THE EFFECT OF INCREASING THE SERUM PROTEIN CONTENT OF COTTAGE CURD ON QUALITY AND YIELD

by

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INTRODUCTION

In the manufacture of rennet type cottage curd from low-heat cheese milk pasteurized at 143° F. for 30 min., the caseins are converted to paracasein by rennin action. The paracasein reacts with calcium to form calcium paracaseinate which is insoluble.

When rennet cottage curd is made from low-heat cheese milk, the heat labile serum (whey) proteins remain with the whey and represent an average protein loss of about 15%. However, if the cheese milk is processed at high temperatures 70 to 80% of the serum proteins are denatured and rendered coagulable with the calcium paracaseinate. If cheese milk is processed at high temperatures and used for making cottage cheese curd by conventional methods, however, the gel strength of the coagulum is low and the curd frequently shatters during cooking thereby decreasing yield. Also, curd defects such as pasty, weak, free whey, and high acid often appear in the cooked curd.

As the acidity of the coagulum is increased by the lactic bacteria to an optimum, the calcium of the paracaseinate is partly dissolved, whey is expelled, and the curd develops a desirable texture. If too much acid development is permitted, whey expulsion is slow and a high moisture soft curd is produced.

Several workers (15,21,58,71,80,83,88) have reported that as the intensity of heat treatment of the milk is increased between 143 and 180° F. for 30 min., the gel strength of the coagulum is decreased. Recently it was found that the optimum pH for cutting and cooking of cottage curd is higher and closer observation of rate of acid development is required when cottage curd is made from high heat cheese milk than when made from low heat cheese milk. The recent development of the Acid Coagulation (A-C) test (18) has made this close observation possible, thus making feasible the manufacture of high quality cottage curd from high heat cheese milk. Further, it appears that blending of low heat and high heat cheese milk might be a practical procedure for making excellent quality cottage curd containing a high percentage of the serum porteins. The purpose of this study is to determine the influence on quality and yield of increasing the serum portein content of cottage curd.

REVIEW OF LITERATURE

Milk Composition and Nomenclature

Milk proteins consist of two major groups, the caseins and serum proteins. The continuing research to identify and classify these proteins has necessitated a deviation in the classification and nomenclature. The older classical system of identification consisted of four fractions. These were designated by Rowland (68) as casein, lactalbumin, lactoglobulin, and proteose-peptone. He defines caseins as the milk proteins precipitated from raw milk at a pH of 4.6 to 4.7. Lactalbumin and lactoglobulin, when denatured (boiled for 20 min.), will precipitate under the same conditions which cause casein to precipitate. The proteose-peptone fraction is heat stable and remains soluble under the conditions which precipitate casein.

Brunner, et al. (8) in a report of the committee on milk nomenclature, classification and methodology of the manufacturing section of the American Dairy Science Association for 1958-1959 have suggested the following classification for bovine skimmilk. Caseins, which consist of three identifiable fractions, alpha-, beta-, and gamma-casein, make up 80% of the total protein in milk. These workers cited evidence that indicates alpha-casein may consist of more than one homogeneous fraction. For this reason, they point out the desirability of withholding a recommended nomenclature for the alpha-casein complex until the components and physical-chemical equilibrium involved are more precisely and completely understood.

The noncasein fractions (serum proteins), which make up the remaining 20% are grouped as follows: beta-lactoglobulin A and beta-lactoglobulin B making up 7 to 12% of the total skimmilk protein; alpha-lactalbumin 2 to 5%; blood serum albumin 0.7 to 1.3%; euglobulin 0.8 to 1.7%; pseudoglobulin 0.6 to 1.4%. The latter two fractions are frequently designated immune globulins, so called because they are antibody carriers. Also listed is the proteose-peptone fraction, 2 to 6% which consists of glycoprotein and other minor fractions which are poorly defined.

As more pure, homogeneous proteins are separated and identified, revisions in the classification of bovine milk will be necessary.

Effect of Heat on Milk Protein

The heat treatment of skimmilk is an important factor in the manufacture of cottage cheese. It has been known for many years that high heat treatment of skimmilk brings about numerous chemical and physical changes. Several studies of the effect of heat on the serum proteins were summarized by Rowland (67) when he reported on denaturation of albumin and globulin in milk. He obtained information on the rate of denaturation at different temperatures in the range 63 to 75° C. This was accomplished by heating portions of the same milk for varying periods at each of several temperatures and determining the nitrogen content of the albumin and globulin fractions by the semi-micro-Kjeldahl procedure. He observed that there was a constant increase in velocity of denaturation for each rise in temperature taken at one degree centigrade increments. Harland (33) conducted a similar study using the turbidimetric method of Harland and Ashworth (32). He reported that for the range 145 to 175° F. there was a ten fold increase in the rate of milk serum protein denaturation for each 13.5° F. increase in temperature. He further states (34) that for 80% serum protein denaturation in skimmilk, a temperature of 172.2° F. for 30 min. is required. Larson and Rollerie (45) heated milk at eight temperatures between 50 and 96° C. for 30 min., and the proteins in the serum obtained after removal of the denatured serum proteins with the casein at pH 4.6 were examined by a quantitative electrophoretic procedure. They observed that the denaturation curves obtained for each of the milk serum proteins indicated that the immune globulins are the least, and alpha-lactalbumin the most, heat resistant, with beta-lactoglobulin and serum albumin showing an intermediate sensitivity.

While determining the effect of heat on skimmilk, Davies (13) observed that the stability of the casein complex in skimmilk is increased progressively on heating from 50 to 70° C. for 30 min., but is decreased when heated from 80 to 120° C. He suggests that a fall in calcium ions was responsible for the increase in stability from 50 to 70° C., whereas absorption of denatured whey protein by the casein micelles is responsible for the decrease in stability between 80 and 120° C.

In past years there has been some conflict, and/or careless use of the terms denaturation and coagulation, concerning heat treatment of milk. For example, Shahani and Sommer (76) report that albumin and globulin are coagulated at the rate of 9 and 5%, respectively, at a pasteurization temperature of 143° F. for 30 min. Ramsdell and Whittier (64) cited several authors who gave coagulation values for albumin and globulin.

Ramsdell points out that the albumin and globulin of milk may be denatured by heating the milk and thus rendered coagulable by acid, salts, or rennet, but not coagulated by heating.

The above views are in agreement with the statements of Rowland (67) concerning denaturation and coagulation of milk proteins. In fact, he states them more forcibly when he says, "the term denaturation and not coagulation is applied to the change which takes place in the albumin and globulin when milk is heated. There is no visible coagulation, but the conditions determining the dispersion of the albumin and globulin are changed. The larger associated particles of denatured albumin and globulin are readily precipitated by acid and by salt solutions. 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 heated milk."

Effect of Heat on Milk Flavor

The findings of many workers in the field of dairy research have demonstrated that sulfur compounds are implicated in flavor changes resulting from the heating of milk. Josephson and Doan (42) and Gould and Sommer (28) obtained the first extensive data relating the heat labile sulfur of milk to cooked flavor.

As a result of research on sulfide liberation in milk, Townley and Gould (84) found that sulfide liberation is decreased by either a low pH or a pH above 9.0; also, that sulfide liberation from milk may be decreased by treating milk so that denaturation and coagulation of serum proteins are retarded or prevented; conversely, sulfide liberation may be enhanced by treating milk so that denaturation and coagulation of serum proteins are favored. In closely related research, Townley and Gould (85) have shown that the critical temperature for sulfide liberation is 76 to 78° C. for whole milk and 80 to 82° C. for skimmilk and whey. They also indicate that more sulfide is liberated from whey than from skimmilk.

Hutton and Patton (40) ran tests to determine the -SH content of a number of milk-protein fractions and to ascertain, insofar as possible, the contributions of these fractions to cooked flavor. They found that casein and protein-free milk serum were devoid of -SH groups, but that beta-lactoglobulin can account for practically all the -SH groups present. They conclude that conversion of -SH groups to H_2S as a result of heat treatment may explain, in a general way, the mechanism whereby beta-lactoglobulin gives rise to cooked flavor. Zwieg and Block (92) determined the sulfhydryl groups in milk proteins by the amperometric-argentometric method of Kolthoff (43). They found that all or almost all of the -SH groups in milk are present in the whey proteins. This agrees with the findings of Hutton and Patton (40) and Larsen and Jenness (44). Further, Zwieg shows that heating milk causes an initial small rise in titratable -SH groups, followed by a marked decrease in -SH. The temperature at which the first sharp decrease in -SH groups is seen has been called the "critical temperature" (58 to 69° C.). They indicate that there is an apparent relationship between the "critical temperature" and the appearance of cooked flavor.

The "critical temperature" listed above is lower than the "critical temperature" given by Townley and Gould (85).

Factors Affecting Cottage Curd Yield and Quality

Starter Activity

Good culture and starter practices are essential if success is to be realized in the manufacture of high quality cottage cheese. There have been many reports published on the factors which influence culture propagation. Foster (24), in working with heat treatments of milk for lactic culture medium, observed that increased heat treatment of the milk caused better growth of the lactic acid bacteria. He further suggests that the evidence indicates milk is deficient in readily available nitrogen sources for these organisms and that improved growth in heated milk was the result of partial hydrolysis of the casein. Green and Jezeski (30) in a study on the effect of heat on starter activity found that, in general, heating raw milk improved its ability to support starter activity, but a continued increase in heat treatment did not result in a consistent and uniform improvement in starter response. About 72° C. for 30 min. seemed to contribute the optimum stimulation. They further indicate that the above stimulation cycle can be duplicated by the addition, to milk, of denatured serum protein or cysteine hydrochloride.

Speck and Ledford (79) have indicated the practicality of accelerating starter culture growth, by adding pancreas extract, in cottage cheese manufacture. Upon adding pancreas extract at the rate of 0.4%, they found the reduction in ripening and cooking times to be 20.2 to 24.8 and 43.4 to 44.9%, respectively. They suggest that these decreased times should be important economically, but that other considerations might be of equal or more importance. That is: the cleaner fermentation resulting from faster acid production; the less dependence of the manufacturer on variations in the ability of milk to support optimum culture development; and the decreased importance of whether or not a culture happens to be as "fast" as desired at any given time.

The rate of starter added to cheese milk and its effect on ripening time has been studied by Morgan et al. (53). They made cottage cheese using 5, 10, 15, and 20% starter. Average times from setting to cutting were 5 hr. 20 min.; 3 hr. 47 min.; 3 hr. 21 min.; and 3 hr. 5 min., respectively. Yields and losses did not vary significantly and they suggest using the higher rates of inoculum in order to save time and give better protection against bacteriophage. Lundstedt (49) has also compiled figures showing the relationship between setting temperature, percent of starter added to cheese milk, and time from setting to cutting. Using the following incubation temperatures and starter percentages, respectively, the reported resultant times from setting to cutting were 70° F. and one percent starter, 12 hr.; 75° F. and 2% starter, 10 hr.; 80° F. and 3% starter, 8 hr.; 85° F. and 4% starter, 6 hr.; 90° F. and 5% starter, 5 hr.

Heat Treatment of Cheese Milk

Thurston and Barnhart (83) investigated the effects of heating skimmilk on the pH of coagulation by lactic cultures. As the heat treatments of the skimmilk progressed from 145 to 198° F. for 30 min., they found that the pH of coagulation increased from 4.60 to 5.03. They believed this was caused by the effect of heat on the casein. In a similar study, Emmons *et al*. (20) state that the increased pH at coagulation, due to the denaturation of serum proteins, is caused by a completely different protein system forming the curd from high heat skimmilk; casein and denatured whey proteins apparently form this gel instead of only the various fractions of casein as indicated by Thurston and Barnhart (83).

Dill and Roberts (15) conclude that denatured serum proteins might interfere physically with normal curd formation or form complexes that retard or reduce curd strength. They found, however, that the curd strength could be increased to its original level by adding calcium chloride to the heated milk. This would work satisfactorily only on heat treatments up to 165° F. Emmons et al. (21) on the other hand have indicated that calcium chloride is unsatisfactory in restoring the normal curd tension properties of skimmilk when legal amounts (0.02%) are used.

Stone et al. (80) observed that preheat treatments of the skimmilk at 185° F. for 10 min. produced non-fat dry milk with poor curd forming properties. Emmons et al. (21) in heating skimmilk to 175° F. for 30 min. previous to curd manufacture found that a weak, mealy curd was the result. Tuckey (88) indicates that the minimum pasteurization temperature that provides for negative phosphatase is best for cottage cheese milk. He further states that lower yields due to shattering can be expected from milk heated above normal pasteurization temperatures, as well as securing cheese having a weak body and texture. The effect of heat on the sulfhydryl groups in milk have prompted Patton and Josephson (58) to indicate that these sulfhydryl substances (heat denatured serum proteins) associate themselves physically, and/or, chemically with the casein in heated skimmilk. They suggest that this phenomenon may be an important factor in explaining the soft curd characteristics of high heated milk. They further suggest that the effect of heat in reducing the amount of calcium ions in milk also must be considered as a factor in influencing curd tension and curd particle size. Rudnick (71) showed a marked reduction in whey expelling properties of curd from over-heated skimmilk that was cut at the same pH as the control lot of curd from pasteurized skimmilk. Emmons et al. (20) now indicate that these decreased whey expelling powers were probably caused by cutting the curd at pH levels far below those at the A-C endpoint, since it is known that whey expulsion rates are decreased when the pH at cutting is too low.

Emmons et al. (21) have demonstrated that increasing the level of rennet in high heat (175° F. for 30 min.) cheese milk improved the body, texture and whey expelling properties of the curd. Further, they observed that the average yield per 100 lb. of low-heat skimmilk was 13.90 lb., from the high-heat skimmilk, 15.35 lb., an average increase of 10.4%. The percentage of skimmilk solids recovered in cottage cheese made from low-heat skimmilk was 32.0%, but the recovery of solids from the high-heat skimmilk was 36.0%. They deducted that the increase in yield was almost certainly due to the retention of whey proteins in the curd and suggest that the prospect of increasing yields by heat treatments to include denatured whey proteins in the curd has an attractive economic significance for the cottage cheese industry.

These favorable results, they point out, were made possible only by using increased amounts of rennet in conjunction with the A-C test, which detects the optimum condition of the curd for cutting. Difficulty would certainly have been encountered had the high heat vats been cut at the same acidities as the low heat, control vats.

Solids Content of Cheese Milk

Olsen (57) was the first to make a study of the quantitative relationships existing between solids of the milk and yield of cottage cheese. He showed that 39.8% of the solids in high solids milk was recovered in the cheese, whereas in low solids milk recovery was only 33.6%.

Bender and Tuckey (7), studying the recovery of skimmilk solids in cottage cheese reported that 38.8% of the solids was recovered from skimmilk with 9.71% solids content as compared to 32.2% recovery for skimmilk with 8.92% solids. Ashworth and Nebe (2) recommended standardizing cheese milk to levels above 9% to obtain higher yields of cottage cheese and to prevent losses due to soft curd formation from excessive heat treatment. Tuckey (88) indicates that it is possible to recover 38 to 39% of total solids of skimmilk in cottage cheese with high solids milk, but only 31 to 33% if low solids milk is used.

Cutting Time of Curd

Recently, considerable interest has been directed toward more satisfactory means of determining the desirable time for cutting cottage curd and some of the factors involved. It is well known that a poor quality curd will result if close control over time of cutting is not observed. Price *et al*. (62) reported that if the acidity of cottage cheese at cutting is too low, the cheese will be tough and rubbery in body and will leak whey in the package. If the acidity is too high, the curd particles will be broken, and the cheese will show gritty, hard particles or pastiness. It will be fragile and easily broken in cooking.

