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Proceedings from the 27th Annual Marschall Italian Cheese Seminar

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SEPTEMBER 12 & 13, 1990
THE FORUM
DANE COUNTY EXPOSITION CENTER
FAIRGROUNDS DRIVE
MADISON, WISCONSIN
PROCEEDINGS
from the
27th ANNUAL MARSCHALL
ITALIAN CHEESE SEMINAR

September 12 & 13, 1990

Sponsored by:
Rhône-Poulenc
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P.O. Box 592
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Federal milk marketing orders have changed slowly and incrementally since their inception in the 1930s. Usually, amendatory hearings are confined to a single order or a few related orders and deal with “fine tuning” of existing provisions. USDA normally seeks to determine whether there is consensus among interested parties before deciding whether to even call a hearing.

In light of the past history of order revisions, July 1990 was a momentous month in the annals of federal orders. Three national hearings were announced to consider substantial changes in the way orders price and pool milk. This paper examines the issues surrounding these hearings and the implications for Italian cheese of some of the changes proposed.

**Butterfat Differentials**

A national hearing was held in late July to consider proposals to modify the way butterfat differentials are calculated under federal orders and in adjusting the M-W price to a 3.5 percent butterfat basis. Proposals considered would lower the butterfat differential in relation to the price of butter. Proponents of this change argue that: (1) Butterfat is in surplus supply and farmers should be sent a market signal that will encourage them to produce less butterfat; and (2) Butterfat values calculated using current formulas are too high relative to the value of butter in the marketplace, resulting in losses to sellers of cream and butter.

The current formula used in federal orders to establish butterfat differentials is based on the wholesale price of Grade A butter in Chicago and the assumed yield of butter per pound of butterfat. The specific formula is:

\[ 0.115 \times \text{Chicago Grade A Price/Lb.} \]

The formula results in a “per point” (one-tenth of one percent) value of butterfat. This butterfat differential dictates what farmers receive for milk testing above or below 3.5 percent. More important, especially for makers of Italian cheese, the butterfat differential establishes the value of skim milk. Under federal orders, the minimum price for skim milk used for making cheese is the M-W price minus 35 times the butterfat differential. In effect, this is the residual value of milk after stripping off the value of butterfat as determined by the butterfat differential.
While varying in method, the proposed changes in calculating federal order butter-fat differentials uniformly reduce the differential relative to the price of butter. Table 1 compares the effect of one proposal (submitted by Agri-Mark, Prairie Farms, and the Milk Industry Foundation/International Ice Cream Association) to the current method. The proposal would calculate the butterfat differential as follows:

$$0.138 \times \text{Chicago Grade A Butter Price/Lb.} - 0.0028 \times \text{M-W Price}$$

Table 1. Fat and Nonfat values under Current and Proposed Method of Calculating Butterfat Differential, Chicago Grade A Butter Price of $0.9825/Lb.

<table>
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<tr>
<th>M-W</th>
<th>BF Diff.</th>
<th>BF Value</th>
<th>Skim Value</th>
<th>Relative Butter Value</th>
<th>BF Diff.</th>
<th>BF Value</th>
<th>Skim Value</th>
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<td>$/Cwt.</td>
<td>$/Point</td>
<td>$/Cwt.</td>
<td>$/Cwt.</td>
<td>%</td>
<td>$/Point</td>
<td>$/Cwt.</td>
<td>$/Cwt.</td>
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<td>0.113</td>
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<td>4.05</td>
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<td>3.96</td>
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<td>4.55</td>
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Note from Table 1 that the modified butterfat differential would be lower than the current differential except at very low M-W prices. That means that the value of butterfat per hundredweight of milk would also be lower than currently, which, in turn, means that skim milk values would be higher.

For makers of Italian and specialty cheeses, there are several important implications of the proposed modifications in calculating butterfat differentials:

1. The cost of farm milk that contains more than 3.5 percent butterfat would be less and the cost of milk testing less than 3.5 percent would be greater. Despite the fact that the average fat test of farm milk is about 3.7 percent, the average cost of milk would not likely change because of an offsetting higher base price (see #3).

2. The cost of standardizing cheese milk using concentrated skim or nonfat dry milk would likely increase, since order minimum skim milk prices would be higher.

3. Other factors constant, the M-W price would increase slightly because proposed changes also apply to converting the “at test” M-W price to 3.5 percent butterfat and the average butterfat test of M-W milk generally exceeds 3.5 percent.

4. Whey cream prices should be about the same for any given level of butter price. Remember that the proposed changes do not alter butter prices; only the butterfat differential relative to butter prices. Cream prices are usually tied to the price of butter.

5. Finally, the cost of Italian and other lower-fat cheeses relative to cheddar would likely be higher. The intent of the proposed changes is to increase the value of the nonfat portion of milk relative to the fat portion. Italian cheese has a higher SNF to fat ratio than cheddar.

The last implication raises the question of how Italian cheese should be priced. In particular, the proposed changes in calculating butterfat differentials highlight the distinction between cheddar cheese and Italian and other specialty cheeses. Tying Italian cheese prices to the National Cheese Exchange “opinion” for cheddar blocks simply doesn’t make any sense given the differences in composition between cheddar and Italian cheese.

In the way of a final comment on the butterfat differential hearing, the proposed changes will have little or no effect on butterfat production at the farm, at least in the short run. The link between fat and protein content of milk is very strong. The value of protein is increasing at the same time that the value of fat is declining. But to produce more of the high-value component, dairy farmers must also produce more fat. Changes in feeding don’t have much of an effect on the fat/protein ratio of milk, and genetic alteration is a slow process. More important, the proposed
changes have little effect of the absolute level of the differential, at least compared to changes in the Commodity Credit Corporation (CCC) butter purchase price. CCC butter price changes have lowered the butterfat differential substantially in recent years (Figure 1), and further reductions are specified in the current House and Senate versions of the new farm bill.

Figure 1

**Butterfat Differential - Chicago Order 1987-92**

Dollars per Point

Projection• based on current status of 1990 farm bill.

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4 Genetic engineering has considerably more potential for significantly changing the composition of milk than genetic selection. But progress to date is limited to the laboratory.
Class I and II Pricing and Classification

In March, Secretary of Agriculture Yuetter announced a national hearing to consider several aspects of pricing and classification of milk used to produce Class I and Class II products (fluid beverages and soft manufactured products, respectively). Proposals were due May 31, and the hearing notice was issued in early July. The notice included more than 50 proposals in four categories: (1) Class I milk prices and related issues; (2) Class II milk prices and related issues; (3) Treatment of reconstituted milk; and (4) Product classification.

The primary motivation for this national hearing is to address concerns about the current single basing point method of pricing Class I milk. Minimum Class I prices are set by adding differentials to the M-W price from two months earlier. The differentials in markets east of the Rocky Mountains vary directly with distance from Eau Claire Wisconsin, from 1.20 in the Upper Midwest (Minneapolis) order to $4.18 in the Southeast Florida (Miami) order. Critics of this pricing method, most from the dairy regions of the Upper Midwest, argue that prices established in this fashion are leading to distorted production incentives. Many of the Class I price proposals offer alternative methods of setting prices that do not rely on distance from a single location.

The Class I pricing issue will undoubtedly yield much smoke and fire at the national hearing, with those seeking change and those supporting the status quo locked in verbal combat in order to make the hearing record demonstrate the irrefutable logic of their respective cases. But the Class I pricing proposals have little economic relevance to Italian cheesemakers. Milk used for cheese is priced at the lowest class price (usually Class III) under all orders.

Proposals dealing with product classification will involve much less fanfare but potentially have much more bearing on the pocketbooks of cheesemakers. In particular, two of the thirteen proposals for changes in product classification could change Italian cheese to a Class I product. Both would amend all orders to allow only two classes. One would place "short shelf-life" products in Class I, with no definition of "short." The other would specifically include as Class I cheeses less than 90 days old. If adopted, either of these proposals could put the raw product cost of Italian cheese higher than lower moisture cheese.

Several proposals to adopt multiple component pricing (MCP) in all federal orders were submitted for consideration at the national hearing. These proposals would have had a major economic impact on cheese plants. Curiously, none of the MCP proposals were included in the hearing notice. Apparently, USDA made a policy decision to consider MCP on an order-by-order basis, and only if requested by interested parties. Hence, it would appear that universal adoption of MCP is several years down the road.
Replacing the M-W Price

The third national hearing that was announced in July 1990 will not take place until late 1991. That hearing will consider a replacement for the M-W price as the basic formula price under all federal orders.\(^5\)

Currently, the M-W price (Minnesota-Wisconsin Price Series) sets the minimum order price for all Grade A milk purchased by order-regulated plants. The M-W price is announced on or before the fifth of the following month. It is the estimated f.o.b. plant pay price for milk of 3.5 percent butterfat for Grade B plants in Minnesota and Wisconsin, including all premiums but excluding any hauling subsidies.

The M-W for the current month is the minimum Class III price for all orders with three Classes and the minimum Class II price for two-class orders. Minimum Class II prices in two-class orders are based on formulas using the previous month's M-W price. Minimum Class I prices are set by adding a differential to the M-W price from two months earlier.

The M-W price is broadly accepted as a valid indicator of the competitive value of milk used to produce hard manufactured products — in spite of some serious problems with unreported hauling subsidies, failure to adjust for SNF premiums in high butterfat milk, and limited competition for Grade B milk, especially in Minnesota. Nobody is particularly keen on replacing the M-W as the basic federal order formula price. The problem is that Grade B milk is disappearing, and replacing the M-W price is no longer an option. The National Agricultural Statistics Service (NASS) has given official notice that it will no longer stand behind the M-W price after July 1, 1992.

Given this ultimatum, the Agricultural Marketing Service of USDA (AMS) has announced a systematic procedure for replacing the M-W price. Starting in September 1990, AMS and NASS will test proposed alternative pricing mechanisms for a one-year period. The alternatives to be tested will be developed based on a recent report on the M-W price issued by the U.S. General Accounting Office (GAO)\(^6\) and industry suggestions.

Following the one-year test, AMS will report how the alternatives compared with the M-W price over the test period and invite proposals supporting the tested alternatives. The national hearing on these proposals is slated for November 1991, and the new basic formula should become effective in May 1992, two months before NASS's deadline for expiration of the M-W price.

While the specific alternatives to be tested are not known at this writing, two types of replacements will be proposed: a competitive indicator based on pay

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prices of order-regulated Grade A plants using milk primarily for Class III products and a product price formula based on reported selling prices of butter, nonfat dry milk, and cheese.

**Competitive Pay Price**

The current M-W price is a competitive pay price. It is an estimate of what Grade B plants in the most competitive manufacturing region of the country have to pay to get milk. The replacement competitive pay price would be similar except Grade A plants would be surveyed, either in addition to or instead of Grade B plants. The geographical base might also be expanded to include plants in other important milk manufacturing states (e.g., New York, California). Since most Grade A plants are regulated under marketing orders, some means of exempting these plants from minimum order pricing rules would need to be devised, and their reported pay price would need to be adjusted for monies obtained from order producer settlement funds (pool draws.) Presumably, further adjustments would be made for hauling subsidies and protein premiums not accounted for by butterfat differential adjustments.

Continued use of a competitive pay price as the order basic formula price has the advantage of involving little change from current practice. NASS would continue to collect and report pay prices which, in turn, would be used to establish order minimum Class prices. Order administration would remain separate from data collection.

A more important advantage is that a competitive pay price represents what plants in competitive areas are actually paying for milk, not what they should be paying or can afford to pay. The distinction is important in setting minimum Class III prices, especially from the perspective of the Upper Midwest. Class III milk in regions where most milk is used for fluid consumption is considered "surplus." If the minimum Class III price is below the manufacturing value in regions where manufacturing is the primary use of milk, then "surplus" milk will be priced at the minimum. This would lead to a competitive imbalance, with varying raw product values. Indeed, a major reason for universal adoption of the M-W price as the Class III price was to equalize competition among Grade B plants and Grade A manufacturing plants selling the same hard products in the same national markets.

A major problem with adopting a competitive pay price based on the value of Grade A milk used for manufacturing is that the basic formula price would be higher than the current M-W price, perhaps by as much as 50-80 cents per hundredweight. This is because Grade A plants outpay Grade B competitors, at least in the Upper Midwest and other manufacturing regions, even after pool draws are accounted for.\(^7\) Using a Grade A competitive pay price would, therefore, be opposed by Class

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\(^7\) See Halvorson, Victor, Prices Paid for Grade A Milk by Selected Manufacturing Plants in Minnesota and Wisconsin. Staff Paper 89-01, Upper Midwest Marketing Area, Minneapolis, October 1989.
III handlers in regions where the M-W price is actually the effective price, since their raw product cost would be elevated. Supporters would likely be in the Upper Midwest, where the higher price is already being paid. These supporters will likely argue that adoption of a Grade A manufacturing price is necessary to achieve the equalization of competition that the M-W price is supposed to accomplish, but is increasingly failing to do.

