

2001 MAFMA Final Report

Project Title: **Effect of Adding Milk Solids on the Quality and Economics of Swiss Cheese Manufacture**

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1. Objective Summary:

The primary objectives of the study were to understand the effects of adding milk solids to cheese milk on Swiss cheese characteristics and to determine the optimum source and concentration of milk solids that provide for a high quality Swiss cheese. The study would also explore the effect of added milk solids on the growth and fermentation products of the starter bacteria, with special attention to *P. freudenreichii* subsp. *shermanii*, and their relationship to eye formation and flavor. The economics of milk solids addition were to be determined under commercial conditions based on pilot plant studies.

2. Objective Accomplishments:

The establishment of the best type and concentration of milk solids to add to milk for Swiss cheese manufacture under commercial conditions was not achieved, and because of this the economics of the addition of milk solids was not determined. This was caused by the use of a reduced cooking temperature, recommended by industry, for pilot plant studies that resulted in unsatisfactory eye formation that was independent of the type or concentration of solids. (See Unexpected Results below for an expanded explanation.)

The industry has strong evidence that the limitation to the amount of nonfat milk solids that can be added to milk for cheese making primarily is the lactose level in the final cheese milk. Residual lactose and/or galactose at the time the cheese enters the warm room can result in excess gas production and overset eyes, which may be a function of the specific strain of propionibacteria used in the starter. A method was developed that permitted alteration in the milk lactose level.

Five-pound Swiss cheeses were made in the OSU pilot plant. Low heat nonfat dry milk or 70% protein milk protein concentrate (MPC) was substituted for fluid milk at different levels (1.5 or 3% on a protein basis) while keeping the protein content in the cheese constant. For MPC, this resulted in a reduction of 2.3 and 4.7% lactose at the 1.5% and 3% substitution levels, respectively. Six cheeses were made at a time, with 0% (control), 1.5%, and 3.0% of each milk solids type made on the same day.

Other studies have established that there are interactions between the lactic acid producing and propionic acid producing bacteria in Swiss cheese. Thus, the starter cultures utilized contained

the same strain of *Streptococcus thermophilus* and *Lactobacillus helveticus*, whereas three different strains *Propionibacterium freudenreichii* subsp. *shermanii* (P835, P873, and P318) were used. These strains have previously been shown to have different fermentation patterns and different amino acid requirements. Cheeses were analyzed after 1 day, after 7 days cold storage, after 3 weeks in the warm from (25°C), and at 60 and 90 days of ripening at 4°C. Analyses were made for pH, salt, moisture, protein fat, texture, number of the three starter organisms, free amino acids and free fatty acids.

Protein, fat and moisture contents of the cheeses were relatively constant. Also, initial counts of *S. thermophilus*, *L. helveticus* and *P. freudenreichii* subsp. *shermanii* were about 8-9, 6-7 and 4-5 log cfu/g for the three organisms, respectively, and were not influenced by the type or amount of milk solids substitution.

The addition of MPC resulted in a higher pH in all cheeses at one day of age, with the pH being about 0.1 pH unit higher in cheeses with either 1.5 or 3% substitution. During cold room treatment, there was a continued decrease in pH, which was about the same for all cheeses. During warm room treatment, some cheeses continued to decrease in pH, but others increased. Both MPC addition and *Propionibacterium* strain affected pH. For strain P835, the control showed an increase in pH during warm room treatment (WRT), but there was little change in pH with added MPC. For strain P873, the pH increased during WRT in all cases. For P318, the pH continued to decrease in all three cheeses during WT. A 2 to 5% reduction in the lactose level in the milk was sufficient to have a significant effect on the pH of the cheese, which also influenced the strain of *Propionibacterium* that was used.

Free amino acid levels increased in all cheeses during WTR. The degree of increase was related statistically to the level of MPC addition with some strains (P873 & P318), but not with P835. For P873 & P318, the increase over the control was 15 & 55% respectively for those cheese made with 1.5% added MPC.

