INVESTIGATIONS ON THE EFFECTS OF AGE OF MILK AND STARTER, AND ACIDITY CONTROL OF WHEY IN THE MANUFACTURE OF COTTAGE CHEESE

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Kapilrai Shantilal Shroff

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J. M. Jensen
Major professor

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INVESTIGATIONS ON THE EFFECTS OF AGE OF MILK AND STARTER, AND ACIDITY CONTROL OF WHEY IN THE MANUFACTURE OF COTTAGE CHEESE

By

KAPILRAI SHANTILAL SHROFF

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INTRODUCTION

Cottage cheese is a skim milk product that has become of commercial importance throughout the United States. Its manufacture has in the past largely been confined to plants whose main enterprise consisted of marketing bottled fluid milk. In several instances in Michigan however, the manufacture of cottage cheese has attained such proportions that its manufacture has become the major operation of some dairy plants. Attending the manufacture of cottage cheese there exists a big waste disposal problem that becomes quite important in cities where waste treatment in sewage disposal plants is limited. Approximately 85 percent of the skim milk used in cottage cheese making becomes whey, a product that is usually too low in food value after normal cheese making practices to make it useful for animal feeding or for processing by means of condensing. A further loss occurs when milk and bacterial cultures respond abnormally causing spoiled batches.

The following study was made in order to determine the effect of quality of milk and starter on batch losses and further to investigate the possibility of reducing the volume of whey that would have to be disposed of without sacrificing cheese quality.

REVIEW OF LITERATURE

COTTAGE CHEESE

1- Kinds of Cottage cheese

Cottage cheese is essentially an unripened skim milk curd. It may be made from reconstituted skim milk, dried skim milk or concentrated skim milk. Cottage cheese consists of small particles or flakes of curd which have a meaty consistency (57). The particles may be as small as kernels of wheat or as large as popped kernels of corn. The large flake cheese is known as pot cheese in some markets. Pot cheese is uncreamed. Cottage cheese is sold as cottage cheese curd and also as creamed cottage cheese. The creamed cottage cheese contains not less than four percent fat.

When cottage cheese is made in large flakes by the use of rennet, the product is known as low acid, sweet curd, rennet-type, or flake-type cottage cheese. Baker's cheese is a special type of cottage cheese.

The rennet-type cottage cheese is very popular in critical markets and probably is responsible for the rapid increase in cottage cheese sales and production. According to United States Department of Agriculture, Bureau of Agricultural Economics, the production of cottage cheese curd for 1948 was 255,606,000 pounds, a rise of eight percent over the 1947 production figures. The cottage, pot, and baker's cheese production in skim milk equivalents in 1948 was 1,598 million pounds of skim milk. The production of cottage cheese curd and of creamed cottage cheese in Michigan during 1948 was 18,350,000 and 23,373,000 pounds respectively. The State of Michigan ranked fourth in cottage cheese curd production while it was third in creamed cottage cheese production.

2- Flavor and quality of cottage cheese

The flavor of cottage cheese should be clean and very mildly acid (48). Lucas (22) says a perfect flavor in cottage cheese somewhat resembles that of fresh butter. According to Hales (14) a good grade of cottage cheese should have a clean, sweet, creamy flavor; a meaty smooth body, a uniform appearance and just enough salt to intensify the natural flavor of the curd. The common defects in cottage cheese are acid flavor, bitter flavor, fermented or yeasty flavors, rubbery curd, crumbly curd, slow setting curd, gaseous curd, and low yields. (7,14,35,36,47,48) Different workers have tried to evaluate the steps of manufacturing cheese either in general or with a view to find out an important step particularly to be watched. According to Wilson and Trimble (60), one of the most important factors that control the flavor of the final product

was proper pasteurization of the skim milk. While, according to Thurston (49), whey acidity at the time of cutting the curd was the most important single factor concerned in the manufacturing of cottage cheese. Reichart and Davis (38), say that the success of the entire cheese making depends on the use of a fresh starter with a clean, distinct, pleasant and mildly acid flavor. Ruehe (44) discusses the method, equipment and cost in making cottage cheese, while Tretsven (55), has tried to evaluate the steps followed in the manufacture of cottage cheese. Wilson (59) in 'Quality and Uniformity of Cottage cheese and its practical control' says," to maintain the characteristic appearance of cottage cheese it is necessary to develop a curd that after cutting, cooking, washing, chilling and creaming will largely retain its original shape and have a very mild acid flavor. To control the quality and uniformity of cottage cheese and especially that of the low-acid rennet-coagulated type, it is necessary to have proper and adequate equipment that is kept in a sanitary condition, and to use only good quality skim milk that has been properly pasteurized."

MANUFACTURE OF COTTAGE CHEESE

1- Methods of Manufacturing

The methods of manufacturing cottage cheese are under slow evolution. There are in general two methods by which cottage cheese is made. These differ in the time allowed for curd to form. The long set or overnight coagulation method required 14-16 hours for curdling while in the short set method it needed about 4-6 hours for the curd to form. The long or overnight set method is one of the first methods of making cottage cheese(8).

Long Set Method

The literature is full of directions on how to make a good cottage cheese. Lucas (22) suggested 70°F as the setting temperature for the over night set. In 1927 Reichart and Davis(38) suggested two distinct temperatures varying with the season. They recommended 90- 95°F as the setting temperature during the winter months, while 70- 75°F for the summer for the overnight set. Martin (24) has put down the range of 68°F to 72°F as the setting temperature for the long set method. According to Tracy (52) it takes fifteen to twenty hours for complete coagulation when set at 70°F with two to three percent starter and 0.2 ml rennet for each ten gallons of milk. When the long set method for cottage cheese manufactures is used Glover and Burgwald(6) employ 72°F as their setting temperature. Hales (14) also advises 72°F as the proper setting temperature if the long set method is employed. Flavor Line Incorporated Publications (8) contains 68-70°F for the long set.

Short Set Method

The trend in the past two decades is definitely towards the short set method. The short set method has three definite advantages over the long set method. Thurston and Gould (51) report that the setting temperature of 90°F is preferable to 70°F because the higher setting temperature reduces the time required for completing the process of manufacture, thus enabling the worker to complete the whole procedure during the normal working day. This, in general, results in a closer control of the whole process, because the worker has the chance of watching throughout the entire setting period. He can make occasional acidity tests and thus is sure to cut it at the right time. Furthermore, they also observed that fermentations producing undesirable off flavors did not occur often in the high temperature set. Flavor Line Incorporated's publication(8) also reports similar conclusions. The five hours set is more desirable as usually it works out in the daily plant operation and thus can be watched more closely. In the line of checking undesirable fermentations they have something more to say. According to them by using large quantities of starter, the bacterial population of desirable bacteria is increased and thus undesirable bacteria giving out off flavors do not get an easy chance to take possession. Also the rapid development of acidity checks the activity of undesirable fermentation prematurely.

Rennin in Manufacture

Because of the capacity of giving softer curd and at lower acidities, rennin is almost always used now in the manufacture of cottage cheese. There are other coagulators also on the market, but Tretsven (56) prefers rennin to pepsin and other proteolytic enzymes because it only coagulates and does not break down by hydrolysis the protein in curd. Thurston and Gould (51) from their experiments on concentrations of rennin and their effects on the curd of cottage cheese conclude that the true function of rennin in this type of cheese is not related to its coagulating property. According to them its coagulating properties are of secondary importance while its important function is to prevent matting of the curd flakes. Rennin should be used at the rate such that it will not produce coagulation very far in the advance of the proper acidity of cutting, otherwise a large part or all of the calcium paracaseinate due to the later development of acid after rennin coagulation thus resulting into a curd that lacks cohesive properties. According to them, 0.75 to 1.5 ml of rennin for every 1000 pounds of skim milk is the useful range for rennin. To produce a more desirable curd there must be a balance obtained between rennin action and acid development. They advise as much rennin as possibly could be used should be used in order to reduce matting. An attempt to obtain this balance is made by Angevine (1) by adding the rennin extract as late as one and a half hours after the starter has been stirred in.

The procedure for manufacturing cottage cheese (11,12, 13,14,19,22,32,35,38,47,53) give 1.0 ml of rennin extract per 1000 pounds of skim milk as the required amount for good results. Tracy (51) has suggested the using of rennin at the rate of 0.2 ml for every ten gallons of milk. Thurston (46) found that varying the rennet extract from 1.33 to 3.33 ml per 100 pounds of milk had no effect upon the manufacturing process or character of the curd produced from the skim milk pasteurized at 185°F for twenty seconds. The dilution of rennet into a cup of water plus agitation of milk after the rennet is added will ensure against local action of the enzyme. It is believed that excess agitation at this time may render the rennin inactive. Thus it is best to mix the starter and the skim milk thoroughly, prior to the addition of rennet and then mix gently the diluted rennet after sometime after the starter has been added. Parfitt (30) concluded that too much enzyme may lead to a soft, pasty cottage cheese. Thurston and Gould (51) and Thurston (49,50) report that use of Calcium Chloride proved of no value in hastening coagulation by rennin or in firming of the curd during cooking.

COOKING OF COTTAGE CHEESE

Whey expulsion

Sommer (48) writes that as soon as the curd is cut some whey will be excluded but this takes place to a limited extent only. Janoschek (17) has studied the whey draining from casein curd. According to him the wheying off starts when the milk thickens, rises to a maximum rate after cutting and then diminishes. To produce the desired whey separation heating is necessary. In the process of heating, enough stirring must be employed to prevent the cohesion of curd particles. Until some shrinking and firming of the curd particles has taken place, they are very fragile and to prevent shattering the agitation must be very gentle. Above 90°F the curds shrink and become more firm thus facilitating mechanical stirring.

