

YIELD AND CURD CHARACTERISTICS OF COTTAGE CHEESE MADE  
BY THE CULTURE AND DIRECT-ACID-SET METHODS

by

H. SATYANARAYAN SHARMA

B.V.Sc. & A.H. (Vet.), A. P. Agricultural University, Hyderabad, India, 1966

M. Sc. (Dairy Science), A. P. Agricultural University, Hyderabad, India, 1970

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TABLE OF CONTENTS

	<u>PAGE</u>
INTRODUCTION . . . . .	1
REVIEW OF LITERATURE . . . . .	4
<u>Development of the Direct-Acidification Method</u> . . . . .	4
Ester hydrolysis . . . . .	4
Organic and inorganic acidification . . . . .	5
Direct-acidification method . . . . .	6
<u>Yield and Curd Characteristics</u> . . . . .	7
Skim milk for cottage cheese . . . . .	7
Heat treatment . . . . .	9
Cultures for cottage cheese . . . . .	10
Direct-acidification method . . . . .	12
Psychrotrophic bacteria and yield . . . . .	12
Yield formulas . . . . .	13
<u>Properties of Cottage Cheese Curd</u> . . . . .	16
Curd size . . . . .	16
Curd fines . . . . .	17
Curd firmness (Texture) . . . . .	18
Dressing retention . . . . .	19
MATERIALS AND METHODS . . . . .	22
<u>Experimental Design</u> . . . . .	22
<u>Manufacturing Methods</u> . . . . .	22
<u>Analytical Procedures</u> . . . . .	23
RESULTS AND DISCUSSION . . . . .	24
<u>Curd Yield</u> . . . . .	24

## TABLE OF CONTENTS (cont.)

	PAGE
<u>Total Solids Recovery</u> . . . . .	29
<u>Protein Recovery</u> . . . . .	30
<u>Curd Size Distribution</u> . . . . .	30
<u>Curd Fines</u> . . . . .	31
<u>Curd Firmness</u> . . . . .	33
<u>Dressing Retention</u> . . . . .	33
CONCLUSIONS . . . . .	36
ACKNOWLEDGEMENTS . . . . .	38
REFERENCES . . . . .	39
APPENDIX . . . . .	43

## LIST OF TABLES

<u>Table</u>	<u>Description</u>	<u>page</u>
1.	Analysis of variance comparing yields and solids recovery for two methods of making cottage cheese from skim milk with three protein concentrations . . . . .	25
2.	Analysis of variance of yields between two methods of making cottage cheese at each of two protein concentrations .	28
3.	Analysis of variance comparing recovery of protein and properties of curd by the two methods and at the three protein concentrations . . . . .	32
4.	Comparison of means of nine replications for the following combination of treatments . . . . .	34

## FIGURE

### Figure

1.	Average yields of cottage cheese by culture and direct-set methods from skim milks containing three protein concentrations . . . . .	26
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## INTRODUCTION

Mabbitt et al. in 1955 (31) reviewed early attempts to make cheese by substituting acidulants for bacterial starters. They also presented procedures for manufacturing Cheddar or Cheshire type cheese using lactic, hydrochloric and gluconic acid lactone. A number of related patents followed that review. Deane and Hammond in 1960 (9) used D-glucono-delta lactone and mesolactides in manufacturing cottage cheese. These compounds slowly hydrolyze in solution to produce acids. When added to milk, they induce a characteristic coagulum while the milk remains quiescent. Hammond and Deane patented that process in 1961 (23). In 1963, Ernstrom patented a process for cottage cheese employing hydrochloric acid in place of the more expensive gluconolactone (17). Corbin (5) then developed and patented a procedure employing phosphoric acid as the initial and partial acidulating agent and D-glucono-delta lactone for the final milk acidification. This patented batch process (1971) was approved as an alternate method of manufacture in Standards of Identity, for Cottage Cheese Dry Curd (20).

An in-line acidification system similar to Corbin's patented method (Vitex 750-850 system<sup>TM</sup>) based on a modification of the Hammond-Deane patent was introduced by the Vitex/American Laboratories (21,47). This process involves continuously metering Vitex 750<sup>TM</sup>, into the cold milk instead of batch addition of the acidulant and has been accepted commercially by some plants. Gerson (22), General Manager of Vitex/American,

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Vitex 750<sup>TM</sup> - A mixture of phosphoric and lactic acids, diacetyl and artificial flavors. It is used with Vitex 850 to make cheese curd under U. S. Patent 2,982,654.

predicted that by the end of 1977, 8-10% of the cottage cheese manufactured in the U. S. would be by the direct-set method.

Use of a direct-set method that would replace starter cultures with all their inherent problems (e.g. bacteriophage, antibiotics, slow cultures, contaminant organisms, etc.) and at the same time reduce the manufacturing time by almost half indeed is attractive. However, before such a process achieves wide acceptance, it must be shown to yield a quality product and be economical.

White and Ray (49) in 1977 reported lower yields for cottage cheese made by the direct acidification method than by other methods when yields were expressed as kg curd/kg of solids, disregarding moisture content of the curd. Lower yield for the direct acidification method, however, reflected a higher total-solids curd. Although the yields were lower, solids recoveries were similar for the direct acidification and continuous fermentation methods and as high or higher than other methods when curd solids were adjusted to 20%. High solids curd reported by White and Ray does not appear to be characteristic of the direct-acid-set method and may have reflected over-cooking.

A recent study comparing the direct-set method and the culture method was particularly interesting to us because it was so similar to ours (44). It differed, however, in the following ways: we standardized protein content in the skim milk, they did not; we used in-line acidification for initial acidification of cheese milk whereas they used a batch system. In addition, we compared a number of cottage-cheese curd properties from the two methods.

Satterness et al. (44) reported no difference in yields ( $P < .05$ ) between the direct-set and culture methods with three types of milk: fresh

skim milk, fortified skim milk, and reconstituted NFDM. Some differences in results of these two studies will be considered in the Results and Discussion of this paper.

The objectives of our research were to compare yields and properties of cottage cheese obtained by the culture and the direct acidification method at each of the three protein concentrations.

## REVIEW OF LITERATURE

### Development of the Direct-Acidification Method

Success or failure of making cottage cheese by the culture method depends on the bacterial fermentation of lactose with concurrent production of lactic acid. A good quality cottage cheese is dependent upon production of sufficient lactic acid to bring about coagulation of casein in skim milk (18). Cottage cheese manufacturers, however, encounter a wide variety of problems associated with the bacterial starters, ranging from slow acid production, lack of product uniformity, low yields to vat failures, all depending on the activity of cultures. As a remedial measure, Ernstrom (18) suggested substitution of concentrated hydrochloric acid in place of bacterial-developed acidity.

