1983

Proceedings from the 20th Annual Marschall Invitational Italian Cheese Seminar 1983

Various Authors
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Wisconsin 53701
PROCEEDINGS

from

the TWENTIETH

MARSCHALL INVITATIONAL ITALIAN CHEESE SEMINAR

held in the FORUM BUILDING

of the DANE COUNTY EXPOSITION CENTER

MADISON, WISCONSIN U.S.A.

SEPTEMBER 14 & 15, 1983

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FACTORS AFFECTING THE BROWNING OF ITALIAN CHEESES

by Professor Norman F. Olson, Michael E. Bley and Dr. Mark E. Johnson

ABSTRACT

Brown discoloration occasionally occurs in process cheeses, Mozzarella cheese and other varieties when subjected to high temperatures. The defect is commonly associated with high sugar levels in cheese. Research reported in this paper indicates that lactose fermentation by certain lactic starter bacteria can result in these higher residual sugar levels in cheese.

Cheese made with Streptococcus thermophilus strains that do not ferment galactose, which were used as adjuncts to direct-to-vat lactic starter concentrates, produced cheese with higher galactose concentrations. This cheese turned brown when processed and cooled slowly whereas control cheese without S. thermophilus did not. Higher salt levels in cheese resulted in more residual sugars and browning of control cheeses, especially cheese made with the galactose-negative S. thermophilus strains. Browning may be controlled by regulating salt levels and by using strains of S. thermophilus and lactobacilli that ferment galactose.

INTRODUCTION

Browning or "burning" of Mozzarella cheese like many other foods usually results from reactions between sugars and proteinaceous materials. the correct degree of browning is desirable in products like bread, french fries and potato chips. Sugar levels in these foods are sometimes adjusted to obtain the correct intensity of browning. This practice is not very feasible in natural cheeses like Mozzarella or other Italian varieties, so steps are usually taken to minimize browning. The research described in this paper deals with factors affecting browning of process cheese but the principles and remedies apply equally as well to Italian cheese varieties. In previous studies, it has been demonstrated that high temperatures and high sugar levels caused browning in process cheese (Thomas, 1969). However, processing temperatures did not seem to effect color development as greatly as longer times of processing. Adding skim milk powder to processed cheese also increased the rate of browning, probably because of the increased amount of lactose. Sugar levels in the natural cheese also influenced degree of browning of process cheese. Process cheese, made from a blend containing 70% 1-3 month old cheese exhibited a greater degree of darkening than did a blend
with 30% of this cheese. The 30% blend also showed more browning than a blend containing 10% young cheese. The effects were ascribed to increased lactose concentrations in the young cheese.

Residual sugar levels in cheese are affected by several factors including the starter culture. An accelerated method of cheese making (Hammond, 1979) using high-temperature cultures, browned during moisture analysis, but cheeses made with regular cultures (S. cremoris type), did not show this browning (Dawson, 1958). The starter culture, \textit{S. thermophilus} T82, used in the accelerated method produced acid from lactose and very slowly from glucose but not from galactose. Cultures not associated with browning produced acid from all three sugars. It was suggested that \textit{S. thermophilus} TS2 used only lactose during cheese making and that glucose and galactose might accumulate in cheese and cause browning. Subsequent research indicated that only 12 of the 31 strains of \textit{S. thermophilus} could ferment lactose, glucose and galactose (Somkuti and Steinberg, 1979). Of those 12, ten required a long adaptation phase (7 hours) before they could use glucose or galactose, if they had been grown previously in a lactose-containing medium. Of the remaining cultures, 18 grew on lactose or glucose only, with one strain growing on lactose only. The reduced ability of \textit{S. thermophilus} strains to use galactose was reported also by Tinson et al. (1982) who found that galactose was utilized only by cells that were grown under conditions of limiting lactose.

Since the sugar, galactose, may accumulate in cheese made with some strains of \textit{S. thermophilus} and that this may cause browning of process cheese, factors which affect this accumulation were studied. \textit{S. thermophilus} comprises at least 50% of a culture used for Mozzarella which makes the study pertinent also for this cheese variety.

\textbf{MATERIALS AND METHODS}

\textbf{Manufacture of Experimental Cheese}

Stirred-curd Cheddar cheese was manufactured from pasteurized (145°F for 30 minutes), whole milk (3.5% fat) at the University of Wisconsin Dairy Products Laboratory in 600 lb capacity vats. All vats of cheese milk were inoculated at 88°F with 36 ml of a commercial, frozen starter concentrate (Sc) typically used for Cheddar cheese. Certain experimental vats of cheese milk were inoculated also with 0.5% of non-galactose-fermenting \textit{Streptococcus thermophilus} grown in 12% reconstituted non-fat milk (NFDM) for 16 hours at 104°F. Single-strength calf rennet (Rennet Extract, Marschall Division, Miles Laboratories, Madison, WI.) was used but no color was added. Curd was cooked at 102°F or 100°F to obtain low-moisture or high-moisture cheeses, respectively, before draining at approximately pH 6.1. The curd was kept granular by hand mixing. One half of the salt was added at approximately pH 5.7. The remaining salt and any experimental additives like galactose and hydrolyzed casein were mixed with the curd when the pH reached approximately 5.6. The curd was hooped 20 minutes after the last addition of salt and pressed overnight into 20-lb rectangular blocks and aged at 40°F or 50°F until analyzed and processed.
The Cheddar cheese of trial 1 was processed at 60 days of age, trial 2 at 93 days of age and trial 3 at 31, 62 and 89 days of age into pasteurized process cheese using a combination of Na₂P₀₄ and Na₃P₀₄ as emulsifying salts. The processed cheese was heated to 176°F, poured into 2-pound loaf-style boxes and cooled at various rates. A portion was cooled slowly from 176°F to 100°F in 50 hours and the remainder of the lot was cooled over that range in 24 hours. The 50 hour cooling rate was chosen to simulate the rate of cooling of palletized process cheese in an industrial setting. The 24 hour rate was chosen as a reasonable alternative cooling period that could be attained commercially.

The color of the process cheeses was determined by an instrumental method using a Hunterlab Colorimeter Model D25-9 and by a sensory panel of 28-31 persons.

Predictive Test for Brown Discoloration

Tests to predict the tendency of natural cheeses to brown when converted into process cheese were developed. The Hunterlab colorimeter was used in a laboratory scale test; visual perception of color was used in the simplified version which could be run in a processing plant, cheese factory or pizzeria. In the laboratory-scale test, approximately 125 grams of grated natural cheese was placed into an aluminum container which was capped and sealed. The container was placed into a beaker containing boiling water and heated for one hour. After heating, the sealed container was placed in an incubator at 158°F for 48 hours. At the end of the 48-hour period, instrumental color indices were measured as described earlier. The simplified, subjective version of the predictive test utilized about 5 grams of cheese placed into a 50-milliliter tube. The tube was capped with a rubber stopper that had one small hole bored into it to allow for the release of pressure. The hole was loosely plugged with a cork to prevent excessive loss of water from cheese during boiling. The sample was heated in the same manner described for the larger sample with the cork stopper firmly in place while heating in the 158°F incubator. In these samples, intensity of brown color was estimated visually.

RESULTS

Trial 1

Four vats of cheese were made with direct-to-vat lactic concentrates but with the following additives in each of the vats: (1) S. thermophilus plus galactose and hydrolyzed casein, (2) S. thermophilus plus hydrolyzed casein, (3) control with only lactic concentrate and (4) S. thermophilus. Composition and pH values of cheeses was normal with cheese in vat 1 having a higher salt content (1.92%) and consequently higher pH (5.25) than other cheeses.

The data from trial 1 indicate that galactose concentration, in the natural cheese at the time of processing, played an important role in the degree of browning in the process cheese. The average color difference (dE) of process cheese and the salt in moisture galactose and lactose contents of natural cheeses are given in Table 1. Process cheese from vat 1 showed the highest dE.
(a higher dE indicates more intense brown color). Natural cheese from vat 1 also contained the greatest amount of galactose which came from two sources, the added galactose and the metabolism of \textit{S. thermophilus}. This high level of galactose, along with the hydrolyzed casein, added at salting, enhanced the development of brown color.

The next darkest samples were those from vats 4 and 2 which contained substantial but lower levels of galactose as compared to cheese from vat 1. The smaller difference between dE values of process cheese from vats 4 and 2 correlated with the similarity of galactose contents found in natural cheeses.

The addition of hydrolyzed casein to cheese in vat 2, did not affect color suggesting that availability of reactive amino groups was not limiting in cheese from these two vats. The lightest color was found in process cheese made from vat 3 natural cheese, which was manufactured with only \textit{S. cremoris} starter concentrate. Natural cheese from this vat contained the least amount of galactose. Color development in process cheeses did not relate as well with lactose content of natural cheese (Table 1). Most of the galactose in the cheeses resulted from \textit{S. thermophilus} metabolism as indicated by cheeses from vats 2 and 4 which contained no added galactose versus cheese from vat 1, to which galactose (.04\%) was added. Some of the galactose accumulation in cheese from vat 1 probably also resulted from the higher salt concentration.

It was also noticed that the brown color that developed in samples that were cooled over a period of 50 hours from 176°F to 100°F did not develop if those samples were stored in a refrigerator shortly after processing. This was especially evident in the samples from vat 1 which was intensely brown after processing and slow cooling, but was nearly white when cooled at room temperature for three hours and then refrigerated. No significant differences (P < .05) in dE values were obtained between the process cheeses manufactured from the natural cheeses cured at 40 or 50°F.

\textbf{Trial 2}

In trial 2, the effects of added \textit{S. thermophilus} and rate of cooling of process cheeses after processing were evaluated. Of the samples cooled slowly, the darkest process cheese was made from cheese manufactured with added \textit{S. thermophilus}. This cheese also contained the highest level of galactose, which again indicates that the level of galactose is important in browning of process cheese. The remaining process cheeses had dE values that were not significantly different. The relative color intensities of process cheese cooled in 24 hours were erratic and could not be related to experimental variables.

However, the rate of cooling influenced intensity since all but one of the slowly cooled samples of process cheese in trial 2 were darker than its paired, faster cooled partner.

The data from trials 1 and 2 indicate that galactose concentration in natural cheese, at time of processing, substantially affected color of process cheese. Most of the accumulated galactose resulted from metabolism by the non-galactose-fermenting strain of \textit{S. thermophilus}. 

4
The importance of salt content and specifically S/M ratio in natural cheese is apparent when trials 1 and 2 are compared. The S/M ratios of cheeses in trial 2 were lower than those of trial 1 which may have resulted in lower galactose and lactose concentration in Trial 2 natural cheeses. The lower pH values of natural cheese in trial 2 reflected the effects of more complete sugar metabolism. It has been shown previously that S/M ratio effected sugar concentration in cheese during aging (Thomas and Pearce, 1981, Turner and Thomas, 1980). Higher S/M ratios retarded sugar fermentation whereas low S/M ratios allowed faster and more complete metabolism. The lower sugar concentration resulted then, in less intense color development.

Trial 3

Trial 3 was designed to investigate effects of age of natural cheese and to verify the effects of salt levels (S/M ratios) and different cooling rates on the browning reaction. As previous trials, natural cheese which contained highest concentrations of galactose and lactose (vat 1) produced the brownest process cheese at each of the three ages when the natural cheese was processed. The high S/M ratio of cheese from vat 1 probably inhibited sugar metabolism in the cheese. Cheese from vat 4 was manufactured using only lactic concentrate (SC) as the lactic starter but was made to have a higher S/M ratio. While S/M ratio reached only 4.34, it apparently was high enough to affect the metabolism of the bacteria and allowed galactose accumulation and retarded lactose utilization during the first two months of aging. This accumulation of galactose again resulted in slightly higher dE values (brown color) of process cheese of this vat compared to process cheeses from vats 2 and 3.

Cheeses from vats 2 and 3 were made with SC and SC plus S. thermophilus. the lower S/M ratio of natural cheese from these two vats resulted in lower galactose levels in the natural cheese and therefore lower dE values in process cheeses as compared to vat 1. The failure of S. thermophilus to cause galactose accumulation in the natural cheese from vat 3, and therefore the lack of intense browning of process cheese also illustrates the effect of low S/M ratios resulting in more extensive sugar fermentation.

The rate of cooling the process cheese was again found to play a role in the brown color that developed. The samples of process cheeses that were cooled in 24 hours were lighter in color, with one exception than their paired samples cooled in 50 hours.

Predictive Test

Since heat induced discoloration of process cheese may be an economic liability, predicting the likelihood of natural cheese to brown after processing and slow cooling should prove worthwhile. If a natural cheese has the potential to brown, appropriate measures can be taken to either minimize or avoid the defect. The predictive test described in the Methods and Materials section was evaluated with cheeses from trial 3. The dE values of the predictive tests of natural cheeses were related to dE values of process...
cheese made from those cheeses. Color intensities were greater in the predictive test samples as compared to those of the process cheese samples but the exaggerated color development is advantageous in predictive tests since it is likely to be assessed visually in commercial situations. The deeper color would increase the sensitivity of the test to detect cheese that may have only a slight potential to undergo browning after processing and cooling.

The dE values of predictive tests were lower for cheese aged three months but were comparable to that aged one month which corresponds to the trends in dE values of process cheeses made from those cheeses.

The relationships between dE values of predictive tests and dE values of process cheese cooled in 50 hours, shown in Figure 1, are quite good as indicated by a correlation coefficient of .834. The color intensities for the simplified visual predictive tests compared very closely, by visual observation, to intensities of the predictive tests shown in Figure 1. This indicates that the simplified test would be a very adequate method for quality assurance programs in a manufacturing plant. Either test should be satisfactory for Italian cheese varieties since the same factors cause browning in these cheese varieties.

DISCUSSION

The results of all trials show that galactose concentration in natural cheeses at processing, is important in affecting color development during processing and cooling. Other factors also played a role in determining the color intensity of process cheese as shown by correlation coefficients of relationships between dE values and compositional factors of natural cheese for trials 1 and 3 (Table 3). Trial 2 was excluded due to lack of significant difference between the process cheese dE values. The S/M ratio in natural cheese was highly correlated to dE values of process cheese samples in trial 3. This resulted from the reduced ability of lactic starters in natural cheese, to ferment lactose and galactose at high S/M ratios. The S/M ratio of natural cheese in trial 1 did not correlate as highly to dE values in process cheese because S/M ratios were very similar in vats 2-4. Also, the high correlation of galactose to dE values in trial 1 overshadowed effects of S/M ratios because of the highly active fermentation by S. thermophilus and slower SC metabolism which would cause galactose accumulation. A high S/M ratio was found by other researchers to result in increased lactose concentration in natural cheese (Thomas and Pearce, 1981, Turner and Thomas, 1980).

The results of this study indicate some of the reasons why Mozzarella cheese tends to burn on pizza whereas varieties like Brick, Muenster, Colby and Monterey cheeses do not. The latter four varieties are made with lactic streptococci, primarily S. cremoris, which ferments lactose without very much accumulation of galactose. Some strains of S. thermophilus used for Mozzarella manufacturing may cause accumulation depending upon characteristics of the strain and cheese composition. These same principles would apply to other Italian cheeses in which S. thermophilus strains are used.

It has been assumed that the lactobacilli in the starter for Mozzarella would ferment some of the residual galactose. This may not be true for some species such as Lactobacillus bulgaricus and L. lactis according to a recent study.
(Turner and Martley, 1983). All strains of these two species that were tested caused considerable accumulation of galactose during growth in milk and were unable to ferment galactose. Very little accumulation of galactose occurred during milk fermentation by test strains of \textit{L. helveticus} which also were able to use galactose.

**RECOMMENDATIONS TO MINIMIZE BROWNING**

1. Control the salt level in Mozzarella cheese so that the salt in moisture phase (S/M) is less than 4 to 4.5%. This is equal to 1.9% salt in a 48% moisture cheese (4% X 48 = 1.9%). Lower salt levels (1.5 - 1.7%) are preferred because the outer edges of cheese loaves are higher in salt, after brine-salting which will restrict sugar fermentation in those areas.

2. Control ratios of \textit{S. thermophilus} to lactobacilli so that streptococci do not predominate. However, high numbers of certain strains of lactobacilli might produce pink ring defect in ripened Italian cheeses (Shannon et al., 1969). This would not be a problem in Mozzarella cheese.

3. Wash cured before molding to remove sugars.

4. Select starter strains that ferment galactose. Strains of \textit{S. thermophilus} that ferment galactose were also used in this study as starter adjuncts in making cheddar cheese. Preliminary results indicate that cheese made with these strains did not brown nearly as intensively as cheese made with galactose-negative strains when compared by the predictive test. Cheese made with one of the galactose positive strains had a color level similar to the control even though salt concentrations were fairly high (about 2.0%). Using galactose-fermenting strains of \textit{S. thermophilus} with strains of lactobacilli that use this sugar should reduce browning in cheese. All of these recommendations should be evaluated carefully to ensure that they do not have adverse effects on other aspects of cheese quality.
REFERENCES


Table 1  Data from trial 1 showing the relationship of dE in process cheese to salt/moisture (S/M) ratio, lactose and galactose contents in natural cheese.

<table>
<thead>
<tr>
<th>Vat</th>
<th>Process cheese dE value</th>
<th>Natural cheese S/M ratio</th>
<th>Lactose</th>
<th>Galactose</th>
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<td>1(^{a,b,c})</td>
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<td>2(^{a,c})</td>
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<td>3</td>
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<td>4(^a)</td>
<td>6.87</td>
<td>4.68</td>
<td>.103</td>
<td>.133</td>
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\(^a\) *S. thermophilus* added, 0.5% of milk weight

\(^b\) galactose added to curd, 9 grams per 44 lb cheese

\(^c\) hydrolyzed casein added to curd, 18g per 44 lb cheese
Table 2  Data from trial 3 showing the relationship of dE in process cheese to S/M ratio, lactose and galactose contents in natural cheese.

<table>
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<th>Vat</th>
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<th>Cooling times</th>
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<tr>
<td></td>
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<td>(h)</td>
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<td>S/M Lactose</td>
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S. thermophilus added, 0.5% of milk weight
Table 3 Correlation coefficients of factors affecting intensity of color (dE) of process cheeses in trials 1 and 3.

| Factors\(^a\) correlated with color intensity (dE) | Correlation coefficients |
|---|---|---|
| | Trial 1 | Trial 3 |
| Galactose | .929 | .90 |
| Lactose | .230 | .888 |
| S/M ratio | .579 | .940 |
| Galactose & Lactose | .966 | .919 |
| Galactose & S/M ratio | .989 | .940 |
| Lactose & S/M ratio | .851 | .951 |
| Galactose & Lactose & S/M ratio |  | .952 |

\(^a\)All factors related to composition of natural cheese.
The following paper was presented by Randy A. West, Manager, New Product Development, Marschall Products, Miles Laboratories, Inc., P.O. Box 592, Madison, Wisconsin 53701, at the 20th Annual Marschall Invitational Italian Cheese Seminar, held in the FORUM Building of the Dane County Exposition Center, Madison, Wisconsin, on September 14 and 15, 1983.

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*By V.W. Christensen and R.A. West*

**ABSTRACT**

A history of modern cheesemaking processes is given, identifying several factors which have contributed to a general decline in the flavor of Italian type cheeses. Methods and theory of obtaining advanced flavor maturation in cheese is reviewed. The commitment of Marschall to develop and market an accelerated cheese maturation process is cited.

In 1982 the Italian Cheese Industry in the United States produced 1,087,781,000 lbs. of all types and varieties of Italian Cheese, to set another all time production record for the 31st consecutive year, dating back to 1952.

This is the first time in the history of the Italian Cheese Industry in the United States, that yearly production records exceeded one billion pounds in a calendar year.

Of the 1,087,781,000 pounds of Italian cheese produced, approximately 81%, or 883,774,000 pounds was Mozzarella, Ricotta, other soft varieties and similar styles. Provolone, Romano, Parmesan, plus other hard Italian varieties, accounted for approximately 19%, or 204,037,000 pounds in 1982.