Addition of water

Sommer (48) further writes that when the vat capacity and the acidity of batch permits, a convenient method of providing for early heating with a minimum of agitation is to add warm water at 110-120°F in amounts up to 50 percent of the volume of the skim milk. Jensen (19) suggests one inch of water over the cheese. Price and Kelley (37) in 1933 said that the use of water in cooking is very beneficial. Water in quantities up to 40 percent or more of the weight of milk in the vat may be added. The temperature of the cooking water they recommend as 100-105°F. The water according to them causes the curd to firm more quickly after the heat is applied and tends to sweeten the flavor of the curd. Tretsven (56) comments on addition of water by saying that addition of hot water reduces friction during agitation, aids in syneresis and dilutes the acidity to some extent.

Temperatures in cooking

Even if 115°F water is added directly to the vat the firming process will last an hour to an hour and a half. According to Sommer (48) three to five minutes should be taken for each degree rise in temperature. However, the temperature and length of cooking time depend upon the firmness desired, the casein content of the original skim milk, pasteurizing temperature, acidity developed during coagulation, salt composition and the degree of enzyme activity. Tracy (52) advises 114-116°F as the final cooking temperature. Lucas (22) has put down the range for cooking temperature as 100-120°F. According to Jensen (19) the final cooking temperature should be 125°F. Mull, Reid and Arbuckle (26) in their new short time method suggest 118°F as the final temperature for cooking and if the curd is not firm by then they advise holding it at that temperature till firm to the required extent. Parmelee and Rosenberger (32) take 115°F to 125°F as the cooking temperatures. A range of 110-140°F for cooking temperature is indicated by Reichart and Davis (38). Schock (46) has kept the range for final cooking temperature between 115 and 120°F. Flavor Line Incorporations Publication (8) mentions 10-20°F difference in temperature between the vat and the jacket. Jensen, J.M. in a private communication suggested a 45 to 50° difference in temperature between the whey temperature and the water temperature, the latter being that much higher.

Determining firmness of curd

The ranges of final cooking temperatures suggested by different writers are thus very great indicating the impossibility of setting up definite standards of time and temperatures of cooking for producing good cheese. Consequently, physical tests must be used to determine the firmness of the curd. The most common method of determining the firmness of the curd is to let drop a flake on the floor from waist high. The cube should not shatter on contacting the ground if it is properly cooked and should retain its form. Other method suggested by Hales (14) is to place the curd particle in cold water. This will make the curd particle more firm and will show the characteristics that can be expected in the finished cheese. The cube should break evenly and should be free of escaping moisture after being broken open. Also, when a handful of cubes is squeezed lightly they should be somewhat springy and tumble apart when released (14). All these methods of testing curd firmness are empirical, or what may be called as 'Practical Methods' and Tretsven (56) has expressed a great need for more accurate methods for determining the firmness of the curd particles.

Draining and Washing

After the curd is properly cooked the whey is drained off and the curd washed with water. This washing serves two main purposes;

1- It washes the excess acid from the curd.

2- It firms the curd by chilling.

Thurston (50) has suggested the use of cold water for washing purposes. Manus (23) on the other hand advised the slow cooling and chilling of the curd. He advises first warm water washing because cold water chills the outside of the curd and thus traps the remaining whey inside. "Only cold water (75°F) helps wash the outside of the cheese flakes but does not remove the acidity from inside the flakes. So, if warm water is substituted for the warm whey early in the cooking procedure, a more rapid movement of lactic acid from the interior of the flakes to the warm water may take place without the excessive firming, thus producing as a result, a good, softer, sweet tasting curd." If the water is too cold, says Hales (14) there is a danger of shattering the curd and making it too tough. This can be said to be something like a cold shock. Hales (14) suggested the use of 85°F water for the first wash. Gross and Mutten (13) ask not to draw off all the warm whey before adding cold wash water. This will stop matting of warm curd. A cube form is retained much better if the curd is not cooled off too rapidly. Both Reuhe (42) and Angevine (1) suggest warm wash water for

first washing and then the use of very cold water. The curd should be carefully yet sufficiently agitated, during washing with a cheese fork to permit all of the curd to come in contact with the fresh water. The first wash water should not be drained for at least five to ten minutes (14). Water at temperatures at 60°F or lower is preferred for chilling. As a rule, two washings are sufficient. Excessive washing may produce a product that is quite flavorless, especially if the original acidity was low; and with certain types of water may produce slippery curd due to a solvent action on curd, especially if the acidity was barely high enough to start with (48).

ACIDITIES AND THEIR ROLE

Whey acidities

Thurston (49) in 1931 concluded that the acidity of the whey at the time of cutting the curd is the most important single factor, concerned in the manufacturing process of cottage cheeses. Regardless of variations in other factors, a whey acidity of 0.35 percent or more was found necessary in order to produce a curd with a desirable body. The upper limit of acid development was set by him as 0.68 percent acidity. However, average acidity at cutting was 0.48 percent. Thurston (50) reports that acidities higher than 0.48 percent for whey tend to favor coarse textured curd. As many changes in milk are associated with changes in pH, rather than titratable acidtties of milk, Price and Kelley (37) took measurements of acidities by both these types of methods during the process of making cottage cheese. Their results show that the relation between the two types of acidity measurements is smooth. There is a marked difference in titratable acidity between curd at cutting and whey which drains off. This is not apparent in pH.

Gross and Mutten (12) showed that the whey acidity immediately after cutting should have an acidity of 0.45 to 0.50 percent. Acidities above 55 percent resulted in a slightly grainy, tough, curd. Thurston and Gould (51) concluded that curd cut at whey acidities of 0.35 percent or lower behaved in cooking as a rennet curd, while that cut at acidities higher than 0.4 percent behaved like acid curd. The average whey acidity of curds producing desirable results at cutting was 0.48 percent. The different processes of manufacture suggest a whey acidity at cutting between 0.5 and 0.55 percent. Angevine (1) uses 0.5 to 0.55 percent while Lucas (22) had used 0.70 percent as the whey acidity at cutting.

Standardization of Acidities

Acidity, as we have seen, has an important function. For some time it has been thought that the true dairy products flavor of cottage cheese and cultured buttermilk is submerged by the ordinary concentration of lactic acid present. It is believed that standardization of acidity at some step of manufacturing cottage cheese, when a high quality starter is used, should produce a full flavored, clean milk product (26). Associates of Rogers (2) state that somewhat unsatisfactory results were obtained when alkalies accompanied by pasteurization, were used to standardize high acid milk previous to its use in cheese-making. Phillip (33) has noted that acidity standardizers are sometimes added to the last wash water in the cottage cheese production. He also says that two or more washings of the curd are required to produce a mild flavored cottage cheese. Mull, Reid and Arbuckle (26) have studied the effects upon the physical and chemical properties of cottage cheese in which variable amounts of standardizing agent 'MINSOL' were added to skim milk, to the wash water, to the storage water, and to the cream used for creaming the curd. An improved flavor of the cottage cheese

resulted from the use of moderate amounts of standardizer in the skim milk and in the wash water. Excess amounts however produced unnatural flavor and impaired keeping quality. The use of standardizing agent at more than one step was not recommended. If cottage cheese is stored for too long a time, usually six days in alkaline water, unnatural flavors are developed and there is a tendency towards matting.

EFFECTS OF QUALITY OF MILK AND ITS TREATMENT ON COTTAGE CHEESE

Effects of milk solids on cottage cheese

Good quality milk is required to produce good quality cottage cheese. Composition of skim milk is an influential factor on the quality of the cottage cheese. Olson (27) found that cottage cheese made from high solids skim milk were superior in quality to the cheese made from low solids content. The high solids skim milk produced a firmer coagulum. Skim milk with higher solids also developed acid more rapidly, the cooking of the curd was accomplished in a shorter time and the losses in handling the curd were less than in low solid milk. Higher percentage of solids in skim milk help in giving a uniform body and firmer texture, which means that the individual particles retained their shape bettwr than in the case of the cheese made from the low solid milk. The total solids content

of 102 samples of commercial cottage cheese manufactured in the North Eastern section of the United States as reported in 1943 by Garrot (9) varied from 14.89 to 28.71 percent. He also showed the mean calcium content of cottage cheese to be 0.80 percent and the mean phosphorus content to be 0.23 percent.