### Ester hydrolysis

Mabbitt et al. (31), as early as 1955, attempted to make cheddar type cheese by substituting acidulants for bacterial cultures. They also presented procedures for manufacturing Cheddar or Cheshire-type cheese using lactic, hydrochloric and gluconic acid lactone. Gluconic acid lactone served an important function of producing acidification by ester hydrolysis and the eventual coagulation essential for good body of the cheese curd. Later in 1960, Deane and Hammond (9) tested the suitability of a number of compounds as acidogens (including anhydrides, esters, lactones and lactides) in cottage cheese manufacture. Selected acidulants had the following characteristics. They were 1) non toxic, 2) non-reactive with milk constituent and did not form toxic material or reduce the nutritive



value of the cheese, 3) soluble in milk, 4) able to produce acid at reasonable rates, 5) did not alter curd properties, 6) did not impart flavor to the finished product, and 7) were inexpensive and readily available. Among the various compounds tested, D-glucono-delta lactone and mesolactides were found suitable for cottage cheese manufacture. These compounds hydrolyze in solution to produce acids. When added to milk, they induce a characteristic coagulum while the milk remains quiescent. Cottage cheese made by this method was similar in appearance to that made by the culture method except that it had a bland flavor. Cost of the anhydrides and time required for hydrolysis were the main disadvantages with this method.

Dodson et al. (10) indicated that satisfactory cheddar cheese curd could be made by substituting D-glucono-delta lactone for lactic starters. The resulting cheddar cheese with a milling pH of 5.8 was indistinguishable from normal curd, but developed bitter and fermented flavors on curing. This defect was rectified when a selected lactobacillus strain and 10 ppm manganese were added to the cheese milk.

#### Organic and inorganic acidification

Tretsven (46), while evaluating procedures for cottage cheese manufacture, indicated that the direct addition of acids to make cottage cheese was neither economical nor feasible. In 1963, Ernstrom patented a process for cottage cheese, employing hydrochloric acid in place of bacterial cultures and expensive gluconolactone (17). The process involved addition of concentrated HCL in sufficient amounts directly to cooled milk at 6C (43F) without causing coagulation.

The cooled acidified milk, when warmed (without agitation) to about 21C (70F) or higher, formed a smooth curd suitable for making cottage

cheese. This process required a long time to heat up large commercial vats of cold acidified milk to the coagulation temperature. A continuous curd former developed by Ernstrom eliminated this problem (19). Cooled milk at 4C was acidified with HCL to approximately pH 4.6. The cold acidified milk then was introduced into the bottom of the curd former, which consisted of a series of tubes .79 cm in diameter surrounded by a heating medium. Coagulation was completed as the curd emerged from the tube. The coagulum was cut with a rotating knife. Cooking took place in a continuous cooker and the curd was washed, drained and creamed. The capacity of this process was 635 kg curd per hour from skim milk containing 9% solids.

Corbin (5) developed and patented a batch process employing phosphoric acid as the initial and partial acidulating agent and D-glucono-delta lactone for the final milk acidification. This patented batch process (1971) was approved as an alternate method of manufacture in Standards of Identity, for Cottage Cheese Dry Curd (20).

#### Direct-acidification method

An in-line acidification system similar to Corbin's patented method (Vitex 750-850<sup>TM</sup> system)\* based on a modification of the Hammond-Deane patent was introduced by the Vitex/American Laboratories (21,47). This process involved continuously metering Vitex 750<sup>TM</sup> into the cold milk instead of batch addition of the acidulants and has been accepted commercially in some plants. Gerson (22), General Manager of Vitex/American,

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Vitex 750<sup>TM</sup> - A mixture of phosphoric and lactic acids, diacetyl and artificial flavors. It is used with Vitex 850 to make cheese curd under U.S. Patent 2,982,654.

Vitex 850<sup>TM</sup> - contains Glucono-Delta-Lactone (GDL). It is used with Vitex 750 to make cheese under U.S. Patent 2,982,654.

\*For procedure, refer to Appendix.

indicated that during 1975, approximately 4½% of all the cottage cheese produced in the United States was made by Vitex/American direct-set method. Cheese made by this process won awards and honors, i. e., blue ribbons at the Illinois State Fair and honors from Food Processing magazine's "Putman Food Awards." Gerson (22) predicted that by the end of 1977, 8-10% of the cottage cheese made in the United States would be made by the direct-set method.

### Yield and Curd Characteristics

Cottage cheese yield is important to manufacturers, since it regulates profits. Consequently, processors and researchers have attempted to improve yield from the time cottage cheese became a commercial product. From a commercial point of view, curd quality is of equal importance.

#### Skim milk for cottage cheese

It is generally recognized that quality cottage cheese requires quality raw materials. Researchers have stressed that milk for making cottage cheese should be fresh, normal in composition, free from antibiotics, and other inhibitory substances, and have a relatively low bacteria count (14,43). Harper (24) investigated problems resulting from antibiotic contamination of cottage cheese milk in which acid developed normally but the milk failed to coagulate. An interaction involving the antibiotic (terramycin or aureomycin), casein and calcium resulted in loss of the antibiotic activity, as well as failure of the milk to coagulate. This interaction resulted in hydration of casein which interfered with normal milk coagulation. It was suggested that the failure of milk to coagulate could be overcome by adding rennet. Penicillin did not produce this kind of interaction.

Naturally occurring antibodies in milk agglutinate some strains of bacteria, resulting in slow acid development or sludge on the bottom of the vat and/or shattered mealy curd (15). Such defects result in poor yield or total vat failures. The following recommendations were made to alleviate the problem associated with agglutination reaction (14,15):

1. heat skim milk at 71C for 30 min;
2. homogenize skim milk at 1500/2000 psi;
3. use starters that do not agglutinate;
4. frequently renew cultures; and
5. reduce stirring of skim milk during addition of starter and rennet.

Olson (39,40) for the first time showed a quantitative relationship between skim milk solids and yield of cottage cheese curd. He showed that 39.8% of the solids in high solids milk was recovered in cheese and only 33.6% from low solids milk. In addition to this, high solid milk had other advantages: the curd was firmer at cutting time, it shattered less, and firmed rapidly during cooking. Later, Bender and Tuckey (3) observed the same trends. Since then, manufacturers began using low heat NFDM solids to fortify skim milk for cottage cheese to increase yields. Emmons (11) has reviewed the extensive use of NFDM in cottage cheese manufacture. This practice of fortifying skim milk with NFDM for greater recovery of cheese curd continued for several years, but in the late 1960's and early 1970's, the USDA changed the relative support price for butter and NFDM as a result of increased consumer demand for low-fat dairy products. Consequently, the use of NFDM to increase cheese yield was no longer profitable (33).

Among the constituents of milk, total solids and protein (especially the casein) in cheese had more effect on yield and quality of the curd (3,25,34,38,39). Yield has been related to concentration of total solids (3,39,43), casein (1,3,25,29,34), and protein (33) in the cheese milk.

Cordes (6) enumerated the following factors that affect yield: composition of skim milk as influenced by breed of cow, stage of lactation and disease of udder, moisture content of curd, and processing procedures. He indicated the importance of exact weight and volume determination of curd and milk in calculating yields. Nielson (38) also expressed concern regarding the lack of accuracy in weighing of cheese curd in many plants. He grouped the factors responsible for cheese yield into four categories:

1. cheese-making techniques (pasteurization of skim milk, setting, cutting, stirring, cooking, washing, etc.) and their influence on recovery of solid and curd fine losses;
2. moisture content of curd;
3. solids content of skim milk; and
4. protein content (casein) of skim milk.

