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To the Graduate Council:

I am submitting herewith a thesis written by Henry Thomas James entitled "A Study of the Manufacture of Cheddar Cheese Made from Heated Milks." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Dairying.

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A STUDY OF THE MANUFACTURE OF CHEDDAR CHEESE
MADE FROM HEATED MILKS

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

Henry Thomas James

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CHAPTER I

INTRODUCTION

In general, the milk used for the manufacture of Cheddar cheese in the Tennessee area is produced on farms which have small herds. Because of the cost of equipment in relation to this dairy operation, most of the producers cool the milk with spring or well water. In the summer months the temperature of this water may exceed 65° F.; consequently, it is almost impossible to have milk with a low bacteria count. It is necessary, therefore, that the milk be pasteurized in order to gain some control of the bacteria in the original milk. The cheese makers have been reluctant in using heat treatments above the very minimum as they assumed that the quality of the cheese suffered. Much of the cheese made in this area has been inferior in quality, especially when aged, and has had to be used in the manufacture of processed cheese.

It is hoped that, through the use of a higher heat treatment to the milk, a better control of the bacteria could be obtained and at the same time a large portion of the bacterial enzyme systems inactivated. If this can be accomplished, it was postulated that the quality of the cheese could be improved materially, thus giving the cheesemakers a greater return for their labor which in turn could be transferred to the farmer by way of higher prices for the producer milk.

CHAPTER II

STATEMENT OF THE PROBLEM

The purpose of this study was to investigate the effect of different heat treatment of the milk in relation to the manufacture of cheddar cheese.

CHAPTER III

REVIEW OF LITERATURE

The bacterial quality of the raw milk used in the manufacture of a dairy product is commonly reflected in the quality of the finished product. This is especially true in the cheese industry. The milk is examined when received by a plant for flavor, odor and appearance. In order to estimate the bacterial quality of milk, the methylene-blue reduction test is commonly used and the sediment test for determining of extraneous matter.

Sommer (30) states that the sediment test is of limited value, and its only logical use is to improve the cleanliness of milk production. Many plant operators are guilty of encouraging the wrong action and apparently teach a fallacious lesson by condemning milk on the basis of the sediment test with one hand and selling producers strainers with the other. The undue emphasis of straining commonly impedes progress in the improvement of milk quality. The visible sediment can be removed by straining, but the harm has been done when the sediment has been allowed to get into the milk. Contamination from the cows' exterior is revolting from the esthetic standpoint, but it also may contribute organisms that cause gassy, putrid fermentations, and tainted flavors to the cheese. Hammer (10) states that the Escherichia-Aerobacter are the most objectionable organisms so contributed to the milk. Arey (2) states that a portion of the extraneous matter dissolves in the milk and cannot be removed by the best type of strainers. This, although invisible, may lower the quality of the milk to such an extent that it will be rejected by the milk plant.

Milk free from sediment will usually have a low bacterial count since it reflects the general cleanliness of the milking operation.

Van Slyke and Price (33) state that it is not surprising to find the bacterial quality of milk as indicated by the methylene-blue test to be an indication of the quality of finished cheese. Wilson, Hall and Rogers found that, although the milk used in their experimental cheese was presumably of good quality as indicated by the methylene-blue test, some of the raw milk cheese developed defects, indicating the difficulty in grading milk that contains bacteria not affecting the test but having an injurious effect on the ultimate quality of the cheese. Table I, (Wilson, Hall and Rogers) (35) shows the percent distribution of the grades of cheese made from raw milk of varying bacterial quality as indicated by methylene-blue reduction time. The effect of the quality of the milk was reflected in the quality of the cheese.

Price (24), in his study to determine the feasibility of pasteurization as a means of improving the quality of Cheddar cheese, noticed that the difference between raw and pasteurized milk cheese seemed greatest when the raw milk was of inferior quality. It may be assumed that, in spite of pasteurization, milk of inferior quality has a tendency to produce an inferior grade of cheese.

Marquardt and Hucher (17) found that cheese made from pasteurized milk scored on an average 2.1 points above the cheese made from a similar unpasteurized milk. They also found that milk containing large numbers of bacteria was not improved in quality by pasteurization to the same extent as milk produced under sanitary conditions.

TABLE I

THE PERCENTAGE DISTRIBUTION OF THE GRADES OF CHEESE
MADE FROM RAW MILK OF VARYING QUALITY AS INDICATED
BY THE METHYLENE-BLUE REDUCTION TIME

Methylene-Blue Reduction Time	Number of Vats	Proportions of Cheese in Each Grade*		
		Score of 92 or Higher	Score of 90 to 91.5	Score of 89.5 or Lower
		%	%	%
Less than 1 hour	16	25	6	69
1 to 2 hours	42	14	48	38
2 hours or more	31	29	61	10

* Cheese cured for 3 months at 34° F.