The future looks very bright, indeed.

When we discuss Italian cheese flavor, we must first relate to those cheeses such as Mozzarella and Pizza cheese that rely heavily on cultures and milk quality for final flavor development in these relatively bland cheeses.

Other Italian varieties such as Provolone, Romano, Parmesan and Asiago, rely heavily on lipase enzymes and/or rennet pastes to give the final flavor development desired. Of course, the hard Italian varieties also use starters for the primary purpose of developing acidity that is essential for flavor development as well as a desirable body and texture.

The reason we have seen growth in the Italian cheese sales has been primarily due to growth in the Mozzarella and Italian soft cheese types where a good quality clean lactic acid flavored product met the needs of the Pizza manufacturer, consumer, and home users cooking purposes.
The increase in sales of the more flavorful and hard cheeses such as Provolone, Romano, and Pecorino was due to standardized body and texture and most importantly cheese flavor due to use of standardized enzyme products such as lipase powders and rennet paste.

Today however, the markets show resistance to continued growth, and the question arises; are the manufacturers of Italian cheese looking more towards mechanization, cost controls, near-sterile raw milk, pasteurization, etc., and forgetting what really sold Italian cheese in the first place?

A vicious cycle has been created. The more "mild" cheeses that are produced, the more people eat them. The more people eat these "mild" cheeses, the more they become accustomed to them. Eventually, other more flavorful foods replace those once held by flavorful cheeses, and total cheese consumption may decline. Far more than 50% of all cheese eaten in the United States today is "mild" natural or processed cheese. Not surprisingly, the preference of the under-30 generation is overwhelmingly in favor of mild, bland flavored cheese. It is not surprising that imitation cheeses have had a relatively easy time encroaching on the market share of "mild" cheese varieties.

Mild cheese, unfortunately, has very little to offer the consumer over imitation cheese, except a lack of off-flavors associated with caseinates and vegetable fats. But natural cheese almost always carries a higher price. It is time for us in the cheese business to accentuate the positive - the most flavorful styles of natural cheese that we are capable of making. Greater per capita consumption of cheese is bound to follow, and a standard of quality will be established which imitation cheeses are not likely to easily attain.

Over the past several years, many new practices have been adopted in cheesemaking. Many of them have "crept" into the cheesemaking regimen for various logical reasons, but singly, or collectively, may contribute to more "muted" cheese flavors. Let's enumerate and expand on some of these for the next few minutes.

I. The Milk Supply - Poor sanitation and lack of sanitation technology on the farm and in the plant in years past, have undoubtedly led in many cases to excellent cheese flavors via contamination with desirable lactic acid producing cultures. But perhaps, a like or greater amount of cheese has been spoiled by contamination due to undesirable contaminants.

I would like to relate a brief history of the modern evolution of milk handling and its relationship to cheese flavor practices. During the 30's, 40's, 50's and 60's, the U.S. cheese industry was generally composed of small factories located centrally within about a 25 mile radius of the local milk patrons. Transportation limitations and inadequate refrigerated storage facilities restricted growth of the plant and made it necessary that milk be picked up on a daily basis. Milk cans were typically emptied of milk and washed at the cheese plant. They were frequently sent back to the dairy farm full of whey. A quick rinse of the milk can and it was placed back in service of holding the milk until it was picked up the following day. There was usually enough whey left in the milk can to re-inoculate the milk that would be returned to the cheese plant the following day.

Cheese was often made from un-pasteurized milk that was not more than 24 hours old. These naturally occurring bacterial contaminants were sometimes responsible for exceptionally good cheese, but on certain occasions cheese resulted with very poor body and texture. The results were very difficult to predict since the precise flora of the contaminated milk was not known, nor easily controlled.
With the advent of refrigerated farm bulk holding tanks and faster and more efficient milk transports, small plants began to consolidate, expand and diversify. In 1982, there were about 720 hard cheese factories in the U.S. In 1940, there were about 3,600 hard cheese factories. The 720 hard cheese factories in 1982 manufactured more than five times the amount of cheese produced in 1940, which demonstrates the rapid growth this industry has undergone in the past 42 years.

As plants grew in size, some factories began to fill vats two or more times per day. This, coupled with stricter regulations, and a more critical buying public, required more sophistication in starter preparation. Pasteurization was now becoming commonplace, and the milk in the vat was virtually free of lactic acid producing organisms. This placed added responsibilities on the prepared starter, to contribute flavor to the cheese in lieu of the desirable organisms and enzymes which were now being destroyed by pasteurization. It is fair to point out, however, that on frequent occasions, organisms and enzymes which were responsible for off-flavors and poor cheese body and texture were also destroyed.

II. Pasteurization - Pasteurization is responsible for the elimination of nearly all of the normally occurring milk flora and many of the enzymes as well. In some cases, these flora and enzymes would have made the difference between a flavorful cheese, and a dull, bland cheese without them. Undeniably, pasteurization is sometimes very fortuitous for cheese flavor when milk has been mishandled and allowed to become contaminated with an undesirable flora. Pasteurization is recognized as generally diminishing the flavor of cheese as compared to a vat made with raw milk. Milk is sometimes overpasteurized and can lead to a cooked or scorched off-flavors, as well as yield losses. Pasteurization can also contribute to less desirable body and texture. The process of pasteurization has now been adopted by nearly all cheese plants in the United States. Though most of us generally agree that the benefits of pasteurization outweigh the negative aspects, it is still essential for us to recognize its effect on cheese flavor development.

III. Vacuum Heat Treatment of Milk - Again, here is a process which can either be a help or a hindrance in the quest for flavorful cheese. Normal milk has flavor due in part to naturally occurring volatile compounds. Those of you who have compared raw milk flavor with vacuum treated pasteurized milk, know organoleptically that this is true. Occasionally, undesirable flavors such as wild onion, are removed from milk, which is very beneficial. But more often, the milk is of normal flavor in the silo, and is reduced to a rather bland liquid following vacuum treatment. I am not advocating the discontinuance of vacuum treatment of milk, but simply add it to a somewhat long list of other possible contributors to less flavorful cheese. It can be said for vacuum treatment of milk, that it does help to standardize cheese flavor (or lack of it) from one load of milk to the next.

IV. Plant Consolidation - Tremendous plant consolidation has occurred in this country in the last 50 years. Emphasis in these larger plants is to produce large quantities of cheese very efficiently. Make times are typically shorter as the emphasis is placed on productivity. Some plants now use programmed make schedules which do not take into account small, but important differences that would have otherwise been altered by an attentive cheesemaker. The mass production of highly uniform, lower flavored, automated varieties, such as loaf mozzarella, seem to be becoming more popular with the large consolidated factories. This has brought about plants which are operated by accounting principles, with little thought being given to the quality of the product, and greater emphasis being placed on lower costs and improved yields.
V. Importance of Starters - Starters are perhaps the most important single ingredient in good quality cheesemaking. If you have a good starter, you can be reasonably sure of getting good acid development and probably good flavor development. However, if your starter is not active, or slightly contaminated, your acid development and flavor development will probably be off also. When your milk supply is of good quality and if your starter is not contaminated and working properly, you should produce top quality cheese. When your starter is not working properly, you will probably get cheese with off-flavors such as bitter, fruity, yeasty, malty, etc. Pin holes and mechanical openings in cheese invariably indicate that the starter is not working properly; or that your milk supply is contaminated badly with gas producing organisms.

Dr. Z.D. Roundy (15) first introduced the information that Streptococcus thermophilus was the organism primarily responsible for the acid development in the milk and which brought the acidity of the curd down to a pH of 5.3. At this pH, the S. thermophilus organisms decline, and the Lactobacillus bulgaricus organisms thrive, and eventually bring the pH of the curd down to about 5.2 when the cheese is 24 hours old. Without these two organisms working together in this symbiotic relationship, there would be many severe problems in the manufacture of Italian cheese. It is important to remember that mesophilic lactic acid producing organisms such as S. lactis and S. cremoris are inhibited in growth at temperatures in excess of approximately 104°F. However, thermophilic Coccus and Rod organisms (S. thermophilus and L. bulgaricus) have the ability to survive cooking temperatures up to approximately 135°F. Thus, if you are going to make cheese that is to be cooked over 104°F, it is essential that you use Coccus and Rod cultures as starters.

Since most Italian cheese varieties are cooked to temperatures over 104°F, you must employ Coccus and Rod starters to give you the body and texture as well as the final flavor development you desire. Mesophilic lactic acid producing organisms (S. lactis and S. cremoris) can be used however, in the manufacture of most Italian varieties where the curd is not cooked over 104°F.

Culture requirements before pasteurization became commonplace, were minimal, and the cheese usually reflected the lack of quality control with respect to starter technology. It was common for a factory to carry a single mother culture for months, or years, with in-plant transferring occurring daily. We can feel safe in assuming that the in-plant culture continually changed due to contamination and dominance of faster strains. Minor starter problems were minimized by the flora of lactic acid producing organisms, present in the daily milk supply. Major starter problems led the cheesemaker to borrowing a culture from a neighboring factory when his starter failed.

By the mid-50's pressure on primitive in-plant starter programs became very intense. What had been minor brushes with starter failure due to bacteriophage in the cheese factories of the 30's had now grown to become a major problem. Some factories made "dead" cheese for days on end, despite borrowing new starters from neighboring factories. The natural lactic bacterial flora which had aided in acid production in raw milk cheese, was now being destroyed by pasteurization, and left the prepared starter to "fend for itself" against bacteriophage, and to be the predominant contributor to cheese flavor, body and texture.

Efforts by Marschall Dairy Laboratory were turned to assist the plants with the very serious problem of bacteriophage control. Cultures were procured, purified and held frozen in our laboratory. Orders were taken by mail and phone and culture prepared
by sterilizing 100 c.c. bottles of milk to which was added a small portion of our stock culture. The starter incubated enroute, and was used as the 'seed' culture at the factory. Dry-flake, and later lyophilized mother cultures were made available to the industry. Selecting cultures which produced lactic acid dependably was of primary importance, and obtaining a culture which gave good flavor was sometimes secondary.

Early in the 60's phage inhibitory media was introduced by Marschall. In 1964, 1 c.c. vials of frozen cultures grown in Marstar® starter medium were offered for sale. 1965 brought an improvement in culture stability as cultures were stored in liquid nitrogen instead of -4°C home type freezers. In 1969 cultures were commercially offered by Marschall which had been concentrated and rapidly frozen. These cultures allowed for the direct setting of bulk starter tanks. In 1973, highly concentrated cultures direct-to-the-vat inoculation were sold under the trade name of Superstart®.

In the last few years, much effort has been turned to the selection of culture blends of "known" composition which are phage resistant, AND pass several other characterization steps, including the ability to produce cheese of acceptable flavor and quality. It is discouraging however to note that many of our cultures which have been long known for their ability to produce exceptional cheese flavor, are not widely used because they are sometimes somewhat slower in their ability to produce acidity in a cheese vat. Unfortunately, we are able to only offer a limited number of cultures for sale, and as the sales for some cultures decline, they must be deleted and replaced by yet other cultures. Unmistakably, the preference for fast cultures has won-out over slower strains, which may be quite capable of producing cheese with excellent flavor, if only a little more starter were to be added to each vat. This is a good example of being "penny-wise and pound foolish". For lack of perhaps another ½¢ per pound cost investment; cheese with little, or no fine cheese flavor, may result. One fourth cent per pound of cheese can add up to a considerable sum for a large factory, but this type of reasoning is partly responsible for the trend toward more and more flavorless cheeses in the market place today. Moreover, this trend is responsible for the direction of our efforts at Marschall towards faster, not necessarily more flavor-producing, cultures. We feel a responsibility to respond to our customers requirements, even if they are not necessarily what we perceive their needs to be.

VI. Less Rennet Used - Just a short number of years ago, the standard usage rate for animal coagulant was 4 ounces of single strength calf rennet per 1000 pounds of milk. Some plants now use calcium chloride to extend a smaller amount of coagulant. Other plants compensate for less rennet in each vat by increasing setting temperature. In both cases, reduction of coagulant can lead to inadequate body breakdown and/or insufficient or delayed flavor production. "Saving" money by cutting back on rennet should be very carefully evaluated before implementing.

VII. High Interest Rates - High interest rates is one of the foremost causes of low flavored cheese being sold to the U.S. market. Cheese with a value of $1.40 per pound at an interest rate of 16%, costs over 1.8¢ per pound per month. When insurance and warehousing charges are added-in, cheese storage costs can reach 2½-3¢ per pound per month. In many cheese factories, aged varieties are often avoided because they disrupt the plant's financial cash flow. A cheese aged for 12 months can cost a factory well over 30¢ per pound in combined aging costs.

VIII. Undergrade Cheese and Market Fluctuation - One of the most risky activities associated with cheesemaking is the cheese aging process. As cheese is aged to allow desirable flavor and body to develop, it is possible that off-flavors and other de-
fects may also develop. Some of the defects occurring in aging cheese may make a cheese worth even less than its value when it was fresh. In some varieties (and if the defect is severe) the cheese may be reduced to only a fraction of its accrued cost of manufacture. A large volume of downgraded product can severely decrease the profitability of a cheese factory. This factor has caused many U.S. cheese factories to emphasize the manufacture of current styles.

Some cheese factories making a large percentage of their total volume in aged cheese varieties, are subject to the prevailing market prices when their cheese has reached maturity. Continuing the aging process beyond maturity, of some, is risking that the product may over-age and "go over the hill". The cheese factory then, has a very narrow 'window' of time in which an aged cheese can be sold. If the cheese is ready when the market is good, the plant does well; but if the market is poor, a loss is sometimes suffered on that lot. This market instability is obviously also responsible for the decision of many plants to cease the manufacture of aged cheese varieties such as Provolone, Romano, Parmesan, and others.

To compensate for some of the lack of flavor due to many factors (including those previously discussed), cheesemakers throughout the world seem to have a renewed interest in the concept of accelerated cheese ripening. The idea of accelerating or enhancing cheese flavor development is not new. In fact, the modern practice of adding lipase enzymes to cheeses such as Provolone and Romano falls into this category, since specially prepared calf, kid, or lamb esterases are expressly added for the sole purpose of generating an accelerated and enhanced flavor. This had, over the past few years, been accepted as a rather standard procedure (1). Over the years, starters, modified starters, enzymes, chemicals, and even flavors themselves, have been added to cheese to implement faster flavor development. Of course the major objective is to produce a cheese of fine quality - economically and within the limits of the cheese standards.

Recently, the International Dairy Federation submitted a questionnaire (1) which solicits the reply of member countries regarding the accelerated ripening of non-cheddar cheese. To summarize, specific non-cheddar cheese varieties are reportedly ripened in an accelerated fashion by using some of the following: temperature control, controlled humidity, lipase addition (both animal and microbial), rennet pastes, unspecified enzyme addition, lactase addition, addition of whole treated bacterial cells, chicken-pepsin added, special bacterial strains, proteolytic enzymes added, and milk homogenization.

Obviously, some procedures are potentially applicable to some cheese varieties, but not to others. Some procedures admittedly caused serious flavor and/or body/texture problems arising from their use, and some are simply not allowed by various regulatory bodies worldwide.

To say that the process of cheese curing is complex, is an understatement. Cheese ripening is a very complex process in which interactions occur between the milk components, enzymes and microorganisms. Several elements influence (10) the microorganisms and enzymes such as:

a.) pH
b.) Ionic strength (salt concentration in the free, un-bound water)
c.) Time and Temperature
d.) Water activity
e.) Oxidation-reduction potential
Since milk (10) is not uniform, the biological interactions occurring in cheesemaking and curing are not as well defined as some found in other biological systems. It is easy to understand then, why predictable, uniform cheese is so difficult to manufacture.

Many philosophies exist pertaining to the type and importance of factors contributing to cheese flavor development. One author (13) cites the importance of contaminating non-starter bacteria on cheese flavor. In work by Reiter and Sharpe (1971) (14), of 8 groups of organisms found in raw milk, only 2 groups survived heat treatment at 155°F for 15 minutes; but 6 groups were later found in the cheese curd, one of which was not even in the raw milk originally. One current theory (16) suggests that the starter bacteria only produce proper conditions subsequent to essential chemical reactions taking place; such as:

a.) Supplying flavor precursors
b.) Provide a pH which helps control reactions
c.) Provide an oxidation-reduction environment which maintains compounds like methanethiol in a reduced form

Several authors have shown that Swiss (5), Gouda (17) and a semi-hard Swedish cheese (17) were all improved in flavor by the apparent effects of proteolytic enzymes of starter origin (16).

It is clear from a review of recent literature that much attention is presently being given to the evaluation of various proteolytic enzymes. A comprehensive international article (8) by Dr. B.A. Law on "Accelerated Ripening of Cheese and Cheese Products", cites research where all cheese given certain proteinase treatments resulted in soft-bodied, crumbly cheese. Additionally, several of these proteinases gave bitter flavors.

The task at hand with regard to proteinases, are to select those which give maximum flavor acceleration, but produce little or no flavor, body and textured defects.

Several years ago, the Marschall Products Division of Miles Laboratories recognized the need for an accelerated cheese maturation product with the following characteristics:

a.) Accelerate normal cheese flavor development.
b.) The resultant cheese must have a body and texture equivalent to that which is normal for a cheese of that flavor intensity.
c.) Must conform to appropriate Regulatory standards in the U.S.
d.) The accelerated cheese maturation must either stop, or slow at a desired place; or be capable of being stopped or slowed by a simple means.
e.) Be convenient to use.
f.) Should not significantly interfere with the normal cheesemaking process.
g.) Be reasonably priced when compared to the derived benefits.

As a result of substantial commitment, and a lot of hard work, significant progress has been made at Marschall, toward meeting the above goals. Some of the goals are more resolved than others, but we plan to continue to fund research in this area, and conduct trials on the manufacture of several cheese styles.
Marschall has long felt a responsibility to develop products that contribute to the progress and success of the cheese industry. Projects such as this, fall clearly into that category. Perhaps at an Italian Cheese conference in the near future, we will introduce a product which meets the goals we have established for an accelerated cheese maturation product.

Thank you for your kind attention.
References


Dairy waste water and its associated BOD (Biological Oxygen Demand) and Total Solids contaminates have always been regarded as a nuisance generated in manufacturing dairy products; however, these milk solids and chemicals should be considered product losses that have been paid for once, and then paid for again as they are carried from a cheese plant along with the waste water.

Membrane processing can reclaim valuable milk solids or chemicals for resale, reuse or less expensive disposal. Therefore, reducing operating costs, and the overall impact on the environment.

Over the past six months, you the cheese plant owner or operator may have had a number of meetings with a representative from DNR (Department of Natural Resources) or the local Sewage Plant Manager, discussing the fact that the cheese plant is contributing 500, 1,000 and 2,000 pounds of BOD/day and this volume of contaminates has now overloaded your ridge and furrow system, settling ponds or local sewage plant. This situation is very familiar to every cheese plant Manager. Therefore, let us examine where these BOD volumes are generated so we can translate what the representative has told us, from pounds of waste, to pounds of product.

The first slide I will show you is a chart of where the waste water and BOD is created in a cheese plant.

If we examine the first three boxes, milk receiving, milk storage, and cream storage, we can see that the typical cheese plant has already generated 42% of the waste water volume and 62% of the BOD load without processing one pound of product.

What we must examine is the actual pounds of product lost and its corresponding value from a plant of 500,000 pounds/day milk processing capacity.

The study that created the previous chart also included reference material on milk, protein, lactose and fat, and what the pound to pound ratio of BOD is for each of these products.
Therefore, by using the information on slide 1 and 2, we can calculate the cost of product lost from a plant of 500,000 pounds/day capacity.

Further multiplying the pounds of product and pounds of BOD equivalent ratio, with the cost of product, we have a total of $438.25/day in product loss.

The product in the receiving area has not been paid for because it is retained on the side wall of the transports, however, it could be paid for in sewer charges, and the other two areas could be paid for twice.