The higher basic formula price associated with adoption of a Grade A manufacturing competitive pay price would also elevate the entire structure of Class I prices. This could be prevented by reducing Class I differentials by the amount the new basic formula price exceeded the M-W price. But in regions where Class III prices are well above current minimums, lower differentials would cause blend prices to fall.

**Product Formula Price**

The second alternative to the M-W price would, in effect, be a residual value for milk based on product prices, assumed product yields, assumed manufacturing costs, and assumed byproduct values. This is the manner in which manufacturing milk prices to producers (Classes 4a and 4b) are derived under the California milk pricing system.

A product formula price is easy to calculate. It does not require the elaborate survey process needed for the M-W or a replacement Grade A competitive pay price. A formula price could be reported earlier than a competitive pay price, facilitating earlier order settlement fund accounting and faster payrolling.

A product formula price would be less-affected by local market conditions than a competitive pay price drawn from a narrow geographical area. It would be a good indicator of what plants can afford to pay for milk — if plants can sell at the product prices used in the formula, they should be able to pay the residual milk value (assuming appropriate yields and make allowances).

On the negative side of the ledger, a product price formula requires hard decisions about what products to use (butter-powder, barrel cheddar, Brie, Mozzarella?), what product prices to use (National cheese exchange, Wisconsin assembly point, Chicago Mercantile Exchange?), product yields (cheese yields in spring or fall; Wisconsin or California?), and make allowances (large or small plant; automated or manual?). Price reporting for manufactured products is currently inadequate to lend much confidence to a product price formula.

Assuming accurate prices, a product formula may do an excellent job of reflecting competition for butter, powder, and cheese. But the formula may not reflect competition for milk used to make these products. The relationship between product value and milk value is weak. For example, in 1989, the monthly imputed value of milk based on cheese and whey prices varied from 89 cents under to $1.03 over the
M-W price. While some might argue that this variability in implied margins supports the use of a formula price to replace the M-W price, the simple fact is that where their is competition, plants will pay what they must to get milk regardless of what minimum price is specified under an order.

Which Option is Best for the Italian Cheese Industry?

The answer to that question is the classical economist's response: It depends. Where competition for milk used to make hard products is keen, a competitive pay price will be supported in order to insure equality in raw product costs. Class III milk handlers in high fluid utilization markets will support a product formula price to help ensure stable manufacturing margins.

It is possible that both options will be employed; a competitive pay price to set Class III prices, and a product formula to move Class I prices. This would tend to diminish the disadvantages of both replacements.

Ed Jesse is Chairman of the Department of Agricultural Economics, University of Wisconsin-Madison, and an ag policy specialist with the Division of Cooperative Extension, University of Wisconsin-Extension. He joined the Department in 1984 following 16 years with USDA's Economic Research Service. Jesse's research and teaching at Wisconsin have been in the areas of dairy marketing and policy and general agricultural policy. His Extension work has involved public policy education relating to milk pricing issues at the state and federal levels.

Jesse serves on several university, state, regional, and national committees and task forces related to dairy issues. Some recent awards include a USDA certificate of merit, an Economic Research Service Administrator's award for outstanding research, a Group Extension award from the American Agricultural Economics Association, and the Wisconsin Farm Bureau Federation's Award for Distinguished Service to Wisconsin Agriculture. He is a Wisconsin native, raised on a dairy farm near Barron.

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See Jesse, E.V., "Alternatives to the M-W Price - The Case for a Regulated Grade A Manufacturing Milk Price," in Novakovic, Andrew (ed.) Dairy Marketing Notes, 1990 No. 3, Department of Agricultural Economics, Cornell University, p. 5.
Outlook for Dairy
James J. Miller
Economic Research Service, USDA

Last year and this year have challenged the dairy industry to cope with unaccustomed forces and developments. The two years form a chain of events, of which the price declines of the last few weeks may be the start of the last link.

Milk Production

Despite turbulent prices, milk production has been fairly predictable and large during 1989-90. A sharp weakening in mid-1989 milk output was recognized in early 1989 as a distinct possibility, if early production of 1989 crop forage did not relieve tight supplies resulting from 1988's drought. Forage problems, along with cost pressures from the drought, caused milk production to collapse in mid-1989, when a moderate decline in milk cow numbers was joined by a rare decrease in milk per cow. During the second half of 1989, sharply improved returns started to overcome mid-year damage to the cows from forage problems. However, recovery in milk per cow was slow, and milk output remained below a year earlier during the rest of 1989. For the year as a whole, milk production was down just a fraction of 1 percent from 1988 and larger than any previous year.

Sharply higher returns have boosted 1990 milk production. Milk cow numbers gradually moved above a year earlier, although growth in milk per cow was held to a moderate rate by modest milk-feed price ratios. When compared with years other than 1989, it is clear that expansion in 1990 milk production has been remarkably steady, although possibly slower than might be expected in light of high returns. Milk production is expected to be about 148 billion pounds in 1990, up about 2 percent from either 1988 or 1989.

Prices and Use

Dairy markets during 1989-90 have been shaped by competing demands for these large milk supplies and by stock levels. In early 1989, two collective miscalculations were made that would have large ramifications later in the year. First, neither American cheese merchandisers nor nonfat dry milk users took the opportunity to build stocks in response to production uncertainty and export demand for nonfat dry milk. Faced with lackluster apparent domestic demand, nonfat dry milk producers then over-committed their 1989 supplies to exporters. Once these miscalculations were made and the production weakness developed, the question became the heights to which prices would go. By late 1989, the answer turned out to be a rise of a third in Cheddar cheese prices, a doubling of nonfat dry milk prices, and a Minnesota-Wisconsin (M-W) price of manufacturing grade milk of almost $15 per cwt—up almost $4 from March.

1 Presented at the Marschall Italian Cheese Seminar, Madison WI, September 12, 1990.
When wholesale product prices and farm milk prices started to decline briskly in early 1990, normalcy seemed ready to reappear, particularly since the export market for nonfat dry milk had disappeared. However, 1990 turned out to be one of the rare years when expected good growth in cheese demand turned into extraordinary growth in commercial use. Along with recovery in butter sales, rises in cheese use are expected to push up 1990 commercial disappearance of all dairy products about 3 percent.

Users of nonfat dry milk and cheese, some of whom had been hurt badly by late-1989 market tightness, were in no mood to take chances with 1990 supplies. When the surge in cheese sales tightened markets more than expected, pipeline stocks of cheese and user holdings of nonfat dry milk were increased quickly. The spiral of tightening markets and stock building generated counter-seasonal price rises of 20-22 cents for cheese and 43 cents for powder. The M-W price rose from $12.02 per cwt in March to $13.43 in July.

In recent weeks, wholesale prices have unraveled, as users decided their stocks were at least adequate. Cheese prices dropped 5-6 cents, while nonfat dry milk prices fell to near the support purchase price. Significant Government purchases of nonfat dry milk were made in early September. Cheese prices probably will not be able to maintain current levels this autumn, although declines may be limited if unreported stocks of nonfat dry milk prove not to be excessive.

1991 Outlook

Early 1991 milk prices will drop rapidly. The effects of falling prices on milk production will clash with upward momentum generated by a year and a half of high returns. Much less favorable milk-feed price ratios probably will limit growth in 1991 milk per cow. Meanwhile, dropping returns probably will gradually bring milk cow numbers below a year earlier as 1991 progresses. For the year as a whole, milk production is expected to grow, possibly by as much as 2 percent.

Unless a recession intervenes, 1991 commercial use probably will be fairly brisk. Cheese use is expected to grow, although gains are unlikely to match those of 1990. Commercial use of butter and other cream-based products probably will continue to respond to much lower milkfat prices. In total, 1991 commercial use probably will rise 1-3 percent.

Government purchases in 1991 probably will be moderate. However, purchases probably will include significant quantities of nonfat dry milk (and possibly cheese) for the first time since 1988.
Prices will average much lower next year, but probably will be more stable. Most of the fear of shortages and erratic stocking probably will dissipate. For the year, farm milk prices probably will average $2 per cwt below 1990's $14.

**Changes in Location of Cheese Production**

In the long run, changes in regional market conditions will pose major challenges to the cheese industry. Milk available for manufacturing probably will decline in the Corn Belt and Northern Plains. Land values in these regions will remain too high to make production of good dairy forage competitive with other regions. A growing fluid market deficit in the Southeast is likely to draw increasing amounts of milk away from northern manufacturing areas.

The traditional cheese production areas of the Lake States and Northeast probably will remain the heart of cheese country. These regions have shown a long-run capability to maintain their milk production shares and cheese yields are good.

The Pacific, Mountain, and Southern Plains regions will continue to gain milk production share. These areas combine very high quality alfalfa with an efficient farm structure to produce milk cheaply. However, cheap milk does not necessarily mean cheap cheese. The southern portions of this combined area will not be major cheese producers unless cheese yields can be raised there. In particular, the feeding of whole cottonseed may need to be curtailed.

The greatest potential growth in cheese output may come in the Northwest—an area with long-run steady increases in production of high-solids milk. Although much of this area was traditionally wedded to butter-powder output, the growing availability of high-yielding milk will prove an irresistible attraction.

**Longrun Outlook for Calf Rennet**

Supply prospects for calf stomachs are considerably less promising. As fewer milk cows are needed to meet the demand for milk, the numbers of male dairy calves born each year will fall. But, changes in the beef industry will be even more important.

In the mid-seventies, beef grading standards were changed, with the effect of allowing two-thirds to three-fourths of a lot of Holstein steers to reach Choice while retaining good feedlot performance. Such beef is almost ideal for the growing number of retailers selling ungraded beef. As beef packers have to adjust to larger beef cattle, the last major barrier to Holstein beef is falling.
More than half of the cost of raising a beef feeder calf is the cost of maintaining the cow. Since the dairy cow pays her own way, dairy steers are available at relatively low cost. As the dairy industry comes to be viewed as a cheap source of desirable feeder calves, the beef industry inevitably will absorb more Holstein calves.

Future calf slaughter probably has begun a long-term downtrend. Decreases will be most pronounced in slaughter of very young calves—the source of the high-chymosin rennet traditionally favored by the U.S. cheese industry. The cheese industry will be forced to rely less on traditional natural calf rennet.
QUALITY CONSIDERATIONS AND MANUFACTURING OF
ITALIAN CHEESE IN AUSTRALIA

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River Falls, WI 54022

ABSTRACT

Italian cheeses, particularly mozzarella and pizza varieties, represent an important and rapidly growing sector of the Australian cheese industry. With increasing popularity of shredding cheeses and emphasis on developing export market for Australian dairy foods, many Italian cheese manufacturers are adopting mechanized and automated processing systems developed in U.S.A. and Europe, and exploring innovative alternatives to conventional processing, e.g. dry salting to optimize quality yield and profitability.

Traditional quality considerations involving compositional quality, functionality and organoleptic characteristics are emphasized, and increased attention is paid to microbiological quality in order to minimize flavor and body defects and assure compliance with standards and specifications.

Common microbiological quality problems in mozzarella and pizza cheese include a soft-body defect caused by high levels of Lactobacillus casei in the finished cheese and late blowing defect associated with high numbers of Lactobacillus brevis in raw milk. Efforts for understanding microbiological aspects of milk, cheese and processing environment quality are generally by cost and labor intensive conventional microbiological methods. The application of rapid and automated methods in assessing microbiological quality of milk and cheese, predicting shelf-life and characterizing contaminants is being explored.

This paper reviews manufacturing and quality considerations, particularly microbiological aspects of Italian cheese in Australia.

Dairying “Down Under”

In Australia, the dairy industry is gaining prominence as a primary industry with an excellent potential for developing domestic and export market through “added-value” processing. Australia is almost the same size as mainland U.S.A. and about half as large as Europe, excluding U.S.S.R. Milk is produced in all states of Australia under a variety of climatic conditions and management practices. Most milk production is confined to coastal areas where open pastures and environment is favorable for dairying (Figure 1), with majority of milk being produced in three

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leading states: Victoria, New South Wales, and Queensland. The state of Victoria dominates milk production (60% of total) and processing (about 70% of total milk products manufacturing) in Australia.

In 1988, Australia had over 1.6 million cows with average annual milk production per cow of 1600 pounds. In comparison, the U.S. had over 10 million cows with an average annual milk production per cow of 3200 pounds (2). According to recent industry statistics, 29% milk fat and 25% of solid non-fat are utilized for cheese production. Though cheddar cheese is the predominant cheese, Italian cheese and specialty cheeses, viz. camembert, havarti, blue and gouda are gaining popularity in Australia.