Wilson, Hall and Rogers (35) added to the milk 500 milliliters of an active culture of either Aerobacter aerogenes or Streptococcus lactis and in some instances mixture of the two. The milk was warmed and allowed to ripen at 73° F. for from 3 to 5 hours, after which it was cooled to 40° F. and held overnight. They found that usually, but not invariably, pasteurization (162° F., 12-15 seconds) improved the quality of cheese made from the uninoculated lots of milk. But in nearly every instance, the cheese made from the inoculated and ripened milk was considerably inferior to that made from the corresponding milk of good quality. Although pasteurization improved the inoculated and ripened milk, nearly all of the cheese was very poor. Their results indicate that pasteurization is only partially effective in avoiding the defects caused by poor quality milk. They state that, while pasteurization destroys the harmful bacteria, it does not entirely remove the effects which the bacteria produced in the milk prior to pasteurization. In general, the quality of the cheese made from pasteurized milk, when made under controlled process, is directly dependent on the bacteriological quality of the milk.

The effect of coliform bacteria in Cheddar cheese was studied by Yale and Marquardt (36). Escherchia coli, Aerobacter aerogenes and A. cloacase were the three most common species isolated. In their studies, gas holes were formed in the cheese when the coliform counts exceeded 10,000,000 per gram, and when no attempt was made to work the gas out of the curd by acid development. Cheeses which were gassy were inferior in flavor when compared with cheese free from gas.

Whitehead (34) found some strains of the coliform organisms had a deleterious influence on the flavor of Cheddar cheese. When they were added to the milk immediately before the start of the process of cheese manufacture, even when present in large numbers, they do not produce gas holes in the cheese provided an active culture of Streptococci lactis was used as a "starter." His experiments demonstrated quite conclusively that various types of colon bacilli, if in large numbers, were capable of producing undesirable flavors in cheese, even though the period of their growth in milk was limited to the time required to make the cheese, and their gas producing properties were checked by the presence of an active "starter."

Hucker (12) found that milk with a bacteria count of more than 12,000,000 and less than 42,000,000 per cubic centimeter produced a cheese of more constant quality than did milk containing less than 12,000,000 to 220,000. None of the cheese in the higher count milk was of the highest quality but neither was it of poorest quality. The quality of the cheese did not fluctuate with variations in the total bacteria count of the milk. All cases of comparatively low count milk were found to produce cheese of grades varying between the two extremes. Hucker states that methods of grading milk based on the number of bacteria present would not apply for cheese making as the quality of the resulting cheese is dependent upon the types of organisms present rather than upon the number. Therefore, specific types of organisms are far more important than the total number present. Stevenson (32) states that under no system of manufacture can the highest quality of cheese be obtained unless the milk is delivered in good condition.

The practice of heating milk is not new as, in many countries of Europe and Asia, boiling milk has been a practice for centuries. The improved keeping quality was the primary purpose. The destruction of pathogenic organisms is the primary purpose of pasteurizing milk as applied to the fluid milk industry. The effect of the time and temperature of heating milk upon the properties and the constituents of milk has been of concern to the dairy industries for over fifty years.

One of the most common concerns of the cheese industry is the effect of heating the milk on the subsequent rennet coagulation rate. Holland and Dahlberg (11) state that pasteurization has been known to retard curd formation. Also after pasteurizing a softer curd was formed which held the moisture more tenaciously and rendered it difficult to expel the whey. They held samples at least 5 hours at 40° F. after pasteurizing before testing, and they found an increase in coagulation time in every case with heated milk. This increase became greater as the temperature and the time of holding were extended, but the increase was not great when common pasteurization practices were followed. They found that with holding periods of 10 minutes, 160° F. is the critical zone when the milk is to be used for cheese making. Above 160° F., the time required for coagulation increased very rapidly and the curd was very soft.

Sammis and Bruhn (28) stated that heated milk coagulates poorly with rennet and the curd obtained did not expel moisture precisely as a raw curd. This effect was more marked the higher the temperature of pasteurization. Sanders, Matheson and Burkey (29) found that pasteurization caused a noticeable softening of milk curd and caused a slight increase

in rennet coagulation time. Benson and Evans (5) report that the heating of milk within certain limits increases the coagulative properties. Coagulation was facilitated in the manufacture of Cheddar cheese by heating the milk to a temperature of about 84° F. before adding rennet. When the milk was heated at 158° F. or higher, a change took place in the albumin which caused it to coagulate. The rate of rennet coagulation on milk so heated was not as rapid as in raw milk heated only to 80° to 90° F. They found that as the boiling point was approached a deposition of salts such as calcium citrate took place. For best results they recommended the milk to be pasteurized and cooled as quickly as possible.

Benson (4) found the rennet coagulation of the heated milk was the chief difficulty anticipated, especially in the cases where the milk was "retained." The coagulation of the instantaneously heated milk (time required 0.5 minutes) presented little difficulty up to 190° F. But milks heated and held for thirty minutes could not withstand temperatures above 170° F.

Rupp (27) reported that the time required for coagulating the casein by rennin is slightly less in milk pasteurized at temperatures up to 149° F. than it is in raw milk. At 158° F. there is a slight retardation, while at 167° F. the time has almost doubled.