Now let us examine what steps can be taken to reduce treatment costs related to total volume and solids.

Presently tests are being conducted in a dairy to reclaim the first rinse from each of these three areas and separate the fat by conventional means, and then concentrate the milk solids on a 5 to 1 or possibly a 10 to 1 ratio by Reverse Osmosis.

The permeate from this process is of sufficient quality to be discharged to an open water system and the concentrate is being hauled for land application.

This membrane application is extremely new and only possible because of the new "thin film composite" membrane with its very high rejection characteristics, plus new lower cost non-sanitary equipment that is now available.

This process has not been completely proven but the preliminary information supports the concept and the ever increasing pressure from the Department of Natural Resources along with escalating sewer charge will assist in making this application as standard as concentrating whey by Reverse Osmosis.

If we carry this concept one step further, we could apply R-O and UF on all the waste water generated in a cheese plant and theoretically reduce the BOD, and TS going to a treatment plant by 75%.

This schematic shows a combination of R-O and UF equipment, treating rinse water and CIP caustic solutions for discharge or reuse of the permeate, and the concentrates are collected and hauled for land application.

This concept is now under consideration and testing will commence within 30 days.

The processes I have just mentioned are in their infancy and yet to be proven; however, the next waste water treatment process I will discuss has been in operation for a number of months.

The application I will describe is that of using a Reverse Osmosis system to clean R-O permeate or evaporator condensate for reuse or open discharge.
Pollution Control in the Dairy Industry

**FIGURE 29: FLOW DIAGRAM FOR CHEDDAR CHEESE MANUFACTURE**

- **Plant Process**: Milk receiving
  - **Waste Generating Process**: Tank truck or can washing
  - **Nature of Waste**: Milk wastes + detergents + sanitizers

- **Plant Process**: Milk storage and standardization
  - **Waste Generating Process**: Storage lines + equipment cleaning sludge from separation
  - **Nature of Waste**: Milk wastes + detergents + sanitizer

- **Plant Process**: Cream storage
  - **Waste Generating Process**: Emptying + cleaning + sanitizing
  - **Nature of Waste**: Cream wastes + detergents + sanitizers

- **Plant Process**: Starter manufacture (skim)
  - **Waste Generating Process**: Starter tank + lime cleaning + sanitizing
  - **Nature of Waste**: Starter (pH 4.6 pH) from cleaning + detergents + sanitizer

- **Plant Process**: Curd making
  - **Waste Generating Process**: Whey draining
  - **Nature of Waste**: Any whey not excluded from drain + residual whey + curd + detergents + sanitizers

- **Plant Process**: Cheddaring
  - **Waste Generating Process**: Whey drained vat cleaning + sanitizing
  - **Nature of Waste**: Whey, salt + curd + detergents + sanitizer

- **Plant Process**: Washing curd processing
  - **Waste Generating Process**: Curd washing vat cleaning
  - **Nature of Waste**: Diluted whey curd + detergent + sanitizer

- **Plant Process**: Hooping forming pressing
  - **Waste Generating Process**: Pressing trimming
  - **Nature of Waste**: Whey curd + detergent + sanitizer

- **Plant Process**: Aging
  - **Waste Generating Process**: Washing cheese surface
  - **Nature of Waste**: Organic matter from washings

- **Plant Process**: Grading trimming shipping
  - **Waste Generating Process**: Trimming off mold and damaged cheese
  - **Nature of Waste**: Cheese solids

**FIGURE 30: WASTE COEFFICIENTS FOR CHEDDAR CHEESE MANUFACTURE**

- **Plant Process**: Milk receiving
  - **Pound Waste Water/Pound Milk Processed**: 0.125
  - **Pound 800/2000 Pounds Milk Processed**: 0.20

- **Plant Process**: Milk storage and standardization
  - **Pound Waste Water/Pound Milk Processed**: 0.10
  - **Pound 800/2000 Pounds Milk Processed**: 0.28

- **Plant Process**: Cream storage
  - **Pound Waste Water/Pound Milk Processed**: 0.10
  - **Pound 800/2000 Pounds Milk Processed**: 0.30

- **Plant Process**: Starter manufacture (skim)
  - **Pound Waste Water/Pound Milk Processed**: 0.10
  - **Pound 800/2000 Pounds Milk Processed**: 0.25

- **Plant Process**: Curd making cutting, cooking + whey milk
  - **Pound Waste Water/Pound Milk Processed**: 0.10
  - **Pound 800/2000 Pounds Milk Processed**: 0.2 (no whey)

- **Plant Process**: Cheddaring, milking, salting
  - **Pound Waste Water/Pound Milk Processed**: 0.10
  - **Pound 800/2000 Pounds Milk Processed**: 0.10

- **Plant Process**: Washing curd, processing, salting
  - **Pound Waste Water/Pound Milk Processed**: 0.20
  - **Pound 800/2000 Pounds Milk Processed**: 0.50

- **Plant Process**: Hooping, forming, pressing
  - **Pound Waste Water/Pound Milk Processed**: 0.30
  - **Pound 800/2000 Pounds Milk Processed**: 0.30

- **Plant Process**: Aging
  - **Pound Waste Water/Pound Milk Processed**: 0.05
  - **Pound 800/2000 Pounds Milk Processed**: 0.05

- **Plant Process**: Grading, trimming, shipping
  - **Pound Waste Water/Pound Milk Processed**: 0.05
  - **Pound 800/2000 Pounds Milk Processed**: 0.05

- **Plant Process**: Total
  - **Pound Waste Water/Pound Milk Processed**: 0.77

Source: EPA Report 12060 EGU, March 1971
REFERENCE SHEET

MILK (FLUID)

9 lbs. MILK = 1 lb. BOD

PROTEIN

1 lb. PROTEIN = 1.1 lbs. BOD

LACTOSE

1 lb. LACTOSE = 0.6 lbs. BOD

FAT

1 lb. FAT = 0.9 lbs. BOD
### PRODUCT LOST IN RINSE WATER FROM RECEIVING TRUCKS & STORAGE TANKS

<table>
<thead>
<tr>
<th>PLANT PROCESS</th>
<th>lbs. / BOD / 1000 lbs.</th>
<th>PRODUCT EQUIVALENT No.</th>
<th>TOTAL PRODUCT (lbs.)</th>
<th>APPROXIMATE COST</th>
<th>TOTAL COST</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk Receiving</td>
<td>500 †</td>
<td>9 **</td>
<td>900</td>
<td>***</td>
<td>$112.50</td>
<td>** Average Price/Year Jan. thru June 1983</td>
</tr>
<tr>
<td></td>
<td>x 0.20</td>
<td></td>
<td></td>
<td>$12.50/100 wt.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk Storage</td>
<td>500</td>
<td>9</td>
<td>1260</td>
<td>$12.50/100 wt.</td>
<td>$157.50</td>
<td>* See Chart *1 for coefficients</td>
</tr>
<tr>
<td></td>
<td>x 0.28</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>140</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Cream Storage</td>
<td>500</td>
<td>0.9</td>
<td>135</td>
<td>$1.25/lb.</td>
<td>$168.75</td>
<td>** See Chart *2</td>
</tr>
<tr>
<td>(40% Butter Fat)</td>
<td>x 0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>150</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>TOTALS</td>
<td>390 lbs.</td>
<td></td>
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<td></td>
<td>$438.25</td>
<td></td>
</tr>
</tbody>
</table>

Typical, cheese plant of 500,000 pounds/day milk processing capacity
Typically Reverse Osmosis system concentrating whey will discharge permeate with a BOD quality from 100 ppm to 1,000 ppm depending on the status and age of the membranes.

Permeate with these BOD levels must be further processed in a treatment plant on a ridge and furrow system of which can be overloaded or saturated.

To eliminate this problem, a second small Reverse Osmosis unit (which I will call a "finishing plant") can be installed and treat the permeate to levels that can be disposed of without further treatment.

For example, slide 5 and 6 are results of test on samples of permeate taken from such a "finishing plant".

The permeate being fed to the second small R-O "finishing plant" had a BOD of approximately 900 ppm and the feed volume was concentrated 10 to 1 giving the concentrate a value of 9,550 ppm.

This application can also be used on evaporator condensate if the BOD level is higher than desired or the BOD varies outside the accepted range for boiler feed or other process applications.

The membranes in this system have been in use for three (3) months and performing with the original flux and cut-off.

These membranes are a standard in the industry and are now available in new low cost systems.

For example, if a plant is generating 200,000 lbs. of R-O permeate or evaporator condensate per day, a small Reverse Osmosis system capable of concentrating the volume 10 to 1 (which would produce 180,000 lbs/day of good clean permeate available for boiler feed water or open discharge) would cost approximately $60,000.

The system that I have described is capable of operating with a minimum amount of operator supervision plus the water being treated has very little effect on the membranes, therefore, virtually eliminating the harsh cleaning requirements related to whey or milk products, plus these membranes can be cleaned with caustic and acid at elevated temperatures.

The last waste treatment application I will describe was mentioned in slide 4.

This application utilizes ultrafiltration to clarify caustic from an evaporator and it has been in daily operation since January of this year.

The procedure is to collect both the first and second caustic solution from the evaporator into a spent caustic tank and separate the particulate matter from the caustic which is reclaimed and reused for the next day cleaning cycle.
## Analysis Report Form

**Date:** June 30, 1983  
**Client:** Viroqua Whey Products  
524 No. Center St.  
Viroqua, WI 54665  
Attn: Claude Sebion  

**Sampling Location:** Effluent  

**Sample No.:** 5396  
**Sample Site:** #1  

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<td>&lt; 1</td>
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</table>

**Collected By:** Client  
**Delivered By:** Client  
**Date Collected:** 6/23/83  
**Date Received:** 6/23/83  

< means "less than"

The laboratory analyses reported above were determined under strict quality control conforming to EPA methodology and the latest edition of Standard Methods. Analyses were performed by myself or under my direct supervision.

Submitted by,  
DAVY LABORATORIES

[Signature]

Paul A. Harris, Director
DATE: June 9, 1983

CLIENT: Viroqua Whey Products, Inc.
524 No. Center St.
Viroqua, WI 54665
Attn: Claude Sebion

SAMPLING LOCATION: RO Unit

CLIENT NO.: 1850
(17140)

COLLECTED BY: Client
DELIVERED BY: Client
DATE COLLECTED: 5/27/83
DATE RECEIVED: 5/27/83

SAMPLE NO.: 5327
SAMPLE SITE: #1

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</table>

*** No adjustment for peroxide made, Client said none present

< means "less than"

The laboratory analyses reported above were determined under strict quality control conforming to EPA methodology and the latest edition of Standard Methods. Analyses were performed by myself or under my direct supervision.

Submitted by,
DAVY LABORATORIES

Paul A. Harris, Director

Paul A. Harris, Director
ADVANTAGE OF RECLAIMING CAUSTIC CIP SOLUTION

RECLAIM APPROXIMATELY 80% OF THE LIQUID CAUSTIC

TO REDUCE THE VOLUME OF SALTS BEING DISCHARGED DAILY

TO REDUCE THE VOLUME OF HARSH LIQUID BEING DISPOSED ON LAND OR IN SEWAGE PLANTS
In this process, the caustic molecules pass through the membrane with the water, and the proteins, minerals or other contaminants are concentrated in the storage tank to a predetermined volume which is approximately a 1 to 5 ratio, or until 80% of the caustic solution is reclaimed.

This slide shows the process and controls necessary so the UF unit can operate without supervision.

The procedure is to collect the entire volume of caustic solution, which in this case is 3,000 gallons in a tank, equipped with a standpipe installed at a predetermined level.

The UF unit is started and the solution flows from the spent caustic tank through the UF and the concentrate is recirculated on a batch basis, with the permeate going to a reclaim tank.

Once the concentrate level goes below the standpipe, the feed stops, and the level control stops the unit and sounds a horn, that the process is complete.

These units are small, compact and self-contained so they can operate without supervision in remote locations.

The units are cleaned, oddly enough, with caustic and EDTA (celate) to remove the dirt layer deposited from the solids in the dirty caustic.

The advantages of this unit are as follows:

1. To reclaim approximately 80% of the liquid caustic.

2. To reduce the volume of salts being discharged daily.

3. To reduce the volume of liquid being disposed of on land or in sewage plants.

All three of the examples must be used to return the investment of such a unit, since the price of caustic fluctuates drastically with supply, and the cost of disposal varies from plant to plant.

However, the application of reclaiming caustic will gain popularity due to the fact that it eliminates one of the most serious disposal problems in a dairy and one of the most detrimental effects on the environment.

In conclusion, I would like to state that many of these applications seem extremely difficult and almost beyond reach, but four years ago on September 12, 1979 I spoke to this Conference on the possible application of concentrating sweet whey by Reverse Osmosis. Today, it is a standard application in most major and minor cheese plants in the U.S.A. Therefore, I am confident that the manufacturers of P-O and UF equipment will work with the cheese plant owners and operators to solve the problem of dairy waste water.
- References -

1. "Pollution Control in the Dairy Industry" copyright 1974 by Harold R. Jones Noyes Data Corp. Publisher Noyes Building, Park Ridge, NJ 07656

2. Viroqua Whey Products, Inc., Viroqua, WI 54665.

3. Davey Laboratories, LaCrosse, WI 54601.

The following paper was presented by La Verne Ausman, Secretary, Wisconsin Department of Agriculture, Trade and Consumer Protection, P. O. Box 8911, Madison, Wisconsin 53708, especially for the 20th Annual Marschall Invitational Italian Cheese Seminar, held in the Forum of the Dane County Exposition Center, Madison, Wisconsin, on September 14 and 15, 1983.

THE DAIRY INDUSTRY LOOKS AHEAD

By La Verne Ausman

ABSTRACT

Changing consumer attitudes and uncertain signals for Congress have resulted in a dairy industry that is in a holding pattern. While there are many positive signs such as expanded marketing orders and new product research, the lack of action in Washington has frustrated planning and marketing. Looking ahead, we see the industry adjusting to market signals with the traditional dairy states continuing in a leadership role.

It is a great pleasure to be with you today and share some of my thoughts about the dairy industry. First, I want to commend you for the commitment to excellence that this seminar has become known for. Italian cheese production has played a very important role in the expanding per capita use of cheese in the United States. It is a very important segment of Wisconsin's cheese industry, being the second leading variety produced in Wisconsin. Italian cheese production accounts for 21 percent of the state's cheese production, and Wisconsin's production accounts for 32 percent of the nation's Italian cheese production. I do not know if those figures surprise anyone here, but they do surprise a few audiences around Wisconsin.

To address the topic, "The Dairy Industry Looks Ahead," at this particular time could well be regarded as foolhardy. Difficult as it might be, it is a worthy project and I will approach it from the perspective of the dairy farmer, not active but certainly interested with a son and two grandsons back on the farm and as Secretary of Agriculture of America's leading dairy state.

After a number of years of expansion, in response to market signals and government programs, the dairy industry finds itself facing some tough decisions. What happens will have long-lasting effects on the future of the dairy industry. Without being dramatic, I believe you could say that dairying is at a crossroad.

What happens in the future will be strongly influenced by a number of factors -- consumer trends - general opportunities in agriculture - marketing efforts - technological advances - national dairy policy. Each of these areas will have a significant impact on the industry, and by industry I mean dairymen, processors, and distributors.
Let's take a look at consumer attitudes. They are changing, everyone in this room knows that, and you have been a part of that change. Taking a look at dairy products alone in the period from 1950 to 1982:

1. Per capita consumption of butter dropped from 10.7 pounds to 4.5 pounds. This is a decline of 58 percent.

2. Fluid milk and cream consumption stood at 350 pounds per capita in 1950; in 1982, 217 pounds, a drop of 38 percent.

Not true of all dairy products. Cottage cheese consumption is up slightly, ice cream is up slightly, and then there's cheese, the shining star of the milky way. In 1950, per capita cheese consumption stood at 7.7 pounds; in 1982, 19.6 pounds per person, an increase of 250 percent. Some records would indicate that certain areas of the United States are at even higher levels. California boasts of per capita consumption of 29 pounds per person.

A recent nationwide food consumption survey shows that, when measured on the basis of frequency of consumption, 5.5 individuals out of every 10 drank milk each day. That is only surpassed by one other food item, bread. Cheese and ice cream were consumed about half as frequently as milk. Despite changes in quantities of various dairy products consumed, dairy products continue to be a mainstay of America's diet.

There is reason to believe that these consumer attitudes can be affected by promotion programs. We know brand name advertising is effective, and a number of studies would indicate the same is true of generic advertising. Henry Kinnucann and Olan D. Forker, Cornell University, recently analyzed a number of these studies and applied them to our current situation. Their conclusion was that a nationwide promotion program funded at the 15¢ per hundredweight level could result in an increase in sales of 4.3 billion pounds milk equivalent. That is 40 percent of the dairy surplus from 1982. That kind of a dollar commitment is now a reality.

I might report to those of you who are not from Wisconsin that Wisconsin dairy farmers, by referendum, implemented a mandatory 5¢ per hundredweight checkoff beginning July 1, 1983. This indicates a commitment on the part of the industry to build market shares. This commitment has to be an important consideration when you look ahead.

Marketing is a complex activity. The per capita consumption of food has remained almost constant for 25 years. It becomes an effort to maintain market shares, market shares that are influenced by fads, health, and trends such as ethnic cooking.

The impact of cholesterol concerns seems to be waning. This is certainly good for the dairy industry.

The current villains in the food industry are salt, sugar, and caffeine. This has resulted in a marketing effort which emphasizes what something does not have. It is hard to build markets for dairy products based on what they do not have because they are nutritionally superior. Changing that attitude deserves attention.
All of this leads to new products, some of which are not natural but are imitations, substitutes, or artificial. Dairy has not escaped those pressures.

The State of Wisconsin has approached this issue from the perspective that the consumer has the right to know. The information should be visible and in language that is understandable, specifically:

1. The food product must bear a statement on the main display panel of the package or container stating that the product is an artificial product in letters not less than one-half the size of the product name but in no case may the letters be smaller than 18 point type size.

2. The label must clearly state the major difference in ingredients and nutritional value between the artificial product and the dairy product it is made to resemble.

Competition for the consumer's food dollar is great. Just to put the $11 million which we anticipate collecting through the Wisconsin Milk Marketing Order in its proper perspective, the California Avocado Commission is spending $8 million, roughly a penny an avocado, to increase its market share.

Predicting where the dairy production might take place in the United States in the years ahead is even more difficult. Recent trends are not without an explanation, but certainly confusing. The five leading dairy states are Wisconsin, California, New York, Minnesota, and Pennsylvania. Wisconsin and California had an increase in their market share for a number of years while New York, Minnesota, and Pennsylvania were dropping back. In the last three years, Wisconsin has plateaued, for all practical purposes; California has a 2.2 percent increase, while New York is 4.8 percent; Minnesota 4.9 percent, Pennsylvania, 6.5 percent. Forty percent of the increased milk production in the last two years has taken place in New York, Minnesota, Pennsylvania, and California. There have been some rather spectacular increases in some western states on the percentage basis, but they were operating from a very small base to start with. Where dairy production will take place 20 years from now will depend on a number of factors:

1. The cost of production as compared to the national average. There will be a general trend to increase milk production in low cost areas. Recently released data for 1981 indicates that Wisconsin is one of the most efficient milk producing states in the country, really the Upper Midwest region, at ($12.45). Others are the Pacific region ($12.34), the Northeast ($12.97). The U. S. national average was $13.00 per cwt. Dairying was most profitable per cow in the Upper Midwest. The Northeast was next followed by California and Washington.

2. Alternate opportunities in agriculture. Dairying fits very well in Wisconsin, Minnesota, New York, and Pennsylvania. Many farmers in these states do not have another opportunity equal to dairying. This is because of the type of land involved and the physical facilities which are in place. This is the reason that many farmers have to turn back to dairying in areas that have witnessed a major
As the general agricultural economy turns around, I would expect this shift to take place in the other direction and dairying would drop off again in most non-dairy states.