Per capita consumption of cheese is increasing to a varying extent in Australia, U.S., and Europe (Figure 2). Consumption of cheese in Asia-Pacific region, e.g. Japan, is also increasing due to popularity of western style fast foods, such as pizza.

Italian cheese production in Australia, particularly mozzarella and other shredding type cheeses is increasing steadily since 1979 (Figure 3). The average annual increase in mozzarella cheese production was 22% compared with a 4.7% increase in total cheese production (Table 1).

Manufacturing Processes

Much of the mozzarella and pizza (shredding types) cheeses in Australia is manufactured using a process similar to that used in the U.S. and elsewhere. With increasing popularity of shredding cheeses and emphasis on developing export market for Australian cheeses, many Italian cheese manufacturers are adopting mechanized and automated systems developed in the U.S. and Europe. There is increased interest in exploring innovative alternatives to conventional processing. In particular, salting options such as dry salting, combination of dry and brine salting and modifications of traditional salting are being investigated.

Typical manufacturing process for mozzarella cheese in Australia involves standardization and pasteurization of milk followed by starter and rennet additives to allow formation of curd. Following cooking of the curd and draining of the whey, the cheese coagulum is subjected to molding, stretching and salting operations (Figure 4). Times, temperatures, acidity levels, etc. are varied depending on manufacturing conditions, customer requirements and variation in the milk supply. Impact of seasonal variations in milk composition on yield and quality of cheese has been studied in the US (3,7). The fluctuations in milk solids, particularly its casein content influence cheese yield. Also variations in calcium and phosphorous content of milk influence quality of Mozzarella cheese (7). While seasonal variations in milk composition is believed to have a significant effect on yield and quality of cheese in Australia no major reports on the subject have appeared in the recent scientific literature nor has the subject been discussed at dairy industry sponsored meetings and seminars.
Quality Considerations

Australia defines cheese quality the same way we do (1,10), i.e. in terms of its attributes (Table 2). Italian cheese supplied to the distributor or processor must conform to regulatory standards and specifications – % moisture, % FDB etc. The cheese must also meet specific requirements before it is labelled "low fat" or "low salt" cheese. Also the cheese must be relatively free from extraneous matter and defects.

The main cheese quality attributes also include meeting customer requirements in terms of functionality of cheese i.e. melting properties, texture, color, shredability, etc. Since different customers have different and often subjective expectations for the quality of cheese they wish to purchase, the cheese manufacturer has to aim to meet the quality expectations of the specific customer. While this is a difficult goal, several manufacturers meet the customer requirements by establishing realistic expectations for cheese quality through frequent and open communications with the customer.

Microbiological aspects of Italian cheese quality mainly include starter culture performance, and detection of coagulase positive Staphylococcus aureus and enumeration of coliforms in fresh cheese. Elaborate analyses of cheese and processing environment for Listeria monocytogenes and other so called emerging pathogens is limited to industry surveys conducted by the regulatory authorities. Several dairy processors in Australia have adopted the HACCP approach for comprehensive quality assurance. A similar approach for assuring safety and quality of Mozzarella cheese has been described earlier (10).

Factors influencing cheese quality include raw materials, starter culture and processing parameters such as pH, acidity, temperature, i.e. rate of cooling and salt equilibration through the cheese.

Microbiological Considerations

Microbiological quality of cheese largely depends on the microbiological quality of cheese milk as well as storage, processing and handling of milk prior to cheese making. The importance of low microbial load along with proper pasteurization and manufacturing process is stressed to minimize quality defects such as soft body and late gas development.

Routine microbiological evaluation of Italian cheese include coliform and yeast and mold counts. Often, cheese may be analyzed for a specific microorganism such as Staphylococcus aureus, Escherichia coli or Salmonella. Microbiological specifications for coliforms, non-starter lactobacilli or Clostridium spores have been occasionally used by vendors to obtain high quality cheese for export.

Among the microbiological quality problems in mozzarella and pizza cheese include late gassing or distention (blowing) of the wrapping and soft and pasty body.
The association of heterofermentative lactic acid bacteria with the “blowing” of the wrapping and “open” texture in cheddar cheese has been reported, e.g. Laleye et al (9) studied the problem of gas formations and open texture in Canadian cheddar and Oak cheeses. Their reports indicated that high numbers of lactobacilli, especially heterofermentative and citrate fermenting organism were associated with defective cheese. They did not detect any correlation between levels of coliforms, staphylococci, yeast molds, and clostridia and formation of late gas during maturation process.

Earlier, a study at the National Institute for Research in Dairying at Reading, U.K. (5) reported that the ability of Lactobacillus casei to produce distention or blowing of the wrapper may be related to fermentation of citric acid by the organism.

Elliot et al (4) reported that a gram positive, asporogenous, pleomorphic, slow-growing anaerobic rod shaped organism was responsible for causing gas formations in nine to twelve month old Canadian cheddar.

The association of Lactobacilli with a soft-body defect in commercial mozzarella cheese was studied by Hull et al in 1984 (6). This soft-body defect was first apparent in the center of the loaf as a soft-pasty body. The default affected slicing and melt-down characteristics. Chemical analysis of soft-body mozzarella showed a large difference in salt concentrations in 1 to 3 week old cheese. However, this difference was not apparent after ten weeks, suggesting normal equilibration. Microbiological analysis showed $10^4$ to $10^6$/gram of non starter lactobacilli, Lactobacillus casei. These were found in low numbers (0-1000/mL) in some supplier’s milk and in milk powder used for standardization. The strains of Lactobacillus casei were able to survive normal heat treatment (pasteurization) and were able to grow to 6 °C. and in presence of 5% NaCl. These bacteria were capable of growing in mozzarella at conditions that will suppress the growth of starters.

The role of non-starter lactobacilli in the development of soft body defect in mozzarella cheese was also investigated in the U.S.(9). Mozzarella cheese exhibiting a soft body defect was found to contain high numbers of non-starter lactobacilli. All isolates obtained from soft cheese were proteolytic and many were psychrotrophic and thermoduric. No lactobacilli were detected in the normal cheese. Mozzarella cheese with soft body defect was produced when cheesemilk was inoculated with certain Lactobacillus isolate prior to cheese making by direct acidification (9).
Rapid and Automated Methods

Seasonal variations in levels of non-starter lactobacilli, and other organisms such as aerobic and anaerobic spore forming bacteria may lead to quality problem in Italian cheese. Consequently, microbiological quality of milk is being stressed. However, the focus of dairy microbiology has largely remained on conventional plating methods and isolation and biochemical characterization of microorganism of interest. The conventional microbiological methods are slow, labor and material intensive and often retrospective in nature. Interest in rapid and automated methods for detection, enumeration and characterization of microorganisms in milk and cheese has been growing steadily. Among the methods designed to estimate total bacterial numbers are the impedimetric methods, bioluminescence (ATP) measurement, and Direct Epifluorescent Filter Technique (DEFT). While instruments such as the Bactometer, Malthus, Bio-Foss and Lumac systems are being evaluated by some dairy factories, the majority of microbiological testing is done by routine conventional methods. The use of rapid methods in isolating and characterizing a specific microorganism of interest is often limited to the diagnostic “kits” and ELISA tests for identifying bacterial isolates. The automated instruments such as AMBIS system or the Vitek AMS are very seldom employed by the dairy industry.

The CSIRO Dairy Research Laboratory at Highett conducted a workshop to familiarize the dairy industry professionals with a variety of rapid and automated systems available for routine microbiological analyses in dairy industry. An on going program of research has been established at the CSIRO - DRL to develop applications of rapid and automated methods in dairy microbiology. It is anticipated that the application of rapid and automated methods in dairy microbiology in Australia will flourish as specific applications are developed and the “alternative” methods are shown to be efficient and reliable as the conventional microbiological methods for enumerating, isolating and identifying various microorganisms of interest to safety and quality of milk and cheese.
REFERENCES


### Table 1. Mozzarella, Pizza and other shredding cheese production in Australia 1979-1989

<table>
<thead>
<tr>
<th>Year Ended (30 June)</th>
<th>MOZZARELLA '000 tonne</th>
<th>Increase from previous year</th>
<th>TOTAL CHEESE '000 tonne</th>
<th>Increase from previous year</th>
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<td>1989</td>
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<td>12%</td>
<td>11.5</td>
<td>190</td>
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</tbody>
</table>

11 Year Average Annual Increase 22% 4.7%

### Table 2. Attributes of Mozzarella Cheese Quality

1. **Regulatory Standards and specifications**
   - % moisture, % FDB, salt content, labeling

2. **Organoleptic attributes**
   - Flavour, Colour, Texture

3. **Functionality**
   - Meltability, stretchability, Shreddability, Slicing

4. **Microbiological**
   - Coliforms, Staphylococcus aureus, yeasts and molds,

5. **Customer requirements**
   - Melting, Stretch, appearance, colour, antifungal agents
Figure 1 Milk producing areas in Australia

![Map of Australia showing milk producing areas]

Figure 2 Cheese Consumption Trends

![Graph showing cheese consumption per capita from 1965/66 to 1994/95]

Source: ADC; team analysis

Figure 2 Cheese Consumption Trends
Figure 3. Comparison of Mozzarella and total cheese production in Australia.
Figure 4 – Manufacturing methods for making Mozzarella cheese.

Times, temperatures and procedures illustrated are varied to suit particular manufacturing conditions, customer requirements and variations in the milk supply.
THE USE OF MOLDS IN CHEESEMAKING

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1/ INTRODUCTION

In most cheese plants, molds are not welcome. They are considered a defect and cheesemakers would happily exterminate them to the last spore. In some operations, however, molds are fed, pampered and loved. Why this difference in treatment? Have some cheesemakers signed a pact with the devil? No, of course, but some cheese operations, instead of fighting the molds, have harnessed their potential to produce a variety of specialties from Gorgonzola to Brie. If you cannot beat it, eat it!

Molds, are part of the fungi family. The simplified chart shown in figure 1, helps situate the mold family relative to their first cousins, the yeasts, or their distant relatives, the bacteria, that grow and multiply in our starter tanks.

Figure 1- The mold's filiation.
Microscopic examination of a mold shows a branched structure, the mycelium, which extremities form small thick-walled spores (Figure 2). The spores are the mold's "seeds". They are very resistant to adverse conditions, and that allows them to survive until they find a favorable environment in which they can develop into a new mycelium.

Figure 2- The Penicillium under the microscope.
The most commonly used mold species are: *Penicillium candidum*, *Geotrichum candidum* for surface ripened cheeses and *Penicillium roqueforti* for Blue cheese.

### 2-1/ *Penicillium candidum*

This white mold, also known as *Penicillium caseicolum*, *Penicillium camembertii*, or *Penicillium album* gives its white rinds to the Bries and Camembert of the world.

Its growth is relatively slow compared to other *Penicillium* species. It can grow between 40°F and 86°F, the optimum temperature being 72°F. The pH has little influence on the growth of the commercial strains between 3.0 and 8.0. Wild strains usually prefer lower pH. Sodium chloride concentrations up to 20% won’t stop the growth, but partial inhibition appears over 5%. This mold is strictly aerobic and produces proteolytic and lipolytic enzymes.

### Geotrichum candidum

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3-1/ Protection

It is certainly the main role of the white molds in surface-ripened cheeses. These soft, high-moisture cheeses constitute prime targets for surface contaminants. It is certain that their tempting surfaces are not going to remain bare, the only question is: “What species is going to cover it?” By inoculating the surface with a high number of selected strains of a desirable species, one can prevent any other microorganism from growing.

3-2/ Flavor and texture

All three species described earlier utilize lactic acid in their metabolism. During the ripening phase, molds consume some of the lactic acid produced earlier by the lactic acid bacteria. This leads to a neutralization of the cheese acidity.

The mold’s proteases play an important role in the curd proteolysis that will give the cheese its final texture and produce peptides that are part of the aroma.

Finally, the lipolytic activity of the Penicillium or Geotrichum produce free fatty acids that are important flavor compounds and serve as precursors for different aromatic products synthesis. The molds also have the enzymatic potential to synthesize some aromatic compounds such as, for example, the methylketones that play a major role in the Blue cheese flavor.

3-3/ Appearance

Who can think of a Blue cheese without its blue veins, or of a Brie without its white rind? Parameters such as vein color, the rind color or thickness can be modified by using different mold strains, or varying the mold’s growth conditions.