Heat treatment. Pasteurized skim milk is used for cottage cheese manufacture (14,43). A minimum heat treatment of 72C for 15-18s or 62.8C for 30 min was recommended. Higher pasteurization temperatures required special manufacturing procedures. Morris et al (36) reported quality cottage cheese from skim milk having 6% denatured serum protein. Skim milk which contained more than 10% denatured serum protein could not be made into cottage cheese by standard procedures. Good quality cottage

cheese was made by Emmons et al. (16) from skim milk heated to 80C (175F) for 30 min by using up to 20 ml rennet per 453.6 kg (1,000 lbs) of skim milk. They reported a 10% increase in yield. Stone et al. (45) reported that skim milk standardized to 11% solids with low heat NFDM and UHT-heat treated at 113 to 158C for .02s could be used to make quality cottage cheese.

White and Ray (49) investigated the influence of different pasteurization treatments and method of acidifying cheese milk on yield. Their results indicated that heating cheese milk to 73.8C for 17s and 100C for 7.9s resulted in slightly greater yield when moisture was considered than pasteurizing at higher temperatures. Higher heat treatment, i.e., 120C and 135C, resulted in lower body and texture scores than lesser heat treatment i.e., 100C and 73.8C.

#### Cultures for cottage cheese

The main purpose of the culture in cottage cheese manufacture is to produce acid for coagulation of skim milk. Selection of good active cultures for uniform acid production is important. Emmons (11) reviewed various aspects of cottage cheese cultures from the selection to propagation and testing for activity. His review included the undesirable effects produced by certain cultures. Some cultures were reported to produce floating curd because of excess gas production; some to agglutinate and produce sediment at the bottom of the vat. This coagulum was difficult to cut and resulted in shattered, mealy curd. A few cultures produced flavor defects. Use of such cultures resulted in poor yields, and also affected curd quality. Emmons and Tuckey (14) and Emmons et al. (15) suggested steps to overcome the various problems associated with cottage

cheese cultures.

Collins (4) compared cottage cheese yields and curd characteristics of cheese made with pairs of single strain and mixed strain cultures. He obtained 1.3% more cottage cheese with single than with mixed strain cultures. He postulated the reason for increased yield was a more rapid and/or uniform coagulation, less shattering of the curd, and consequently, less loss. The resulting cheese from single strain cultures was of high quality. Experienced judges could not distinguish between batches of cottage cheese made with pairs of single strain cultures and that made with commercial mixed strain cultures.

Procedures for preparing bulk starter cultures were outlined by Sandine (43). He recommended use of 9 to 11% reconstituted skim milk, heat treated to 82-88C for 30-60 min and cooled. He suggested 1% inoculum and an incubation period of 14 to 16 h. Active cultures should produce pH 4.6 to 4.8 and a titratable acidity of .65 to .75%. If not used immediately, the starter cultures should be cooled to below 10C but not below 4C. They should be used within 24 h.

Stone et al. (45) observed 8 to 12% higher starter activity in skim milk standardized to 11% solids and in milk UHT-heat treated at 113 to 158C for .02s.

In an attempt to reduce setting time for cottage cheese manufacture, Martin and Bristol (32) employed 25% non-coagulated starters and reported a 35% saving in setting time, compared to that when coagulated culture was used. Preacidification of skim milk with citric acid along with non-coagulated starters decreased the setting time by more than half.

#### Direct-acidification method

White and Ray (49) reported lower yields for cottage cheese made by the direct acidification method than by other methods when yields were expressed as kg curd/kg of solids, disregarding moisture content of the curd. Lower yield for the direct acidification method, however, reflected a higher total solids curd. Although the yields were lower, solid recoveries were similar for the direct acidification and continuous fermentation methods and as high or higher than other methods when curd solids were adjusted to 20%. High solids curd reported (49) does not appear to be characteristic of the direct acidification method and may have reflected over-cooking.

A recent study by Satterness et al. (44) reported no difference in yield ( $p < .05$ ) between the direct-set and culture methods with three types of milk: fresh skim milk, fortified skim milk, and reconstituted NFDM. Cheese made was judged for body, texture, appearance and color. Experienced judges could not detect any difference in the quality or appearance between the curd produced by the culture and the direct acidification methods.

#### Psychrotrophic bacteria and yield

Cousin and Marth (7) observed a decrease in manufacturing time and increased curd firmness in cottage cheese made from skim milk which had been inoculated with psychrotrophic bacteria before processing. The percent yield and percent moisture of cheese made from that milk depended on length of cold storage; longer storage resulted in a decrease of both.

Mohamed and Bassette (35) investigated the effect of separation



temperature of raw skim milk containing high concentrations of psychrotrophic bacteria on cottage cheese yields and vat failures. Their results indicated vat failures occurred only when milk was separated after inoculating (incubating 24 h at 8C) with psychrotrophs. Higher separation temperatures, and higher psychrotrophic counts, increased the tendency for cheese failure. Higher yields were obtained with the direct-acid set than the culture method. Lactic cultures restricted the growth of psychrotrophic Pseudomonas fluorescens and thereby significantly retarded the decrease in yield.

#### Yield Formulas

Bender and Tuckey (3) developed the following equations for predicting cottage cheese yields based on one or more skim milk components:

$$Y = -0.45 + 5.71 \text{ CL (CL = \% casein determined by culture coagulation) . . . . . 1}$$

$$Y = -1.68 + 6.03 \text{ CF (CF = \% casein determined by formal titration) . . . . . 2}$$

$$Y = -29.72 + 4.90 \text{ Sm (Sm = \% total solids in skim milk). 3}$$

$$Y = \text{kg. of cheese/100 kg skim milk containing 80\% moisture.}$$

They concluded that equation 1 had low standard error of estimate and high degree of correlation between the casein content (determined by micro-Kjeldahl method) and yield. Equation 3 would be selected by plant operators because special equipment is not required and the total solids (Sm) determination is simple. It had a lower standard error of estimate and higher degree of correlation than equation 2.

These equations were derived from milk of normal composition within

the range of 8.92 and 9.7% total solids, therefore would not apply to reconstituted milk of 10 to 12% solids.

Kristoffersen et al. (25) examined the determination of casein by the dye method for the purposes of estimating cottage cheese yield.. Based on the casein content of skim milk (normal pasteurized) and considering the cheese contained 79% water and 17% protein (considered as casein), the actual yield could be calculated as follows where the divisor constituted the theoretical yield:

$$\text{Present actual yield} = \frac{\text{kg curd obtained}}{\frac{\text{casein}\%}{100} \times \frac{100-79}{100}} \times 100$$

kg skim x 100 x 0.97 x 17 x 100 - water % in curd

Lundstedt (29) presented tables with estimates of yields of cottage cheese curd at various moisture levels as a function of solids in skim milk. He rated 28% solids recovery as poor and 36% as excellent. Lundstedt (28) gave two formulas for calculating expected yield (y) of cottage cheese from casein content of milk:

$$Y = 6 \times \% \text{ casein (large curd)}$$

$$Y = 5.5 \times \% \text{ casein (small curd)}$$

Most of the available equations for predicting cottage cheese yield were derived from laboratory scale manufacturing data. For industry use, yield formulae need to be derived from large scale manufacturing data. Mickelsen and Dayton (34) calculated yield as kilograms of uncreamed cottage cheese containing 80% moisture per 100 kg skim milk from 46 batches of cottage cheese made in a commercial plant over 1 yr.

$$Y = -17.655 + 1.578 (\text{percent solids not fat in pasteurized skim milk}) + 7.553 (\text{percent casein})$$

$$Y = -10.994 + 5.077 (\text{percent casein}) + 4.016 (\text{percent protein in skim milk starter mixture.})$$

It is evident from the above two equations that yield was related to casein, protein, and solids not fat (SNF) content of skim milk.