Pasteurization of milk and its effect on cottage cheese

Nowadays skim milk is usually pasteurized before being used in manufacturing cottage cheese. It is a law in most of the States that skim milk be pasteurized. Higher temperature is found to have some sort of a stabilizing effect on the protein (48). When rennin is being used as a coagulator, soluble calcium salts are necessary. But pasteurization changes the concentration of soluble calcium salts creating improper coagulation. This is especially true in the case of low solids skim milk necessitating addition of 0.06 to 0.08 percent calcium chloride, (41). Reid and Brock (39) report work done on the disturbance in the natural oxidation reduction equilibrium of milk with special reference to the using of dehydrated milks in the manufacturing of cottage cheese. According to them, normal pasteurization does not alter the character of the oxidation reduction potential (Eh) of raw fluid whole milk appreciably but temperatures exceeding 143°F or holding periods exceeding thirty minutes do affect the character of the Eh in relation to excess time or temperature applied. Eh to them seems to be related to the physical and chemical properties of milk and cheese. Cottage cheese, having an altered Eh when dry milk is used in its manufacture, appears to be more sensitive to oxygen, light, lactose, lactic acid, and electrolytes, with a corresponding change in its physical and chemical properties. The same opinion that higher temperatures of pasteurization are not favorable to cottage cheese has also been voiced from manufacturing experience. According to Wilson and Trimble (60) one of the most important factors in the control of flavor in the finished cheese was pasteurization. Holding method (145°F for 30 minutes) or even flash pasteurization (160-165°F for 15 seconds) was satisfactory if properly controlled. Parfitt E.H. (30) reports that a soft, pasty, cottage cheese may result from too high a temperature of pasteurization. Higher temperatures, say Glover and Burgwald (11) are detrimental to the texture of the resulting curd. Holding milk in H.T.S.T. for twenty three seconds, according to Reuhe(43) will have a slightly greater effect upon the calcium salts in the skim milk than holding for sixteen seconds. This may necessitate addition of slightly higher amounts of calcium chloride to skim milk for the manufacture of cottage cheese. Kloser (20) thinks that the whole process of cottage cheese making would be benefited very much by the accurately controlled operation in the H.T.S.T. Different manufacturing processes suggest 142-145°F for temperature and twenty to thirty minutes for holding during pasteurization of milk that is to be used for the production of cottage cheese. Reichart and Davis (38) suggest 142-145°F for thirty minutes, while Goss and Mutten (13) suggest 142-143°F for thirty minutes. Lucas (22) prefers 145°F for twenty minutes instead of thirty minutes for holding to obtain proper firmness and texture in the resulting curd. Martin(24) advised 145°F for thirty minutes; so also are Thurston and Gould (51). On experimentation they (51) found that temperatures of 165°F and 185°F caused reduction in firming process and necessitated higher cooking temperatures. Also, curd from higher temperatures loses its cohesive property resulting in shattering of flakes. Jensen (19) puts 144°F for thirty minutes as the pasteurization temperature. A temperature of 143½°F for thirty minutes has been put as required temperature for pasteurization by Angevine (1). Goss and Mutten (12), Tracy and Reuhe (53) and Schock (47) all suggest 143°F for thirty minutes for proper pasteurization of skim milk to be used in cottage cheese manufacture.

QUALITY OF STARTER AND COTTAGE CHEESE

Van Slyke and Price (57) say that it is essential to use a lactic culture of high quality in commercial manufacture of cottage cheese. Starter made from skim milk is desirable to use in manufacture of cottage cheese because, when starter made from whole milk is used, it is lighter in density than skim milk in the vat. Also the slight caramel color of curd containing the whole milk starter is sometimes objectionable. Sommer (51) states that a good commercial culture contains S. lactis, S.citrovorous, and S.paracitrovorous. The presence of all three of these is necessary in a starter for a high flavor and aroma. According to Reichart and Davis ((38) the success of the entire cheesemaking process depends on the use of a proper starter. It should have a clean, distinct, pleasant, mildly acid flavor and be fresh to insure the viability of its bacteria. Rapid curdling produces a cleaner flavored curd for cottage cheese than slow curdling. The acidity of a good starter, calculated as lactic acid, should vary between 0.6 to 0.8 percent.

The amount of starter used depends upon the method employed. From 0.5 to 3.0 percent of starter is suggested for the long set method, while five to ten percent is the usual recommended amount for the short set method. Reichart and Davis (38) recommend 0.5 to 3.0 percent for long set and ten percent for short set. Hales (14) has asked to use five percent starter for short set and one percent for long set. Jensen J.M. (19) has recommended ten percent starter for short set method and one percent for overnight.

WHEY DISPOSAL PROBLEMS

The cottage cheese industry utilizes only a portion of the milk solids for the production of cottage cheese. The rest of the unused solids remain in the whey, which is a waste to a cottage cheese manufacturer. Quite a number of ways have been suggested and applied industrially for the utilizing of whey. According to U.S.D.A. statistics about one and one quarter billion pounds of whey are produced by cottage cheese and related types (Bakers cheese, pot cheese etc.) annually. Thus, unused whey is a liability to the factory and it must be hauled away from the factory or vented into the sewage system. Either method is expensive. According to Sanders (46) what is needed for a small plant is a simple and economical method of processing whey in order to compete with similar products from other sources. Backmeyer (3) has discussed the effect of whey upon the operating of an activated sludge plant. The continuous daily dumping of whey into the sewage system and the 'batch' doses create difficult operational problems at an activated sludge plant. Backmeyer(4) discusses a cheese whey disposal process by digestion. The report of the Task Committee on Dairy Waste Disposal of the Dairy Industry Committee (64) outlines a system of waste prevention that can be adopted with little or no expenditure of money by any plant operator.

STORAGE OF COTTAGE CHEESE

Storing in Brine

As soon as the curd is drained after washing it is ready for creaming and salting. The salt may be added to the cream and then the cream added to the curd (19). The amount of the cream will vary according to the butter fat content of the cream. Federal law has put four percent butterfat as the minimum requirements of cottage cheese. It is usually desirable to store cheese uncreamed. Jensen C. (18) has recommended storage of uncreamed cottage cheese in three to four percent brine at 45°F. The cottage cheese thus stored will keep its flavor for two weeks; but if a weaker solution of salt is used, or stored in water, or just dry, it will deteriorate rapidly. Willard (58) has suggested that curd to be stored frozen should be cooked less and should be salted at the rate of one half of one, to one percent. Cottage cheese can also be held in storage in brine solution. Angevine (1) also advises storage in salt water. Jensen J.M. (19)

recommends storage of cottage cheese in a cold room after it is creamed and salted.

Freezing and Storage

Possibilities of making cottage cheese when the skim milk is plentiful and then storing it for the slack time of the year have been long explored. Ellenberger (6,7) in 1919 had suggested the possibility of storing cottage cheese in a frozen condition for six to seven months. According to him cheese held in storage for seven and a half months, from early August and until April developed a decidedly disagreeable flavor. On the whole the texture of the cheese was but slightly changed. Even though higher acidity was not detectable, the flavor criticism on the stored cheese was mostly high acid. The average loss in weight in storage of this cheese was 2.62 percent.

Lucas (22) stated that cottage cheese keeps indefinitely at freezing temperatures. Parfitt (29) says that cottage cheese curd can be kept very satisfactorily for a period of six months if frozen hard in an ice cream storage room and kept frozen until ready for use. According to Willard (58) crumbly body is produced on thawing a frozen cottage cheese curd. He also refers to a patented process of freezing cottage cheese curd.

In this process, cottage cheese is prepared by cutting enzyme coagulated curd at a whey acidity of between 0.25 and 0.45 percent, cooking to obtain a rubbery tough body, freezing the curd to break down the rubbery body, and thawing to produce a firm body and smooth textured product, devoid of a chalky, crumbly, mealy texture.

<u>Effect of Light</u>

Light also has an effect on cottage cheese flavor as shown by Phillip (34). He conducted an experiment on the effects of sunlight on creamed and uncreamed cottage cheese stored in clear glass containers exposed to sunlight. Exposures of one half of one to two hours developed flavor defects. Creamed cottage cheese exposed to the sunlight for one half of one hour developed a tallowy odor and flavor. Uncreamed cottage cheese when given identical treatment, also developed characteristic and objectionable flavor defects. Tracy and Ruehe (53) also state that a disagreeable burnt flavor develops on exposure of cottage cheese in glass or open containers in either direct or indirect sunlight.

<u>Effect of Chlorine</u>

Reid and Painter (40) as reported by Mull, Reid and Arbuckle(26) found that the keeping qualities of uncreamed cottage cheese were improved 80 percent by rinsing in a chlorine rinse. Their work indicated that cottage cheese treated with chlorinated water and subsequently creamed showed deterioration on the fourteenth day, as compared with the control sample which began to deteriorate on the seventh day. The storage is usually done in parchment lined butter tubs (14).

Gelatin in Cottage Cheese

"Addition of gelatin in fractions of one percent improves the quality of the product", Parker (31). It does not affect preparation of the curd, and is added with the cream. Gelatin eliminates the watery appearance or wheying off by preventing separation of moisture from the curd. Gelatin also imparts an impression as if cream of much higher butterfat has been used in creaming it. If ten percent cream is used in combination with gelatin, it will show off as if twenty percent cream were used. According to him the exact amount of gelatin used varies from one fourth to three fourths percent, depending upon the fat content. In using gelatin in cottage cheese curd its greatest value is where the curd is made in the spring, frozen and held till summer or fall. The gelatin enables the thawed curd to hold its shape, so, each individual curd retains its identity. Parfitt (28) writes that gelatin is helpful in storage and in giving appearance. It could be added either in ten percent solution or directly to the cream. It supplies muscle building amino acid lysin also.

ORIGIN OF THE PRESENT STUDY

A review of the methods of manufacturing cottage cheese show that in a number of the processes, addition of a certain amount of water at the time of cooking is recommended. In some processes where addition of water is not mentioned it is not definitely said to omit it. The addition of this water has been followed in order to heat the whey initially and thus help in speeding up the cooking. But there are other effects of this water addition. It is apparent that it dilutes the acid of the whey and also supplies a large volume of liquid for the curd to float in (55, 56), but no experimental work is done on the diluting of the acid or extent of dilution.

There is another feature that comes in the picture as the quantity of cottage cheese manufactured goes on increasing. That is of sewage disposal. This fundamental problem of the dairy industry is also increasing. As it is, the whey given off from curd is voluminous enough to create serious sewage problems. By the addition of water at the time of cooking, the quantity of whey to be disposed is increased. Thus, it adds to the sewage disposal problem if dumped and to the cost of processing if evaporated. In instances where they must be hauled away for

disposal it adds to the cost of transportation. The origin of the present study lies in attempts to solve the problems mentioned.

Preliminary Studies

The literature on cottage cheese even though it is quite vast, is directed mostly towards setting up directions for manufacturing cottage cheese, while a surprisingly small number deals with definite experimental work.

Some insight into the effect of rennet on acid development has been shown by Thurston and Gould (51). They have shown a rise of titratable acidity with time when different amounts of starters ranging from one to ten percent were used. The amounts of rennet used by them were from 0.75 to 3.3 ml per 1000 lbs of skim milk.

