that BST is safe for humans - not too surprising since we have been consuming BST as long as we have consumed milk.

So -- if BST holds such promise for improving the efficiency of dairy farm operations -- why have we seen opposition to BST's introduction? The fact is that there are groups who -- despite what is usually a lack of basic scientific knowledge on their part -- are determined to prevent society from benefiting from new technologies.

These people have resorted to a campaign of fear and distortions which capitalizes on what is, unfortunately, a very limited understanding of science among many consumers. For instance, they have charged at various times either that BST is harmful to humans or that its effects on the
human body are unknown. This, of course, totally ignores that determination by the FDA that meat and milk from BST-treated cows is safe for human consumption. You also hear BST’s opponents describe BST as something that is added to milk, when in fact it simply involves supplementation of the cow’s natural milk-producing regulator. Milk quality and composition remains the same.

No -- the so-called debate over BST does not center on the facts, because if it did, the critics would find that BST is not only natural and safe, but environmentally friendly. As a protein, if BST is left in the environment, it quickly degrades like any other protein you know. The real issue is the survival of the scientific and regulatory processes -- and the right for all of us in society to benefit from advances made in the laboratory. Many applications of biotechnology currently in the labs hold great promise for enhanced food production and health care.

If the foes of new technology can keep one product -- such as BST -- out of the marketplace, then they clearly can keep many other scientific breakthroughs off the market as well -- purely and simply because they are opposed to technology. There won’t have to be a reason -- they’ll just have to argue that science itself is evil, regardless of the facts and the importance of a scientific breakthrough for mankind.

Think, for a moment, of the millions of people waiting for cures for AIDS, cancer and a variety of other fatal diseases. If biotechnology is brought to a halt -- if biological research and experimentation are brought to a halt -- these people will never have a chance to benefit from the efforts of our scientists. What if we had adopted that attitude in the 1940’s, and prevented the development of polio vaccine? Think, also, of where the food industry would be without technological progress. You would not benefit today from pasteurization, freeze-drying, vitamin and mineral fortification, protein engineering or any number of other processes which are now used routinely. You would have no chance to benefit in the future from dozens of new agricultural and food technologies now being developed in the laboratory.

I ask that you consider the implications of this crusade against technology because you -- as providers of the items on grocery shelves -- are some of the ones to whom consumers will turn
with their questions about BST and other biotechnology products used in food production. It is critical that you fully understand both this technology and the vital role that science as a whole plays -- and must continue to play -- in the food industry.

Through you -- and through credible third-party sources in the scientific community to whom we can refer you for additional information -- consumers can come to appreciate more fully both the merits of biotechnology and the need to maintain support for the scientific process. Thanks to scientific advancement, Americans enjoy the highest-quality food supply in the world. Over the years, researchers have worked diligently to find new and better tools and methods to produce and process our food; farmers and food processors have put those tools and methods to work -- and we all have reaped the benefits.

What has technology done for the price of milk? Improvements in milk production technology, specifically, have made it possible for consumers to spend progressively less of their food budget on dairy products without diminishing the profitability of the family dairy farm. This chart reflects the impact of technologies such as artificial insemination, improved feeding practices and computerized record-keeping -- which have enabled us as consumers to pay about $2 per gallon for milk, rather than $4 per gallon we would pay if the dairy industry were still dependent solely on 1950's technology. In 1988, these technologies saved consumers about $12 billion on their purchases of dairy products.

If we look further at what has happened to retail dairy product prices compared to all food, we see that since 1983, dairy product prices have increased at a slower rate than all foods. This chart reflects a 2.2% per year average price increase for dairy products vs. a 3.8% per year average for all food. BST is just one more potential management tool in keeping with that trend toward more efficient production of high-quality, economical dairy products.

I think this quote by Barbara Keating-Edh, president of a very prominent consumer organization - Consumer Alert - speaks to our interest as consumers. She says, and I quote:
"Consumers have no great desire to understand how cows produce milk; but they DO care to know that it's safe ... in that they look to experts in the dairy industry."

"Surely the public would wonder about the dairy industry's judgment if it were known that it rejected a promising new and safe technology that could have enhanced productivity, increased efficiency and lowered milk prices."

In summary, it is critical that those of us involved in developing new technologies support three important goals:

1. That we protect the nation's scientifically based regulatory process from manipulation by special interest groups.

2. That our free markets continue as the sole arbiters of the success of new products deemed safe and effective by the regulators.

3. That the U.S. remains committed to innovation which has provided Americans with an array of safe, nutritious and affordable food products.

The American consumer has come to expect this from the food industry. Let's see that our consumer expectations are met. Thank you.
SPECIALTY CHEESE MARKET IN THE UNITED STATES

by

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Presented at the
9th Biennial Cheese Industry Conference
Utah State University
Logan, Utah

August 21-23, 1990
Specialty Cheese Market in the United States

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A company where I spent a great deal of my life's work was Purity Cheese. In 1970, when Purity Cheese was sold to Anderson/Clayton, they were given 8 specialty purity cheeses that had store placement in the top hundred chains in America.

For a specialty cheese company to achieve that distribution in the 90's, it would be nearly impossible, unless a giant conglomerate owned the company and were prepared to investment-spend.

The penalty for being wrong is so big today, that it is turning off new specialty products. The key is new products. New specialty cheeses have seldom come from food giants, but rather from the small to medium sized entrepreneurial companies (this is, of course, the reason that large companies often pay high premiums to buy up smaller manufacturers.)

The total picture is further complicated by supermarkets which have suffered from junk bond buy-outs, such as Ralph's, Smitty's and Safeway. It has placed the supermarket industry in its most perilous financial condition in the last 40 years.

At the same time, the large food companies have restructured to focus on a few core businesses - meaning that they are competing more fiercely in fewer categories.

General Mills, for example, now competes in two industries - restaurants and foods - compared with 13 in the 1970's. This means these large food companies are trying to take a low growth industry and capture dynamic market-share increases.

This all means that the food industry has serious problems. Commodity costs are low, margins are dropping, and competition is at its most intense. The penalty - supermarkets in today's environment cannot afford to be unique, quality-oriented or different. Instead, they must buy the hot number one and two brands. The small specialty cheese manufacturers have to buy their way onto the store shelves, and the entrance dues will only increase, as more chains consolidate, as the problem of junk bonds dictates.
WHY THE GYRATING MARKETS AND PRICES FOR DAIRY PRODUCTS?

by

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Presented at the
9th Biennial Cheese Industry Conference
Utah State University
Logan, Utah

August 21-23, 1990
Insert copy of presentation here if one has been made available.
PROCEDURES FOR MAKING SAFE HIGH QUALITY HISPANIC STYLE CHEESE.

by

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9th Biennial Cheese Industry Conference
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August, 1990
Procedures for Making Safe High Quality Hispanic Style Cheese

INTRODUCTION

Hispanic cheese is a broad category. It encompasses many varieties of cheese that originate from a large and diverse geographic region. Cheeses having similar characteristics often have different colloquial names. Many of the cheeses are similar to European or American cheeses. Others are part of groups known as soft white or hard white cheeses.

General Knowledge

The hard white cheeses generally, have moisture levels less than 41%, fat levels of about 28%, salt levels around 5%, and pH readings are usually below 5.3. The composition of the hard white cheeses make them generally microbially stable.

The soft white cheeses are divided into two categories. The acid precipitated varieties have been described by Kosokowski (7, 8), as well as others (2, 3, 5, 11), as Queso Blanco types. These cheeses are made by adding food grade acids to hot milk. The coagulum is removed from the whey and salt is added. The cheese is then pressed into its final form. The approximate composition of these cheese types is as follows: moisture greater than 49%, fat less than 20% and salt greater than 2%. The pH of this product is usually lower than 5.3.

Varieties in the other family of soft white cheeses are frequently called Queso Fresco or fresh cheese. These cheeses are made using the rennet coagulation of whole or part skim milk (7, 8 10). Like the Queso Blanco cheeses they are high moisture, but they have pH values higher than 6.10. The high pH is necessary to have the flavor, texture and body that is desired by the consumer. The production and marketing of Mexican Queso Fresco is the topic of this presentation.

Confusion in the Market

There is considerable confusion in the market place concerning Hispanic cheeses. Several articles have been written inviting producers to enter this market (1, 8). But before doing so, a complete market study study must be performed to insure proper product placement in specific market segments within the Hispanic population.

Hispanic cheese, as a whole, has enjoyed good growth during the past few years. The national growth rate has been
estimated at more than 10% per year. In California, production of Queso Fresco has been increasing at more than 25% per year for the last several years. This growth has occurred despite problems with Listeria monocytogenes, which grow very well in this type of cheese, and has been implicated in several deaths.

Normally, the distribution of Queso Blanco has been through traditional Hispanic markets. Consumers purchasing this type of cheese know that it is a fresh product, and must be consumed shortly after production. As production increases the cheese is becoming more available to non-traditional Queso Fresco cheese consumers.

Non-Traditional Consumers

A one page questionnaire was administered to 119 non-Hispanic consumers at Cal Poly, San Luis Obispo, to evaluate their knowledge of Hispanic cheeses. The median response for how often cheese was consumed was 4 times per week (Figure 1). Cheese usage, in descending order of response, was Cheddar, Monterey Jack, Mozzarella, Parmesan, Swiss, other types and processed cheese (Figure 2). When asked if they have heard of several common Hispanic cheeses, about 20% recognized Queso Fresco, but response was less for other varieties (Figure 3). The response rate fell even further, to less than 10% for Queso Fresco, when asked which Hispanic cheeses they had consumed (Figure 4). The main reasons for non-consumption of Hispanic cheeses were listed as: because it is not known, has a poor image, and is not available (Figure 5). The lack of knowledge of the non-Hispanic consumers about these cheeses puts this segment of the market at high risk. They have little information concerning the proper storage and handling of these cheeses. It is very possible that they could consume undesirable or unhealthy products.

Microbial Quality

Bruhn (4) reported that the microbial content of these cheeses varies greatly. Often organisms normally associated with post-pasteurization contamination can be isolated. Work being performed by Dr. Genigeorgis, at University of California-Davis (6) confirms that a wide range of undesirable microorganisms can grow in traditional Queso Fresco. The potential for microbial growth in Queso Fresco should be a prime concern for processors making, or thinking about making, this cheese. Cleaning and sanitation are extremely important in maintaining cheese safety and quality.
Cheese Production

Traditional processing procedures for Queso Fresco are very simple. Whole or partially skim milk is warmed, rennet is added and a coagulum forms. The coagulum is cut and the whey removed. Salt is mixed with the curd, which is then molded into the final shape, packaged and consumed. Each cheesemaker uses variations on this basic procedure to produce cheese unique to that processor.

Analysis of several samples of Queso Fresco purchased in the California market indicates that there are fairly wide ranges for moisture, fat, salt and pH. A suggested standard for composition of 48 to 52% moisture, 24% fat, and 2% salt, with a pH greater than 6.10 has been made to processors by this author. By producing a more uniform product, sales as a category would be expected to increase as consumers gain more confidence in products bearing the specific names. The pH values around 6.10 give the cheese unique flavor and textural qualities. This cheese is primarily used for cooking, and as a condiment, and these qualities are very important.

Cal Poly Processing Procedure

Cheesemakers are always hesitant to share processing procedures, and the Hispanic cheese processors are no different. A processing procedure, (Figure 6) developed at the Dairy Products Technology Center, California Polytechnic State University by Wayne Geilman and Jim Path, has been designed to reduce the risk of contamination and growth of undesirable microorganisms.

When making Queso Fresco the importance of cleaning and sanitation cannot be overemphasized. The use of latex gloves, in combination with frequent use of iodine hand wash stations is a must. The proper use of sanitizers to control the risk of contamination must be performed on a routine basis.

Starter Addition

Milk used for the production of Queso Fresco must be pasteurized. Pasteurization of milk reduces the entire microbial load and eliminates coliform and pathogenic bacteria. If post-pasteurization contamination occurs, rapid growth of the contaminant is usually unchecked by microorganisms that normally would be present. The first step in the Cal Poly procedure is to heat pasteurized whole milk to 31.1°C (88°F). In traditional procedures no starter is added, but in this procedure there is an addition
of 2.5% Lactococcus thermophilus starter culture. The addition of starter provides approximately log 5 colony forming units per ml of milk and helps control the growth of undesirable organisms. If cheese made using this procedure is not refrigerated, the starter culture grows and reduces the pH of the cheese below an acceptable pH of 6.10.

Coagulation and Cutting

After 30 minutes of ripening, rennet is added at a rate of 90 ml (3 oz) per 454 kg (1000 lbs) of milk. Coagulation occurs in approximately 30 minutes and the curd is cut 45 minutes after rennet addition. The coagulum is cut into 13 mm (1/2 in) cubes, using standard curd knives.

Cooking

The curds are cooked to 38° C (100.4° F) over a period of 20 minutes and held for an additional 20 minutes. Many traditional processing procedures do not cook the curd, but extend the stirring time. Other procedures use a higher temperature at the start of processing and depend on the residual heat to encourage syneresis.

Draining and Cooling

The whey is then drained from the curd. In this procedure the drainage is rapid. The curds are very fragile, easily broken and must be handled carefully. Some traditional methods for production of Queso Fresco allow for long drainage times, but because of the inclusion of the lactic starter culture this cannot be done. The curds must be cooled and salted as rapidly as possible in order to control the growth of the lactic starter organisms.

Cooling can be accomplished by using cold air. The curds can also be washed with cold, purified water or brine. When brine is used, exposure times must be limited. An exposure of less than 5 seconds, using saturated brine, results in salt levels approaching the desired 1.5-2% in the finished cheese.

Salting and Molding

Salting of the cheese is traditionally performed by adding dry salt to drained curd, followed by manual mixing. Several different types of grinders are used to perform this step on an industrial scale. This step of the processing procedure presents the greatest risk for contamination. Efforts to reduce the risk resulting from particle size
reduction and hand labor has resulted in the investigation of washing the unpressed curd with purified brine and brine salting. Mechanical mixing and minimal mixing of dry salt have also been investigated. When dry salting is used 1 kg (2.2 lbs) of salt to 50 kg (110 lbs) curd is used.

Molding and pressing is another area in which there is a high risk for the introduction of contaminants. Improper cleaning and sanitation of hoops has the potential to introduce large numbers of undesirable microorganisms. Queso Fresco is sold in a large variety of forms, ranging from 10 kg wheels down to 100 gram loaves molded in the palm of a workers hand. Regardless of presentation, sanitation of molding equipment is very important.

One method being investigated to reduce problems associated with washing and sanitizing hoops, is the use of sanitary sausage stuffers and casings. The salt can be added to the curd before entering the stuffer and is mixed during the filling process. The cheese curd is filled under pressure into sanitized cellulose casings. Unsalted curd can also be put into casings and the casing can be brine salted.

Packaging and Sales

The cheese is cooled overnight, then packaged. Although vacuum packaging of the cheese is common there is a tendency for high vacuum levels to pull moisture from the cheese. The large cheeses are generally cut at the deli, and packaging may consist of loosely wrapping the cheese in a plastic bag. The type of packaging used is determined by availability of materials and preferences of the market segment to which the cheese is being sold.

Due to the perishability of this product, our studies indicate that it should be consumed no later than 3 weeks after date of manufacture. Strict attention should be given to maintaining fresh inventories of this product. This last factor in one that is ignored by many processors. The use of extended code dates as a marketing tool has many negative aspects and should be avoided. Code dates should accurately reflect product quality, not reduce product returns, or fool consumers. In the case of Queso Fresco an accurate code date is the best method to reduce risk associated with this product.

SUMMARY

Queso Fresco, a fresh, soft, white Hispanic cheese can, and is being made in the United States of America. Traditional processing procedures are generally not acceptable and must be modified to produce cheese suitable for this country. To
safely produce high quality Queso Fresco, strict adherence to good manufacturing procedures in combination with extensive sanitation programs are required. Code dating should reflect the actual shelf life of the product, which appears to be 21 days. Direct store sales and extensive consumer education should be part of the marketing program for companies making Queso Fresco.