In another study, cottage cheese yields as affected by the composition of skim milk, season of the year, and commercial plant practices in the Great Plains (Texas, Nebraska and Kansas) were investigated (33). Seasonal changes in the total protein content of skim milk were observed and these variations affected cottage cheese yields.

Mickelsen (33) determined the PYR (protein yield ratio)\* and recommended its use for calculating the exact kg of skim milk needed for cheese making.

Kristoffersen (25) compared the formulas developed by Bender and Tuckey and Lundstedt and showed how they differed. These formulas were reasonably accurate under the conditions they were developed, and could be used to predict yield, provided the following assumptions were met:

1. The milk was pasteurized normally.
2. The curd was adjusted to 80% moisture.
3. The casein was determined by Walker Casein Test, and in addition, adjustments were made in correction factors to allow for conditions peculiar to a particular plant.

Lundstedt (29) was of the opinion that the differences in yield were due to changes in the composition of milk. Increased milk production per cow has resulted in lower fat percentages and corresponding decreases in milk protein.

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\*protein yield ratio: kilograms of protein set divided by kilograms of protein in curd

He expressed concern over the use of formulae for predicting yields. Variation in yields (based on formula) differed because cheese makers were not alike. A good cheese maker with a perfect control of the exact amount and composition of skim milk, better control of manufacturing procedures, no dusting of curd by wash waters, could use a formula to predict yield successfully from solid or casein in skim milk if he could measure the exact amount of curd obtained and its moisture content.

According to Lundstedt (29), to obtain good yield, a cheese maker should recover 99% of the casein and 5% of the soluble components of the skim.

#### Properties of Cottage Cheese Curd

##### Curd size

Curd size determination, especially the grit value, is an important quality control measure in the cottage cheese industry. It indicates the amount of care in handling the curd during cottage cheese manufacture, i.e., while cutting the coagulum, cooking, washing, creaming and packaging.

A unique test for curd size was described by Kosikowski (26). In short, it is conducted as follows:

A carton containing 500 g uncreamed curd is emptied into a beaker with 2 l chilled water. The whole content is gently agitated for 1 min with a spatula. The curd and water mixture then is layered over the topmost of a battery of four equal-weighted, nested copper metal sieves with 12.7 mm (1/2 in), 6.35 mm (1/4 in), 3.18 mm (1/8 in) and 1.59 mm (1/16 in) wire mesh. The interlocked battery of sieves is vigorously shaken for 30 s. Each sieve with curd is separately weighed and the

weight of curd on each determined. The curd particle distribution on each sieve is reported as a percentage of the total weight of curd on the four sieves. The percentage of curd particle on the smallest mesh sieve, 1.6 mm sieve, is called "grit" or cheese dust. It represents the most important value within the distribution pattern, since it reflects shattered curd particles.

Kosikowski (26) reported that type of skim milk and size of cheese knife affect the curd size distribution. For each knife size, he observed a characteristic particle distribution pattern. Changing the (a) type of cheese milk, (b) manufacturing techniques, or (c) administration of coagulating agent, all affect the curd size distribution pattern. Under good manufacturing practices, grit values approach a constant value. A 5% grit value was considered ideal. Higher grit values are undesirable because they indicate curd shattering and loss of small curd particle in the whey and wash waters.

Some grit is always produced during cottage cheese manufacture. The major portion is contributed by mechanical creaming; hand creaming produces very little. Grit also is produced during packaging. Kosikowski (26) indicated that grit produced during various stages of cheese manufacture could be differentiated by mouth feel. Grit produced during cutting and cooking gives a rough mouth feel, whereas grit from tender curd developed during washing, creaming and packaging does not.

#### Curd fines

Curd shattering during cheese manufacture could be measured from the amount of grit produced, but the loss in yield resulting from curd fines

carried away in whey and wash waters could not be estimated by the grit test. Cross et al. (8) recently reported that loss of fines reduced cheese yields and increased pollution problems if the waste products were discharged into sewers. It was estimated that recovery of curd fines from whey and wash waters using a centrifugal separator would save \$160,000 to a plant producing 5.4 million kg of curd per year. Raab et al. (42) developed a procedure using calibrated centrifuge tubes for measuring the quantity of curd fines and subsequent loss of curd in the whey. The method developed is as follows:

Cheese curd was cooked to the desired firmness, agitation stopped and a strainer inserted into the outlet of the cheese vat. After draining, a sufficient amount of whey to remove curd trapped in the valve-outlet, 1 pint sample, was collected. A well-mixed 30 ml aliquot was transferred to a graduated conical centrifuge tube. The tube containing the whey was centrifuged 5 min at 870 rpm in a Babcock centrifuge. The volume of curd fines was read to the nearest 0.1 ml in the graduated tube. The supernatant was poured off and the dry weight of the precipitate was determined by the Mojonnier method. These weights were converted to weight of curd with 80% moisture that would be contained in 378.5 kg (100 gal) of whey. Quadruplicate determinations on seven lots of whey showed there is a direct relationship between volume of curd and weight of dry curd fines obtained.

#### Curd firmness (Texture)

Another important quality of cottage cheese curd is its texture. Emmons and Price (13) reported that curd firmness must be uniform for

optimum control of weight and fat content of creamed cottage cheese under commercial mechanized creaming and packaging operations. Lundstedt (27) designed a curd meter which enabled cheese makers to achieve a uniformly textured product. Using special equipment, Emmons and Price (12) indicated a close relationship between the curd firmness as measured by their instrument and firmness measured by organoleptic method. Man (30) investigated the suitability of Kramer Shear press for texture measurement of commercially-made cottage cheese, and the relationship between texture, moisture, and curd size. Results indicated that cheese samples from four different plants differed significantly from each other in moisture content and shear press values. A significant correlation was observed between shear press values and moisture contents of all samples, but because of high individual variation in moisture content, these values could not be used to predict individual moisture contents.

The Kramer Shear Press test procedure is as follows:

One hundred grams of curd is loaded into the standard 10-blade-shear cell and the sensitivity is adjusted to 22.7 kg (50 lb) to 45.5 kg (100 lb) for full scale recorder deflection. Results then were expressed as the maximum force required to shear the sample and reported as "shear value" in kg per 100 gram sample.

#### Dressing retention

The purpose of creaming cottage cheese is to produce a uniformly flavored and textured product with a minimum of 4% fat in the finished product. It is difficult to obtain uniform creamed cottage cheese, because of the large number of variables involved in curd structure, yield, and composition of creaming mixtures (29).

It is also a difficult problem to combine curd and dressing to meet both standards of fat and total solids. Further difficulty arises if the curd contains less than 20% total solids (41).

Solutions to these problems were suggested by Lundstedt (29) who presented tables indicating the amount of dressing with various fat percentages that could be added to 100 kg of curd to obtain a 4% fat in the finished product. Price (41) presented a simplified graphic method to accomplish the same thing.

Emmons and Price (13) observed the effect of certain variables on firmness of curd and dressing retained by creamed cottage cheese. The amount of dressing retained could be increased and curd firmness decreased by increasing the following: holding time after creaming, curd breakage, pH, and fat in the finished cheese.