Powell (23) found that milk heat treated at 149° F. for 30 minutes and cooled to 95° F. did not retard coagulability, if rennet was added immediately after cooling. The aging of the milk at either 41° F. or 95° F. for 3 hours, only slightly retards its coagulability. Heating the milk at 167° F. to 186° F. for 30 minutes definitely retards its

coagulability with rennet at 95° F. The loss increases as the heating temperature rises. When the milks were heat treated at 75° C. or 85° C. for 30 minutes and cool aged at 5° C. or 35° C., the rate of coagulation became progressively slower. He also found that flash pasteurization of milk at 167° F. slightly retarded the rate of coagulation. Flash pasteurization of milk at (186° F.) 85° C. decreases the rate of coagulation, but the retardation is not as great as milk heated at 75° C. by the holding process. Aging this milk at 5° C. or 35° C. causes further small losses in coagulation.

Mattick and Hallett (19) found that the rate of coagulation of heated milk with rennet became gradually longer during the cool-aging and reached an equilibrium in 5 hours. Heat treatments up to 151° F. for 30 minutes produced milks that, when tested promptly, coagulated more rapidly than the raw milk. Above this heat treatment the milk samples coagulated more slowly than raw milk even when tested promptly and on cool-aging still slower with complete failure at 198° F. (30 minutes) after as short a time as 10 minutes of cool-aging.

Rowland (26) states that heat coagulation consists of two distinct processes: (1) denaturation, or the alteration of the protein under the influence of heat which must precede, (2) flocculation, the rapid separation of the denatured protein in the presence of a suitable electrolyte. The denaturation causes loss of solubility of the protein in water and in dilute salt solutions at its isoelectric point. He also states that denaturation and not coagulation is applied to the change which takes place in the albumin and globulin when milk is heated. The denaturation

which takes place on heating milk is made evident, and its extent measured by the precipitation of albumin and globulin in addition to casein when the heated milk is treated with those reagents which precipitate casein alone from unheated milk.

Rowland (26) found the following percentage of total albumin and globulin denatured; 10.7 percent for 30 minutes and 13.7 percent for 60 minutes at 149° F.; 14.2 percent for 30 minutes and 18.7 percent for 60 minutes at 153° F.; 36.4 percent for 30 minutes at 162° F.; and 52.4 percent for 30 minutes at 158° F. The heating of milk causes denaturation of the lactalbumin and lactoglobulin to an extent depending on both the temperature and the time of heating.

Orla-Jensen and Plattner (22) on heating milk found only slight coagulation below 158°-167° F. They state that the albumin fraction could be precipitated completely after heating milk one hour at 77.5° C., 30 minutes at 176° F., or 5 minutes at 194° F. Freudenreich (8) reported 15-20 percent of the albumin and globulin was coagulated after heating milk at 68°-69.5° C. for 30 minutes. Babcock (3) found no change after 20 minutes at 149° F. Grimmer, Kurtenacker and Berg (9) heated milk one minute and found a coagulation of 5.7 percent, 26.8 percent, 74.6 percent, and 77.4 percent at 70°, 80°, 90°, and 100° C., respectively. Rupp(27) found that the albumin does not coagulate at 145° F., but at 150° F., 5.75 percent of the albumin is rendered insoluble. As the temperature increases the amount of coagulated albumin increases. At 155° F. the amount coagulated increases to 12.75 percent, and at 160° F. it amounts to 30.78 percent.

Rowland (26) reported an average of 10.4 percent of the total soluble protein was denatured for 30 minutes heating at a temperature as low as 63° C. He (25), also, found that the denaturation of albumin and globulin took place rapidly in samples of milk heated at temperatures of 75° C. and above, and was completed in approximately 60, 30, 10-15 and 5-10 minutes at 80°, 90°, 95°, and 100°, respectively. He found no change in the nonprotein nitrogen content of the milk on heating at temperatures up to 100° C.

Sanders, Matheson and Burkey (29) found that the pH values of milk bore a very definite relation to the rennet coagulation time and to the rennet curd tension, and bore a less definite relation to the Hill curd tension. They stated that the pH seemed to be a major factor in influencing the rennet coagulation time, while the percentage of casein was found to be more important in influencing the rennet curd tension. The presence of mastitis caused an increase in pH, an increase in the rennet coagulation time and a decrease in rennet curd tension. They found that the percentage of casein has a greater influence on the rennet curd tension and upon the firmness of rennet curd in the cheese process than upon the rennet coagulation time. It was found that the rennet coagulation time was increased and the rennet curd tension decreased when milk was stored for a few hours to 3 days at a temperature of 2° to 5° C. The influence of pH upon coagulation time seemed to be most marked when the pH is above 6.65, and upon curd tension when below 6.65.

Albrecht (1) found that the pH of milk was lowered immediately after heating and the pH of the heated milk rose to a value above that of

the original raw milk. The rennet coagulation rate followed the same general pattern of an accelerated rate and then a decreased rate of coagulation provided the milk was not heated to temperatures above 65° C. for 30 minutes. He found one of the causitive retarding effects of milks heated to above 65° C. for 30 minutes to be the coagulated albumin.

Lampitt and Bushill (14) found that the dialysable constituents of milk suffer a decrease of 4 percent in organic phosphorus and a similar decrease in calcium when the milk is heated to 100° C. (steamer for one hour). They found an increase of 11 percent in inorganic phosphorus and of 17 percent in calcium in the dialysable fraction during a change in pH of milk from 6.55 - 5.75. An increase in acidity by bacterial action materially increases the proportion of dialysable calcium and of inorganic phosphorus. Dilution of milk causes a decrease in acidity, and results in an increase in dialysable calcium and inorganic phosphorus. Neither change in acidity nor dilution of the milk appears to affect the dialysable organic phosphorus of milk.