ACKNOWLEDGMENTS

This work has been performed at the Dairy Products Technology Center, California Polytechnic State University, San Luis Obispo by W. Geilman, J. Path, C. Kennedy, D. Schmidt and K. Yankov. The financial support of National Dairy Promotion and Research Board and the California Milk Advisory Marketing Board via the California Dairy Foods Research Center has made this work possible.
REFERENCES


Figure 1

WEEKLY CHEESE CONSUMPTION

<table>
<thead>
<tr>
<th>TIMES EATEN PER WEEK</th>
<th>PERCENT RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>0</td>
</tr>
<tr>
<td>TWICE</td>
<td>10</td>
</tr>
<tr>
<td>FOUR</td>
<td>40</td>
</tr>
<tr>
<td>SIX</td>
<td>20</td>
</tr>
<tr>
<td>&gt; SIX</td>
<td>10</td>
</tr>
</tbody>
</table>

119 RESPONDENTS
Figure 2

TYPES OF CHEESE CONSUMED

119 RESPONDENTS
Figure 3

HISPANIC CHEESE KNOWN

PERCENT RESPONSE

0 20 40 60 80 100

FRESCO ASADERO CHIHUAHUA MANCHEGO COTIJA OTHER

CHEESE VARIETIES

119 RESPONDENTS
Figure 4

HISPANIC CHEESE CONSUMED

PERCENT RESPONSE

0

100

80

60

40

20

FRESCO ASADERO CHIHUAHUA MANCHEGO COTIJA OTHER

CHEESE VARIETIES

119 RESPONDENTS
Figure 5

WHY HISPANIC CHEESES ARE NOT CONSUMED

% RESPONSE

NOT AVAILABLE IMAGE NOT KNOWN POOR VALUE OTHER

CHEESE VARIETIES

119 RESPONDENTS
Figure 6
Processing Procedure for
FRESH SOFT WHITE HISPANIC TYPE CHEESE

<table>
<thead>
<tr>
<th>Step</th>
<th>time (min)</th>
<th>temp (F)</th>
<th>pH</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add starter</td>
<td>00</td>
<td>88</td>
<td>6.7</td>
<td>Add 2.5% active thermophilus starter culture.</td>
</tr>
<tr>
<td>Add rennet</td>
<td>30</td>
<td>88</td>
<td>6.60</td>
<td>Use 90 ml per 1000# milk diluted calf rennet 1/40 with cold water</td>
</tr>
<tr>
<td>Cut curd</td>
<td>75</td>
<td>88</td>
<td>6.58</td>
<td>Use 3/8-1/2 knife</td>
</tr>
<tr>
<td>Start stir</td>
<td>85</td>
<td>88</td>
<td></td>
<td>Start heat</td>
</tr>
<tr>
<td>Predrain</td>
<td>105</td>
<td>100</td>
<td></td>
<td>Remove whey to top of curd</td>
</tr>
<tr>
<td>Drain</td>
<td>125</td>
<td></td>
<td></td>
<td>Separate curds from whey with strainer</td>
</tr>
<tr>
<td>Salt*</td>
<td>130</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Brine wash</td>
<td></td>
<td></td>
<td></td>
<td>Immerse curds in 45°F saturated salt brine until salt content is 1.5%</td>
</tr>
<tr>
<td>2. Dry Salt</td>
<td></td>
<td></td>
<td></td>
<td>Mix 2% salt with the dry curd. Curd identity can be lost.</td>
</tr>
<tr>
<td>Mold</td>
<td></td>
<td></td>
<td></td>
<td>Place curds in plastic molds, or extrude. Place in 45°F refrigerator.</td>
</tr>
<tr>
<td>Press</td>
<td></td>
<td></td>
<td></td>
<td>Turn hoops every 30 minutes for 3 turns, then let drain 6 hours.</td>
</tr>
<tr>
<td>Package</td>
<td></td>
<td></td>
<td></td>
<td>Either Cryovac bags or consumer size draw-down vacuum packages</td>
</tr>
</tbody>
</table>
PHYSICAL AND CHEMICAL METHODS FOR CONTROLLING 
THE BODY AND TEXTURE OF MOZZARELLA CHEESE

by

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Presented at the
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The following paper was presented by Paul S. Kindstedt, Assistant Professor of Dairy Science and by L. Joseph Kiely, Research Scientist, Department of Animal Sciences, University of Vermont, Burlington, Vermont 05405, especially for the Ninth Biennial Cheese Industry Conference at Utah State University, Logan, Utah on August 21-23, 1990.

PHYSICAL AND CHEMICAL METHODS FOR CONTROLLING THE BODY AND TEXTURE OF MOZARELLA CHEESE

By Paul S. Kindstedt and L. Joseph Kiely

INTRODUCTION

Low-moisture and low-moisture part-skim Mozzarella cheeses are primarily used as an ingredient for pizza and related foods. Both unmelted and melted texture are important to end users of Mozzarella. The unmelted cheese must have desirable shredding properties since it is generally shredded before use in cooking applications. The melted cheese must possess a complex combination of attributes that include meltability, stretchability and elasticity. Further complicating the matter is that different end users have different expectations and specifications with respect to these attributes. This makes the job of the cheesemaker in controlling cheese texture quite challenging.

Unfortunately, our understanding of the factors that govern Mozzarella body and texture is far from complete. However, a renewed research emphasis has occurred in the past few years and rapid progress is being made. The purpose of this paper is to examine some of the past research on Mozzarella along with some recent findings that we hope will enable cheesemakers to gain better control over cheese body and texture.

UNMELTED BODY AND TEXTURE

Mozzarella cheese is usually shredded or diced to facilitate uniform melting. A serious defect in texture occurs when the unmelted cheese is excessively soft and gummy. Such cheese shreds poorly and quickly forms a gummy mass that often clogs the mechanical shredding device.
Information relating to factors that affect shreddability of Mozzarella is scarce. Indeed, a precise definition of shreddability and standard objective methods for its assessment are lacking. For example, USDA specifications state simply that "shredded or diced Mozzarella cheeses shall be loose and free from clumps except those that readily break up with slight pressure" (16).

A number of researchers have used the Instron Universal Testing Machine to study body and textural properties of unmelted Mozzarella (6). Unfortunately, in no case did the investigators relate Instron measurements to cheese shredding properties, thus we can glean only limited information from these reports. One study, conducted by Masi and Addeo (9), is worth mentioning because it offers objective data to support what cheesemakers know through experience: that cheese becomes softer and less shreddable with increasing FDB and moisture content. The investigators manufactured experimental cheeses with different FDB levels and measured the modulus of elasticity, an index of rigidity, by Instron analysis. Their data show clearly that cheese rigidity (modulus of elasticity) decreases with increasing FDB and moisture content. Thus, the combination of high moisture and high FDB leads to a softer cheese that becomes more difficult to shred. This relationship between FDB and firmness is taking on added importance as Mozzarella cheesemakers continue to edge FDB levels upwards in response to declining cream prices. Cheesemakers need to keep in mind that higher FDB in Mozzarella, while economically attractive at present, has important implications for cheese functionality.

The reader is also referred to the report of Cervantes et al. (2) regarding the effects of freezing and salt on unmelted body and texture.

Several specific textural defects may occur in Mozzarella cheese. These include soft rind defect, soft body defect and soft surface defect. Each will be discussed separately.

**Soft Rind Defect.** Soft rind defect was first reported in Gouda cheese by Geurts et al. (3). It is characterized by a soft, wet, sometimes slimy layer at the cheese surface immediately after the cheese is removed from the brine. The defect occurs when brine is used for the first time and disappears after the brine has been used repeatedly. The investigators determined that the defect was due to the absence of soluble calcium in the fresh brine, causing calcium to leach from the cheese into the brine. Calcium loss led to a partial solubilization of casein at the cheese surface which resulted in a soft wet surface layer. They reported that the defect was eliminated by adding calcium (as calcium chloride) to the fresh brine.
Does soft rind defect occur in Mozzarella cheese? We could find no reference to it in the literature. However, some informal observations made during student cheesemaking laboratories suggest that it may occur and its effect may be quite severe. We observed that cheeses salted in fresh brine had an incohesive surface that sloughed off readily when handled. In contrast, cheeses salted in used brine were firm and dry at the surface.

The following experiment was conducted to determine whether calcium leaching occurs during brining of Mozzarella cheese. Four 2.73kg blocks of low-moisture, part-skim Mozzarella were taken consecutively from the molding machine (before brining) at a commercial manufacturing plant. Three of the unbrined blocks were brined for four hours in 22% (w/w) salt brine (pH = 5.3, 4 C) containing 0, .06 and .6% added calcium, respectively. The fourth block was an unbrined control. After brining, blocks were divided into exterior and interior sections consisting of the outer 1.5 cm surface layer and the interior core, respectively.

Total calcium contents of cheeses before and after brining are given in Table 1. Total calcium decreased by 6.6% in the block that was salted in 0% calcium brine. In contrast, when blocks were salted in brines containing .06 and .6% added calcium, total cheese calcium increased by 1.8% and 4.5%, respectively. The effect of brining on calcium content at the exterior and interior of each block is shown in Figure 1. Brine with 0% added calcium caused a substantial depletion of surface calcium. However, calcium levels in the block brined with .06% added calcium were comparable to those in the unbrined control block, and higher in the block brined at .6% added calcium. Thus, the results are consistent with those of Geurts et.al. (3) in showing that calcium leaching to the fresh brine can be controlled by addition of soluble calcium.

It is unlikely that soft rind defect is a common problem for Mozzarella cheesemakers since most manufacturers rarely prepare fresh brine. Instead, the used brine is recycled by filtering, pasteurizing and replenishing the salt content. Because of this, the brine always contains soluble calcium derived from previous cheeses. However, in the event that fresh brine is prepared, the cheesemaker should be aware that potential problems with soft rind may be avoided by calcifying the brine before use with food grade calcium chloride. The brine at the commercial plant from which we obtained our experimental cheeses contained .06% calcium. Based on this and the results shown in Figure 1, we recommend calcifying fresh brine to .06% Ca++ using food grade calcium chloride. The brine also should be acidified with food grade acid to the approximate pH of the cheese (e.g. pH 5.2) before use.

**Soft Body Defect.** Soft body defect is characterized by a soft pasty body and poor shredding properties that develop during aging, especially in the cheese center. Hull et.al. (5) and Ryan (14)
reported that this defect is caused by excessive growth of \textit{Lactobacillus casei}, a common contaminant of raw milk that survives pasteurization. This organism has an extensive battery of proteases and peptidases which, presumably, are responsible for the breakdown and softening of the curd structure. The defect has been linked to slow cooling in the interior of the warm fresh cheese and can be minimized by rapidly cooling the entire curd mass. This is usually accomplished by brine salting the cheese at refrigeration temperature (e.g., 5 C).

\textbf{Soft surface defect.} Ironically, the practice of salting Mozzarella in cold brine to facilitate rapid cooling may lead to the development of a different textural defect that we will refer to as soft surface defect. This defect is characterized by a soft pasty layer at the cheese surface that develops as the cheese ages. The interior of the cheese, however, remains firm and appears as a dry core. Soft surface defect can lead to shredding problems as the cheese ages.

The defect appears to be related to the practice of salting very warm curd in very cold brine, which is peculiar to Mozzarella. Most brine salted cheeses are brined at ambient or moderately cool temperatures (e.g. 12-20 C). When brining is conducted at these temperatures, moisture is rapidly lost from the cheese as salt diffuses inward. This results in very low moisture levels at the cheese surface upon completion of brining. During aging, moisture is drawn osmotically from the low salt interior to the high salt exterior. Over time the very low moisture content at the surface is elevated to approximate parity with the rest of the cheese (4).

A different situation occurs when cold brining is practiced. Nilson (10) showed that moisture loss is substantially reduced under conditions of cold brining. As a consequence, the surface of cold brined cheese remains comparatively high in moisture at the completion of brining. During aging, as water is drawn osmotically outwards towards the high salt exterior, the surface gains moisture and becomes progressively wetter. The end result is a cheese with highest moisture at the surface and lowest at the center, leading to increased risk of soft surface defect.

Figures 3 and 4 show the migration patterns of salt and moisture during aging of two 2.73kg rectangular blocks of commercial brine salted low-moisture part-skim Mozzarella cheese. At each time point, plug samples representing core, midsection and surface were taken along the diagonals of the block crosssection according to the sampling plan shown in Figure 2.

Salt showed a nonlinear distribution on d2 postmanufacture, with most of the salt still at the cheese surface. By d7 the salt gradient had become approximately linear and thereafter progressively decreased in magnitude as salt diffused inward. Like
salt, moisture also developed a linear gradient during aging, with highest concentration occurring at the cheese surface. However, the magnitude of the gradient increased over time as moisture was drawn osmotically outwards. By d28, the cheese surface was 3.5 to 4.5% higher in moisture than the core.

The data illustrate the inherent tendency of brine salted Mozzarella to develop a high moisture, soft surface during aging. Susceptibility to this defect probably increases as average cheese moisture content increases. What can the cheesemaker do to prevent this defect? One strategy is to use the cheese as quickly as is feasible, before elevated moisture at the surface has a chance to cause excessive softening. Another strategy is to minimize the osmotic driving force that results from nonuniform salt distribution. This can be accomplished, at least in theory, by dry salting the curd prior to brining and reducing brining time accordingly. This would result in a smaller salt gradient and reduced osmotic pressure. Unfortunately, effective presalting of Mozzarella curd is not easily achieved, although advances in presalting technology and equipment are making this option more attractive.

MELTED BODY AND TEXTURE

At least three important functional attributes, namely meltability, stretchability and elasticity, contribute to melted body and texture of Mozzarella. Precise definitions for these attributes and standard objective methods for their assessment do not exist. In general terms, meltability refers to the capacity of cheese particles to form a uniform continuous melt, stretchability is the ability of the melted cheese to form fibrous strands that elongate without breaking under tension, and elasticity, or "strength of the stretch", is the ability of the fibrous strands to resist permanent elongation when stretched. Although we speak of these as though they are separate and independent properties, in reality they overlap and the demarcation between attributes is not always obvious.

Assessment of Melted Functionality. Such overlap of definition has clouded the development of effective analytical methods to evaluate these properties. As cheesemakers attempt to use research findings such as those presented below to gain better control over melted Mozzarella body and texture, it is important that they understand the limitations of existing analytical tests and interpret melted functionality research with caution. In light of this, a brief discussion of several commonly used methods for assessing cheese melting properties will be presented next.
1. Subjective assessment

The most simple and straightforward approach is to subjectively evaluate the performance of melted cheese on pizza under commercial conditions. This approached is practiced widely in industry and is the basis for USDA specifications relating to meltability and stretchability (16). With respect to the former, USDA specifications simply state: "The melted cheese shall be evenly distributed over the surface of the pizza..." For stretchability the following guidelines apply: "Insert the tip of a fork into the cheese and lift vertically at least 3 inches from the surface of the pizza. The cheese shall be stringy, and unbroken from the fork to the surface of the pizza. The cheese may be chewy but not gummy." This type of subjective evaluation is useful for industrial quality control purposes but it is not suitable for research unless it is used in combination with meaningful objective measurements.

Another limitation of this approach is that melting properties are highly temperature dependent. A wide range of pizza oven configurations and time-temperature regimens are used commercially. Thus, cheese temperature profile during baking may vary quite markedly depending on the commercial oven design. Consequently, cheese performance may largely depend on baking conditions (11). Manufacturers should take into account the specific baking conditions used by their customers when developing specifications for melted functionality based on performance during baking.

2. Disk meltability test

Another common method to assess melted functionality is to subject a disk of cheese of specified dimensions to heating in an oven (14) or in a boiling water bath (1,12) under defined conditions. Meltability is expressed as a function of increase in disk area or decrease in disk height. The resulting measurement gives some indication of how readily the cheese will coalesce and form a uniform melt. It does not provide direct information concerning stretchability and elasticity and thus should be interpreted with caution when relating this measurement to performance on pizza.

A major limitation of this method is in obtaining representative measurements. We have seen that composition within brine salted Mozzarella cheese is far from uniform (Figure 3,4). This means that melting properties within a single block also are highly variable. Consequently, the meltability value measured from a single disk of cheese will depend on where in the cheese the disk was taken. Data in Figure 5 illustrate the dilemma. Core samples extending from surface to surface through the center of two 2.73kg blocks of commercial Mozzarella were taken using a No. 10 cork borer. Cores were sectioned into 5mm disks and analyzed by the meltability test. Results show extreme disk-to-disk variability
along the core samples. Thus, to obtain a representative picture of the entire cheese it is necessary to analyze many disks taken from strategic locations throughout the block.

3. Tube flow test

This test was originally developed for processed cheese spread (13) but it has also been used for Mozzarella. In this test 15g of cheese are packed into the end of a large diameter (30mm) glass tube. The sealed tube is placed horizontally in a forced draft oven (110°C) and remains there for a specified period of time (e.g., 10 min). The tube is then removed from the oven and the distance traveled by the leading edge of the melted sample is measured. This measurement provides an index of the flow properties of the sample and gives some indication of how readily the sample will coalesce to a uniform melt. It does not provide direct information concerning stretchability or elasticity and thus should be interpreted with caution when relating this measurement to performance on pizza.

It should be noted that determinants of flow properties of melted cheese are quite complex and a cautious interpretation of flow data is required. Figures 6 and 7 illustrate one difficulty in interpretation that may arise with this test. Figure 6 shows flow vs. time curves for 5 different processed cheeses. It is evident that different cheeses begin to flow at different times and at different rates. Consequently, the flow test gives variable results depending on how long the samples are kept in the oven before the flow measurement is made. Figure 7 illustrates the dilemma. The upper and lower graphs compare the ranking of the 5 cheeses according to flow measurements taken after 8 and 12 min in the oven, respectively. Rankings of four out of the five cheeses differed when flow measurements were taken at 12 min rather than 8 min. In short, one may arrive at very different conclusions depending on which time one chooses to take the flow measurement. Which ranking is correct? They both are, which is why this test is difficult to interpret. Although the example in figures 6 and 7 refers to processed cheeses, the same problems occur with mozzarella.

A factor which strongly influences flow properties and which is not taken into account in the tube flow test is sample temperature. Figure 8 compares temperature vs. time and flow vs. time profiles of 3 processed cheeses. It is evident that the temperature profiles of the three cheeses were not identical. As a consequence, cheeses were at different temperatures when flow measurements were taken. Again, this complicates the interpretation of flow measurements. In summary, the tube flow test provides useful general information concerning cheese melting properties; however, test results should be interpreted cautiously and their limitations recognized.
4. Helical viscometry

Helical viscometry is used widely in the food industry to measure rheological properties of very viscous foods. A protocol for analyzing melted Mozzarella cheese was developed (8) and recently improved (7) by our research group. In this procedure, a rotating t-bar spindle is raised through a column of melted cheese at 60°C and the resistance exerted on the spindle is measured. Cheeses that form tough fibrous strands that accumulate around the rotating spindle exert greater resistance than those that form gelatinous soft strands or no strands. Therefore, resistance measurement gives some indication of stretchability and elasticity; e.g., very high resistance indicates a tough elastic consistency while very low resistance indicates that the melted cheese is soft, gelatinous and "soupy". Temperature variability effects are minimized with this test because all samples are at the same temperature (60°C) during analysis. Representative measurements are comparatively easy to obtain because the test utilizes a ground sample.

