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The Influence of Amounts of Propionibacterium Shermanii on Eye Formation and Flavor of Cheese

Dan G. Turner
Utah State University

THE INFLUENCE OF AMOUNTS OF PROPIONIBACTERIUM SHERMANII ON EYE FORMATION AND FLAVOR OF SWISS CHEESE

by

Dan G. Turner

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Dan Turner

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INTRODUCTION

Swiss cheese has been rightly called "king of the cheeses." It has been prized the world over for its stately appearance and sweet "hazelnut" flavor. In grading Swiss cheese, these two things, appearance and flavor, are important considerations in determining the cheese score. Appearance is judged according to the number, type, and size of eyes present in the cheese, with color and body and texture also considered. Flavor is judged according to the degree of sweetness and the amount and kinds of off flavors present.

In the past, there has been considerable variation in the quality of the Swiss cheese produced. Causes of this variation were little understood, since wide ranges in grades of cheese were obtained from seemingly similar milk and manufacturing procedures. Technique has been greatly improved by research conducted in both private industry and experiment stations. Much has been done to produce beneficial effects in the cheese, and to reduce detrimental effects.

One question, still debated, is the amount of eye forming bacteria necessary to produce the best eye formation. Propionibacterium shermanii, by its production of carbon dioxide, is thought to be the most important bacteria in producing the eyes. Some Swiss cheese makers

see no necessity in adding prepared cultures of P. shermanii to their milk. They allow the milk to become "seeded" from organisms already present in the vats and on the equipment. Other cheese makers add small amounts of prepared cultures of P. shermanii, while still others add rather large quantities. Procedure varies from plant to plant.

Propionic acid and acetic acid are also produced in the life processes of P. shermanii. These two acids are important factors in the development of flavor in Swiss cheese. Therefore, a change in the amount of P. shermanii added, would also have an effect on the flavor of the cheese.

Swiss cheese is usually made from either raw or heat-treated milk. More recently, hydrogen peroxide and catalase have been successfully used in treating the milk. It should be helpful to determine the effect each of these treatments has on the growth and development of P. shermanii in the Swiss cheese, and the subsequent effect on eye formation and flavor.

It is the purpose of this experiment to determine the general effects that variations in the size of the inoculation of P. shermanii will produce on eye formation and flavor development. The effects, if any, of the three milk treatments mentioned above will also be noted.

REVIEW OF LITERATURE

Good Swiss cheese contains round holes or "eyes" that are large, shiny, smooth, few in number, and evenly spaced. It has no cracks and no small gas holes. The rind is smooth, uniform, clean, and free from cracks (3).

Swiss cheese is a hard rennet cheese made from cow's milk and is somewhat sweetish in flavor. This cheese originated in the Emmental Valley of Switzerland, and is a very old variety, being reported as early as the fifteenth century in the Canton of Emmental.

Propionic acid bacteria

In 1908 von Freudenrich and Orla-Jensen (37) reported an organism that they felt was responsible for the formation of eyes in Swiss cheese. In their experiments they also found the same organism to be responsible for the sweet flavor of Swiss cheese. They named the organism Bacterium acidi-propionici.

Other investigators, Sherman (35) and Clark (8), also found the same or a similar organism to be the cause of the eye formation and characteristic flavor of Swiss cheese. Early experiments with prepared cultures of propion bacteria were failures. This was due mainly to a lack of a suitable broth for growing the organism. Von Freudenrich and Orla-Jensen had used a calcium lactate broth. This was unsuitable since bacteria grew only re-

luctantly in it. Sherman (35) by substituting sodium lactate for calcium lactate, was able to obtain a much better growth.

The propionic acid organism was found to be a minute rod about twice as long as it is broad. Its growth is comparatively slow, and considerable oxygen is required. The organism is facultative, however, and grows best in a reduced oxygen tension. The lactates in the cheese act as the food source. They are fermented to give propionic acid, acetic acid, and carbon dioxide (35). Large amounts of catalase are also produced.

But the lactates are not the only source of volatile acid production in Swiss cheese. Shaw and Sherman (34) found that the propionic acid organism could also utilize succinic acid, glycerol, and some nitrogenous constituents in the cheese. They found some indication that the organism can break down butterfat, and even suggested that the whiteness of Swiss cheese may be due to this breakdown.

Experiments by Clark (8) disclosed that the eyes in Swiss cheese are formed by collections of gas which separates in the cheese in accordance with the laws governing separation of gases from supersaturated solutions. He found that the eyes did not form within the curds of the cheese, but rather between the curds. Further investigation showed that there were no great concentrations of propionic acid bacteria in the eyes. The bacteria were found to be distributed rather unequally throughout the cheese. It was found that the gas produced by

these organisms moved through the cheese, between the curds, and collected in pockets to form the eyes. In "nissler" cheese, eye formation took place within the curd, and the gas present was mostly hydrogen rather than the carbon dioxide found in the eyes of normal Swiss cheese.

Work by Babel and Hammer (5) indicates that propionic acid bacteria are not the only cause of eye formation in Swiss cheese. Their findings show that good eye formation did not always accompany additions of propion bacteria cultures. In some instances, good eye formation was obtained in cheese to which no propion culture had been added. This cheese was usually lacking in flavor. The work did indicate that sweetness of flavor increased with an increase in size of propion bacteria inoculations. In some instances the increased inoculation produced eyes that were larger than usual, but this was not always true. In this respect, Frazier and Wing (20) found that large inoculations of propion bacteria caused "overset" in cheese they were working with. They also found that excessive growth of propion bacteria, especially in the later stages of ripening, tended to cause "glass" and checking.

Babel and Hammer (5) were concerned with several strains of propion bacteria in their work. They found that some strains consistently produced good flavored cheese, other strains were variable. None of the cultures were consistent in producing good eye formation.

There is some reason to believe that some failures of Swiss cheese to ripen properly are due to death of

the propion bacteria during the cooking period. Frazier and Wing (19) found that resistance of propion bacteria to heat varied with the age of the culture. Their experiments showed that less than 1% of cultures not over 4 days old will survive the cooking temperature (53° C. for 30 minutes), with a 2 week old culture, 15% survived, while 80% of the propion bacteria in a 2 month old culture survived.