In order to obtain some preliminary information regarding curd properties of skim milk, studies were made of lots of milk to which various amounts of rennet were added.

Titratable Acidity and pH studies

In order to determine the coagulation point of milk set at 32-33°C (90°F) and 25-26°C (70°F) with five percent starter and using varying concentrations of rennet extract from

0.0 ml to 1.0 ml of rennet per 1000 pounds of skim milk, the following procedure was used. This is the short set method.

Experimental: Six beakers of 1 litre capacity each were filled with a measured quantity (1 litre) of skim milk pasteurized at 143°F for thirty minutes and five percent starter was stirred in each. After the starter was thoroughly mixed by stirring, the rennet of properly diluted strengths was added according to the following scheme:

Lot No.	Ml. rennet added per 1000 lbs skim milk
1	0.0
2	0.2
3	0.4
4	0.6
5	0.8
6	1.0

This scheme is used throughout this investigation.

After the rennin was mixed with the milk, the prepared milk was transferred to small bottles and two sets of such bottles were obtained. There were thus six bottles in each set. It was necessary to use the large beakers to facilitate the rennet addition and to avoid large errors. The bottles were placed in a constant temperature bath, thermostatically controlled at 32-33°C (90°F).

From one set of the bottles changes in pH and titratable acidity were noted every hour till coagulated; while the second set was allowed to rest quietly till coagulated. Curd strength from the second set of curds was measured by a curd tensiometer. This was done approximately thirty minutes after complete coagulation.

A second series of experiments was done just as above but with the setting temperature at 25-26°C (70°F). The titratable Acidity (T.A.) is expressed as percent lactic acid.

Table 1 Showing pH, total acidity and curdling points in milk containing varying amounts of rennet

Hours set	Beaker number											
	1		2		3		4		5		6	
	pH	T.A.	pH	T.A.	pH	T.A.	pH	T.A.	pH	T.A.	pH	T.A.
1	6.51	.22	6.57	.21	6.54	.215	6.55	.21	6.55	.225	6.52	.225
2	6.00	.39	6.02	.37	6.10	.275	6.40	.37	6.2	.365	6.2	.365
3	5.50	.44	5.55	.41	5.60	.415	5.60	.42	5.55	.425	5.50	.43
4	4.95	.55	5.07	.52	5.00	.545	5.00	.545	5.00	.535	4.99	.54
4½	4.70	.69	4.80	.67	4.70	.675	4.70	.665	4.7	.675	4.7	.67

Conditions of Experiment:

At Start		Amount of Starter	Temperature of Bath
Ph	T.A.		
6.7	0.19	5 percent	32.5°C (90°F)

Table 2

Showing pH, total acidity and curdling points in milk containing varying amounts of rennet and set at 70°F

Hours after setting	Beaker number 1		2		3		4		5		6	
	pH	T.A.	pH	T.A.	pH	T.A.	pH	T.A.	pH	T.A.	pH	T.A.
1	6.6	.21	6.61	.21	6.63	.215	6.61	.21	6.62	.205	6.67	.21
2	6.57	.225	6.58	.22	6.58	.215	6.58	.22	6.56	.22	6.55	.225
3	6.30	.255	6.32	.25	6.33	.245	6.32	.24	6.32	.25	6.31	.25
4	6.00	.28	6.05	.27	6.08	.275	6.04	.275	6.00	.275	6.00	.275
5	5.67	.36	5.7	.305	5.66	.355	5.65	.35	5.65	.35	5.65	.365
6	5.07	.57	5.11	.56	5.09	.550	5.09	.555	5.07	.56	5.05	.565
7	4.81	.69	4.77	.71	4.78	.7	4.76	.71	4.80	.70	4.8	.705

Conditions of Experiment:

Time set	At start	Amount of Starter	Temp. of bath
10 A.M.	pH 6.65 T.A. .205	5 percent	25.5°C (70°F)

In order to determine the whey acidities the curdled milk was broken up and the whey given off was collected after about fifteen minutes, and was centrifuged in small tubes for clarification. This clarified whey was used for the determination of the T.A. and pH of whey.

Table 3. T.A. and pH of whey from milk set at 32-35°C (90°F) and 25-26°C (70°F) using five percent starter.

SETTING temp.	time req'd to coagulate	Beaker number											
		1		2		3		4		5		6	
		pH	T.A.	pH	T.A.	pH	T.A.	pH	T.A.	pH	T.A.	pH	T.A.
32.5°C (90°F)	4-6 hrs.	4.6	.515	4.6	.49	4.59	.51	4.6	.505	4.59	.515	4.6	52
26.5°C (70°F)	5-7 hrs.	4.81	.690	4.77	.71	4.78	.7	4.76	.71	4.80	.70	4.8	.705

The curd strength was measured from the second set of the bottles by means of the curdtensiometer. The results obtained are shown in Table 4. The readings were quite variable but the results shown are an average of three to five experiments which were in the same vicinity.

Table 4- Curd tensions for milk set at 32-33°C containing five percent starter and different amounts of rennet.

	Beaker number					
Curd strength in gms for milk set	1	2	3	4	5	6
at 32.5°C. average	7 gms	5	2.5	2	2	2.5
curd strength in gms for milk set at 25.5°C. average	4	3	5.5	2.5	3.5	5.5

Discussion of Results: These results show that there is little difference in the final pH and titratable acidity of milks of the same series containing varying amounts of rennet. However, the milk with the highest amount of rennet (Beaker No.6) which contained 1 ml per 1000 pounds of skim milk, shows a slightly higher acid development than the rest of the milks except the first. This may be due to the softer curd affording more freedom to the bacteria to act.

There is a slightly higher increase in titratable acidity and lowering in pH of the final curds in the series which was set at 25.5°C than in the series that was set at 32.5°C. This is attributable to the longer time required for coagulation at the lower temperature which gave more time for acid production.

The final acidities of the curd and of the whey show that there is about 0.2 percent acidity retained in the curd. There is no difference in the final pH of the curd and the pH of the whey. This agrees with the findings of Price and Kelley (37).

STUDY OF WHEY EXPULSION PROPERTIES

In order to study the amount of whey given off by curd containing 0.0; 0.2; 0.4; 0.6; 0.8; and 1.0 ml of rennet extract per 1000 pounds of skim milk in a definite time, the following experiment was devised.

Experimental- For the purpose of this experiment small amounts of milk were required, but, in order to facilitate the measurements of rennet extract, 1000 ml of skim milk in six beakers were prepared as under titratable acidity and pH measurements.

One hundred ml of this prepared milk was measured out from each beaker into small beakers (150 ml capacity). Thus six samples were obtained. These small beakers were incubated in the constant temperature bath kept at 32-33°C and allowed to coagulate without disturbing.

Six measuring cylinders and six funnels of the same size were taken. Six equal pieces of cheese cloth were cut and folded (three folds) to fit into the funnels. The size of each piece was three square inches after folding. The cheese cloth pieces were moistened with water before placing into the funnels. The curd from all the 100 ml milks was first broken up by stirring in the beakers and then immediately poured one by one on the cheese cloth in the centre of the funnel and the time was noted. The curd was levelled out in the funnels by means of a stirring rod if necessary. As much time was not lost during the operation, the wheying-off could be taken to have been of curd at 90°F at least for the first fifteen minutes. The readings were taken every few minutes as shown in Table 5 and the amount of whey collected at the time elapsed were noted for each.

The cheese cloth was moistened to avoid absorption of the whey by the cloth; but care was taken to see that it was not dripping with water. The amount of whey collected after fifty-five minutes was so insignificant that the amount of whey collected at the end of the fifty-five minutes has been taken for the purpose of this experiment as the total available whey. The results are an average of three trials.

Table 5 Amount of whey given off by curds containing different amounts of rennin

Time in minutes	Amount of whey collected (in ml.)					
	1	2	3	4	5	6
	0.0 ml rennet per 1000 lbs skim milk	0.2ml rennet	0.4 ml rennet	0.6 ml rennet	0.8 ml rennet	1.0 ml rennet
0	0	0	0	0	0	0
2	20	21	22	26	29	34
3	25	26	28	35	39	43
5	27	29	32	40	42	46
	All the curds were stirred after first five minutes reading					
10	36	38	41	50	52	54
15	40	42	45	53	55	56
20	43	45	48	56	57	57
55	55	56	57	61	61	61

These results clearly show that the curd with the maximum amount of rennet gives off the maximum amount of whey in the shortest time. However, the amount of whey given off will always depend upon the characteristics of the milk used. Within the first two minutes the one containing no rennet has given off twenty ml of whey while the one containing 1.0 ml rennet has given of thirty four ml of whey. At the end of five minutes almost seventy five percent of the total whey collected was available from 1.0 ml rennet curd. On the basis of the assumption that the total available whey is collected at the end of fifty five minutes; at the end of five minutes the whey yield is approximately 49 percent, 52 percent, 56 percent, 67.0 percent and 75 percent of the total collected whey for curds containing 0.0; 0.2; 0.4; 0.6; 0.8; and 1.0 ml rennet per 1000 pounds of skim milk respectively. At the end of ten minutes the percentages are approximately 66 percent, 68 percent, 72 percent, 82 percent, 85 percent and 87 percent respectively.

Thus it is quite apparent that by the end of the first ten minutes the cylinder numbers four and five containing whey from the curd having rennet at the rate of 0.6 and 0.8 ml per 1000 pounds of skim milk are close to the 1.0 ml rennet containing milk's wheying off speed. There is a clear distinction noticeable between curd numbers one to three and four to six; the first being slow, tending toward the properties of curd containing 0.0 ml rennet, while the other group tends towards the wheying off characteristics of curd containing extract at the rate of 1.0 ml per thousand pounds of skim milk.