The resistance profile (apparent viscosity) of a typical Mozzarella cheese is shown in Figure 9. We use the maximum peak height (maximum resistance) as a quantitative index of melting properties. The shape of the peak also provides useful information.

**Controlling Melted Body and Texture.** For several years we have pursued an ambitious research program aimed at understanding the factors that govern Mozzarella cheese melting properties. Although much work is still in progress and much more planned, some advances have been made. The remainder of this paper will focus on factors that are important to effective control of melted body and texture.

1. Age

The significance of cheese age on melting properties is not always appreciated by Mozzarella cheesemakers. Although Mozzarella is considered an unripened or fresh type cheese, it in fact undergoes a rather dramatic and characteristic change in melted functionality over the course of its shelflife. The change in apparent viscosity of a typical commercial low-moisture part-skim Mozzarella during one month of refrigerated aging is shown in Figure 10. Values are the averages of eight cheeses from different vats. Apparent viscosity decreases precipitously during the first two weeks of aging and thereafter continues to decrease but at a slower rate. The data provide quantitative confirmation of what cheesemakers know through experience; i.e., young Mozzarella cheese melts to an excessively tough elastic consistency (i.e., very high
apparent viscosity) that is unacceptable for use on pizza. During the first week or so of aging, however, melted consistency "mellows" substantially and the cheese soon melts to a desirable moderately elastic state. Eventually, the cheese becomes excessively soft and gelatinous and is no longer acceptable for use on pizza.

In short, there is a relatively narrow window of acceptability spanning perhaps three to four weeks during which Mozzarella possesses acceptable functional properties. With respect to apparent viscosity, this window corresponds roughly to the range of 10% to 40%, as indicated in Figure 10. Cheese above 40% AV tends to be too tough for pizza while that below 10% is too gelatinous. The challenge to the cheesemaker is to reach the acceptable range as quickly as possible (to minimize aging requirement) and then stay within that range as long as possible (to maximize shelf life).

2. Starter performance/Moisture control

In order for cheese curd to be workable in hot water it must be partially demineralized (6). One of the functions of the starter culture is to demineralize the curd through production of lactic acid. It is imperative that the starter bacteria produce sufficient acid during manufacture so that 1.) the curd is properly demineralized by the time it reaches the cooker-stretcher and 2.) it has the correct moisture content. In the industrial setting, proper curd demineralization is controlled through achieving an appropriate target curd pH (e.g. pH 5.2). Thus, it is necessary that starter acid production occurs at a rate that produces a curd of appropriate moisture content at the target pH.

In situations where acid production is abnormally slow, for example due to phage infection, the cheesemaker has little choice but to delay cooking-stretching until the curd pH drops and the curd becomes sufficiently demineralized. In the meantime, however, excess moisture is lost and the curd becomes abnormally low in moisture.

The effects of slow starter activity on cheese moisture content and apparent viscosity are illustrated in Figures 11 and 12, respectively. Five vats of cheese were sampled from two industrial cheese plants, A and B, on five different occasions during a ten week period. All samples were analyzed on day 12 postmanufacture. Plant A reported severe phage problems during the 10 week period which necessitated adjustments in manufacture. A common problem during this period was decreasing starter activity as the day progressed. To compensate, make times of vats towards the end of the production day were increased by an hour or more over normal practice. In contrast, Plant B experienced no problems in operation during the sampling period.
Plant A showed substantial variation in moisture from week to week and within a single day, while moisture at Plant B was far more consistent (Figure 11). Apparent viscosity of cheeses at the two plants are shown in Figure 12. It is clear that cheese melting properties were highly variable at Plant A and highly uniform at Plant B. Statistical analysis of the data indicated a highly significant association between apparent viscosity and moisture content. The nature of the relationship is seen in Figure 13. Cheeses became tougher and more elastic (higher AV) with decreasing moisture content. One can conclude from the experience of Plant A that uniform starter performance with respect to acid production and moisture control is absolutely critical in achieving subsequent uniformity in melted body and texture.

3. Salt content

Salt content is a major determinant of melted functionality. We recently used the inherent disparity in salt distribution within freshly brined Mozzarella as a model system to investigate the effect of salt on melting properties. In this study, eight 2.73kg blocks of commercial cheese were obtained immediately after brining. Each block was cut in half and each half was sectioned into the outer 1.5cm exterior surface and interior core. Exterior and interior sections from one half of each block were tested for apparent viscosity and composition immediately (d2 postmanufacture) while sections from the other half were vacuum packaged separately and held at 4 C for 14 days, then analyzed as above (d16 postmanufacture).

The average apparent viscosity for the low salt interior (x salt = .38%) and high salt exterior (x salt = 3.04%) sections on days 2 and 16 postmanufacture are compared in Figure 14. Also shown in Figure 14 for reference is the "typical" AV vs. time curve that was presented earlier in Figure 10. It is evident that the AV curve for the low salt interior is displaced downwards while that for the high salt exterior is displaced upwards relative to the "typical" curve. That is, the low salt interior initially was quite soft and gelatinous and became excessively so by d16. In contrast, the high salt exterior initially was extremely tough and elastic and even after 16d of aging was far too tough for use on pizza.

A second approach used to evaluate the effect of salt on melted consistency was to add salt directly to unbrined curd. A 2.73kg block of low-moisture part-skim Mozzarella was obtained from the molding machine at a commercial cheese plant, vacuum packaged, cooled overnight at 4 C, and then cut in half. One half was then ground completely in a blender. Salt was added to portions of ground cheese at levels of 1, 2 and 4%, respectively. The salt was thoroughly mixed into the cheese and then each sample was vacuum packaged and stored at 4 C overnight to allow for salt equilibration. The following day (d2 postmanufacture) samples were
tested for apparent viscosity. The second half of the block was treated identically after it had aged at 4 C for six days (d7 postmanufacture).

Figure 15 shows the AV of two and six day old samples containing different levels of added salt. AV increased with increasing salt content. At 4% added salt, two day old samples melted poorly and became so tough that it was impossible to obtain AV measurements. Again, it is evident that salt content strongly influences melted consistency, with higher salt levels leading to a tougher, more elastic melted cheese.

4. Mozzarella blends

A growing practice in the pizza trade is to use Mozzarella in combination with other cheeses, either to increase flavor or to economize by extending Mozzarella with a less expensive cheese. This practice can lead to substantial changes in melted consistency. Figure 16 shows the effect on apparent viscosity of blending non-Mozzarella cheeses purchased from a local supermarket with 15 day old low-moisture part-skim Mozzarella at various ratios. Apparent viscosity decreased with increasing blend ratio because Cheddar and Jack cheeses do not melt to a fibrous elastic consistency. As the practice of blending becomes more widespread it will become increasingly necessary for cheesemakers to tailor the melting properties of their Mozzarella cheese to compensate for and compliment the specific blend formulations used by their buyers.

CONCLUSIONS

Undoubtedly, many other factors are relevant to the control of Mozzarella body and texture. Two of them, proteolytic activity and freezing, are presently under investigation. Much remains to be learned with respect to Mozzarella melting properties. Despite this, considerable advancement can be made with respect to improving body and texture simply by sticking to the basics. For example, careful control over moisture and salt content, consistent starter performance and getting the cheese to the end user while it is within in its window of acceptability will go a long way towards gaining effective control over the body and texture of Mozzarella cheese.
ACKNOWLEDGMENTS

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REFERENCES


TABLE 1. Effect of brine composition (calcium concentration) on total calcium content in low-moisture part-skim Mozzarella cheese.

% Calcium in Brine | Total Cheese Calcium (g) Prebrine | Postbrine | % Change
---|---|---|---
0 | 19.513 | 18.230 | -6.6
.06 | 19.507 | 19.857 | +1.8
.6 | 19.530 | 20.420 | +4.6
FIGURE LEGENDS

1. Effect of brine composition (calcium concentration) on calcium distribution in Mozzarella cheese.

2. Cross-sectional sampling plan used to evaluate salt and moisture levels at core, midsection and surface of rectangular 2.73 kg blocks of brine salted Mozzarella cheeses.

3. Cross-sectional distribution of salt and moisture within a 2.73 kg rectangular block of brine salted Mozzarella cheese during one month of refrigerated storage at 4 C (Cheese A).

4. Cross-sectional distribution of salt and moisture within a 2.73 kg rectangular block of brine salted Mozzarella cheese during one month of refrigerated storage at 4 C (Cheese B).

5. Meltability values along core samples taken from two 2.73 kg blocks of Mozzarella cheese. Core samples were obtained using a No. 10 cork borer. Disks were cut at 5 mm intervals along each core.

6. Flow vs. time profiles of selected processed cheeses (PC), cheese foods (CF) and cheese spreads (CS) by the tube flow test.

7. Ranking of selected processed cheeses (PC), cheese foods (CF) and cheese spreads (CS) according to distance flowed at 8 vs. 12 minutes.

8. Comparison of temperature and flow profiles of a processed cheese (PC), cheese food (CF) and cheese spread (CS).

9. Apparent viscosity profile of a Mozzarella cheese by helical viscometry.

10. Change in apparent viscosity of low-moisture part-skim Mozzarella cheese during storage at 4 C. Each value is the average of eight different cheeses.

11. Average moisture content for five vats of Mozzarella cheese sampled at two commercial cheese plants (A and B) during biweekly sampling.

12. Average apparent viscosity for five vats of Mozzarella cheese sampled at two commercial cheese plants (A and B) during biweekly sampling. Cheeses were analyzed on day 12 postmanufacture.

13. Relationship between moisture content (nonfat substance basis - MNFS) and apparent viscosity of Mozzarella cheeses obtained from two commercial cheese plants. Cheeses were analyzed on day 12 postmanufacture.
14. Effect of nonuniform salt concentration within Mozzarella cheese on apparent viscosity

15. Effect of added salt on apparent viscosity of two and six day old unbrined Mozzarella cheese.

16. Apparent viscosity of Mozzarella cheese blended with non-Mozzarella cheeses at selected blend ratios.
The graph shows the concentration of Ca/NFS (%) in different brine conditions. The x-axis represents the concentration of Ca in the brine, while the y-axis represents the concentration of Ca/NFS (%). The graph compares the interior and exterior conditions for each brine concentration level. The brine conditions are labeled as Unbrined, 0% Ca, 0.06% Ca, and 0.6% Ca.
C = CORE (ca. 13 mm from center)
M = MIDSECTION (ca. 33 mm from center)
S = SURFACE (ca. 55 mm from center)
Fig 1

FLOW DISTANCE (mm)

<table>
<thead>
<tr>
<th>PC1</th>
<th>PC2</th>
<th>CF1</th>
<th>CF2</th>
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<td></td>
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FLOW DISTANCE (mm)

<table>
<thead>
<tr>
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<th>PC1</th>
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<td>120</td>
<td>130</td>
<td>140</td>
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</table>

12 MIN
AV (% YIELD)

DAY POST MANUFACTURE

TOO TOUGH

ACCEPTABLE

TOO SOFT
APPARENT VISCOSITY (%)
INTERIOR (.38% SALT)

EXTERIOR (3.04% SALT)

AV (% YIELD)

DAY POST MANUFACTURE

TOO TIGHT

ACCEPTABLE

TOO SOFT
INCOMPLETE MELT AT 4%

APPARENT VISCOSITY (%) vs % ADDED SALT

- DAY 2
- DAY 6
MOZZARELLA : NON-MOZZARELLA BLEND RATIO

APPEARANT VISCOSITY (%)
CONTROLLING THE BODY AND TEXTURE OF MOZZARELLA CHEESE: MICROBIOLOGICAL METHODS

by

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9th Biennial Cheese Industry Conference
Utah State University
Logan, Utah

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MICROBIOLOGICAL METHODS FOR CONTROLLING THE BODY
AND TEXTURE OF MOZZARELLA CHEESE

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Presented at the Ninth Biennial Cheese Industry Conference

INTRODUCTION

Per capita consumption of Mozzarella cheese in the U.S. has increased from .4 pounds in 1960 to 4.1 pounds in 1984 (2). An eight to 10 percent annual increase in Mozzarella production has occurred for at least the last ten years in the U.S. Production of Mozzarella cheese now ranks second to Cheddar cheese and this trend has been predicted to continue at least through the year 2000 (17).

Major purchasers of Mozzarella or pizza cheese are concerned about deterioration in physical properties that can occur as early as the first two weeks of storage (2). In a nationwide survey, only 92% of Mozzarella cheese examined was of acceptable quality, and there was a large variation in melting quality (14). Some buyers require that cheese be graded and frozen to stabilize stretch, blistering, melt, oiling off, and browning during cooking.

Proteinase-deficient mesophilic starter cultures used in production of Cheddar cheese, cottage cheese, and acid casein have advantages over proteinase-positive cultures. These advantages include improved yield, less bitterness, and increased resistance to bacteriophage and antibiotics. It has also been shown that proteinase-deficient mesophilic cultures favorably alter body and texture of Cheddar cheese when compared to proteinase-positive cultures (16).

The proteolytic properties of mesophilic lactic bacteria have been characterized, but few studies have addressed proteolysis in thermophilic lactic bacteria, particularly Lactobacillus delbrueckii spp. bulgaricus and Streptococcus salivarius ssp. thermophilus (1). The proteolytic activity in L. delbrueckii spp. bulgaricus varies more than in other
lactic organisms (4, 20). Modifications in the proteolytic characteristics of thermolactic Mozzarella cultures may result in improvement in the physical properties of the cheese.

**PROTEOLYTIC CHARACTERIZATION OF THERMOPHILIC CULTURES**

The o-phthaldialdehyde (OPA) test and amino acid analysis were used to characterize proteolysis of milk proteins during growth of *Lactobacillus delbrueckii* ssp. *bulgaricus* (9). Thirty four strains were incubated in sterile 10% non-fat dry milk for 12 h. Extent of proteolysis as estimated by the OPA test revealed a large variance in total proteolysis. For seven strains, trichloroacetic acid filtrates of inoculated 10% non-fat dry milk were analyzed by classical ion exchange amino acid analysis. Each strain had a distinct pattern of individual amino acid concentrations. Amino acid profiles provided information about the proteolytic activity of these strains than was not available from the OPA test. Cluster analysis, based on amino acid profiles of each strain, was then used to differentiate the seven strains beyond what is possible by visually comparing the amino acid analysis results.

Extent of proteolysis based upon OPA values was variable among the 34 strains of *L. delbrueckii* ssp. *bulgaricus* examined (Figure 1). Absorbance readings ranged from .20 to 1.29 for cultures that were incubated in 10% NDM for 12 h. The extreme range of proteolysis noted for strains of *L. delbrueckii* ssp. *bulgaricus* was not observed among samples of other lactic genera and species examined by the same procedure (Table 1).

Seven of the 34 strains of *L. delbrueckii* ssp. *bulgaricus* screened by the OPA method were examined by amino acid analysis. Fifteen amino acids were selected to profile each strain (15). The profiles in Figure 2 show the concentrations of amino acids in NDM medium after incubation, divided by an uninoculated control. The average coefficient of variation for the seven strains measured in triplicate was 7.3%. Since relative concentrations of individual amino acids differed among strains, amino acid profiles also differed. Figure 2 adds detail to what is available from the ranking in Figure 1. For example, the prominence of the His peak in strains 133, 100, and 132 contrasts with the His valley for the other four strains.
Total amino acid concentration correlates with the OPA method \((R^2 = .95)\) (21). Relative percentages of amino acids appeared similar among strains 117, 118, 111, and 114, which promoted more proteolysis. Greater variability in amino acid profiles was observed among strains 133, 100, and 132, which were least proteolytic.

Cluster analysis was run using triplicate measurements of concentrations of fifteen amino acids as quantitative variables for each culture strain. Canonical variables are linear combinations that allow reduction of amino acid concentrations to two dimensions. A two dimensional arrangement of the cultures plotted as first versus second canonical variables is shown in Figure 3. The value of such plots is in identifying similarities and differences among samples, in this case among strains. Those points closest to each other are most similar and those furthest apart are least similar. Absolute distances between the 21 possible pairs of points in Figure 3 are listed in Table 2.

These three methods represent a succession of increasing ability to assess proteolysis associated with culture strains. The OPA procedure reveals a wide variation in amount of proteolysis. Amino acid analysis profiles provides more information about the kind of proteolysis associated with each strain. Application of statistical procedures is necessary to accurately extract similarities and differences among strains from the amino acid analysis data. The kinds of information presented in Figures 1, 2, and 3 are all needed for a complete picture.