4/ SELECTION AND PRODUCTION

4-1/ Selection

The first strains used as fungal starters, were simply isolates from good quality cheeses. With time, the pressure for more control over the ripening phase increased and the selection process had to be refined. The selection criteria are in general the following:

- Rind’s microscopical aspect
- Color and color stability with aging
- Lag phase and growth rate
- Resistance to mechanical treatments
- No undesirable odor or flavor
- Enzymatic activities: proteolytic, lipolytic, aroma production
- Influence of salt, pH, temperature and humidity on growth
- Behavior in the presence of other molds
4-2/ Production

Commercially available cultures contain mold spores that are dried, freeze-dried, or in a liquid suspension.

Traditionally, the molds, being aerobic microorganisms, were produced by surface fermentation. The Penicillium candidum were grown on liquid media in flat flasks. The mycelium would form a "skin" on the surface of the liquid, that was collected to harvest the spores. Blue molds have been produced for ages on... bread, an inexpensive and readily available media. During the past few years, with the progress in fermentation technology, molds suppliers have increasingly switched their productions to submerged cultures in fermentors.

Following, the fermentation, the spores are separated from the mycelium, usually by centrifugation. The resulting concentrate is then freeze-dried or suspended in a protective solution and packaged.

5/ CONCLUSION

Even though molds have been around for a long time, they might not have been exploited to their full potential. In these days of increasing demand for specialty and "natural" products, molds, as well as other ripening cultures, can provide a wide range of coloring, flavoring and texturing properties at a very low cost. It may well be, that in the future, Molds will not been seen as natural calamities, but as reliable production auxiliaries.
GENETIC APPROACHES FOR THE IMPROVEMENT OF STRAINS FOR ITALIAN CHEESE MANUFACTURE

Mary Ellen Sanders, Ph.D.
Consultant

I. Introduction

Issues facing the modern cheese manufacturer including strict production schedules, demands for consistent quality product, and maximizing efficiency and profit margin make cheesemaking more challenging today than ever. The modern cheesemaker needs cultures that will help him meet these challenges. Research efforts worldwide are directed toward culture improvement strategies that will enable directed strain development using the techniques of modern molecular biology and recombinant DNA (rDNA) technology. These techniques will allow: (i) directed changes (increases or decreases in expression) in traits already expressed in the lactics; (ii) an exchange of traits among strains or species to provide new genes from closely related bacteria; or (iii) introduction of foreign genes (e.g. chymosin, lipases, etc.) from unrelated sources. These techniques are very powerful because entire gene systems can be introduced, deleted, or altered. This is in contrast to classical techniques where changes can be exacted only in genes currently harbored by the strain, and these changes are usually incremental. The potential for genetically improved cultures is great. However, especially for the strains used in Italian cheese manufacture, that potential has not been realized. This paper will address the state of genetic research with Italian cheese strains and discuss what has been achieved and what may lie ahead.

II. Microbiological Considerations for Use of Italian Starters

Italian cheeses include a diversity of products including mozzarella, parmesan, asiago, provolone, gorgonzola and ricotta. The microbiology, enzymology and processing of each of these products is different. However, in the United States, where pasteurized milk is used and most starters are intentionally added starters of consistent composition, the predominant cultures used are Streptococcus thermophilus, Lactobacillus bulgaricus, and Lactobacillus helveticus. Although taxonomic designations for these species has recently been changed to Streptococcus salivarius subsp. thermophilus and Lactobacillus delbreuckii subsp. bulgaricus, respectively, the aforementioned designations will be used for simplicity. Factors affecting starter performance are numerous. This section will briefly discuss several microbiological considerations in the day-to-day use of starters for Italian cheese.

Synergism. Italian cheese starters are special in that the rod and coccus components interact in a synergistic manner. The mechanism of this synergism is the release of formate by S. thermophilus which stimulates the growth of Lactobacillus, and the release of peptides by the more proteolytic Lactobacillus which stimulates the growth of S. thermophilus.
This synergism is significant in that mixed cultures of rods and cocci generally perform better than their single strain components. Also, it is important that strains be evaluated and used as components of known mixtures to enhance this synergistic response. Random blending of rod/coccus strains may result in disappointing performance due to poor synergism, incompatibility or poor strain balance. Therefore, an understanding of the blends of strains that are being used is important.

**Phage.** There are many examples, both published and unpublished, which demonstrate the presence of phage in the Italian cheesemaking environment (Rajagopal and Sandine, 1989; Reddy, 1974). However, unlike mesophilic cultures, the degree to which phages disturb acid production by starters is somewhat unclear. This uncertainty stems from several factors. First, thermophilic phages seem to have diverse requirements for growth and plaque development. Although efforts have been made to determine the best medium for phage propagation (Sozzi, et al., 1976), it seems no one medium works for all thermophilic phages. Therefore, phage presence may be missed. Secondly, the use of undefined mixtures of strains makes it more difficult to identify the phage-inhibited strain. Inhibition of one strain in an undefined blend may be difficult to prove due to masking of the inhibition by growth of other uninhibited strains in the blend. Therefore, defined single strain starter systems are best for tracing a phage problem. Thirdly, starter inhibition can have many causes other than phage, including chemical inhibitors, antibiotics, strain incompatibility, temperature sensitivity, disinfectants, detergents, insecticides, peroxidase systems, agglutinins, bacteriocins or too much oxygen. However, recently Rajagopal and Sandine (1989) sampled whey from six Italian cheese plants experiencing slow acidifications problems. Of these six samples, phage were found in five, suggesting the involvement of phage in starter inhibition. Results also showed that only one whey sample had phage activity against the rod component, where as five were active against *S. thermophilus*. This supports a widely held belief that phage problems in thermophilic starters are much more common and devastating against the coccus portion of the blends. To confirm the presence of disturbing phage in a cheese plant, a commitment must be made on the part of the manufacturer to collect suitable samples and conduct appropriate tests. Otherwise, the cause of starter inhibition may never be known.

A multi-faceted approach must be used for phage control. The importance of good sanitation can not be under emphasized. Sanitation serves a critical role in breaking the phage infection cycle by reducing levels of phage to an insignificant number. In addition, starter handling, phage inhibitory media, strain selection, strain rotation, monitoring whey for phage, and removal of cultures that do not perform in the particular environment all contribute to control of phage.

**Management of starter activity.** The activity level of a starter culture is important to the make time and the quality of the cheese. A starter should be neither too fast nor too slow, and the development of acid should be at a predictable rate through the course of manufacture. The temperature sensitivity of strains allows some control
of acid production through temperature adjustment. Acid production can be influenced by the presence of chemical inhibitors, phage, media and starter ripening system. The medium and starter ripening strategy (internal or external pH control) should promote good rod and coccus development and minimize acid damage of a developing starter. Recently, whey based phage inhibitory Italian bulk starter media were evaluated (Rajagopol, et al., 1990) demonstrating that activity levels and degree of phage control can vary greatly among commercially available products.

**Galactose metabolism.** Residual galactose in mozzarella cheese is associated with a browning defect in cooked products. Solutions to this problem focus on either the cultures or on processing steps which eliminate residual galactose. Although reports of rod/coccus cultures which utilize galactose have appeared in the literature (for review, see Hutkins and Morris, 1987), it has been difficult to find strains which possess all the necessary criteria (phage resistance suitable activity, compatibility in blends). Furthermore, *S. thermophilus* strains which utilize galactose do not appear to retain the characteristic permanently, but only under certain physiological conditions (Thomas and Crow, 1984). Although *L. bulgaricus* strains which ferment galactose are not common, other lactobacilli do possess this property and may be suitable for Italian cheese applications. It seems that approaches have not been exhausted in the development of Gal+ Italian cheese strains.

**Strain Differences.** Although strains may be taxonomically assigned to one genus and species, significant physiological and metabolic differences can exist within *Streptococcus thermophilus, Lactobacillus bulgaricus* and *Lactobacillus helveticus* groups. This strain to strain variability exists with sugar metabolism, phage sensitivity, rates of acid production, salt tolerance, proteolytic activity, genetic accessibility, and growth rates. These differences are very useful in identifying strains for specific applications, but can be problematic when trying to find several strains to yield similar cheese makes.

**III. Requirements for Directed Genetic Strain Construction** Although strain to strain differences do exist among strains used for Italian cheese manufacture, it is not an easy task to find one strain which can perform all the necessary tasks under the rigors of tight production schedules and quality standards. As the field of molecular biology advanced and techniques in gene manipulation were developed, researchers began applying this knowledge to lactic acid bacteria in the hopes of constructing improved dairy strains in a very directed fashion. New technology in gene manipulation, gene isolation and gene transfer held much promise for solving genetic deficiencies in strains given to us by nature. Defined genes encoding industrially important traits could theoretically be introduced into desirable strains giving them functions not previously possessed. A furious period of technique development ensued and successes mounted as more and more laboratories worldwide entered into the field of genetics of lactic acid bacteria.
In order to apply rDNA techniques to dairy strains, some tools are required. First, certain techniques must be available. A method to introduce DNA into new strains is essential. Techniques to accomplish this include conjugation, transformation and transduction. All of these are "natural" methods of genetic transfer, i.e. have been shown to occur in nature without interference from man. However, certain laboratory manipulations can drastically improve the efficiencies of all of these processes. Transformation is the process whereby a cell takes up naked DNA from the environment. Natural efficiencies for this process can be quite low, and treatment of the cells with certain cations, polyethylene glycol or with an electric current can drastically improve efficiencies. Conjugation is the process whereby DNA is transferred from one viable cell (donor) to another viable cell (recipient). Transduction is a phage-mediated transfer of DNA. Phage particles package non-phage DNA and deliver it via phage injection into a recipient cell. To perform these techniques in a laboratory in a meaningful, controlled fashion, the DNA to be transferred must be marked with a trait that can be detected in recipient cells. For convenience, antibiotic resistance markers have been used. However, antibiotic resistance is not a trait desirable in food-grade microorganisms and therefore naturally occurring genes from the lactic cultures, such as nisin production or resistance, carbohydrate fermentation, proteolysis or phage resistance can be used to follow gene transfers.

Secondly, evidence needed to be obtained that standard DNA manipulation techniques worked with lactic acid bacteria. Although DNA isolation techniques specific for lactic cultures were required, methods for DNA cutting, ligation, polymerization, hybridization, and sequencing were no different than for microbes as a whole. Therefore, little optimization was necessary for lactic DNA manipulation.

Third, it was necessary to develop genetic markers which expressed and plasmid vectors which replicated in the lactics. The first example of a food-grade vector was recently reported for the lactococci (von Wright, et al, 1990). No such vector has yet been developed for the thermophilic lactics, although a variety of non-food grade vectors have been developed and used (for review, see Batt, 1986).

Lastly, realistic targets needed to be defined and an appropriate level of knowledge about the physiology and biochemistry of these traits needed to be accumulated. Thermophilic starter cultures must express proper levels of the following: phage resistance, lactic acid producing ability, proteolysis, salt tolerance, resistance to phosphated media, polysaccharide formation, flavor production (absence of flavor defects) and galactose metabolism. Therefore, these are tempting phenotypes to approach for genetic manipulation. However, gene manipulation for these and other traits requires knowledge of the structure and location of the genes encoding these properties. In most cases for the thermophilic starters, this is not known.
Although recombinant DNA technologies hold great potential, and given adequate resources accomplishments seem limitless, it is important to keep sight of what the classical methodologies of selection, mutation and screening for strains has done and will continue to do for the industry. Essentially all of the strains currently available for Italian cheese manufacture have come from nature. The challenge has been in finding, describing and fine tuning them. When a strain failed to perform due to phage sensitivity, mutants could be isolated, characterized and returned to production. Entire defined strain programs for both mesophilic and thermophilic cultures are based on the ability to replace phaged-out strains with comparable replacement cultures, usually mutants of the original culture. Similar approaches have been used regularly when requiring different strains for new applications.

IV. Genetic Advances with Italian Cheese Starters

This section will address progress made in the genetic manipulation of thermophilic cultures.

**Genetic Transfer Systems.** Transformation and conjugation systems have been reported for both *S. thermophilus* and *L. bulgaricus*. Mercenier, et al (1988) and Somkuti and Steinberg (1988) established conditions for the transformations of several strains of *S. thermophilus*. Mercenier et al (1988) reported much strain to strain variability for transformation conditions. Luchansky, et al (1988) transformed a variety of Gram-positive bacteria, including *Lactococcus acidophilus*, *L. casei*, *L. fermentum*, *L. plantarum*, and *L. reuteri* (no *L. bulgaricus* or *L. helveticus* were done). Their results suggest that the technique is general enough to work for other *Lactobacillus* strains and species, although only one unconfirmed report (Batt, 1986) of transformation with *L. bulgaricus* has been published.