Flavor of Swiss cheese

The characteristic sweet flavor of Swiss cheese is thought to be due to the presence of the lower fatty acids or their salts (propionates, acetates, etc.). Babel and Hammer (4) found that the degree of sweet flavor was directly related to the amount of volatile acids present. These acids, in themselves, do not have a sweet flavor. The salt, calcium propionate, suggests first a sweet then a bitter flavor. Potassium and sodium propionates also suggest a sweetness. The acetates of calcium, sodium, and potassium have very little sweet flavor. However, when calcium and sodium propionates are added to processed Swiss cheese, they have a very pronounced effect, the calcium more so than the sodium. They also found that the amounts of propionates added influenced the body and produced a body more like that of natural Swiss cheese.

Other Swiss cheese starters

In general, the bacteria that produce the most desireable effects in Swiss cheese, are the ones that

grow the best under conditions prevailing in most manufacturing procedures (20). The important starters usually used in Swiss cheese are Propionibacterium shermanii, Streptococcus thermophilus, and either Lactobacillus bulgaricus, or L. casei. Frazier, et al., (13) states that for many years only the importance of the Lactobacillus and the propion organisms was recognized. Then it was found that a raw whey starter containing a mixture of Lactobacillus casei and Streptococcus thermophilus bacteria seemed to produce a much better cheese. Work done by these men showed the improvement to be due to the presence of a heat resistant Streptococci. Cheese made from kettle whey showed no improvement over cheese made with pure cultures of Streptococcus thermophilus and Lactobacillus casei. They found that pure cultures of Lactobacillus casei had a bitter flavor that was absent when Streptococcus thermophilus was added. Under most conditions the addition of Streptococcus thermophilus improved the cheese. The improvement was quite marked in eye formation, texture, and flavor.

Bacteriological experiments by Frazier, et al., (16) reveal a definite relationship between acidity of the starter and the quality of Swiss cheese. A titratable acidity of 1.0 to 1.09% in the Lactobacillus casei starter produced the largest number of fancy grade and number one cheese. Acidities of 1.10 to 1.14% were almost as good. Acids of 1.2% or over, produced cheese of considerably poorer quality. With a milk grown Streptococcus thermophilus starter, the most desireable acidity was found to be .70%

to .75%. Associative action of the bacteria when grown together seems to stimulate activity. However, in carrying a mixed starter over a period of time, there is considerable variation in the number of each organism present.

Bacterial counts of milk in the cheese kettle (Frazier, et al.) (18) indicate that the Streptococcus thermophilus population increases from addition to dipping. The most rapid growth took place in the later part of the process. Lactobacillus casei decreases in number in the kettle, especially after cooking temperature is reached. There is also a decrease in number of propion bacteria. Gas formers present in the milk remain about the same.

Work by Frazier, et al., (14) indicates that Streptococcus thermophilus grows most rapidly, when in the press, up until the 6-8 hour after dipping. Lactobacillus casei decreases slightly in the press then increases fairly rapidly after the eighth hour. There seems to be no detectable growth of propion bacteria until the second or third week in the warm room. Frazier and Wing (19) found propion bacteria to be the most numerous organism present in two month old Swiss cheese.

pH indications

Where pH of Swiss cheese is concerned, Babel and Hammer (5) found little correlation between pH of ripened cheese and quality of the cheese. However, with cheese still in the press, Frazier, et al. (16), found pH at 21 hours after dipping to be an indication of the quality the cheese would later attain. A pH at 21 hours of 5.0

to 5.09% is most likely to produce the highest percentage of good quality cheese. A pH of 5.10 to 5.14% is almost as good. Cheese with a pH at 21 hours of 5.2% or higher is likely to be poor quality.

Aerobacter contamination

Occasionally, abnormal gassy fermentations occur in Swiss cheese. Most investigators agree that the colon-aerogenes bacteria cause most of the trouble (1). In most cases the presence of these organisms is more objectionable from the standpoint of eye formation than from flavor defects. They cause eyes to form that are ragged and numerous. In some cases free butyric acid is formed which causes an objectionable flavor. These off flavors usually increase with the age of the cheese. Demeter (10) found that inoculations of the milk with good Swiss cheese starters, especially Streptococcus thermophilus organisms, will usually prevent the growth of undesireable gas formers. This was true even in heavily contaminated milk. The findings of Frazier, et al. (18), supports this conclusion. Frazier and associates recommend that the Streptococcus thermophilus starter be added early (when the milk first enters the kettle) to ensure better control of the aerobacter present.

Methylene blue reduction time

One of the most important factors influencing the quality of Swiss cheese is the bacteriological condition of the milk. This can be satisfactorily determined for manufacturing purposes by the methylene blue test.

Rogers, et al. (30), reported that when the methylene blue test is not over three hours, the chances of obtaining an A or B grade cheese are about 1 in 3. If the reduction time is over 3 hours, the chances of obtaining an A or B grade cheese are about 2 in 3. The chances of making an A or B cheese out of the later milk may be increased to 3 in 4 by adjusting the starters and manufacturing procedures to secure a pH at dipping above 6.35 but not over 6.51. If the pH at dipping is above 6.51, there is only 1 chance in 9 or 10 that the cheese will be A or B quality.

Ripening the milk

Milk with a methylene blue reducing time of 6 hours or over, sometimes sets dead and lacks proper "grip" in the kettle. Frazier, et al. (17), investigated the possibilities of purposely ripening the milk before beginning the making process. They found that ripening was beneficial only when the methylene blue reduction time of the milk was 5 to 6 hours or longer. The organism they used was S. thermophilus. A temperature of 50° C. for 30 to 60 minutes was found to produce the best results. Ripening the milk over night at a lower temperature with S. lactis did not produce satisfactory results.