Differences among amino acid profiles reflect differences in proteinase, peptidase, and transport activities of lactic culture strains. A specific amino acid profile might correlate with a particular type of enzymic activity. *L. delbrueckii* ssp. *bulgaricus* is used in the manufacture of Mozzarella cheese where the physical properties of the cheese are critical to quality. The wide variation in total proteolysis among strains of this organism has major implications for physical properties of Mozzarella cheese. Profiling cultures by statistical analysis of amino acid analysis data can show which strains will give the most desirable characteristics in cultured products.
PHYSICAL PROPERTIES OF MOZZARELLA CHEESE

Review of Physical Analysis Methods

Few studies concern physical properties of Mozzarella cheese, possibly because there is a lack of objective methods to measure these properties. Nilson and LaClair (14) measured melt by placing 5 mm thick, 6.2 cm$^3$ discs of cheese on filter paper and heating and compared the change in area. Fernandez and Kosikowski (11) used the same method to study meltability of Mozzarella cheese made with ultrafiltered whole milk retentates and also measured changes in cheese texture with an Instron Universal Testing Machine. Park and Rosenau (19) found the Arnott test more accurately measured melt in Mozzarella cheese than the Schreiber test. In the Arnott test, a cylinder of cheese approximately 17 x 17 mm is placed on a glass tray and heated at 100°C for 15 min (3). Kindstedt and Rippe (13) found the helical viscometer most accurately measures apparent viscosity of Mozzarella cheese.

Creamer (9) found less casein degradation, particularly of $\alpha_s$-casein, in Mozzarella cheese than in Gouda or Cheddar and suggested that stretching properties may be related to higher concentrations of intact casein and large peptides. He also correlated this to a decrease in bacterial proteinase activity in Mozzarella cheese owing to higher manufacturing temperatures. Cervantes et al. (7) noted that longer storage times following thawing of Mozzarella cheese resulted in softening of the body. DiPalma et al. (10) used strains of $\alpha_s$-casein to find that less proteolytic strains of Lactobacillus helveticus gave cheese a firm, elastic body and more proteolytic strains gave cheese a soft, crumbly body. Johnson and Olson (12), using a Hunterlab colorimeter, found a positive correlation between galactose concentration and brown color intensity in Mozzarella cheese during cooking.

Selection of Proteinase-Deficient Strains

Strains of L. delbrueckii spp. bulgaricus and L. helveticus were chosen for Mozzarella cheese manufacture based on their proteolytic activity as measured by the OPA test. A six-fold difference in total proteolysis was found between proteinase-deficient and proteinase-positive strains. OPA analysis of the Streptococcus
salivarius spp. thermophilus isolates and parents showed only small differences in total proteolysis.

**Mozzarella Manufacturing Procedure**

Mozzarella cheese was made from single strains of *L. delbrueckii* spp. *bulgaricus* or *L. helveticus*. Mozzarella cheese was also made from paired cultures containing a single strain of *L. delbrueckii* spp. *bulgaricus* or *L. helveticus* and a single strain of *S. salivarius* ssp. *thermophilus*. The paired strains contained either a set of strongly proteolytic or a set of weakly proteolytic organisms. Six-liter vats of Mozzarella cheese were made from raw milk from Utah State Dairy Products Lab that was standardized to a casein/fat ratio of 1.2 and pasteurized at 63°C for 30 min. The milk was cooled to 32°C, placed in stainless steel containers and 2% starter was added. Bulk starter cultures were grown in a commercially available internal pH-control medium where 1% yeast extract was added to grow the proteinase-deficient strains. The stainless steel cheese vats were heated in a water bath. Inoculated cheese milk was ripened for 1 h at 32°C. Single strength calf rennet, 1 ml diluted 1:20 in cold water, was added and the milk was set for 30 min. Curd was cut and heated to 41°C over 30 min with periodic stirring. Whey was drained when whey pH reached 5.9 (measured at 41°C). Curd patties were Cheddared until a pH of 5.2 was reached, then milled, mixed, and molded in fresh 82°C water until curd balls were smooth and elastic. This required approximately 5 min for each sample. Molded curd balls were placed in ice water to firm the curd, then placed in a saturated NaCl brine for 8 h at 22°C. The same brine solution was used repeatedly for all the samples. Each cheese sample was kept at 4°C until tested. Mozzarella cheese made by direct acidification was used as the culture-free control. The method of Breene et al. (6) was followed. All cheese samples were made from the same milk and with the same levels of coagulating enzyme (185 RU/ml). Composition of individual cheese samples was not measured. When cheese was made with paired strains of *L. delbrueckii* ssp. *bulgaricus* and *S. salivarius* ssp. *thermophilus* the curd pH dropped more rapidly than with only single strains of *L. delbrueckii* ssp. *bulgaricus*. Manufacturing times decreased by 2 h when compared to cheese made with
single strains. Proteinase-positive pairs produced more acid than proteinase-deficient pairs.

**Stretch Test Procedure**

The helical viscometer method of Kindstedt et al. was used with modifications (13). We use the term "stretch" as it is used empirically in the Mozzarella industry to describe the combination of rheological properties measured by helical viscometry. Fifteen grams of shredded cheese were packed into a 25 x 150 mm test tube and placed in a 60°C water bath for 10 min. A Brookfield LVT helipath viscometer equipped with a T-bar spindle (TE with a 1.075 cm crossbar) was used. The T-bar spindle was gradually lowered by the helipath stand to the bottom of the tube containing the tempered cheese sample. The helipath stand was then turned off and the viscometer was adjusted to a speed of 1.5 rpm. Once a full-scale reading was reached the helipath stand was turned on to raise the rotating spindle. Ten readings were taken in the 10 min it took for the helipath to raise the viscometer to the upper limit. The sum of the area under the curve was used to objectively portray the stretch of each sample. Instead of using a MVT helical viscometer (100 to 8 x 10^6 centipoise), a LVT helical viscometer (50 to 2 x 10^6 centipoise) was used. It appeared to be more sensitive in measuring smaller strings of cheese carried by the spindle after it rose out of the body of the cheese sample.

**Browning Test Procedure**

Test tubes of grated cheese used in the stretch test were put in a boiling water bath (96°C) for 60 min. Color differences were measured with a Minolta Chroma Meter CR-100. The selector switch was set to Illuminant C (6774K) and the chromaticity mode was L*a*b*. The bottom of the test tube was clamped into close contact with the measurement head. Eight readings were taken from the bottom of the tube. The tube was rotated approximately 45° between each reading. The mean b* values indicating color change differences from yellow to blue were used to compare cook colors.

**Melt Test Procedure**

A modification of the method used by Olson and Price (18) was used to measure meltability. Fifteen grams of grated cheese was put in one end of a Pyrex glass tube (30 X 250 mm) and lightly tamped with the end of a spatula until all samples filled the
same volume (ca. 5 cm). The end containing the cheese was stoppered with a #7 solid rubber stopper and the same size stopper with a hole bored through it was inserted in the opposite end. The vertical tube was tempered at 4°C for 30 min with diced cheese at the bottom then placed horizontally on a tilt-control rack in an oven at 110°C for 60 min. After cooling to room temperature the cheese flow was measured.

Physical Properties of *L. delbrueckii* spp. *bulgaricus* Cheese

In Mozzarella cheese manufactured only with single strains of either proteinase-positive or proteinase-deficient *L. delbrueckii* spp. *bulgaricus*, significant differences in stretch were noted (Figure 4). Analysis of variance showed the effect of cultures and time and their interaction to be significant (α < .01 for each variable and the interaction). By day-seven cheese made with proteinase-deficient cultures showed a slight reduction in stretch and by day-fourteen this loss of stretch was pronounced. Cheese made with proteinase-positive cultures lost about half of its stretch over 28 d. Cheese made with proteinase-deficient strains rapidly lost its ability to stretch after 7 d. Direct acid cheese had lost most of its stretch by day-seven. After 14 d, there was no difference between the stretch of cheese made with direct acid or with proteinase-deficient cultures. A large inverse correlation (R² = -.73) was found between stretch and time.

Cheese made with single strains of *L. delbrueckii* spp. *bulgaricus* showed greater melting with time. Cheese made with proteinase-deficient strains melted more easily than cheese made with proteinase-positive strains (Figure 5). Proteinase-deficient cheese showed a rapid increase in melt by day-seven, but by day-twenty eight the differences were less dramatic. Analysis of variance showed the effects of cultures and time to be significant (α < .01 for both). The interaction between cultures and time was also significant (α < .01). Direct acid cheese melted more easily at day-one than cultured cheeses, but its melting properties remained about same throughout the 28 d. At 28 d of age, direct acid cheese and proteinase-positive cheese had the same degree of meltability. Correlation between stretch and time was significant with R² = .71.

Cheese made with proteinase-positive single strains of *L. delbrueckii* spp. *bulgaricus* was darker after cooking than either cheese made with proteinase-deficient
strains or by direct acid (Figure 6). Analysis of variance showed the effect of cultures and time and their interaction to be significant (a < .01 for each of the main effects and the interaction). Direct acid cheese remained much lighter after cooking throughout the testing period than did the cultured cheeses.

**Physical Properties - Paired Cultures**

No differences between proteinase-positive pairs containing one strain of *L. delbrueckii* spp. *bulgaricus* and one of *S. salivarius* ssp. *thermophilus* and proteinase-deficient paired strains were found (Figure 7). A 60:40 rod to cocci ratio was used. Cheese rapidly lost stretch by day-seven and by day-fourteen had little measurable stretch. Direct acid cheese showed much less stretch at day-one but at days fourteen and twenty-eight it had slightly more than the cultured cheeses.

Cheese made with proteinase-positive pairs showed better melting characteristics than cheese made from proteinase-deficient cultures (Figure 8). Proteinase-positive cheeses melted better throughout the storage period. Direct acid cheese had much less meltability for the entire period and did not display a large rise in melt with time as did the cultured cheeses.

Cheese made from proteinase-deficient pairs showed less browning after cooking than proteinase-positive cheeses (Figure 9). All cheese made with cultures increased in browning with time. Direct acid cheese showed little browning and no significant increase in browning over time.

**Effect of Rod:Cocci Ratios**

Mozzarella cheese was manufactured with an 80:20 ratio of rods to cocci or a 20:80 ratio of rods to cocci. For each ratio either a pair of highly proteolytic cultures or a pair of weakly proteolytic cultures were used, resulting in two cheese types for each ratio. No differences were observed between the various ratios, but differences were found between the highly proteolytic cultures and the proteinase-deficient cultures as mentioned in the previous section. A rapid decrease in stretch was observed by day 7, with the proteinase-deficient cultures showing a slightly higher amount of stretch (Figure 10). By day 14, all cheeses were showed the same degree of melt, and this continued through day 28.
Cheese made from proteinase-positive culture pairs of either ratio showed more melt than proteinase-deficient cheeses (Figure 11). The large rise in melt at day 7 may be due to a higher concentration of salt on the surface of the cheese were the sample was taken from. These results confirm the melt observations discussed in the previous section also.

Cheese made from the proteinase-deficient pairs showed less cook color over the entire 28 day test period (Figure 12). The cook color results are comparable to the results for the cheese made from the 60:40 ratio. Cheese made with 20:80 proteinase positive rod:cocci ratio did show significantly more browning than the other cheeses.

**Effect of Using *L. helveticus* Cultures on Physical Properties**

Cheese made with *L. helveticus* cultures, either single strains or paired with a *S. salivarius* ssp. *thermophilus*, showed a decrease in stretch over time (Figure 13). This decrease, however, was considerably less than observed with paired strains containing a *L. delbrueckii* ssp. *bulgaricus*. Cheese made with the proteinase-positive pair retained the most stretch over time.

All cheeses showed a very rapid rise in melt by day 7 (Figure 14). After day 7 very little change in melt was observed, with the exception of the cheese made with the proteinase-deficient *L. helveticus* paired with the cocci, which showed a drop in melt at day 14.

Three of the four cheese types showed a decrease in cook color over time (Figure 15). Cheese made with the proteinase-positive *L. helveticus* pair showed the typical rise in cook color over time. The decrease in cook color over time may be due to the fact that *L. helveticus* cultures are galactose-positive, while *L. delbrueckii* ssp. *bulgaricus* cultures do not ferment galactose.

**Effect of milk-coagulating enzymes on Physical Properties**

No statistical differences were found in the physical properties of cheese made by direct acidification using four different milk-coagulating enzymes (chymosin, bovine pepsin, porcine pepsin, and *Mucor miehei* protease). Overall effects on stretch, melt, and cook color are found in Figures 16, 17, and 18 respectively. As previous mentioned, the most dramatic decrease in stretch occurs by day 7 and the most rapid increase in
melt by day 14. No significant changes in cook color were observed, with all the cheese maintaining a white color throughout the test period.

CONCLUSIONS

Mozzarella cheese can be manufactured with proteinase-deficient strains of *L. delbrueckii* spp. *bulgaricus*, *L. helveticus*, and *S. salivarius* spp. *thermophilus*. Changes in the proteolytic nature of cultures used to manufacture Mozzarella cheese influences the melt, cook color, and stretch properties.

Cheese made with single strains of proteinase-deficient *L. delbrueckii* spp. *bulgaricus* melted more and browned less when cooked when compared to cheese made with paired strains (Figure 20). It did not stretch as much as cheese made with proteinase-positive single strains (Figure 21). Using proteinase-positive mixed pairs of *L. delbrueckii* spp. *bulgaricus* and *S. salivarius* spp. *thermophilus* increased melt and browning during cooking when compared to single strains of *L. delbrueckii* spp. *bulgaricus*. No differences in stretch were detected when compared to cheese made with proteinase-deficient paired strains. Cheese made with either single strains or paired cultures of *L. helveticus* stretched more than cheese made with paired strains of *L. delbrueckii* spp. *bulgaricus* and *S. salivarius* spp. *thermophilus*, but not as well as cheese made with proteinase-positive strains of *L. delbrueckii* spp. *bulgaricus* (Figure 22). Cheese made with either pairs or single strains of *L. helveticus* showed the same melt as cheese made with paired strains *L. delbrueckii* spp. *bulgaricus* and *S. salivarius* spp. *thermophilus*, while cheese made with single strains of *L. delbrueckii* spp. *bulgaricus* showed the least melt over time (Figure 23).

Cheese manufactured with single strains of proteinase-positive *L. delbrueckii* spp. *bulgaricus* retained more stretch over the entire testing period when compared with cheese made with paired strains of *L. delbrueckii* spp. *bulgaricus* and *S. salivarius* spp. *thermophilus* or *L. helveticus* (Figure 19). Cheese made with paired cultures had better melting properties than cheese made with single strains of either proteinase-positive or deficient *L. delbrueckii* spp. *bulgaricus* (Figure 20).
In cheese made with single strains of *L. delbrueckii* spp. *bulgaricus*, proteinase-deficient strains improve melt but lessen stretch. There is an inverse correlation between melt and stretch properties in cheese made with single rod strains ($R^2 = -.83$). This relationship is even more pronounced when stretch is compared to melt in the direct acidification cheese made with various milk-coagulating enzymes (Figure 21). Comparison of melt and stretch properties in Mozzarella cheese made with single pairs of *L. delbrueckii* spp. *bulgaricus* indicates that increased stretch showed no such correlation ($R^2 = .22$).

The proteinase-deficient strains all reduced the browning effect during cooking. Cheese made with single strains of *L. delbrueckii* spp. *bulgaricus* had little change in cook color after 7 d of storage, while cheese made with mixed pairs continued to increase in browning. Both paired and single strain *L. helveticus* cultured cheese showed a decrease in cook color over time and the browning was considerably less than for cheese made with *L. delbrueckii* spp. *bulgaricus* cultures. Some enzymic activity in the cheese made with mixed pairs of *L. delbrueckii* spp. *bulgaricus* and *S. salivarius* spp. *thermophilus* released either amino acids or galactose for the browning reaction. In cheese made with single strains of *L. delbrueckii* spp. *bulgaricus* a significant correlation ($R^2 = -.65$) was observed between moisture and color intensity. As moisture in the cheese increased, less cook color developed.

Mozzarella cheese made by the direct acid method melted poorly and had almost no browning. Comparing the melting properties of direct acid cheese with cultured cheese indicates the important role bacterial cultures play in development of these physical properties. This was also shown in the results of the enzyme study. Direct acid cheese is deficient in either galactose or amino groups or both to contribute to color changes during cooking. Direct acid cheese was comparable in stretch properties to the mixed pair cheese (*L. delbrueckii* spp. *bulgaricus*), but not with the single strain cheese (*L. delbrueckii* spp. *bulgaricus*). Loss of stretch in direct acid cheese during storage suggests proteolytic activity of milk coagulating enzymes or native milk proteases. The use of *L. helveticus* cultures can increase stretch properties, decrease cook color, and...
maintain melting properties when compared to the use of *L. delbrueckii* spp. *bulgaricus* cultures. Single strains of highly proteolytic *L. delbrueckii* spp. *bulgaricus* cultures showed the most stretch, but had less melt and more cook color the other culture types.

**ACKNOWLEDGEMENTS**

I would like to thank the National Dairy Promotion and Research Board and the Western Dairy Foods Research Center for funding this research. I would also like to thank Amos Wang, Richard Merrill, Lynn Moyes, Rodney Brown, and Gary Richardson for their assistance.
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Table 1. Proteolysis ranges for selected dairy strains using the OPA test.

<table>
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<th>Culture</th>
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<th>Incubation Time (h)</th>
<th>Range (A₃₄₀)</th>
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<td>5</td>
<td>24</td>
<td>.14 - .17</td>
</tr>
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<td>.15 - .29</td>
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<td>12</td>
<td>.45 - .71</td>
</tr>
<tr>
<td>Streptococcus salivarius ssp. thermophilus</td>
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<td>12</td>
<td>.21 - .39</td>
</tr>
<tr>
<td>Lactobacillus delbrueckii ssp. bulgaricus</td>
<td>34</td>
<td>12</td>
<td>.20 - 1.3</td>
</tr>
</tbody>
</table>

Table 2. Relative distances between pairs of strains of *Lactobacillus delbrueckii* ssp. *bulgaricus* based on amino acid profiles in filtered NDM media following growth. Units match those in Figure 3.