Conjugation has been demonstrated repeatedly for many members of the lactic acid bacteria. However, examples of this type of genetic transfer are less common with the Italian cheese strains. Thompson and Collins (1988) reported on the conjugal transfer of pLP501 from lactic streptococci to *L. helveticus* and *S. thermophilus*. pLP501 is a broad host range conjugal plasmid which confers resistance to erythromycin and chloramphenicol. Romero, et al (1987) also demonstrated conjugal transfer in *S. thermophilus* using the broad host range plasmid pVA797. No transduction system has yet been identified for the thermophilic cultures.

These studies have begun to demonstrate that the Italian cheese strains can be accessed genetically. However, *L. bulgaricus* seems to be less amenable to genetic manipulation than *S. thermophilus*, and both of these species are far behind the state of the mesophilic lactic strains. More research is clearly needed to develop a comprehensive body of knowledge on the genetics of these strains so directed genetic manipulation of a broad base of strains can begin.
Phage Characterization. Some excellent and in depth molecular biology has been published on _Lactobacillus_ phages. Unfortunately for our search for information on Italian cheese starters, most of the research been done on phages of _Lactobacillus casei_ and _L. lactis_. These studies were mainly conducted by three investigators, M. Shimizu-Kadota, T. Alatossava, and K. Watanabe. A summary of their results is presented in two recent reviews (Sanders, 1989; Sechaud, et al, 1988). _L. bulgaricus_ phage have been studied relative to morphology (Accolas and Spillmann, 1979; Sozzi, et al., 1981); genome size, structural proteins and growth kinetics (Chow, et al, 1988); taxonomy (Lahbib-Mansais, 1988); incidence of lysogeny (Cluzel, et al, 1987); DNA homology (Mata, et al, 1986); and incidence in Italian cheese whey (Reddy, 1974; Rajagopal and Sandine, 1989).

_Streptococcus thermophilus_ phages have been surveyed more frequently than those of the lactobacilli, but fewer in depth molecular and biochemical studies have been performed with them. Three comprehensive studies with _Streptococcus thermophilus_ phages were conducted: Krusch, et al (1987) examined 76 different phage isolates for morphology and host range; Kivi, et al (1987) studied the morphology, host range, adsorption capabilities, structural proteins and serological properties of nine phages; and Neve, et al (1989) studied the genomes and structural proteins of twelve phages.

Phage Resistance. There is very little information on the phage resistance of thermophilic starters. This is unlike mesophilic cultures, where a variety of phage resistance mechanisms have been discovered and studied in depth and strains with improved phage resistance have been constructed using directed genetic techniques. The one exception to this is the identification of host dependent phage replication abilities in _S. thermophilus_ (Mercenier and Lemoine, In Press), which is indicative of restriction/modification systems. The lack of information on phage resistance phenotypes has prevented genetic manipulation of this very important trait for Italian cheese strains. It is likely that efforts will be directed at determining if mesophilic phage defense mechanisms are functional in thermophilic strains. However, this so far has not been published. For a recent review of phage resistance mechanisms in the mesophilic strains see Sanders (1988).

Cloning and Sequencing. Cloning and sequencing efforts for the thermophilic strains have focused primarily on metabolic genes. The B-galactosidase gene of _Lactobacillus bulgaricus_ was cloned into _E. coli_ and the nucleotide sequence was determined (Schmidt, et al, 1989). The B-D-galactosidase gene from _Streptococcus thermophilus_ was cloned and expressed in _E. coli_ (Herman and McKay, 1986), but sequence data is awaiting publication (Schroeder, Robert, Lenzen, McKay, and Mercenier, submitted for publication). Genes encoding aldose 1-epimerase (catalyzing enzymatic mutarotation between alpha and beta D-glucose isomers) and UDPglucose 4-epimerase (a Leloir pathway enzyme) were also cloned from _S. thermophilus_ and sequenced (Poolman, et al, 1990).
These efforts are important to providing basic information on the structure and regulation of genes for expression vector construction and for targets for genetic engineering of the thermophilic strains.

**Plasmid Characterization and Vector Development.** Plasmids are extrachromosomal pieces of DNA that usually encode genes which are not essential for cell survival, but can aid growth and competitive ability under certain conditions. Plasmids exist autonomously from the bacterial chromosome, since they direct their own replication. Plasmids are numerous in the mesophilic lactic cultures and code for many industrially important traits, including lactose metabolism, proteolytic ability, bacteriophage resistance, flavor production and conjugal transfer (Sandine, 1987). Lactococci may harbor as many as 12 plasmids per strain. However, plasmids are much less common in the thermophilic starter strains. Among the lactobacilli tested, only *L. plantarum* appears to harbor a large diversity of plasmids (Ahrne, et al. 1989). Even so, plasmid-linked traits in lactobacilli include β-D-phosphogalactosidase in *L. casei* (Chassy, et al., 1978), drug resistance in *L. acidophilus* (Vescovo, et al, 1982), and acetyl-D-glucosamine fermentation in *L. helveticus* (Smiley and Fryder, 1978). Surveys looking for plasmids in *S. thermophilus* have shown that plasmid DNA is not common (Herman and McKay, 1985). Most strains of *S. thermophilus* are void of plasmids, and those that harbor plasmids rarely contain more than one. These plasmids tend to be small and are related to each other. Those that are present, though, will provide good candidates for the development of vectors.

Plasmids are critical to genetic engineering efforts. They provide selectable markers for genetic transfer system development and serve as carrier DNA for introducing new DNA into host cells. Although a variety of vectors containing antibiotic resistance genes and backbones from non-lactic sources have been used with lactic acid bacteria, ideally vectors for these efforts should consist entirely of DNA from lactic cultures. This should facilitate their acceptance in food products by both consumers and the government. Furthermore, vectors are more likely to replicate in microbes similar to the ones from which they were derived. Takiguchi, et al. (1989) sequenced a small cryptic plasmid from *Lactobacillus helveticus* for use as a cloning vector. von Wright, et al (1990) recently reported the construction of the first functional food-grade vector, pVS40, for use in the mesophilic lactococci. pVS40 contains only lactococcal DNA and carries a single selective marker, nisin resistance. Although this vector is not likely to function in rod/coccus cultures, it is a good model on which to proceed. Additional vectors for use with *Lactobacillus* strains have been developed using lactose metabolism genes (for review, see Batt, 1986).
V. Conclusions

The tools for the directed genetic improvement of thermophilic starter strains are being rapidly developed, although the pace lags far behind that set for the mesophilic starter strains. Sequenced genes, vectors, and gene transfer systems are now available for thermophilic strain development efforts. Although these strains are not yet available for commercial use, the potential is great that soon we will see strains with enhanced phage resistance, galactose fermenting *S. thermophilus* or *L. bulgaricus* strains, or more proteolytic *S. thermophilus* in regular use. These strains will hopefully give the cheesemaker greater control of his process, greater consistency, and perhaps expanded capabilities that previously were not possible. Those involved in these development activities must deal with several important issues, such as (i) the cost of development and subsequent return on investment, (ii) how to protect or patent the cultures once the investment in development is made, (iii) government reaction to the existence of genetically altered strains, and finally (iv) consumer acceptance of products made from these strains. However, the extent of research currently being conducted or the molecular biology of lactic acid bacteria suggests that the worldwide climate is one of acceptance of rDNA approaches and optimism for the future position of such strains in food manufacture.
REFERENCES


SANITIZERS
BASIC SANITIZER TYPES
Selection and Proper Use for Best Results
Jon G. Porter
KLENZADE A Service of Ecolab Inc. - Training Material

TOPICS:
Sanitizing of Flow-Through Areas (C.I.P.)
Surface Sanitizing
Area Sanitizing
Sanitizing of Working Environment

The most important principle concerning sanitizing/disinfection is that a dirty surface can not be sanitary. The sanitizer cannot come into contact with bacteria trapped in and under soil.

The undisturbed growth of microorganism under ideal conditions is shown below. One bacterium under perfect conditions could produce one billion bacteria in ten hours. Clean and sanitary conditions are critical for product quality.

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Characteristics of sanitizers

ACTIVE CHLORINE:

Active chlorine has been in use for many years as a disinfectant in the food industry because of its broad bactericidal spectrum and economic advantage. The active chlorine carrier has taken several forms with the liquid types based on inorganic chlorine compounds, such as sodium hypochlorites and the powder form based on organic chlorine compounds, such as the dichloroisocyanurate group.

Most often the bactericidal effect of active chlorine is best in a neutral or weakly acidic condition (pH 5 to pH 7), but the chlorinated alkaline cleaners also have an excellent bactericidal effect against all groups of microbes. Many tests, according to various methods, have proved that chlorine renders a very fast kill on viruses, bacteria, yeasts, and molds. The activity against spore-forming bacteria is slightly slower.

The question of the corrosiveness of hypochlorite solutions on metals such as stainless steel and aluminum is still a matter of intense discussion, resulting in certain reservations regarding chlorine-based products.

CHLORINE SANITIZERS HAVE THESE ADDITIONAL ADVANTAGES:

- unaffected by hard water scales,
- non-filming,
- can be utilized at cool water temperatures without affecting activity.

DISADVANTAGES INCLUDE:

- precipitation when used in iron-laden water,
- short residual effect after sanitizing.

The rule of thumb is that if chlorine is used as a sanitizer prior to production, the equipment should be used within one hour after the sanitizing procedure.

HYDROGEN PEROXIDE:

Sanitizers based on hydrogen peroxide are most suitable for use in the dairy industry. This is attributed to its non-contaminating residues of water and oxygen. It has been used in the pharmaceutical and food processing industry for the aseptic packaging area. UHT milk in Europe is heated to 212°F with a 25 - 50% concentration of hydrogen peroxide and a short contact time. There is complete microbial destruction, including the destruction of *Bacillus* spores.
THE FOLLOWING DENOTE ADVANTAGES AND DISADVANTAGES OF DIFFERENT TYPES OF SANITIZERS:

IODOPHOR SANITIZERS:

Acidic iodine-based sanitizers have a universal killing effect on all types of microbes. The amount of active ingredients to achieve the same killing power is lower in iodophors than in active chlorine-based products.

Usually by increasing the temperature of the sanitizing solution, the killing time is reduced, and this is true for the iodine type products as well. Iodine will gas off at temperatures of 102°F-120°F and the loss of the iodine is high. This and the possibilities of corrosion make it standard practice to use iodophors at room temperature.

ADVANTAGES INCLUDE:

1. Stable, long shelf-life.
2. They are active against all microorganisms except bactericidal spores and phages.
3. They are unaffected by hard water salts, with the exception of water which contains large amounts of chlorides, leading to corrosion of stainless steel and aluminum.

DISADVANTAGES INCLUDE:

1. They are not as effective against spores and phages as chlorine.
2. They are expensive.
3. Iodophors stain porous metal surfaces and plastics.
4. Iodophors are severely affected by alkaline conditions above pH 7.

HYPOCHLORITES:

ADVANTAGES:

1. Powerful germicides controlling a wide range of microorganisms.
2. Deodorizer.
3. Non-poisonous to man at use concentrations.
4. Free of poisonous residuals.
5. Colorless and non-staining.
6. Easy to handle.
7. Most economical to use.
DISADVANTAGES:
1. Short shelf life.
2. Adverse effect on skin.
3. Corrosive on some metals.

USE CONCENTRATIONS:
50-100 ppm available chlorine should be employed for sanitizing large equipment and utensils and 200 ppm for spraying applications of large equipment. The contact time for effective sanitation should be long enough to produce complete kill of bacteria, usually 10 seconds or longer.

ACID ANIONIC:

ADVANTAGES:
1. Non-staining, stable, long shelf life.
2. No objectionable odor.
3. Removes and prevents milkstone and waterstone formation.
4. Effective against a wide spectrum of organisms.
5. Stable in concentrated form or use dilutions, action enhanced by high temperatures.
7. Provides short duration residual bacteriostatic effect on stainless steel equipment.

DISADVANTAGES:
1. Effectiveness at acid pH only.
2. Generation of foam.
3. Low activity against spore forming organisms.
4. Corrosive to metals other than stainless steel.

Use concentration: 100 - 200 ppm

QUATERNARY AMMONIUM COMPOUND (QUAT)

ADVANTAGES:
1. Stable, long shelf life.
2. Active against many microorganisms.
3. Forms a bacteriostatic film.
4. Non-corrosive and non-irritating to skin.
(ADVANTAGES CONT.)
5. Stable in the presence of organic matter.
6. Stable to temperature changes.
7. Good penetration qualities.
8. Combined with non-ionic wetting agents, it makes a good detergent sanitizer.

DISADVANTAGES:
1. Expensive!
2. Incompatible with common anionic detergent components.
3. Slow to dissipate (residual problem).
4. Germicidal efficiency varied and selective.
5. Foam problem in mechanical application.