Heinemann (36) found that the starter used in the manufacture of cottage cheese significantly affects firmness of the curd at time of cutting (0.55% whey acidity). He assumed this to be due to variations in the proteolytic activity of different types of organisms present in the different cultures. Emmons _et_ _al_. (22) in conducting research on the relationship between pH and titratable acidity observed that at the same titratable acidity, curd strength varied widely with different cultures. They give a possible explanation for this effect by plotting pH values of coagulation against the time elapsing between the addition of rennet and the time of coagulation. This relationship suggests that those cultures which change the pH of skimmilk more slowly allow more time for rennet action, so that the skimmilk coagulates at a higher pH. They further indicate that differences in the relationship between pH of the curd and titratable acidity of whey for the commercial lactic cultures were wide. They suggest that this is due to the production of weakly dissociated acids, such as carbonic or acetic acid, by certain cultures. They further state that active cultures show better correlation between pH and curd strength than between titratable acidity and curd strength and conclude that measurement of pH appears to be a more reliable index of the handling and cooking properties of cottage cheese curd than titratable acidity of whey.

The A-C test of Emmons et al. (18) is a new and practical method of determining the optimum time to cut cottage cheese curd. This test determines exactly when acid starter action (without rennet) coagulates skimmilk. The A-C endpoint is that point at which the curd in the A-C test sample will show a line of whey where it has been cut with a knife or spatula.

When comparing pH and titratable acidity measurements with the A-C endpoint for cutting cottage cheese curd, Emmons et al. (21) showed cutting acidities, at the A-C endpoint, to be lower than current recommendations for properly pasteurized skimmilk. An analysis of differences in scores of curd using each of the three methods of determining cutting time showed that the curd cut at the A-C endpoint was significantly better in uniformity and quality.

Lundstedt (49) makes the following statements in regard to methods for determining the cutting point of cottage cheese. The A-C test when used correctly, is very useful in dealing with over-pasteurized milk, reconstituted skimmilk from low heat powder, and different milks of unknown solids content. Also when rennet coagulation precedes the acid coagulation, the A-C test aids in distinguishing between the two.

The use of titratable acidity to indicate cutting time has often caused a lot of poor quality cottage cheese and many failures. Lundstedt, citing Emmons and Price (paper read at A.D.S.A. meeting, North Carolina State College, June, 1958) gave information on 15 commercial starters and found, when curd from normal skimmilk reached a pH of 4.75, the corresponding whey acidities from these starters varied from 0.46 to 0.63% and no matter what the titratable acidity was, the pH of coagulation would always be the same in a given milk. Lundstedt and Emmons are in close agreement when Emmons says, "Cottage cheese is cut at various whey acidities and nobody knows what the pH is." (Private correspondence between Lundstedt and Emmons.)

<u>Nutritive Value</u>

Garrett (26) analyzed 102 samples of commercially made cottage cheese and found the following averages: 22.80% total solids, 1.22% ash, 0.80% calcium, and 0.23% phosphorus. He concluded that cottage cheese is a good source of calcium and phosphorus as compared with other human foods in the diet.

Using egg as a reference protein, Watts et al. (89) observed the relative value of milk, milk and egg, and cottage cheese. They found that the availability of amino acids in cottage cheese was higher than in milk, but lower except for isoleucine, leucine, and lycine than in milk and eggs. Williams (91) in giving the amino acid requirements of humans, indicates that in order to supply the minimum daily requirements of the essential amino acids for adults, 22.4 g. of milk protein are required. This corresponds to about 700 g. or about one and one-half pints of whole milk per day.

Milk and milk products are known to be important foods nutritionally. They provide about two-thirds of the total calcium in our diets, nearly half the riboflavin, and more than one-fifth of the protein. The dairy industry has a large responsibility in continuing to improve its products from a nutritional standpoint as well as from a quality standpoint. By adding a portion of the serum proteins of milk to cottage curd through heat denaturation, the serum proteins are made available as human food. These proteins in combination with the casein of milk may add further to the nutritive value of cottage cheese and utilize valuable proteins which would otherwise be wasted.

It was the purpose of this research to determine the effects of adding serum protein, by heat denaturation and subsequent coagulation, on cottage curd yield and quality. The highest heat treatment of milk which could be used for making satisfactory cottage cheese curd was determined. Milk of this heat treatment was then mixed with milk pasteurized at normal temperature in order to observe what the effects of various blends would be on quality and yield.

MATERIALS

Equipment Used

A Nu-processor, direct steam injection, insulated vat, for rapid heating of cheese milk in five gallon cans.

Water bath--For holding at specific temperatures and cooling five gallon cans of cheese milk.

Scales--Capacity, 1500 g.

Flasks--250 ml. Erlenmeyer, screw cap, for collecting samples at various points throughout the cheese making process and 500 ml. Erlenmeyer, screw cap, for culture propagation.

Autoclave--Scanlan-Morris, type A-420.

Culture incubator--Frigidaire with Fisher B.O.D. incubator. Set at 71° ± 0.1° F.

Culture bottles--Screw cap, for preparing cheese starter.

Water bath--Mojonnier, Model M536, temperature range 90 to 212° F., for pasteurizing quart bottles of starter milk.

pH meter--Beckman Model G, equipped with five inch external glass and calomel reference electrodes.

Cheese vats--Two sets of stainless steel, twin compartment vats each compartment measuring 16 by 8-1/2 by 8-1/2 in. and holding about 25 lb. of cheese milk.

Pump--Centrifugal self-priming, 1/3 h.p., 1725 r.p.m., for removing whey from cheese vats.

Water bath--For holding the two sets of the twin cheese vats. Used for incubation of cheese milk and cooking of curd. Adjustable from 90 to 130° F.

Curd knives--Pair of 3/4 in. cut, 8 x 12-1/2 in. stainless steel.

Curd scoops--Stainless steel, strainer bottom, 8 by 9 by 3-1/2 in.

Curd strainer--8 in. diameter and 8 in. high. Perforations 1/8 in., stainless steel.

Fairbanks scales--F type, capacity 120 lb. Used for weighing cheese milk and drained whey.

Beakers--Berzelius, tall form without lip, for A-C test.

Weighing dish--Aluminum, 60 mm. diameter, disposable.

Drying oven--Precision Scientific Company, serial number 825-617, temperature range to 260° C. Forced draft, type A.

Centrifuge--International, size 1, type S - B, serial number W 2482, equipped with an eight place head.

Waring blender--10,000 r.p.m. heavy duty blades, for homogenizing cottage cheese curd.

Balance--Harvard trip, double beam, round stainless steel plates. Capacity 2000 grams, sensitivity 0.1 gram.

Water bath--Constant temperature, set at 40° $\pm$ 0.1° C., for salting out in whey separation procedure.

Filter paper--Whatman No. 2, 11 centimeter.

Test tubes--Pyrex, 25 x 200 mm., Folin Wu blood digestion, marked at 35 and 50 ml.

Babcock centrifuge--20 inch diameter, variable speed.

Digestion rack--Rotary, electrically heated, 12 flask capacity. Equipped with fume hood. American Instrument Company, Silver Spring, Md.

Kjeldahl distillation apparatus--Distillation head and Hopkins type condenser. Equipped with a 100 ml. vacuum jacketed distillation flask. An entrance tube is provided for the addition of alkali and for the turbulent introduction of steam into the solution contained in the flask. American Instrument Co.

Microburette--10 ml. capacity, graduated in 0.05 ml. for measurement of nitrogen standard and for colorimetric titration of nitrogen.

Volumetric flask--100 ml. pyrex.

Graduated cylinder--100 ml. glass stoppered.

Analytical balance--Gram-atic, model B5, serial number 37,418. Fisher Scientific Co.

Heater--Electric, type RH with built-in rheostat. Used as a heat source for steam distillation of nitrogen.

<u>Reagents and Materials Used</u>

Standard buffer--pH 6.28.

Sodium chloride--Granular, reagent grade.

Sodium hydroxide--0.5 N. and 50% solution.

Protein precipitating reagent--Prepared by dissolving in distilled water, 30 g. zinc sulfate, 6 g. copper sulfate, and 6 g. mercuric chloride to a total volume of 1.0 l.

Sulfuric acid--Concentrated, C.P., sp. gr. 1.84.

Phenolphthalein indicator--1% alcoholic solution.

Boric acid--Reagent grade, 2% solution.

Methyl red-Methylene blue indicator--Prepared by mixing two parts of 0.2% alcoholic methyl red solution with one part of 0.2% alcoholic methylene blue solution.

Hydrochloric acid--Ca. 0.01 normal. Prepared by adding concentrated HCl to distilled water and standardizing with C.P. sodium carbonate.

Nitrogen standard--Containing 0.1 mg. nitrogen per ml.

Hengar granule--A selenized granule which serves as a digestion catalyst and boiling chip.

Lactic culture--Mixed strain No. 4 (dried). Chris Hansen's Laboratory, Inc.

Nonfat dry milk--Lo temp, certified to be free from inhibitory substances. Westerville Creamery Company, Cincinnati, Ohio.

Rennet extract--Chris Hansen's Laboratory, Inc.

METHODS

For this study it was desirable to obtain skimmilk relatively uniform in solids content and representative of commercial quality; therefore, it was purchased[1] from a plant buying raw whole milk from a large geographical area. The raw milk was received and stored in a continuously agitated, 10,000 gal. storage tank which kept the milk at 40° F. Before separation, the milk was preheated to 105° F. and 10 gal. of skimmilk were collected at the separator; thus, obtaining a composite sample from a large initial volume of raw whole milk.

The effect of high heat milk on yield and quality of cottage curd was studied using two methods for the preparation of cheese milk. Method one consisted of pasteurizing cheese milk at increments of five degrees from 145 to 180° F. Method two consisted of preparing two lots of cheese milk. One was pasteurized at 143° F. for 30 min. (low heat) and the other at 170° F. for 30 min. (high heat). Then blends were made from these milks in increments of 5%, containing 10 to 95% of the high heat cheese milk.

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1 Raw skimmilk was purchased from Sealtest Foods Corporation, a subsidiary of National Dairies Corporation.

The procedures used for the manufacture of cottage curd and for analysis of the samples taken during the various steps of manufacture were the same for both methods of cheese milk preparation.

Preparation of Cheese Milk by Method I

The raw skimmilk was warmed to 110° F. and low heat nonfat dry milk (NDM) added to increase the total solids to approximately 11%. After thorough mixing, a 3 gal. (about 25 lb.) aliquot was transferred to each of three 5 gal., stainless steel, milk cans. In each run a control and two experimental vats of curd were made.

The cans were placed in an insulated, pasteurizing vat and the temperature of the milk raised rapidly to 143° F. The control can of milk was placed in a steam jacketed water bath containing water preheated to 143° F. and held for 30 min. The two remaining experimental cans of milk were heated to the designated temperature for each specific run and held for 30 min. Experimental cheese milks were pasteurized at increments of five degrees from 145 to 180° F.

At the end of each pasteurization period, the cans of cheese milk were placed in a 50 gal. vat containing cold running water and were cooled to 70° F. Then they were placed in a cold room (40° F.) until the following morning.

Preparation of Cheese Milk by Method II

Cheese milk (11% solids) was divided into two batches. One was pasteurized at 143° F. for 30 min. (the control); the other at 170° F. for 30 min. (the high heat batch). After pasteurization, 25 lb. batches of cheese milk were standardized to contain 10 to 95% of the high heat milk. The increment of increase was 5%. Three vats of curd were made in each run consisting of the control and two different standardized lots of milk.

Preparation of Cheese Culture

The preparation of culture for cottage cheese making plays a major role in the success or failure of a batch of cheese. Clean equipment and a high grade of sterile milk are prime prerequisites to successful culture propagation.

The culture milk for this study was made from reconstituted Matrix. Each 74 g. package of this product was dissolved in 600 ml. of water, resulting in a total solids content of 11%. After mixing thoroughly, 300 ml. aliquots of the culture milk were transferred to 500 ml. screw cap Erlenmeyer flasks. The culture milk was sterilized at 15 lb. pressure for 10 min., allowed to cool to room temperature and stored at 40° F. until needed.

To start culture growth the entire contents of a 5.0 g. bottle of a dry, mixed strain, cheese culture was added to 300 ml. of the sterile milk which had been tempered to 70° F. The culture was thoroughly mixed and incubated at 70° F., until coagulation occurred. Two or three further propagations were made to condition the various strains of bacteria and put them in an active growing stage. A 1.0% inoculation was used and all transfers were made under sterile conditions. Each inoculated culture was mixed thoroughly and incubated at 70° F. until coagulated (14 to 16 hr.).

Preparation of Cheese Starter

High quality NDM was mixed with water making a reconstituted milk containing 11% solids. The milk was transferred into quart, screw cap, culture flasks in 600 ml. portions. The starter milk was pasteurized in a water bath at 170° F. for 30 min. and immediately cooled to 70° F. The cheese culture was added to the starter milk at the rate of 0.5 to 1.0%, using sterile technique. After thorough mixing, the starter was incubated at 70° F. for about 14 hr. The starter may be used immediately upon coagulation or placed in an ice bath until preparations are made prior to use.

<u>Cottage Curd Manufacture</u>

Twenty-five lb. of the pasteurized cheese milk for each of three cheese vats were warmed to 95° F. The pH was determined and active lactic cheese starter added to each batch at the rate of 10% (two and one-half lb. per batch). The resultant cheese milk was mixed thoroughly, weighed, and another pH determination made. Each batch of milk was transferred to the small cheese vats which were immersed in a water bath preheated to 95° F.

A sample of each of the above batches was taken for the A-C test. About 30 min. after adding the starter, rennet was added at the rate of 0.25 ml. per 100 lb. of cheese milk. The pH was determined at this time and at hourly intervals until the A-C endpoint was reached.

At the A-C endpoint the cheese was cut with three-fourth in. curd knives and left undisturbed for 10 min. Then the curd was heated, taking about 90 min. to reach 125° F. It was cooked at this temperature for 30 min. Following cooking, the whey was removed from each batch of cheese with a centrifugal self-priming pump (Figure 1) which forced the whey through a pressure hose into each of three 3 gal. milk buckets. All of the whey from each batch was saved for weighing and sampling. To prevent any excessive loss of curd, it was not washed after draining.

This made possible a more accurate determination of yield as well as protein and solids distribution in curd and whey. After removing the whey, the curd was left in the cheese vats which were tilted, thus allowing the remaining whey to drain from the curd to the lower end of the vats. Stainless steel scoops were used to hold the curd at the upper end of the vats (Figure 2). Finally, the curd was covered, placed in a cold room (45° F.) and allowed to drain overnight. The following morning the curd was packaged in 12 oz. waxed cottage cheese containers and weighed.

Acid Coagulation Test

A slight modification of the A-C test as described by Emmons *et al*. (18) was used to determine accurately the proper time for cutting cottage cheese curd.

A Berzelius, tall form beaker, without lip, was filled about one-third full with the cheese milk after starter had been added, but just before adding rennet. The beaker was then covered with aluminum foil and suspended in a water bath the same temperature as the cheese milk. The level of the milk in the beaker was placed a little below the level of the water in the vat to make certain that both remained at the same temperature. As the cheese milk in the vat approached the pH of clot formation, the sample in the beaker was observed closely for signs of coagulation. As

Figure 1.

Electrically heated water bath for temperature control during manufacture of cottage curd and self priming centrifugal pump for removing whey.

Figure 2.

Strainer bottom cheese scoops fitted into the cheese vats for draining curd.

soon as coagulation was detected in the A-C test sample, the curd was cut two or three times with a spatula. This cutting was repeated every 5 min. The A-C endpoint occurs when fine lines of whey formed by cutting the soft curd first appear.

Determination of Solids

Raw Milk and Cheese Milk

The method described in A.O.A.C. (3) was used for the determination of solids. A 2 g. sample was weighed into a tared disposable aluminum weighing dish. The sample was heated over a steam bath for 10 to 15 min., placed in a forced draft oven and dried at 212 °F. for 3.0 hr. After cooling in a desiccator, the pan was reweighed and the residue reported as total solids.

$$\% \text{ Total solids} = \frac{(\text{Weight of solids} + \text{pan}) - (\text{Weight of pan})}{(\text{Weight of sample} + \text{pan}) - (\text{Weight of pan})} \times 100$$

Whey

For determining solids of the drained cheese whey, a representative sample (30 to 40 ml.) was placed in a 50 ml. polyethylene centifuge tube and centrifuged at 3500 r.p.m. for 10 min. Two ml. of the centrifuged whey was weighed into a tared disposable aluminum weighing dish. Total solids was determined by the above procedure for cheese milk.