The economic forces that located the dairy industry where it is today are still present and appear strong in the foreseeable future.

Another influence on the future is technology. Who is to say what it will do for us (or should I say to us) in the production and processing areas?

Apparently production per cow has not met its limits. Embryo transplants are now common, hormones are being studied and, if perfected, might increase per cow output by 40 percent.

New enzymes for cheese production are being developed. Such processes as ultra-filtration and reverse osmosis will have a substantive impact on the industry.

I believe it is reasonable to assume that national dairy policy will have a major impact on the dairy industry. National dairy policy was relatively constant from 1949 until 1981. It was a basic support price based on supply and parity. It had to have considerable adjustment from time to time, was widely debated, but basically stayed the same. The past two years have been a period of mixed signals to the industry. Price support has been frozen since October 1, 1980. Considerable discussion has been taking place on new dairy policy ranging from quotas or bases to direct price support cuts. The assessment program implemented by Congress has been on again, off again, and the entire situation has resulted in considerable confusion. This period of uncertainty has adversely affected long-range planning.

The compromise dairy bill certainly cannot be regarded as long-term legislation. What it will accomplish in 15 months is uncertain. I would point out that since 1949, any time the price remained flat or declined for a three-year period, the supply/demand situation would be corrected. October 1, 1983, marks three years since there was any increase in the price of milk and a 50¢ reduction in the last few months. However, it perhaps will buy us time until January 1, 1985, when farm legislation will again be reviewed by Congress. I believe it is reasonable to assume that we will see a movement to programs aimed at balancing supply and demand.

As the dairy industry looks ahead, clearly we will have to pay attention to consumer attitudes, new products that address those changing attitudes, and continuing emphasis on quality and promotion. I believe that attitude is shared today by a greater cross-section of the dairy industry than any time in my memory.

The dairy industry today is characterized by heavy investment in special facilities that are not easily converted to alternate uses. Therefore, we must seek to develop national policy that builds a maximum stability into the dairy industry of equal benefit to processors and producers. Supply management is not a new concept. It has been widely discussed over the last twenty years, but I do not believe it had the support that exists today. There is considerable interest in this state in that approach. There is actually considerable support throughout the nation for this type of approach.
The difficult trends of the last three years have not resulted in the dairy industry abandoning the ship. Actually, it has resulted in a careful evaluation of the dairy industry and considerable in-depth discussion about the direction we should go.

While the dairy industry is frustrated by the action in Washington, or the lack of action, it is moving ahead.

It is more committed to market development than at any time in my memory.

It is characterized by modern facilities on the farm and at the processing points.

I can only conclude that the Dairy Industry is Looking Ahead.
The following paper was presented by Mr. Peter Sandfort, Jr., Marketing Manager, Wiegand Evaporators, Oakland Center, 8940 Route 108, Columbia, MD 21045, especially for the 20th Annual Marschall Invitational Italian Cheese Seminar, held in the Forum of the Dane County Exposition Center, Madison, Wisconsin, on September 14 and 15, 1983.

THE INFLUENCE OF WHEY QUALITY ON EVAPORATOR PERFORMANCE

By Peter Sandfort, Jr.
Wiegand Evaporators, Inc.

ABSTRACT

A general review of the factors which influence whey quality and character. The influence of the evaporator process on whey. Various evaporator functions and objectives. A general review of most commercial quality problems associated with cheese whey. Latest evaporator developments for the smaller dairy.

There is intense pressure on U.S. cheese manufacturers to find profitable whey products to produce, practical and dependable production equipment and to find and keep customers for their whey products. In the long run, product quality will have a strong influence on successful processing, sales and profits.

Cheese whey is an extremely complex chemical compound. Whole, part skim, or skim milk of all possible qualities is subjected to a variety of possible heat treatments on the way to the cheese vat. A wide variety of cheese types are produced ranging from soft to hard cheese. Each plant has its own "secret" make procedure. Continuous, semi-continuous and batch or vat procedures are available for many cheese varieties. A wide range of culture strains, types and combinations are used. Additives are permitted to adjust pH and change mineral balance. Colorants are used in many plants. Some cheese varieties are produced with direct acidification. Coagulants from animal or microbial sources are used. A wide range of cook-out procedures are practiced depending on variety and individual plant preference. Is there any wonder that whey technologists are hard pressed to define cheese whey exactly?

In addition to the hundreds of possible factors which influence the exact nature of cheese whey at the vat, whey handling and processing procedures will strongly influence the nature of the final product. The need to process whey in a manner which limits acid production is not yet universally practiced. All possible combinations of times and temperatures can be observed between the cheese production plant and the whey processing plant. The cheese-maker has refined his art to maintaining specified times to the minute and specified temperatures to the half degree (0.5° F). Why then are some whey plant operators surprised that whey storage time and temperature has a significant effect on the final product? No matter what end product is selected (whole whey, protein, lactose, etc.) and what potential intermediate
steps (R.O., U.F., etc.) may be involved, nearly every drop of marketable whey product must eventually be concentrated in an evaporator. While the purpose of evaporation may be to concentrate the whey product economically, the result can be to cause dramatic whey product quality changes. Evaporation is a thermal process and whey constituents are heat sensitive. The acceptable evaporator heat treatment often is determined by the ultimate use for the finished whey product. For example, whole whey and demineralized whey for use in baby food formulation cannot be subjected to excessive heat treatments or the protein will become insoluble and less digestable. For the most part, falling film evaporators with minimum systemic holding times meet this criteria; whey protein for baby food application requires significantly reduced boiling temperatures during evaporation which cannot be achieved on the older rising film evaporation equipment and must be specifically designed into the newer generation of falling film evaporation equipment.

The old rising film equipment, particularly when "pushed" to maximum capacity with elevated steam heating temperatures, caused substantial protein denaturation. To a large extent, the capacity of a whole whey drier is improved as the evaporator heat treatment increases. The new falling film evaporators are designed for efficiency; their lower energy consumption also reduces heat treatment to the point where a special heat treatment station may be required. The heat treatment station may be located after the whey is concentrated, somewhere within the evaporator design, or before the whey enters the evaporator. There is no one single preferred heat treatment method. The correct heat treatment system location depends upon the (1) type of cheese whey to be concentrated, (2) the individual whey quality when it reaches the evaporator, and (3) the final intended use for the finished whey solids.

The quality of the whey entering the given evaporator will affect evaporator operation and performance in the following ways:

1. **Efficiency** (energy consumption) - See Item 2

2. Fouling or Encrustation: Fouling by protein burn-on or encrustation by mineral deposition is a function of the whey quality. The greater the acid, the lower the quality, the greater the fouling and the lower the efficiency.

3. Cleanability: The ability to rapidly, efficiently, and economically CIP an evaporator after a production run is materially influenced by the extent of fouling and encrustation. The less you soil your equipment, the easier it is to clean.

4. Condensate Quality: While evaporator design is predominantly responsible for the level of suspended solids, the overall quality of whey condensate is strongly influenced by the amount of volatile acids contained in the whey. The type and
volume of volatile acids are functions of the type and quality of the cheese whey entering the evaporator.

5. **Bacteriological Profile:** The type and quantity of bacteria in the feed material can influence final bacteriological counts. Excessive quantities of thermoduric cells and/or spores in the feed stock could cause raised bacteria counts after long runs. Although this is seldom a problem, suffice it to say that good quality control prevents trouble.

6. **Heat Treatment:** Required product heat treatment within the evaporator design is a function of prior whey treatment(s) and intended use. Whey and whey protein that have been exposed to high heat treatment prior to evaporation generally cause increased fouling rates.

7. **Corrosion:** The years of maintenance free service expected from the evaporation plant can be strongly influenced by whey quality. Salt whey and excessive hydrogen peroxide have caused excessive corrosion in some plants. Some of the new whey hydrolysis procedures include the use of highly corrosive additives.

8. **Controlability:** Even the best control systems may not be able to compensate for wide fluctuations in feed flow, temperature, solids and volume. The feed material should be relatively free from dissolved or occluded air.

Evaporators generally need less than 2% fluctuation in product and utility criteria to run smoothly.

The finished whey product will have characteristics that are the result of the original whey quality and the processing steps. This conclusion is not always so obvious. Some specific finished product characteristics that are important to control, but often overlooked, are:

**CRYSTAL SIZE**

Lactose crystal size is influenced by total concentration (T.S.), temperature (especially cooling rate), solution viscosity, agitation, heat treatment and type of whey. The degree or amount of crystallization and the individual crystal size influence the transportability of the product, the ability or capacity to dry the concentrate to powder, or the yield of lactose for example.

**PROTEIN DENATURATION**

The degree of protein denaturation is a direct result of heat treatment. The heat treatment will influence viscosity, solubility, drying ability (drier capacity), flavor, odor, and finished product application.
COLOR

To some degree, heat treatment will influence color mainly due to sugar browning (maillard reaction). Recent data may suggest that Streptococcus thermophilus culture and salt content may also influence browning. Some large lots of dried whey stored for several months in a warm southern warehouse turned absolutely brown; the whey manufacturer had to take back the product and sell it for animal feed. The customer (consuming several million pounds of whey per year) was lost to another supplier.

FLAVOR/ODOR

The flavor and odor of whey and whey products are obviously influenced by the nature of the original whey, the sanitary handling practices, and processing techniques. Excessive heat treatment will result in cooked off flavors. Improper handling procedures can result in the various typical off flavors associated with dairy products such as old cream, rancid, oxidized, whey taint, unclean, etc. Most consumer products that use whey as an ingredient are very delicately flavored. Products such as ice cream, puddings, whipped topping, etc. will readily reflect off flavors carried by the whey ingredient.

SUGAR CONTENT

The specific sugar constituents are significant factors in whey processing and quality problems. As mentioned above, some strains of Streptococcus thermophilus culture result in increased galactose sugar content which can cause browning in cheese, tends to increase the difficulty in drying whey and will reduce lactose recovery.

ENZYME ACTIVITY

It is appropriate to include this aspect of whey quality in light of the program's sponsor. Enzymes come from the original milk from the cow, from psychrotrophs that grow in improperly handled milk, from extraneous bacteria contaminants, from the culture bacteria as well as from the added coagulant. Although the early problems with microbial rennet activity have been technically solved, some precautions are in order. In the last two years, several examples of enzyme problems that had disastrous results on the finished product (processed cheese, ice cream, etc.) were identified as whey/whey product related.

I had disastrous problems with ice cream mix that kept separating (synereisis) a decade ago. I was not able to solve the problem and was forced to alter the HTST process to a modified batch/continuous method to attain product stability. I did not realize that I needed more heat (holding time) to inactivate the enzyme. I tried to eliminate whey as the possible source of the problem by substituting a whey supply from a different Italian cheese plant. Ironically I learned nine years later
that both whey suppliers had switched to microbial rennet. The rennet activity was causing the ice cream mix to break-down, and it took batch pasteurization to inactivate the enzymes.

Even today some coagulant enzyme residues are not completely inactivated at legal pasteurization temperatures. I believe that it is the whey processor's responsibility to insure that his product is free of enzyme activity.

It certainly is in the whey processor's best interest to produce whey products that will perform well for their customers. Most suppliers already have such whey product characteristics as moisture, hygroscopicity, weight (per package), etc. under control. The previously mentioned quality characteristics should also receive proper consideration.

EVAPORATOR EFFICIENCY PROGRESS

Whey quality obviously does have a significant influence on evaporator performance. Evaporator design also significantly influences the process effect during concentration. It is constructive to review briefly evaporation systems design. I shall emphasize the efficiency aspect because of the popularity of that issue.

During the last decade, essentially all dairy evaporator manufacturers have stopped building rising film evaporators. The rising film design is obsolete because of its inherent energy inefficiency, its cleaning problems and its high heat treatment. Falling film design evaporators permit the use of long tubes to incorporate large surface areas into each calendria economically. Up to seven calendria are being serially connected to achieve highly efficient multiple-effect TVR (thermal vapor recompression) steam driven evaporators. Seven-effect Wiegand evaporators in Iowa and California are now removing 11.5 pounds of water per pound of steam supplied in concentrating cheese whey from 6 to 55% TS. Although slightly higher efficiencies could be achieved on TVR evaporators by adding one or more effects, in nearly every case economies will favor the more recent innovation, MVR (mechanical vapor recompression).

MVR technology was invented over a century ago. However, its importance to the dairy industry was not generally recognized until the energy crisis a decade ago. The first dairy evaporators to utilize MVR were in single effect design which permitted an economy of about 65 pounds water removal per compressor consumed horsepower. As the demand for high efficiency increased, the double-effect MVR design was introduced. Wiegand was first to build a triple-effect MVR in 1978. Last year Wiegand extended the technology still further by completing several quadruple-effect MVR evaporators. At about 260 pounds water removal per compressor consumed kW, the quadruple-effect evaporators at Brewster Dairy, Brewster, Ohio; Dairymen's Cooperative Creamery Association, Tulare, California; and Consolidated Dairy Products (“Darigold”),
Lynden, Washington are the most efficient dairy evaporators in the world today.

The charts below show approximate efficiencies associated with the number of effects in the evaporator design:

**TVR EFFICIENCIES**

<table>
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<th>Lbs. of water removed / lb. of steam supplied</th>
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</thead>
<tbody>
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</tr>
<tr>
<td>2-EFFECT</td>
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</tr>
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<td>10.5</td>
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<tr>
<td>7-EFFECT</td>
<td>11.5</td>
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**MVR EFFICIENCIES**

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<th>Effects</th>
<th>Lbs. of water removed / kW consumed by compressor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-EFFECT</td>
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<tr>
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<td>190</td>
</tr>
<tr>
<td>4-EFFECT</td>
<td>260</td>
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</table>

However, the efficiency of a given evaporator design only indicates expected energy consumption during operation. Efficiency does not indicate durability, dependability, heat treatment, CIP features, ease of operation, control system quality, flexibility, and the effect of the concentration step on the whey product.

The best advice to any company considering an evaporator purchase is to take your time, thoroughly investigate all aspects of your project and deal with reputable and experienced suppliers.

**NEW EVAPORATOR DESIGN INNOVATIONS**

As the quest for higher efficiency progressed, the previously mentioned truly remarkable advances in TVR and MVR evaporators developed. However, those impressive efficiencies were and are often only justified by large cheese producers with huge whey volumes.
Fortunately, the new technology has been translated into a practical MVR design for the smaller cheese producers. Wiegand now has several single-effect MVR plants operating which utilize a "ventilator" type fan as the vapor recompressor. The fan is a relatively trouble free, low speed, economical alternative to the extremely expensive turbocompressors which are appropriate for the large MVR evaporation systems. Because of the relative simplicity of a single-effect fan MVR evaporator, the cost for this type system is now within reach of the small cheese producer who formerly could only justify a TVR design in 4 to 5 effects. Furthermore, the system economy at 10-15 kW/metric ton evaporation (220-275 lb. water evaporation per kW) is excellent. Because of the fact that the fan compressors work on a very low compression ratio compared to a turbocompressor, product concentrate final solids will be limited to about 45% TS. Nevertheless, these new fan MVR systems should become very popular in smaller volume dairy plants.

Any plant that requires higher product solids than can be achieved on the fan MVR can always purchase a small TVR finishing effect (or have it built from obsolete equipment at their site) to achieve desired final solids.

SUMMARY

Perhaps the most important factor which influences whey quality is the attitude of the plant management. Technology and equipment is available to produce high quality whey products at relatively low cost. To make a successful and profitable whey market for any of us, all of us must rededicate ourselves towards producing and selling quality products that perform well in our customers' products.
AN INTRODUCTION TO ULTRAFILTRATION AND VACUUM EVAPORATION PROCESSES IN ITALIAN CHEESEMAKING

By Frank V. Kosikowski

ABSTRACT

Low temperature milk concentrates for producing Italian type cheeses are MMV precheese whole milk retentates at 5:1 total protein or higher, retentate supplemented or ultrafiltered cheese milks up to 2:1 protein concentration, and vacuum evaporated milks with all milk components concentrated up to 1.5:1.

MMV processes show marked advantages where applicable to cheesemaking, because of significant yield increases, potential continuous operation and little or no whey. Where MMV cannot be applied for technical or legal reasons, concentrating skim or whole milk by ultrafiltering at 52°C to an optimum level between 1:1 to 2:1 total protein increases cheesemaking efficiency, reduces energy requirements, improves quality of marginal cheeses and leads to whey of increased nutritional value. Condensed whole milk has value in cheesemaking but limiting factors may be excess lactose and salts.

Competitive forces are striving toward more efficiency in cheesemaking and conservation of energy through the application of milk concentrates from membrane separation technology and vacuum evaporation. This technology essentially is in place, but more information is required regarding quality of resulting cheeses, cheese yield, economics and the concentration limitations. Research on Italian cheese such as Mozzarella, using ultrafiltration, an important membrane separation technique, is not new. In 1975, Covacevich and Kosikowski (1,2) reported in an optimistic vein, their efforts to make this cheese by the MMV ultrafiltration precheese principle. The report was presented at the 12th Annual Marschall Invitational Italian Cheese Seminar. These early efforts are bearing fruit for in Denmark acceptable Mozzarella cheese is now being manufactured by the MMV process.

Many advances have been made since on a broad front and it is my intention to bring them to your attention in another paper after first introducing you to cheesemaking processes utilizing ultrafiltration (UF) or vacuum evaporation.
The MMV Ultrafiltration Cheesemaking Process

In 1969, three highly respected French scientists, J.L. Maubois, G. Mocquot and L. Vassal (9), patented in France, a novel concept for making many cheeses based on the direct use of highly concentrated (7:1) skim milk retentates of ultrafiltration. This concentrate was called precheese and the name MMV stemmed from the first letter of the authors' last names. A United States patent also has been issued (10).

Ultrafiltration is a traditional method for selectively separating biological components in mixtures. Applied to milk and whey the same objective can be achieved but a scale-up of membrane and support equipment accompanies the process. Essentially, the key element in ultrafiltration is the membranes across which feed stock moves. Originally made up of cellulose acetate, most membranes for ultrafiltration now are composed of polysulfones. Eventually zirconium oxide, a metallic substance may be the dominating material.

Set on stainless steel standards, these membranes in tubular, plate, spiral, or hollow fiber forms operate in a batch or continuous mode at low pressures, 25 to 45 psi, and temperatures, 52-54°C. In moving across the membrane the milk undergoes a transfer phenomenon at a molecular level. Water, lactose, soluble salts and non-protein nitrogen as free amino acids and small peptides pass through, or permeate, the pores of the membranes usually of molecular weight cut-off approximating 20,000 daltons. This clear yellow liquid exiting is called permeate. Retained in the recycling tank are fat, protein and insoluble salts in a decreasing pool of milk serum containing lactose, soluble salts and non-protein nitrogen. During ultrafiltration then, the total solids, fats, proteins and considerable calcium and phosphorous concentrate. For example a 3.2% protein concentration in skim milk may rise to 22% consisting of casein, albumin and globulin. The last two proteins, nominally, are lost to the whey in standard cheesemaking. Conversely, lactose decreases.

In the MMV process, the plastic-like retentate, or precheese, has metered into it starter, rennet, salt, color and mold spores, if the latter are essential as for Camembert cheese. This inoculated liquid precheese is pumped into the suitable forms and coagulation occurs in a few minutes. Thereafter, the wheels of curd are removed and placed in ripening rooms. Fresh, soft, acid cheeses made by MMV process are embellished by condiments and the cheeses then are chilled and packaged.

Advantages of the MMV process for cheesemaking include obtaining a much higher yield, 12-15%, due to albumin and globulin protein retention, an 80% reduction in rennet, a potential for continuous cheesemaking requiring no vats and a neutral pH permeate liquid free of proteins.

For many cheeses, including Camembert, St. Paulin and Feta, the MMV concept apparently works well and for this reason a number of European cheese manufacturers have adopted the process.