Zoller (38) found that the loss of calcium was progressive with the time and intensity of heat treatment. The decrease in the hydrogen ion concentration aids in the removal of buffering material (phosphates) through the precipitation of $\text{Ca}_3(\text{PO}_4)_2$. He found by doubling the quantity of citrates above normal, although not changing the initial pH of the solution, greatly reduces the precipitation of the calcium phosphates and at the same time maintained a higher pH. Lactates and maltates acted likewise.

Magee and Harvey (15) found about 26 percent of the total calcium was in diffusible form in fresh milk, about 20 percent when pasteurized

at 65° C. for 30 minutes, and about 15 percent when kept at the boiling point for one hour.

Mattick and Hallett (19) found that heating milk to 175° F. and above for 30 minutes appeared to reduce the diffusibility of the phosphorus content of the milk. They found that at 135° to 140° F. the amount of total calcium (0.6 percent) which became indiffusible increased to about 2 percent at 145° to 150° F. and varies from 2.5 to 3.6 percent at higher temperatures. At all temperatures from 125° to 209° F. the amount of calcium which had diffused from the raw milk was definitely greater than that which had diffused from the same milk after heating.

Rupp (27) found that milk pasteurized by the holder process at 145° F. for 30 minutes does not undergo any appreciable chemical change. The soluble phosphates of lime and magnesia do not become insoluble at (155° F.) 68.3° C., and the quantity of phosphoric acid, lime and magnesia in the serum of both raw and pasteurized milk are practically the same.

Mattick (18) found that, in the cheese examined, 57-58 percent of the calcium and 50-51 percent of the phosphorus present in the original milk remains in the hard pressed (Cheddar) ripe cheese, but that only 6-8 percent of the calcium and 27 percent of the phosphorus was left in the unpressed variety (Stilton) when ripe.

Holland and Dahlberg (11) found no significant changes in the relative amounts of CaHPO_4 and $\text{Ca}_3(\text{PO}_4)_2$ at the time and temperatures which might be used for commercial pasteurization. There was no correlation between the changes noted in coagulation time and the relative

amounts of these salts. This was found to hold true with casein and heat coagulable protein. Where the holding times were extended at the higher temperatures above those useful for commercial pasteurization, there was some slight indication of a reduction in the heat coagulable proteins. Residual nitrogen was increased by heating in nearly every instance.

Benson (4) found that instantaneously (flash, 1-2 minutes) heated milk at 190° F., quite a firm curd was produced, though it was obvious that the curd was beginning to lose its elasticity. When the milk was kept at 170° F. for 30 minutes, it was noticed that the curd was considerably weakened, showed signs of flocculence, and appeared powdery when pressed between the fingers. From the experiments, he states that they seem to show that if it is desired to obtain a typical Cheddar, instantaneous (flash, 1-2 minutes) heating should not be higher than 190° F., or if the period of heating be prolonged for 15 to 30 minutes the temperature should not be greater than from 160° to 170° F.

Moir (20) found that through analysis of the whey, a tendency was shown for pasteurization to cause more of the soluble milk proteins to be incorporated in the cheese, especially with milk of low hygienic quality. When acidity developed rapidly in the whey after cutting, the resulting cheese was depleted of a portion of its mineral constituents. He found that the cheese made from milk pasteurized at 165° F. developed more soluble nitrogen than the raw control. The raw control cheese showed much greater development of free amino groups.

Bosworth (6) states that soluble nitrogen is always present, but the amounts are not always constant and seemed to have no relation to

the amount of casein, or of the amount of rennet used.

Mattick and Hallett (19) state that about 4 percent of total nitrogen is always present in diffused form. They found no change in the diffusibility of the nitrogenous substances in milk after heating to temperatures varying from 105° to 209° F. for 30 minutes.

Benson and Evans (5) found that when milk was heated in steam jacketed vats, the time occupied in heating of the milk ranged from 20 to 35 minutes. Cheese made from milk pasteurized at temperatures from 150° to 165° F. were a success, but cheese made from milk pasteurized at 170° F. and above were disappointing. They found that cheese made from pasteurized milk possesses better keeping quality than raw milk cheese.

Their first trial was made with the object of testing pasteurizing temperature of 160° F. In each succeeding trial the pasteurizing temperature was increased 5° F. until 200° F. was reached. The difficulties in manufacture of the cheese were:

1. In procuring a sufficiently firm coagulation of the curd.
2. In inducing the separation of the whey from the curd.
3. In getting a satisfactory cohesion of the curd, which had a strong tendency to remain in a granular condition.
4. In difficulty of eliminating the surplus whey from the cheese while in the press.
5. A risk of development of bitterness in the ripening stage.

Stevenson (32) found that when the flash system of pasteurization was used above 165° F., the casein content of milk was so injured that the curd obtained lost its cohesive properties to a very great extent. Such

curd will remain more or less broken during the process of manufacture, which results in a mealy bodied cheese. This, also, has been traced to irregular heating.