After ripening for 60 and 90 days, there was a difference in texture in the different cheeses. Springiness and cohesiveness were higher in the cheeses with added MPC than in the control at both 60 and 90 days, and was not influenced by the strain of *Propionibacterium* that was utilized. Hardness was lowest in the cheese with 3% MPC substitution, but again there was no effect of *Propionibacterium* strains.

Substitution of small amounts (1.5 and 3.0%) of MPC on a protein basis had a marked effect on both the concentration of acetic (C2) and propionic (C3) acids formed during warm room treatment (WRT), and altered the ratio of C3/C2. Not all *Propionibacterium* strains responded in the same way. For cheese made using P873 and P318, concentrations of C2 and C3 increased markedly with increasing MPC substitution. Cheese made with P835 had quite different results, with no stimulation of C2 production and limited formation of C3. For cheese made with P873 and P318, the increase in acetic acid with 3% MPC substitution was about 120 and 200%, respectively, whereas the increase in propionic acid was >400 and 600%, respectively. This degree of stimulation of propionic acid concentration was not expected at the relatively low levels of substitution. Of greater significance was the effect of MPC on the ratios of C3/C2. For cheese made with P873 and P318, increasing the level of MPC increased the amount of propionic acid compared to acetic acid compared to the control. The ratio of C3/C2 for the

control was about 1.0 for cheese made with both strains. For cheese made with P873 the ratios of C3/C2 were 1.6 and 3.0 at 1.5 and 3.0% substitution, respectively. For P318, the ratios were 1.9 and 2.7 for 1.5 and 3.0% substitution, respectively. The change in the ratio of C3/C2 is an important finding, which cannot be explained by the effect of MPC on pH. The data suggest a shift in the fermentation pattern of the propionibacteria from formation of propionic acid via the action of aspartase in the control, which would account for the relatively low C3/C2 ratio. It would appear that the MPC resulted in a shift to the normal fermentation of lactic acid to form propionic acid with more propionic acid than acetic acid being formed. The optimum level of MPC substitution remains to be determined.

Generally, eye formation was excessive (overset) in all cases, regardless of the presence or absence of MPC, but the number and size of the eyes was slightly affected by the strain of propionibacteria. This was attributed to the low temperature (kosher) cook procedure (see below).

After recognition of the problem with overset eyes, which appeared to be related primarily to the low curd cooking temperature and was unrelated to solids addition; attention was directed to the development of a rapid, laboratory-scale, miniature Swiss cheese making procedure. Up to 8 cheeses (150g) can be made in a day using 1.5 L of milk per cheese. Salting time was 5 minutes, cold room treatment was reduced from 7 to 2 days, but warm room treatment remained three weeks. With these small cheeses, eyes were formed that were equal to those in commercial Swiss cheese (see table below).

Analysis	Minature scale cheese (150g)	Commercial cheese
pH	5.2-5.6	5.2-5.6
% moisture	36-38	35-40
% protein	26-28	27-28
% fat	30-32	30-32
Free amino acids (mM./g)	0.15-0.30	0.15-0.21
% L lactic acid	0.2-0.3	0.2-0.4
Eye diameter (mm)	8-25	15-21

This method lends itself to rapid screening of variables that control pH and eye formation because of cooking temperature and different types and levels of non-fat milk solids addition. Attention has been directed to screening the effect of cooking temperature and pH on these two important parameters.

3. Unexpected findings:

Three major unexpected findings had a major impact on the project:

Failure of accelerated screening method to differentiate individual starter organisms:

A previously developed accelerated screening procedure (slurry system) in which the fermentation obtained during 6 months for standard cheese could be achieved in 6 days was proposed to screen a broad range of types and concentrations of milk solids. This system failed

because of non-starter microorganisms normally present under commercial conditions, could not be eliminated from the cheese curd made in the pilot plant and used for the slurries. This interfered with enumeration of three individual starter organisms, which are known to be influenced by the addition of nonfat milk solids. The failure of this method resulted in starting pilot plant work without the prior screening information.