Preparation of Curd

The A.O.A.C. procedure (4) was followed for preparing the cheese curd for solids determination. A 300 to 600 g. sample of curd, which had been cooled to 15° C., was placed in a high speed Waring blender and mixed for the minimum time required to obtain a homogeneous mixture. The temperature of the curd after blending should not exceed 25° C. There was considerable channeling of the cheese at the beginning of the blending operation. This necessitated stopping the blender and scraping the curd down around the blades. It was necessary to repeat this several times until blending action began.

Curd Solids

The solids content of the cheese curd was determined by three methods: (1) A.O.A.C. rapid screening method (4), (2) by drying in a forced draft oven for 4.0 hr., and (3) by calculation. The A.O.A.C. procedure consists of weighing a 2 to 3 g. sample of the prepared homogeneous mixture into a flat bottom, aluminum weighing dish. The dish was placed in a forced draft oven at 130° ± 1° C. for 1.25 hr. After placing in a desiccator to cool, the dish was reweighed and the residue reported as total solids.

$$\% \text{ Total solids} = \frac{(\text{Weight of solids} + \text{pan}) - (\text{Weight of pan})}{(\text{Weight of sample} + \text{pan}) - (\text{Weight of pan})} \times 100$$

The other drying method used was similar to the above with the exception of the drying temperature and time. The sample was placed in the forced draft oven at 100° C. for 4.0 hr. and percent total solids determined as above.

Since the cheese milk solids and cheese whey solids of each vat of curd were determined by the official A.O.A.C. method, it was possible to use the results obtained to calculate the solids of the cottage curd.

The following formula was used:

Weight of cheese milk solids - Weight of cheese whey solids = Weight of curd solids

$$\frac{\text{Weight of curd solids}}{\text{Weight of finished curd}} \times 100 = \% \text{ solids in curd}$$

The data obtained by the three methods for curd solids were correlated.

Determination of Nitrogen

This study required numerous protein nitrogen determinations, consequently, it was desirable to formulate a protein precipitation procedure which was rapid and convenient.

Salwin (73) has contributed a procedure for total serum protein which consists of acidification of whey sample with trichloroacetic acid (TCA) and centrifugation of the precipitate. The precipitate is then dissolved in 3% sodium hydroxide solution and protein nitrogen determined by the biuret method.

The A.O.A.C. does not make available a direct method for total protein. Total milk protein is determined by two procedures: (1) precipitation of the casein with acetic acid and filtration; and (2) neutralization of whey and precipitation of albumin with acetic acid plus heat. Each precipitate plus filter is digested and nitrogen is determined by the Kjeldahl procedure. The casein plus albumin equals total protein of the sample. The main drawback to this method is the time involved. For this reason, a procedure was developed using heavy metal salts ($ZnSO_4$, $CuSO_4$, $HgCl_2$) as the precipitating agent. It was found that this mixture has several advantages. The digestion time is reduced and the metals serve as a catalyst during digestion. Table 1 shows the relative protein values of certain milks when TCA, Zn, and Zn-Cu-Hg precipitating reagents were used. Following precipitation with TCA, nitrogen was determined by Kjeldahl digestion and distillation.

Table 1

Comparison of protein content of certain milks using various protein precipitating agents.

Sample No.	Percent protein		
	TCA	Zn	Zn, Cu, Hg
1	2.64	3.07	3.14
2	2.97	3.16	3.27
3	2.93	3.20	3.29
4	2.82	3.18	3.23
5	2.79	3.14	3.25
6	2.86	3.14	3.20
7	3.81	4.19	4.33

Serum Protein Nitrogen in NDM

The procedure of Harland and Ashworth (32) was followed, using the formula of Salwin (73) for the preparation of sample and calculation of nitrogen, respectively.

Eight gr. of sodium chloride were weighed into a 25 x 150 mm. test tube. Two g. of the NDM were then added along with 20 ml. of distilled water. The mixture was shaken until a homogeneous mixture was obtained (about 40 sec.), and immersed, without further agitation, in a 40° C. water bath for 30 min. The mixture was then filtered through an 11 cm. Whatman No. 2 filter paper into another test tube. If the first portion of the filtrate was not clear, it was refiltered. The filter was covered with a watch glass to prevent evaporation and held at room temperature until used.

Two ml. of the serum was transferred to a Folin Wu, blood digestion tube. Twelve ml. of distilled water and 2.0 ml. of heavy metal precipitating reagent were added. Sodium hydroxide (0.5 N) was then added dropwise, with constant swirling, until the phenolphthalein endpoint was reached. The mixture was diluted to 35 ml., allowed to stand 5 min., and centrifuged for 10 min. in a Babcock cream testing centrifuge. (The Babcock centrifuge has the advantage in that it holds 18 tubes.) The supernatant was carefully decanted through capillary tubing with the aid of a vacuum (8 to 10 in.). Serum protein nitrogen was determined by a slight modification of the A.O.A.C. (5) micro-Kjeldahl procedure. Two ml. of concentrated sulfuric acid and one Hengar granule were added to the precipitate and the mixture was digested until water clear. The digestion flask was rinsed four times with 5 ml. portions of ammonia free distilled water to make certain that all of the digest was transferred. The distillation flask was then attached to the steam distillation unit. Twenty-five ml. of 50% sodium hydroxide were added and the mixture was steam distilled for 10 min. The distillate was received in 25 ml. of 2.0% boric acid solution containing 4 or 5 drops of indicator. Immediately following distillation, the distillate was titrated with standard hydrochloric acid solution to the first tinge of purple. The nitrogen content was then calculated using the following formula:

$$\frac{\text{ml.} \times N \times E \times 11.75}{\text{g.}} = \text{mg. SPN/g. SNF}$$

where:

ml. = Milliliters of standard HCl
N = Normality of HCl
E = Equivalent weight of nitrogen
g. = Grams of sample used for determination
11.75 = Salwin factor (73) represents the ml. of whey/g. SNF when the whey is separated by the above procedure

$$\text{mg. SPN/g. SNF} \times 6.38 = \text{mg. SP/g. SNF}$$

$$\frac{\text{mg. SP}}{10} = \text{\% SP in SNF}$$

<u>Nitrogen in Drained Whey</u>

One ml. of the previously centrifuged whey was transferred to a 25 x 200 ml. Folin Wu blood digestion tube. The procedure for precipitation, digestion, distillation, and titration was the same as that used for the determination of serum protein nitrogen in NDM.

The following formula was used to determine the percent whey protein nitrogen.

$$\frac{\text{ml.} \times N \times M}{\text{g.}} \times 100 = \%\ N \text{ in whey}$$

where:

ml. = Milliliters of standard HCl solution
N = Normality of HCl
M = Millequivalent weight of nitrogen
g. = Grams of sample used for determination

$$\%\ N \text{ in whey} \times 6.38 = \%\ \text{protein}$$

Nitrogen in Cheese Milk

Ten g. of the thoroughly mixed cheese milk, containing skimmilk plus starter, was weighed into a 100 ml. volumetric flask. The milk was diluted to the mark with distilled water. One ml. of the diluted sample was introduced into a Folin Wu digestion tube. The same procedure was used for the precipitation, digestion, distillation, and titration as was used for the determination of serum protein nitrogen in NDM. The following formula for determining nitrogen was used.

$$\frac{\text{ml. x N x M x 10}}{\text{g.}} \times 100 = \%\ \text{nitrogen in milk}$$

where:

ml. = Milliliters of standard HCl solution
N = Normality of HCl
M = Millequivalent weight of nitrogen
10 = Dilution factor of cheese milk
g. = Grams of diluted milk for determination

% N in milk x 6.38 = % protein in milk

Serum Protein Nitrogen of Cheese Milk

The serum protein separation procedure of Harland and Ashworth (32) as modified by Stone and Holmes (81) was used. The total milk solids were determined and this value used as a basis for standardizing the milk to 8.0 g. of SNF and 92 g. of water.

The standardization formula was:

$$\text{Weight of milk sample} = \frac{8.0 \times 100}{\text{SNF}}$$

$$\text{Weight of water to add} = 92 - \frac{8.0}{\%\ \text{SNF}} \times 100 \times (100 - \text{SNF})$$

The caseins and insoluble whey proteins were precipitated from a 100 ml. volume of standardized milk, which had been measured into a 250 ml. Erlenmeyer flask. The sample was warmed to 40° C. and sodium chloride added to form a saturated solution (40 g. per 100 ml. of the milk).

The solution was shaken vigorously in a vertical motion, for about 40 sec., then immersed in a 40° C. water bath for 30 min. without further agitation. The whey was filtered through a fluted filter prepared from Whatman No. 2 paper. A 65 mm. funnel containing the filter rested on the top rim of a glass stoppered graduated cylinder which was provided with a ground glass stopper. The top of the funnel was covered with a watch glass to prevent excessive evaporation. Upon completion of filtration, the cylinder was stoppered and the whey allowed to remain at room temperature until used.

Two ml. of the prepared whey was transferred to a 25 x 200 Folin Wu blood digestion tube.

The procedure for precipitation, digestion, distillation, and titration was the same as that used for the serum protein nitrogen in NDM.

The serum protein nitrogen content of the milk solids may be calculated using the following formula:

$$\frac{ml. \times N \times E}{m} = \text{Mg. N/ml. sample}$$

where:

ml. = Milliliters standard HCl
N = Normality of standard HCl
E = Equivalent weight of N
m = Milliliters of sample

Mg. N/ml. sample x 13.59[2] = Mg. N/g. SNF

$$\frac{\text{Mg. N/g. SNF}}{1000} \times 100 = \text{\% SPN in SNF}$$

% SPN in SNF x % solids in original milk = % SPN in original milk

% SPN in milk x 6.38 = % SP in original milk

Nitrogen in Cottage Curd

The homogeneous mixture of cottage curd that was prepared for total solids determination was also used for the nitrogen determination. A 100 to 200 mg. sample of the mixture was weighed into a tared, disposable aluminum dish, and rinsed with distilled water into a 25 x 200 Folin Wu blood digestion tube. Three ml. of concentrated sulfuric acid and one Hengar granule were added. The tube was placed on the digestion rack, brought to boiling, and a small amount of antifoam A added to prevent excessive

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2 This factor, as stated by Stone and Holmes (81), represents the milliliters of whey per gram of solids-not-fat when the whey is separated by the above procedure.

foaming. Complete digestion of the mixture required 1 to 2 hr., depending upon the amount of sample. The procedures for distillation and titration were the same as those used for the determination of serum protein nitrogen in NDM.

The following formula was used for determining the percent nitrogen in the curd.

$$\frac{\text{ml.} \times N \times M}{\text{g.}} \times 100 = \%\ N \text{ in curd}$$

where:

ml. = Milliliters of standard HCl
N = Normality of standard HCl
M = Millequivalent weight of N
g. = Grams of sample for determination

$$\%\ N \text{ in curd} \times 6.38 = \%\ \text{protein in curd}$$

Scoring of Cottage Curd

Scoring of the cottage curd was performed by an experienced judge. After packaging the curd in 12 oz. cartons, one carton from each batch was chosen at random. The judge was not aware of the heat treatment or manufacturing procedure which had been used in making the curd. This served to eliminate as much as possible any bias on the scoring. The curd was rated[3] on flavor, on

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3 The score card used was the one adopted at the proceedings of the annual meeting of the American Dairy Science Association. Stillwater, Oklahoma. June 1957.

body and texture, and on color and appearance. The container was not included in the rating.

The values that are designated as a perfect score for flavor, body and texture, and color and appearance are 45, 35, and 15, respectively. The normal range for flavor is 32 to 42 with no criticism in the range 40 to 45. The normal range for body and texture is 31 to 34.5 and 11 to 14.5 for color and appearance.

Calculation of Yield

The yield of cottage curd from each batch was calculated using the following formula.

$$Y = \frac{W \times S}{21 \times L}$$

where:

Y = Pounds of finished curd/pound of cheese milk solids
W = Pounds of finished curd
S = Percent solids of finished curd
L = Pounds of solids in the cheese milk

Yield was also calculated as pounds of curd per pound of protein using the following formula.

$$Y = \frac{W \times P}{18 \times C}$$

where:

Y = Pounds of finished curd/pound of cheese milk protein
P = Percent protein in finished curd
W = Pounds of finished curd
C = Pounds of protein in cheese milk

RESULTS AND DISCUSSION

The holding time for all heat treatments of cheese milks in this study was 30 min. unless otherwise stated.

Method I

The effect of various heat treatments on the denaturation and subsequent coagulation of cheese milk serum proteins when making rennet type cottage curd is shown in Tables 2 and 3. The data in Table 2 show that when cheese milk was heated at temperatures from 145 to 180° F., and used for making cottage curd, the serum protein content of the drained whey was reduced from 1.13 to 0.41%. When using the control batch as a standard at each heat treatment, the percent denaturation of the drained whey ranged from 11.34% at 150° F. to 60.01% at 180° F. This relationship is illustrated in Figure 3.

Several samples of cheese milk were analyzed following heat treatment at 143 and 170° F., for the purpose of determining the percent serum protein denaturation prior to curd manufacture. The results are shown in Table 3. The pasteurization of cheese milk at 143° F. resulted in a serum protein denaturation varying from 0.0 to 5.0%, an average of 2.4%. When cheese milk was pasteurized at

Table 2

The effect of various heat treatments of cheese milk on the denaturation of serum protein in drained whey

Heat treatment[a] for 30 min.	Serum protein	Serum protein in drained whey			Denaturation
	Control	Batch I[b]	Batch II[b]	Average	Average
°F.	%	%	%	%	%
145	1.10	1.13	1.13	1.13	--
150	1.06	0.95	0.93	0.94	11.34
155	0.97	0.84	0.87	0.86	11.86
160	1.00	0.72	0.73	0.73	27.50
165	1.10	0.69	0.77	0.73	33.64
170	1.13	0.61	0.61	0.61	46.02
175	1.09	0.57	0.56	0.57	48.17
180	1.05	0.41	0.43	0.42	60.01

a All heat treatments were made in duplicate.

b Values are averages of duplicate determinations.

Table 3

Denaturation of serum protein by heat treatment of cheese milk at 143 °F. for 30 min. and at 170° F. for 30 min.

Batch[a] No.	Serum protein in cheese milk					Serum protein in cheese milk		
	11% Raw		Pasteurized at 143° F.		Denaturation[b]	Pasteurized at 170° F.		Denaturation[b]
	A %	B %	A %	B %	%	A %	B %	%
1	0.72	0.73	0.72	0.72	0.69	0.30	0.29	59.32
2	0.70	0.69	0.69	0.70	0.00	0.34	0.33	51.80
3	0.70	0.70	0.67	0.66	5.00	0.25	0.25	64.29
4	0.67	0.68	0.66	0.66	2.23	0.27	0.27	60.00
5	0.69	0.67	0.67	0.67	1.48	0.22	0.22	67.65
6	0.67	0.66	0.65	0.65	2.26	0.25	0.24	63.16
7	0.67	0.67	0.64	0.64	4.48	0.22	0.20	68.71
8	0.65	0.65	0.63	0.63	3.08	0.35	0.35	46.16
Average	0.68	0.68	0.67	0.67	2.40	0.28	0.27	60.14

a The various cheese milks from each batch were all analyzed in duplicate (represented by A and B).

b Average of duplicate determinations.