Conclusions

All these preliminary experiments show that curd containing rennet extract at the rate of 0.6 ml per 1000 lbs of skim milk has quite suitable properties. It generates enough acidity, the time required for setting is comparable to higher rennet content milk studied here, has a nice soft, compact curd and gives off enough whey within ten minutes. It was decided that in all the subsequent experiments rennet at the rate of 0.6 ml per 1000 pounds of skim milk should be used, unless otherwise required.

THE PROBLEM

The literature survey revealed that little attention has been paid to the standardization of acidity in the manufacture of cottage cheese. The only work of importance in this direction has been done by Mull, Reid and Arbuckle (26). This work was concerned with standardizing the acidities of skim milk, washwater, cream and storage water used in production and storage of cottage cheese. No attention has been paid to standardizing the acidities of the whey itself.

Primary attempts at cooking cottage cheese batches by the short set method as suggested by Jensen (19) , but cooked in absence of water was either not satisfactory or failed completely. The difficulty encountered involved the production of crumbly curd with a pronounced tendency to mat together. According to Thurston and Gould (51) this may be due to high acidity at cutting, or insufficent rennet content, or there was too rapid expulsion of whey from some of the curd, probably due to high temperature differences between the vat and the jacket.

The short set method was selected because of its advantages of completing the work faster, as well as the ease of control of conditions like temperature and arrest of unfavorable fermentations. But, with this, the short set method also brings some problems of its own to be faced, especially of quality of milk and starter.

Scope of Investigation

The present study was designed to determine:

(1)- The effects of standardizing the whey acidity on the manufacture of cottage cheese.

(2)- The effect of controlling the ages of milk and the starter on the curd and final product.

(3)- The effect of rate of cooking on cheese making properties.

(4)- Final cooking temperatures of cheese with standardizing acidity.

(5)- Differences in body, texture, and flavor of final product when neutralized with caustic soda and lime.

(6)- Possibility of manufacturing a uniform product.

EXPERIMENTAL PROCEDURE

About thirty successful batches of cottage cheese are reported in this work. In order to have as far as possible near commercial conditions, fifty gallons of skim milk were used for every batch in a hundred gallon vat.

The short time, five hour method of manufacture was employed. Two different methods of cooking were followed according as to whether the batch was to be neutralized (standardized) or was to be cooked in presence of water by the standard method (19).

METHOD 1

Fifty gallons of skim milk pasteurized at 143°F for thirty minutes were processed into popcorn type cottage cheese in a hundred gallon stainless steel vat. The milk was heated to 90°F and ten percent starter was added to it. After the starter was thoroughly mixed with the milk the temperature was adjusted to 90°F. The water in the jacket was kept at 92-93°F. Fifteen minutes after the starter was added, rennet extract was added at the rate of 0.6 ml per 1000 pounds of skim milk. The concentrated rennet extract was diluted to approximately a litre with water before adding to the milk. Thus prepared milk, was allowed to coagulate. Since coagulation occured in advance of the acidity that was desired for cutting the coagulum, a cavity was made in the curd where whey was collected and drawn off for acid testing. When the titratable acidity reached the desired value, the curd was cut first horizontally and then vertically with half inch cheese harps. After the curd was cut, the temperature in the water jacket was raised to 100°F in order to bring the temperature of the curd to 90°F. A fall of approximately 10°F occured during the five to six hours required for coagulating. After the cheese was cut it was allowed to stand for fifteen minutes in order to expel the whey and firm up to some extent. Thurston and Gould (51) also give this period of time to accomplish the freshly cut surfaces to what they call " heal up" . After the whey was expelled, the titratable acidity was again tested. At this step a neutralizer or an acidifier or both were added if, and as, necessary. The acidity desirable for best results appeared to be 0.45 to 0.48 percent. The sodium hydroxide flakes or the calcium hydroxide or concentrated hydrochloric acid used for these purposes, were mixed with one gallon of cold water and then sprinkled on the cheese as evenly as possible. The neutralizer was allowed to act for twenty to twenty five minutes during which time the curd was stirred very very gently twice or thrice. At the end of the time allowed for the action of the neutralizer the acidity was again checked. As soon as the desirable acidity was obtained the cooking was started.

The jacket was heated slowly throughout the cooking period. A temperature difference of 20-25°F was kept between the jacket and the vat during cooking. The curd was stirred very carefully and slowly after each increase of two degrees was obtained in the cheese. In order to insure a reasonably standard procedure of cooking for all batches, the temperature in the jacket was npt raised till temperatures in all parts of the vat were almost equal and constant. There was always a difference of a degree or two between the sides and the centre, the sides being hotter. The jacket temperature was then raised and held there till the cheese temperature was steady again. This process of heating was continued till the cheese was properly cooked. It was necessary to be very cautious in stirring till the temperature of the cheese reached 110°F, otherwise the curd particles broke and uneven cheese resulted. The curd was in most cases cooked at 116-117°F. The cheese was allowed to stay at this temperature for fifteen minutes. As soon as the cheese temperature was reached the maximum the water jacket was drained off in order to awoid raising the vat temperature beyond this point. The extent pf cooking was determined by the firmness test as suggested by Hales (14). Individual cheese cubes were allowed to drop on the floor from waist heigh, and as soon as they did not smash upon striking the floor, the cheese was taken as properly cooked. It took about one and a half to two hours to cook the cheese.

After the final fifteen minutes holding period was over,

the whey was drained off through a gate strainer till sufficient whey remained to cover the cheese on the bottom of the vat. This has two effects;

(1)- It avoids mushing up of the hot curd particles under their own weight.

(2)- It helps to warm up the first wash water, as suggested by Gross and Mutten (13) and Manus (23).

The gate valve was closed and cold water allowed to enter the vat in the quantity equal to the original quantity of milk. The curd was stirred slowly to wash, then drained completely. At this time the jacket was filled with cold water. Cold water was once more run into the vat, this time filling it completely. The curd was stirred to wash and then kept under cold water for ten minutes to ensure proper chilling of the curd particles. The water was drained off and the cheese drainage time was allowed for twenty five minutes.

After the cheese was drained it was either creamed and salted or stored dry. When the cheese was creamed and salted in the vat, the salt was mixed with cream before adding it to the cheese in order to facilitate salting.

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METHOD 2

All the steps were done just as in Method 1 except that at the time of cooking water in quantity equal to thirty two gallons (40 percent of the original volume of milk) was added in place of the neutralizer. Here the temperature difference between the jacket and the vat was kept at about 50-55°F otherwise the rate of heating was too slow. The stirring could be done with less fear of the coagulum breaking. The final cooking temperature was 120°F. The cooking for each batch was generally completed after two hours of heating.

RESULTS

Acidities required at Cutting

In order to effectively standardize whey acidity it was necessary to determine first the acidity at cutting that would give best results. Both Methods 1 and 2 were used in obtaining the results shown in Table 6. In order to secure curd formation at lower acidities it was necessary to use 1.0 ml of rennet per 1000 pounds of skim milk instead of at the rate of 0.6 ml which was used for acidities higher than 0.47 percent.

Table 6 also shows the final acidities of whey, i.e. acidities of whey at the end of cooking and just before draining. The curd was cut at the acidities of whey shown in the Table and the cooking started. The body, texture, and flavor of final product were noted and they were the guides in selecting the proper whey acidities. Final temperatures of cooking have also been noted.

These results tend to show that the best whey acidities at cutting time, for cheese made from normal milk that is to be cooked with water is in the vicinity of 0.50 to 0.54 percent. These results are in line with recommendations advised by different writers. The addition of water reduced the acidity of whey. The acidities here obtained did not exceed 0.2 percent at the end of

Table 6 Effect of acidity, temperature of cooking, and cooking methods on flavor, body and texture of cottage cheese

whey acidity at cutting	Body and texture		Flavor		temp. of cooking °F		Final acidity of whey	
	with water	without water	with water	without water	with water	without water	with water	without water
.40 to .42	Rubbery	Rubbery	flat	Flat	110	105	.12-.14	.45-.47
.44 to .45	slightly rubbery	slightly tough but even	flat	good	120	116	.12-.15	.49-.50
.47 to .50	good smooth inside gritty outside	smooth creamy	very good	very good	120	116	.13-.17	.50-.53
.52 to .54	"	crumbly and hard	Acidic	quite acidic	120	118	.14-.19	.54-.47

Conditions of Experiment:

Ten percent Starter. Setting Temperature 90°F. Amount of Renn Extract used was varied at 1.0 ml p.t.# of skim. for low acidities and 0.6 ml for higher acidities. These acidities are Titratable Acidities.

cooking. These acidities were well in the range of those where rubbery curds are frequently formed.

When the cheese was cooked without water, the results show that the coagulum was cut best at whey acidities ranging from 0.47 to 0.50 percent. Cheese cooked from a coagulum cut at these acidities had smooth and creamy texture and the flavor was good. The final whey acidities at the end of cooking were 0.50 to 0.53 percent. At the higher acidities of cutting (0.52-0.55) the curd was crumbly and hard. Thus in further experiments of neutralization acidities of 0.47 to 0.50 percent were used.

Studies on Rate of Cooking

During the process of manufacturing cottage cheese in absence of water it was noted in the beginning that the cheese had a tendency to mat together and stick to the bottom, forming big chunks. This could be avoided if stirred continuously and vigorously, but that meant shattering the curd particles. The temperature of the jacket was kept 45-50°F higher than the vat when the same procedure was used for cooking cheese in presence of water. The matting was very well avoided here by the much more free stirring permitted by the large volume of water. It was necessary to determine the rate of cooking i.e the difference in temperature between the vat and the jacket.