CHAPTER IV

EXPERIMENTAL PROCEDURE

Cheese Manufacturing Methods. Five lots of manufacturing grade milk were obtained from Pet Milk Company, Morristown Receiving Station. The milk was a composite of a large number of patrons which had been cooled to 40° F. and transferred to 10-gallon cans for shipment to the University of Tennessee.

After arrival at the University of Tennessee the milk was weighed and transferred to the cheese vats. The vats of milk were heated to the following temperatures: vat No. 1 (100-gallon capacity) was heated to 143° F.; vat No. 2 (50-gallon capacity) was heated to 147° F.; vat No. 3 (50-gallon capacity) was heated to 151° F.; and vat No. 4 (50-gallon capacity) was heated to 155° F. The heating tolerance was 1° F. and the holding time was 30 minutes in all cases. The milk was cooled with cold water to a temperature of 88° F. as rapidly as possible, and a lactic acid starter was added.

One lot of mixed grade "A" milk was obtained from the University of Tennessee Creamery that had been cooled to 40° F. and held overnight. Three 10-gallon cans of milk were inoculated with the following organisms and allowed to remain overnight at room temperature (approximately 70° F.): One 10-gallon can of milk was inoculated with 100-milliliter culture of Escherichia coli, the second with 100-milliliter culture of Aerobacter aerogenes, and the third with a mixture of 50-milliliter culture of E. coli and 50-milliliter culture of A. aerogenes. The milk was distributed in the vats in the following manner. The 100-gallon vat

contained 80 gallons of the cooled milk and was designated as the control. One of the 50-gallon vats contained 30 gallons of the cooled milk and the 10 gallons of milk inoculated with the E. coli organisms. The second 50-gallon vat contained 30 gallons of the cooled milk plus the 10 gallons of milk inoculated with the A. aerogenes organisms. The third 50-gallon vat contained 30 gallons of the cooled milk and the 10 gallons of milk inoculated with the E. coli and A. aerogenes organisms. The milk was pasteurized in the vats at 145° F. and held for 30 minutes. It was cooled to 86°-88° F. with water, and the lactic acid culture was added.

The manufacturing procedure of Jarman (13) was used in the making of all the Cheddar cheese.

The cheese was stored at 40° and 50° F. for curing. At the time of paraffining, the cheese was analyzed for total protein, fat, moisture, pH, and water soluble nitrogen. The pH and water soluble nitrogen analysis was again determined after the cheese had been aged three months at 40° F.

Method of Analysis. The samples for analysis were taken with a cheese trier. Four plugs were drawn from a cheese of each lot. These plugs were placed immediately in a glass jar and stored in a refrigerator at 40° F. until the determinations were made. The moisture determination was begun immediately after sampling. The fat, total protein, water soluble protein and pH determinations were made within three days of sampling.

The moisture was determined by the method outlined in Official Methods of Analysis of the Association of Official Agricultural Chemists (21) except that the vacuum varied from 17 to 28 inches, and the samples

were dried for 12 hours.

The fat content of the cheese was determined by the Babcock method as outlined by Burke (7), except Paley 20 percent cheese test bottles were used instead of a 50 percent cream test bottle. A 4.5 gram sample was used and the results multiplied by two. The test in all of the analyses were made in duplicate.

The total nitrogen content was determined by the Kjeldahl method as described by Markley and Hann (16).

Water soluble nitrogen determinations were made by the method outlined by Zimmerman (37) and was as follows: Twenty-five grams of ground cheese was weighed to the nearest tenth of a gram on a Torsion balance. The cheese was added to 240 milliliters of distilled water and mixed for 10 minutes in a Waring Blender. The resulting suspension was poured into a 300-milliliter Erlenmeyer flask and incubated in a water bath at 60° C. for one hour. The suspension was shaken at 15-minute intervals while being incubated. At the end of one hour the suspension was mixed thoroughly and filtered through a Whatman No. 12 fluted filter. After filtering, a 25-milliliter volumetric sample of the filtrate was transferred into a Kjeldahl flask containing 109 grams of sodium sulfate and 0.1 gram of copper sulfate. To this mixture 20 milliliters of concentrated sulphuric acid was added, and the nitrogen was determined according to the regular Kjeldahl method.

The percent soluble nitrogen was calculated on the basis that 25 milliliters of the filtrate represents 2.5 grams of the original cheese, for example: $\text{Milliliters of HCl} \times \text{normality of the HCl} \times 14/1000 \times 100 =$

percent soluble nitrogen in cheese. The results were expressed as soluble nitrogen as percent of total nitrogen.

The pH determinations, at the time of paraffining, were made by the potentiometric method described by Price (33) and at three months of age by using the Beckman pH meter.

The estimation of the number of bacteria in the milk was made, using the method as outlined in Standard Methods for the Examination of Dairy Products (31).

CHAPTER V

EXPERIMENTAL RESULTS

The experimental work was designed to study the influence upon the manufacture of Cheddar cheese when manufacturing grades of milk were used and the milk was subjected to heat treatments above 143° F. with a holding period of 30 minutes. The temperatures of the heat treatments given five comparisons were 143° F., 147° F., 151° F., and 155° F. The cheese was made on five different days during the month of April. One additional lot of milk of a fluid milk grade was divided between the four cheese vats and the raw milk was inoculated with coliform organism. This milk was pasteurized only at 145° F. for 30 minutes.