USE CONCENTRATIONS:
For sanitizing of equipment a 200 ppm solution is sufficient to reduce bacterial counts with a one minute exposure.

PEROXYACETIC ACID:

ADVANTAGES:
1. Wide spectrum of efficacy: gram positive, gram negative, spore forming bacteria, viruses, bacteriophages, yeast, and molds.
2. Rapid action, even at freezing temperatures.
3. Incidental food contact does not affect taste of milk or beverages.
4. Residuals turn into water and acetic acid (vinegar).
5. VERY LOW toxicity!
6. Low corrosivity at use concentration.
7. Compatible with acid rinse.
8. No staining!
10. NO foaming!

DISADVANTAGES:
1. Concentrate has a strong odor.
2. Concentrate is to be handled carefully.

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CAUSES AND PREVENTION OF OILING OFF IN MOZZARELLA CHEESE

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INTRODUCTION

Oiling off in Mozzarella cheese refers to the separation of liquid fat from the melted cheese mass resulting in accumulation and pooling of free oil. This property, also known as fat leakage and free oil formation, was first studied during the early 1960's (1,5) and has continually undermined the physical appearance of the melted cheese. More recently, this defect has taken on added importance due to heightened consumer concern about dietary fat. The visible accumulation of free oil on the surface of pizza quickly erodes the positive image pizza has hitherto enjoyed as a healthy and nutritious food.

Personal communications with several industry leaders have suggested that oiling off is one of the most serious quality problems facing the Italian cheese industry. Results from a recent questionnaire survey of pizza restaurants in Vermont support this view. The survey found that two-thirds of the restaurants experience excessive free oil formation either occasionally or frequently (6). Mozzarella cheesemakers and the pizza trade need to be extremely sensitive to consumer perceptions about dietary fat. Should oiling off continue to be a common problem at the level of the pizza restaurant, pizza's positive image will disappear.

Unfortunately, our understanding of the causes and prevention of oiling off is far from complete. However, a renewed research emphasis has occurred in the past few years and rapid progress is being made. The purpose of this report is to examine some recent research that we hope will enable cheesemakers to more effectively combat the problem of oiling off.

ASSESSMENT OF OILING OFF

Several approaches have been used to evaluate oiling off. A brief discussion of three commonly used methods and their limitations will be presented next.

Subjective assessment.

The most straightforward and simple approach is to subjectively evaluate the performance of melted cheese on pizza under commercial baking conditions. This approach is practiced widely in industry and is the basis for USDA specifications relating to free fat (7). The latter simply states "There shall be no free fat drippage when a wedge shaped cut is removed from the pizza." This type of subjective evaluation is useful for industrial quality control purposes but it is not suitable for research unless it is used in combination with meaningful objective measurements.
Another limitation of this approach is that melting properties are highly temperature dependent. A wide range of pizza oven configurations and time-temperature regimens are used commercially. Thus, cheese temperature profile during baking may vary quite markedly depending on commercial oven design. Consequently, cheese performance may largely depend on baking conditions (4). Manufacturers should take into account the specific baking conditions used by their customers when developing specifications for oiling off based on performance during baking.

**Disk/filter paper test.**

Oiling off is also measured by melting disks of cheese of specified dimensions on filter paper under defined conditions of time and temperature. Free oil from the melted cheese is absorbed into the filter paper and forms an oil ring, the area of which is related to the amount of free oil.

A major limitation of this method is in obtaining representative measurements. Composition of Mozzarella cheese is not uniform because it is usually brine-salted. Consequently, oiling off within a single cheese also is variable, as will be discussed below. Thus, the oiling off value measured from a single disk of cheese will depend on where in the cheese the disk was taken. Data in Figure 1 illustrate the dilemma. Core samples extending from surface to surface through the center of two 2.73kg blocks of commercial Mozzarella were taken using a No. 10 cork borer. Cores were sectioned into 5mm disks and heated at 110°C for 10 min. Results show extreme disk-to-disk variability in oiling off along the core samples. Thus, to obtain a representative picture of the entire cheese it is necessary to analyze many disks taken from strategic locations throughout the block.

**Centrifugal free oil test.**

This test was developed in our laboratory and recently was published (3). The test utilizes standard Babcock equipment and is similar to the modified Babcock test for total fat in cheese except that free oil from the melted cheese is measured rather than total fat. Representative measurements are comparatively easy to obtain because the test utilizes a ground sample. An advantage is that free oil can be expressed quantitatively as percentage in cheese or percentage in cheese fat (i.e., free oil-fat basis).
FACTORS AFFECTING OILING OFF

Cheese age.

Although Mozzarella is considered an unripened or fresh type cheese, it does in fact, undergo a characteristic change in melted functionality over the course of its shelflife. The change in free oil formation of a typical commercial low-moisture, part-skim (LMPS) Mozzarella during three weeks of refrigerated aging is shown in Figure 2. Free oil increased from 5% to 9% during the first two weeks of aging but showed little increase thereafter. Expressed as a percentage of total cheese fat, free oil increased from 25% to almost 50% during aging. That is, almost 50% of the total fat content of this cheese formed free oil at three weeks.

Cheese FDB.

Free oil formation is strongly dependent on the level of total fat in the cheese and specifically on cheese FDB. In general, oiling off increases as cheese FDB increases. Consequently, Mozzarella and low moisture (LM) Mozzarella generally give higher free oil than their part-skim counterparts. This is illustrated in Figure 3, which shows the average free oil levels, expressed as percentage in cheese (free oil (%)) and as percentage in cheese fat (free oil-fat basis (%)), of Mozzarella, LM, LMPS and part-skim (PS) Mozarellas collected from supermarkets and two commercial cheese plants. A total of 64 cheeses were analyzed. Free oil levels were significantly higher in Mozzarella (average FDB = 45.9%) and LM Mozzarella (average FDB = 47%) than in PS (average FDB = 39.1%) and LMPS (average FDB = 36%) Mozzarella.

The relationship between cheese FDB and free oil (free oil-fat basis) is shown in Figure 4 (Figure 5). At low FDB levels (ca. 30 to 37%), free oil was low but increased progressively at higher FDB. The data in Figure 5 demonstrate that as FDB increases, a higher percentage of the total cheese fat becomes susceptible to fat leakage. Free oil as a percentage of total fat ranged as high as 85% in one cheese with FDB of 44.6%.

The relationship between cheese moisture content (expressed on a nonfat substance basis) and free oil is shown in Figure 6. Moisture was not significantly related to free oil, as is evidenced by the lack of a definable pattern in the data, even though large differences in moisture content existed among the cheeses.

The positive relationship between FDB and oiling off has taken on added importance as cheesemakers continue to edge FDB levels upwards in response to declining cream prices. Cheesemakers need to keep in mind that higher FDB in Mozzarella, while economically attractive at present, has important implications for cheese functionality.
Cheese salt content.

Oiling off is strongly influenced by cheese salt content. In general, free oil formation decreases with increasing salt content. Since brine salted cheeses have a disparate salt concentration (decreasing from surface to center), a series of experiments were conducted to investigate oiling off behavior in the high salt surface region vs. the low salt interior.

Experiment one

Two 6 lb blocks each of LM and LMPS Mozzarella cheese were obtained from a commercial manufacturer on the day after brining (day 2 post-manufacture). Each block was cut in half. One half from each block was then divided to give a “center” and an “end” quarter. Core samples were then taken along the crosssection diagonals of the center and end quarters according to the sampling plan shown in Figure 7, and free oil, salt, fat and moisture concentrations were determined. Thus, free oil was measured at different regions within a single cheese that differed widely in salt concentration.

The second half from each block was vacuum packaged on day 2 and then held at 4 C for 13 days. On day 15 each half was divided into center and end quarters, sampled and analyzed as above. The overall experimental design is illustrated in Figure 8.

The relationship between free oil and salt concentration within the LM and LMPS cheeses is shown in Figures 9 and 10, respectively. On both day 2 and day 15, high salt regions of the cheeses had lower free oil than low salt regions. These differences were highly significant from a statistical standpoint. Also, there was a significant interaction with time. That is, the effect of salt on free oil was greater on day 15 than on day 2, as is evidenced by much greater decrease in free oil with increasing salt on day 15 compared to day 2. Thus, the importance of salt in controlling oiling off increases as the cheese ages. Finally, free oil was significantly higher in LM cheeses (FDB ca. 45%) than in LMPS cheeses (FDB ca. 38%) regardless of salt content. Consequently, cheese with low salt and high FDB is particularly prone to excessive oiling off.

It should be noted that moisture content was not significantly related to free oil. Thus, salt concentration and FDB appear to be the dominant compositional factors that govern oiling off behavior.

Experiment Two

A second experiment was conducted to gain additional insight into how salt affects oiling off. Four 6 lb blocks each of LM and LMPS Mozzarella cheeses were obtained from a commercial manufacturer on the day after brining (day 2 post-manufacture). Each block was immediately cut in half, and each half sectioned into the outer 1.5cm exterior surface and interior core according to the scheme
illustrated in Figure 11. Interior and exterior sections from one half of each block were analyzed for free oil, salt, fat and moisture immediately on day 2 post-manufacture. Interior and exterior sections from the second half of each block were vacuum packaged individually and held at 4°C for 14 days and then analyzed as above.

The experiment was conducted according to a sophisticated experimental design. The objective was to study the effects of the following three factors on oiling off: 1. high salt exterior vs. low salt interior; 2. high FDB LM Mozzarella vs. low FDB LMPS Mozzarella; 3. day 2 vs. day 16. The statistically significant results are present below.

A. Free oil was higher in LM Mozzarella than in LMPS Mozzarella, as shown in Figure 12. This was due primarily to higher FDB in the former.

B. Free oil was higher in the low salt interior than the high salt exterior of the cheeses, as shown in Figure 13. Again, the importance of salt to oiling off is apparent.

C. Free oil was higher on day 16 than on day 2, as shown in Figure 14. Again, the characteristic increase in free oil during aging is apparent.

D. There was an interaction of sample location with time. That is, free oil increased from day 2 to day 16 in both the low salt interior and the high salt exterior; however, the increase was greater in the low salt interior, as is illustrated in Figure 15. Again, it is evident that the impact of salt on oiling off increases as the cheese ages.

E. There was an interaction of sample location with cheese type. That is, free oil was higher in the low salt interior of both LM and LMPS Mozzarellas than in the high salt exterior; however, the difference between interior and exterior was greater for the LM Mozzarella, as is illustrated in Figure 16. Therefore, salt had a greater effect on free oil in the high FDB LM cheese than in the low FDB LMPS cheese. Again, it is evident that cheese with low salt and high FDB is particularly prone to excessive oiling off.

F. There was an interaction of time with cheese type. That is, free oil increased from day 2 to day 16 in both LM and LMPS Mozzarellas; however, the increase was greater for the LM cheese with higher FDB, as is illustrated in Figure 17.

To summarize, the data suggest that a balance between salt concentration and cheese FDB is necessary to control oiling off. The combination of low salt and high FDB is likely to lead to excessive oiling off.
Experiment 3.

A third approach used to investigate the effect of salt on oiling off was to add salt directly to unsalted Mozzarella curd. Six pound blocks of LMPS Mozzarella cheese were obtained from the molding machine prior to brining at a commercial cheese plant. Cheeses were vacuum packaged and held at 4 °C for 1, 5 and 12 days. At each time point, cheese was ground completely in a blender and salt was added to portions of the ground sample in increments ranging from 1 to 4% added salt. The salt was thoroughly mixed into the cheese and then each sample was vacuum packaged and stored at 4 °C overnight to allow for salt equilibration. The following day samples were analyzed for free oil.

Figure 18 shows the effect of added salt on 2, 6 and 13 day old unsalted Mozzarella. Free oil decreased with increasing salt addition, and decreases were largest for the 13 day old cheese. Again, salt had a greater effect on free oil as the cheese aged.

Mozzarella/non-Mozzarella blends.

A growing practice in the pizza trade is to use mozzarella in combination with other cheeses, either to increase flavor or to economize by extending Mozzarella with a less expensive cheese. This practice can lead to extensive changes in oiling off properties. Figure 19 shows the effect on free oil of blending non-mozzarella cheeses purchased from a local supermarket with 15 day old LMPS Mozzarella at various blend ratios. Free oil increased with increasing blend ratio because Cheddar and Jack cheeses are less completely emulsified than Mozzarella. As the practice of blending becomes more widespread, it will become increasingly necessary for cheesemakers to tailor the melting properties of their Mozzarella cheese to compensate for and compliment the specific blend formulations used by their buyers.

CONCLUSIONS

Undoubtedly, many other factors are relevant to the control of oiling off in Mozzarella. For example, curd pH is clearly a major factor. Below pH 5.0, Mozzarella curd loses its ability to retain fat in the melted cheese. This is particularly evident when "overripe" curd (i.e., curd pH < 5.0) is subjected to cooking/stretching. Excessive fat losses to the stretching water inevitably result.