Table 7 Experiment on the effect of temperature difference between the vat and the jacket on cooking and the characteristics of the curd

Temperature Difference °F	Cooking with water		Cooking without water	
	Rate of cooking	Nature of curd	Rate of cooking	Nature of curd
10	Almost nil	soft, easily crushed	very slow	soft
20	very slow	soft and separate	good	soft and separate
30	slow	"	rapid	separate, but tendency toward matting.
40	good	"	"	sticks to the bottom of vat and forms a sticky mass.
50	rapid	tendency toward sticking to the bottom	very rapid	too much sticking to the bottom.

Conditions of experiment:

For cooking with water and without water:

Ten percent starter. 0.6 ml rennin per 1000 pounds of skim milk. Temperature of setting 90°F.

These results show that when cooking cottage cheese with water the temperature difference should be 40 to 50 degrees F. while for cooking without water the optimum difference in temperature between the jacket and the inside of the vat should be 20-30°F.

Nature of curd as cooking progresses

None of the literature studied presented observations in regard to the nature of the curd at different stages of cooking either without water or with water; the process most used. Here, the 'normal curd' has been taken as the curd obtained from the regularly pasteurized fresh skim milk and fresh starter. The curd was cut at the acidities suggested by Table 7 for both the methods No. 1 and 2 respectively. The results are reported in Table 8.

Table 8 Effect of time and temperature on the nature of the normal curd cooked with and without water.

Temp. °F.	Length of time held.	cooked with water		cooked without water		Remarks
		Rate of cooking	Nature of curd	Rate of cooking	Nature of curd	
95	till the temp. in the different parts of the vat were almost const.	Progressive	soft	Progressive	soft	
100	"	"	"	"	"	
105	"	"	tendency toward mashing together	"	slightly hard	
110	"	"	"	"	cooking hardness enough to permit faster stirring. forms clumps which can easily be separated.	
115	"	"	started hardening	"	cooking almost completed	
117	"	"	half cooked	"	cooking completed	cooked curd was held here for 15 minutes
120	"	"	cooking completed	"	"	"

Table 8 (continued)

Conditions of Experiment

Ten percent starter. 0.6 ml rennin per 1000 pounds of skim milk. Setting temperature 90°F. Number of trials reported; four per each method.

The results here give a good directive as regards the nature of the curd at different temperatures. Under a particular set of conditions; with the sources of milk reasonably constant and the starter prepared by the same process daily the results as obtained above should not vary much for a particular plant. Thus as soon as a particular temperature is reached any worker should be reasonably sure of the nature of the curd at that particular time. Two temperatures were obvious with cooking in the whey;

(1)- 110°F after which faster stirring and thus rapid cooking were facilitated.

(2)- 117°F when the cooking should be completed.

120°F was the cooking temperature for cheese cooked with water dilution.

Studies on Standardization of Whey Acidities

The previous experiments have shown that when cheese is to be cooked in its own whey;

1- The best whey acidity to start cooking cheese is 0.47- 0.50 percent.

2- The vat temperature should be 20-30°F lower than the jacket temperature.

3- The final cooking temperature would be in the vicinity of 117°F.

In order to study the effects of standardizing the whey, three series of experiments have been conducted here.

1- Coagulum cut at a low acidity and increased in acidity to the optimum of 0.47- 0.50 percent by addition of hydrochloric acid. In order to secure coagulation at low acidity 1.00 ml of rennet per 1000 pounds of skim milk was used.

2- Cutting at higher acidity and reduced downward to the optimum by:

2.1 sodium hydroxide

2.2 calcium hydroxide

3- Cutting at higher acidity and bringing down to a much lower acidity by Sodium hydroxide and then bringing up with hydrochloric acid.

Method No. 1 of Manufacture was used here.

Table 9

Effect of standardizing the whey acidity in various directions by use of acid reductants and inorganic acids

No. of trials reported	whey acidity at cutting	whey acidity brought to	Agent used	Body & texture	Flavor	Final cooking temp °F	Final whey acidity
2	0.4 -.42	.47-.48	HCl	sticky rubbery	slightly flat	115-120	
8	.52 -.55	.46-.49	NaOH	smooth creamy	Excellent	116-117	.51-.53
3	.52 -.55	.46-.49	$Ca(OH)_2$	"	"	"	"
1	.52 -.55	0.4 -.42	NaOH	rubbery	Acidic	115-120	.43-.45
3	.52 -.55	.46-.49	NaOH & HCl	smooth creamy	Excellent	116-117	.51-.53

Conditions of Experiment:

Ten percent Starter. 0.6 ml rennet extract. Setting temperature 90°F.

When the coagulum was cut at a low acidity of 0.4 - 0.42 percent and the whey acidity was brought up to the optimum of 0.47 - 0.50 percent by the addition of hydrochloric acid, the resulting cheese was rubbery. The whey acidity therefore does not affect the physical properties of the coagulated milk. The low acidity of the cubed coagulum was unaffected by the acid surrounding them and the heat that was applied caused the typical rubbery mass that accompanies that condition.

When the whey acidity at cutting was 0.52 - 0.55 percent and it was brought down to the lower limits of 0.4 - 0.42 percent with acid reductants, it was noted that such curd when cooked was also rubbery. Here the cheese acidity was considerably above the limit for rubbery texture, yet, as the whey was brought within the rubbery texture limit by over-neutralization, the resulting effect was to form a rubbery cheese.

In a third experiment a combination of acidity reduction and acidity increase was used. The curd was cut at high acidity (0.52 - 0.55) the whey brought within lower limits (0.4 - 0.42) by over neutralizing and then was brought up to the optimum acidity (0.46 - 0.49) by the addition of hydrochloric acid, and cooked. The result was a fine, creamy textured cheese with excellent flavor. These experiments clearly show the importance of keeping both whey acidities as well as the acidities of curd particles above 0.42 percent (best within 0.45 - 0.5) if a rubbery curd is to be avoided. The results in Table 6 have shown the effects of higher acidities of 0.52 to 0.56.

A further series of experiments were conducted using various acid reductants. The curd was cut at higher acidity, 0.52 to 0.55 percent and then neutralized to the optimum acidities. Both sodium hydroxide and calcium hydroxide were used. By bringing down the acidity to the optimum 0.46 to 0.49 percent a fine product was obtained from both. No difference in the body, texture and flavor of the cheese obtained with caustic soda and lime as acid reducing agents was noticed. The caustic soda would thus be preferable to use because of its easy solubility necessitating less stirring, which means a more uniform product. Besides, as most of the salts from neutralizing are to be washed away caustic soda would be preferable because of higher solubility of sodium compounds than of Calcium compounds.

The results of these experiments are thus quite significant. If the curd has been cut at a sufficiently high acidity it can be brought to the optimum acidity of 0.45 to 0.49 percent by any of the neutralizing methods used here without adverse effects on the resulting cheese.

Effects of Age of milk and age of starter

It is not always possible to get a fresh supply of milk and a fresh supply of starter, which are ideal for making a good quality cottage cheese. It was thus thought advisable to note the effect of ages of milk and starter on the curd, and the cheese obtained from it. These observations were made as a part of the other experiments that have been reported here. The results are summarized in Table 10.

Table 10 Effect of age of milk and age of starter on curdling time, nature of the curd, and the nature of the cheese

No. of trials reported	Age of milk	Age of starter	Curdling time	Nature of the curd	Body and texture of cheese
12	fresh	fresh	4-6 hrs	smooth, compact	Excellent
5	one day	fresh	5-6 hrs	very slight gassy	Irregular
5	fresh	one day	5-7 hrs	"	very "
5	one day	one day	6-8 hrs	gassy open	" "
2	fresh	two days	6-9 hrs	"	" "
1	two day	two days	7-10 hrs	very gassy and open	breaks down to fine particles

Conditions of experiment:

Ten percent starter. 0.6 ml rennin per 1000 pounds of milk. Setting temperature 90°F. Cooked without addition of water.

The few batches studied here have shown that excellent results were obtained when fresh milk and fresh starter combination was used in preparing the cottage cheese. As long as one of them was fresh and the other a day old satisfactory results were obtained, but as the ages went beyond that, adverse effects on the cottage cheese production were apparent. A two day old milk with a two day old starter was impossible to cook into an acceptable pop-corn type cottage cheese.

DISCUSSION

Cottage cheese of good quality could be produced with cooking in the whey only. It is customary to cook cheese with addition of water because of the initial heating that could be obtained by addition of hot water and also the free stirring provided by the large volume of liquid media available for the curd to float in. The water also dilutes the whey acidity.

According to Table 6 the acidity of whey at the end of cooking did not go above 0.2 percent when 40.0 percent water was used for cooking. The final whey acidity for cheese cooked in its own whey was 0.57 percent (maximum) under the conditions of the experiment. The proper whey acidities for cutting a coagulum in order to obtain a cottage cheese with smooth creamy texture and good flavor, cooked with and without water were found to be 0.52 percent to 0.54 percent and 0.47 to 0.50 percent respectively. If a coagulum was cut at acidities of 0.40 to 0.42 percent the resulting curd after cooking was rubbery. In the case of cottage cheese that was made by cutting at higher acidities of 0.52 to 0.54 percent and by cooking in absence of water, the curd was crumbly and hard and had quite an acidic flavor. The final temperature obtained during cooking increases as the whey acidity at cutting is increased. Thus for a cottage cheese to be cooked without resorting to water dilution the coagulum should be cut when the whey acidities reach 0.47 to 0.50 percent.