Clarification

Experiments by Matheson, et al. (25), have demonstrated that clarification of milk produces a marked and consistent improvement in the quality of Swiss cheese. Specific effects of clarification include a marked decrease

in number and an increase in size and uniformity of eyes. There is also an increase in the firmness of the cheese and a decrease in the moisture content. Clarification decreases the tendency of the fat to form aggregates, and it removes a large portion of the leucocytes from the milk. This is thought to be due to the reduced leucocyte count.

Moisture and fat content

Investigations by Sanders, et al. (33), revealed that the greatest number of A and B grade Swiss cheese had a moisture content below 37%. They found that the most desireable moisture range is 33-35%, with the upper limit at 38.2%. Above this, quality decreases as moisture increases. Rapid acid development, higher cooking temperatures, prolonged heating period, and coarsely harped curd all help to reduce moisture content. Some of the procedures used to increase moisture actually cause an overall loss. This is because of the higher loss of milk solids and fat in the whey.

Where fat is concerned, Sanders, et al. (32), there is usually a decrease in moisture content with an increase in fat content of the cheese. The most desireable fat content is 45-46% in the dry matter. A cheese with too high fat content may be soft, weak, and pasty in body and have "glass" and splits in the curd. A slightly higher per cent fat in cheese that is too firm often increases quality.

Hydrogen peroxide treatment

Hydrogen peroxide has been found by Johnson (22) and Nagmoush (27) to be an excellent sporicide and it greatly reduces the incidence of gas and flavor defects caused by Aerobacter organisms. They also found hydrogen peroxide cheese to have increased absorptive capacity and thus a higher moisture content. Johnson reported that eye development, flavor, and body and texture were all superior in cheese made from hydrogen peroxide treated milk. This was in comparison to raw and pasteurized milk cheese.

In work done by Roundy (31) it was found that hydrogen peroxide is capable of destroying most of the organisms harmful in milk, yet leaving intact most of the natural enzymes that are so necessary in ripening of the cheese. He found that hydrogen peroxide destroys approximately 99.9% of the Escherichia-Aerobacter organisms in milk and about 75% of the total bacterial flora.

METHODS OF PROCEDURE

This Swiss cheese experiment was conducted at the Utah State Agricultural College. The milk used was mostly grade A from the college herds. A few lots were made from manufacturing grade milk produced by the farmers in Cache Valley.

All cheese was made using Swiss cheese methods as adapted to cheddar cheese equipment and facilities.

Milk treatment

Raw, heat-treated, and hydrogen peroxide treated milk was used in this experiment. The milk in all treatments was standardized to 2.9% fat with grade A skim milk.

Each 1320 pound batch of milk was divided into 440 pound portions and pumped into three small cheddar cheese vats.

The standardized raw milk was heated to 92° F. in a pasteurizing vat, then pumped through a clarifier into the cheese vats.

The heat-treated milk was heated quite rapidly to 158° F. in a pasteurizing vat, cooled immediately to 92° F., then pumped through the clarifier and into the cheese vats.

The hydrogen peroxide treated milk was first heated to 120° F. in a pasteurizing vat to inactivate most of

the catalase normally present in milk, and to improve the effectiveness of the hydrogen peroxide. U. S. P. edible grade 35% hydrogen peroxide was then added at the rate of 0.20%. The hydrogen peroxide ("perone") used was manufactured by the E. I. Du Pont Nemours Company, Electrochemical Division, Elmonte, California. Ten volumes of cold water was added to the hydrogen peroxide before it was added to the milk.

After the addition of hydrogen peroxide, the milk was immediately cooled to 100° F. Catalase (number 30, produced by Armour and Company, Chicago, Illinois), diluted 30 to 40 times its volume with cold water, was then added at the rate of 0.50 grams per 2000 pounds of milk. The decomposition of hydrogen peroxide by the catalase required 30 to 40 minutes. The presence or absence of hydrogen peroxide was tested by the use of potassium iodide. This test consisted of adding 5 c.c. of a 30% potassium iodide solution to 10 c.c. of the treated milk. A pink to brown color indicated a positive test for hydrogen peroxide, a natural colored milk indicated a negative test. As soon as a negative test was obtained, the treated milk was cooled to 92° F. and pumped through the clarifier and into the cheese vats.

Starters

Two strains of Lactobacillus bulgaricus, two strains of Streptococcus thermophilus, and one strain of Propionibacterium shermanii were used. The L. Bulgaricus and S. thermophilus were transferred daily in grade A, homo-

genized, whole milk. This milk had previously been sterilized at 15 pounds pressure for 15 minutes. The two starters were incubated at 100° F. for 14 to 16 hours.

The P. shermanii was grown in a sterile broth containing 5 grams beta lactose, 10 grams tryptone, 10 grams peptone, and made up to 500 ml. with distilled water. These cultures were incubated at 86° F. for about three days or until the turbidity of the broth indicated a good growth of the organism. They were then placed in a refrigerator for three days before being used for cheese making.

The titratable acidity of the L. bulgaricus ranged from 1.30 to 1.80 per cent, and that of the S. thermophilus from .68 to .75 per cent.

Three vats of cheese were made in each lot. L. bulgaricus was added to all three vats at the rate of 300 ml. per 1,000 pounds of milk. S. thermophilus was added to each vat at the rate of 600 ml. per 1000 pounds of milk. P. shermanii broth was varied between vats of each lot as follows: Vat 1, 30 ml. per 1,000 pounds of milk, and vat 2, 5 ml. per 1,000 pounds of milk. Vat 3 received no P. shermanii culture.

Cheese making process

The making procedure used in this experiment was adapted from that used by Johnson (22) and Greer (9). The only difference was a 40 to 45 minute period of alternate stirring and settling of the curd, after cutting and before heating, used in this experiment. This

procedure is thought to improve moisture content in the final cheese.

The milk was pumped into the vats at the setting temperature of 92° F. The starters were added and stirred in for 2 to 3 minutes. Rennet, diluted with cold water, was added at the rate of 60 ml. per 1,000 of milk and well stirred in. Setting time was 25 to 30 minutes.