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<td>229</td>
<td>104</td>
<td>181</td>
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</tr>
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</table>
Figure 1.  
Proteolytic activity of *Lactobacillus delbrueckii* ssp. *bulgaricus* strains using the OPA test. Cultures were incubated for 12 h in 10% NDM. Points are means of two samples (Each sample is the average of ten spectrophotometer readings) and error bars are standard errors of the means.

Figure 2.  
Comparison of amino acid profiles in filtered NDM media following growth for 12 h of seven strains of *Lactobacillus delbrueckii* ssp. *bulgaricus*. Each profile was divided by a control (no culture). Readings represent means of three samples.

Figure 3.  
Clustering of seven strains of *Lactobacillus delbrueckii* ssp. *bulgaricus* based on amino acid profiles in filtered NDM media following growth. Each point represents the mean of three samples. Error bars showing standard errors of the means are so small they are hidden by the symbols.
Figure 4. Stretch measurements (relative units) of Mozzarella cheese made with either proteinase-positive or deficient single strains of *Lactobacillus delbrueckii* spp. *bulgaricus*. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 5. Melt measurements of Mozzarella cheese made with either proteinase-positive or deficient single strains of *Lactobacillus delbrueckii* spp. *bulgaricus*. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 6. Cook color measurements of Mozzarella cheese made with either proteinase-positive or deficient single strains of *Lactobacillus delbrueckii* spp. *bulgaricus*. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)
Figure 7.
Stretch measurements (relative units) of Mozzarella cheese made with single strain pairs of Lactobacillus delbrueckii spp. bulgaricus and Streptococcus salivarius spp. thermophilus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 8.
Melt measurements of Mozzarella cheese made with single strain pairs of Lactobacillus delbrueckii spp. bulgaricus and Streptococcus salivarius spp. thermophilus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 9.
Cook color measurements of Mozzarella cheese made with single strain pairs of Lactobacillus delbrueckii spp. bulgaricus and Streptococcus salivarius spp. thermophilus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)
Figure 10.
Stretch measurements (relative units) of Mozzarella cheese made with various ratios of single strain pairs of Lactobacillus delbrueckii spp. bulgaricus and Streptococcus salivarius spp. thermophilus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 11.
Melt measurements of Mozzarella cheese made with various ratios of single strain pairs of Lactobacillus delbrueckii spp. bulgaricus and Streptococcus salivarius spp. thermophilus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 12.
Cook color measurements of Mozzarella cheese made with various ratios of single strain pairs of Lactobacillus delbrueckii spp. bulgaricus and Streptococcus salivarius spp. thermophilus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)
Figure 13.
Stretch measurements (relative units) of Mozzarella cheese made with either single strains or mixed single strain pairs of Lactobacillus helveticus and Streptococcus salivarius spp. thermophilus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 14.
Melt measurements of Mozzarella cheese made with either single strains or mixed of single strain pairs of Lactobacillus helveticus and Streptococcus salivarius spp. thermophilus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 15.
Cook color measurements of Mozzarella cheese made with either single strains or mixed of single strain pairs of Lactobacillus helveticus and Streptococcus salivarius spp. thermophilus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)
Figure 16. Stretch measurements (relative units) of Mozzarella cheese made by direct acidification using different coagulants.

Figure 17. Melt measurements of Mozzarella cheese made by direct acidification using different coagulants.

Figure 18. Cook color measurements of Mozzarella cheese made by direct acidification using different coagulants.
Figure 19. Comparison of stretch between paired cultures of Lactobacillus delbrueckii spp. bulgaricus and Streptococcus salivarius spp. thermophilus and single strains of Lactobacillus delbrueckii spp. bulgaricus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 20. Comparison of melt between paired cultures of Lactobacillus delbrueckii spp. bulgaricus and Streptococcus salivarius spp. thermophilus and single strains of Lactobacillus delbrueckii spp. bulgaricus. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 21. Correlation between stretch and melt in Mozzarella cheese made by direct acidification.
Figure 22. Comparison of stretch between a paired culture of *Lactobacillus delbrueckii* spp. *bulgaricus* and *Streptococcus salivarius* spp. *thermophilus*, a single strain of *Lactobacillus delbrueckii* spp. *bulgaricus*, and paired and single strains of *L. helveticus*. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)

Figure 23. Comparison of melt between a paired culture of *Lactobacillus delbrueckii* spp. *bulgaricus* and *Streptococcus salivarius* spp. *thermophilus*, a single strain of *Lactobacillus delbrueckii* spp. *bulgaricus*, and paired and single strains of *L. helveticus*. (Solid symbols - proteinase positive cultures; open symbols - proteinase deficient cultures)
Reduced Fat Cheese: Problems and Opportunities

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Emphasis on the development and improvement of low fat cheese has intensified in the last five years although research on this type of cheese has been underway for 30-40 years. Considerable debate has occurred that has both illuminated and obscured logical evolution of these products. The need for low-fat cheese was underscored by a recent announcement of dietary recommendations by the American Heart Association (Anon., 1990). This association plus eight other major private and governmental health organizations agreed upon dietary recommendations that emphasized reduced consumption of total fat and saturated fat. Pressure from health organizations, nutritionists, governmental initiatives plus market-driven forces will further intensify the need to develop high quality lowfat products.

Lowfat cheeses, including natural and processed varieties, are in the market place. Consumer acceptance is good but the products do not precisely simulate their traditional counterparts. It is essential that high quality lowfat cheese be offered on the market since users of low-calorie products stated that taste improvement was the number one change that they would like to see in these products (La Bell, 1990). Undesirable taste was cited as the reason for rejection of low-calorie products by non-users.

Improvement of the flavor and body of lowfat cheese require an understanding of the role of milkfat in cheese. Most varieties of cheese can be visualized as a viscoelastic solid in which the protein matrix serves as the principal structural component. The milk proteins, caseins, form a continuous network during cheesemaking which entraps the aqueous serum and milkfat either physically or by chemical bonding (Kimber et al., 1974; Green et al., 1981).
Milkfat exists as spherical globules in milk; their association with the protein matrix in a clotted milk gel depends upon the surface characteristics of the fat globules (van Vliet and Dentener-Kikkert, 1982). This probably applies also to cheese curd. Shrinkage of the gel (curd particles) and increased temperatures during cheese manufacturing distorts the fat globules and ruptures the surface membrane on the fat globules (Green et al., 1981). The final cheese consists of islands of fat entrapped in the curd matrix as shown by electron microscopy.

Levels of fat in cheese have a direct impact on acceptability. Flavor and physical properties of Cheddar-type cheese in which the fat level was reduced by 25% compared reasonably well with Cheddar cheese (Banks et al., 1989). We found that reduction of fat content by 33% yields Cheddar-type cheeses that are acceptable but reduction of 50% or greater resulted in cheese of poorer flavor quality and physical properties (Rank, 1985). Similar results were observed with Cheddar cheese by Banks et al. (1989) and for Edam cheese (Wilby, 1988).

Role of Fat in Cheese

Milkfat serves multiple functions in cheese but not all have been defined. Some of the properties of cheese that are affected by fat are listed in Table 1. The impact on various physical properties including firmness, stickiness and mouthfeel are apparent when fat is removed from cheese. The influence of fat on cheese flavor is variety specific. In some cheese varieties, free fatty acids and their metabolites are important. The flavor of many varieties, including Cheddar, does not depend upon free fatty acids for major flavor notes. The solvent function may be more important in these varieties. Yield of cheese depends primarily upon the fat and casein concentrations of milk.
These constituents comprise about 90% of the solids in cheeses. Milkfat serves other functions, one being a solvent for fat-soluble vitamins.

**Effect on Body of Cheese**

Relative amounts of water, protein and fat are dominant factors affecting cheese firmness (Prentice 1987; Walstra et al., 1987). The amounts and ratios of water and protein seem to have the greatest affect. Hardness of cheese varieties with diverse composition correlated most closely with protein content but was not related to fat content (Chen et al., 1979). Prentice (1987) described several reports of a direct relationship between firmness and cheese moisture content.

The development of more objective methods for grading cheese has included the concept of using the level of moisture in the nonfat substance (MNFS = % H$_2$O/100 - % fat) as one of the indices (Burton, 1989). This is essentially a ratio of water to protein. Adjusting the fat content of cheese, within certain limits, while maintaining a constant MNFS should yield cheeses with fairly uniform firmness. However, this can not be extrapolated to cheese in which fat content has been reduced by more than 33%. Emmons et al. (1980) and we have observed that the MNFS had to be higher than predicted in lowfat Cheddar cheese to attain firmness approximating that of Cheddar cheese. This was attributed to a greater amount of protein (30% more) per unit volume of lowfat cheese as compared to Cheddar cheese.

Firmness of cheese was affected by the meltabilities of different milkfats (Prentice, 1987). An indirect linear relationship was observed between penetrometer readings of cheese and iodine number of milkfat which is a measurement of saturation and an indication of meltability. The physical state of the fat, as measured by the
proportion of solid to liquid fat, at different temperatures might affect the firmness and stickiness of cheese. A sharp decrease in this ratio occurs at 12-15°C which is slightly above cheese maturation temperatures. However, the impact of fat on temperature-induced softening may be negligible since changes in relative firmness were linear and similar between 5°C and 30°C for cheeses of varying composition (Prentice, 1987). However, lowfat (30% fat reduction) cheeses were not evaluated.

A linear decrease in elasticity of Mozzarella cheeses was observed as the ratio of fat to solids-not-fat increased (Masi and Addeo, 1986). The effect of fat may not have been direct since a similar trend could be constructed between elasticity and MNFS although the relationship was not as close as that observed with the fat to solids-not-fat ratio. Chen et al. (1979) observed that protein levels were the dominant component affecting elasticity of cheese varieties of varying composition. However, fat played a more dominant role in this rheological property than any other measured property.

The effect of milkfat on cheese elasticity may result from the interaction between the fat globule surface membrane and the cheese protein matrix. Globules that were washed to remove the surface membrane did not contribute to the elasticity of acid milk gels. (van Vliet and Dentener-Kikkert, 1982). Globules coated with casein micelles by homogenization contributed substantially to gel elasticity. The impact may also be lessened in ripened cheese since the globule membrane appears to be disrupted.
Lowfat cheeses exhibit a stickiness when eaten. This is especially evident in cheeses with higher moisture content, with fat contents of 15% or less and after the cheese has been aged. Protein content was the dominant factor influencing adhesiveness of cheese with varying composition (Chen et al., 1979). It has not been demonstrated whether removing a portion of the fat in cheese affects adhesiveness directly or if the effect was indirect because of the concomitant increase in the protein level.

Effect on Flavor of Cheese

The flavor of milkfat is unique because of high concentrations of short chain fatty acids that are flavor-active. Free fatty acids contribute substantially to flavor of several varieties such as Romano, Blue and Feta cheeses. They do not seem to be very important and are detrimental at high concentrations in other varieties such as Cheddar and Gouda. Lack of flavor in lowfat cheeses are not related to lack of fat since intense free fatty acid flavors can be produced in these cheeses with added lipases. It is difficult to induce lipolysis in lowfat Cheddar-type cheese without producing excessive hydrolytic rancidity (Hargrove et al., 1967).

Comparisons of several vegetable fats, mineral oil and milkfat used to make Cheddar cheese provided some interesting functions of fat in cheese but did not define its precise role (Foda et al., 1974). All cheeses possessed reasonably pleasant flavors but cheese made from milk with the undisturbed fat globules had a significantly better flavor. The acceptability of mineral oil as the fat source in cheese suggests that fat serves as a reservoir for fat-soluble flavors and provides a fat-water interface for reactions. Cheeses with vegetable fats developed undesirable flavors which may have
related to the quality of fat source. The role of short-chain fatty acids was unresolved, even though one vegetable fat was transesterified to contain levels of butyric and caproic acids equivalent to milkfat. Cheese made with the transesterified fat was not better than mineral oil but this may have been caused by the off-flavors in the cheese containing the vegetable fat.

The superior flavor in cheese made with the natural milk emulsion suggests that the milkfat globule surface membrane is important in flavor development. Experimental conditions precluded conclusive assessment but Foda et al. (1974) felt that the type of membrane material was not significant. They stated that the fat-water interface is important in development of Cheddar cheese flavor but the reasons for this are obscure.

There are several reasons that the fat-protein-serum interface should be investigated for effects on flavor development and structure of lowfat cheeses. Bacteria tended to congregate at the fat-protein interface of Cheddar cheese (Dean et al., 1959). Yiu (1985) observed larger fat globules in the vicinity of mold in blue cheese. The close proximity of flavor-producing bacteria and fat globules may have implications for flavor development in cheese since Manning (1974) suggested that flavor compounds generated in the protein phase may be held and protected in the fat phase of cheese. Lowfat cheese would have fewer fat globules that were more widely dispersed which would lessen the access of flavor compounds generated in the serum to the protective solvent, fat, in lowfat cheeses.
Manufacturing Technology

Lowfat cheese technology has been developed to simulate existing varieties of cheese and to develop unique types (Reisfield and Harper, 1955; Yamamoto, et al., 1959; leRoux and Abbot, 1962; Hargrove et al., 1966; Madsen et al., 1970; Emmons et al., 1980; deKoning et al., 1981; Rank, 1985; El-Neshawy, et al., 1986; Jameson, 1987; Banks et al., 1989). Research and commercial development has been active recently in the United States and in Europe (Anon., 1989).

Several factors may have caused the extended delay in development and commercialization of lowfat cheeses. Substantial consumer demand and, consequently, commercial interest in lowfat products have been relatively recent phenomena. Early research on lowfat cheeses focused on levels of fat that were unrealistically low to readily simulate traditional cheeses. A great deal of basic research has been done in the last ten years that aids in understanding the principles of cheesemaking and factors affecting the structure and flavor of cheeses (Lawrence et al., 1987; Fox, 1989). Research on genetics and metabolism of lactic acid bacteria has allowed greater control over their effects on cheese. This basic information will be valuable in further improving the flavor and texture of lowfat cheeses.

Standardization of fat content in most previous research was typically done by separating milkfat by centrifugation and blending skimmilk and cream. Adding nonfat dry milk (NDM), condensed skimmilk and skimmilk to whole milk are alternatives that may be more economically attractive. Heat treatments in preparing these products must by regulated to avoid problems with inferior milk clotting, loss of cheese yield and poor cheese texture. Amounts of condensed skimmilk and NDM used to fortify whole milk have to be limited to avoid problems with milk clotting, curd handling and
excessive lactose levels in cheese. Industry experience suggests that nonfat milk solids should not be increased by more than 1 to 2%. Increasing the total solids of lowfat (0.5-1.0% fat) milk to 10.5% to 11% total solids produced cheese of higher quality than that from non-fortified milk (Hargrove et al., 1967). This would be equivalent to adding 0.7 to 1.7% nonfat solids. Improved quality of lowfat cheese in these experiments was attributed to increased buffering capacity of the fortified milk which would minimize high-acid and bitter flavors.

Lowfat Gouda cheese was made by deKoning et al. (1981) from skimmilk ultrafiltered and diafiltered to 32.5% total solids and 27.5% protein before standardization with cream (78% fat). Cheese was made without whey syneresis which resulted in almost complete incorporation of the whey proteins in the cheese. Quality and cheese characteristics were not discussed but it was implied that the undenatured whey proteins would reduce the undesirable toughness of lowfat cheese. Flavor intensity is generally lower in cheese made from ultrafiltered milk. This could create additional problems since lowfat cheeses generally lack flavor.

McGregor and White (1990a, 1990b) compared the characteristics of lowfat Cheddar cheese made from standardized milk and ultrafiltered milk, with and without diafiltration-acidification. Flavor and physical properties were improved by the latter treatments which would regulate lactose concentrations to control cheese pH and would lower calcium levels that would soften the protein matrix. The combined impact of ultrafiltration and low fat contents on retardation of ripening were noted by McGregor and White (1990a). Sensory panelists noted a flat flavor and lack of Cheddar flavor even in cheese aged for 12 months. The fat levels were 15-16% which is about a 50% reduction from concentrations of fat in Cheddar cheese.
Sweet cream buttermilk and gums have been added to standardize milk to enhance lowfat cheeses. Reisfield and Harper (1955) obtained the most desirable physical characteristics in cheese made from milk, containing 1.5 to 2.0% fat, to which 10 to 15% (w/w) fluid sweet-cream buttermilk was added. Adding 0.1% carboxymethylcellulose or 0.02% carrageenan to milk containing 1 to 2% fat enhanced the softness and smoothness of Cephalotyre (Ras) cheese. The stabilizers also increased flavor of cheese made from milk with 2% fat but had no effect on cheese from milks with the lower fat contents.

Homogenizing milk containing 1.4% fat produced a slightly softer, less elastic Cheddar-type cheese. This effect was related, in part, to a higher moisture content (Hargrove et al., 1967; Emmons et al., 1980). Dispersion of fat globules by homogenization did not directly affect the physical properties of lowfat cheeses but indirect effects on moisture retention were evident. Excessively high homogenization pressures produced brittle, inferior cheese.