Holding the dressed curd less than 5 min produced measurable changes in firmness and dressing retention. Changes in the amount of dressing retained continued throughout an observation period of 96 h. Relatively small decreases were observed in curd firmness 24 h after creaming. More dressing was retained when softer curd or curd with lower solids was used. Emmons and Price postulated that breakage of softer curd during creaming partially accounted for the relationship among dressing retention, curd firmness, and total solids. They demonstrated experimentally that broken curd had the capacity to hold more dressing.

Adjustment of curd pH by adding acid or base to the dressing before creaming the curd influenced dressing retention but in different ways. For example, adding acid (lactic acid) increased the viscosity of dressing so that it adhered better to the curd. Increasing pH by adding base decreased curd firmness with more dressing retained.



Increasing fat in the dressed cheese from 4.5 to 6.0% by adding more dressing (with the same fat content) increased the amount of dressing retained. Increasing the fat content of the dressing used to dress the curd from 12 to 18%, increased the percent dressing retained when curd was dressed to either 4.5 or 6.0% fat. The curd dressed with higher concentrations of fat also was firmer. In addition, the following observations also were reported (13):

Dressed curd with 1 and 2% added salt retained a maximum amount of dressing and demonstrated a minimum curd firmness. Temperature at which creamed curd was held did not affect the amount of dressing retained, but high storage temperatures, 10C-21C (50F-70F), decreased curd firmness. There was little affect on firmness between 1.1C-10C (30F-50F).

Increasing homogenization pressure increased viscosity, and use of stabilizers increased thickness and body of the dressing. Both increased dressing retention, i.e., more dressing adhered to the curd.

It was concluded that two separate mechanisms were involved in dressing retention by the curd: one was absorption of serum from the dressing by the curd, and the other was the physical clinging of dressing to the curd.

## MATERIALS AND METHODS

### Experimental Design

Raw skim milk with 3.1 or 3.5 or 3.9  $\pm$  .1% protein was pasteurized, divided into two lots, and manufactured into cottage cheese by the culture and direct-acid methods on the same day. Nine replicate pairs of each skim milk-protein concentration were made into cottage cheese over 2-3 months and the two methods compared for yields and curd characteristics.

### Manufacturing Methods

Milk for the 3.1% protein concentration was collected from the University Dairy Herd. The 3.5 and 3.9  $\pm$  .1% protein milks were obtained by blending University herd and a local Guernsey herd-milk. Milk was separated and pasteurized (72.5C/16 s) in the University Dairy plant on the day received, held at 2-5C, and made into cottage cheese the next day. Two cheese vats used were 378.5-1 (100 gal) and 757-1 (200 gal) capacity and were alternated throughout the study for the two methods.

Culture cottage cheese was made by the short-set method using 5% Hansen's culture #56. Rennet was added at the rate of 5.8ml/100kg of skim milk set and curd cut according to a positive AC test at about pH 4.7. Cooking procedures were essentially as described by Emmons and Tuckey (14). Draining of the curd after the second wash was terminated when the drain rate reached 1 ml/3.78 l of skim milk set. After they were thoroughly mixed, samples of curd were collected for analysis and further testing (solids, protein, curd size, firmness and dressing retention).

Direct-acid cottage cheese was made according to Vitex/American

procedures (47) which consisted of adding a prepared food-grade acid mixture, Vitex 750<sup>TM</sup>, through an in-line mixer directly to 2-5C skim milk to adjust the pH to  $5.1 \pm .15$ ; heating the milk to 32C and adding a measured amount (based on the pH and weight of milk) of D-glucono-delta lactone (GDL) Vitex 850<sup>TM</sup> and a coagulator (13ml/100kg skim milk); mixing the acidified milk thoroughly before allowing it to remain at 32C for 1-hr in a quiescent state; and adding sufficient Vitex 750<sup>TM</sup> to adjust the pH to 4.5 after cutting the curd. Cooking, draining, and sampling were the same as with the culture method.

#### Analytical Procedures

Skim milk was measured by volume in the vats and curd was weighed on the creamery scales. Solids were determined gravimetrically (33); both total protein and casein were determined by AOAC methods (2). Curd size was measured by the method of Kosikowski (26), curd fines by the method of Raab et al. (42), and dressing retention by a modification of the method of Emmons and Price (13). This modification involved first adjusting curd to 20% solids and dressing 100g curd with measured amounts of 14% fat-dressing containing sufficient salt to give 1% in the final product. After mixing the salted dressing and curd, and storing it in a closed carton 5C for 24 h, it was remixed and transferred to a circular 8-mesh screen placed horizontally in a 15 cm funnel to hold the cheese. Sheets of aluminum foil were used to cover the curd to minimize drying while collecting dressing that drained into tared 100ml cylinders. After 30 min, the cylinders were reweighed and amounts of dressing retained calculated by difference.

## RESULTS AND DISCUSSION

### Curd Yields

The direct-set method of making cottage cheese produced higher average-mean yields than the culture method ( $P < .001$ ) when expressed as kg curd/100 kg skim milk, or as kg curd/kg of protein, or kg curd/kg of casein, or when expressed as kg curd/kg of total solids (see Table 1).

Increasing the protein concentration in the skim milk (3.1, 3.5, 3.9%) increased yields ( $P < .001$ ) when based on 100 kg of skim milk and means of the two methods were combined. When comparing yields as kg of curd per kg protein or kg total solids, yield-means from the 3.5 and 3.9% protein skim milk were not different ( $P < .01$ ); however, the yield from 3.1% protein skim milk was lower (Table 1). There were no differences in yields at the three protein concentration when based on kg curd/kg casein; this merely reflected the correlation between casein and yield of cottage cheese. Individual average yields for both methods and each concentration of protein are presented in Table 4.

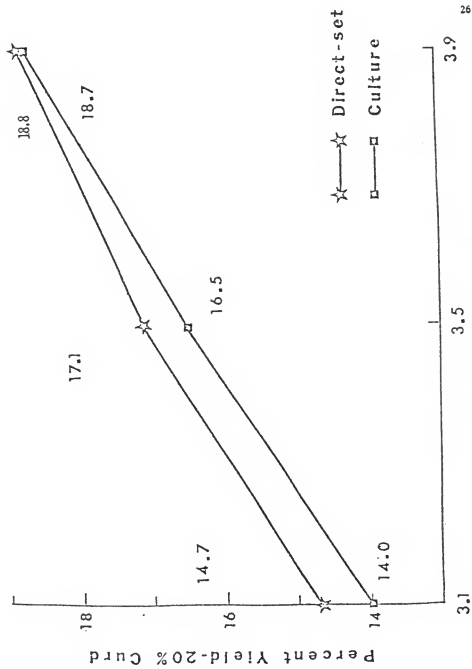
Fig. 1 illustrates the effect of method and skim milk-protein concentration on yield. The nearly parallel lines of the two methods between 3.1 and 3.5% protein in the figure represents a similar rate of increase in curd yield for the two methods from increased protein concentrations in the skim milk. The direct-set method shows approximately 5% greater yield than the culture method for normal mixed herd milk (3.1 or 3.5% protein). We have no explanation at this time for the convergence of the lines representing loss in advantage of yield in the high-protein (3.9%) milk. However, from a practical point of view, this is of little consequence with today's milk supply.