The curd was cut when firm enough to break evenly when rolled over with a scoop. Cuts were made with quarter-inch knives followed by a half-inch vertical curd knife. The half-inch knife was used as a harp to cut the quarter-inch cubes into particles about the size of a kernel of wheat.

Having been cut to the desired size, the curd was allowed to settle for five minutes. It was then stirred up with a paddle for five minutes and allowed to settle for ten minutes. After another five minutes of stirring, it was settled for fifteen minutes. The curd was broken up into individual particles and heating was begun. The temperature was brought from the setting temperature of 92° F. to the cooking temperature in thirty minutes. The raw and heat-treated cheese was cooked at 122° F., and the hydrogen peroxide treated cheese at 124° F. as it retains more moisture.

The cooking end point was determined by physical and by brine methods. A handful of curd was compressed firmly in the palms of the hands, then bent over the finger. If the curd broke apart easily without sticking

it was ready to dip, providing the individual curd particles would sink when dropped into a 7.5% (by weight) salt solution in 15 to 30 seconds.

Dipping consisted of draining the whey to the top of the curd and then inserting a perforated screen at one side of the vat and forcing the curd to the other. Wooden stays were placed against the screen so that the curd was held in the shape of two cheddar cheese hoops. The remainder of the whey was then drained and the cheese was allowed to mat for about 10 minutes. It was then cut approximately in half and placed in two 20 pound Wilson cheddar cheese hoops. The cheese was dressed and pressed the same as cheddar cheese for 14 to 18 hours. After pressing, the cheese was placed in saturated brine solution at 55° F. for 30 hours.

Curing

The cheese was removed from the brine, wrapped in "Parakote", and strapped in 20 pound cheddar cheese boxes. The boxed cheese was left in a warm room for 24 hours to get a good seal on the wrapper, then placed in a 45° to 50° F. cold room for two weeks. After the two weeks in the cold room one cheese from each vat was moved to a warm room for eye development. The other cheese from each vat was left to be cured entirely in the cold room. The warm room was kept at 75° to 85° F. When the cheese of each lot having 5 ml. of added propion culture showed the desired eye development, all three cheeses of that lot were removed to the cold room for further curing.

Score and analysis

When the cheese was 120 days old, it was examined and scored by Professor A. J. Morris and Professor Paul S. Larsen according to the following score card:

Flavor	35 points
Eye appearance	30 points
Texture and body	20 points
Salt	10 points
General appearance	5 points
Total score	100 points

Samples were taken for pH, butter fat, and moisture analysis.

Determination of fat and moisture

Cheese samples were analysed as soon as possible without unnecessary exposure to the air. Official methods for routine laboratory analysis were used to determine fat and moisture content (38).

RESULTS AND DISCUSSION

The results of the experiment are summarized in the tables 1 through 5. Tables 6 through 11 show the scores and analysis of each individual cheese. The tables on Analysis of Variance, numbers 3, 4, and 5, were prepared by Morgan (26). Morgan conducted a separate experiment on the same cheese. His problem was to find the effect that the variation in P. shermanii additions had on the lower fatty acid content of the Swiss cheese. His results show a highly significant variation in both propionic and acetic acid content. The amount of propionic acid was found to increase with an increase in the size of the propion culture inoculation. Only small amounts of propionic acid were found in the cheese with no propion culture added. There were greater amounts of propionic acid present in the cheese containing 5 ml. of propion culture, with the largest amounts being found in the cheese with 30 ml. of added propion culture. The acetic acid content was about equal in both the cheese containing 5 ml. and that containing 30 ml. of propion culture but was considerably lower in the cheese with no added propion culture. Propionic acid was present to a greater extent than was acetic acid in both sets of cheese having P. shermanii added. In the cheese with no propion culture inoculation, both acids were present, but in smaller

amounts, with the acetic acid being present in larger amounts than the propionic acid.

In the present experiment, it was found that the intensity of flavor in the cheese increased with an increase in the size of the P. shermanii inoculation. The 30 ml. inoculation produced the sweetest flavor. In most lots, the cheese with no added P. shermanii received the lowest flavor score (Table 1). This cheese was usually criticized as flat and lacking in flavor. These results coincide with the findings of Morgan (26). An increase in flavor was accompanied by an increase in lower fatty acids content, especially propionic acid. The flavor of Swiss cheese is thought to be due to the amounts of lower fatty acids present in the cheese. The results of this experiment seem to substantiate this theory.

It was noticed that at4 months mush of the cheese containing 30 ml. added propion culture was criticized as harsh and stringent in flavor. Several of the cheeses containing 5 ml. of propion culture also received this criticism, but very few of the cheeses with no added propion culture did. The defect may have been partly due to a slightly higher eye forming temperature (75°-85° F.) than normal. However, the defect became more apparent with an increase in P. shermanii inoculation.

In general, the cheese with 5 ml. P. shermanii had the best eye formation (Tables 6, 7, and 8). The 30 ml. cheese contained the most numerous eyes, some of these cheeses even being criticized as overset. The

cheese with no added propion culture developed fewer and smaller eyes, some cheeses being almost "blind." (See figures 1 to 3). In the cheese with no added propion culture, an increase of flavor with a slight increase in number of eyes was very noticeable. An increase of just one or two eyes was accompanied by a definite increase in degree of flavor, although the cheese was still scored down as lacking in both.

Where treatment of the milk was concerned, the hydrogen peroxide treatment was the most consistent in producing good eye appearance (Table 2). Heat treated milk showed more tendency to produce good eye appearance in the cheese than did raw milk. Tables 6, 7, and 8 show the amount of variation in eye formation between the individual cheeses of each treatment. The hydrogen peroxide treatment produced the least amount of variation in eye appearance between cheeses. The heat treated cheese showed more variation, while the cheeses made from raw milk showed considerable variation in eye appearance. The improvement in eye appearance brought about by treating the milk was probably due to a reduction in the numbers of undesireable gas forming bacteria present. The hydrogen peroxide treatment was seemingly more efficient in this respect than was the heat treatment of the milk.