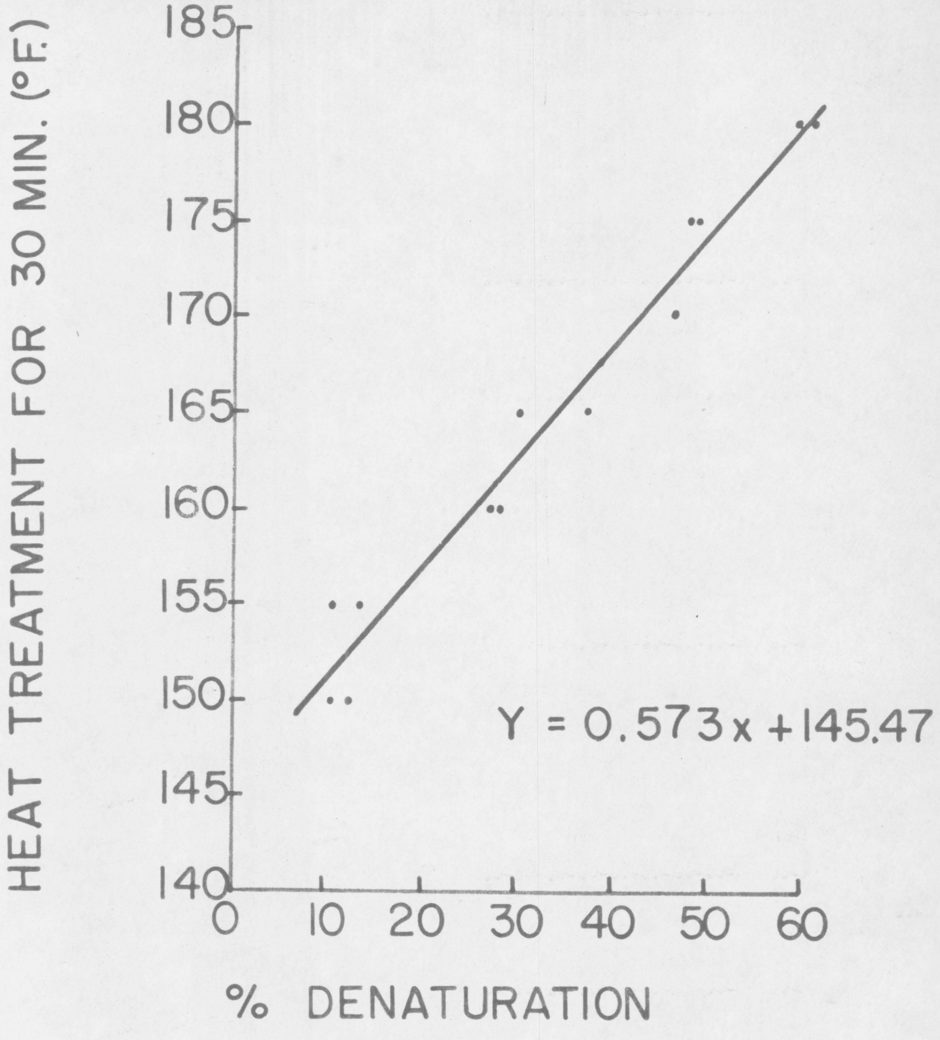

FIGURE 3. RELATIONSHIP BETWEEN HEAT TREATMENT OF CHEESE MILK AND PERCENT DENATURATION OF THE SERUM PROTEINS

170° F., the denaturation of the serum proteins varied from 46.16 to 68.71%, with an average denaturation of 60.14%.

The denaturation of the serum protein resulting from varying heat treatments showed lower values following the manufacture of cottage curd than prior to curd manufacture. This phenomenon may be observed by comparing Table 2 with Table 3. When cheese milk, pasteurized at 170° F., was tested for serum protein denaturation, following the manufacture of cottage curd, a value of 46.02% was observed. When determined prior to cottage curd manufacture, the serum protein denaturation was 60.14%. The lower denaturation values found in drained whey following cheese making may be attributed to rennin and certain lactic bacteria that exhibit proteolytic activity. During curd manufacture, some of the proteins may be broken down in such a way that they are not incorporated into the curd by coagulation. These hydrolyzed proteins may, however, be precipitated by heavy metals when analyzing for proteins remaining in the whey. Thus, higher protein values and lower denaturation values are feasible.

The percent denaturation of serum protein was lower in this study than the 80% denaturation reported by

Harland *et al*. (34) when they heated skimmilk at 172.2° F. for 30 min. These workers tested serum protein denaturation from skimmilk containing 9.12% solids using the Harland-Ashworth (32) turbidimetric procedure. There are several factors which may contribute to these differences. One may be the relationship between the total solids of cheese milk and heat denaturation of the serum protein. Harland *et al*. (33) reported that the effect of solids concentration on serum protein denaturation was not large, but when pasteurizing milk at 160 and 170° F., they found some decrease in serum protein denaturation with increasing solids concentration. Other variables that should be taken into consideration are, procedures used for pasteurization, size of the batches being pasteurized, and the method used in determining the percent denaturation of serum protein.

The distribution of total cheese milk protein between the drained whey and cottage curd is shown in Table 4. The average percent of cheese milk protein in the drained whey following pasteurization of the cheese milk at 143° F. was 20.47%. The average percent of cheese milk protein in the curd was 79.81%. However, when the cheese milk was heated at 180° F., the protein in the drained whey and curd

Table 4

Effect of heat treatment of cheese milk on the distribution of cheese milk protein between curd and drained whey

Heat treatment[a] for 30 min.	Grams of total protein per 25 lb. batch in:			Percent of total protein in:		
	Cheese milk	Curd	Drained whey	Curd	Drained whey	Total
°F.	g.	g.	g.	%	%	%
Control	494	424	103	85.8	20.9	106.7
145	482	376	105	78.0	21.8	99.8
145	480	370	104	77.1	21.7	98.8
Control	481	380	102	79.0	21.2	100.2
150	479	384	89	80.2	18.6	98.8
150	477	370	88	77.6	18.4	96.0
Control	522	404	100	77.4	19.2	96.6
155	508	409	73	80.5	14.4	94.9
155	513	395	82	77.0	16.0	93.0
Control	503	409	99	81.3	19.7	101.0
160	504	424	67	84.1	13.3	97.4
160	505	452	68	89.5	13.5	103.0
Control	517	414	109	80.1	21.1	101.2
165	529	479	65	90.5	12.3	102.8
165	535	461	73	86.2	13.6	99.8
Control	509	400	105	78.6	20.6	99.2
170	527	476	75	90.3	10.8	101.1
170	521	479	57	91.9	10.9	102.8
Control	494	397	105	80.4	21.3	101.7
175	510	480	54	94.1	10.6	104.7
175	506	458	53	90.5	10.5	101.0
Control	519	394	103	75.9	19.8	95.7
180	529	481	40	90.9	7.6	98.5
180	531	480	42	90.4	7.9	98.3
Control Average				79.81	20.47	99.7

[a] All heat treatments were made in duplicate.

was 7.6 and 90.9% of the total cheese milk protein, respectively. This decrease of protein in the whey, due to the increased heat treatment of cheese milk, was 66.18%.

The percent solids in drained whey and the percent reduction of solids in the drained whey as the heat treatment of the cheese milk was increased is shown in Table 5. When the cheese milk was heated to 180° F., the reduction in total whey solids was 7.06%. The relationship between heat treatment of cheese milk and percent reduction of total solids in drained whey is illustrated in Figure 4.

When the total solids and the total protein content of drained whey made from milk receiving varying heat treatments were compared, it appeared that the decrease in solids was due, primarily, to denaturation and transfer of the serum proteins to the curd. The constituents, except for the serum proteins, which were denatured by heat, and rendered coagulable during the curd making process, remained fairly constant in the wheys from the cheese milks of different heat treatments. These relationships are shown in Table 6.

There are several methods whereby curd yield may be determined. The method that has been most commonly used is lb. of curd per 100 lb. of skimmilk. Yield has also been expressed as lb. of curd per lb. of cheese milk solids.

Table 5

Percent changes in total solids as a result of increasing heat treatments of cheese milk

Control	Heat treatment[a] for 30 min.	Solids A[b]	Solids B[b]	Solids Average	Reduction Average
%	°F.	%	%	%	%
8.31	145	8.41	8.43	8.42	----
8.24	150	8.31	8.32	8.32	----
8.54	155	8.33	8.38	8.36	2.17
8.45	160	8.18	8.26	8.22	2.73
8.35	165	8.08	8.09	8.09	3.18
8.27	170	7.74	7.74	7.74	6.41
8.12	175	7.61	7.61	7.61	6.29
8.43	180	7.80	7.87	7.84	7.06

a All heat treatments were made in duplicate.

b Solids A and B each represent the average of duplicate determinations made on drained whey from milks receiving various heat treatments.

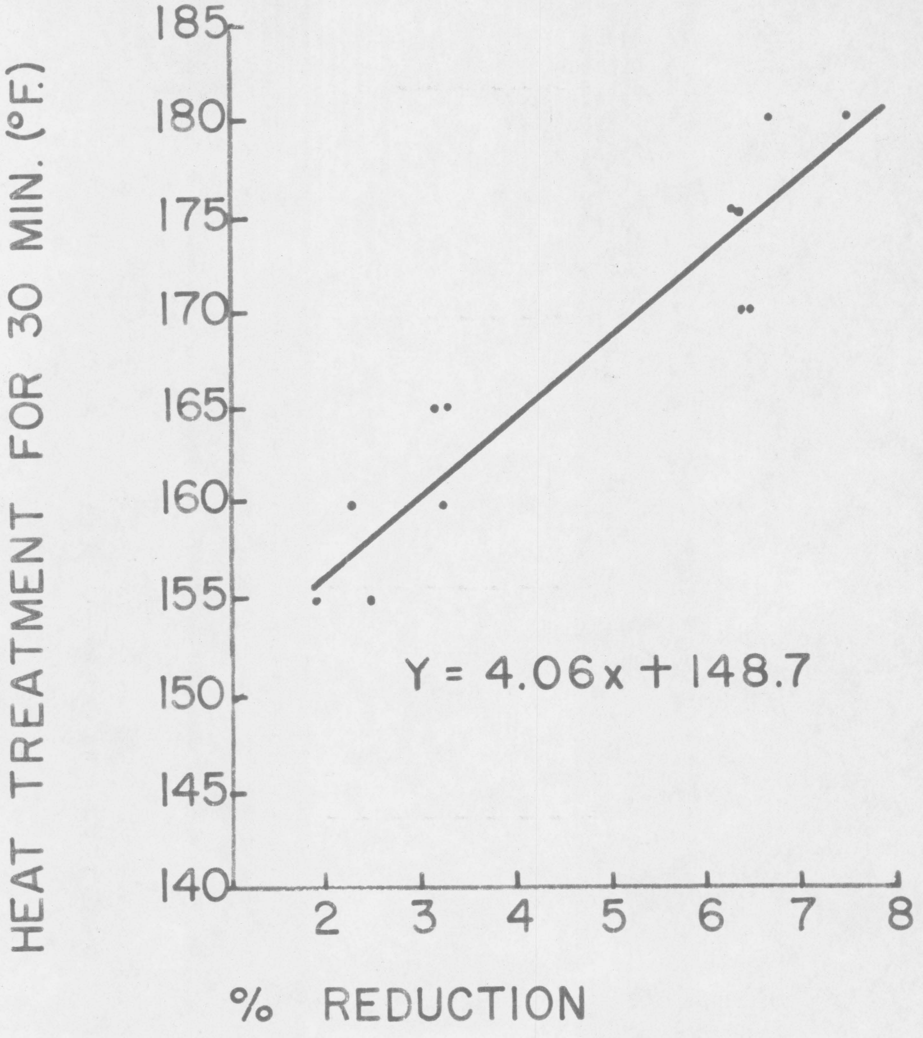

FIGURE 4. RELATIONSHIP BETWEEN HEAT TREATMENT OF CHEESE MILK AND THE REDUCTION OF TOTAL SOLIDS IN DRAINED WHEY

Table 6

Relationship between protein and solids reduction in drained whey as a result of varying heat treatments of cheese milk. All values were adjusted to represent 20 lb. of drained whey per batch.

Heat treatment[a]	Solids in whey	Solids in whey	Reduction from control	Protein in whey	Protein in whey	Reduction from control
°F.	%	g.	g.	%	g.	g.
Control	8.31	755	--	1.10	100	--
145	8.41	764	--	1.13	103	--
145	8.43	765	--	1.13	103	--
Control	8.24	748	--	1.06	96	--
150	8.31	755	--	0.95	86	10
150	8.32	755	--	0.93	84	12
Control	8.54	775	--	0.97	88	--
155	8.33	756	19	0.84	76	12
155	8.38	761	14	0.87	79	9
Control	8.45	767	--	1.00	91	--
160	8.18	743	24	0.72	65	26
160	8.26	750	17	0.73	66	25
Control	8.35	758	--	1.10	100	--
165	8.08	734	24	0.69	63	17
165	8.09	735	23	0.77	70	30
Control	8.27	751	--	1.13	103	--
170	7.74	703	48	0.61	55	48
170	7.74	703	48	0.61	55	48
Control	8.12	737	--	1.09	99	--
175	7.61	691	46	0.57	52	47
175	7.61	691	46	0.56	51	48
Control	8.43	765	--	1.05	95	--
180	7.80	708	57	0.41	37	58
180	7.87	715	50	0.43	39	56

[a] All heat treatments were made in duplicate.

It is well known that the protein content of cheese milk is the principal determining factor in yield insofar as the composition of milk is concerned. Therefore, if accurate determinations of yield are to be made, the composition of the cheese milk must be taken into consideration. This is especially true where variations in the solids content and in heat treatment of the cheese milk are the case.

Cottage curd yield was determined by two methods in this study: (1) by calculating lb. of curd per lb. of cheese milk solids and (2) lb. of curd per lb. of cheese milk protein.

The yield of cottage curd from cheese milk subjected to heat treatments from 145 to 180° F., at increments of 5° F., is shown in Table 7. These data indicate that as the heat treatment of cheese milk is increased, yield based on protein content of the cheese milk and curd gives a more consistent increase in curd yield than when cheese milk and curd solids are used as a basis for the curd yield determination.

Cheese milk that received a heat treatment of 170° F. gave the maximum yield of curd that was high in quality. Cheese milk pasteurized at this temperature produced 2.20 lb. of curd per lb. of cheese milk solids, an

Table 7

Yield of cottage curd from cheese milk subjected to varying heat treatments

Heat treatment for 30 min.	Net cheese milk[a]	Cheese milk protein	Cheese milk solids	Cottage curd	Curd yield[b]	Yield[e,f] increase	Curd yield[c]	Yield[e] increase
°F.	lb.	lb.	lb.	lb.	lb./lb. SNF	%	lb./lb. cheese milk protein	%
Control[d]	25.69	1.09	2.90	5.19	1.97		4.51	
145	25.05	1.06	2.83	4.55	1.87		4.11	
145	24.94	1.06	2.81	4.69	1.86		4.07	
Control	25.86	1.06	2.90	4.68	1.89		4.16	
150	25.72	1.06	2.90	4.87	1.94		4.21	
150	25.61	1.05	2.90	4.80	1.92	2.08	4.09	1.19
Control	25.46	1.15	3.09	3.96	1.73		4.08	
155	26.02	1.12	3.04	6.39	2.16		4.22	
155	26.09	1.13	3.06	5.84	2.13	19.35	4.05	3.32
Control	26.16	1.11	3.02	4.41	1.86		4.27	
160	26.17	1.11	3.01	5.67	2.10		4.43	
160	26.25	1.11	3.03	5.75	2.11	11.64	4.71	7.09
Control	25.75	1.14	2.93	4.06	1.82		4.23	
165	26.26	1.17	3.02	5.51	2.11		4.76	
165	26.56	1.18	3.06	5.71	2.13	14.16	4.54	9.93
Control	25.38	1.12	2.87	4.82	1.94		4.13	
170	26.13	1.16	2.95	5.57	2.20		4.76	
170	26.14	1.15	2.96	5.64	2.20	11.82	4.84	16.22
Control	25.65	1.09	2.86	4.47	1.90		4.23	
175	25.91	1.12	2.90	4.91	2.13		4.95	
175	25.52	1.12	2.85	4.58	2.11	10.38	4.76	14.89
Control	26.04	1.14	3.01	4.48	1.88		4.00	
180	26.56	1.17	3.07	5.12	2.17		4.79	
180	26.46	1.17	3.06	5.08	2.15	12.97	4.75	19.25

[a] Less weight of milk for analysis.

[b] Pound of curd per lb. of cheese milk solids.