Reasons for the slower acceptance of the MMV process in other world regions include consideration of capital costs, attitudes of food and drug officials regarding standards of identity and limitations of the method for making traditional hard cheeses such as Cheddar or Swiss or soft, cooked cheeses like Cottage cheese. Eventually these barriers will be removed, but for the present one must deal with reality.

Use of Lower Concentrated Retentate Supplemented Cheese Milks

Mozzarella cheese can be made by the MMV concept through application of sodium to replace some of the calcium and through a pre-fermentation of the retentate. Alternatively,
retentate supplementation of cheese milk, or its direct ultrafiltration, at lower levels of fat and protein concentration than precheese, leads to excellent Mozzarella cheese. This alternative process increases cheesemaking efficiency and reduces rennet requirements. But other major benefits associated with MMV such as highly increased cheese yields, do not materialize because excess whey proteins are not incorporated.

In 1973, Chapman et al. (3) ultrafiltered whole milk to a 2:1 protein concentration level and made Cheddar and a soft ripened cheese, a principle adopted by elements of the English cheesemaking industry.

Kosikowski (7) and Fernandez and Kosikowski (5) in the U.S.A. sought, through retentate supplementation, or direct ultrafiltration, of skim and whole milks, to explore optimum cheesemaking performance for Mozzarella, Cheddar and Cottage cheeses, made from milk mixtures over a range up to 2:1 protein concentration. Observations on many experimental cheeses led to the conclusion that a milk selectively concentrated by ultrafiltration at 2:1 did not give the best quality cheese. Optimum quality was attained at protein concentrations of between 1.4:1 and 1.8:1.

Retentate supplementation, or direct ultrafiltration, of cheese milks to such optimum protein concentration improves cheesemaking efficiencies, lowers energy requirements and demands for rennet and improves product quality when it is low.

In making retentate supplemented cheeses one can concentrate whole milk 3:1 at the farm or collecting station and transport the UF concentrate to an Italian cheese factory miles away where it could be added to cheesemilk to the optimum concentration observed in our pilot-plant studies. Savings in transportation costs and in producing more cheese per cheesemaking unit could be significant as shown by Maubois (8) for French cheese.

Vacuum Evaporation Process

In the search for more efficient methods of making Italian cheeses, another more traditional form of milk concentrates was prepared and studied. This was low temperature condensed whole milk produced by vacuum evaporation. Cheese milk was supplemented with this concentrate and made into Mozzarella and Cheddar cheese.

Wider use of vacuum condensed milk for cheesemaking has been hampered by the traditional high heat treatment to which these milks have been exposed. Quality of the cheese, particularly body and texture, is usually adversely affected at low concentration levels of supplementation due to excess heat denaturation of protein. Even our condensed whole milks initially prepared for low temperature whole milk powder at large industrial installations is initially heated to 78°C before going through the evaporation cycle. Despite this we produced good quality Mozzarella cheese at 1.4:1 protein concentration. However, to attain the full potential of whole milk concentrates from vacuum evaporation for cheesemaking by supplementation, the heat tailoring of the concentrate for a specific cheese is desirable.

Unlike ultrafiltration where selective concentration of milk components essential to cheese occurs, vacuum evaporation of milk entails only the removal of water. All components in the retained mixture are concentrated equally, including lactose and soluble and insoluble salts. In a milk condensed 2:1, approximately 10% lactose will exist in the cheesemilk mixture which could have a derogatory effect on cheese quality.

Although excess lactose may adversely affect cheese quality, the critical level at which this happens has not been adequately determined for Mozzarella cheese. It remains an objective for our future research as excess lactose in Mozzarella cheese may intensify browning during oven baking of the Pizza pie.
Although the key to successful ripened cheesemaking depends on a minimum heat treatment of the evaporated milk, rancidity can result in raw or heat treated milks if turbulence in a standard evaporator is excessive. Rancidity developed so strongly in one raw evaporated milk through fat hydrolysis by activated milk lipase that the finished cheese was unacceptable. Studies are to be conducted with an APV falling film plate evaporator designed to create minimum turbulence. The free fat acidity of the milk fat then should not rise appreciatively permitting the making of high flavored hard Italian and Cheddar cheese types from heat-treated condensed whole milk. Although Mozzarella is considered a fresh cheese and legally must display almost zero phosphatase levels, cheese melting and stretching qualities might be improved if UF or evaporated milk concentrates were pasteurized at minimum heat treatment.

Reverse osmosis whole milk concentrates are similar in composition and properties to low temperature condensed milk obtained by vacuum evaporation at the same concentration. Both differ from milk concentrates made by ultrafiltration. During reverse osmosis water is removed through the more dense RO membrane and the components of milk concentrate equally. Thus a 2:1 reverse osmosis whole milk retentate should show approximately 10% lactose, whereas the same milk ultrafiltered to 2:1 protein concentration might show only a 4.5% lactose.

In 1980, DeBoer & Nooy, (4) reported that the movement of raw whole milk under high pressure across the membrane of their reverse osmosis unit caused excessive rancidity. They corrected this problem satisfactorily with the complete disappearance of rancidity by connecting 2m x 16m capillary tubes to the outlet of the reverse osmosis unit.

This brief introduction summarizes several primary methods that produce low temperature milk concentrates for cheesemaking. Vacuum evaporation provides milk concentrates that are essentially the same in composition as those obtained by reverse osmosis inasmuch as water is the main component removed. Such concentrates used for cheesemaking theoretically will produce similar cheese and cheese yields. Their acceptability therefore would be based on relative capital and operating costs, sanitation problems posed, space requirements and government regulatory acceptance.

Milk retentates from ultrafiltration because of their selective concentration differ significantly from the other two concentrates. In a 2:1 concentrated UF retentate the lactose and sodium levels are lower than normal while protein and fat are approximately doubled over that in the original milk. Also, rancidity does not develop in UF retentates from unpasteurized whole milk processed at 52-54°C.

In cheese technology, applications of the various processes for producing concentrates to be made into cheese can fill a need depending upon individual circumstances, but continuing research is required to establish such needs and circumstances. Thus, in our laboratory we are now making stirred curd Cheddar cheese from ultrafiltered whole milks and also we will be determining the role of calcium and phosphorous in the quality of Mozzarella cheese made with milk retentates. The results of these experiments should prove interesting.
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MOZZARELLA AND RICOTTA CHEESE FROM ULTRAFILTRATION RETENTATES

By Frank V. Kosikowski

ABSTRACT

Mozzarella and Ricotta cheese can be made from cheese milks directly concentrated by ultrafiltration, or supplemented with milk retentates. Starting materials are highly concentrated MMV precheeses, or retentate milks concentrated between 1:1 and 2:1 total protein. Whole milk Ricotta produced by MMV in a potentially continuous cycle gives excellent cheese with long keeping qualities. Also, optimum quality Ricotta cheese is obtainable from cheese milk directly ultrafiltered or supplemented to between 1.5:1 and 2:1 total protein concentration. Greater cheesemaking efficiency, less energy utilization, improved Italian cheese quality and development of new forms of whey powders with increased protein and reduced lactose are possible with ultrafiltration.

The state of the art for making cheeses by ultrafiltering milk has advanced to such a point elsewhere that it is essential to examine its potential for Mozzarella and Ricotta cheeses. Questions that require serious consideration revolve about the quality of the resulting product, the various means to apply ultrafiltration, how cheesemaking efficiency and energy savings are attained and other basic advantages or disadvantages.

In 1969, Maubois, Mocquot and Vassal (9) presented their unique concept for utilizing highly concentrated ultrafiltered milk retentates, or precheese, for cheesemaking. The idea was applied successfully in Europe very soon thereafter to a number of cheeses, but not to Mozzarella. Basic studies on this cheese, using the MMV concept were reported in 1975 by Covacevich and Kosikowski (1). Their assessment then was that Mozzarella cheese could be made by MMV principles, but more satisfactory melt-down was attained by holding the cheese for about four weeks.

Ricotta cheese was not considered previously for MMV processing until 1978 when Maubois and Kosikowski (10) reported on their precheese continuous method. Up to then it was difficult to comprehend how a high moisture, non-renneted whole milk Ricotta pre-cheese could be concentrated and retain its water binding stability, and produce the smoothness and flavor required of a good quality Ricotta cheese. It is well known that this cheese possesses great fragility.

In more recent studies with Cheddar, Cottage, Mozzarella and Ricotta cheese, milks were directly ultrafiltered or retentate supplemented to give highly acceptable quality...
cheese (4,5). As a result, the major avenues now available for making Italian cheese from milk retentates were expanded to include not only MMV precheese processes at 5:1 to 7:1 protein concentration but retentate supplementation and direct ultrafiltration of the latter between 1:1 to 2:1 protein concentration. These methods are outlined with performance information and some relevant comments.

**MMV Process for Mozzarella Cheese**

The MMV method has the following advantages in cheesemaking: significantly higher yields are realized, less rennet is required, continuous processing is possible, the liquid permeate has a neutral pH and contains less BOD than whey. Its disadvantages are limited application to some cheese, high capital investment and utilization of a lactose dominant permeate.

Mozzarella cheeses made in our early experiments at Cornell by the MMV concept were from direct ultrafiltered skim milk retentates of approximately 7:1 concentration. These liquid retentates were adjusted to about 34% total solids with freeze-dried retentates and blended at 32°C. Then plastic cream was added to increase the total solids about 50%. The mixture was warmed to 60°C and low pressure homogenized. However, now standardized whole milk instead of skim milk can be used for retentate production.

To the homogenized precheese, were added 5% of an active lactic acid culture (*Streptococcus cremoris*), rennet (about 4 times less than normal) and salt and the whole mass blended for 3 minutes. The above precheese mixes were sealed in Cryovac bags and acid fermented at 32°C to a pH of 5.1 to 5.2. Mozzarella cheese was produced by stretching and molding the curd in hot water followed by cooling and salting in brine.

The differences than between traditional and MMV Mozzarella cheesemaking revolve about the precheese. With MMV processes, about 80% less rennet than normal was used. No vats were required and there was little or no free whey. However, a new type of protein-free, clear yellow liquid called permeate results from the ultrafiltration of milk. Cheese yield from full fat milk increases to 8% or more, because whey proteins ordinarily lost are retained with the curd.

These early direct ultrafiltration MMV experiments on Mozzarella cheese showed a slower than normal attainment of optimum pH due to a strongly buffered system. This condition along with the prior homogenization of the precheeses may adversely affect stretching qualities in the young cheeses.

A modification of direct ultrafiltration is diafiltration in which water is added to the concentrated retentates during ultrafiltration to remove more lactose and calcium. When diafiltration was introduced in the Cornell experiments, satisfactory stretching of cheese was attained in about 24 hours at 5°C, along with excellent flavor and body. Melting properties developed satisfactorily when MMV cheese of pH 5.1 was held for 4 weeks at 50°C.

Much progress now is being made in applying MMV principles to Mozzarella cheese, particularly in Denmark where several industrial firms are conducting intensive research. Using MMV principles it is expected that excellent quality Mozzarella cheese of good stretchability and meltdown soon will be commercially available and will be produced in the United States.

**Supplementation and Direct Ultrafiltration at Lower Protein Concentrates**

Studies during the past three years on Mozzarella cheese by Fernandez and Kosikowski (2, 3, 4) have led to the making of this cheese from low concentrated retentate supplemented
milks and by direct ultrafiltration.

In one supplementation series excellent Mozzarella cheese of pH 5.2 was made from retentate supplemented whole milk of 1.4:1 protein concentration. Moisture in the resulting Mozzarella cheeses were about 2 percentage points higher than in final control cheeses while fat and protein were about 1.5 percentage points lower.

Cheese weight per 100 pounds of milk increased with retentate supplementation. In one experimental cheese series, the average weight from 4 control, unsupplemented milks was 11.8 lbs. per 100 lbs. milk, and from 4 milks supplemented to 1.4:1 protein level it was 16 lbs. Yield efficiency defined as weight of cheese per pound of total solids was increased using retentate supplemented milks. Mozzarella cheese from such milk mixtures was slightly harder, but stretching qualities, meltdown and appearance were excellent.

Similar results were obtained when cheese milks were directly ultrafiltered to 1.4:1 protein concentrations rather than being supplemented with retentates.

Major apparent advantages for using retentate supplementation, or direct ultrafiltration of milk, concentrated to total protein less than 2:1 for Mozzarella cheese includes improved cheesemaking efficiency and energy savings and reduced rennet. Much still has to be learned of the effect of higher milk protein levels on cheese texture so retentate increases for industrial usage should be done gradually.

Making Processed Retentate Cheeses with Retentates

Very early, Kosikowski and Silverman (6,7) applied their efforts to making a processed Mozzarella cheese from raw curd using processing cheese salts at 72-80°C. The processed Mozzarella cheese after cooling, was smooth and resembled natural traditional cheese, but a lack of stringiness was evident. Later, Sood and Kosikowski (12) reported on the use of highly concentrated retentates to supplant up to 50% ripened Cheddar cheese in processed cheesemaking.

Our recent activities in making natural Mozzarella cheese using retentate supplementation and direct ultrafiltration of milk prompted a reexamination of the virtues of processed Mozzarella cheeses. The presence of whole milk retentates either in the cheese or the processing cooker may play an important role in making good quality processed cheese. Processed Mozzarella cheese of long keeping quality can provide competition to imitation Mozzarella cheese which essentially is a heat processed product.

Continuous Ricotta Cheesemaking by MMV

Whole milk Ricotta cheese differs greatly from Mozzarella. Its curd is not coagulated by rennet, but by high temperature at pH 6.0. It is a very moist, fragile product resembling soft creamed Cottage cheese. Although much of its whey proteins, albumin and globulin, are precipitated in the process, considerable amounts remain in the heated whey.

Traditional Ricotta cheesemaking is a time consuming, relatively inefficient process and could be improved. This was the major objective of Maubois and Kosikowski (10), in making whole milk Ricotta with a new, continuous process using MMV principles.

The availability of suitable equipment has held back the continuous method, but the necessary heating chambers should be available soon. A stepwise batch procedure illustrates the ultimate continuous flow pattern.
Chilled, pasteurized skim milk is heated to 28°C and 1% commercial lactic acid culture is introduced. Ultrafiltration of this inoculated skim milk is conducted at 28°C to a total protein concentration of about 11.5 - 12.5% and a pH of 5.9. Thirty minutes before the end of ultrafiltration heavy cream is added. The temperature is then raised to 54°C and ultrafiltration continued until a 4:1 concentration and pH 5.9 is attained at about the same time. Ultrafiltration time at the higher temperature is short. Also enough heavy cream is added at this point to give 11.5% fat. However, it is now possible to use standardized whole milk rather than a combination of skim milk and cream.

The plastic liquid precheese possessing the composition of whole milk Ricotta is directed into a heating chamber with agitator, slightly salted and heated to 80°C. Coagulation occurs immediately, but to obtain proper texture the hot curd is agitated gently, a principle directly opposite to that for standard Ricotta cheesemaking. Curd from the chamber is propelled into a hopper and the agitated, smooth product is packaged hot directly into consumer cartons.

Ricotta cheese resulting possessed a normal composition, and its flavor and texture was preferred over that of standard fresh commercial Ricotta cheese by 70% of a sensory panel. The product displayed a shelf life of about 9 weeks at 4°C and in the closed controlled process no physical loss of curd or whey was experienced, leading to improved yields.

This continuous process permits the use of direct acidification of whole milk using lactic starter, acid whey powder, or food grade acids.

Making Ricotta Cheese from Retentate Supplemented Milks

In the absence of a continuous Ricotta cheesemaking unit, consideration was given to increasing cheesemaking efficiency of Ricotta by introducing whole milk retentates to milk in the kettle, or by direct UF. Mini-scale studies indicate that at total protein levels between 1.5:1 and 2:1, the resulting cheese quality equals that of standard Ricotta and the amount of cheese produced is larger (3). Also, proportionately less amounts of acid whey powder are required. For example only 50% of the normal amount of acid whey powder gave a pH 5.9 leading to satisfactory heat coagulation and good quality cheese.

New Forms of Whey Powders

Wheys resulting from Mozzarella, Cottage, and Cheddar cheeses of direct ultrafiltration or retentate supplementation between 1:1 and 2:1 concentration differ significantly in composition from standard cheese wheys (2,4). Produced in powder form, these retentate wheys would show significantly more protein and less lactose with about the same ash. Such new types of whey powder will have increased nutritive value but not at the expense of yield efficiency because the amount of whey components per unit weight of cheese obtained is generally lower in retentate wheys. It has also been possible to demonstrate that new forms of more nutritious retentate skim milk and cream powders are possible when produced from fresh products of the mechanical separation of whole milk retentates (4,5).

The Future

At Cornell my research group has been studying the potential and application of retentates from ultrafiltration for the past 10 years and more recently milk concentrates from vacuum evaporation. Also, a major effort has gone into the basic chemistry and physical properties of retentates. This has led to a reduced sodium Cheddar cheese
and a natural low lactose ice cream. Also, skim milks of 7% protein and .05% fat and excellent quality cream have been produced by mechanically separating 2:1 and 3:1 concentrated whole milk retentates. Butter and buttermilk were obtained from the cream.

In the past year, our experiments were conducted with fresh, farm milk of body heat received directly after milking at a Holstein cow farm situated within a few hundred yards of the pilot plant. Ultrafiltering milk on the farm, particularly for cheese-making, is a reality as a result of the pioneering work of Maubois (8). In France since 1979 it has been standard practice to ultrafiltrate the milk on selected farms and ship the retentate to cheese factories while retaining the permeate for feeding cattle, thus reducing significantly transportation costs. Slack et al. (11) found that under U.S.A. conditions, the optimum economic benefits of ultrafiltering milk on the farms in this manner would occur with dairy herds of 100 or more cows.

With large cow numbers, it might be more beneficial from a total economic view to move cheese factories adjacent to milking centers, thus utilizing ultrafiltration or other forms of milk concentration. The retentate simply could be pumped directly into the adjoining cheese plant.

A high potential for ultrafiltration retentates exists in the Italian cheese industry, although first there must be retentates to test this hypothesis and so some economic risk taking is involved. But once proved on an industrial scale, the benefits may be important leading to more efficient cheesemaking, greater savings of energy, quality improvement of marginal products and production of new forms of whey and milk concentrates with enhanced nutritional qualities.
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EVPOLUTION OF RENNEN IN CHEESEMAKING

By Ronald Weiss, Ph.D.

ABSTRACT

Driving forces leading to the development and acceptance of microbial rennets were commercial, that is, shortage of calf stomachs, growth in cheese consumption and the resultant price increase of calf rennet. Recent developments in recombinant DNA technology are being directed to products where this technique could be demonstrated as having commercial significance. This new technical driving force led to the identification of calf rennin as an attractive model because of its apparent characteristics. The ultimate commercial success of an FDA approved microbial calf rennet will be the assessment by cheesemakers of its performance in making cheese, the quality of the cheese and overall economics.

Coagulation of milk is the basic step in the manufacture of all cheeses. While coagulation may be induced in many ways, none compares to the specific action of rennin, the active component of rennet, a protease enzyme isolated from the fourth stomach of a calf. Rennin occurs in the mucosa as prorennin (inactive form) and in the presence of acid is converted to the active form. One specific peptide bond in kappa-casein of milk is cleaved by rennin forming the calcium paracaseinate precipitate and the resulting curd. The curd obtained with calf rennet is elastic, retains a portion of the salts, most of the fat and ultimately yields a good cheese. Moreover, the enzyme is retained in the fresh cheese contributing through proteolysis to the ripening process which generates the flavor and texture of aged cheese. Calf rennet extract is on Food and Drug Administration's Generally Recognized As Safe (GRAS) list.

Conversion of milk, a nutritious and perishable liquid, into a food which is nutritious, stable and valuable makes calf rennet commercially and economically important to cheesemakers and the consuming public. The history of milk coagulants includes the use of calf and other animal sources, plants and microorganisms, depending on technology, raw materials and cultural norms. Today we hear of a new technique, recombinant DNA, which will give us the ability to produce calf rennin from a microorganism. Tomorrow we may be speaking of commercially producing calf rennin from culturing calf stomach tissue or from technology we are not aware of today.