The amount of propion starter added seemed to have little effect on the body and texture of the cheese. Treatment of the milk had considerable influence on the body and texture. (Tables 6, 7, and 8). In comparing

the body and texture of the cheese made from the three treatments, the hydrogen peroxide treatment produced the most waxy and pliable body. The raw milk cheese was slightly more firm and dry, while the body of the heat treated cheese was quite firm and dry.

In moisture analysis of the cheese, tables 9, 10, and 11, the hydrogen peroxide cheese did not have a significantly higher moisture content even though it did have a better body and texture. In work done by Johnson (22), Swiss cheese made from hydrogen peroxide treated milk was found to have about 2% more moisture than raw milk cheese. A higher moisture content was not evident in the present experiment. This may have been partly due to the higher cooking temperature used with the hydrogen peroxide cheese.

Slight variations in the fat content of this cheese seemed to be due more to errors in standardizing the fat content of the original milk than to manufacturing procedures or to bacterial action.

Tables 9, 10, and 11 show that the pH of the cheese, at 4 months, varied with the size of the propion culture inoculation. The cheese with 30 ml. of propion culture added had the lowest pH. This was expected since the 30 ml. cheese contained the greater amounts of the lower fatty acids as was shown by Morgan (26). Raw milk cheese had a lower pH than did the cheese from either of the other two milk treatments. This was probably due to acid production by foreign bacteria present in the raw

milk, but killed in the heat treated and hydrogen peroxide treated milk.

The cheese that remained in the cold room was found to have few of the qualities of Swiss cheese. No eyes were formed in this cheese, although some of the cheese developed a few small sweet holes. This cheese cured quite slowly. At 4 months it was criticized as flat and lacking in flavor. The flavor that did develop was somewhere between a Swiss and a cheddar flavor. One curious thing about this cold room cheese was the marvelous body it developed. The body was long and waxy, with a well knit body and texture. It had an ideal cheddar cheese body. The moisture and fat content of the cold room cheese remained about the same as that of the duplicate cheese in which the eyes were allowed to form.

There was nothing in the experiment that would indicate why the one lot of hydrogen peroxide cheese became "stinkers" (Table 8). All three of the cheeses of this lot that were placed in the warm room for eye development showed the defect. The duplicate cheeses that were held in the cold room remained normal.

Table 1. Average score and analysis of all 15 lots of Swiss cheese as affected by P. shermanii variations.

Items scored & analyzed	mls. of P. shermanii added per 1000 lbs. of milk		
	30	5	0
Butterfat	29.46	29.30	29.43
Moisture	35.73	36.15	35.78
pH*	5.69	5.72	5.75
Flavor**	32.70	32.73	31.78
Eye appearance**	25.45	27.25	24.90
Body and texture**	18.38	18.32	18.32
Total**	92.20	92.90	89.57

* pH taken at 120 days.
** Score

Table 2. Average score and analysis of Swiss cheese as affected by milk treatment and P. shermanii culture variations.*

Items scored and analyzed	Milk treatment								
	Raw			Heat-treatment			Hydrogen peroxide		
	mls. P. shermanii culture								
	30	5	0	30	5	0	30	5	0
Butterfat	29.60	29.60	29.30	29.60	29.30	29.40	29.30	29.00	29.20
Moisture	35.02	36.59	36.02	35.51	35.74	35.39	36.66	36.11	35.95
pH	5.64	5.68	5.72	5.70	5.75	5.75	5.72	5.75	5.81
Flavor	33.00	33.40	32.00	32.80	31.80	31.60	32.50	33.00	31.75
Eye appearance	22.40	27.20	22.60	26.20	26.80	26.00	27.75	27.75	25.00
Body and texture	18.40	18.40	18.40	18.00	17.80	17.80	18.75	18.75	18.75
Total score	90.80	92.00	87.80	91.20	92.20	90.40	94.00	94.50	90.50

* Scored at 120 days.

Analysis of Variance*

Table 3. Flavor.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Starters	2	15.0750	7.5375	8.55**
Milks	2	1.2350	0.6125	----
Starters by milk	4	1.1500	0.2875	----
Error	36	31.7500	0.8819	----
Total	44	49.2000		

Table 4. Eye appearance.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Starters	2	68.0361	34.0180	7.21**
Milks	2	26.3445	13.1722	2.79ns
Starters by milk	4	30.1722	7.5430	1.60ns
Error	36	169.9000	4.7194	----
Total	44	294.4528		

Table 5. Texture.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Starters	2	0.0445	0.02225	----
Milks	2	5.9362	2.96810	9.33**
Starters by milk	4	0.0888	0.02220	----
Error	36	11.4500	0.31805	----
Total	44	17.5195		

* These tables prepared by Morgan (26).
** Highly significant
ns Not significant

Table 6. Flavor, eye appearance, and body and texture scores of Swiss cheese made from raw milk.

	mls. of P. shermanii culture added per 1000 lbs. milk								
	30			5			0		
Lot no.	flavor*	eyes**	b&t***	flavor	eyes	b&t	flavor	eyes	b&t
1.	34	25	18	34	28	18	34	26	18
2.	33	29	19	34	29	19	30	22	19
3.	33	26	18	33	27	18	32	24	18
4.	33	20	19	32	24	19	32	22	19
5.	32	24	18	33	28	18	30	20	18
Ave.	33.0	22.4	18.4	33.4	27.2	18.4	32.0	22.6	18.4

* Flavor based on a total of 35 points.
** Eye appearance based on a total of 30 points.
*** Body and texture based on a total of 20 points.
Scored at 120 days.