[c] Pound of curd per lb. of cheese milk protein

[d] Pasteurized at 143° F. for 30 min.

[e] Percent increase in yield

$$= \frac{\text{yield from heat treated milk} - \text{yield from control milk}}{\text{yield from heat treated milk}} \times 100 .$$

[f] Average of duplicate determinations.

increase of 11.82% over the control. When protein was used as the basis for calculation, 4.80 lb. of curd per lb. of cheese milk protein was produced, an increase over the control of 16.22%.

Varying heat treatments of cheese milk and the resultant effects on the time from setting to cutting and pH at the A-C endpoints are shown in Table 8. As the heat treatment of cheese milk was increased from 143 to 180° F., the pH at the A-C endpoint increased from 4.72 to 5.10. This is further illustrated in Figure 5. These variations in pH are in close agreement with the pH of coagulation (4.60 to 5.03) reported by Thurston and Barnhart (83) when they heated skimmilk progressively from 145 to 198° F., and with the data of Emmons et al. (18) who observed an increase in pH (4.61 to 5.07 at the A-C endpoint) as a result of increasing the heat treatment of skimmilk from 145 to 185° F.

The time from setting to cutting of cottage curd is a factor which was greatly influenced by the varying heat treatments of cheese milk, as shown in Figure 6. When the heat treatment of cheese milk was increased from 145 to 180° F., the time from setting to cutting of cottage curd decreased from 4.75 to 2.50 hr.

Table 8

The effect of varying heat treatments of cheese milk on time from setting to cutting and pH at the A-C endpoint of cottage curd

Heat treatment[a]	Time from setting to cutting	pH at A-C endpoint
°F.	hr.	pH
145	4.25	4.78
150	4.25	4.76
155	4.75	4.80
160	3.50	4.90
165	3.50	4.87
170	3.00	5.04
175	2.75	4.94
180	2.50	5.10

[a] Two batches of curd were made from cheese milk receiving each heat treatment.

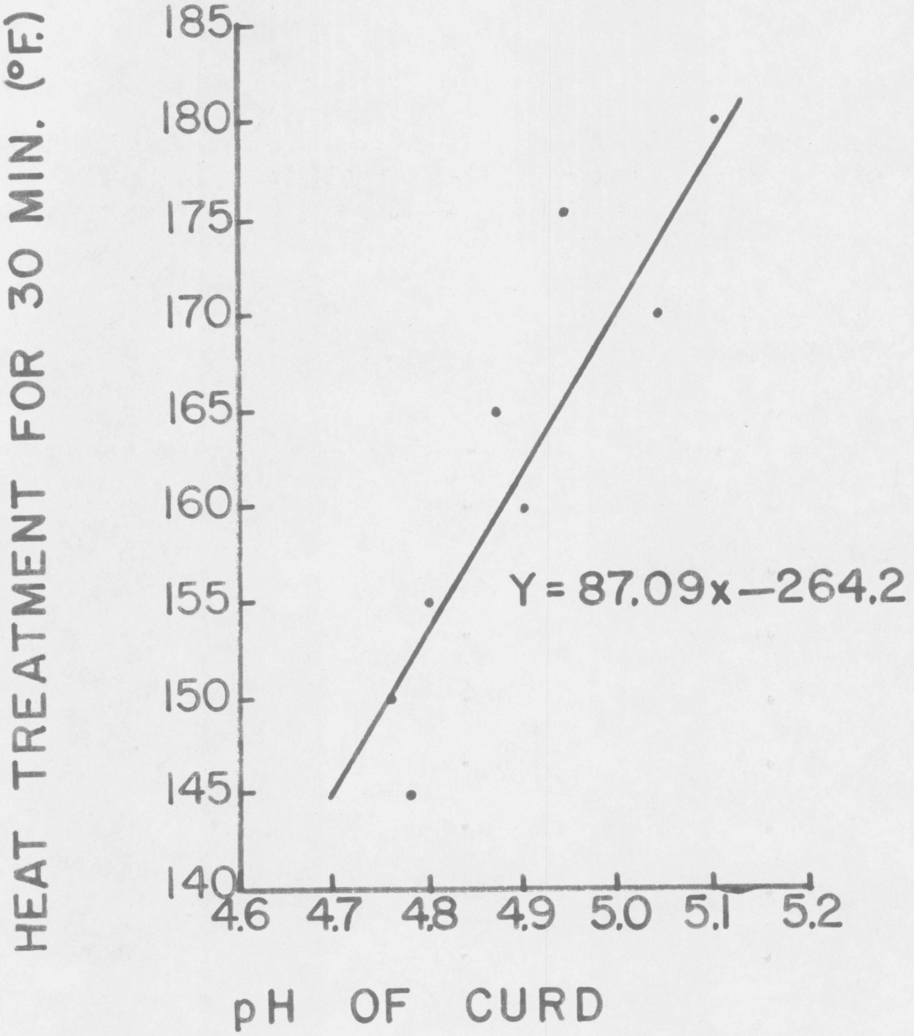

FIGURE 5. RELATIONSHIP BETWEEN HEAT TREATMENT OF CHEESE MILK AND pH OF CURD AT THE A-C END POINT

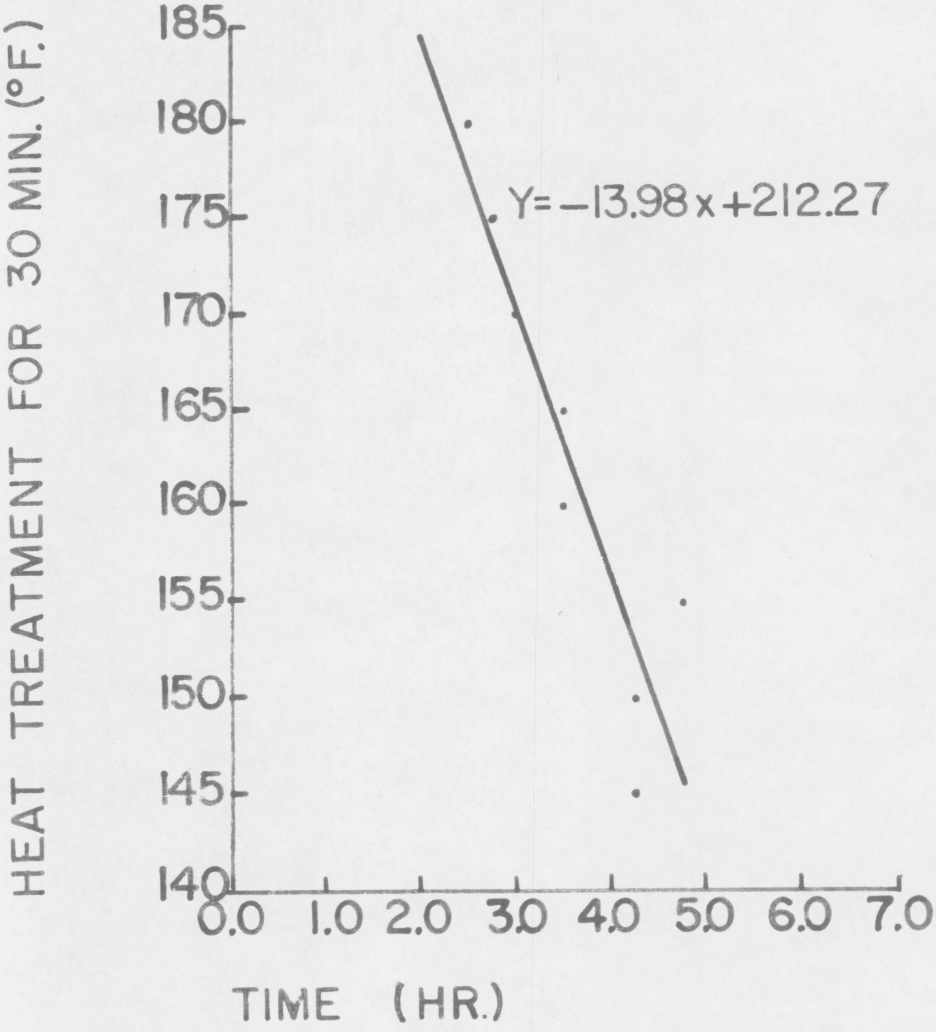

FIGURE 6. RELATIONSHIP BETWEEN HEAT TREATMENT OF CHEESE MILK AND TIME FROM SETTING TO CUTTING OF COTTAGE CURD

Apparently, the heat treatments resulted in either a chemical or a physical change in milk, thus supplying the lactic bacteria with essential growth factors normally deficient in milk. This growth stimulation could be due to an increased availability of nitrogen sources as the result of partial hydrolysis of the casein as suggested by Foster (24). Green and Jezeski (30) have stated that starter activity can be stimulated by adding denatured serum protein to milk. Since high heat treatment of milk results in the denaturation of serum proteins which are subsequently coagulated in the cheese making process, the above statement seems to be a logical conclusion.

It is well known that when milk is heated to high temperatures, numerous chemical and physical changes take place. One of the most obvious is the reaction whereby cooked flavor is produced in milk. Several workers (28,40, 42,44,84,85,92) have indicated that this cooked flavor is due to the breakdown of the proteins that liberate sulfhydryl compounds. All agree that these sulfhydryl groups are found primarily if not entirely in the serum proteins. When cheese milk is pasteurized at 143° F., there is very little denaturation of the serum proteins; thus when it is used for making cottage curd, essentially no compounds accused of being responsible for cooked flavor are formed. When cheese milks receiving high heat treatments are used for cottage curd manufacture, the components which induce cooked flavor must be taken into consideration. Evaluation of all curds made in this study did not indicate the presence of cooked flavor. This may have been attributable to masking by lactic acid and other flavor producing bacteria. Hutton and Patton (40) indicate that the conversion of sulfhydryl groups to hydrogen sulfide is the mechanism whereby beta-lactoglobulin gives rise to cooked flavor. If this is the case essentially all of the cooked flavor would be drained from cottage curd since hydrogen sulfide is very soluble in water.

The quality score of cottage curd was not appreciably changed as a result of increasing heat treatments of the cheese milk. This is graphically illustrated in Figure 7. The most common criticism encountered was lack of curd uniformity. This was due to the fact that curd was made in relatively small vats. During cutting, the curd near the edge of the vats had a tendency to break up as the knives were introduced into the curd. There was no loss in curd yield due to this condition.

One other criticism that occasionally appeared in curd made from high heat cheese milk was high acid. This

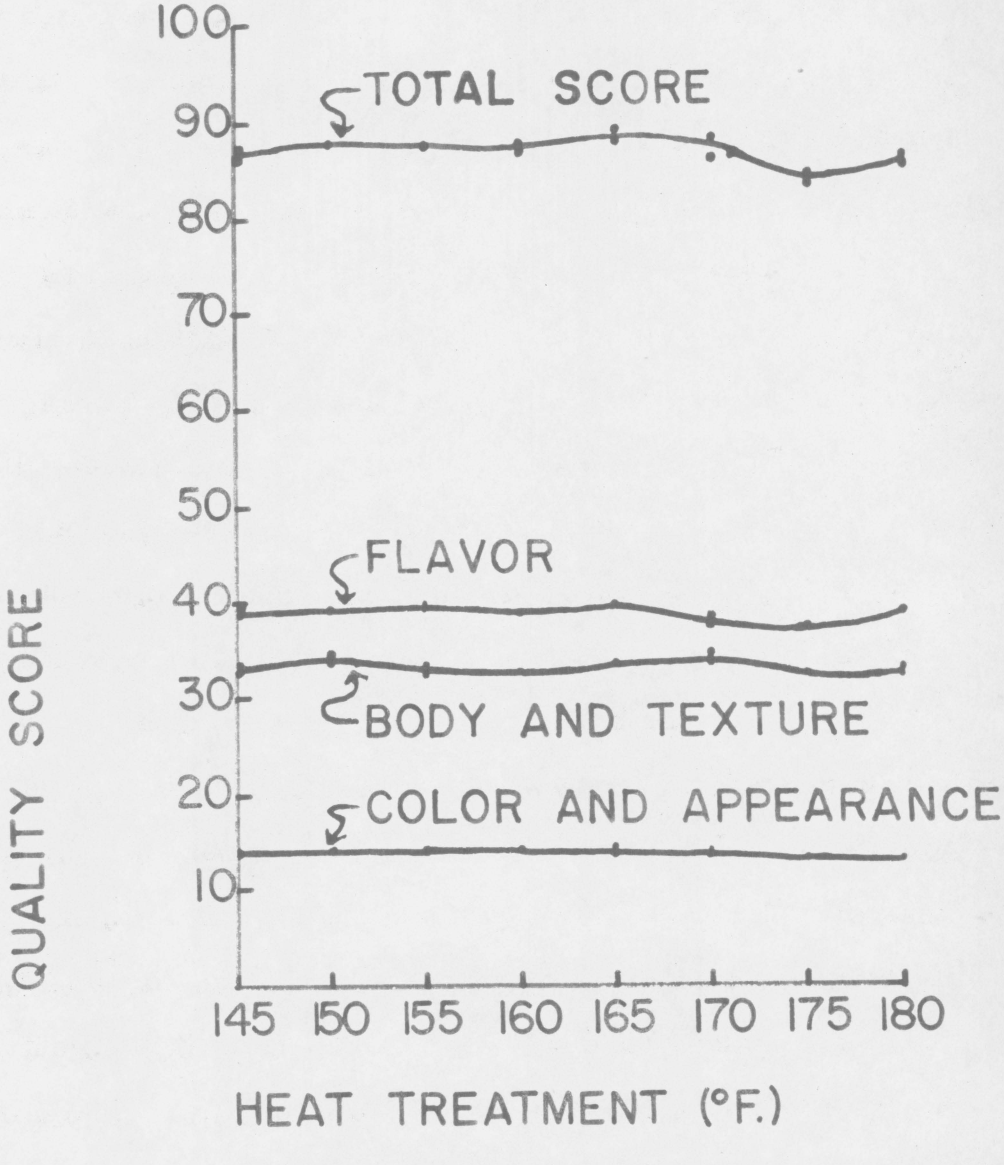

FIGURE 7. THE EFFECT OF VARIOUS HEAT TREATMENTS OF COTTAGE CHEESE MILK ON THE QUALITY SCORE OF COTTAGE CURD

is one defect which is very easily encountered when making curd from cheese milk pasteurized at high temperatures. As was previously stated, an increase in heat treatment of cheese milk results in an increase of curd pH at the A-C endpoint. When cottage curd was made from cheese milk pasteurized at 170° F., the pH at the A-C endpoint was found to be 5.05. At this high pH, Lactic bacteria are still in the logarithmic growth phase, which means the pH of the curd can and does change very rapidly. Therefore, high acid development may be a common occurrence unless very close control over cutting time of curd is observed.

The whey expelling properties of curd made from milk receiving higher than normal (143° F. 30 min.) heat treatments were not reduced when the curd was cooked at the A-C endpoint. Rudnick (71) subjected portions of identical skimmilk to different heat treatments and made them into cottage cheese. He found that when curd was cut at the same pH, the presence of denatured whey proteins in the skimmilk reduced the whey expelling properties of the curd. This test was performed before the advent of the A-C test. It is now known that as the heat treatment of cheese milk is increased, the pH at cutting must also be increased and the ideal time for this cutting can be determined accurately by the use of the A-C test, regardless of the composition or heat treatment of the cheese milk.

Method II

During the manufacture of cottage cheese curd (Method I) from cheese milk that had received different intensities of heat treatment it was found that a heat treatment of 170° F. for 30 min. produced the maximum yield of satisfactory quality curd. As a result of this finding, blends of cheese milk were formulated from skimmilk previously pasteurized at 170° F. and at 143° F. It was thought that this would give practical information that may lead to industrial use of blends of low-heat skimmilk with high-heat skimmilk, condensed skimmilk, or high-heat nonfat dry milk.