The characteristics of lactic starter cultures have a pronounced effect on all cheeses, but especially lowfat cheeses. A commercial culture possessing higher proteolytic activity produced lower quality lowfat Colby-type cheese than a less proteolytic culture (Rank, 1985). The latter culture also contained Leuconostoc species. Hargrove et al., (1967) produced higher quality lowfat Cheddar-type cheese with a culture containing Streptococcus cremoris and Leuconostoc species than a culture containing Streptococcus lactis or Streptococcus lactis ssp. diacetylactis. In contrast, a starter adjunct consisting of a 1:1 ratio of S. lactis ssp. lactis and Lactobacillus casei plus MnCl₂ enhanced the flavor of Ras cheese (El-Neshawy et al., 1986). Hargrove et al. (1966) also observed improved flavor quality of lowfat
Cheddar-type cheese when *L. casei* was used as a supplemental starter.

The more proteolytic commercial culture (SG1) that was evaluated by Rank (1985) was associated with more flavor defects than a commercial culture (FCJB) that exhibited less proteolytic activity. Differences in proteolytic activities were evident by the more extensive degrading of the major caseins and the greater amounts of extractable peptides in cheese made with SG1 than that made with FCJB. Protein metabolism also appeared to be related to meaty and brothy flavors which are more prevalent in lowfat cheeses than cheeses with normal fat levels. Sensory panel data indicated that 87% of the moderate to definite meaty citations were associated with lowfat cheese made with SG1 and 28% with the use of FCJB as the lactic starter culture. Similarly, 75% of the brothy flavor citations occurred in cheese made with SG1. Bitterness was perceived by the panel more prevalently in lowfat cheese and in cheese made with SG1. Of the total notations of bitterness, 89% were associated with cheese made with SG1.

Detailed laboratory and pilot-plant scale manufacturing procedures for lowfat cheeses have been published. None have apparently produced lowfat cheese that is optimum and fully comparable with the whole milk counterparts. However, there are some principles that can be used to guide further development.

Lactic starter culture strains should have lower proteolytic activities to avoid bitter, brothy and meaty flavors as indicated earlier. Research at UW-Madison (Lindsay et al. 1989) is investigating Strecker type unclean flavors in low-sodium cheeses. Similar mechanisms may be involved in production of the off-flavors in lowfat cheeses.
Cooking temperatures typically are lower in manufacturing lowfat cheeses. Selection of lactic bacteria strains that will not impart bitterness with the use of lower temperatures is important. Although the reasons are obscure, pH values at whey drainage and salting should be higher during manufacture of lowfat Cheddar-type cheese to obtain better quality. It is advisable to use lower levels of milk-clotting enzymes. Washing lowfat cheese curd or partial dilution of whey with water may be necessary to control the pH of the cheese. This would be more critical in cheeses of higher moisture content and consequently higher lactose concentrations. Washing curd before salting will reduce lactose and lactic acid concentrations in cheese but results in large quantities of salt-drippings expelled during pressing. Reducing the typically high lactic acid levels in lowfat cheese may be necessary to avoid calcium lactate crystals on the cheese surface (Severn et al., 1986).

Economic Evaluation of Standardization

Desired composition of lowfat cheese is obtained by standardization of milk composition, specifically the casein to fat (C/F) ratio, and by regulating the cheese moisture content. Adjustment of the C/F ratio of milk is usually done by removing fat in the form of cream or adding casein in the form of skimmilk, condensed skimmilk and NDM. Combinations of these methods may be used. Choice of methods depends upon capabilities of the manufacturing plant, availability of nonfat ingredients and economics.
The net returns in converting 100 pounds of whole milk into Cheddar cheese or lowfat cheese are shown in Tables 2 and 3. These data were obtained with a copyrighted computer-based decision-support software program for the calculation and economic evaluation of standardizing milk for cheesemaking. (Kerrigan and Johnson, 1981). The moisture content of 43% in the tables was selected to illustrate lowfat Cheddar-type cheese with good shelf-life; lowfat cheese with 47% moisture would be more suitable as mild-flavored cheese that would have a shorter shelf-life.

The fat content of 19.5% used for these calculations assumed a one-third reduction in fat content from that in Cheddar cheese. Prices of milk, cheese, milkfat, and nonfat ingredients were market prices representative of those in April for Table 2 and in July for Table 3. Whole milk prices were based upon reported M-W prices plus a butterfat differential of $0.125 per 0.1% fat. Prices used for calculations in Tables 2 and 3, respectively, were sweet cream - $1.25 per pound of fat for both, whey cream - $1.20 per pound of fat for both, NDM - $0.96 and $1.25 per pound and skimmilk - $8.64 and $9.25 per 100 pounds. The prices for skimmilk were calculated as the differences between the whole milk prices and the value of fat using the butterfat differential as the value basis. Cheese yield equations fit commercial data on yields.

The net return in manufacturing Cheddar cheese in Table 2 was $2.33 per 100 pounds of whole milk using prices prevalent in April but had decreased to $1.67 using July prices as shown in Table 3. The net return from the same 100 pounds of milk that had been standardized by removing cream and converted into lowfat cheese containing 47% moisture was only $1.84 and $1.18 in April and July. Manufacturing lowfat cheese priced at $1.45 per pound and containing 43% moisture from this standardized milk yielded no net return in July, a net return of only $0.66 in April. To
obtain the equivalent net return of $2.33 per 100 pounds of milk, the prices of lowfat cheese would have to be $1.51 and $1.68 per pound for cheese of 47 and 43% moisture contents (Table 2). Alternatively, the price per pound of fat in cream removed would have to be $1.51 or $2.03 rather than the assumed market value of $1.25. Target prices for cheese and fat did not change in July (Table 3). However, these target prices would only yield the net return of $1.67 per hundred-weight of milk rather than the $2.33 realized in April. Obtaining these increased prices for milkfat is highly unlikely in present markets.

Standardizing milk with NDM or skimmilk is attractive for lowfat cheese containing 47% moisture at the prices in April but not in July. A dramatic decrease ($4.23 to $0.79) occurred between April and July with the use of NDM as the sole standardizing ingredient (Tables 2 and 3). The target price of NDM of $1.16 would yield net returns equivalent to the $2.33 and $1.67 for Cheddar cheese. However, the actual price of $1.25 in July resulted in a lower net return of $0.79 for lowfat cheese containing 47% moisture. Manufacturing 43% moisture was not attractive under any situation when NDM was used (Tables 2 and 3). A drastic loss was calculated for conditions in July (Table 3). The only alternative with those pricing schedules is pricing the lowfat cheese of $1.50 and $1.66 per pound to yield a net return equivalent to the $1.67 return per hundredweight of milk with Cheddar cheese. Using skimmilk appears to be attractive with the calculated prices of $8.64 and $9.25 per hundredweight in April and July with the exception of lowfat cheese containing 43% moisture (Table 2 and 3). However, the maximum price for skimmilk for the lowfat cheeses could only be $10.68 and $8.64 in April and $10.75 and $8.64 in July to yield net returns equivalent to Cheddar cheese. It is unlikely that skimmilk would be readily available at
those prices. The net returns are based upon ingredient costs and do not include fixed and variable costs for standardizing milk and for manufacturing and storing cheese. Other alternatives for standardization are possible such as using condensed skim milk and UF retentate. The latter may be attractive since less lactose would be added to the standardized milk. Reducing lactose levels is often necessary in lowfat cheese of higher moisture contents. The levels of NDM, condensed skim milk or UF-retentate required for standardization may necessitate their dilution to avoid undesirably high lactose or protein levels in the standardized milk.

Requirements to Improve Lowfat Cheese

Obtaining lowfat cheeses with superior flavor and body require strict attention to the basics of cheese manufacturing. These include control of the cheese moisture: protein ratio, acidity development during manufacturing, metabolic characteristics of lactic starter cultures, and control of secondary flora in cheese.

Composition and processing controls must be more precise for low fat cheeses as compared to traditional cheeses. For example, bitter peptides seem to be more evident in lowfat cheese than in cheese of regular content. Rank (1985) proposed that the bitter peptides may migrate into or onto fat. The greater amounts of fat in traditional cheese would lower concentrations of peptides in the serum of cheese and make these peptides less perceptible. This effect could also apply to other compounds creating the meaty and brothy flavors. Alternatively, the fat could lower our ability to taste these flavor-active compounds.
Lactic starters may have to be closely evaluated for proteolytic and peptidolytic activities and for the specificity of these enzymes. This information has not been obtained as it relates to effects on lowfat cheeses. Similarly, control of growth and metabolism of secondary flora by starter adjuncts have been evaluated for whole milk cheeses. Further research is necessary to extend this information to lowfat cheeses.

Pricing of lowfat cheeses and determining optimum techniques for milk standardization are complex in this period of price volatility as indicated in Tables 2 and 3. The computer-derived calculation in these tables allow rapid and accurate procedures for optimizing net returns. More sophisticated computer programs permit the economic optimization of combinations of standardization options. Successful development of lowfat cheese manufacturing will obviously depend heavily on these economic evaluations as well as technological developments.
References


Table 1 — Properties of cheese that are affected by fat

<table>
<thead>
<tr>
<th>Physical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firmness</td>
</tr>
<tr>
<td>Adhesiveness (lubricity)</td>
</tr>
<tr>
<td>Mouthfeel</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flavor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty acids</td>
</tr>
<tr>
<td>Solvent for flavors</td>
</tr>
</tbody>
</table>

| Yield of cheese            |

<table>
<thead>
<tr>
<th>Nutrition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier for fat-soluble vitamins</td>
</tr>
</tbody>
</table>
Table 2 — Net return on 100 pounds of milk containing 3.7% fat and 2.50% casein and priced at $12.87, based upon April 1990 prices, when converted into Cheddar cheese or standardized by various means and converted into lowfat cheese.

<table>
<thead>
<tr>
<th>Cheese type and standardization method</th>
<th>Cheese composition</th>
<th>Net(^a) return</th>
<th>Target(^b) cheese price</th>
<th>Target prices(^c) for fat and non-fat ingredients ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H(_2)O (%)</td>
<td>Fat (%)</td>
<td>($)</td>
<td>($)</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-------------</td>
<td>--------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Cheddar not standardized</td>
<td>38.0</td>
<td>33.5</td>
<td>2.33</td>
<td>1.45</td>
</tr>
<tr>
<td>Lowfat Cheese cream removal</td>
<td>47.0</td>
<td>19.5</td>
<td>1.84</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>43.0</td>
<td>19.5</td>
<td>0.66</td>
<td>1.68</td>
</tr>
<tr>
<td>Lowfat Cheese NDM added</td>
<td>47.0</td>
<td>19.5</td>
<td>4.23</td>
<td>1.34</td>
</tr>
<tr>
<td></td>
<td>43.0</td>
<td>19.5</td>
<td>2.00</td>
<td>1.47</td>
</tr>
<tr>
<td>Lowfat Cheese skim milk added</td>
<td>47.0</td>
<td>19.5</td>
<td>4.52</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>43.0</td>
<td>19.5</td>
<td>2.34</td>
<td>1.45</td>
</tr>
</tbody>
</table>

\(^a\) Net return is based on cheese price of $1.45 per pound and does not include cheese manufacturing and storage costs.

\(^b\) Target lowfat cheese prices indicate the required prices to yield a net return of $2.33 per 100 pounds of milk.

\(^c\) Target prices indicate the required prices per pound of fat in cream, per pound of NDM, or per 100 pounds of skim milk to yield the return of $2.33
Table 3 — Net return on 100 pounds of milk containing 3.7% fat and 2.50% casein and priced at $12.87, based upon July 1990 prices, when converted into Cheddar cheese or standardized by various means and converted into lowfat cheese.

<table>
<thead>
<tr>
<th>Cheese type and standardization method</th>
<th>Cheese composition</th>
<th>Net return</th>
<th>Target price for fat</th>
<th>Target prices for lowfat cheese</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H₂O (%)</td>
<td>Fat (%)</td>
<td>($)</td>
<td>($)</td>
</tr>
<tr>
<td>Cheddar not standardized</td>
<td>38.0</td>
<td>33.5</td>
<td>1.67</td>
<td>1.45</td>
</tr>
<tr>
<td>Lowfat Cheese cream removal</td>
<td>47.0</td>
<td>19.5</td>
<td>1.18</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>43.0</td>
<td>19.5</td>
<td>0.00</td>
<td>1.68</td>
</tr>
<tr>
<td>Lowfat Cheese NDM added</td>
<td>47.0</td>
<td>19.5</td>
<td>0.79</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>43.0</td>
<td>19.5</td>
<td>-2.19</td>
<td>1.66</td>
</tr>
<tr>
<td>Lowfat Cheese skimmilk added</td>
<td>47.0</td>
<td>19.5</td>
<td>3.23</td>
<td>1.36</td>
</tr>
<tr>
<td></td>
<td>43.0</td>
<td>19.5</td>
<td>0.88</td>
<td>1.49</td>
</tr>
</tbody>
</table>

* Net return is based on cheese price of $1.45 per pound and does not include cheese manufacturing and storage costs.

b Target lowfat cheese prices indicate the required prices to yield a net return of $2.33 per 100 pounds of milk.

c Target prices indicate the required prices per pound of fat in cream, per pound of NDM, or per 100 pounds of skimmilk to yield the return of $2.33
CAN WE SELL MORE FAT IN CHEESE?

by

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Logan, UT 84322-8700

Presented at the
9th Biennial Cheese Industry Conference
Utah State University
Logan, Utah

August 21-23, 1990
Insert copy of presentation here if one has been made available.
CONTROLLING FAT LOSSES IN CHEDDAR CHEESE

by

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Presented at the
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August 21-23, 1990
Controlling Fat Losses in Cheddar Cheese

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Control of fat losses during the manufacture of Cheddar cheese requires constant monitoring of processing and manufacturing conditions. Factors affecting fat losses into whey start at the farm and continue through the manufacturing of the Cheddar cheese. Monitoring of fat loss often becomes a difficult task because the cheese manufacturer does not always know the original fat content of the milk or the amount of degradation that the fat has undergone before the milk reaches the silo.

Errors in sampling

Several problems must be overcome to get an accurate account of the fat in a silo. First and foremost is the problem of layering of milk in the silo. When milk is pumped into a silo the milk essentially forms a layer in the silo with the last milk in being near the bottom. Air agitation does not adequately mix most silos. As milk is drawn out of a silo for manufacturing the total solids and fat vary with the amount of solids and fat contained in the various layers within the silo. Standardized milk placed in cheese vats taken from one silo can be expected to vary several tenths of a percent in solids and fat concentrations because of the various layers that are in the silo. Therefore, a single sampling from a silo is probably quite misleading because it
represents only one layer. A better understanding of the fat content within a cheese vat is determined from the milk in the vat prior to the time that the rennet is added. Vat milk should be well mixed if the sample is to be representative of the vat.

Fat assays

Once a representative sample or samples are obtained another problem arises. The manufacturer must determine the concentration of fat and the amount of degradation or hydrolysis that the fat has incurred. By accurately determining these parameters the manufacturer will gain the information necessary to determine where the fat losses are occurring prior to cheese manufacture. Two types of assays are necessary for the manufacturer to get an understanding of the fat content and the hydrolysis of fat. Fat concentration is easily monitored by using chemical procedures such as the Babcock, Gerber, or Majonnier or standardized spectral procedures such as the Milko Tester™ or IRMA™. Chemical and spectral procedures assay the amount of fat in both the globular and free form. However, neither procedure gives the manufacturer an understanding of the amount of fat that has been hydrolyzed by lipase. An assay that looks at the hydrolyzed fat or amount of free fatty acids present in milk is the Acid Degree Value (ADV) procedure. The amount of hydrolyzed fat present in milk is important because most of these fatty acids are lost into the whey.

Milk source

Milk source and the microbial population can affect fat loss. Cheese manufactured from milk that is received from the farm within 36 to 40 h from milking with low bacterial populations and somatic cell counts will have the greatest

amount of fat retained in the cheese.

**Effect of psychrotrophic organisms on fat loss.**

Psychrothrophic bacteria are microorganisms that grow in refrigerated milk. These organism produce proteinases and lipases that decrease cheeses yield. Lipases from psychrotrophic organism increase the hydrolysis of fat which increases the ADV's in the stored milk (Figure 1) and resulting whey.

![Figure 1. Effect of inoculum added on acid degree value of the stored milk. After inoculation, milk was stored at 10⁰C for 6 and 10 d for Pseudomonas and Bacillus organisms, respectively, before manufacturing cheese.](image)

Hicks et al., 1982, *J. Food Protection* 45:331.

When ADV's increase in the milk and whey the amount of fat in the cheese decreases (Figure 2a). These changes become apparent when the psychrotrophic population exceeds 10⁶ bacteria/ml prior to pasteurization. However, yield loss also relates to the age of the milk (Figure 2b). Grade A milk held at a receiving station that is 6 days old and has a psychrotrophic population of 10⁶ bacteria/ml causes a greater yield loss than 2 day old milk from the farm with an equal psychrotrophic population. The reason that the older milk has greater loss relates to the enzymatic degradation that the

milk has undergone.

![Graph 1](image1)

Figure 2a. Effect of milk storage time on percent fat in cheese. (●—●) Manufacturing grade milk, (○—○) grade A milk. Each data point is an average of nine observations.

![Graph 2](image2)

Figure 2b. Effect of milk storage time on yield of cheese solids. (●—●) Manufacturing grade milk, (○—○) grade A milk. Initial yield differences are due to different total solid concentrations in the milk. Each data point is an average of nine observations.


**Effect of somatic cells on fat loss.** Milk with high somatic cell counts contains a lower concentration of casein which forms a weaker coagulum. Cheese produced from this type of milk has greater yield loss because the curd is fragile and shatters. Shattered curd releases the globular fat on the new surface, thus whey fat increases. Somatic cells also increase the proteolytic and lipolytic activity in the milk so ADV’s also increase.