It has been noted that one part of calf rennet to 5000 parts of milk, or one part of pure calf rennin to five million parts of milk brings about the required coagulation. Based on a use rate of three ounces of standardized single-strength calf rennet extract per thousand pounds of milk, a gallon
of calf rennet extract would contain approximately 4 grams of rennin. However, the ultimate measure is coagulation activity.

Calf slaughtering, as reported by the USDA, declined in the United States from 7.8 million calves in 1965 to 2.9 million in 1981. During this same period, U.S. cheese production (not including cottage cheese) increased from 1.75 billion pounds in 1965 to 4.2 billion pounds in 1981. The world cheese production (with the exception of Eastern Europe and the Soviet Union) has been estimated by the Foreign Agricultural Service at 15.7 billion pounds in 1981. As would be expected from these statistics, changes in calf stomach prices were reflected in the price of calf rennet extract. The anticipated shortages of calf stomachs and higher calf rennet extract prices were among the commercial driving forces to develop a substitute for calf rennet extract.

Calf rennet had been used for so many years throughout the world that cheese made from rennet set the standards of taste, flavor consistency and texture to which a substitute must measure. Additionally, a substitute must be considered in overall cheesemaking performance, utility of the resultant whey and economics to the cheesemaker. The development of microbial rennet started with the screening of microorganisms for protease activity. The microorganisms were then mutated (conventional genetic modification) for selecting specific protease activity on milk protein as a calf rennet substitute. The Code of Federal Regulations (CFR) 21, under section 173.150, lists approved milk-clotting enzymes produced by pure culture fermentation for use in cheese production as: (1) Endothia parasitica, (2) Bacillus cereus, (3) Mucor pusillus and (4) Mucor miehei. The section further states: the strains of these organisms are nonpathogenic and nontoxic in man or other animals. The additive is produced by a process that completely removes the generating organism from the milk clotting enzyme product. The additive is used in an amount not in excess of the minimum required to produce its intended effect in the production of those cheeses for which it is permitted by standards established pursuant to section 401 of the act.

The microbial rennets are classified by the FDA as food additives and regulated as to how they are manufactured, how much is used in what food products and for what intended technical effects. Safety data is an integral part of the food additive procedure and must be supplied to the FDA by the petitioner. A food additive must be approved by the FDA before it can be marketed, thus the term premarket clearance.

Mucor miehei was commercially introduced in 1969, and currently has the largest share of the U.S. microbial rennet market. Initially Mucor miehei was found to have a higher heat stability than calf rennet. While residual calf rennet in cheese whey is inactivated during pasteurization, the microbial rennet displayed proteolytic action which could damage food applications using the whey. A chemical modification of the enzyme was developed by Miles decreasing the heat stability of Mucor miehei microbial rennet to a level where the whey is useful for commercial application.

It is estimated that the 1981 coagulant market for the U.S. and Canada approximated one million gallons of single-strength calf rennet equivalent. Of this amount, it is estimated that microbial coagulants have a 60-70% market share,
calf rennet 10-15%, and blends 20-25%. Prices of microbial coagulant were approximately one-fourth of the price of calf rennet extract in 1981. Depending on the cost of calf stomachs, the price and market share of calf rennet varies. Currently, microbial rennet (Marzyme II) is 45% of the calf rennet price.

Biotechnology can be defined as the use of biological systems for conducting chemical transformations. Biotechnology is not new. Production of cheese, spirits and bread by fermentation was practiced before recorded history. During the twentieth century, development of the biosciences has allowed specific products to be made on a commercial basis, e.g., ethanol, citric acid, vitamins, amino acids, steroids and antibiotics. Today we have additional knowledge in designing and manufacturing microorganisms to carry out specific and novel processes, that is, genetic engineering. What is new about genetic engineering is that no longer do we have to search for an organism to produce a particular product and then manipulate until the total process is commercially feasible. Today the gene that will produce a desired product in animal, plant or microorganism, can be moved into a new host which is more commercially attractive. The opportunities inherent in biotechnology offer an alternate for the manufacture of current products, otherwise uneconomical products, or otherwise unavailable products.

Genetic Engineering has the characteristics of a high growth technology, that is, it is derived from fundamental advances in knowledge. This is in contrast to a mature technology which is characterized by evolutionary rather than revolutionary improvements. Recombinant DNA is one technique of genetic engineering and its potential is defined by the compatibility of a transferred gene within the new host microorganism, plant or animal and its required condition for functioning. One of the first major products to come out of recombinant DNA technology is the bacterial production of human insulin. The organism used was E. coli.

Recent developments in genetic engineering led to a search for products where this technique could be demonstrated as having commercial significance. This new technical driving force led to the identification of calf rennin or chymosin as an attractive model because of its apparent characteristics: (1) high price ($78 per gallon in 1981), (2) large potential market (1981 world coagulant market $85MM), (3) only available from nature (microbial rennet is accepted and has a share of the market because of price, but is considered less desirable for several reasons), (4) a protein which recombinant DNA technology is capable of expressing, and (5) considered easier to obtain approval from the FDA than for a pharmaceutical.

A number of companies, including Marschall, have announced programs to develop a microbial calf rennin. The basic concept is to take the gene responsible for rennin production from the calf cell and transfer it into a host microorganism which can be utilized in producing the rennin. Selected strains of E. coli are commonly used as the host organism for recombinant DNA because its genetics are well understood and it has been found not to colonize in the intestinal tract of man. The apparent position of the FDA on recombinant DNA products for the food industry is that a food additive petition with the appropriate safety data will be required. The suitability of the gene source, the host organism and the expressed product will be based on scientific evidence provided by the petitioner. The successful commercial development of a microbial
calf rennet will require, as did a microbial rennet, FDA approval, manufacturing capabilities, acceptable performance in cheesemaking, acceptable cheese quality and economic competitiveness.

A microbial calf rennet will not expand the coagulant market and its acceptability will be relative to other coagulants and its use in various cheeses. There is no public evidence that a microbial calf rennet has the necessary attributes to produce the flavor and texture of long hold cheese or can be used in all of the various varieties of cheese. Furthermore, it is unknown at this time if the various groups developing microbial calf rennets will ultimately have the same manufacturing procedure (significantly different procedures will require separate food additive petitions) or in fact the same product, that is, all microbial calf rennets may not be the same.

Marschall will participate in the development of a microbial calf rennet and will offer an FDA approved product only when its safety, functionality, product quality and economics are acceptable to the cheesemaker and the consuming public.
The following paper was presented by Dr. Truman F. Graf, Professor, Department of Agricultural Economics, University of Wisconsin, Madison, Wisconsin, 53706, especially for the 20th Annual Marschall Invitational Italian Cheese Seminar, held in the Forum of the Dane County Exposition Center, Madison, Wisconsin, on September 14 and 15, 1983.

**ECONOMIC OUTLOOK FOR ITALIAN CHEESE**

By Truman F. Graf, Ph.D.

**ABSTRACT**

Positive factors for the U.S. Italian cheese industry, far outweigh the one major negative factor—imitation cheese. Wholesale prices for natural Italian cheese average $.78 per pound (118%) more than for imitation Italian cheese, and natural retail prices average $.95 per pound (48%) more than imitation prices. Positive factors include:

(a) A seven fold increase in production nationwide, per plant, and in milk utilization since 1960.

(b) A 5.1 cent and 6.9 cent per pound respective increase in unsupported mozzarella and provolone wholesale prices compared to supported 40 pound block cheddar prices since 1980, indicating strong market strength for Italian cheese in a surplus market condition.

(c) A decline of Italian cheese imports from 11% of total cheese imports in 1960, to 5% in 1982, and from 4% of U.S. Italian cheese production in 1960 to 1% in 1982.

(d) An almost four fold increase in per capita consumption of Italian cheese since 1960, as contrasted with a decrease of 1/6th in per capita consumption of all dairy products combined. Major consumers of Italian cheese offer further potential for increased consumption.

Italian cheese has experienced dramatic production, consumption, pricing and other marketing changes for over a decade. These trends are analyzed in this paper. Results are used in projecting the economic outlook for the product, and pinpointing marketing adjustments and factors it will be important to take into consideration in developing future marketing programs.

**Production**

Italian cheese production nationwide and per plant, have both increased approximately seven fold since 1960. This rapid increase in production has occurred with relatively constant plant numbers (Table 1).

Milk used in Italian cheese has also increased almost seven fold since 1960, reaching 9.5 billion pounds in 1982. This was 7% of 1982 milk production, 12% of milk used in manufactured dairy products, 24% of milk used for all cheese, and 34% of milk used for American cheese, -- double to quintuple increases since 1960 (Table 2). Thus the Italian cheese industry has made a major contribution to reducing milk surpluses, currently confronting, and threatening the dairy industry.

1/ Unless otherwise specified, data on which this analysis is based was obtained from USDA publications.
Table 1
U.S. Italian Cheese Production 1960-82

<table>
<thead>
<tr>
<th>Year</th>
<th>Production Million Pounds % of 1960</th>
<th>Production Per Plant Million Pounds % of 1960</th>
<th>Number of Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>157.5</td>
<td>.8</td>
<td>193</td>
</tr>
<tr>
<td>1965</td>
<td>244.5</td>
<td>1.3</td>
<td>182</td>
</tr>
<tr>
<td>1970</td>
<td>393.7</td>
<td>2.0</td>
<td>197</td>
</tr>
<tr>
<td>1975</td>
<td>671.9</td>
<td>3.6</td>
<td>185</td>
</tr>
<tr>
<td>1980</td>
<td>982.7</td>
<td>5.3</td>
<td>187</td>
</tr>
<tr>
<td>1981</td>
<td>994.4</td>
<td>5.6</td>
<td>179</td>
</tr>
<tr>
<td>1982</td>
<td>1087.8</td>
<td>6.1</td>
<td>179</td>
</tr>
</tbody>
</table>

Table 2
U.S. Milk Utilized in Italian Cheese 1960-82

| Year | Milk Used in Italian Cheese (Mil. PDS.) | Total Milk Production Milk Used For Manufactured Dairy Products Milk Used For All Dairy Products Milk Used for American Cheese |
|------|----------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| 1960 | 1.4                                    | 1.1%                                            | 2.1%                                            | 10.2%                                           | 13.7%                                           |
| 1965 | 2.1                                    | 1.7                                            | 3.3                                            | 13.5                                           | 17.4                                           |
| 1970 | 3.4                                    | 2.9                                            | 5.5                                            | 17.5                                           | 24.0                                           |
| 1975 | 5.8                                    | 5.1                                            | 9.4                                            | 24.4                                           | 36.3                                           |
| 1980 | 8.5                                    | 6.6                                            | 11.4                                           | 25.2                                           | 36.0                                           |
| 1981 | 8.6                                    | 6.5                                            | 10.9                                           | 23.7                                           | 32.7                                           |
| 1982 | 9.5                                    | 7.0                                            | 11.5                                           | 24.4                                           | 34.4                                           |

The increasing geographic diversification of the U.S. Italian cheese industry is demonstrated in Table 3. Data in this table indicates that although Wisconsin continues to rank first in the production of Italian cheese, currently less than one-third of U.S. Italian cheese is manufactured in the state, as contrasted with over 60% in 1960. The Italian cheese industry is important nationwide, and the product has a nationwide impact.
Table 3
Percent of U.S. Italian Cheese Manufactured in Wisconsin, 1960-82

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>60.3</td>
</tr>
<tr>
<td>1965</td>
<td>48.5</td>
</tr>
<tr>
<td>1970</td>
<td>39.2</td>
</tr>
<tr>
<td>1975</td>
<td>34.4</td>
</tr>
<tr>
<td>1980</td>
<td>31.8</td>
</tr>
<tr>
<td>1981</td>
<td>30.9</td>
</tr>
<tr>
<td>1982</td>
<td>31.6</td>
</tr>
</tbody>
</table>

Prices

Until recently mozzarella cheese prices closely paralleled cheddar prices, with the range between the two generally varying by less than a cent a pound from year to year. The provolone-cheddar price range variation from year to year was also generally quite small. However, milk surpluses resulted in flat support prices for cheddar cheese since October 1, 1980, in turn resulting in flat wholesale prices for the product. As a result mozzarella and provolone prices rose 5.1 cents and 6.9 cents per pound respectively, relative to cheddar prices since 1980 (Table 4). This increase in unsupported Italian cheese prices relative to supported cheddar prices, demonstrate underlying demand strength for Italian cheese, a positive factor for the product in the future.

Table 4
Cheddar, Mozzarella, Provolone Cheese Wholesale Prices Relationships, 1973-82

<table>
<thead>
<tr>
<th>Year</th>
<th>Cents Per Pound Cheddar Cheese Above or Below</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mozzarella</td>
</tr>
<tr>
<td>1973</td>
<td>+ 4.8¢</td>
</tr>
<tr>
<td>1974</td>
<td>+ 6.1¢</td>
</tr>
<tr>
<td>1975</td>
<td>+ 4.2¢</td>
</tr>
<tr>
<td>1976</td>
<td>+ 4.8¢</td>
</tr>
<tr>
<td>1977</td>
<td>+ 4.9¢</td>
</tr>
<tr>
<td>1978</td>
<td>+ 5.7¢</td>
</tr>
<tr>
<td>1979</td>
<td>+ 6.0¢</td>
</tr>
<tr>
<td>1980</td>
<td>+ 4.6¢</td>
</tr>
<tr>
<td>1981</td>
<td>+ 1.0¢</td>
</tr>
<tr>
<td>1982</td>
<td>-.5¢</td>
</tr>
</tbody>
</table>

Note: Chicago wholesale selling price for 40 pound block cheddar, 25 pound and up provolone, (Giganti) and Wisconsin wholesale selling price for mozzarella.
Imports

Italian cheese imports have not been a significant factor for the U.S. Italian cheese industry. Imports of the product have been relatively small in the past two decades, in contrast with substantial increases in overall cheese and dairy imports, and domestic production of Italian cheese. As a result Italian cheese imports declined from 11% of total cheese imports in 1960, to 5% in 1982, and from 4% of U.S. Italian cheese production in 1960, to 1% in 1982 (Table 5).

Table 5

<table>
<thead>
<tr>
<th>Year</th>
<th>Million Pounds</th>
<th>% of 1960</th>
<th>% of Total Cheese Imports</th>
<th>% of U.S. Italian Cheese Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>7.0</td>
<td>100</td>
<td>11.1</td>
<td>4.4</td>
</tr>
<tr>
<td>1965</td>
<td>7.8</td>
<td>111</td>
<td>9.8</td>
<td>3.2</td>
</tr>
<tr>
<td>1970</td>
<td>7.3</td>
<td>104</td>
<td>4.5</td>
<td>1.8</td>
</tr>
<tr>
<td>1975</td>
<td>11.4</td>
<td>163</td>
<td>6.4</td>
<td>1.7</td>
</tr>
<tr>
<td>1980</td>
<td>7.2</td>
<td>102</td>
<td>3.1</td>
<td>.7</td>
</tr>
<tr>
<td>1981</td>
<td>8.5</td>
<td>121</td>
<td>3.4</td>
<td>.8</td>
</tr>
<tr>
<td>1982</td>
<td>13.6</td>
<td>194</td>
<td>5.0</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Domestically manufactured Italian cheese has improved its competitive price position with imported Italian cheese in the past decade. This is likely a major reason for the relatively small import volume quantified above. The price of imported provolone has increased from $.82 per pound above domestic provolone in 1973, to $1.39 per pound above in 1982 (Table 6). The competitive price strength of U.S. Italian cheese with imported Italian cheese, is a strong plus for the future of the domestic Italian cheese industry.

Table 6

<table>
<thead>
<tr>
<th>Year</th>
<th>Domestic Dollars Per Pound</th>
<th>Imported Dollars Per Pound</th>
<th>Amount Imported Exceeds Domestic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>$1.10</td>
<td>$1.92</td>
<td>$.82</td>
</tr>
<tr>
<td>1974</td>
<td>1.28</td>
<td>2.15</td>
<td>.87</td>
</tr>
<tr>
<td>1975</td>
<td>1.45</td>
<td>2.11</td>
<td>.66</td>
</tr>
<tr>
<td>1976</td>
<td>1.51</td>
<td>2.76</td>
<td>1.25</td>
</tr>
<tr>
<td>1977</td>
<td>1.54</td>
<td>2.90</td>
<td>1.36</td>
</tr>
<tr>
<td>1978</td>
<td>1.66</td>
<td>2.90</td>
<td>1.24</td>
</tr>
<tr>
<td>1979</td>
<td>1.90</td>
<td>3.38</td>
<td>1.48</td>
</tr>
<tr>
<td>1980</td>
<td>2.02</td>
<td>3.41</td>
<td>1.39</td>
</tr>
<tr>
<td>1981</td>
<td>2.13</td>
<td>3.49</td>
<td>1.36</td>
</tr>
<tr>
<td>1982</td>
<td>2.19</td>
<td>3.58</td>
<td>1.39</td>
</tr>
</tbody>
</table>

a/ Wholesale selling price at Chicago sellers dock for provolone (Giganti) 25 pd. units and up.
Consumption

Rapid increases in consumption of Italian cheese has been a bright spot not only for the Italian cheese industry, but also for the dairy industry as a whole. Per capita consumption of Italian cheese almost quadrupled since 1960, reaching 4.7 pounds in 1982. This contrasts with only slightly more than a doubling since 1960 in per capita consumption of all hard cheeses, and a decrease of 1/6th in per capita consumption of all dairy products combined (Table 7). Although future increases in consumption of Italian cheese will by no means be automatic, the strong increases in the past provide much promise for the future. Continued vigorous promotion and merchandising programs will likely result in continued increases in sales of Italian cheese.

Table 7
Per Capita Consumption of Italian Cheese, All Hard Cheese, and All Dairy Products Combined, 1960-82

<table>
<thead>
<tr>
<th>Year</th>
<th>Italian Cheese</th>
<th>All Hard Cheese</th>
<th>Italian Cheese</th>
<th>All Hard Cheese</th>
<th>All Dairy Products a/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pounds Per Capita Consumption</td>
<td>% of 1960 Per Capita Consumption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>1.0</td>
<td>8.3</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1965</td>
<td>1.4</td>
<td>9.6</td>
<td>140</td>
<td>116</td>
<td>95</td>
</tr>
<tr>
<td>1970</td>
<td>2.1</td>
<td>11.5</td>
<td>210</td>
<td>139</td>
<td>86</td>
</tr>
<tr>
<td>1975</td>
<td>3.3</td>
<td>14.3</td>
<td>330</td>
<td>172</td>
<td>83</td>
</tr>
<tr>
<td>1980</td>
<td>4.5</td>
<td>17.7</td>
<td>450</td>
<td>213</td>
<td>83</td>
</tr>
<tr>
<td>1981</td>
<td>4.5</td>
<td>18.1</td>
<td>450</td>
<td>218</td>
<td>83</td>
</tr>
<tr>
<td>1982</td>
<td>4.7</td>
<td>19.6</td>
<td>470</td>
<td>236</td>
<td>84</td>
</tr>
</tbody>
</table>

a/ Milk equivalent basis.

Imitation Competition

Imitation Italian cheese is an increasing problem for natural Italian cheese. Based on U.S. Government reports, imitation cheese production was 4.8% of total hard cheese production in 1981, compared to 2% in 1978. Approximately 5.6% of total Italian and American cheese production is now imitation, and 36% of all imported casein is used for imitation cheese. Casein imports hit a record high 177 million pounds in 1982, -- an increase of 38% over 1981.