Percent of denatured serum protein in each of the blended milks was determined by analysis of whey prepared from the milk by salting out the caseins and by analysis of the drained whey obtained from the vats of cottage cheese. The percent of denatured serum protein (Table 9) was higher when calculated from the percent of serum protein in the whey prepared by the saturated salt procedure than when calculated from the percent of serum protein in the drained whey (Table 10). As the high-heat

Table 9

Relationship between percent of high-heat milk in blended cheese milks and the percent of denatured serum protein in the blended milks

H. H.[c] in blend	Serum protein of cheese milk[a]		Denatured serum protein[b]
	Control	Blend	
%	%	%	%
20	0.718	0.629	12.40
40	0.718	0.549	23.54
30	0.632	0.548	13.29
35	0.632	0.562	11.08
40	0.644	0.473	26.55
45	0.644	0.452	29.81
50	0.692	0.514	25.72
55	0.692	0.496	28.32
60	0.667	0.418	37.33
65	0.667	0.398	40.33
70	0.657	0.389	40.79
75	0.657	0.370	43.68
80	0.670	0.309	53.88
85	0.670	0.287	57.16
90	0.651	0.286	56.07
95	0.651	0.265	59.29

[a] Average of duplicate determinations.

[b] Percent denatured serum protein

$$= \frac{\text{Percent serum protein in control milk} - \text{Percent serum protein in blended milk}}{\text{Percent protein in control milk}} \times 100$$

[c] Milk heated at 170° F. for 30 min.

Table 10

Relationship between percent of high-heat milk and percent of denatured serum protein in the blended milk

	Percent serum protein in drained whey[a]		
H. H.[b] in blend	Control	Blend	Denatured serum protein
%	%	%	%
20	1.05	1.00	4.8
30	0.97	0.90	7.3
35	0.97	0.85	12.4
40	1.05	0.87	17.2
40	1.03	0.88	14.6
50	1.17	0.98	16.3
55	1.17	0.94	19.7
60	1.04	0.78	25.0
65	1.04	0.76	27.0
70	1.08	0.78	27.8
75	1.08	0.74	31.5
80	1.07	0.70	34.6
85	1.07	0.66	38.4
90	1.05	0.68	35.3
95	1.05	0.66	37.2

[a] Average of duplicate determinations.

[b] Milk heated at 170° F. for 30 min.

milk in blended cheese milk was increased from 20 to 95%, the percent of denatured serum protein increased from 12.4 to 59.3% and from 4.8 to 37.2%, respectively, when determined on whey prepared by the salting out procedure and on drained whey. The latter relationship is illustrated in Figure 8.

When using blended milks for the manufacture of cottage curd, the percent of total cheese milk protein in the drained whey decreased as the percent of high-heat milk in the blend was increased (Table 11).

The average percent of cheese milk protein present in the whey when cottage curd was made from the control milk was 20.78. However, when made from a blend containing 85% high-heat milk 11.7% was present in the whey. By using this blend an additional 8.1% of the total cheese milk protein was incorporated into the curd.

Analyses of the drained whey from cottage curd made from blended cheese milks showed that when the percent of high-heat milk in blends was increased, the solids content of drained whey decreased (Table 12). When cheese milks containing 20 to 95% high-heat milk were analyzed, the percent reduction of total solids in the drained whey ranged from 1.09 to 5.25%. This relationship is illustrated in Figure 9.

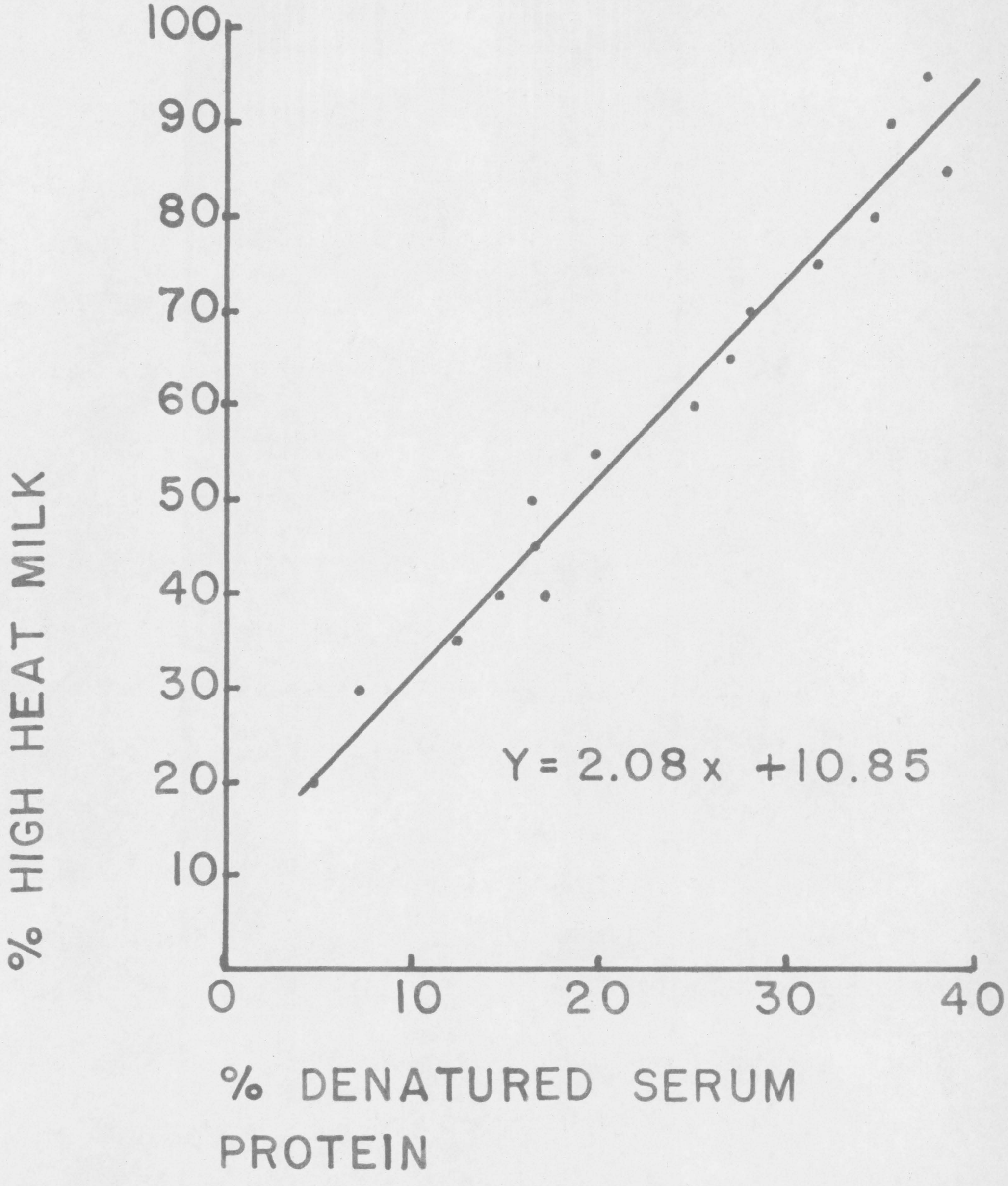

FIGURE 8. RELATIONSHIP BETWEEN PERCENT OF HIGH HEAT MILK AND PERCENT OF DENATURED SERUM PROTEIN IN THE BLENDED MILK

Table 11

Effect of increasing high-heat milk in blended cheese milks on the distribution of cheese milk protein between curd and drained whey

H. H.[a] in blend	Grams of total protein in:			Percent of total protein in:		
	Cheese milk	Curd	Drained whey	Curd	Drained whey	Total
%	g.	g.	g.	%	%	%
10 (Control)[b]	506	427	104	84.4	20.5	104.9
20	483	426	93	88.2	19.3	107.5
40	497	443	79	89.1	15.9	105.0
10 (Control)	479	392	92	81.8	19.2	101.0
30	479	397	83	82.9	17.3	100.2
35	481	405	79	84.2	16.4	100.6
10 (Control)	474	376	99	79.3	20.8	100.1
40	480	404	83	84.2	17.3	101.5
45	471	383	81	81.3	17.2	98.5
10 (Control)	499	399	114	80.0	22.8	102.8
50	489	405	88	82.8	21.7	104.5
55	485	407	84	83.9	20.6	104.5
10 (Control)	479	387	98	80.8	20.5	101.3
60	482	411	73	85.3	15.1	100.4
65	476	401	70	84.2	14.7	98.9
10 (Control)	492	390	106	79.3	21.5	100.8
70	508	423	78	83.3	15.4	98.7
75	498	424	70	85.1	14.1	99.2
10 (Control)	484	380	95	78.5	19.6	98.1
80	515	446	64	86.6	12.4	99.0
85	504	434	59	86.1	11.7	97.8
10 (Control)	465	341	99	73.3	21.3	94.6
90	482	436	64	90.5	13.3	103.8
95	479	437	62	91.2	12.9	104.1
Control Average				79.68	20.78	100.45

a Milk heated at 170° F. for 30 min.

b Cheese starter added to control is equivalent to 10% H. H.

Table 12

The effect of increasing the percent of high-heat milk in blended cheese milks on the solids content of the drained whey

	Percent total solids[a]		
H. H.[c] in blend	Control	Blend	Reduction in total solids[b]
%	%	%	%
20	8.33	8.24	1.09
30	8.49	8.38	1.30
35	8.49	8.33	1.99
40	8.33	8.19	1.69
40	8.45	8.31	1.66
45	8.45	8.23	2.61
50	8.75	8.56	2.18
55	8.75	8.47	3.20
60	8.36	8.13	2.76
65	8.36	8.09	3.23
70	8.21	7.93	3.42
75	8.21	7.87	4.25
80	8.34	7.99	4.20
85	8.34	7.93	4.92
90	8.39	8.01	4.53
95	8.39	7.95	5.25

a Average of duplicate determinations.

b Percent reduction of total solids

$$= \frac{\text{Total solids of control milk} - \text{Total solids of blended milk}}{\text{Total solids of control milk}} \times 100 .$$

c Milk heated at 170° F. for 30 min.

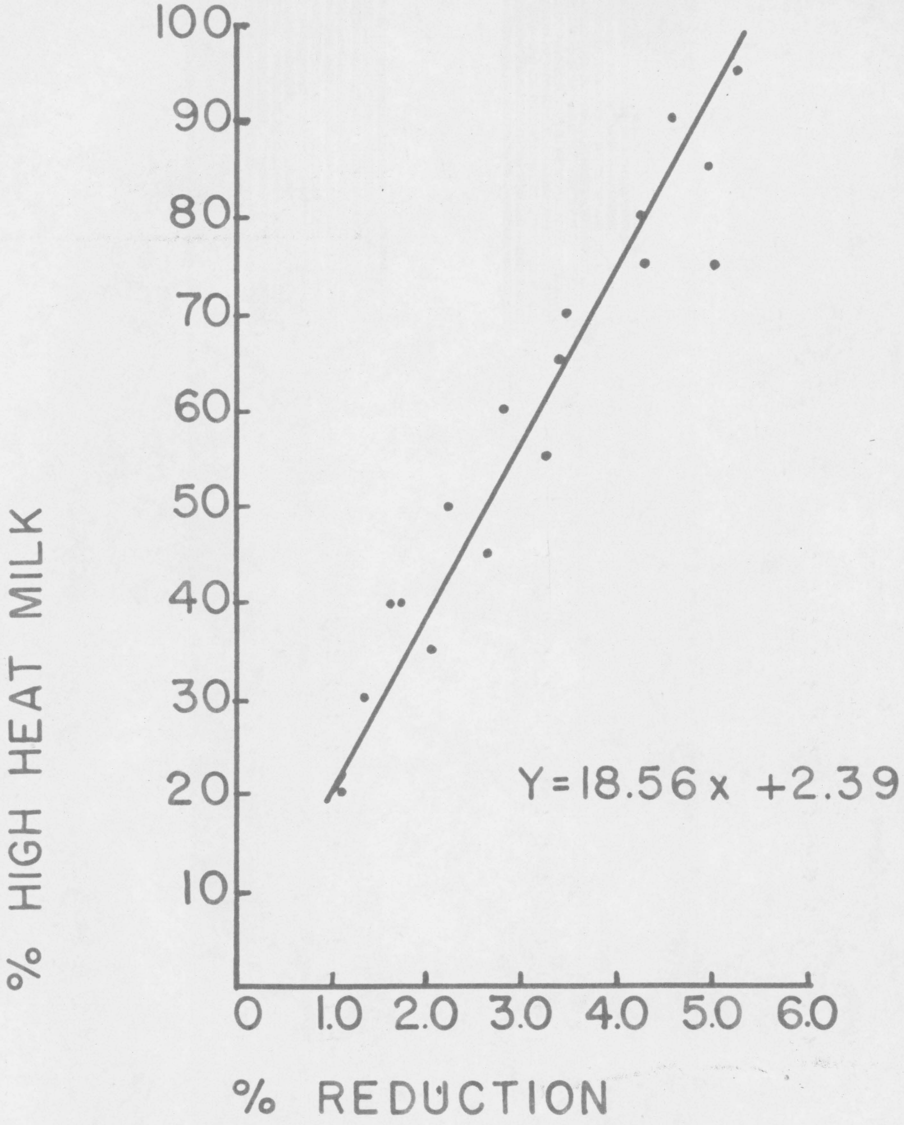

FIGURE 9. RELATIONSHIP BETWEEN PERCENT OF HIGH HEAT MILK IN BLENDED CHEESE MILKS AND REDUCTION OF TOTAL SOLIDS IN DRAINED WHEY

The procedures and basis for determining curd yield used in Method I were also used for determining curd yield in blends. Table 13 shows curd yield when high- and low-heat cheese milks were blended in various proportions. It was found that a more uniform increase in curd yield resulted when the calculations were based on lb. of curd per lb. of cheese milk protein than when yield was based on lb. of curd per lb. of cheese milk solids. When the percent high-heat milk in blended cheese milks was increased from 20 to 85%, the curd yield, based on cheese milk solids, was increased from 5.82 to 10.99% above the control. When yield calculations were based on cheese milk protein, the percent increase was 4.48 to 9.61% above the control.

Larger yields were obtained when the percent high-heat milk in blends was higher than 85%. The percent increase (compared with the control) in yield of curd made from cheese milk containing 95% high-heat milk was 22.94% and 24.32% based on solids and protein, respectively.

Total cottage curd solids were determined using three different procedures: (1) by heating in a forced draft oven at 100° C. for 4 hr.; (2) by heating in a forced draft oven at 130° C. for 1.25 hr.; and (3) by calculation. A comparison of results by the three procedures for

Table 13

Relationship between percent of high-heat milk in blended milks and the yield of cottage cheese curd

H. H.[d] in blend	Cheese[a] milk	Cheese milk solids	Cottage curd	Curd[b] yield	Yield increase	Curd[c] yield	Yield increase
%	lb.	lb.	lb.	lb./lb. solids	%	lb./lb. protein	%
10 (Control)[e]	26.11	2.98	4.17	1.89	----	4.69	----
20	24.92	2.84	4.48	2.00	5.82	4.90	4.48
40	25.65	2.93	5.52	2.11	11.64	4.95	5.54
10 (Control)	25.41	2.88	4.60	1.89	----	4.55	----
30	25.41	2.88	4.97	1.92	1.59	4.60	1.10
35	25.52	2.89	4.96	1.95	3.17	4.68	2.86
10 (Control)	25.75	2.89	4.44	1.79	----	4.41	----
40	26.13	2.93	5.19	1.94	7.74	4.67	5.57
45	25.61	2.88	4.92	1.94	7.74	4.52	2.44
10 (Control)	25.06	2.93	3.56	1.78	----	4.44	----
50	24.53	2.85	4.59	1.94	8.99	4.60	3.60
55	24.43	2.84	4.74	1.97	10.67	4.66	4.95
10 (Control)	25.70	2.90	5.07	1.90	----	4.50	----
60	25.88	2.92	5.25	2.00	5.26	4.73	5.11
65	25.59	2.88	5.15	1.97	3.68	4.68	4.00
10 (Control)	26.10	2.96	4.41	1.79	----	4.41	----
70	27.00	3.03	5.00	1.96	9.50	4.62	4.76
75	26.15	2.93	5.15	1.99	11.17	4.72	7.03
10 (Control)	24.39	2.80	4.89	1.91	----	4.37	----
80	25.94	2.98	5.63	2.09	9.42	4.81	10.07
85	25.39	2.92	5.76	2.12	10.99	4.79	9.61
10 (Control)	24.98	2.79	4.23	1.70	----	4.07	----
90	25.87	2.89	5.31	2.12	24.71	5.03	23.59
95	25.76	2.88	5.01	2.09	22.94	5.06	24.32

[a] Less weight of milk for analysis.