Heating the coagulum after cooking is resorted to firm the curd particles by facilitating rapid whey expulsion. In order to avoid over heating of coagulum and as a result too rapid whey expulsion from a few curd particles in contact with the sides of the jacket, it is necessary to stir the whole mass; otherwise they would form a matted mass and have a tendency to stick to the bottom of the vat. The stirring also helps in transferring heat to the rest of the bulk and thus increase the rate of temperature rise. But the stirring has to be done very carefully as the coagulum at the beginning (till temperature reaches 110°F) is very soft and is liable to be crushed. Thus when curd is cooked in presence of added water, higher rate of cooking could be used because the large liquid medium would permit stronger and faster stirring. The same rate of heating could not be used when cooking cheese in its own whey because of the large mass of coagulum floating in a small quantity of the whey. Any attempt at stirring faster here meant breaking down the 'popcorn' curd particles. Table 8 shows the nature of the curd at different temperatures between water in the jacket and the whey in the vat. While a difference of 40 - 50°F was suitable for cooking in presence of added water, only 20- 30°F difference was found suitable for cooking in absence of water. At this rate of heating quite an even cottage cheese was obtained.

As the cooking progresses the cubes become firmer and firmer and when the temperature reaches approximately 112-115°F, when cooking with water, and 110°F when cooking in the whey only, the curd particles have hardened enough to permit faster and more frequent stirrings without the fear of shattering the cubes completely.

Acidity of the whey at the time of cutting plays an important part in determining the quality of final product to be obtained. From the experiment (Table 6) it was observed that for the cheese to be cooked in absence of added water, the desirable whey acidities at cutting time were 0.46-0.49 percent. This acidity could be attained either by keeping a close track of the acid development in the coagulum or by standardization after cutting a firm coagulum at any acidity. Table 9 shows that if the coagulum is cut at 0.4 - 0.42 percent acidities and then the whey brought up to the optimum acidity of 0.46 - 0.49 percent the resulting cheese curd is rubbery. The acidification of whey while changing acidity of the surrounding curd, is not capable of changing the nature of the curd which remains more of a rennet curd. If the coagulum is cut at higher acidities of 0.52 - 0.55 percent and then brought down by neutralization to 0.46 - 0.49 a very good final product was obtained. But if the whey was over-neutralized to 0.4 - 0.42 percent acidity a rubbery curd resulted on cooking. Now when the over-neutralized whey was acidified and brought to the optimum acidity of 0.46 - 0.49 and then cooked a very good cottage cheese resulted. These results tend to indicate that first a rennet type coagulum is formed which converts into acid type as the acidity is allowed to increase without cutting the coagulum. A rennet type coagulum could not be brought to acid type after cutting simply by acidifying the whey; but a coagulum advanced in acidity could be brought down to rennet type curd by neutralizing the whey. If an over-neutralized whey is acidified the original curd is got back. The optimum acidity of 0.45 to 0.49 can be said to show a balance point between rennet type curd and acid type curd. No difference in the action of lime and caustic soda was noticeable.

These results show that with this method of whey standardization and of cooking employed, a product reasonably standard in body, texture and flavor was obtained with different skim milks. Thus successful production of comparable quality cottage cheese by cooking in absence of added water would help the dairy industry by not complicating the already existing sewage disposal problem.

SUMMARY AND CONCLUSIONS

(1)- Rennet at the rate of 0.6 ml per 1000 pounds of skim milk was found to be the suitable amount of rennin to use for the short set method employed.

(2)- For the cheese to be cooked without water, the optimum whey acidity at cutting was 0.47 to 0.50 percent.

(3)- For the cheese to be cooked with water, the acidities of whey at cutting were found to be 0.50 to 0.54 percent.

(4)- The difference in temperature between the vat and the jacket for cheese to be cooked without water should be 20 - 30°F for a reasonably rapid rate of cooking without harming the body and texture of the curd.

(5)- The final cooking temperature attained for cheese to be cooked in its own whey was 116-118°F.

(6)- There was no difference noticed in the action of caustic soda or lime neutralizer.

(7)- A fine cheese could be obtained by cutting at whey acidity of 0.52 - 0.55 percent and then neutralizing to 0.47-0.49 percent of whey acidity.

(8)- A rubbery cheese is obtained if cut at whey acidity of 0.4 -0.42 percent and then the whey acidity brought to the optimum by the addition of hydrochloric acid.

(9)- A rubbery curd also resulted if the curd was cut at 0.52- 0.55 percent whey acidity and then the whey acidity over neutralized to 0.4 percent or less.

(10)- A good quality cottage cheese resulted if cut at high acidity, overneutralized, and then reacidified with HCl to optimum acidity.

(11)- Whey acidity as well as the acidity of whey at cutting were noticed to be important.

(12)- Fresh milk and fresh starter gave the best results.

(13)- When either the milk or starter was one day old and the other fresh, good cottage cheese was produced.

(14)- Two day old milk and two day old starter gave a highly gassy curd which was impossible to cook into cottage cheese of the type that was attempted to manufacture here.

Appendix 1

METHOD FOR MANUFACTURING COTTAGE CHEESE BY SHORT-SET METHOD, UTILIZING STANDARDIZATION OF WHEY ACIDITY AND COOKING IN ITS OWN WHEY

(1)- Take fresh skim milk pasteurized at 143°F for thirty minutes, heat it up to 90°F and add ten percent fresh starter to it. Mix the starter thoroughly with it.

(2)- After fifteen minutes after adding starter add rennet at the rate of 0.6 ml per 1000 pounds of skim milk, diluted with a quart of water. Mix the rennet with slow stirring and long enough to ensure proper dispersion of the enzyme.

(3)- Bring the temperature to 90°F if lowered and let stand till coagulated.

(4)- Cut the curd (see appendix 3 for directions) first horizontally and then vertically when the whey acidity as tested is between 0.5 and 0.54 percent.

(5)- As soon as the curd is cut, heat the jacket to 100°F, this will bring the temperature of the curd slowly to 90°F.

(6)- Dissolve Caustic Soda (About 30 grams for 50 gallons of skim milk used) in a gallon of water and add sufficient to bring the whey acidity to 0.45- 0.48 percent. If the acidity is still more add till tests to the requirement; if less than the required, acidify with hydrochloric acid to the right extent. Mix by slow stirring. Let stand for twenty minutes with occasional stirring.

(7)- Start cooking. Keep the difference in temperature between the vat and jacket at 20- 30°F. Stir occasionally and slowly.

(8)- When the temperature has reached 110°F the cheese would have hardened enough to permit faster stirring.

(9)- At 115°F start testing the extent of firming by dropping a flake on the ground.

(10)- Heat till 117°F is reached. Then drain off the jacket and let stand the whey at 117°F for fifteen minutes.

(11)- Drain off the whey till just enough remains to cover all the cheese and the bottom.

(12)- Add cold water in amounts approximately equal to the amount of original skim milk. Let stand for five minutes with occasional stirring. Drain off. Start running cold water through the jacket.

(13)- Add cold water to the cheese- as cold as possible. Fill up the vat. Let stand for ten minutes with stirring to wash all cheese thoroughly as well as chill them. Drain off the water.

(14)- Let the curd drain.

(15)- Cream and salt if to be used immediately or the next day. Otherwise, store dry in parchment lined tins in a cold storage, if to be used within two or three days. Cream and salt at the time of using.

Appendix 2

A SUGGESTED COTTAGE CHEESE DATA SHEET

Milk

Pasteurization	Age of Milk . . . .
Gallons of Milk	Pounds of Milk . . . .

Setting

Pounds of Starter.	Age of Starter . . . .
Setting Temperature	Amount of rennet . . . .
Acidity at setting	Percent of Starter . . . . .
Time when set	Gallons of Starter . . . . .

Cutting

Time when cut	Acidity at cutting . . . . .
Temperature when cut	Hours to set . . . .
Acidity after neutralization	Neutralizer used . . . .

Cooking

Cooking Started	Cooking Completed . . . .
Final whey acidity	Hours to cook . . . .
Highest cooking temp.	

Washing

Times washed	Total gallons of water used for washing . . . .
Drainage time	Final temp. of cheese . . . .

Creaming and salting

Pounds of cheese used	Test of cream . . . .
Pounds of salt	Percent of salt. . . . .
Actual pounds of cottage cheese . .	Flavor, body, texture . . . .
Percent yield	Percent butterfat in creamed cheese . . . .

Cost

Cost of milk	Cost of Starter . . . .
Value of cheese	Cost of cream . . . .
Packaging data	Gross gain . . . .

Appendix 3

METHOD OF CUTTING COTTAGE CHEESE AS SUGGESTED BY HALES (14)

"First, the horizontal knife is used to cut the curd lengthwise of the vat. The top of the knife is held on the end of the vat, while the other end is swung down through the curd and brought to rest in an upright position against the wall of the vat. In an upright position, the knife is drawn the full length of the vat. It is then rotated on its cutting edge and lined up so that it is in the proper position for making another cut directly beside the preceding one. Again the knife is drawn the full length of the vat and the operation described above is continued until lengthwise cutting of the curd is completed.

The vertical knife is now used for the remaining cutting of the curd. Standing at one side of the vat, the cheese-maker places the cutting end of the knife just above the curd on the opposite side. He then pushes the knife downward with the cutting end sliding down the side of the vat until it strikes the bottom. During this operation the knife is held at about a 35 degree angle in respect to the side of the vat opposite the one from which the cheese-maker is standing. After the knife has been pushed downward, it is straightened up against the side of the vat and in this position drawn across and removed from the curd.

This operation is repeated as many times as required. Following this operation curd is cut lengthwise with the same knife and in the same manner as it was cut crosswise."

BIBLIOGRAPHY

(1) Angevine, N.C.
1950. Improved sweet curd cottage cheese. Milk Plant Monthly. 39 (1):58-60, 67.

(2) Associates of Regers, L.A.
1935. Fundamentals of Dairy Science. 2nd ed. Reinhold Publishing Co. ; New York. 616 pp.
p. 245.