Table 1. Analysis of variance comparing yields and solids recovery for two methods of making cottage cheese from skim milk with three protein concentrations.

Source of variation	Curd recovered			Solids recovered in					
	100 kg of df skim milk	kg of protein	kg of casein	per kg of solids	wh $\bar{y}$	1st wash	2nd wash	curd	
Method	1	2.58***	.210***	.465***	.0315***	312.2***	159.412***	18.680***	11.612***
Method & Protein	2	.52	.037	.110*	.0064*	39.5	14.332	.611	2.442
Residual	24	.16	.015	.021	.0017	13.4	6.117	1.394	.807
Mean squares									
Protein	2	86.36***	.268**	.014	.3736***	231.6***	.728	1.816	151.701***
Rep/prot.	24	.68	.045	.070	.0061	17.5	12.674	2.282	2.569
METHOD									
Culture	16	407	4.681	6.230	1.765	45.167	9.349	4.731	35.339
Direct-set	16	844	4.805	6.416	1.813	49.976	12.785	5.908	36.267
PROTEIN									
3-1	14	361	4.603	6.299a	1.635	51.675	11.028a	5.623a	32.695
3-5	16	783	4.810a	6.354a	1.810a	46.011	11.284a	4.989a	36.269
3-9	18	733	4.818a	6.316a	1.921a	45.029	10.889a	5.347a	38.445

\* Significant at 5%  
 \*\* Significant at 1%  
 \*\*\* 0.1%

<sup>1</sup> Means not significantly different at the 1% level are joined by a common letter.



### Percent Protein

Fig. 1. Average yields of cottage cheese by culture and direct-acid methods from skim milks containing three protein concentrations.

In comparing yields by the two methods and at protein concentrations of 3.1 and 3.5%, differences are more distinct (Table 2). The direct-set method produced higher yields ( $P < .001$ ) for all four methods of expressing yields. Those from 3.5% protein-skim milk were higher ( $P < .001$ ) than from 3.1% protein except when expressed as kg curd/kg casein. Again, this is not surprising when one recognizes the relationship of casein to cottage cheese curd. The method x protein interaction that was observed with the three protein concentrations (Table 1) disappeared when only the two protein concentrations (Table 2) were considered.

Satterness et al. (44), in comparing cottage cheese yields between the culture and direct-set methods from fresh skim milk containing an average 3.04% protein, reported no difference ( $P < .05$ ) due to method. The yield differences ( $P < .001$ ) between these two methods observed by us from skim milk containing  $3.1 \pm .1\%$  protein reflect less variability among replicates in our laboratory. It is interesting that differences between the yield-means by the two methods in both of these studies were remarkably similar. Our yields expressed as kg of curd/100 kg of skim milk were 14.04 vs. 14.68 for culture and direct-set, and theirs were 15.25 vs. 15.94. Our differences between methods was .64 and theirs .69, both in favor of the direct-set method.

Factors reducing our variations were protein standardization and in-line acidification of the skim milk. Since it is well established that protein concentrations in skim milk contribute to cottage cheese yields, we standardized milk into three groups: 3.1, 3.5, and  $3.9 \pm .1\%$  protein. In-line acidification, in which the initial acidulating agent is metered into the milk at a constant rate, is an improvement over the

Table 2. Analysis of variance of yields between two methods of making cottage cheese at each of two protein concentrations.

Source of variation	d.f.	Curd recovered			
		100 kg of skim milk	kg of protein	kg of casein	kg of solids
		per			
		kg			
		Mean square			
Methods	1	3.61***	.283***	.672***	.044***
Methods x protein	1	.00	.000	.012	.000
Residual	16	.100	.014	.017	.001
Protein	1	52.80***	.386***	.027	.273***
Rep/protein	16	.330	.018	.043	.002
METHODS		Means <sup>1</sup>			
Culture		15.25	4.62	6.19	1.688
Direct-set		15.89	4.79	6.46	1.758
PROTEIN					
3.1		14.36	4.60	6.30a	1.635
3.5		16.78	4.81	6.35a	1.810

\* Significance at 5%

\*\* Significance at 1%

\*\*\* Significance at 0.1%

<sup>1</sup>Means not significantly different at the 1% level are joined by a common letter.



batch addition of acid and probably reduces variability. Certainly, the relatively large volume of milk we set, 380 kg, tended to reduce variations due to small errors in measurements. These factors contributed to precision and the small variability among our replicates.

The high fat content in skim milk used by Satterness et al. (44) resulted in an excess fat recovery in the curd. This contributed to 1-2% higher yields for both methods from fresh or fortified skim milk. Fat in the cheese curd was 1.68-2.46%, whereas one should expect the fat content of uncreamed curd to be less than 0.4% (48) from efficiently skimmed cheese milk.

#### Total Solids Recovery

A total solids and protein accountability study was designed to help us explain difference in yields. The contribution of added acids, Vitex 750<sup>TM</sup> and Vitex 850<sup>TM</sup> (GDL), which contributed to the solids in the whey and wash waters but probably only to a small degree to the curd, complicated interpretation of these data. Table 1 presents the solids recovery data without including GDL as part of the milk total solids used. Partial accountability was made for the Vitex 750<sup>TM</sup> since the volume measurement employed in the vat included the added liquid acid. The greater than 100% recovery of solids in direct-set whey and wash waters (Table 1) and to a much lesser extent in the curd reflects these added acidulants. Milk solids both with and without GDL solids were used to calculate the distribution of total solids into whey, wash waters and curd, and are shown in Table 4. When GDL was considered as part of the milk solids entering the vat, calculated total solids distributed in the whey, wash waters and curd were lower.

Table 1 shows that more milk solids were recovered in the curd by the direct-acid method than by the culture method ( $P < .001$ ). This probably reflected less loss of protein in the whey by the direct-acid set method (Table 3). Differences in solids recovered in the curd was greater from 3.1 and 3.5% protein skim milk than 3.9% (see curd less GDL, Table 4).

Increasing the protein in the skim milk (3.1, 3.5, and 3.9%) resulted in lower solids losses in the whey and a simultaneous increased recovery in the curd when means for two methods were combined ( $P < .001$ ). Total solids lost in the first and second wash were not different ( $P < .01$ ) at each protein concentration.

#### Protein Recovery

Results of protein accountability are presented in Table 3. Protein recoveries distributed among wash waters and curd by the two methods and for the three protein levels were not significantly different ( $P < .01$ ). However, more was lost in the whey by the culture than the direct-set method ( $P < .05$ ). Increasing protein in the skim milk (3.1-3.5%) reduced protein losses in the whey ( $P < .01$ ) when means for the two methods were combined. However, that lost in the whey was not different when the protein level was further increased to 3.9%.