Table 7. Flavor, eye appearance, and body and texture scores of Swiss cheese made from heat-treated milk.

	lbs. of P. shermanii culture added per 1000 lbs. milk								
	30			5			0		
Lot no.	Flavor*	eyes**	body***	flavor	eyes	body	flavor	eyes	body
1.	34	27	18	32	24	17	31	26	18
2.	32	24	18	32	25	18	33	28	18
3.	32	27	19	33	28	19	32	27	18
4.	33	26	18	34	28	18	31	25	18
5.	32	27	17	32	29	17	31	24	17
Ave.	32.6	26.2	18.0	31.8	26.8	17.8	31.6	26.0	17.8

* Flavor based on a total of 35 points.
** Eye appearance based on a total of 30 points.
*** Body and texture based on a total of 20 points.
Scored at 120 days.

Table 8. Flavor, eye appearance, and body and texture scores of Swiss cheese made from hydrogen peroxide treated milk.

	mls. of P. shermanii culture added per 1000 lbs. milk								
	30			5			0		
Lot no.	flavor*	eyes**	b&t***	flavor	eyes	b&t	flavor	eyes	b&t
1.	33	29	18	33	29	18	30	20	18
2.	stinker	18	15	stinker	18	15	stinker	20	15
3.	32	28	19	33	28	19	33	29	19
4.	33	28	19	33	27	19	33	26	19
5.	32	26	19	33	27	19	31	25	19
Ave.	32.5	27.75	18.75	33.0	27.75	18.75	31.75	25.0	19.75

* Flavor based on a total of 35 points.
** Eye appearance based on a total of 30 points.
*** Body and texture based on a total of 20 points.
Scored at 120 days.

Table 9. Total scores, fat and moisture analysis, and pH of Swiss cheese made from raw milk.

	mls. of P. shermanii culture added per 1000 lbs. milk											
	30				5				0			
Lot no.	score*	fat	moist	pH**	score	fat	moist.	pH	score	fat	moist.	pH
1.	92	30.5	36.41	5.66	95	30.5	36.12	5.70	93	37.59	37.89	5.80
2.	94	30.0	35.20	5.62	97	30.0	34.33	5.58	86	29.0	36.43	5.59
3.	92	28.0	35.35	5.76	93	29.0	36.41	5.92	89	28.5	35.97	5.81
4.	87	29.0	33.96	5.53	91	30.0	37.00	5.60	88	29.5	36.72	5.70
5.	89	29.0	34.19	5.62	94	28.5	37.12	5.70	83	30.0	33.40	5.58
Ave.	90.8	29.5	35.02	5.64	92.0	29.8	36.59	5.68	87.8	29.3	36.02	5.70

* Total score based on 100 points.
** pH taken at 120 days.

Table 10. Total scores, fat and moisture analysis, and pH of Swiss cheese made from heat-treated milk.

	mls. of P. shermanii culture added per 1000 lbs. milk											
	30				5				0			
Lot no.	score*	fat	moist.	pH**	score	fat	moist.	pH	score	fat	moist.	pH
1.	94	30.5	34.96	5.68	88	30.0	36.80	5.65	90	30.0	35.54	5.80
2.	89	28.0	35.96	5.89	90	28.5	36.11	5.80	94	29.0	36.30	5.71
3.	93	30.5	35.61	5.73	95	29.5	35.87	5.75	92	30.0	33.40	5.72
4.	92	30.0	36.64	5.70	95	29.5	35.12	5.76	89	29.5	35.59	5.66
5.	91	29.0	35.40	5.71	93	29.0	35.23	5.80	87	28.5	36.15	5.87
Ave.	91.8	29.6	35.51	5.70	92.2	29.3	35.74	5.75	90.4	29.4	35.39	5.75

* Total score based on 100 points.
** pH taken at 120 days.

Table 11. Total score, fat and moisture analysis, and pH of Swiss cheese made from hydrogen peroxide treated milk.

	mls. of P. shermanii culture added per 1000 lbs. milk											
	30				5				0			
Lot no.	score	fat	moist.	pH	score	fat	moist.	pH	score	fat	moist.	pH
1.	95	29.5	35.68	5.80	95	28.5	34.35	5.71	83	29.0	35.50	6.05
2.	stinker	28.5	38.32	6.12	stinker	28.5	36.95	5.85	stinker	29.0	35.39	6.08
3.	94	28.5	38.32	5.72	95	29.0	36.49	5.79	96	30.0	36.38	5.71
4.	95	31.0	34.97	5.79	94	29.5	37.01	5.81	93	29.0	36.53	5.78
5.	92	29.0	36.01	5.68	94	28.5	35.73	5.70	90	29.0	35.95	5.68
Ave.	94.0	29.3	35.66	5.72	94.5	29.0	36.11	5.75	90.5	29.2	35.95	5.81

* Total score based on 100 points.
** pH taken at 120 days.

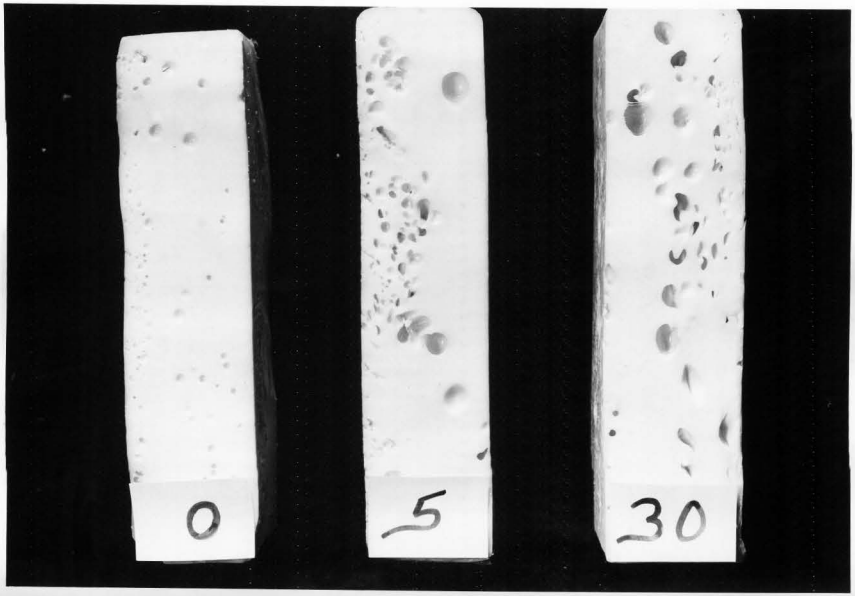

Figure 1. Eye formation as affected by the addition of 0 mls., 5 mls., and 30 mls. of *P. shermanii* culture.