FDB and salt content are vital compositional factors that govern oiling off, and both can be adjusted by the cheesemaker with comparative ease. Thus, significant advancement can be made with respect to preventing oiling off by maintaining cheese FDB and salt concentrations at appropriate balanced levels. It is particularly important to avoid cheese with high FDB and low salt. However, it is also important to avoid excessively high salt concentration, as this leads to undesirable changes in melted consistency (2), and has obvious nutritional implications.
The vital role of salt and FDB, and indeed pH, in the development of oiling off is evident when one considers the basic chemistry that underlies free oil formation. Oil- ing off occurs because some of the fat in cheese is not emulsified. The principal emulsifying agent in cheese is casein, therefore, oiling off depends on how effectively casein molecules emulsify the cheese fat. The ability of casein to emulsify cheese fat dramatically increases when the casein molecule possesses a negative charge. Casein becomes negatively charged when calcium (a positively charged atom) is removed from the casein molecule. In contrast, casein loses its negative charge when positively charged hydrogen ions combine with casein, as occurs when pH decreases below around 5.0. Thus, oiling off is prone to occur when there is 1.) not enough casein to adequately emulsify the cheese fat (e.g., when FDB is too high); 2.) inadequate removal of calcium from casein, resulting in poor emulsification capacity; 3.) low curd pH, resulting in poor emulsification capacity.

In processed cheese, phosphate and citrate salts are used to remove calcium from casein and to control curd pH, thereby maximizing casein’s emulsifying capacity. In Mozzarella cheese, curd pH is determined by the manufacturing process, while salt acts to increase casein’s emulsifying capacity through sodium exchange with casein-bound calcium. A proposed model for the effect of salt and pH on Mozzarella cheese emulsification is shown in Figure 20. It is hoped that advancements in our understanding of the underlying chemistry of oiling off will ultimately lead to its eradication as a defect in Mozzarella cheese.

ACKNOWLEDGEMENTS

The excellent technical assistance of S.L. McConnell and J.K. Rippe is much appreciated.

The financial support of the Northeast Dairy Foods Research Center and the National Dairy Promotion and Research Board is gratefully acknowledged.

REFERENCES


FIGURE LEGENDS

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

2. Change in free oil formation in low-moisture, part-skim Mozzarella cheese during three weeks of storage at 4°C.

3. Average free oil levels in Mozzarella (M), low-moisture (LM), low-moisture, part-skim (LMPS), and part-skim (PS) Mozzarella cheeses collected from supermarkets and two commercial cheese plants. A total of 64 samples were analyzed.

4. Relationship between free oil and FDB of Mozzarella cheeses obtained from two commercial cheese plants. Cheeses were analyzed on day 12 postmanufacture.

5. Relationship between free oil-fat basis and FDB of Mozzarella cheeses obtained from two commercial cheese plants. Cheeses were analyzed on day 12 postmanufacture.

6. Relationship between free oil and moisture (nfat solids basis) of Mozzarella cheeses obtained from two commercial cheese plants. Cheeses were analyzed on day 12 postmanufacture.

7. Crosssectional sampling plan used to evaluate salt and free oil levels at designated locations within rectangular 2.73kg blocks of brine salted Mozzarella cheese.

8. Experimental design used to study oiling off at designated locations that differed widely in salt content within rectangular 2.73kg blocks of brine salted Mozzarella cheese.
9. Relationship between free oil and salt concentration within rectangular 2.73kg blocks of brine salted low-moisture Mozzarella cheese.

10. Relationship between free oil and salt concentration within rectangular 2.73kg blocks of brine salted low-moisture, part-skim Mozzarella cheese.

11. Experimental design used to study oiling off at designated locations within rectangular 2.73kg blocks of brine salted Mozzarella cheese.

12. Effect of Mozzarella cheese type (low-moisture vs. low-moisture, part-skim) on free oil.

13. Effect of location in cheese block (interior vs. exterior) on free oil.

14. Effect of cheese age (day 2 vs. day 16) on free oil.

15. Interaction effect on free oil of location in cheese block with cheese age.

16. Interaction effect on free oil of location in cheese block with cheese type.

17. Interaction effect on free oil of cheese type with time.

18. Effect of added salt on free oil in 2, 6 and 13 day old unsalted Mozzarella cheese.

19. Free oil in Mozzarella cheese blended with non-Mozzarella cheese at selected blend ratios.

20. Proposed model for the effect of salt and pH on Mozzarella cheese emulsification.

Figure 1
Figure 5

Figure 6

Figure 7

C = CORE (ca. 13 mm from center)
M = MIDSECTION (ca. 33 mm from center)
S = SURFACE (ca. 55 mm from center)

Figure 8

DAY 2
END CENTER
-3 vac. phg.,
-13 days
-4°C

DAY 15
Figure 16

Figure 17

Figure 18
Figure 19

Figure 20
Production of Fontina, Semisoft and Gorgonzola-Type Cheeses From Retentate

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Cal-Poly State, San Luis Obespo, CA 93407

Introduction

Over the last several years there has been a steady increase in the quantity of specialty cheeses that are being consumed. Fontina and Gorgonzola have had growth rates higher than 10%. The semi-soft cheeses also offer an excellent growth opportunity. Many of these specialty cheeses are known in the United States by their trade names, which often are also registered trademarks. Any inappropriate use of trademark or other name restriction or convention in this paper is unintentional.

Ultrafiltration is a membrane filtration process which can separate components of a liquid feed stream according to molecule size. Much of the work concerning the use of UF in the dairy industry has focused on increasing cheese yield. Cheddar, Monterey, Feta, Mozzarella, Edam, Gouda, Camembert, Blue, Brick, Colby, St. Paulin-Type, Gruyere-Type, Emmental, Quarg, Ricotta, Cream and Lactic Goat cheese have been made using ultrafiltration. Generally, cheese made from UF concentrate, commonly referred to as retentate, has had physical characteristics different than cheese made via conventional methods.

Researchers at the Dairy Products Technology Center, California Polytechnic State University, have developed processing procedures for Fontina, Semi-soft and Gorgonzola cheese types from milk using American equipment. Methods to produce these cheeses from retentate, capitalizing on unique product attributes of cheeses made from retentate, were also investigated.

Ultrafiltration and Cheese Making

Jensen et al.(3), Geilman (1) and Lawrence(4) have all reviewed the literature concerning the production of cheese from retentate. Attributes of UF cheese include; hard, rubbery body, mealy, grainy, crumbly texture, high moisture, slow aging profile, slow flavor development, softer less springy, more sticky body and reduced meltability. Although these attributes may be considered defects when compared to conventionally made products, they could be manipulated to make cheeses that have unique properties.
There are many factors that could affect characteristics of cheese made using ultrafiltration. Raw milk quality and composition, the concentration factor of the retentate, changes in milk chemistry, pre-acidification pH, amount of diafiltration water used, UF equipment design, and cheese processing procedure followed, may change cheese attributes.

Many of the characteristics attributed to UF may have resulted because of peripheral factors. The observation technique used to determine differences between control and experimental samples is important. For example, when disks of standard and UF Cheddar cheese were placed on a pad of filter paper and heated for 10 sec. The flow of the UF cheese was less than standard cheese at the beginning an aging period of 30 days. But the increase in deformation of the UF cheese paralleled the control at any given point as the cheese matured. Fat release for UF cheese was very irregular and increased as aging time increased, which was opposite of the control cheese. In this case it was assumed that the cheese aged slower, as manifested by decreased melt. But in reality it merely started from a different point.

The effect of shear that a UF system could have on characteristics of cheese made from retentate was also studied at the Dairy Products Technology Center. Cheddar cheese was made from homogenized and standard milk. The acid development of cheese made from homogenized milk was slower from set to salt when compared to control, but was greater in the pressed cheese, resulting in lower 24 hr pH readings.

Shear generated by pumping the milk was also studied. To increase shear, a back pressure valve was used. Depending on the amount of shear used, observed yields increased as shear increased. Actual yields decreased with low levels of shear, but as shear increased yield approximated normal levels. Moisture levels in the cheese generally increased with increasing shear. As shear increased, the cheese received lower flavor, body and texture scores and had increasingly lighter color. This study indicated that many of the attributes ascribed to the concentration of milk via UF may actually be a result of shear, not concentration.

Why Use Ultrafiltration

There are several reasons to make cheese from retentate, the first of which is to increase yield. Even though yield increases have not met industry expectations, moderate increases can be obtained. UF can be used to standardize milk composition resulting in a more uniform product. By reducing the volume of milk via UF, increased vat throughput can be achieved. Throughout this study, retentate was concentrated to one third the original volume, which resulted in a dramatic increase in plant throughput. Changing the milk chemistry using techniques afforded by UF could affect the functionality of the products made from retentates. By manipulating functional characteristics attained by using UF, new products can be engineered to meet consumer expectations.
Processing Differences Between Milk and Retentate

Traditionally, the development of acid in cheese has been monitored using titratable acidity values. Due to the increased solids levels and increased buffering capacity of retentate, titratable acidities are of little value. The use of pH values are a more useful processing tool.

The strength of the rennet coagulation of milk is generally determined by the cheesemaker. The test consists of making a judgement, based on experience, of how the coagulum breaks as it is lifted by spatula. Over the years, a database concerning the amount of rennet, the time needed for coagulation and how the coagulum should look, has been accumulated. The coagulation characteristics of the retentate do not conform to conventional wisdom. Trying to determine coagulation of retentate using information gathered about milk will lead to erroneous conclusions and affect product quality.

Cutting curd made from retentate can also be difficult. The increased protein levels usually results in a coagulum that is much firmer than that of milk. Knives must be used that can cut this firmer curd. Syneresis of the curd is also affected by the use of retentate. Initial whey release is slower, but once initiated proceeds quite rapidly. There is less whey obtained, and it has higher total solids and fat levels than does conventional whey.

Cheese Production

During the 1989 Marschall Italian Cheese Seminar, processing procedures for making Fontina and Italian semi-soft cheese types from milk were presented (2). These procedures, as well as a procedure for a Gorgonzola-type cheese from milk, are summarized in the processing diagrams contained in the appendices of this paper (Figures 1, 3, 5). Processing procedures for making these cheeses from retentate are also included (Figures 2, 4, 6).

FONTINA-TYPE CHEESE

Fontina-Type Using Milk

There are several processing points which are important for the production of Fontina-type cheese (Figure 1). The first of these was the use of a 1.5-2.0% inoculation of a mixed mesophilic lactic starter culture to the milk. Proper eye and flavor development required the addition of small quantities of Propionibacterium shermanii (2-6 g per 1,000 lbs milk (454 kg)). The milk was ripened until a pH of 6.54 was obtained. Coagulation was performed by adding 3 oz (90 ml) of rennet per 1000 lbs (454 kg) of milk and allowing a 30 minute coagulation time. The coagulum was cut using 3/8 inch (9.5 mm) wire knives. Healing and pre-work required 15 minutes. Cooking was performed by removing 1/3 the original milk volume as whey and replacing it with an equivalent volume of 130°F (54°C) water. By adjusting the volume of water used, lactose/calcium/protein ratios could be adjusted and final pH
and body and texture fixed. Following cooking, the curd was pressed under the whey. After the whey was drained, uniform portions of curd were placed in cheese molds and pressed for at least 6 hours. The pressed cheese was brined until a salt content of 0.7 to 1.0% was obtained. The cheese was dried, vacuum packaged in heat shrinkable, breathable plastic bags and stored in the cold, 45°F (7.2°C) for 10 days, prior to a warm room treatment at 65°F (18°C). Warm room treatment was for 12-18 days or until there was desirable eye development. The cheese was then cooled and stored until marketed.

**Fontina-Type Using Retentate**

When Fontina-type cheese was made from retentate, there were several minor modifications had to be made to the procedure that was developed using milk (Figure 2). The amount of starter added was adjusted to the amount needed to lower the pH of the retentate to 6.54 in one hour. This correlates to the amount needed to inoculate an equivalent volume of milk, or 5% to 6% of the weight of the retentate. Rennet was added at a rate of 5 oz (148 mls) per 1000 lbs (454 kg) of retentate. Due to the increased solids level, coagulation occurred very quickly, and the coagulum was cut 10 minutes after rennet addition. A 15 minute prework was followed by a 30 minute cook. A cook temperature of 102°F (38.9°C) was used, and heating was accomplished via the steam jacket of the vat. No water was added since the lactose/calcium/protein ratios had been adjusted during ultrafiltration. The cheese was pressed under the whey for 30 minutes. The procedure from this point forward was very similar to that used for milk, with the exception that salting times may be slightly longer and the time needed for eye development in the warm room may be as long as 21 days.