The major reason for the increased pressure from imitation Italian cheese, is its price competitiveness. The price advantage results from the fact that import prices for casein used is imitation Italian cheese have been averaged less than one-half of the price for domestic nonfat milk solids used in natural cheese. As a result wholesale prices for natural Italian cheese average $.78 per pound (118%) more than for imitation cheese, and natural retail prices average $.95 per pound (48%) more than imitation prices. Marketing margins on natural Italian cheese average $.17 per pound (13%) more than on imitation cheese (Table 8).
The lower prices for imitation cheese, also results in a retail price advantage for pizza made with imitation cheese, compared to pizza made with only natural cheese, -- averaging $.29 per pound (13%) in major markets (Table 9). This price advantage in turn resulted in approximately 57% of pizza shelf space in super markets being devoted to pizza made from imitation cheese. Imitation brands outnumber natural brands 18 to 14 (Table 10).

Imitation cheese is therefore a strong competitive factor for the Italian cheese industry. Furthermore, competition from imitation cheese is likely to increase rather than decrease, and therefore must be given serious consideration in formulating future plans.

Table 8
Natural and Imitation Mozzarella Cheese Price Comparison

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Natural Price</th>
<th>Imitation Price</th>
<th>Amount Natural Price Exceeds Imitation Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dollars Per Pound</td>
<td></td>
<td>Percent</td>
</tr>
<tr>
<td>Retail Price</td>
<td>$2.93</td>
<td>$1.98</td>
<td>$.95</td>
</tr>
<tr>
<td>Wholesale Price</td>
<td>1.44</td>
<td>.66</td>
<td>.78</td>
</tr>
<tr>
<td>Marketing Margin</td>
<td>1.49</td>
<td>1.32</td>
<td>.17</td>
</tr>
</tbody>
</table>

*a/ Based on random sample by author in 1980 of 28 supermarkets in states where considerable quantities of imitation cheese were sold -- Arizona, California, Florida, Illinois, Tennessee, Virginia, and Washington, D.C.

Table 9
Retail Price Comparisons Between Pizza Using Imitation Italian Cheese, and Pizza Using Only Natural Cheese

<table>
<thead>
<tr>
<th>State</th>
<th>Natural Price</th>
<th>Imitation Price</th>
<th>Amount Natural Price Exceeds Imitation Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dollars Per Pound</td>
<td></td>
<td>Percent</td>
</tr>
<tr>
<td>Iowa</td>
<td>$2.17</td>
<td>$2.02</td>
<td>$.15</td>
</tr>
<tr>
<td>Minnesota</td>
<td>2.53</td>
<td>2.03</td>
<td>.50</td>
</tr>
<tr>
<td>Ohio</td>
<td>2.46</td>
<td>1.98</td>
<td>.48</td>
</tr>
<tr>
<td>Illinois</td>
<td>2.65</td>
<td>2.52</td>
<td>.13</td>
</tr>
<tr>
<td>Arizona</td>
<td>2.65</td>
<td>2.29</td>
<td>.36</td>
</tr>
<tr>
<td>California</td>
<td>2.74</td>
<td>2.39</td>
<td>.35</td>
</tr>
<tr>
<td>Washington, D.C.</td>
<td>2.24</td>
<td>2.41</td>
<td>-.17</td>
</tr>
<tr>
<td>Kentucky</td>
<td>2.40</td>
<td>2.00</td>
<td>.40</td>
</tr>
<tr>
<td>Tennessee</td>
<td>2.56</td>
<td>1.74</td>
<td>.82</td>
</tr>
<tr>
<td>Florida</td>
<td>2.77</td>
<td>2.45</td>
<td>.32</td>
</tr>
<tr>
<td>New York-New Jersey</td>
<td>2.36</td>
<td>2.48</td>
<td>-.12</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>2.53</td>
<td>2.29</td>
<td>.24</td>
</tr>
</tbody>
</table>

| Average              | 2.51          | 2.22            | .29                                         |

Table 10
Retail Shelf Space and Number of Brands, -- Pizza Using Imitation Compared to Only Natural Cheese a/

<table>
<thead>
<tr>
<th>State</th>
<th>% Shelf Space</th>
<th></th>
<th>Number of Brands</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Imitation</td>
<td>Natural</td>
<td>Imitation</td>
<td>Natural</td>
</tr>
<tr>
<td>Iowa</td>
<td>53</td>
<td>47</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Minnesota</td>
<td>43</td>
<td>57</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Ohio</td>
<td>71</td>
<td>29</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Illinois</td>
<td>52</td>
<td>48</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
<td>Arizona</td>
<td>82</td>
<td>18</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>California</td>
<td>74</td>
<td>26</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>Washington, D.C.</td>
<td>40</td>
<td>60</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Kentucky</td>
<td>64</td>
<td>36</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Tennessee</td>
<td>62</td>
<td>38</td>
<td>25</td>
<td>16</td>
</tr>
<tr>
<td>Florida</td>
<td>58</td>
<td>42</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>New York-New Jersey</td>
<td>31</td>
<td>69</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>51</td>
<td>49</td>
<td>29</td>
<td>27</td>
</tr>
<tr>
<td>Average</td>
<td>57</td>
<td>43</td>
<td>18</td>
<td>14</td>
</tr>
</tbody>
</table>

a/ See Table 9, footnote a/ for source of data.

Demand

In the final analysis consumers hold the key to the future of the Italian cheese industry. Ascertaining the strong and weak points of Italian cheese with consumers, is therefore critical for the industry. Data recently reported by United Dairy Industry Association reveals information of this type (Table 11).

Data from this study indicates major consumers of Italian cheese include; females, 35-44 year age group, professionals, "some" college, Mid-Atlantic residents, residents in cities over 2 million population, and dieters attempting to lose up to 10 pounds of weight. All offer potential for increased consumption.

Data from this study also suggests the Italian cheese industry would find it profitable to concentrate more sales efforts on:
(a) males
(b) elder citizens
(c) white collar workers
(d) poorly educated
(e) East South Central and Western U.S.
(f) small towns
(g) people not concerned about their weight

Developing marketing programs based on consumer purchase patterns will be critical for the Italian cheese industry.
### Table 11

Frequency of Consumption of Italian Cheese

<table>
<thead>
<tr>
<th>Differentiation</th>
<th>Highest Consumption Category</th>
<th>Score</th>
<th>Lowest Consumption Category</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Females</td>
<td>3.39</td>
<td>Males</td>
<td>3.26</td>
</tr>
<tr>
<td>Age</td>
<td>35-44 yrs.</td>
<td>3.69</td>
<td>over 54 yrs.</td>
<td>2.77</td>
</tr>
<tr>
<td>Occupation</td>
<td>Professionals</td>
<td>3.64</td>
<td>White collar</td>
<td>3.28</td>
</tr>
<tr>
<td>Education</td>
<td>Some college</td>
<td>3.53</td>
<td>Only grade school</td>
<td>2.87</td>
</tr>
<tr>
<td>Geographic area</td>
<td>Mid Atlantic</td>
<td>3.89</td>
<td>West South</td>
<td>2.74</td>
</tr>
<tr>
<td>Population Density</td>
<td>Over 2 million</td>
<td>3.60</td>
<td>Small towns</td>
<td>3.05</td>
</tr>
<tr>
<td>Diet Status</td>
<td>Dieting to lose up to 10 lbs.</td>
<td>3.52</td>
<td>Not concerned with weight</td>
<td>3.21</td>
</tr>
</tbody>
</table>

**a/** From representative samples in 1982, of 3,779 U.S. people 13 years old and older, based on "Attitude and Usage Study" conducted by United Dairy Industry Association.

**b/** Based on 7 point scale of frequency of consumption as follows:

- 7 = nearly every day
- 6 = several times a week
- 5 = once a week
- 4 = several times a month
- 3 = once a month
- 2 = several times a year
- 1 = once a year or less
- 0 = never used

### Summary

Italian cheese has had a bright past, and can have a bright future if market trends and market potential are capitalized on.

Positive factors for U.S. Italian cheese include:

(a) A seven fold increase in production nationwide, per plant, and in milk utilization since 1960.

(b) A 5.1 cent and 6.9 cent per pound respective increase in unsupported mozzarella and provolone wholesale prices compared to supported 40 pound block cheddar cheese prices since 1980, indicating strong market strength for Italian cheese in a surplus market condition.

(c) A decline of Italian cheese imports from 11% of total cheese imports in 1960, to 5% in 1982, and from 4% of U.S. Italian cheese production in 1960 to 1% in 1982. Domestic provolone improved its price competitive position with imported provolone by $.57 per pound between 1973 and 1982, averaging $1.39 per pound less at wholesale in 1982 than imported provolone.

(d) Per capita consumption of Italian cheese almost quadrupled since 1960, as contrasted with a decrease of 1/6 in per capita consumption of all dairy products combined.

(e) Major consumers of Italian cheese include: females, 35-44 years age group, professionals, "some" college, Mid-Atlantic residents, residents in cities over 2 million population, and dieters attempting to lose up to 10 pounds of weight. All offer potential for increased consumption.
Negative factors for U.S. Italian cheese include:

(a) Imitation cheese production was 4.8% of total hard cheese production in 1981, compared to 2% in 1978, and approximately 5.6% of Italian and American cheese production is now imitation.

(b) Wholesale prices for natural Italian cheese average $.78 per pound (118%) more than for imitation Italian cheese, and natural retail prices average $.95 per pound (48%) more than imitation process.

(c) Retail prices for pizza made with only natural cheese average $.29 per pound (13%) more than for pizza made with imitation cheese.

(d) Approximately 57% of pizza shelf space in supermarkets is devoted to pizza made with imitation cheese, and imitation brands outnumber natural brands 18 to 14.

Imitation cheese is therefore a strong competitive factor for the Italian cheese industry, and must be given serious consideration in formulating future plans.
YIELD AS A FUNCTION OF SOMATIC LEVELS:
RAPID MILK QUALITY SCREENING USING THE NEW FOSSOMATIC 90
by W. William Rudolph

ABSTRACT

Yield is a key to profitability in the Italian cheese making industry. It has been demonstrated that yield is adversely affected by milk containing high counts of somatic cells. A dairy can improve the yield of its cheese producing operation by improving the quality of its raw milk. Raw milk quality can be improved using a program of somatic cell monitoring and incentive payment to milk producers who deliver a high quality product. The Fossomatic 90, distributed and serviced by DICKEY-john Corporation, allows the dairy to make the rapid, precise and inexpensive measurements necessary to properly administer an incentive payment program based on somatic cell counts.

The modern Italian cheese industry is growing. The industry is growing in terms of total production, in its adherence to strict quality procedures and in its sophistication with regard to efficiency. This morning we are going to focus on efficiency.

One of the primary measurements of the efficiency of any cheese making operation is yield; the pounds of high value end product derived from a given amount of relatively inexpensive raw product, in this case, milk. It isn't too difficult to understand that if the yield of a dairy can be increased, there exists a greater potential for profit. Profitability is actually enhanced when the cost of attaining an increased yield does not exceed the added value of the increased production of high value product, in this case, Italian cheese.

One relatively inexpensive way for many cheese plants to improve their yield is to improve the quality of the raw milk being utilized. In particular an improvement in yield is most assured by an improvement in the somatic cell count of the raw milk.

Somatic cells are indicative of a disease in dairy cattle known as mastitis. Mastitis is an udder infection. It disrupts the normal operation of the cow's milk producing organs. Mastitis is
also a very common disease. It is estimated that at least 40% of all dairy cows are infected with some kind of mastitis in one or more quarters. Most of these animals are suffering from subclinical mastitis; mastitis infection where there is no readily apparent changes in the udder or in the milk withdrawn from the infected udder.

There are two primary consequences of mastitis infection. First, the producer experiences a loss in production, even if the infection has not developed to a noticeable stage. As an example, it has been determined that a herd with somatic cell counts between 400,000 and 800,000 somatic cells per ml, too small an infection to be noticeable without laboratory analysis of the milk, loses approximately 10% of production. The second consequence is of more interest to you as cheese producers. Somatic cell count is closely related to the manufactural characteristics of the raw milk. The most distinct influences on cheese production are:

- Longer coagulation time in the cheese production
- Less yield per pound of milk due to a lower content of casein and fat
- Possible shorter storage time of products

The effects of mastitis on cheese yield are quite dramatic. During practical field experiments conducted by Wisconsin Dairies Cooperative it was found that cheddar cheese yield was affected consistently by a relatively low somatic cell count. In these experiments, the Wisconsin Dairies researchers used milk at 240,000 cells/ml as the baseline, or healthy condition. In these experiments, the Wisconsin Dairies researchers used milk at 240,000 cells/ml as the baseline, or healthy condition. Their research showed that milk with 496,000 cells/ml caused a 0.6% yield loss and milk with 640,000 cells/ml caused a 3.0% yield loss when compared to the yield from "healthy" milk. Of particular significance in light of these findings is the fact that it is extremely difficult to identify differences in somatic levels in these ranges, yet the effect on cheese production is readily apparent.

Professor Olson at the University of Wisconsin has also attempted to quantify the effects of high somatic cell counts in raw milk on the yield of a cheese plant. Using a nominal plant of 1/2 million pounds daily throughput and assuming 10% of the raw milk originated from mastitis infected cows exceeding 1 million cells/ml, Dr. Olson estimated the plant potentially loses 585 lbs of cheese per day. The cheesemaker is in the best position to put a dollar value on this loss, but it will probably be assessed at between $500 and $1000 per day. Looked at another way, the manager of this hypothetical cheese plant has an opportunity to increase his plant's gross income by $500 to $1000 per day. For this kind of an incremental return he can afford to invest some time and money. Now, what does he have to do?

Obviously, the manager of this hypothetical cheese plant must invest his resources toward improving the somatic cell count in the raw milk used in his plant. This can be done in two ways.
First, the manager can screen incoming loads of milk and refuse any loads with greater than some maximum somatic cell count. This may be the most obvious solution but from a practical standpoint most cheese plants do not enjoy such autocratic control over their producer/suppliers. Instead, most plants must compete for their raw materials just as they then must compete for a market for their finished products.

Competition for producer's milk requires that the plant manager use some very ingenious means of improving the somatic quality of his raw milk. There must be an incentive for the producer to supply low cell count milk. The best way to accomplish this is to establish a payment scheme based on somatic count which rewards the good quality producer and penalizes the producer who delivers milk with a high somatic cell count.

It is not the intent here to recommend a specific payment scheme. The payment formula which will work best for a particular plant will depend on the quality of milk currently being delivered, the competitiveness of the situation (how many plants are competing for the producer's milk and how much they are willing to pay for it) and economic considerations (how much money can the plant afford to invest in the improvement program).

All milk quality payment programs, however, should have a number of common elements. All incentive payment milk quality programs must be based on some target, average somatic cell count acceptable to the plant manager. There should also be some maximum allowable cell count which triggers a substantial discount in payment. All milk quality payment programs should be designed to attract the milk from the best, most conscientious local producers and encourage the worst, poorest quality producers to take their milk to the plant's competitor on the other side of town. Finally, the success of any milk quality payment program depends on the ability of the plant to rapidly and accurately screen incoming producer's milk with respect to somatic cell count.

Incentive payment programs can work. Based on their previous studies, Wisconsin Dairy Cooperatives introduced an incentive payment program in 1978. Within one year, the program had successfully decreased the average somatic cell count of their raw milk by 10%. This improvement in quality was translated into extra profits to Wisconsin Dairies Cooperative as well as extra income to their best producers.

The ability to actually measure somatic cells in producer milk samples is the key to the desired program of improving the quality of milk used in the cheese plant. To effectively administer an incentive payment scheme the dairy must be able to determine the actual somatic cell count in a standard raw milk sample rapidly, inexpensively and precisely.

The official standard method to determine somatic cell count is the Direct Microscope Cell Count. A small portion of milk is
smeared on a degreased microscope slide. The slide is allowed to dry, then dipped into a dye solution. The dye can be either passive, as is methylene blue, or actively fluorescing as is ethidium bromide. Of course the fluorescent dye improves the discrimination between the colored somatic cells and the general background. The sample slide is then observed with a microscope with a magnification of up to 500x and each cell is counted.

The microscopic method is characterized by being tedious, time consuming and labor intensive. Also, the performance of manual microscopic somatic cell counts is characterized by low precision and accuracy. Multiple slides of the same sample will give widely varying results, especially if more than one observer is involved in the test. Consequently, direct microscopic counting must be discounted for use in the dairy's milk quality incentive payment program. It is too time consuming, costly and imprecise due to differences in sample handling.

However, there exists an instrument which uses the basic principal of direct cell counting, the exception being that it improves and automates the procedure. The Fossomatic, designed and manufactured by N. Foss Electric of Denmark and distributed and serviced in the USA and Canada by DICKEY-john Corporation, performs a specific, direct, electronic count of the number of somatic cells in the milk. No chemical treatment prior to the measurement is necessary, except for preheating the milk sample to 40 C. Ethidium bromide is used as the dye and is specific as it only reacts with the DNA material in the cell nucleus. Therefore direct particles, fat globules and air bubbles will not add to the cell count erroneously as is the case with some other electronic cell counting instruments.

Two models are available, a fully automatic instrument which will measure up to 215 samples per hour and a semi-automatic unit which will measure up to 90 samples per hour. The Fossomatic will count somatic cells in the range between 50,000 and 10,000,000 cells/ml. The variable cost per sample is typically less than $0.05.

The advantages of the Fossomatic electronic cell counting instrument are obvious. It is independent of the operator, it has an accuracy and precision which exceeds that possible using the standard method, it is fast and the sample processing cost is low. The initial cost of the instrument is high, however; if the plant is serious about improving the yield rate by improving the quality of its raw milk, the cost of the instrument can be easily justified.

Consider the moderately sized cheese plant described previously as borrowed from Dr. Olson. Such a plant, if it were to embark upon an incentive payment program, may need the ability to analyze up to 1000 samples per week for somatic cell count. Assume the plant purchases a Fossomatic 90 and depreciates it over 5 years (disregarding investment tax credit). Assume a conservative average of 50 samples per hour and an operator
expense of $15.00/hour. Finally, assume an average of $1200.00 per year for miscellaneous expenses and maintenance. The resulting conservative operating cost estimate is:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual depreciation</td>
<td>$6000</td>
</tr>
<tr>
<td>Variable sample cost</td>
<td>$2600</td>
</tr>
<tr>
<td>Operator cost</td>
<td>$15,600</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$1200</td>
</tr>
<tr>
<td><strong>Total annual expense</strong></td>
<td><strong>$25,400</strong></td>
</tr>
</tbody>
</table>

Reviewing the original scenario, the plant manager of the hypothetical plant has the potential to increase his plant's gross income by $500 to $1000 per day. Assume the plant averages 90% on line or 324 days per year. The range of possible revenue from an increase in yield resulting from higher quality raw milk is $162,000 to $324,000. Compare this to the cost of operating a somatic cell counting instrument ($25,400) and it is apparent that the plant manager has between $136,600 and $298,600 to utilize for incentive payments and PROFIT.

In conclusion, mastitis is robbing cheese manufacturers of yield even when counts are well below 1,000,000 cells/ml. Improvements of the quality of raw milk entering the cheese plant will result in increased revenues. Improvement of the quality of the incoming producer milk can be encouraged with an incentive payment program that is backed up with a fast, precise means of measuring the somatic cell count in producer milk samples. DICKEY-john Corporation has the instrumentation which can make the monitoring program a success, the FOSSOMATIC. Improving yields by improving milk quality can be cost effective and results in increased profit to the cheese plant.

080883
MANUFACTURE AND GROWTH OF STRING CHEESE

By Dr. Clem Honer

ABSTRACT

String cheese, the fastest growing variety in the United States, was introduced in Southern California in the early 1970's. It came to the Midwest a few years later, and, in both areas, was readily accepted by consumers despite only token promotional effort. String cheese production now totals one percent of the total United States Mozzarella volume, and continues to increase. Children and adults alike are attracted to its mild flavor in both snack food and gourmet applications. String cheese looks like a promising segment for the cheese industry, and it could easily become the next sensation on the food horizon.

String cheese is creating a new round of excitement in the cheese industry and is attracting a wide range of consumers to the product. It's opening new opportunities for the cheese marketer with a product that finds ready acceptance with young children, young adults, and adults alike.