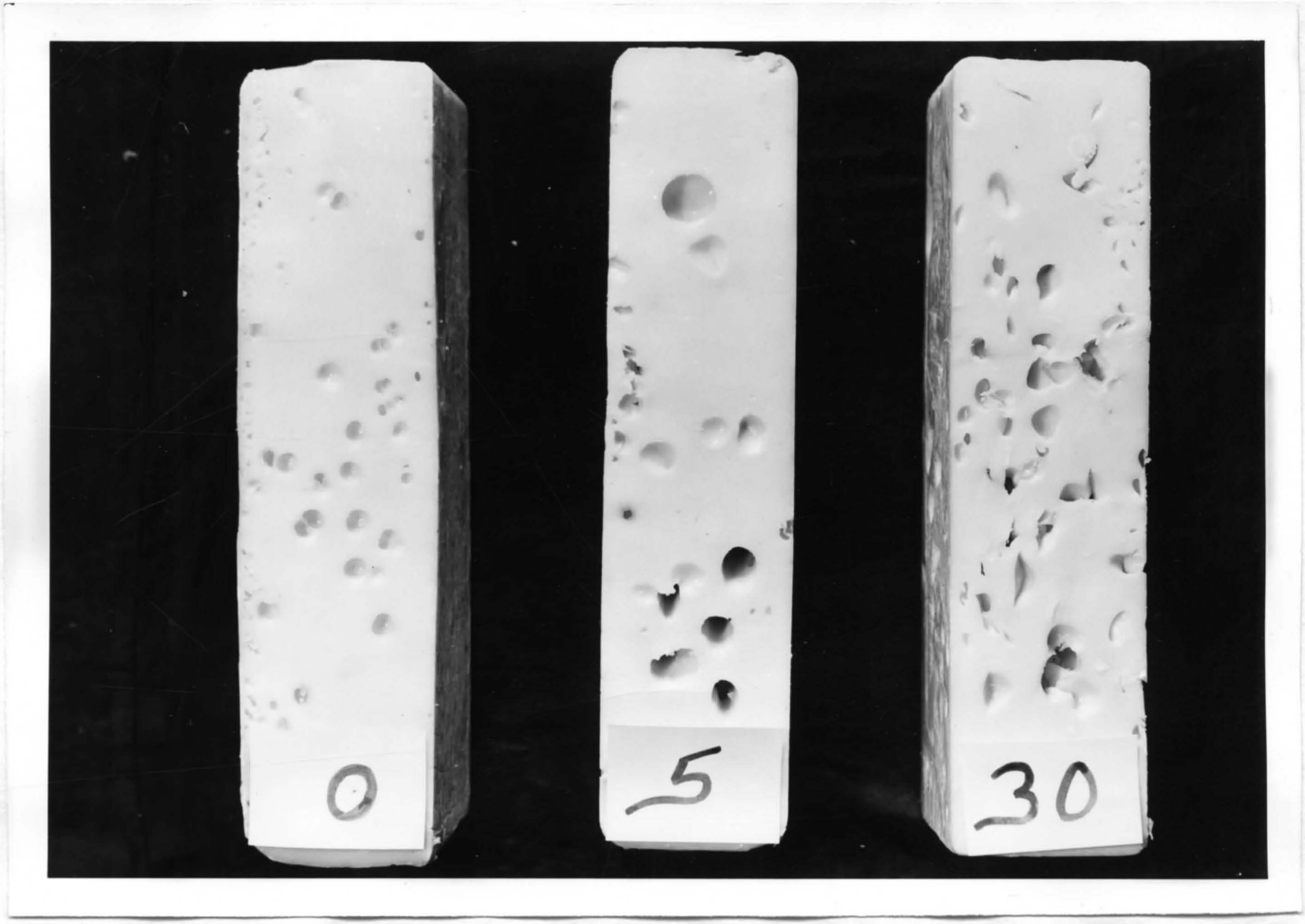

Figure 2. Eye formation as affected by the addition of 0 mls., 5 mls., and 30 mls. of P. shermanii culture.