**SEMI-SOFT CHEESE**

**Semi-Soft Cheese From Milk**

This procedure (Figure 3) starts with milk at a temperature of 104°F (40°C). Inoculation was with 0.5% mesophilic and 0.5% thermophilic starter culture. Rennet was added at a rate of 3 oz. (90 ml) per 1000 lbs (454 kg) of milk. After 30 minutes, the vat was cut, allowed to heal for 10 minutes, then gently stirred for an additional 30 minutes. The temperature was maintained at 104°F (40°C). The curds were dipped into molds which were turned every thirty minutes for 4 hours. Once a pH of 5.3 was attained, the cheese was cooled, removed from the hoop, and brine salted. The final salt content was 1-1.5%.

**SEMI-SOFT CHEESE FROM RETENTATE**

The procedure was the same as that used for semi-soft cheese from milk, with a few exceptions (Figure 4). Inoculation rates were increased to 2% for each of the starters that were used. Rennet was increased to 5 oz (148 mls) per 1,000 lbs (454 kg) of retentate. The coagulation and cook times were reduced to 10 minutes and 15 minutes, respectively.
GORGONZOLA-TYPE CHEESE

Gorgonzola-Type Cheese From Milk

Traditionally, Gorgonzola cheese has involved mixing curd made in the evening with curd made in the morning. This gives the cheese a unique body and flavor. In the Cal Poly procedure (Figure 5), a washed curd make procedure was used to make an acceptable product. Milk, at 88° F (38.8° C), was inoculated with 1.8% mesophilic lactic starter culture. Rennet was added at a rate of 3 oz (90 ml) per 1,000 lbs (450 kg) of milk. The vat was cut 30 minutes after set using 1/2 inch (12.7 mm) wire cheese knives. After a 10 minute heal, the temperature was raised to 98° F (36.6° C) over 30 minutes. The curds and whey were gently stirred for 1 hour, then whey, equaling 40% of the initial volume, was removed. Water, at 54° F (12.2° C), equal to 13% of the initial volume was added. The curd was washed for 15 minutes, drained and dry stirred for 45 minutes. Salt was added to the curd at a rate of 0.39% of the initial milk volume and stirred for 15 minutes. Mold spores were added with the salt, at a rate of 2 grams per 1000 lbs (454 kg) of milk. The cheese was hooped, pressed overnight, packaged in airtight bags and stored for 10 days before being punctured. The mold was allowed to grow for 14 days, then the cheese was repackaged in airtight bags and held for 2-3 months to allow flavor development.

Gorgonzola-Type Cheese From Retentate

When whole milk concentrated to 1/3 the original volume was used, the following modifications were made (Figure 6). Instead of using 1.8% milk-based starter culture, 720 mls per 1,000 lbs (454 kg) of retentate, direct to vat concentrated frozen starter culture was used. After 1 hour of ripening, 5 oz (148 ml) of rennet per 1,000 lbs (450 kg) retentate was added. The vat was cut 10 minutes later, followed by a 15 minute heal time. Cooking required 30 minutes, using a cook temperature of 98° F (38.6° C), followed by 20 minutes of stirring. No wash water was added but the drained curd was dry stirred for 45 minutes. Salt and mold addition was the same as that used for production of Gorgonzola-type cheese from milk, calculated on the initial volume of milk before concentration. The cheese made from retentate had a body, texture and flavor which was very similar to commercially produced cheeses.

Conclusion

Ultrafiltration is a technology which can be used to concentrate milk and make retentates. The retentates can then be used to make cheeses that are similar to those made from milk. By adjusting the processing parameters used in the production of the retentates, as well as the cheese processing procedures, cheeses with unique attributes, which may meet special market niches, can be produced. Although yield increases actually obtained from the use of retentates have not met industry expectations, other factors such as increased throughput and retarded aging of semisoft cheeses might offer processing advantages.
REFERENCES


CHEESEMAKING CHART
Cal Poly UF Fontina Type

Figure 1

Figure 2
CHEESEMAKING CHART
Cal Poly Modified Semi Soft Type

<table>
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<td>Add Starter</td>
</tr>
<tr>
<td>6.5-6.54</td>
<td>Add Rennet</td>
</tr>
<tr>
<td></td>
<td>Cutting</td>
</tr>
<tr>
<td></td>
<td>Stir &amp; Firm</td>
</tr>
<tr>
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<td>Hoop</td>
</tr>
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<td></td>
<td>Turn Every</td>
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<td>30 Min</td>
</tr>
<tr>
<td>5.3-5.4</td>
<td>Cool</td>
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<td>Brine</td>
</tr>
<tr>
<td></td>
<td>Saturated Salt Solution</td>
</tr>
<tr>
<td></td>
<td>Dry &amp; Package</td>
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- 104°F 45 Minutes 1 Hour 55 Minutes
- 104°F 20-30 Minutes
- 104°F 40 Minutes
- 104°F 10 Minutes
- 104°F 15 Minutes
- 104-108°F at 86% Humidity Approx 4 Hours
- 45°F 40 Minutes
- 50°F 16 Hours
- Age 2 - 3 Months

Figure 3

CHEESEMAKING CHART
Cal Poly UF Semi Soft Type

<table>
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- 104°F 45 Minutes 1 Hour 10 Minutes
- 104°F 10 Minutes
- 104°F 15 Minutes
- 104-108°F at 86% Humidity Approx 4 Hours
- 45°F 40 Minutes
- 50°F 16 Hours
- Age 2 - 3 Months

Figure 4
### CHEESEMAKING CHART

#### Cal Poly Modified Gorgonzola Type

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<td>Add Rennet</td>
<td>30 Minutes</td>
</tr>
<tr>
<td>Cut Vat</td>
<td>10 Minutes</td>
</tr>
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<td>Start Cook</td>
<td>30 Minutes</td>
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<tr>
<td>End Cook 98°F</td>
<td>1 Hour</td>
</tr>
<tr>
<td>Stir and Firm</td>
<td>10 Minutes</td>
</tr>
<tr>
<td>Drain Whey to curd</td>
<td>5 Minutes</td>
</tr>
<tr>
<td>Add Water</td>
<td>15 Minutes</td>
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<tr>
<td>Drain</td>
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</tr>
<tr>
<td>Salt</td>
<td>10 Minutes</td>
</tr>
<tr>
<td>Hoop &amp; Press</td>
<td>Overnight</td>
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<td>In Cooler</td>
<td>10 Days</td>
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<td>Puncture</td>
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<td>Allow mold growth</td>
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<tr>
<td>Storage</td>
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#### Cal Poly UF Gorgonzola Type

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<td>Cut Vat</td>
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<td>Allow whey to expell</td>
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<td>Start Cook</td>
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Figure 5

Figure 6
WHAT’S SO SPECIAL ABOUT SPECIALTY CHEESES?

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Americans consumed nearly 5.9 billion pounds of cheese during 1989.

That’s about 1.9 billion pounds more than the 4 billion pounds consumed in 1980.

The average annual increase in sales for each of the nine years was 211 million pounds.

The International Dairy Foods Association (IDFA) estimates that cheese sales in 1993 will total 7.024 billion pounds, an increase of nearly 1.2 billion pounds.

Based on this projection, sales during the next four years will increase at an average annual rate of nearly 300 million pounds.

These numbers suggest a bright future for the cheese business, but there is a lot more to the story. More than 200 varieties of cheese are produced in the United States and each has its own growth pattern. The total cheese market is composed of commodity cheeses and literally dozens of niche, value-added, specialty cheeses.

Growth in the American cheese category, for example, has been flat at best for the past several years. Meanwhile, mozzarella cheese sales have more than doubled during the 1980s, and numerous other specialty cheeses have been experiencing sales growth rates that outpace the increase in total cheese sales.

Opportunities for cheesemakers...

IDFA and others foresee continued strong growth in specialty cheese sales. For example, the Association notes that lowfat cheese (cheese containing at least one third less fat than dictated by its current standard of identity) sales totaled 174 million pounds in 1984, and IDFA forecasts sales of 1.053 billion pounds by 1993; a six-fold increase.

Deli operators told Cornell University researchers last fall, they expect gourmet cheese sales in the supermarket deli to increase 6.7 percent annually into the mid-1990s.

The introduction (two years ago) of microwaveable cheese sauces is just beginning to favorably impact sales. Consumers, always looking for convenience, are just discovering these items now that several competitors are vying for consumer dollars in the category.

The same can be said for spreadable cheeses where several competitors are now fighting for marketshare. This competitive battle is building category awareness and sales for sauces and spreads.
Sales opportunities go beyond the supermarket. In fact, total dairy case (typically commodity cheeses) sales of cheese for at-home use have been flat. Sales growth has come in the foodservice business where cheese adds perceived value to entrees, salads and side dishes.

Cheese also adds value as an ingredient in prepared foods — shelf-stable, refrigerated and frozen dinners, entrees, side dishes, crackers, snacks, breads, soups...

**THINGS WE NEED TO CHANGE TO IMPROVE SALES**

Today, most reduced-fat and reduced-sodium products lack flavor and appropriate texture. If this category is to achieve a six-fold increase by 1993, cheesemakers and cheese processors will need help developing better tasting and better textured cheeses.

Tailor-made cheeses that perform specific functions when used as ingredients in prepared foods require special make procedures and ingredients. Italian cheesemakers already have expertise with mozzarella cheese (being made to the individual pizza makers specifications). Now, that expertise needs to be transferred to numerous other Italian varieties that can be used as ingredients in dozen of other foods.

Long-hold or aged products are gaining renewed popularity among consumers. These cheeses also require special make procedures, the finest quality ingredients and, frequently, flavor enhancement.

**ITALIAN SPECIALTIES**

Italian cheeses now account for about 36 percent of all cheese produced in the United States.

Mozzarella is the driving force in the Italian category, but several other varieties have experienced excellent growth.

Ricotta cheese production nearly doubled during the decade to 185 million pounds in 1989. Output grew an average or more than 10 million pounds annually between 1985 and 1989.

Provolone cheese production increased from 94 million pounds in 1980 to 149 million pounds in 1989; however, the annual increases slowed during the second half of the decade.

Parmesan cheese production grew from 60 million pounds in 1980 to 90 million pounds in 1989; like provolone, the annual increases slowed during the second half of the decade.

Romano cheese production dropped from 21 million pounds in 1980 to less than 17 million pounds in 1989.
Average Production: During the decade, the average output per mozzarella plant more than doubled from 4.68 million pounds to 10.54 million pounds. The output of plants producing other Italian cheeses also increased sharply during the decade; moving from 2.37 million pounds in 1980 to 4.26 million pounds in 1989.

Opportunities...

Mozzarella sales have been growing at 7 percent to 12 percent annually for more than a decade and there is no end in sight. Consumers are convinced that pizza is 'pretty' healthy and it is easy to find — there's a pizzeria on every street corner, or it can be delivered to their home, or they can buy it fresh or frozen at the grocery store for easy preparation at home, or they can buy all of the fixings in a box and have a party making it 'from scratch' at home.

Now, McDonald's wants into the pizza business. That will build the total market. McDonald's will take some business away from others, but think about the other competitors. Pizza Hut, etc. — table cloth and waiter/waitress; Domino's, etc. — home delivery; Pizza Hut, Domino's, grocery stores — take home; McDonald's — eat-on-the-run. Additionally, McDonald's marketing bucks will spell greater consumer awareness. Their entry into the pizza business will do more damage to their hamburger and cheeseburger business than to other pizza businesses.

Ricotta cheese is being positioned as a dessert cheese by Kraft and others. That should yield new growth opportunities.

Marpcoreone, a cheese new to the U.S. market, is getting good marketing support and will build the market for dessert cheeses — a low calorie, healthy alternative to many other sweets.

Parmesan needs help. Most of the volume is in foodservice where many suppliers blend whey and/or nonfat dry milk with parmesan and destroy product integrity. However, parmesan has enjoyed considerable, and growing, use as an ingredient in prepared foods. Sales will continue to grow and the United States will be the low-cost producers within a very few years. That will limit imports.

Provolone is a flavorful alternative to cheddar for cheeseburgers, but marketers have not capitalized on this sales opportunity. It is white and so perceived as lowfat. That will keep sales growing at their current pace.

Romano (and a number of other cheeses) cheese has some interesting, but longer-term possibilities. The U.S. Department of Agriculture does not keep tabs on sheep and goat milk production or the production of cheeses from them. However, both are becoming well established in the United States and offer some unique opportunities.

Total it all up and it is obvious: Italian cheesemakers have a lot of work to do. But they have the expertise to do the job right. And the opportunities to sell more Italian cheese has never been greater.