Kosher cook procedure used in pilot plant studies caused oversight eye formation independent of solids addition:

The further processing of whey from the manufacture of Swiss cheese has become economically important during recent years, and the Swiss cheese industry wished to be able to sell the resulting whey products as Kosher. To achieve this, the cooking temperature for the Swiss cheese curd cannot exceed 120°F, instead of the traditional 125-130°F. This is a recent development, and the Swiss cheese Consortium supporting this project suggested that the kosher cook procedure be used in the pilot plant studies. Results of pilot plant studies have shown that unsatisfactory eye formation resulted from the kosher cook method, which was independent of the type of level of added non-fat milk solids. However, there were differences in the quantity and quality of eyes using different strains of propionibacteria. Subsequently, the Swiss cheese industry has also reported problems with eye formation using the kosher cook procedure in standard cheese milk.

Reducing the temperature of cooking stimulates acid production by *S. thermophilus*. This organism selectively ferments the glucose portion of the lactose, leaving galactose. If galactose is not fermented during the cold room treatment, then its fermentation during the warm room treatment can lead to increased gas production and oversight eyes.

The finding of the problem with eye formation due to the cook procedure resulted in abandoning plans for cheese manufacture with added milk solids under commercial conditions until this problem is solved.

Stimulation of propionic acid formation and an increase in the ratio of C3/C2 by the substitution of low levels of 70% protein MPC:

The degree of stimulation of propionic acid production during warm room treatment and the increase propionic compared to acetic acid by the substitution of relative low levels of MPC for milk was not anticipated. This opens up new opportunities for control of propionic acid production, which is recognized to be one of the most important compounds associated with Swiss cheese quality.

4. Practical impacts of research efforts:

An important result from this investigation was the recognition of unsatisfactory eye formation resulting from the use of curd cooking temperatures to meet kosher requirements for whey products. These problems were unrelated to the addition of milk solids. This has short term effects for those Swiss cheese manufacturers that have stopped using the “kosher cook” to avoid under-grade cheese, as well as long term effects for those manufacturers that have chosen to continue the “kosher cook” procedure. The latter may lose money from cheese that does not meet top grade requirements until a solution is found for the eye formation problem. This has become an industry wide problem, which has been given a high priority.

The most important finding was the effect of low levels of milk solids substitution on both the stimulation of propionic acid production and the apparent shift in the fermentation pathway to increase the ratio of propionic acid to acetic acid. Elucidation of the mechanisms involved and optimizing the MPC concentration promises to have an important impact of Swiss cheese quality. Because of the reduction of pH by MPC substitution, higher levels may minimize the eye formation problem with Swiss cheese made by the kosher cook procedure, as well as further stimulate propionic acid production.

Developing knowledge that permits economical optimization of non-fat milk solids addition, especially MPC, to milk for Swiss cheese making continues to be important to Swiss cheese manufacturers. Increasingly, there are shortages of milk for Swiss cheese manufacture in Ohio and other Midwest states. The shifting of cheese manufacture to the Western part of the United States (California, Idaho and New Mexico) will make this problem more important in the future. If not solved, long term effects may cause closure of some of the Swiss cheese plants that are now concentrated in the Midwest.

5. Further Research in the area of this research:

The direction of the principle investigators research on Swiss cheese has shifted to solving the improper eye formation caused by those in the industry meeting the “kosher cook” requirement for whey to be further processed., as well as to gaining more knowledge of the effect of substitution of milk solids, especially MPC, to milk for cheese making..

At the end of this project, a rapid, miniature cheese procedure (150 g cheese) was developed that gives similar eye, lactic acid and free amino acid values as those in commercial Swiss cheese of the same age. This method allows up to 8 cheese to be made for day and is being used to assist in solving both the “kosher cook” and solids addition problems.

The Swiss Cheese Consortium has indicated that the In-Kind support that was not used for this project, will be available for use in commercial production when further information is available.