It is to the cheese industry as the ice cream bar and ice cream sandwich is to the frozen dessert industry. It is bringing a novelty item to the hard cheese industry. String cheese is the one cheese that is closest to the cutting edge of changing consumer trends toward more snack foods for children and young adults, and fits naturally into the trend of increased home entertainment using gourmet foods. It also goes well with wine and beer, even filling a demand niche as a snack in place of pretzels and chips.

String cheese is a mild, fresh flavored product that can be consumed when made. It doesn't age like Cheddar and other hard cheeses. It is packaged air-tight and is distributed, displayed, and sold refrigerated. It can be manufactured in its natural state or with added flavors, such as onion, garlic, smoked, taco, and other spices.

The product derives its name from the characteristic to form strands of strings resisting separation as pieces are pulled away from the cheese body. These strands of cheese are then popped into the mouth of the consumer. This is the reason children call it a fun cheese.

As such, String cheese finds a wide acceptance among a large segment of the population. It provides many new, as yet unexplored, opportunities for increasing the per capita consumption of cheese.

History - Sketchy records indicate that String cheese originated in Turkey and Armenia, and to a certain extent, Western Asia. It was made at home, molded and stretched by hand, and consumed locally. It was made from sheep, goat, buffalo, and cow milk.

The product first appeared in the United States during the early 1950's in Southern California, when persons of Armenia descent asked the Gardenia Cheese Company, South Gate, California to make the cheese. At first, Gardenia experimented with the concept and then began selling String cheese in bulk packages to restaurants.
It wasn't until the early 1970's that the company rolled-out the first consumer-sized package of String cheese for supermarket distribution. From then on, the product's acceptance grew rapidly in that area. It soon came to Wisconsin during 1974, and as area plants started String cheese production, so also did its popularity increase in the Midwest.

Now, conservative estimates of String cheese production in the United States are figured to be about one percent of the total Mozzarella production. But percentage wise, String cheese is growing at a faster rate than Mozzarella.

A similar product, called ribbon or strip cheese, has gained popularity in Mexico. Like String cheese, this product may be extruded mechanically but as a ribbon that can be rolled up into a ball.

Pasta Filata Cheese - String cheese is normally manufactured as a cultured-enzyme coagulated curd. When the curds are cooked out and the whey is drained, the curds are heated in hot water to a plasticized state for molding into a long rope-like configuration.

Mozzarella and Provolone cheese plants are ideally suited for the manufacture of String cheese. String cheese is merely an extension of the Mozzarella process in which the plasticized curd is formed into a long rope instead of the conventional Mozzarella forms. This rope of curd is then chilled, cut into five or six inch lengths, brine salted, dried and vacuum packaged.

Manufacturing - Most String cheese manufacturers begin with milk standardized at two percent butterfat. Some processors accomplish this by removing cream from whole milk, while others add skim milk solids to whole milk.

This standardized milk is then pasteurized at the legal minimum time temperature combination required and then cooled to 90°F for setting and coagulation. Rod and coccus cultures, primarily Lactobacillus bulgaricus and Streptococcus thermophilus are added at the rate of about one percent.

Some processors have used Streptococcus lactis with the rod and coccus mixture. In Europe, Micrococcus freudenreichii and Streptococcus faecalis have been used.

Rennet at the rate of 40 milliliters per 2,000 pounds of milk are stirred into the milk. Twenty five minutes later, the coagulation is cut into ¹⁄₈ inch cubes.

The curds are cooked out at about 104°F, usually within 25 minutes, or when the whey develops a pH of 5.9. At this time, the whey is drained and the curds are ditched and trenched similar to the conventional Cheddar procedure.

After whey drainage, the curd mass is cut into slabs, which are turned, piled, and re-piled. Again, similar to the cheddaring process. Meanwhile, the curd is kept warm to facilitate continual acid development.

When the whey acidity attains a pH of 5.1 and when the curd meets the stretch test (determined by heating the curd to 135°F and then showing the capability of stretching one meter in length), the curd is ready for milling.

The milled curd falls into hot water supported in a chamber containing counter-rotating twin augers. The length and pitch of these augers optimizes the transfer of heat from the water heating the curd to 135°F, and at the same time, kneading and stretching the curd. The water temperature and time of contact, together with the kneading action, is mechanically controlled such that the curd is now plasticized and ready to be molded.
into various Mozzarella shapes.

For String cheese, the plasticized curd mass may be manually stretched or mechanically extruded into a long rope-like configuration.

Manual stretching is practiced by some processors. In this case, approximately an eight-pound chunk of the plasticized curd is manually pulled (stretched) into a long rope. Some processors use a confining channel to confine and hold the stretched curd to facilitate the formation of a round, symmetrical rope. This channel also makes it more convenient to immerse the stretched mass into hot or cold water during the process.

When the curd mass is cooled, the rope is cut into specific lengths, usually determined according to measured slots inserted along the channel length.

Manufacturers using this method claim a greater stringing or strand formation characteristic with this method as compared with the extrusion procedure.

Most String cheese processors are mechanically extruding the plasticized curd with another downstream equipment from the pasta filata machine. This extruder maintains the temperature of the plasticized curd at 135°F to 138°F with hot water in a jacket maintained at near 142°F.

Augers then force the soft mass of curd through a head containing several openings through which strings or ropes of cheese are extruded. These ropes (some eight to ten feet in length) continuously move forward, passing through a shallow salt water bath maintained at 45°F, toward the cutting section.

Cutting into individual units of String cheese may be manual or semiautomatic. In either case, the rope is cut into desired stick lengths and is now ready for salting.

The individual units are salted by soaking in a near-saturated sodium chloride solution for a period varying from one to one and one-half hours, depending upon the size of the stick. After this, the sticks are dried and vacuum packaged.

Packaging varies from an institutional size to the single stick package. The bulk package weighs about five pounds and contains String cheese vacuum packaged for institutional and delicatessen outlets. Consumer-sized units for supermarket sales may vary from one, four, eight, and sixteen ounce packages. Taverns prefer the single stick units, while home entertaining customers use the sixteen ounce size.

Marketing-Advertising - It's a natural to target young children with String cheese advertising, especially as a nutritious snack food, which they call a fun food. They like it for its mild flavor and the fact that it can be consumed by strands separated from the cheese. It will replace candy, cookies, and other snack foods now largely consumed by children. Mothers especially like String cheese for their children because of the abundant protein and calcium available.

Promoting String cheese as an hors d'oeuvre item is another natural. It fits easily into the increased trend toward home entertaining and the health attitudes of many young adults. This mild flavored product can be portioned into bite-size units and dipped into a cocktail sauce or various dip preparations thereby providing a new, exciting flavor contrast.

Not only will the String cheese attract the gourmet seeking guest looking for new ideas, but the nutrition concerned party-goer will immediately recognize the health aspects of
the product compared to the usual party foods.

Targeting advertising toward young women offers another excellent opportunity for String cheese. This consumer group seeks a low calorie food, but are becoming increasingly aware of the need for a good source of calcium and protein. Recent USDA reports teen-aged women are getting less than the recommended daily allowance (RDA) of calcium in their diet. This fact coupled with the increasing concern that osteoporosis in older women is related to insufficient calcium intake during younger years provides a golden opportunity for advertising String cheese.

One ounce of String cheese provides 200 milligrams of calcium and seven grams of protein. Relating this to the RDA suggested for calcium and protein for teen women at 1,400 milligrams and 46 grams, respectively, it is easy to see the potential for String cheese as a snack food for this consumer group.

Promotion Needed - String cheese presents a golden opportunity for the industry to increase cheese consumption. It is a new product that has made its own way largely on its own merits. There are many potential consumers that have never heard of String cheese.

Considering the nutritional aspects of String cheese together with its appeal as a snack food, it would be very interesting to see what the pretzel and chip industry would do with such an advantage.

It is time for the cheese industry to latch on to this new cheese novelty and to promote it nationally. To do any less would not only be an opportunity missed, but a disservice to the cheese industry.
ITALIAN CHEESE YIELDS

by David M. Barbano

ABSTRACT

Milk composition, particularly milk casein content, determines the cheese yield potential of milk. Seasonal variation in milk casein content influences both cheese yield and composition. Once milk arrives at a cheese plant the objective is to recover the highest possible percentage of the cheese yield potential of that milk as top quality product. Because of the complexity of the chemistry of cheese making, a large number of factors can cause yield losses during cheese manufacturing. An approach to evaluating and improving cheese yield performance is discussed.

The goal of all cheese making is to obtain the maximum yield of top quality cheese from the available milk supply. The two major factors that influence cheese yield are (a) milk composition and (b) the efficiency with which a cheese plant recovers the potential cheese solids from the milk supply. Previous research that has been done at Cornell University, on Cheddar cheese yields in New York, has evaluated cheese yields in a systematic and objective fashion. The same approach can be taken in the Italian cheese industry.

Approach for Evaluation and Improvement of Cheese Yield Performance

1. Determine the Cheese Yield Potential of the Milk.
2. Measure the Actual Cheese Yield.
3. Calculate Composition Adjusted Yield.
5. Identify the Causes of Yield Losses.


The cheese yield potential of milk used for the manufacture of low moisture part skim Mozzarella cheese is determined by the casein and fat content of the milk used, and the desired moisture content of the finished cheese. Why are casein, fat, and moisture the most important determinants of cheese yield potential? In Table 1, we can see that the casein plus fat content of low moisture part skim Mozzarella makes up more than 91.5 percent of the milk solids content of the cheese. Casein content of milk is more important than
the fat content because the fat content of milk used for cheese making is standardized to a lower level than that found in the original milk. Thus, casein content is truly the limiting factor for cheese yield potential of a given milk supply.

What is the relationship between the casein and fat content of milk and the low moisture part skim Mozzarella cheese yield potential? Any formula that is designed to establish the cheese yield potential of milk should be based on observations of fat and casein recoveries under optimum cheese manufacturing conditions. This formula should reflect the goal of good manufacturing practice. Because of the proprietary nature of the Italian cheese industry there is not much data available on actual casein and fat recovery. Based on my experience with Cheddar cheese fat and casein recoveries, I will propose the following formula as a goal against which we can evaluate cheese yield performance.

Cheese Yield Potential = \((0.90 \times \text{Fat} + (\text{Casein} - 0.1)) \times 1.13 \div \left(1 - \frac{\text{Cheese Moisture}}{100}\right)\)

This formula states that under ideal manufacturing conditions, 90% of the milk fat in standardized milk should be recovered in the cheese. Casein recovery, as in Cheddar cheese manufacture, is expressed as \((\text{Casein} - 0.1)\) and is equivalent to a 95 to 96 percent recovery. The 1.13 factor accounts for the amount of non-fat/non-casein solids content of the cheese plus an assumed salt content of 1.7%. In Table 2, the non-fat, non-protein, non-salt solids content of 16 commercial samples of low moisture part skim Mozzarella are shown. If each of these cheeses had contained 1.7% salt, the average factor for non-fat/non-casein solids content of low moisture part skim Mozzarella cheese would be 1.13. By using this formula plus the casein and fat content of milk, you can estimate the cheese yield potential (pounds cheese/100 pounds milk) of milk.

This estimation of cheese yield potential of milk is very dependent on good quality test results for fat and casein content of milk. If a casein test is not available, the milk casein content can be estimated from the protein content of milk. It is becoming much more common for milk protein testing equipment to be readily available in cheese plants. In New York, we find that the equation shown below can be used as an approximation of the milk casein level. This equation works reasonably well for milk from large silos.

Estimated \%Casein = 0.80 \times (\%Protein - (\%Protein \times 0.05))

Protein content of milk is usually determined on a total nitrogen basis. About 5% of the nitrogen content of milk is due to nonprotein nitrogen and thus we correct for that in the above equation to obtain a more realistic estimation of true protein. Approximately 80% of the true protein content of milk is casein. The proportion of total true protein that is casein may vary seasonally and from one geographic area to another.

How much does seasonal variation in milk casein content influence low moisture part skim Mozzarella cheese yields? Previous studies in New York have indicated that an average cheese plant can expect a 0.3% high/low seasonal variation in milk casein content. At a 50% moisture content, the low moisture part skim Mozzarella cheese yield will change 0.22 pounds per 100 pounds of milk for every change of 0.1% in the milk casein content.
2. Measure the Actual Cheese Yield.

The key factors for measurement of actual cheese yield are accurate determinations of the weight of milk plus starter used and the total weight of cheese produced for a day. Accurate calibration of cheese vats and good record keeping by the cheesemaker are very important. It is best to have a separate calibration for each cheese vat. Normally, the total weights of cheese made in a day are accurately determined. The weight of cheese divided by the weight of milk plus starter is the actual cheese yield which would be expressed as pounds of cheese per 100 pounds of milk plus starter.

\[
\text{Actual Yield} = \frac{\text{pounds of cheese}}{\text{pounds of milk + starter}}
\]

3. Calculate Composition Adjusted Yield.

To make yield comparisons from day to day or from plant to plant it is important that cheese yields be adjusted to an equal moisture basis. It is also possible to adjust cheese composition to an equal salt basis if there is salt analysis data available. Composition adjustment is also necessary for comparison to theoretical yield calculated from the casein and fat content of milk plus starter. As you will recall the theoretical yield formula assumes a cheese with 1.7% salt and the target moisture specified for the type of product. The result of the actual yield determination described above is adjusted to the same moisture content as that used in the theoretical yield formula. To be able to do this calculation it is necessary to know the actual moisture content and the desired moisture content of the finished product.

\[
\text{Moisture Adjusted Yield} = \frac{\text{actual yield} \times (100 - \text{actual } \% \text{ moisture})}{(100 - \text{desired } \% \text{ moisture})}
\]

If the moisture adjusted yield is different from the actual yield, then this indicates that you did not control finished product moisture. If the moisture adjusted yield is less than the theoretical cheese yield, then there has been a greater loss of milk fat and/or casein than was predicted by the formula for cheese yield potential. All of these simple calculations can be quickly done on a personal computer in the QC lab of a cheese plant.


In most cheese plants the easily found and corrected points of yield loss have been identified. Excessive amounts of cheese on the floor due to obvious mechanical problems is usually not tolerated in well managed cheese plants. Large quantities of fines removed from the whey by a fine saver is another sign of significant problems. Large quantities of fines usually indicate that the milk coagulation was extremely weak, improper agitation after cutting caused excessive shattering of the curd, or that the device used for separation of the curd from whey was not working properly.

Most yield loss problems are much more subtle than those just mentioned. In general, if a cheese plant is doing an adequate job of procuring good quality milk, then usually the largest yield loss during the manufacture of low moisture part skim Mozzarella is due to low fat recovery. Fortunately most cheese plants can do a very good job of testing for fat content of milk, whey,
and cheese. The first step in evaluating fat recovery is to calculate the total pounds of fat in the cheese. Next, total pounds of fat available in the milk plus starter is determined. The total pounds of fat in the cheese divided by the total pounds of fat available will give the fat recovery in the cheese. The cheese yield potential formula stated that 90% fat recovery in the cheese was our goal. In many instances fat recoveries observed may be in the low 80's. Low efficiency of fat recovery in the cheese represents an economic loss. Milk fat is worth more as cheese yield than it is as whey cream. If the cheese price is $1.40 per pound and whey cream is $1.75 per pound of fat, then every increase of 1% fat recovery will give an additional return of about 3 cents per hundred weight of milk.

In most Mozzarella cheese manufacturing processes we can divide the fat loss into two broad categories (a) fat loss into the whey up to the time of draw and (b) fat loss after draw, primarily at the mixer/molder. The amount of fat in the whey at draw can be measured very accurately with a modified Babcock test. The amount of whey present at draw can be estimated by subtracting the pounds of finished cheese from the pounds of milk plus starter. Now you can estimate the pounds of fat lost up to draw as a percentage of the total fat that was initially available. Identifying what proportion of the fat loss is occurring in the vats in comparison to the proportion lost at the mixer/molder will be useful in identifying where to focus your attention to improve fat recovery.

5. Identify Causes of Yield Losses.

As in most endeavors in life there are many more possible ways to do a job wrong than there are ways to do a job right. In cheese making there are many different factors that can cause yield losses. If we focus specifically on fat losses as an example, some of the important factors are:

1. Proper milk coagulum firmness at cutting.
2. Proper agitation speed after cutting.
3. Proper temperature of the milk coagulum at cut.
4. Time and temperature of curd handling between the vat and the mixer/molder.
5. Optimum pH of the curd during the mixer/molding process.
6. Proper temperature and residence time in the mixer/molder.

Many other factors, that may be specific to particular types of cheese making equipment or procedures, could be added to this list.


Before any changes or adjustments are made in manufacturing procedures it is best to establish what the normal cheese yield performance is for your cheese plant. Establishing an accurate record of actual yield, composition adjusted yield, and yield potential is extremely important. Cheese yield potential is a moving target that is hard to hit if you do not know what it is for your
particular plant. A record of fat recovery in the cheese and where fat losses are occurring will help identify where to focus your attention for improvement of cheese yield.

The key to success is to thoroughly understand what you are currently doing and then decide on one parameter to change in the manufacturing procedure. After the change has been made, continue monitoring yield and losses over a period of time to compare against previous history for the plant.

As an example, a factor that is quite significant with respect to fat loss into the whey prior to draw is the temperature of milk at set. Many times set temperatures of 97 to 98 F are used in the cheese manufacturing process. My first question is - do you really need to be at 97 to 98 F at this stage of cheese making or could you start at 92 to 93 F without adversely influencing product quality? This seemingly small difference in temperature of the milk at set can make a significant difference in the amount of fat lost into the whey prior to draw. At about 95 to 96 F most of the fat in milk melts. When milk fat is in a liquid or melted form within the milk fat globules, it is much more easily lost from the curd structure. After the curd has had a chance to firm up at a temperature below the melting point of milk fat, there will be less fat loss from the curd as temperature is increased above the melting point of milk fat during cooking.

Summary

Small changes in cheese yield potential and efficiency of recovery of milk fat and casein can make very economically significant changes in the profitability of Italian cheese manufacture. The key to improving cheese yield and maintaining good performance is a systematic approach to performance evaluation and improvement.

ACKNOWLEDGEMENT

The author wishes to thank Maureen Chapman and Mary DellaValle for their assistance in the analysis of cheese samples. The author also appreciates the input from management personnel of several Italian cheese manufacturing companies.
TABLE 1. Low Moisture Part Skim Mozzarella Cheese Composition. a

<table>
<thead>
<tr>
<th>Total Solids</th>
<th>Fat</th>
<th>Protein</th>
<th>Salt</th>
<th>Fat + Protein Milk Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>51.36%</td>
<td>18.93%</td>
<td>26.63%</td>
<td>1.58%</td>
<td>91.52%</td>
</tr>
</tbody>
</table>

aAverage composition for 16 commercial brands of Mozzarella cheese.
Table 2. Composition of 16 Commercial Samples of Low Moisture Part Skim Mozzarella Cheese.

<table>
<thead>
<tr>
<th>Source</th>
<th>Total Solids</th>
<th>Fat</th>
<th>Protein</th>
<th>Salt</th>
<th>Other$^a$ Milk Solids</th>
<th>Factor$^b$ for Yield Potential Formula</th>
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</thead>
<tbody>
<tr>
<td>NY-1</td>
<td>50.16</td>
<td>20.75</td>
<td>24.30</td>
<td>1.34</td>
<td>3.77</td>
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<td>NY-2</td>
<td>52.85</td>
<td>17.90</td>
<td>29.65</td>
<td>1.61</td>
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<tr>
<td>NY-3</td>
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<td>1.58</td>
<td>4.22</td>
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</tbody>
</table>

$^a$Total Solids - (Fat + Protein + Salt) = Other Milk Solids.

$^b$Factor for Yield Potential Formula =

\[
1 + [(1.7\% \text{ Salt} + \text{ Other Milk Solids})/(\text{Fat} + \text{ Protein})].
\]