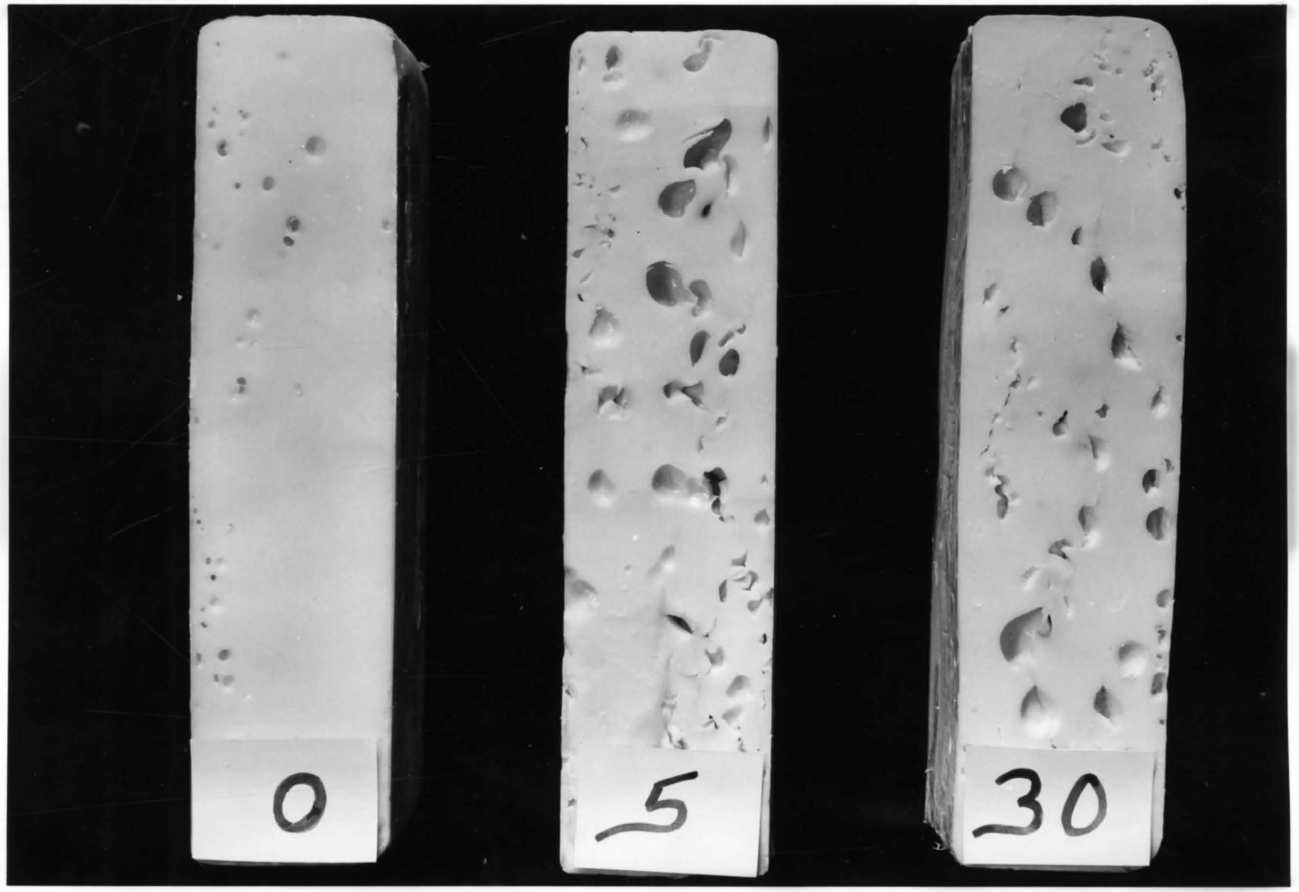

Figure 3. Rye formation as affected by the addition of 0 mls., 5 mls., and 30 mls. of P. shermanii culture.

SUMMARY

Adaption of Swiss cheese manufacturing procedures to cheddar cheese equipment was found to be quite easy and successful. Small, stainless steel, cheddar cheese vats were used. The cheese was cut and harped with conventional cheddar cheese curd knives. The cheese was pressed in twenty pound, stainless steel, Wilson cheese hoops. It was then wrapped in Laminated Natural Cheese Wrappers, or "parakote."

The following are the results observed in the experiment:

1. Morgan (26), working on the same cheese, found the amounts of lower fatty acids, propionic and acetic acid, increased with an increase in the amount of P. shermanii added.

2. The intensity of flavor increased with an increase in the size of P. shermanii inoculation, the most intense flavor was found in the 30 ml. cheese. Much of the 30 ml. cheese was harsh and stringent in flavor. The cheese with no added propion culture was usually flat and lacking in flavor.

3. The cheese with 5 ml. of P. shermanii added, produced the best eye formation. Cheese containing 30 ml. of P. shermanii usually had larger and more numerous eyes, and was in some cases, overset. The cheese with no

added propion culture produced fewer and smaller eyes.

4. Milk treated with hydrogen peroxide was most consistent in producing cheese with good eye appearance. The heat treated milk showed more tendency to produce good eye formation in the cheese than did the raw milk.

5. The hydrogen peroxide cheese was found to have the best body and texture. Its body was waxy and pliable. The raw milk cheese had a fairly good body being slightly more firm and dry than the hydrogen peroxide cheese. The body of the heat treated cheese was the most firm and dry.

6. The pH of the cheese became lower with an increase in size of propion culture inoculation. This was probably due to the higher propionic and acetic acid content that developed. The raw milk cheese was found to have a lower average pH than did the cheese from the other two milk treatments.

7. The cheese that remained in the cold room developed a long, waxy, and pliable body, with a well knit body and texture. This cheese was slow to cure and was still lacking in flavor after 4 months time.

CONCLUSIONS

It was not the purpose of this experiment to establish a definite quantity of P. shermanii to be added to the milk for Swiss cheese. Rather, its purpose was to observe the general effects that various amounts of the propion starter had on the cheese. These results could be used as a guide for those who might improve their cheese by either reducing or increasing the amount of propion culture added to their cheese milk.

As evidenced by the small amount of eye formation and flavor development in the cheese with no propion inoculation, some propion starter should be added to improve the cheese. In other areas the natural seeding of the cheese with the organism may be heavier, and not as much propion culture would be needed. Perhaps in some areas the natural contamination is adquate to insure eye and flavor development without adding propion organisms. At any rate, it would be difficult to say that any one quantity of propion culture is the bet amount for obtaining good quality Swiss cheese.

In determining the amount of propion culture needed, it may be possible that a compromise must be established. The most suitable quantity of propion culture for producing good flavor is not always the most suitable amount for producing good eye formation. The best eye formation

seems to be obtained with less propion culture than is required for the best flavor development. It may be necessary to choose an amount somewhere in between.

In this experiment, there was definite correlation between amount of eye formation and the amount of flavor. This has not always proved true in other investigations (5). The correlation was very noticeable in the cheese with no added propion culture. Here an increase of only one or two eyes was accompanied by a increase in sweetness of flavor. A more marked relationship existed in comparing the cheese containing 5 ml of propion culture with the cheese containing no propion culture. In this case the addition of a small amount of propion starter brought about a tremendous improvement in both eye formation and flavor.

The use of hydrogen peroxide for resting the milk seems to be beneficial in improving the quality of Swiss cheese. This improvement is most noticable in body and texture and eye formation of the cheese. However, the use of hydrogen peroxide in milk has not yet been accepted by the United States Public Health Service. Further work must be done to determine more fully the effects that hydrogen peroxide has on the milk, as also, its effectiveness in killing pathogenic organisms.

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