[b] Pound of curd per lb. of cheese milk solids.

[c] Pound of curd per lb. of cheese milk protein.

[d] Milk heated at 170° F. for 30 min.

[e] Cheese starter added to control is equivalent to 10% H. H.

determining total curd solids is tabulated in Table 14. Correlation coefficients between (1) and (2), between (1) and (3), and between (2) and (3), as stated above, are 0.96, 0.90, and 0.92, respectively. These relationships are shown in Figures 10, 11, and 12. When determining total curd solids by heating at 100° C. for 4 hr., the standard error was ± 0.28 for a single determination. However, when the curd solids were determined by heating the curd in a forced draft oven at 130° C. for 1.25 hr. the standard error was ± 0.05 for a single determination. The above statistical analyses substantiate that heating curd at 130° C. for 1.25 hr. is a better method for determining curd solids than heating at 100° C. for 4 hr. The high correlation between heating curd at 130° F. for 1.25 hr. and the calculated method for determining curd solids, plus the fact that the means of the two methods were 24.52 and 24.63%, respectively, indicates that a high degree of accuracy may be obtained when curd solids are determined by calculation.

The effect of increasing high-heat milk in blended cheese milks on time from setting to cutting and on pH at the A-C endpoint is shown in Table 15. As the percent of high-heat milk in blended cheese milk was increased from 20 to 95%, the pH at the A-C endpoint increased

Table 14

Comparison between percent solids of cottage curd determined by calculation and by oven drying using different heating procedures

H. H.[b] in blend %	Calculated[a] %	100° C. - 4 hr.[a] %	130° C. - 1.25 hr.[a] %
10 (Control)[c]	27.58	30.48	28.36
20	25.89	27.69	26.67
40	23.19	24.45	23.55
10 (Control)	24.13	25.50	24.85
30	23.54	24.24	23.40
35	23.79	24.76	23.86
10 (Control)	24.55	25.64	24.87
40	23.01	24.04	23.18
45	23.84	24.24	23.46
10 (Control)	29.49	31.48	30.80
50	25.27	26.98	25.33
55	24.68	26.56	24.82
10 (Control)	23.08	23.70	22.87
60	23.61	24.57	23.34
65	23.88	24.82	23.18
10 (Control)	26.76	26.26	25.31
70	25.60	27.56	24.95
75	24.85	25.89	23.78
10 (Control)	23.93	23.75	23.01
80	24.16	24.80	23.29
85	23.61	23.90	22.55
10 (Control)	24.82	24.33	23.56
90	23.35	25.96	24.22
95	24.55	27.28	25.29
Average	24.63	25.79	24.52

[a] Average of duplicate determinations.

[b] Milk heated at 170° F. for 30 min.

[c] Cheese starter added to control is equivalent to 10% H. H.

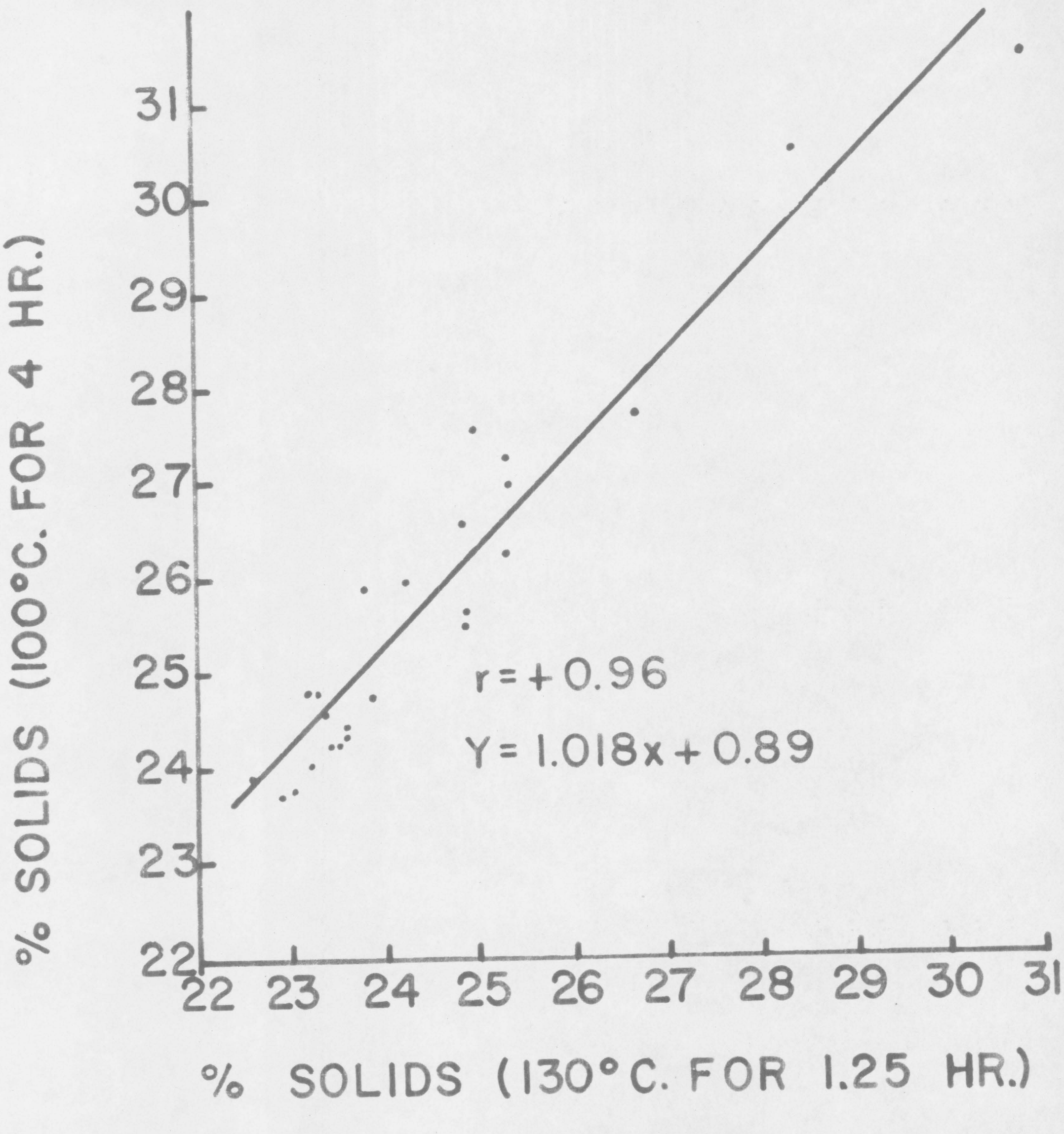

FIGURE 10. RELATIONSHIP BETWEEN TOTAL SOLIDS OF COTTAGE CURD BY DRYING AT 100°C. FOR 4 HR. AND AT 130° C. FOR 1.25 HR.

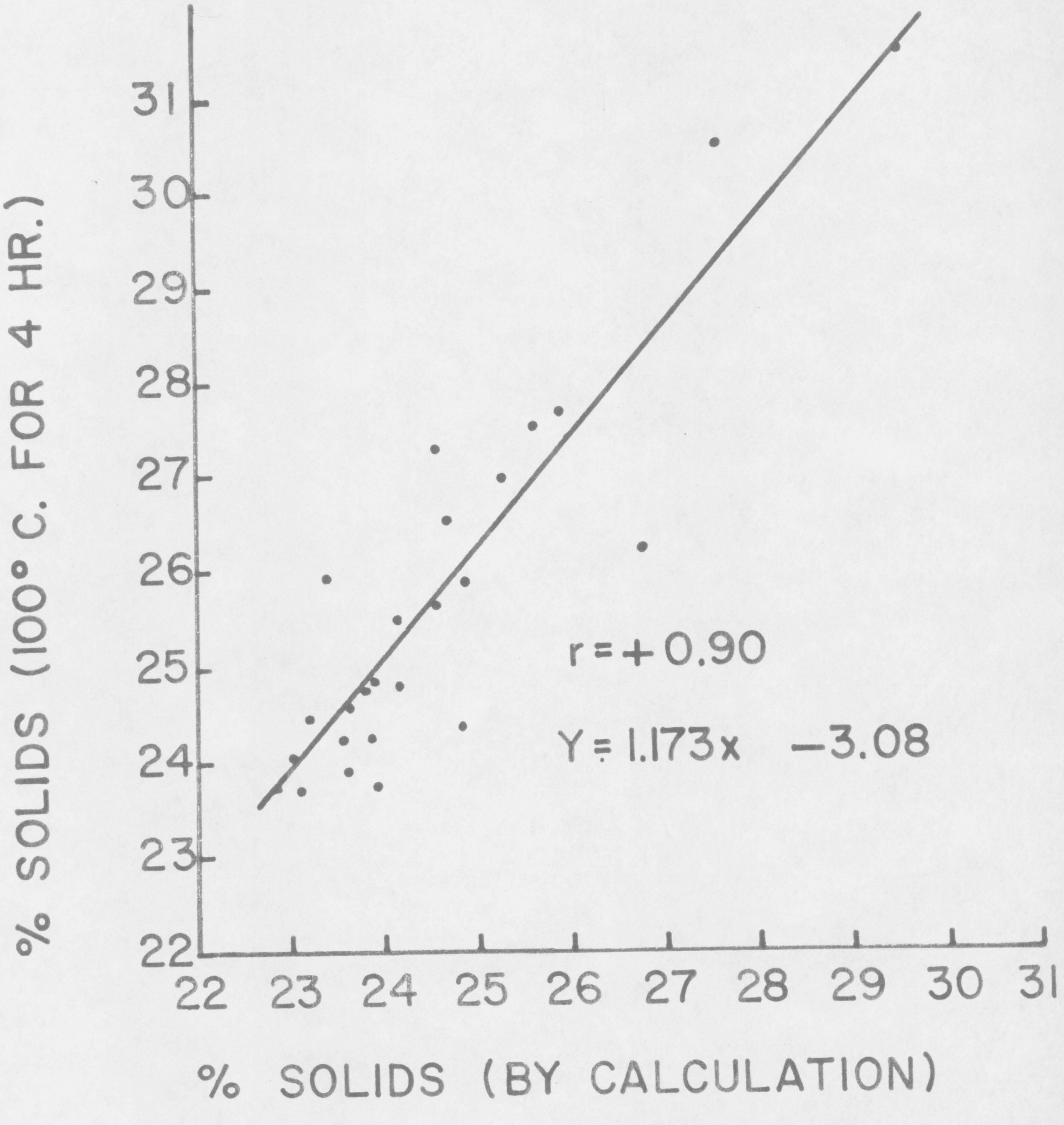

FIGURE II. RELATIONSHIP BETWEEN TOTAL SOLIDS OF COTTAGE CURD BY DRYING AT 100°C. FOR 4 HR. AND BY CALCULATION

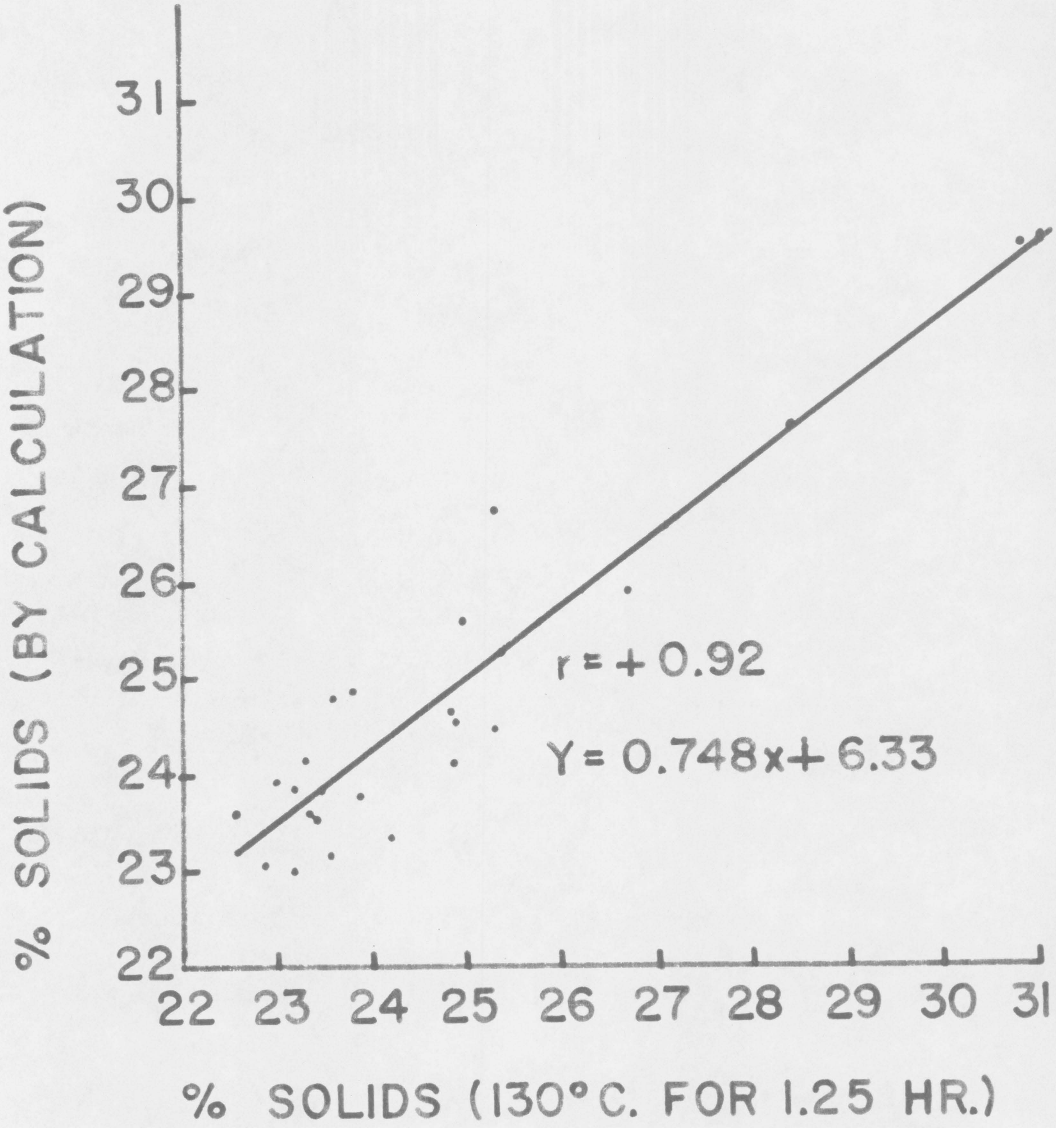

FIGURE 12. RELATIONSHIP BETWEEN TOTAL SOLIDS OF COTTAGE CURD BY DRYING AT 130° C. FOR 1.25 HR. AND BY CALCULATION

Table 15

The effects of increasing the percent of high-heat milk in blended cheese milks on pH at the A-C endpoint and on time from setting to cutting of cottage curd

H. H.[a] in blend	Time from setting to cutting	pH at the A-C endpoint
%	hr.	pH
10 (Control)[b]	6.00	4.80
20	5.50	4.80
40	5.00	4.80
10 (Control)	3.75	4.70
30	3.50	4.80
35	3.50	4.78
10 (Control)	4.50	4.75
40	4.50	4.75
45	4.00	4.85
10 (Control)	5.50	4.80
50	5.00	4.90
55	5.00	4.90
10 (Control)	5.00	4.75
60	3.75	4.96
65	3.75	4.95
10 (Control)	5.00	4.80
70	3.25	4.90
75	3.00	4.95
10 (Control)	5.00	4.78
80	2.75	5.05
85	2.75	5.05
10 (Control)	4.25	4.78
90	2.50	5.05
95	2.50	5.05

[a] Milk heated at 170° F. for 30 min.