#### Curd Size Distribution

Curd size distribution for each protein concentration and the two methods for cheese-making are shown in Table 4 and results of the statistical analysis for the large and small curd particles (e.g. those retained on 12.7 mm (1/2") and 1.4 mm (1/18") sieve, combined) is presented in

Table 3. Those particle sizes were considered because they indicate problems associated with cheese manufacture. Small curd particles deposited on 1.4 mm sieve are called "grit." A high grit value is undesirable in cottage cheese because it indicates curd shattering and can lead to poor yields (8). Particles retained on 12.7 mm sieve indicate matting which was more prevalent for the culture than the direct-set method. A combination of curd particle sizes distributed on 12.7 mm + 1.4 mm (1/2" + 1/18") was chosen because matting may be associated with shattering (resulting from excessive agitation necessary to break lumpy curd). Table 3 shows more large and small curds from the culture (8.09) than the direct-acid method (5.8)  $P < .05$ . Since cheese milk for both methods was identical, and the personnel involved in making the cheese were the same, the difference in the curd particle size observed were assumed to be due to the method. Lower means values for the combined particle size 12.7 mm + 1.4 mm for the direct-acid method ( $P < .01$ ) indicate more uniform curd size. Increasing the percent protein in the skim milk (3.1, 3.5, 3.9%) did not affect the combined curd particle size distribution significantly when the means for the two methods were combined ( $P < .01$ ).

#### Curd Fines

The average yield losses as curd fines for the two methods of making cottage cheese and for three protein concentrations in the skim milk are presented in Table 4. Analysis of variance (Table 3) showed that neither the protein concentration in skim milk nor the method of making cheese had any effect on losses from curd fines in whey and wash waters. Although mean values increased with the increases in protein concentrations, the

Table 3. Analysis of variance comparing recovery of protein and properties of curd by the two methods and at the three protein concentrations.

Source of variation	d.f.	whey	Protein recovered in		curd	Mean squares		
			1st wash	2nd wash		size <sup>1</sup>	Curd properties <sup>2</sup> fines <sup>2</sup>	firmness <sup>3</sup>
Method	1	10.1*	2.003	.254	3.894	68.07**	.002	$3.8 \times 10^2$
Methods x protein	2	5.6	.987	.189	2.321	5.698	.130	$1.2 \times 10^{3*}$
Residual	24	1.8	.635	.281	3.943	8.532	.057	$2.9 \times 10^2$
-----								
Protein	2	26.7**	.067	.859	15.950	12.72	.197	$1.9 \times 10^{4**}$
Rep/protein	24	2.7	1.422	.333	6.601	7.160	.111	$1.7 \times 10^3$
-----								
METHODS								
Culture		15.90	3.296a	1.915a	77.989a	8.09	.621a	94.4a
Direct-set		15.04	3.681a	1.778a	78.526a	5.85	.632a	99.7a
-----								
PROTEIN								
3.1		16.85	3.550a	2.017a	77.517a	6.70a	.507a	135.2
3.5		15.01a	3.428a	1.600a	77.939a	6.30a	.704a	76.6a
3.9		14.55a	3.489a	1.922a	79.317a	7.92a	.668a	79.3a

\*Significance at 5%

\*\*Significance at 1%

<sup>1</sup>Curd retained by 12.7 mm + 1.4 mm sieves.

<sup>2</sup>Whey and 1st + 2nd wash fines. Percent yield lost as curd fines.

<sup>3</sup>Curd firmness = shear value, kg per 100g curd.

<sup>4</sup>Means not significantly different at the 1% level are joined by a common letter.

differences were not significant ( $P < .05$ ). Losses of curd fines in the whey and wash waters in this study are lower than those reported by Cross et al. (8) and Satterness et al. (44).

#### Curd Firmness

No statistically significant difference was found between the mean-curd firmness of cottage cheese made by the culture and direct-set methods using three protein concentrations in the skim milk. The combined mean for the culture and direct-set methods utilizing 3.1% protein in the skim milk was significantly firmer ( $P < .01$ ), compared to the means obtained using 3.5 or 3.9% protein skim milk. Increasing protein of cheese-skim milk (3.5 and 3.9%) decreased firmness, although differences at 3.5 and 3.9% were not significant.

#### Dressing Retention

Results of the dressing retained by culture and direct acid curd are presented in Table 4. The analysis of variance showed that protein concentration had no effect on the amount of dressing retained by the curd. Only curd made by the direct-set method from 3.1% protein-skim milk retained more dressing ( $P < .05$ ) when 1.25 times the normal amount (44g of 14% fat dressing/100g curd) was used. There were no differences in the amount retained at normal, or 1.5 and 2.0 times the normal level ( $P < .05$ ).

Table 4. Comparison of means of nine replications for the following combination of treatments.

	3.1% Protein		3.5% Protein		3.9% Protein	
	Culture	Direct-set	Culture	Direct-set	Culture	Direct-set
YIELD						
1. Kg curd/100kg skim milk	14.044	14.678	16.467	17.100	18.711	18.755
2. Kg curd/kg protein	4.517	4.689	4.719	4.901	4.808	4.828
3. Kg curd/kg casein	6.144	6.454	6.235	6.472	6.310	6.520
4. Kg curd/kg T.S.	1.599	1.672	1.776	1.844	1.919	1.924
TOTAL SOLIDS DISTRIBUTION						
1. Whey + GDL <sub>1</sub>	49.922	53.427	44.650	47.372	40.928	49.129
Less-GDL <sub>1</sub>	"	49.500	"	44.568	"	44.780
2. 1st wash + GDL <sub>2</sub>	8.798	13.258	9.047	13.521	10.200	11.576
Less-GDL <sub>1</sub>	"	12.272	"	12.027	"	10.636
3. 2nd wash + GDL <sub>2</sub>	4.843	6.402	4.415	5.563	4.935	5.758
Less-GDL <sub>1</sub>	"	5.933	"	5.151	"	5.255
4. Curd + GDL <sub>1</sub>	31.937	33.452	35.686	36.852	38.394	38.495
Less-GDL <sub>1</sub>	"	30.982	"	34.222	"	34.443

Table 4 cont.

	<u>3.1% Protein</u>		<u>3.5% Protein</u>		<u>3.9% Protein</u>	
	Culture	Direct-set	Culture	Direct-set	Culture	Direct-set
<b>PROTEIN DISTRIBUTION</b>						
1. Whey	17.844	15.856	15.433	14.589	14.433	14.667
2. 1st wash	3.222	3.878	3.100	3.755	3.567	3.411
3. 2nd wash	2.111	1.922	1.556	1.644	2.078	1.767
4. Curd	77.111	77.922	77.400	78.478	79.455	79.178
<b>CURD SIZE DISTRIBUTION</b>						
1. 1.4 mm (1/18")	5.262	4.033	3.133	2.619	3.722	3.121
2. 2.83 mm (1/9")	67.501	67.908	55.233	56.902	52.209	60.357
3. 6.35 mm (1/4")	25.039	26.143	37.607	37.649	37.441	33.497
4. 12.7 mm (1/2")	2.179	1.907	4.024	2.832	5.963	3.026
164 1.4 + 12.7 mm	7.441	5.950	7.158	5.451	9.686	6.147
<b>LOSSES AS CURD FINES</b>						
	.529	.485	.602	.807	.732	.605
<b>CURD FIRMINESS*</b>						
	140.4	130.0	74.2	78.9	68.5	90.1
<b>DRESSING RETENTION</b>						
Normal**	84.4	92.0	-	-	-	-
1.25 x Normal	73.2	90.5	-	-	-	-
1.5 x Normal	-	-	86.7	89.2	81.8	75.8
2 x Normal	-	-	68.8	65.6	64.7	61.

\* Curd Firmness = shear value, kg/100g curd.

\*\* Normal = 44 grams dressing/100 grams curd.