**Manufacture of Cheddar Cheese**

Fat losses often occurs at points in cheese manufacture where they are least expected. Therefore, this portion of the paper will discuss all key aspects of the manufacturing process and discuss what conditions lead to fat loss.

Effect of pumping milk. Normal handling of milk from the silo through pasteurizer to the vat has essentially no effect on the state of the fat nor does it increase fat loss. However, there are two processing situations that can increase fat loss when the vats are filled with milk. The first occurs when NFDM solids are used to standardize the milk to a constant casein to fat ratio. If the powdered NFDM is added to the milk through a powder funnel and a centrifugal pump, excess pumping with the incorporation of air into the milk can occur. The combination of air being incorporated into the milk and the shear force resulting from pumping the milk repeatedly through the pump causes lipase activation to occur. Activated lipase causes fat to be hydrolyzed (Figure 3a) which increases fat loss and decreases cheese yield (Figure 3b).

Hicks et al., 1990. Culture Dairy Products J. 25:20

The second situation is similar to the first, but involves the use of retentate to standardize casein to fat ratios or fortify the total solids in the vat. Again if retentates are prepared under a situation where air is drawn into the milk during ultrafiltration, lipase is rapidly activated and fat loss will increase (Table 1). When ADV's are above the plant average look for places where air is being incorporated into the milk stream.

### Table 1. Effect of pumping time on ADV's while ultrafiltering milk.

<table>
<thead>
<tr>
<th>Pumping time</th>
<th>Milk wt. (kg) replication</th>
<th>Acid degree value (ADV) replication</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>0</td>
<td>76.9</td>
<td>78.7</td>
</tr>
<tr>
<td>3</td>
<td>1.67</td>
<td>1.23</td>
</tr>
<tr>
<td>5</td>
<td>1.78</td>
<td>1.55</td>
</tr>
<tr>
<td>7</td>
<td>2.77</td>
<td>2.13</td>
</tr>
<tr>
<td>8</td>
<td>3.02</td>
<td>2.90</td>
</tr>
<tr>
<td>9</td>
<td>3.37</td>
<td>3.23</td>
</tr>
<tr>
<td>10</td>
<td>3.71</td>
<td>3.61</td>
</tr>
<tr>
<td>12</td>
<td>4.44</td>
<td>3.97</td>
</tr>
<tr>
<td>13</td>
<td>4.62</td>
<td>4.27</td>
</tr>
<tr>
<td>14</td>
<td>4.87</td>
<td>4.80</td>
</tr>
</tbody>
</table>


**Effect of churned fat on fat loss and cheese appearance.**

Repeated pumping or stirring at churning temperatures (9-16 C) increases the amount of fat that is converted from the globular to the free fat form. When the emulsion is broken the fat coalesces together to form small clumps. When the curd is cooked some of this fat is found floating on the surface of the whey. This translates to higher fat losses in the whey. This free fat also coats the milled curd and causes a seamy defect.

**Effect of culture on cheese yield.** Different cultures produce different cheese yields (Table 2). Many cultures are more proteolytic and/or lipolytic than others. Although these enzyme systems are important in flavor development they can decrease cheese yield. The use of a particular culture should depend on the purpose of that culture. In Italian type cheese the need for flavor enhancement by the culture may be limited, therefore a low proteinase/lipase culture could be used. Whereas in aged Cheddar cheese flavor development derived from the culture may be much more important, so a culture with moderate proteinase and lipase activity might be best.

TABLE 2. YIELD RELATIONSHIPS OF FOURTEEN STARTER CULTURES COMMON TO MORE THAN ONE CHEESE MANUFACTURER.

<table>
<thead>
<tr>
<th>CULTURE</th>
<th>MANUFACTURER 1</th>
<th>MANUFACTURER 2</th>
<th>MANUFACTURER 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N'</td>
<td>YIELD'</td>
<td>N'</td>
</tr>
<tr>
<td>8</td>
<td>21</td>
<td>5.78</td>
<td>114</td>
</tr>
<tr>
<td>9</td>
<td>--</td>
<td>--</td>
<td>186</td>
</tr>
<tr>
<td>11</td>
<td>--</td>
<td>--</td>
<td>222</td>
</tr>
<tr>
<td>12</td>
<td>--</td>
<td>--</td>
<td>123</td>
</tr>
<tr>
<td>15</td>
<td>--</td>
<td>--</td>
<td>168</td>
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<tr>
<td>23</td>
<td>--</td>
<td>--</td>
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<td>25</td>
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<td>--</td>
<td>204</td>
</tr>
<tr>
<td>41</td>
<td>--</td>
<td>--</td>
<td>62</td>
</tr>
<tr>
<td>51</td>
<td>--</td>
<td>--</td>
<td>40</td>
</tr>
<tr>
<td>911</td>
<td>--</td>
<td>--</td>
<td>131</td>
</tr>
<tr>
<td>940</td>
<td>--</td>
<td>--</td>
<td>127</td>
</tr>
<tr>
<td>970</td>
<td>--</td>
<td>--</td>
<td>123</td>
</tr>
<tr>
<td>980</td>
<td>--</td>
<td>--</td>
<td>124</td>
</tr>
<tr>
<td>991</td>
<td>--</td>
<td>--</td>
<td>148</td>
</tr>
</tbody>
</table>

* Number of observations per culture.

| b Mean cheese yield for all vats made using this culture.


*Effect of flavor enhancing enzymes on fat loss.* Most flavor enhancing enzyme systems for Cheddar cheese have both proteolytic and lipolytic enzymes present. When these enzymes are added to the milk at the time of renneting they hydrolyze the milk proteins and fat to reduce cheese yield (Table 3). Most of the hydrolysates are lost into the whey until after cheddaring when the cheese mass locks in the remaining moisture.

Table 3. Effect of a flavor enhancing system on cheese yield.

<table>
<thead>
<tr>
<th>Parameters Studied</th>
<th>Flavor Enhancer added to milk</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Degree Value</td>
<td>3.8</td>
<td>1.3</td>
</tr>
<tr>
<td>Moisture</td>
<td>44.6%</td>
<td>43.0%</td>
</tr>
<tr>
<td>Dry Matter yield (kg/100kg milk)</td>
<td>6.17</td>
<td>6.19</td>
</tr>
</tbody>
</table>


When flavor enhancing enzymes are added to the curd protein and fat loss are inhibited because the contact time is shorter and whey release is minimal. However, the curd may develop soft junctions due to the enzymatic activity on the surface of the curd particle. If the cheese particles remain small, as in stirred curd cheddar, this problem is reduced because the surface enzyme concentration decreases as particle size decreases or as surface area increases.

Effect of coagulants on fat losses. Some milk coagulants decrease cheese yield more than others (Table 4). Fungal coagulants from *E. parasitica* and *M. Miehei* have been observed to reduce cheese yield. These fungal coagulants have been reported to have greater proteolytic activity than chymosin or calf rennet. Most of the coagulants have a lipase component that affects the amount of fat in the whey (Table 5) and the whey ADV (Table 6). Both recombinant chymosin and calf rennet have a lipase component which increases whey fat loss and ADV whereas *M. pusillus* var. lindt coagulant produces minimal whey fat loss and a lower whey ADV. Since *M. pusillus* var. lindt coagulant has the lowest lipase component it produces a dry matter yield which was the same as the recombinant chymosin.

<table>
<thead>
<tr>
<th>TABLE 4. Effect of milk-cloning enzymes on dry matter yield.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>50:50&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td><em>Mucor pusillus</em> var. Lindt</td>
</tr>
<tr>
<td><em>Endothia parasitica</em></td>
</tr>
<tr>
<td><em>Mucor miehei</em></td>
</tr>
<tr>
<td>Calf rennet</td>
</tr>
<tr>
<td>Recombinant chymosin</td>
</tr>
</tbody>
</table>

<sup>1</sup>Kilograms of cheese solids/100 kg milk. Coefficient of variation = 1.1%, \(n = 8\) for all treatments. A least significant difference of ±.07 kg of cheese/100 kg milk was calculated when \(P = .05\). LSM = Least squares means.

<sup>2</sup>A 50:50 blend of calf rennet and bovine pepsin.


TABLE 5. Effect of milk-clotting enzymes on whey fat and protein.1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Whey fat (%)</th>
<th>Whey protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50:502</td>
<td>.33</td>
<td>1.02</td>
</tr>
<tr>
<td><em>Mucor pusillus</em> var. Lindt</td>
<td>.30</td>
<td>1.05</td>
</tr>
<tr>
<td><em>Endothia parasitica</em></td>
<td>.34</td>
<td>1.07</td>
</tr>
<tr>
<td><em>Mucor miehei</em></td>
<td>.32</td>
<td>1.03</td>
</tr>
<tr>
<td>Calf rennet</td>
<td>.33</td>
<td>1.04</td>
</tr>
<tr>
<td>Recombinant chymosin</td>
<td>.33</td>
<td>1.04</td>
</tr>
</tbody>
</table>

1Least squares means. Standard deviations are ± .06 for whey fat and ± .26 for whey protein.
2A 50:50 blend of calf rennet and bovine pepsin.

TABLE 6. Effect of milk clotting enzymes on acid degree values (ADV) of whey.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ADV Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>50:502</td>
<td>1.6c</td>
</tr>
<tr>
<td><em>Mucor pusillus</em> var. Lindt</td>
<td>1.5c</td>
</tr>
<tr>
<td><em>Endothia parasitica</em></td>
<td>1.6c</td>
</tr>
<tr>
<td><em>Mucor miehei</em></td>
<td>1.7a</td>
</tr>
<tr>
<td>Calf rennet</td>
<td>1.9a</td>
</tr>
<tr>
<td>Recombinant chymosin</td>
<td>1.9a</td>
</tr>
</tbody>
</table>

1, 2Means with the same superscript are not significantly different (P<.1).
3n = 8 for all treatments. Standard deviation is ± .17 for ADV.
4A 50:50 blend of calf rennet and bovine pepsin.


Effect of curd firmness on fat loss. Cheddar cheese coagulum can be cut over a rather wide range of firmness without affecting the cheese yield (Table 7). As long as the coagulating flocs are knitted together little additional fat loss is observed. Even firm curd resists fat loss, as long as the curd is not shattered during the cooking process. Once the curd shatters with agitation greater amounts of fat are liberated.

TABLE 7. Effect of curd firmness on whey fat content in study 3.

<table>
<thead>
<tr>
<th>Curd firmness at cutting (mV)</th>
<th>LS Means whey fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>.354</td>
</tr>
<tr>
<td>75</td>
<td>.334</td>
</tr>
<tr>
<td>100</td>
<td>.331</td>
</tr>
<tr>
<td>125</td>
<td>.357</td>
</tr>
</tbody>
</table>

1Probability of differences; n = 4 for all treatments; calf rennet. Coefficient of variation = 7.98%.


Effect of heal time on fat loss. Heal time is one of the more important factors that affect fat loss. As heal time increases, fat lost into the whey decreases (Table 8), yield from the press increases (Table 9), but moisture content in the curd increases (Table 10). When curd is stirred immediately after cutting fat diffuses away from the cut surface into the whey. However, if the curd is allowed to heal, the casein locks the fat globule into the curd matrix. This is one reason that large vats generally have a lower fat loss than small vats, because it takes longer to cut the vat and get the cooking started before agitation begins. In double O vats where the curd is cut slowly over an extended period the curd heals rather well under these gentle conditions. However, if agitation is increased and/or cutting speed, fat losses will be increased.

**TABLE 8. Effect of heal time on whey fat content in study 2.**

<table>
<thead>
<tr>
<th>Heal time (min)</th>
<th>Least squares means whey fat (%)</th>
<th>Heal time (min) comparisons (probability of differences)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>.38</td>
<td>.2191</td>
</tr>
<tr>
<td>15</td>
<td>.36</td>
<td>.0022</td>
</tr>
<tr>
<td>30</td>
<td>.31</td>
<td>.0017</td>
</tr>
</tbody>
</table>

Coefficient of variation = 3.69%; n = 4 for all treatments.

**TABLE 9. Effect of heal time on raw cheese yield in study 2.**

<table>
<thead>
<tr>
<th>Heal time (min)</th>
<th>Least squares means raw cheese yield (kg/100 kg milk)</th>
<th>Heal time (min) comparisons (probability of differences)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10.81</td>
<td>.0046</td>
</tr>
<tr>
<td>15</td>
<td>10.94</td>
<td>.0018</td>
</tr>
<tr>
<td>30</td>
<td>10.97</td>
<td>.4741</td>
</tr>
</tbody>
</table>

Coefficient of variation = .44%; n = 4 for all treatments.


TABLE 10. Effect of heat time on cheese moisture content in study 2.¹

<table>
<thead>
<tr>
<th>Heal time (min)</th>
<th>Least squares means cheese moisture (%)</th>
<th>Heal time (min) comparisons (probability of differences)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>39.55</td>
<td>.0279</td>
</tr>
<tr>
<td>15</td>
<td>40.43</td>
<td>.0108</td>
</tr>
<tr>
<td>30</td>
<td>40.64</td>
<td>.5199</td>
</tr>
</tbody>
</table>

¹ Coefficient of variation = 1.12%; n = 4 for all treatments.


**Effect of cooking on fat loss.** Slow gentle cooking is the key to reduced fat loss. This means that the curd is not broken or shattered during the cooking process. When broken surfaces become exposed, the fat which was entrapped in the curd matrix becomes exposed on the new surface and is free to diffuse into the whey.

**Effect of cheddaring and milling on fat loss.** Curd that has been drained, but has started to mat together in the cheddaring process has a higher amount of fat in the whey. However, the amount of whey removed is this step is small compared to the cooking step and the fat loss is moderate compared to the total fat loss. Again curd fracturing, cutting, or tearing may contribute to this loss. Whey fat is highest after milling, because new surface areas are exposed and the globular fat is washed away by the expelled whey.

INFRA RED ANALYSIS OF MILK

by

Dr. Rodney J. Brown

Department Head
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Logan, UT 84322-8700

Presented at the
9th Biennial Cheese Industry Conference
Utah State University
Logan, Utah

August 21-23, 1990
Insert copy of presentation here if one has been made available.
The abnormal milk tests have been correlated to somatic cell counts and differences in intensity of a color that are a function of the salt or NAGase enzyme content of the milk are measured (Figure 5). This, and use of the instrument as a color quality measuring devise, are added bonuses since it is used without constant sample incubation. Thus results are available upon the first readings of the instrument. Full color development is completed before transfer to the instrument.

**Abnormal Milk**

1. ADD REAGENT
2. ADD SAMPLE
3. START INSTRUMENT (NO INCUBATION)
4. PRINT OUT RESULTS

SOMATIC CELLS CORRELATE TO THE COLOR INTENSITY

LIGHT - DARK

HI SSC - MEDIUM SSC - LO SSC

**Yeasts & Molds**

1. ADD REAGENT
2. ADD SAMPLE
3. START INSTRUMENT

ANTIBIOTICS PREVENT BACTERIAL INTERFERENCE

FAST - SLOW

HI Y & M - MEDIUM Y & M - LO Y & M
Reflectance colorimetry can be tailored to measure various enzymatic activities like proteinases and lipases and milk coagulation².

The costs of conducting colorimetric analysis are much less than with conventional plating techniques and alternative methods (Figure 7). Dr. Daniel Y.C. Fung has calculated the costs of different methods. In the Figure; SPC = Standard Plate Count where dilutions are required to estimate high counts, RG = Redi Gel™ plating, PF = Petri Film™ plating, SPL = Spiral Plating, and ISO = Iso Grid™ filter plating technique. We have added the estimate for RF = Reflectance Colorimetry as conducted with the Omnispec.

**Per Sample Costs**

- SPC $13.62 w/ Dilutions
- RG $8.22 w/ Dilutions
- PF $8.22 w/ Dilusions
- SPL $2.27
- ISO $3.33
- (Source, D.Y.C. Fung, 1990)
- RC <$.30

Those involved in evaluation and potential approval of the Omnispec have been very encouraging in their responses (Figure 8). Since this is new technology a trial/purchase plan is being offered to those developing new applications for the instrument (Figure 9). Some dairy laboratories in Europe have shown great interest, to the extent of wanting to explore their entire quality control testing program based upon the use of the Omnispec. Others are using samplers like the Probe™ 1000⁵ to prepare up to 2,000 samples daily for coliforms and antibiotics. They are interested in using the Omnispec to automatically quantitate the results.
Recent Comments

"We love it!"
"It makes microbiology fun!"
"You can't have it back!"
"It saves me five hours per week in counting plates alone!"
"Even if it does not get AOAC approval we will use it to screen total counts then run the SPC on only the one or two percent of high counts for confirmation."
"Get it approved to replace the SPC not just for screening!"
"It is easy to justify the initial cost."
"We want to establish our national quality assurance program based upon reflectance colorimetry!"

Trial/Purchase Plan

*$1,500/ Mo for 3 Mo
applied to purchase price of
$35,000 for
OMNISPEC™ 4000 Complete
with Computer, Printer, Color Monitor,
Software, Pipettors, and Initial Supplies

We acknowledge the financial support of Utah State University, The National Dairy Promotion and Research Board, The Western Dairy Foods Research Center, Applied BioElectronics, Inc., and Wescor, Inc.