(3) Backmeyer, D.P.
1949. The effect of whey upon the operation of an activated sludge plant. Pub. Health Engin. Abs. S33. (Proceedings of Third Industrial Waste Conference, Purdue Univ. Lafayette, Ind. p. 288-92, May 21-22, 1947.)

(4) Backmeyer, D.P.
1948. Disposal of cheese whey by digestion. (Pub. Health Engin. Abs. 29 (4):S39, 1949) Sewage Works Journal. 20:115-18, Nov. 1948)

(5) Bennitt, K.E.
1943. Home cheese making. Calif. Agr. Ext. Service Leaflet. 4pp .

(6) Ellenberger, H.B.
1919. Cottage Cheese. Vt. Agr. Exp. Sta. Bul. 213: 3-22.

(7) Ellenberger, H.B.
1919. Cold storage of cottage cheese. Vt. Agr. Expt. Sta. Bul. 213. 22 pp.

(8) Flavorline incorporated of Chicago published bulletin.
1948. Better cottage cheese can be made. pp.4

(9) Garrett, O.F.
1943. The calcium and phosphorus content of commercially made cottage cheese. Jour. Dairy Sci. 26: 305- 308.

(10) Glover, D.L. and Burgwald, L.H.
1940. The use of homogenized milk in manufacture of cottage cheese. Bul. Ohio State. (not numbered).

(11) Glover, D.L. and Burgwald, L.H.
1941. Manufacture of acid rennet type cottage cheese. Milk Dealer. 30 (8): 42.

(12) Goss, E.F. and Mutten, G.
1931. Manufacture of cottage cheese in Iowa. Milk Plant Monthly. 20 (7): 72.

(13) Goss, E.F. and Mutten, G.
1931. Manufacturing of cottage cheese in Iowa creameries and milk plants. Iowa Agr. Expt. Sta. Cir. 126. pp. 16 figs 11.

(14) Hales, M.W.
Cottage Cheese a Chris. Hansen Lab. Publication. (not dated) 12 pp.

(15) Hammer, B.W.
1939. Flavor development in buttermilk and cottage cheese. Int. Assoc. Milk Dealers; Assoc. Bul. 31.

(16) Harrison, D.B. and Roberts, W.M.
1946. Matting of cottage cheese. Jour. Dairy Sci. 29 : A2.

(17) Janoschek, A.
1937. Uniformity of whey drainage from cut curd. Proceedings XI th World's Dairy Congress, Berlin, 1937, 439-441. (Brit. Chem. and Physio. Abs. p. 580; 1938).

(18) Jensen, C.
1942. Preservation of cottage cheese. N. Dak. Agr. Expt. Sta. Bul. 4, 19 pp.

(19) Jensen, J.M.
Sweet curd cottage cheese. Mich. Agr. Expt. Sta. unpublished data. 2 pp.

(20) Kloser, M.M.
1947. Experiences using the S.T.H.T. on cottage cheese. Milk Plant Monthly. 36 (3):38,40, 41, 86.

(21) Lochry, H.R.
1948. The manufacture of low-acid rennet type cottage cheese. U.S. Dept. of Agriculture. Misc. Pub. 119. (Issued October 1931, revised April 1948) pp 14 figs 7.

(22) Lucas, P.S.
1926. Manufacture of cottage cheese. Mich. Agr. Expt. Sta. Cir. Bul. 97. 10 pp fig 3.

(23) Manus, L.J.
1938. Warm water washing improves sweet curd cottage cheese. Milk Dealer. 27 (12) : 40,70,71.

(24) Martin, W.H.
1929. Cottage cheese and how to make it. Milk Dealer. 18 (7) : 54, 55, 114, 116.

(25) Marquardt, J.C.
1941. Rate of rennet coagulation and curd tension of milk with special regard to problems in cheese manufacture. New York State Agr. Expt. Sta. Tech. Bul. 257. 16 pp. fig. 2.

(26) Mull, Reid, and Arbuckle.
1940. The effect of standardizing the acid on the manufacture of cottage cheese and cultured buttermilk. Mo. Agr. Expt. Sta. Bul. 319. 36 pp. fig. 4.

(27) Olson, H.C.
1943. The influence of composition of skim milk on the yield and quality of cottage cheese. Jour. Dairy Sci. 26 : 772.

(28) Parfitt, E.H.
1933. Gelatin in cottage cheese. Milk Plant Monthly. 22 (7) : 52.

(29) Parfitt, E.H.
1938. Keep curd frozen when storing for making cottage cheese. Milk Plant Monthly. 27 (5): 69.

(30) Parfitt, E.H.
1939. Preventing soft cottage cheese. Milk Plant Monthly. 28 (9): 70.

(31) Parker, Willis.
1931. Improving creamed cottage cheese through the use of gelatin. Milk Dealer. 20 (5): 57.

(32) Parmelee, C.E. and Rosenberger, W.S.
· Procedure for making cottage cheese from special low heat treatment non fat dry milk solids. Dept. of Dairy Industry, Iowa State College, Ames. Pub. S-521. Misc. (Not dated) 4 pp.

(33) Phillip, C.A.
1930. Manufacture of cottage cheese. Cal. Agr. Expt. Sta. Cir. 48. Revised 1944. 18 pp.

(34) Phillip, C.A.
1931. Effect of light on creamed and uncreamed cottage cheese. Cal. Agr. Expt. Sta. Report for 1931. p. 64.

(35) Price, W.V.
1935. Common defects in the body and cottage cheese. Milk Dealer. 24 (7): 34,35.

(36) Price, W.V.
1935. The preventing of some common defects in cottage cheese. Milk Dealer. 24 (6):46,48, 50, 52.

(37) Price, W.V. and Kelley, M.F.
1933. Improved method of making cottage cheese. Wis. Agr. Expt. Sta. Bul. 217.

(38) Reichart, E.L. and Davis, H.P.
1927. Manufacture of cottage cheese in dairy plants. Neb. Agr. Expt. Sta. Bul. 217. 16 pp. fig 7.

(39) Reid, W.H.E. and Brock, R.L.
1934. Disturbance in the natural oxidation-reduction equilibrium of milk with special reference to the use of dehydrated milks in the manufacture of cottage cheese. Mo. Agr. Expt. Sta. Res. Bul. 216; 26 pp. fig. 19.

(40) Reid, W.H.E. and Painter, W.E.
The relation of chlorine to keeping quality of cottage cheese. Univ. of Missouri, Dairy Dept. (Refer No. 24) unpublished.

(41) Ruehe, H.A.
1947. Use of calcium chloride for improvement of cottage cheese. Milk Plant Monthly. 36 (12):61.

(42) Ruehe, H.A.
1947. Keeping quality of cottage cheese. Milk Plant Monthly. 36 (12): 60.

(43) Ruehe, H.A.
1949. H.T.S.T. pasteurization of milk for cottage cheese. Milk Plant Monthly. 38 (10): 66.

(44) Ruehe, H.A.
1939. Method equipment and cost in making cottage cheese. Milk Plant Monthly. 16 (2):23-25.

(45) Sanders, G.P., Matheson, J.K., and Burkey, L.A.
1936. Curd tensions of milk and its relation to firmness of curd in cheese making. Jour. Dairy Sci. 19: 395-404.

(46) Sanders, M.D.
1949. What can be done with whey. Pub. Health Engin. Abs. 29 (4): S 33. (Proceedings of Third Industrial Waste Conference, Purdue Univ. Lafayette, Ind. pp 288-92, May 21-22 1947).

(47) Schock, A.A.
1947. The manufacture of cottage cheese. Milk Plant Monthly. 36 (10): 82- 86.

(48) Sommer, H.H.
1938. Market milk and related products. 2nd ed. Author, Madison, Wis. pp. 578-588, 661-670, 699 + XIV pp.

(49) Thurston, L.M.
1931. Manufacture of sweet-curd rennet-coagulated cheese. W. Va. Sta. Bul. 244: 20 pp.

(50) Thurston, L.M.
1933. Controlling the process of making sweet-curd cottage cheese. Milk Dealer. 23 (2): 36-38, 23 (3): 30-31; 23(4): 54,56,58.

(51) Thurston, L.M. and Gould, I. (Jr.)
1933. Factors governing the manufacture of sweet curd cottage cheese. Jour. Dairy Sci. 16 : 467-480.

(52) Tracy, P.H.
1931. How to make sweet curd cottage cheese. Milk Dealer. 20 (5) : 53-55.

(53) Tracy, P.H. and Ruehe, H.A.
1936. Sweet curd cottage cheese. Ill. Agr. Expt. Sta. Cir. 445. 12 pp. Fig. 6.

(54) Tracy, P.H.
1931. Cold storage of cottage cheese. Milk Dealer. 20 (5) : 55.

(55) Tretsven, W.I.
1947. Evaluation of procedures for the manufacturing of cottage cheese. Milk Plant Monthly. 36 (11): 28-30, 70, 72.

(56) Tretsven, W.I.
1947. Cottage cheese manufacture. Milk Plant Monthly. 36 (5) : 24-27,32.

(57) Van Slyke, L.L. and Price, W.V.
1949. Cheese. Orange Judd Pub. Co. Inc. New York. 382-405,431,444, 522 + Xpp.

(58) Willard,H.S.
1949. Storage of cottage cheese. Milk Plant Monthly. 38 (3): 87,92.

(59) Wilson, H.L.
1933. Quality and uniformity of cottage cheese and its practical control. Milk Plant Monthly. 22 (5) : 34,36,37,48.

(60) Wilson, H.L. and Trimble, C.S.
1931. Manufacture of low-acid rennet type cottage cheese. Milk Plant Monthly. 20(5): 27.