## CONCLUSIONS

1. Highly significant differences were observed in yield between the culture and direct-acid-set method of making cottage cheese ( $P < .001$ ) when all the three protein concentrations were considered. There was approximately a 5% increase in yield of curd by the direct-set method when cheese was made from skim milk containing 3.1 or 3.5% protein. This yield advantage dropped to less than 1% when it was made from 3.9% protein skim milk.

2. More milk solids were recovered in the curd by the direct-set method than by the culture method ( $P < .001$ ).

3. Mean values for the protein recovered in the curd by the direct-set method were slightly higher than those by the culture method, although not significantly different ( $P < .01$ ). More protein was lost in the whey by the culture method than the direct-set method ( $P < .05$ ).

4. No statistically significant difference was found between the mean-curd firmness of cottage cheese made by the culture and direct-set methods using three protein concentrations in the skim milk. The combined means for the culture and direct-set methods utilizing 3.1% protein in the skim milk were significantly firmer ( $P < .01$ ) compared to the means obtained using 3.5 or 3.9% protein skim milk. Increasing protein of cheese-skim milk (3.5 and 3.9%) decreased firmness, although differences at 3.5 and 3.9% were not significant.

5. Direct-set curd was more uniform with less small and large curd particles ( $P < .01$ ); however, there were no differences attributed to differences in skim milk protein.

6. Yield lost as curd fines was not different between the two methods ( $P < .01$ ) or between the three protein concentrations.



7. Direct-set curd retained more dressing ( $P < .01$ ) than culture curd only when made from 3.1% protein skim milk and 1.25 times the normal amount of dressing was used.

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APPENDIX

VITEX/AMERICAN  
IN-LINE COTTAGE CHEESE ACIDIFICATION SYSTEM

-INSTRUCTIONS-

VITEX/AMERICAN  
DIAMOND SHAMROCK CORPORATION  
10616 TRENTON AVENUE  
ST. LOUIS, MISSOURI 63132  
(314)-426-2611



## IN-LINE OPERATING INSTRUCTIONS

1. Install in-line mixer at most convenient place between source of milk and cheese vat, making sure it has been sanitized.
2. Place drums of Vitex 750 near in-line mixer.
  - A. Use two full drums when possible, putting both on line.
3. Hook up metering pump to the drums of Vitex 750.
  - A. Be sure all connections are air-tight.
  - B. Set metering pump by micrometer gauge to proper flow.
  - C. Prime metering pump.
  - D. Hook up discharge line from metering pump to in-line mixer.
4. Start milk through the pipes at 40<sup>o</sup> - 55<sup>o</sup> F. and immediately start Vitex 750 metering pump.
  - A. Be sure temperature of milk does not exceed 55<sup>o</sup> F. while metering in Vitex 750.
  - B. Always turn off metering pump when milk flow stops; on installations containing automatic pressure switches, the metering pump will be automatically controlled.
5. Measure pH milk on discharge side of in-line mixer, being sure to set compensator on pH meter to convert fahrenheit temperature reading to centigrade.
  - A. pH should be 4.95 - 5.00.
  - B. pH measurement should be made at least twice at beginning of filling of each vat, or until proper pH is reached.
6. Check the titratable acidity; this reading will vary with solids.
7. Start filling vat jacket with water when entire bottom of vat is covered with milk. Turn jacket water pump on when jacket is full.
8. Hook up stirring paddles; start agitation when milk reaches paddles.
9. Begin heating milk to 90<sup>o</sup> F.
  - A. Maintain about 20<sup>o</sup> differential between heat of jacket discharge water and milk in vat. Never more than 25<sup>o</sup> F. Condition of vat will dictate temperature differential.

IN-LINE OPERATING INSTRUCTIONS

10. When temperature of milk has reached approximately 80° F., take pH reading.
- A. This will give you the final equilibrated pH of skim. The desired pH range at this time 5.05 - 5.15.
  - B. Should the final pH of skim milk not be between 5.05 and 5.15, use the levels of Vitex 850 setting powder given in the chart below.

<u>pH</u>	<u>Vitex 850/100 gal. skim milk</u>
5.00 -- 5.05 . . . . .	3.25 lbs.
5.05 -- 5.15 . . . . .	3.50 lbs.
5.15 -- 5.20 . . . . .	4.00 lbs.
5.20 -- 5.25 . . . . .	4.50 lbs.
5.25 -- 5.30 . . . . .	5.00 lbs.
5.30 -- 5.40 . . . . .	6.00 lbs.

11. At 88° - 90°F. milk temperature:
- A. Turn off steam.
  - B. Add Vitex 850 and Vitex Coagulator (per instructions below).
    - 1. Vitex Coagulator
      - Small curd - 1.75 fl. oz. per 100 gal. skim
      - Large curd - 2.75 fl. oz. per 100 gal. skim
    - 2. Vitex 850 per instructions in #10.
    - 3. Mix Vitex 850 powder and Vitex Coagulator into cold water (up to 30 lbs. powder mixes well into 5 gal. water). Use 10 gal. milk can.

CAUTION: DO NOT USE HOT WATER.
    - 4. Distribute mixture immediately. Do not hold. Mix in well.

NOTE: Rinse cans with clear water after each use.
    - 5. Continue agitation for 6 minutes.

IN-LINE OPERATING INSTRUCTIONS

6. Stop agitator and remove paddles.
7. Turn off jacket water pump.
12. Cut at 1 hour  $\pm$  5 minutes.
  - A. Whey pH at cutting should be 4.7 with allowable variance of  $\pm$  .05.
13. Add 3 oz. Vitex 750 per 100 gal. skim.
  - A. After thorough agitation pH of whey should have adjusted to 4.4 - 4.5.
14. Cook in usual manner.

YIELD AND CURD CHARACTERISTICS OF COTTAGE CHEESE MADE  
BY THE CULTURE AND DIRECT-ACID-SET METHODS

by

H. SATYANARAYAN SHARMA

B.V.Sc. & A.H. (Vet.), A.P. Agricultural University, Hyderabad, India, 1966  
M.Sc. (Dairy Science), A.P. Agricultural University, Hyderabad, India, 1970

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the  
requirements for the degree

MASTER OF SCIENCE

FOOD SCIENCE

Department of Animal Sciences & Industry

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1978

## ABSTRACT

Yield and curd characteristics of cottage cheese made by the short-set culture and direct-acid set methods were compared using three skim milk protein concentrations, 3.1, 3.5, and 3.9  $\pm$  .1%. For each method of manufacture, approximately 380 kg of the same skim milk was set per experimental vat. Representative samples of whey, wash waters and curd were collected for analysis and the total quantities of whey, wash water and curd were measured carefully. Recovery of solids and protein in whey, wash water and curd from those in the milk were related to yields for each method. The same curd samples also were used for curd size distribution, curd firmness and dressing retention.

Analysis of variance showed highly significant differences in yield between the two methods when all the three protein concentrations were considered. There was approximately a 5% increase in yield of curd by the direct acid method when made from skim milk containing 3.1 or 3.5% protein. This yield advantage dropped to less than 1% when cheese was made from 3.9% protein skim milk. No statistically significant difference was found between the mean-curd firmness of cottage cheese made by the culture and direct-set methods using three protein concentrations in the skim milk. Direct-acid curd was more uniform with less small and large curd particles. It retained dressing better only when made from 3.1% protein skim milk and 1.25 times the normal amount of dressing was used.