5 Roeland Papen, Personal Communication, Canberra Packard, Pontbeeklaan 57, Zellik, Belgium.
OMNISPEC™
BIOACTIVITY MONITOR

AUTOMATED MICROBIOLOGY
WITH OPAQUE OR CLEAR SUBSTANCES

WESCOR
"MY INDUSTRY EXPERIENCE ON THE APPLICATION OF NEW ANALYTICAL TECHNOLOGY FOR MOISTURE ANALYSIS"

I was asked to present my experiences at this conference on the application of new analytical technology for the analysis of dairy products. This technology is providing exciting opportunities to better utilize product analysis data, which can result in improved product quality/yields for the company.

The extensive use of traditional wet chemistry and/or microbial methods is very time consuming with the result that often management didn't know how "good" or "bad" a product was until some time after its manufacturing process was completed. However, new rapid analytical techniques are appearing which can analyze for various chemical components, antibiotic residues, and microbial contents in a matter of minutes or hours. These new techniques will give the company a better opportunity to ask, "Are we doing things right?", not, "Did we do the right things to make a good product?"

The utilization of rapid analytical technology will enable a company to utilize the data in an expanded Quality Assurance role in addition to the traditional QA/QC role. Thus a company can expect to improve profitability through any one or a combination of:

a) Increased analytical productivity or decreased turnaround time for analytical data.
b) More consistent and/or improved product yields.
c) Improved product quality.

With a little bit of extra effort the company should be able to document these improvements and show the cost effectiveness of rapid analytical technology.

The performance of any new analytical method must be judged on both the practicability and reliability of the method.

In evaluating the method's practicability, you should consider the following parameters: Speed, cost efficiency, user friendliness, technical skill required, dependability/ruggedness, service, etc.

In evaluating the method's reliability, you must compare the system's precision and accuracy with respect to the accepted reference method. As the rapid system is utilized, occasional routine cross checks against the reference method should be performed to ensure the rapid system's reliability. For further information on analytical methods in the dairy industry, please refer to the 15th edition of "Standard Methods for the Examination of Dairy Products," edited by Dr. Gary Richardson.
I recently had an opportunity to evaluate the CSC Digital Moisture balance and was impressed by its performance when compared against the vacuum oven method for moisture analysis. The digital moisture balance is basically the old Cenco moisture balance which has been upgraded with the latest electronic technology. The digital balance is finding use in a wide range of products and industries. The unit was evaluated at Cache Valley Cheese for: reliability/dependability, accuracy/precision, speed, cost efficiency, technical skill required, and service. The time required for analysis was approximately 10 minutes per sample. In our application, utilization of the CSC digital moisture balance was advantageous and the data was comparable to vacuum oven analysis as shown below. In conclusion, the upgrading of the Cenco balance by electronic technology has increased the flexibility and application of the unit to moisture analysis. The time length required for analysis of a sample will depend on sample size, initial moisture content, and environmental conditions.

The following statistical data was obtained from the analysis of Mozzarella cheese:

<table>
<thead>
<tr>
<th>Trial #</th>
<th>% Moist V.O. A</th>
<th>% Moist V.O. B</th>
<th>% Moist V.O. X</th>
<th>% Moist CSC A</th>
<th>% Moist CSC B</th>
<th>% Moist CSC C</th>
<th>% Moist CSC X</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48.09</td>
<td>47.98</td>
<td>48.07</td>
<td>48.2</td>
<td>48.0</td>
<td>48.2</td>
<td>48.1</td>
</tr>
<tr>
<td>2</td>
<td>45.99</td>
<td>46.07</td>
<td>46.03</td>
<td>46.1</td>
<td>46.1</td>
<td>45.9</td>
<td>46.0</td>
</tr>
<tr>
<td>3</td>
<td>48.11</td>
<td>48.11</td>
<td>48.11</td>
<td>48.4</td>
<td>47.8</td>
<td>48.2</td>
<td>48.1</td>
</tr>
<tr>
<td>4</td>
<td>45.93</td>
<td>45.57</td>
<td>45.75</td>
<td>45.9</td>
<td>45.8</td>
<td>45.8</td>
<td>45.8</td>
</tr>
</tbody>
</table>

* % Moisture vacuum oven method  
** % Moisture CSC digital moisture balance


The RUGGED DIGITAL MOISTURE BALANCE THAT DETERMINES PERCENT MOISTURE OR PERCENT SOLIDS WITH THE TOUCH OF A KEY

FEATUREING

FLEXIBILITY — Simplifies sample preparation and loading.
- No limitations on sample size (0 to 100 grams)
- Measures moisture or solids from 0.0% to 100.0%

VERSATILITY — Allows fine tuning to individual testing needs.
- Multiple testing modes — automatic, timed and manual operation
- Wide selection of heat settings
- Accommodates either solid or liquid samples

DURABILITY — Withstands the hard knocks of day-to-day use.
- Rugged cast-aluminum construction
- Enclosed sample chamber

SIMPLICITY — Enables inexperienced personnel to perform tests accurately on the first day.
- User-friendly microprocessor technology

ACCURACY — Increases precision and is adaptable to critical moisture and solids testing.
- Readable to 0.1% moisture and solids

ECONOMICAL — Eliminates costly operator error and increases testing efficiency.
- Affordable electronics for the lab or the production line
- Built in RS232 interface for easy test recording

The CSC Digital Moisture Balance carries the Cenco® Moisture Balance tradition of performance to a new level for laboratories and industrial plants interested in rapid determination of moisture or solids content in a wide variety of materials. These range from food products such as snack foods, dairy products, cereals, grains, candy and cookies to substances as diverse as sand, cement, ceramics, paper, plastics, pharmaceuticals, chemicals, sludge and slurries.

The CSC Digital Moisture Balance Provides

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HANDS FREE TESTING
BUILT-IN RS232 INTERFACE
PRECISE DIGITAL READOUT
ELIMINATION OF COSTLY OPERATOR ERROR

CSC SCIENTIFIC COMPANY, INC.

MANUFACTURERS AND DISTRIBUTORS OF LABORATORY EQUIPMENT
8315 LEE HIGHWAY, SUITE 303, FAIRFAX, VA 22031
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The CSC Digital Moisture Balance provides easy, fast, reproducible results directly in percent moisture or percent solids. No more tedious test procedures! No more operator error! No more guesswork! Since time and test results translate directly into dollars, you need an instrument you can count on. Before you buy just any moisture testing instrument, consider this:

....Freedom to load any sample size up to 100 grams!

....Opportunity to choose testing modes - automatic, timed or manual - with the push of a button!

....Convenience of direct digital read-out of % moisture, % solids or weight!

....Technology that offers "hands free testing," eliminates operator error and provides RS232 interface capability to automatically record your data!

....Precision to within +/- 0.1% for more accurate moisture determination!

....Priced at $2495

The CSC DIGITAL will increase productivity and reduce costs. Let’s talk about your application and how the CSC Digital Moisture Balance can help you! Call me at 1-800-458-2558.

Sincerely,

Barbara Weber
Product Specialist
DETECTING ADDITION OF NON-NORMAL PROTEINS TO DAIRY PRODUCTS

by

Miss Marie Walsh

Department of Food Sciences
North Carolina State University
Raleigh, NC

Presented at the
9th Biennial Cheese Industry Conference
Utah State University
Logan, Utah

August 21-23, 1990
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NEW APPLICATIONS FOR WHEY PROTEIN CONCENTRATES

by

Dr. Charles V. Morr

Haas Chair in Food Industries and Professor
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Columbus, OH 43210-1097

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NEW APPLICATIONS FOR WHEY PROTEIN CONCENTRATES

Charles V. Morr, Ph.D.
Haas Chair in Food Industries and Professor
Department of Food Science and Technology
The Ohio State University
Columbus, OH 43210-1097

INTRODUCTION:

Commercial whey protein concentrates (WPCs) were developed for use as functional and nutritional food ingredients in the early 1970's (Morr et al., 1973). Although a number of protein fractionation processes, i.e., centrifugal gel filtration, metaphosphate complexation, CMC complexation, and electrodialysis, were initially considered (Morr et al., 1973), ultrafiltration (UF) has became the process of choice for making WPC. This process provides for the efficient fractionation, recovery and concentration of the major whey proteins with a minimum of protein denaturation. However, one major disadvantage of this latter process is that it concentrates the lipids and lipoproteins along with the proteins.

The U.S. dairy industry is currently producing in the order of 150 million lbs of whey protein concentrates (WPC) annually (Anonymous, 1990a) and additional quantities are being manufactured around the world (Morr, 1989). Although WPCs are classed as Generally Recognized As Safe (GRAS) for food product applications not specifically restricted by "Standards of Identity," it is generally agreed that they lack consistency of composition and sensory and functional properties. This lack of consistancy is due largely to the use of different whey sources with variations in
composition, pretreatment, fractionation and processing conditions for manufacturing the WPCs. These variations in composition, sensory properties and functionality are counter-productive to efforts to improve the quality image of WPC (Hugunin, 1987; Morr, 1990).

The industry has more recently produced and introduced whey protein isolates (WPIs), which are manufactured by an ion exchange adsorption process. These latter products contain a higher protein concentration, are essentially fat-free and provide excellent sensory and functional properties (Anonymous, 1990b).

A SURVEY OF COMMERCIAL WHEY PROTEIN CONCENTRATES AND ISOLATES

A comprehensive study was done to assess the composition, sensory and functional properties of 8 commercial WPCs and 3 commercial WPIs manufactured in 1987-88 in the U.S., England, Ireland, New Zealand, West Germany and Denmark (Morr and Foegeding, 1990). It was assumed that the WPIs were manufactured by ion exchange adsorption and that the WPCs were manufactured by ultrafiltration (UF/DF) processes. Although no specific information was provided by the manufacturers on the type or source of whey, pretreatment, fractionation or other processing conditions; product brochures indicated that several of the WPCs had been "modified" to improve their gel-forming properties.

The whey protein products were examined for chemical composition, i.e., moisture, ash, total solvent-extractible lipids, phospholipids, neutral lipids, micro-Kjeldahl protein, lactose and minerals (sodium, potassium, phosphorus, calcium, magnesium,
copper, zinc, iron and aluminum). They were also assessed for protein denaturation by solubility, SDS gel electrophoresis and size exclusion (SE) HPLC. Functional properties were determined using generally accepted procedures, i.e., maximum foam expansion and stability, solubility as a function of pH and heat-induced gelation by Least Concentration Effect (LCE) at pH 3 to 7.5 and by a detailed rheological characterization of their 10% protein gels formed. The protein products were also examined for color in dry form and dissolved in distilled water and examined for flavor by a three member expert panel.

Moisture contents of all products ranged from 2.4 to 6.0%. Ash contents ranged from 1.37 to 2.15% for WPIs and from 2.52 to 6.0% for WPCs. Major minerals in all products were sodium, potassium, phosphorus and calcium. Five of the WPCs contained ≥ 1.0% sodium and one WPC contained 1.3% phosphorus. WPIs contained lowest concentrations of sodium, phosphorus and potassium, but similar concentrations of all other minerals as contained by the WPCs. Protein contents of WPIs and WPCs ranged from 89 to 93% and 72 to 77%, respectively. Lactose contents of WPIs were 0.4 to 0.5% and for WPCs from 2.1 to 5.8%. Total lipid contents of the three WPIs ranged from 0.4 to 0.65% compared to values ranging from 3.3 to 7.4% for the WPCs. Trends in phospholipid contents of these products were similar to those for total lipids. Major differences were observed in SDS gel electrophoretic properties of the whey protein products and SE HPLC that reflect variations in whey and whey protein processing.
Minimum protein solubility values at pH 4.5 ranged from 85 to 95 for WPis and from 49 to 88% for WPCs. Least concentration effect (LCE) gelation results were generally similar for WPis and WPCs. Instron gel strength data revealed that WPis produced consistently stronger gels than WPCs at pH 6, 7 and 8. Under most experimental conditions investigated (protein concentration 6%; pH 4.5, 7 and 9.5 and 25 or 55°C for 30 min temperature pretreatment) WPis produced much higher foam expansion values with much greater stability than for WPCs.

WHEY PRETREATMENT AND MICROFILTRATION

A number of different pretreatment processes have been reported for removing residual lipid, phospholipoprotein complexes and colloidal calcium phosphate from whey in order to improve subsequent UF flux rate and alter the composition and functionality of the resulting WPC (Maubois et al., 1987; Kim et al., 1989; Rinn et al. 1990).

A typical whey pretreatment process involves cooling sweet cheese whey to 0-5°C to dissolve colloidal phosphate; addition of Ca\(^{2+}\) ion and NaOH to bring the pH to 7.3; rapid warming to ≥ 50°C to promote aggregation of colloidal phosphate-phospholipoprotein complexes so that they can subsequently be removed by centrifugal clarification (Kim et al., 1989) or by 0.6-1.0 μm perpendicular flow microfiltration cartridges (Millipore Corp., Bedford, MA)(Rinn, et al., 1990).

We recently investigated the ability of the Dupont-CARRE metallic membrane unit for microfiltering cheese whey to remove
colloidal phospholipoprotein complexes from whey without prior chemical pretreatment (BOUCHET et al., 1989). Sweet cheese whey was pasteurized, cooled and held at 0-5°C for several hours, adjusted to pH 6.8 with NaOH, rapidly warmed to 50°C and microfiltered with the Dupont-CARRE metallic membrane unit. The resulting microfiltrate was adjusted to pH 6.2 and concentrated 25:1 (v/v) with a Romicon PM-10 hollow-fiber UF unit. The UF retentate was diafiltered (DF) against 3 volumes distilled water and aliquots were flash evaporated from 15 to 25 and 50% total solids prior to spray drying.

Preliminary results indicated that pretreatments and metallic membrane microfiltration effectively removed most of the lipids from whey, resulting in whey with residual lipid concentrations in the order of 0.01%, reduced the bacteria count by a factor of 2, and reduced the turbidity to values in the range of 0.005 (Abs. at 600 nm). Metallic membrane microfiltration caused the loss of about 20% of the whey proteins, which were mainly the lipoproteins and other large proteins that failed to permeate the membrane. Pretreated and microfiltered whey provided ≥ 2X initial and average UF membrane flux rates compared to control whey.

Results obtained by size exclusion high performance liquid chromatography indicated that UF retentate from metallic membrane-microfiltered whey contained 15-16% protein and resulting spray dried WPC contained 87-90% protein. Some of the smaller proteins, mainly α-lactalbumin, were lost during UF/DF processing. Approximately 72% of the total initial whey proteins were recovered
by the complete process. Resulting spray dried WPC exhibited protein solubility values of 90-94% at pH 3 and 7 and good gelation and emulsification properties.

Additional research was done to investigate the influence of mineral ions on the heat induced gelation properties of whey proteins in four of the commercial WPCs and whey protein isolates (WPIs) used above. A 15% (w/v) solution of each WPC and WPI was prepared in distilled water and subjected to centrifugal Sephadex gel filtration to remove residual minerals and lactose (Holley, 1990). The centrifugal gel filtration treatment removed 85-95% of the residual lactose, 5-34% of the minerals, but none of the residual lipids. This treatment had little effect on the percentages of the major whey proteins, except that it removed the largest molecular weight protein fraction, which was assumed to be incompletely solubilized protein aggregates and the smallest sized components, i.e., peptides.

Gelation properties of the four WPC/WPI solutions were not significantly altered by the centrifugal gel filtration treatment when examined by the least concentration endpoint (LCE) and gel strength (shear stress and strain) as determined by Instron. Experimental conditions included four cation types (Ca, Na, K, and PO₄); three ion concentrations (0, 0.1M and 0.2M); four pH values (3.0, 4.5, 6.0, and 7.5); and six protein concentrations (2, 4, 6, 8, 10 and 12%) for the LCE study and one protein concentration (10%) for the Instron study. Gelation of the protein solutions was induced by heating 30 min at 80°C. Three-dimensional graphs were
prepared to provide a better comparison of results from this study.

Addition of all four ion types resulted in improved gelation properties of all four whey protein products by the LCE test, i.e., lower protein concentrations were required to form stable gels. Sodium, potassium and calcium resulted in lowest LCE values. pH 6.0 also resulted in generally lowest LCE values.

WPI gels exhibited higher stress and strain values (stronger gels) than for WPC gels, indicating their superior gelation properties. The differences in gel strength for these protein products may be due to variations in lipid, mineral or protein composition, or to physico-chemical damage to their proteins during manufacture. Addition of 0.1 M ions resulted in gels with greater shear stress and strain values. Highest shear stress and strain values were obtained at pH 6.0 and 7.5, where the cations would be most likely to be bound by the proteins.

CONCLUSION

Results of these studies confirm conclusively the wide range of compositional, functional and sensory properties exhibited by commercial WPCs and WPIs. It will be necessary to produce more uniform WPC and WPI products in order to facilitate their wider use as ingredients by the food industry.

REFERENCES


EXPORT OPPORTUNITIES FOR WHEY, LACTOSE, W.P.C. AND OTHER DAIRY PRODUCTS

by

Mr. Christoph Largiader

Senior International Market Manager
M.E. Franks, Inc.
St. Daniels, PA

Presented at the
9th Biennial Cheese Industry Conference
Utah State University
Logan, Utah

August 21-23, 1990
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BENEFITS OF USING LOOSE REVERSE OSMOSIS IN LACTOSE MANUFACTURING AND OTHER WHEY PROCESSING

by

Mr. Bernard S. Horton
Horton International, Inc.
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Presented at the
9th Biennial Cheese Industry Conference
Utah State University
Logan, Utah

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