The range in coagulation time of the milk for the lower temperature (143°-147° F.) of pasteurization was 10 to 12 minutes, and at the higher temperatures (151°-155° F.) it was 11 to 13 minutes.

With the 151° and 155° F. heat treatment of the milk, the curd was somewhat crumbly right after draining. The curd, therefore, was allowed to knit a few minutes longer before it was cut into slabs and turned. These slabs of curd had to be handled with more care than those where the lower pasteurization temperatures were used. After the first turnings, very little difference in the appearance of the curd could be noticed. After pressing and before paraffining, the plugs taken from the cheese appeared to have the same texture and body.

A comparison of the moisture, protein, and fat percentages is shown in Table II. There was a variation in moisture with a range of 36.93 to

TABLE II

RESULTS OF ANALYSIS OF CHEESE FOR MOISTURE, PROTEINS,
FAT, PERCENT FAT IN DRY MATTER AND PERCENT
PROTEIN IN DRY MATTER

Cheese Identification	Percent Moisture	Percent Protein	Percent Fat	Percent Fat in Dry Matter	Percent Protein in Dry Matter
2-29-52 - 1 *	38.08	24.47	32.0	51.34	39.52
- 2	37.52	24.84	32.2	51.53	39.76
- 3	38.61	24.46	32.0	52.12	39.84
- 4	37.29	24.61	32.2	51.34	39.24
4- 2-52 - 1	37.74	23.26	32.6	52.36	37.36
- 2	38.62	23.11	32.8	53.43	37.65
- 3	39.23	23.53	32.7	53.80	38.72
- 4	39.35	22.40	32.6	53.75	36.93
4- 8-52 - 1	37.78	24.69	34.0	54.64	39.68
- 2	39.39	23.08	32.7	53.95	38.08
- 3	38.59	22.99	32.5	51.92	37.44
- 4	39.12	23.05	32.6	53.54	37.86
4-16-52 - 1	37.98	24.26	32.0	51.59	39.12
- 2	38.22	23.83	31.9	51.63	38.57
- 3	38.86	24.84	31.4	51.35	40.63
- 4	38.23	24.10	31.8	51.48	39.02
4-23-52 - 1	37.43	23.73	32.4	51.78	37.93
- 2	37.88	23.94	32.4	52.15	38.54
- 3	37.80	24.00	32.4	52.09	38.59
- 4	38.32	23.36	32.0	51.88	37.87
4-30-52 - 1	37.47	23.43	33.0	52.77	37.47
- 2	36.93	23.95	32.8	52.00	37.97
- 3	38.84	23.18	32.8	53.63	37.90
- 4	38.20	23.09	32.4	52.42	37.36

*Vat number.

39.39 percent. In most cases, the cheese made from the higher heat treated milks contained the higher moisture content when the four vats containing the same milk were compared. The percentage of protein in the cheese shows a variation from 22.40 to 24.84 percent. In almost all cases, there was less protein (percentage) in the cheese made from the highest heat treated milk. The greatest retention of the protein in the cheese appears to be at the 151° F. heating level. The percentage of protein in dry matter of the cheese for the highest heat treated milk in almost all cases decreased from the maximum reached at 151° F.

The variations in the fat percentages ranged from 31.4 to 34 percent.

The percentage of water soluble nitrogen is shown in Table III. The percentage of water soluble nitrogen as percent of total nitrogen of the cheese ranged from 9.86 percent to 16.03 percent, with the exception of the lot of cheese (4-2-42) which went to a high of 28.75 percent. The percent of water soluble nitrogen of the unaged cheese increased as the pasteurization temperature increased. After aging for three months the percentage of water soluble nitrogen as percent of the total nitrogen increased to a range of 26.55 to 35.49 percent. The lot of cheese (4-2-52) which was higher in water soluble nitrogen originally did not increase as rapidly; consequently there appears to be a leveling effect or possibly an error in the chemical manipulation during analysis. The protein breakdown in the cheese aged three months, as reflected by water soluble nitrogen, was more rapid in the higher heat treated milk cheese.