[b] Cheese starter added to control is equivalent to 10% H. H.

from 4.80 to 5.05. When the high-heat milk in cheese milk was increased from 20 to 95%, the time from setting to cutting of cottage curd decreased from 5.50 to 2.50 hr. The above relationships are illustrated in Figures 13 and 14.

The quality score of cottage curd was not significantly altered as a result of increasing the percent of high-heat milk in the blended cheese milks (Figure 15). The most common scoring criticisms encountered were lack of curd uniformity and high acid development.

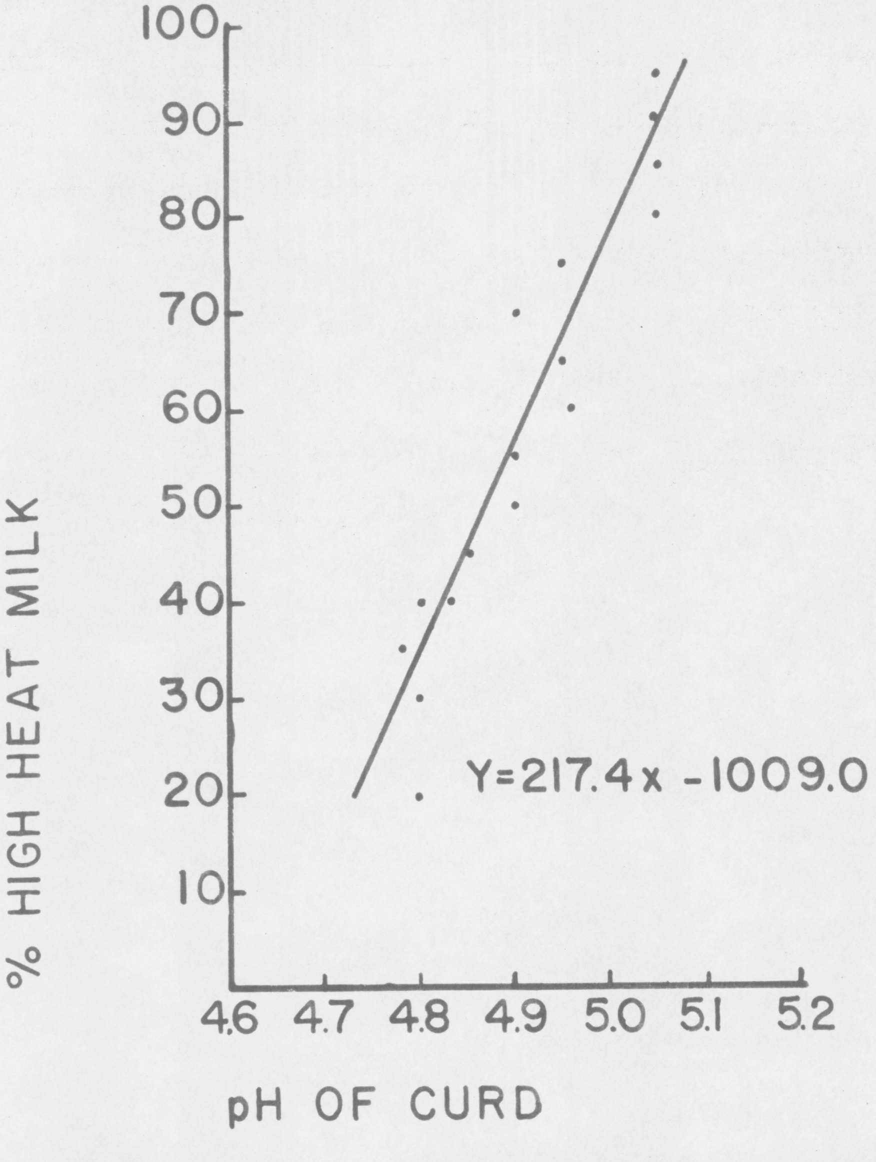

FIGURE 13. RELATIONSHIP BETWEEN PERCENT OF HIGH HEAT MILK IN BLENDED CHEESE MILKS AND pH AT THE A-C END POINT

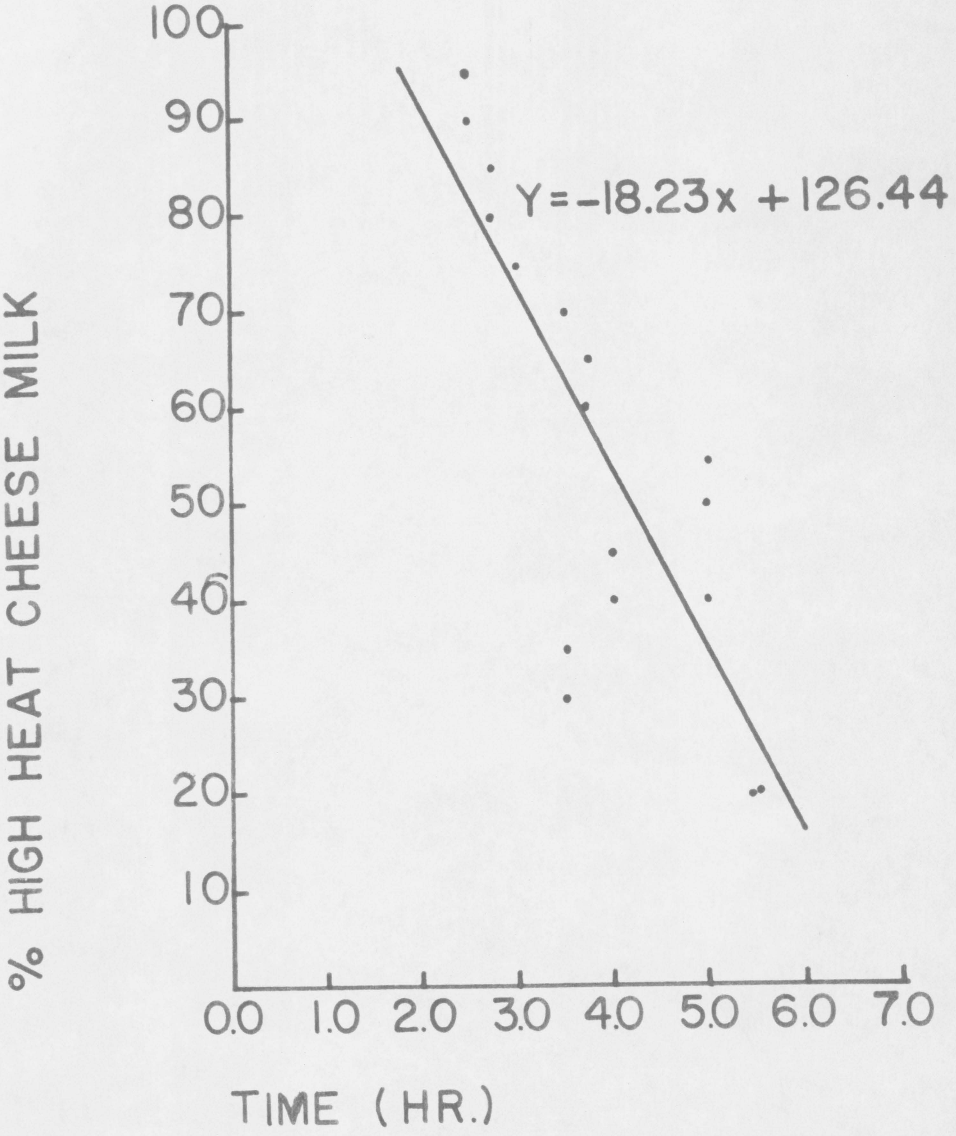

FIGURE 14. RELATIONSHIP BETWEEN PERCENT OF HIGH HEAT MILK IN BLENDED CHEESE MILKS AND TIME FROM SETTING TO CUTTING OF COTTAGE CURD

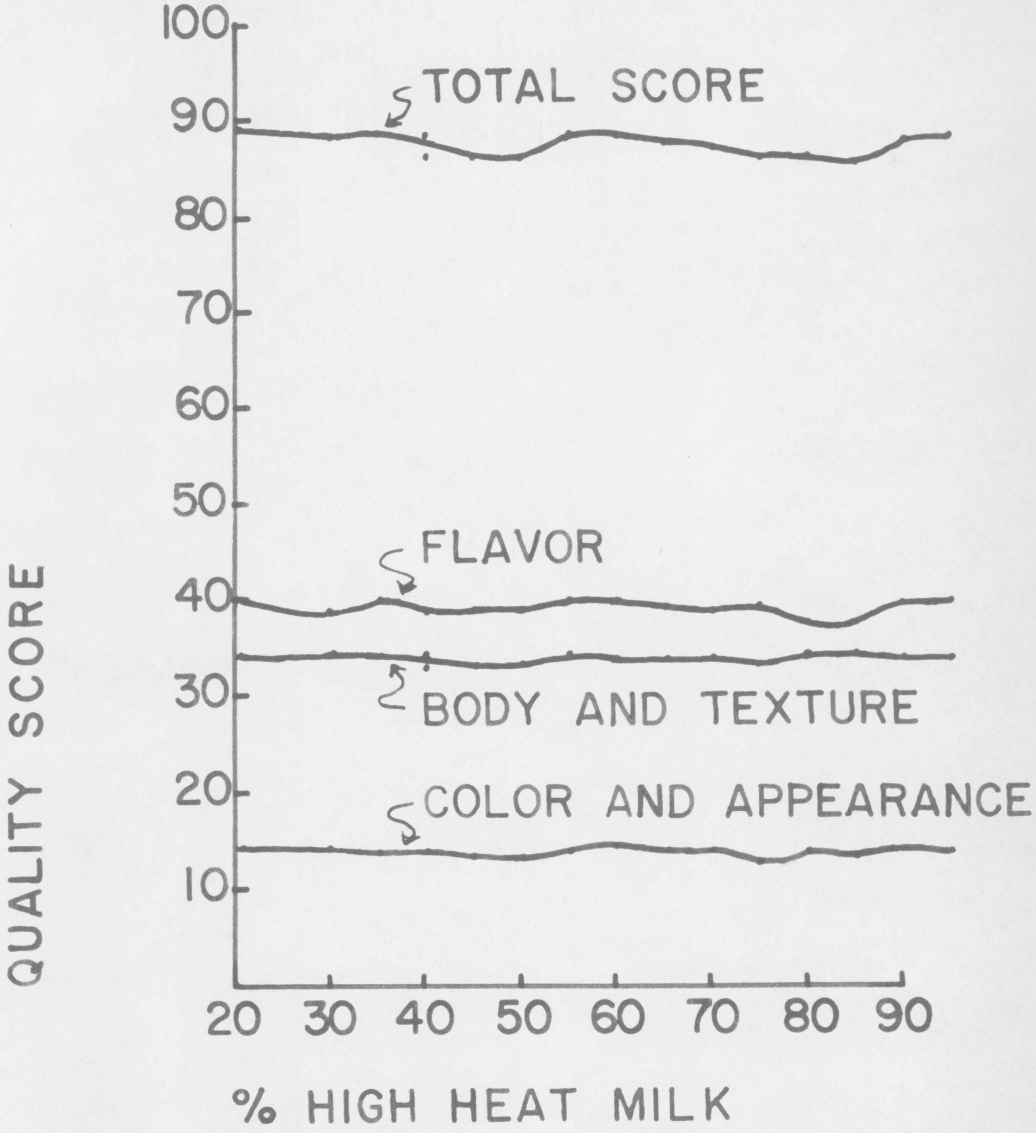

FIGURE 15. THE EFFECT OF USING VARYING PROPORTIONS OF HIGH HEAT MILK IN BLENDED MILKS ON THE QUALITY SCORE OF COTTAGE CURD

SUMMARY AND CONCLUSIONS

Raw skimmilk was standardized to 11% solids by adding low heat NDM. The resulting cheese milks were heated at temperatures from 145 to 180° F. in increments of 5° F. Duplicate batches of cottage cheese curd were made from each cheese milk along with a control cheese milk pasteurized at 143° F. Determinations of pH were made before adding the starter, after adding the starter, and at intervals of one hour until the pH of the curd was optimum for cutting. The conditions for cutting were determined by the A-C test. The final cooking temperature was 125° F.

Total protein and total serum protein were determined on each cheese milk before and after adding starter. Total protein was also determined on the whey and on the curd. Percent serum protein denaturation attributable to each heat treatment was calculated and the relationship to yield was shown.

Total solids were determined on each batch of raw skimmilk, cheese milk, cottage curd, and drained whey. Curd yield was calculated as lb. of curd per lb. of cheese milk solids and as lb. of curd per lb. of cheese milk protein. These two procedures for calculating and expressing yield were compared and evaluated.

Each curd was evaluated by an experienced judge for flavor and texture using the score card adopted by the American Dairy Science Association.

As the heat treatment of cheese milk was increased from 145 to 180° F., serum protein denaturation increased, yield of curd increased, total cheese milk protein incorporated into the curd increased, total solids in the drained whey decreased, pH of curd at the A-C endpoint increased, and the time from setting to cutting decreased. When cheese milk was heated at 170° F., the curd yield was increased 11.82% and 16.22% when the determination was based on cheese milk solids and cheese milk protein, respectively.

Quality scores on curd from cheese milk heated up to 170° F. were essentially the same as those scores on curd made from control cheese milk. Additional heat treatment slightly lowered the quality score of curd.

Similar results were obtained when the serum protein content of cottage curd was increased by blending low-heat and high-heat cheese milk.

Blends of high-heat (170° F. for 30 min.) and low-heat (143° F. for 30 min.) cheese milk were prepared in increments of 5% high-heat milk. The same analyses were made at the various steps of curd manufacture that were made during manufacture of curd from the cheese milks having different heat treatments. In addition, three procedures for determining total curd solids were compared and evaluated.

As the percent of high-heat milk in blended cheese milk was increased from 20 to 95%, the percent of denatured serum protein increased, yield of curd increased, total cheese milk protein incorporated into the curd increased, total solids in drained whey decreased, pH of curd at the A-C endpoint increased, and time from setting to cutting of curd decreased. Drying in a forced draft oven at 130° C. for 1.25 hr. was a more accurate procedure for determining curd solids than drying at 100° C. for 4.0 hr.

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ABSTRACT

When rennet type cottage curd was made from cheese milk pasteurized at 143° F. for 30 min. the heat labile serum proteins remained with the whey and represented a loss of approximately 15% of the total cheese milk protein. However, when higher heat treatments than pasteurization were applied, up to 65% of the serum proteins of cheese milk were denatured, rendered coagulable with the caseins and incorporated into the cottage curd. Similar results were obtained by blending high- and low-heat cheese milk. Composition and flavor quality of curds containing increased amounts of serum protein were closely comparable to curds made from conventional pasteurized cheese milk. The yield of curd was increased.

As the heat treatment of cheese milk was increased from 143 to 180° F., the denaturation of serum protein in drained whey increased from 0.0 to 60.01%, the percent of whey solids decreased 7.1%, pH at the A-C endpoint increased from 4.72 to 5.10, and time from setting to cutting decreased from 4.75 to 2.50 hr. When the percent of high-heat milk in blended cheese milks was increased from 20 to 95%, the percent of denatured serum protein in drained whey increased from 4.8 to 37.2%, the percent of

whey solids decreased from 1.1 to 5.3%, pH at the A-C endpoint increased from 4.70 to 5.05, and time from setting to cutting decreased from 5.50 to 2.50 hr.

High quality curd comparable to the control was made from cheese milks receiving heat treatments up to 170° F. for 30 min. and from blends containing up to 95% high-heat milk. Heat treatments over 170° F. slightly lowered the quality score of curd.

Pounds of curd per lb. of cheese milk protein was found to be the best procedure for calculating and expressing yield. When curd was made from cheese milk heated at 170° F. and from blends containing 85% high-heat milk, the curd yield was increased 16.22 and 9.61% above the control, respectively.