TABLE III

RESULTS OF ANALYSIS OF CHEESE FOR WATER SOLUBLE NITROGEN
AFTER AGING ONE WEEK AND THREE MONTHS

Cheese Identi- fication	Percent Protein	Cheese One Week Old		Cheese Three Months Old	
		Percent Water Soluble Nitrogen	Water Soluble Nitrogen as Percent of Total Nitrogen	Percent Water Soluble Nitrogen	Water Soluble Nitrogen as Percent of Total Nitrogen
2-29-52 - 1	24.47	2.80	11.44	7.84	32.03*
- 2	24.84	2.80	11.27	7.84	31.56*
- 3	24.46	2.74	11.20	7.60	31.07*
- 4	24.61	2.80	11.37	8.04	32.66*
4- 2-52 - 1	23.26	4.93	21.19	7.67	32.97
- 2	23.11	5.65	24.44	7.47	32.22
- 3	23.53	5.79	24.60	7.73	32.88
- 4	22.40	6.44	28.75	7.95	35.49
4- 8-52 - 1	24.69	3.53	14.29	7.28	29.50
- 2	23.08	3.70	16.03	7.61	32.99
- 3	22.99	3.53	15.35	7.61	33.12
- 4	23.05	3.47	15.05	7.61	33.04
4-16-52 - 1	24.26	2.57	10.59	6.44	26.55
- 2	23.83	2.35	9.86	6.72	28.20
- 3	24.84	2.57	10.34	7.28	29.31
- 4	24.10	2.68	11.12	7.17	29.74
4-23-52 - 1	23.73	2.88	12.13	6.83	28.79
- 2	23.94	2.97	12.40	7.11	29.70
- 3	24.00	3.22	13.41	7.56	31.50
- 4	23.36	3.22	13.78	7.72	33.08
4-30-52 - 1	23.43	2.50	10.67	6.61	28.21
- 2	23.95	2.40	10.02	6.78	28.31
- 3	23.18	2.80	12.07	7.11	30.67
- 4	23.09	2.68	11.60	7.00	30.32

* Cheese stored at 50° F.

Lot designated as (2-29-52) was cured at 50° F., but does not show the characteristic increase commonly observed when cheese is aged at the higher temperature.

The bacteria estimations are shown in Table IV. The bacteria count of the raw milk ranged from three to seven million, and after pasteurization from one to five thousand. The higher heat treatments show a greater kill of the bacteria. Because of incomplete sterilization of a new batch of nutrient agar, the last two lots of milk could not be reported for an estimation of the number of bacteria in the milk.

The pH determinations are shown in Table V. No significant difference was found in either the cheese at one week of age or after three months of aging.

The pounds of cheese per 100 pounds of milk and per pound of fat are shown in Table VI. In almost every instance, the efficiency of the larger vat (100 gallons) was greater than the 50-gallon vats. In a comparison of the three 50-gallon vats, the yields of cheese were increased as the temperature of pasteurization was increased.

Table VII shows the pounds of dry cheese per 100 pounds of milk. This was determined to get away from the variation in the moisture content of the cheese. In a comparison of the 50-gallon vats there was an increase, in almost all cases, in pounds of dry cheese per 100 pounds of milk for the higher heat treated milk cheese. An average of the increased yield as the cheese milk was heated to higher temperature was evident if the comparison was made between the vats of the same size (50-gallon), since the larger vat (100-gallon) appears to be more efficient

TABLE IV

ESTIMATION OF THE BACTERIAL QUALITY
OF THE MILK

(Organisms per Cubic Centimeter)

Cheese Identification	Raw	Heat Treated
4- 2-52 - 1	7,000,000	3,000
- 2		2,000
- 3		2,000
- 4		1,000
4- 8-52 - 1	4,500,000	5,000
- 2		3,000
- 3		2,000
- 4		2,000
4-16-52	3,500,000	

TABLE V

RESULTS OF ANALYSIS OF THE CHEESE FOR pH
AFTER ONE WEEK AND THREE MONTHS

Cheese Identification	pH on Cheese* One Week Old	pH on Cheese** Three Months Old
2-29-52	5.02	5.15
4- 2-52 - 1	4.91	5.10
- 2	4.96	5.10
- 3	5.00	5.10
- 4	4.98	5.10
4- 8-52 - 1	5.15	5.10
- 2	5.12	5.10
- 3	5.12	5.10
- 4	5.12	5.10
4-16-52 - 1	5.20	5.20
- 2	5.20	5.20
- 3	5.20	5.20
- 4	5.17	5.20
4-23-52 - 1	5.15	5.00
- 2	5.13	5.00
- 3	5.13	5.01
- 4	5.15	5.00
4-30-52 - 1	5.00	5.03
- 2	4.89	5.03
- 3	4.85	5.00
- 4	4.85	5.00

* Potentiometer used for pH determination.

** Beckman pH meter used for pH determination.

TABLE VI

THE YIELDS OF CHEESE PER HUNDRED POUNDS OF
MILK AND PER POUND OF FAT

Cheese Identi- fication	Pounds of Milk	Pounds of Fat in Milk	Pounds of Cheese	Pounds of Cheese Per Hundred Pounds Milk	Pounds of Cheese per Pound of Fat
2-29-52	1700*	68.00	179.0	10.53	2.63
4- 2-52 - 1	672	28.22	75.0	11.16	2.66
- 2	336	14.11	37.0	11.01	2.62
- 3	338	14.20	38.5	11.39	2.71
- 4	341.5	14.34	37.5	10.98	2.62
4- 8-52 - 1	674	28.31	76.0	11.28	2.68
- 2	341	14.32	37.0	10.85	2.58
- 3	340	14.28	38.0	11.18	2.66
- 4	340	14.28	38.25	11.25	2.68
4-16-52 - 1	671	26.17	74.9	11.16	2.86
- 2	347	13.53	37.9	10.92	2.80
- 3	328	12.79	33.9	10.34	2.65
- 4	349	13.61	40.2	11.52	2.95
4-23-52 - 1	674	28.31	75.5	11.20	2.67
- 2	336	14.11	37.75	11.24	2.68
- 3	339	14.24	38.0	11.21	2.67
- 4	342	14.36	39.0	11.40	2.72
4-30-52 - 1	656	27.55	77.0	11.74	2.79
- 2	326	13.69	38.0	11.66	2.78
- 3	328	13.78	39.0	11.89	2.83
- 4	327.5	13.76	39.5	12.06	2.87

* Estimated Yield.

TABLE VII

THE YIELD OF DRY CHEESE PER HUNDRED POUNDS OF MILK

Cheese Identi- fication	Pounds Cheese	Pounds of Dry Matter	Pounds of Milk	Pounds Dry Cheese per 100 Pounds of Milk
4- 2-52 - 1	75.00	46.70	672	6.95
- 2	37.00	22.71	336	6.76
- 3	38.50	23.40	338	6.92
- 4	37.50	22.74	341.5	6.66
4- 8-52 - 1	76.00	47.29	674	7.02
- 2	37.00	22.43	341	6.58
- 3	38.00	23.34	340	6.86
- 4	38.25	23.29	340	6.85
4-16-52 - 1	74.90	46.45	671	6.92
- 2	37.90	23.41	347	6.75
- 3	33.90	20.73	328	6.32
- 4	40.20	24.83	349	7.11
4-23-52 - 1	75.50	47.24	674	7.01
- 2	37.75	23.45	336	6.98
- 3	38.00	23.64	339	6.97
- 4	39.00	24.06	342	7.04
4-30-52 - 1	77.00	48.15	656	7.34
- 2	38.00	23.97	326	7.35
- 3	39.00	23.86	328	7.27
- 4	39.50	24.41	327.5	7.45

than the smaller vats. The average increase of cheese per 100 pounds of milk was 0.30 pounds (Table VI); the increase per pound of fat was 0.06 pounds (Table VI); the increase per 100 pounds of milk compared with the dried cheese was 0.15 pounds (Table VII).



CHAPTER VI

DISCUSSION

The findings of many earlier cheese investigators working with heat treated milk has been confirmed and extended. The time required for the rennet to coagulate the milk increased slightly as the pasteurization temperature was raised from 143° to 155° F. Holland and Dahlberg (11), Sammis and Bruhn (28), and Sanders, Matheson and Burkey (29) all found it harder to expel the whey from the cheese curd when the milk had been heated to pasteurization temperatures above 143° F. with a thirty-minute holding period. This in turn produces a cheese containing a slightly higher moisture content.

The cheese in these experiments was made under as like conditions as possible, the only variable being the heat treatment of the milk prior to the addition of the "starter." Therefore, the only factor influencing the expulsion of the whey was the action of the rennet. The squeezing action of the enzyme rennin is dependent upon (1) acidity of the milk (or curd), (2) the abundance of calcium ions, (3) the concentration of the casein in the milk, (4) and/or inhibiting substances in the milk. The first three conditions remained relatively constant, but an inhibiting factor produced in the milk during the heat treatment very likely was the factor that retarded the coagulation and squeezing. Albrecht (1) found that coagulated albumin caused the rate of coagulation of milk to be retarded, which can manifest its action in the finished cheese; consequently the moisture would not be expelled from the curd as efficiently and a higher moisture cheese would result. This condition, therefore, can

be corrected through additional acid development of the starter, or adding soluble calcium ions to the milk. The latter two suggestions were recommended by Sammis and Bruhn (28) as early as 1913.

Moir (20) reports an increase in the protein solids of the cheese made from milk subjected to higher temperatures of pasteurization. This then can be considered a trapping action of the clot forming paracasein. The cheese made in this investigation does show an increase in yield per 100 pounds of milk, per pound of fat, and on the dried cheese per 100 pounds of milk. Yet the total protein (percentage) decreases as the temperature of the heat treatment increased even when figured as percentage of the dry matter (see Table VII). The Kjeldahl method was used in the determination of the total protein. It appears that an investigation will have to be conducted to account for this discrepancy.

The increase in the water soluble nitrogen has been used for a number of years as an indicator of cheese ripening. It is interesting to note the increase in water soluble nitrogen (Table III) as the heat treatment of the milk was increased. This increase in water soluble nitrogen was contrary to that reported by Price (33) who found the reverse to be true. It appears that the enzymes responsible for the protein breakdown were able to hydrolyze the coagulated water soluble proteins at a more rapid rate; consequently, as the amount of coagulated albumin increases in the cheese, the corresponding breakdown was greater.

None of the cheese was analyzed for differences in body and flavor because of the limited time of aging at 40° F.

CHAPTER VII

SUMMARY

Using a standardized making procedure, the moisture in the finished Cheddar cheese increased as the temperature of pasteurization was elevated.

The percentage of water soluble nitrogen in the Cheddar cheese increased as the temperature of pasteurization was raised. This factor remained even after three months of aging at 40° F.

The percentage of protein in the cheese, as measured by the Kjeldahl method, decreased as the temperature of pasteurization was increased.

The yield of cheese per 100 pounds of milk increased 0.3 pounds; the yield per pound of fat increased 0.06 pounds; and the cheese on a dry basis increased 0.15 pounds per 100 pounds of milk.



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