5-1973

Some Factors Affecting the Body and Texture of Direct Acid Cottage Cheese

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SOME FACTORS AFFECTING THE BODY AND TEXTURE OF DIRECT ACID COTTAGE CHEESE

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Nutrition and Food Sciences

Approved:

UTAH STATE UNIVERSITY

Logan, Utah

1973

ACKNOWLEDGEMENT

I am indebted to Dr. C.A. Ernstrom for his helpful suggestions and guidance throughout this work. I want to express my deep appreciation and gratitude to him.

In gratitude, I acknowledge the help of my committee members, Dr. G.H. Richardson and Prof. P.B. Larsen, who shared their time, experience, and training. I extend my thanks to Dr. V.T. Mendenhall for his encouragement.

I give appreciation to Dr. N.R. Gandhi, Dr. R.V. Chaudhari, Dr. G.Y. Vahora, and my other friends who shared their companionship, criticism, and encouragement.

I bestow heartfelt thanks upon my late father who gave me life, love, and the opportunity to further my education. Without his exemplary life, I wouldn't have reached my goals.

Finally, I am particularly grateful to my mother for her moral and spiritual support and her patience. I extend courage and strength to my brother and thank him for sharing family responsibilities.

Chandarrao G. Kale

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SOME FACTORS AFFECTING THE BODY AND TEXTURE OF DIRECT ACID COTTAGE CHEESE

ABSTRACT

by

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Utah State University, 1973

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Department: Nutrition and Food Sciences

Four lots of Cottage cheese were made from the same pasteurized skimmilk; three lots by a direct acid procedure, and a fourth control lot by a conventional culture method. Direct acid curd was formed by cooling the skimmilk to 4C, acidifying to pH 4.6 with concentrated HCl, and warming by electrical resistance to 32C without agitation. Prior to acidification, the three direct-acid lots were treated as follows: 1- No culture, 2- 5% lactic culture added and the pH allowed to reach 6.0, 3- Same as 2 except the pH was allowed to reach 5.5. The control lot was set at 32C with 5% lactic culture, and cut at the A-C end point. All lots were cut with 6.35 mm knives, cooked to 62C in 120 min, washed, drained and creamed. Growth of lactic streptococci in skimmilk prior to making direct-acid Cottage cheese increased the non-protein nitrogen in the milk, increased the firmness and moisture content of the uncreamed curd, and significantly improved the meatiness and body and texture scores of the creamed Cottage cheese. Addition of calcium chloride, disodium phosphate, and sodium citrate to Cottage cheese milk did not improve the body and texture of direct acid Cottage cheese.

(45 pages)

INTRODUCTION

Cottage cheese, historically a popular food of Central Europe, was made in farmhouses, and colonial America adopted the cheese-making practice in its cottages. This gave the cheese its present name. Modern industrial Cottage cheese making originated in the United States 50 years ago. Creamed Cottage cheese with a soft, meaty body, has become a food staple of this country (24).

Cottage cheese is usually formed when lactic acid organisms produce enough acid from the fermentation of lactose to cause coagulation of casein in skimmilk (20). It is a soft, unripened, white cheese to which cream and salt are eventually added. Its flavor may range from bland to high acid. The Untied States requires that creamed Cottage cheese contain 4% fat and not more than 80% moisture (34). Standards now permit a partially creamed Cottage cheese containing at least 2% fat (18).

Fermentation of lactose is the source of many of the problems in Cottage cheese making. Variations in the behavior of microorganisms makes the process subject to such problems as dead vats, slow vats, and lack of product uniformity. A suggested solution to these problems may be the elimination of starter and use of non-bacteriological agents for acidifying Cottage cheese milk (20).

Recent investigations have shown that the Cottage cheese prepared by direct acidification was acceptable to the consumer, but was a little softer and more mealy than the cheese made with cultures (5,25,40).

The use of direct acidification for Cottage cheese making is based on the assumption that acid production is the only important function performed by starter organisms. Consistent differences, even though slight, between the body and texture of conventional and direct acid curd prompted this study to look for effects produced by starter organisms other than those due to acid production. Even though the lactic streptococci are not highly proteolytic, several workers (1,42,57,61,62,63) have shown that proteases are produced by these organisms.

REVIEW OF LITERATURE

Cheese making by nonbacteriological methods.

One of the vital steps in the manufacture of many varieties of cheese is the development of lactic acid by a lactic starter culture. This step is also the source of many problems. The use of microorganisms for this purpose necessarily imposes certain limitations on the conditions that may be employed. The activity of cultures must be maintained, temperatures must be controlled during the process to obtain the desired rate of acid production, and the presence of inhibitory agents must be avoided (11). In an effort to avoid these difficulties various investigators (7,8,13,20,30,37,48,52) have attempted to bring about acidification and coagulation by the direct addition of various acids to the milk. The two general approaches in starterless cheese making have been: a) the use of chemicals that hydrolyse in an aqueous system to produce an acid and b) the direct addition of acid.

Ester hydrolysis. Mabbit et al. (37) combined the two approaches by using hydrochloric acid in combination with D-glucoco-delta-lactone in Cheddar cheese making. They added only enough acid to skimmilk to reduce the pH to 5.8 or 6.4. Additional D-glucono-delta-lactone was added to the milled curd before pressing. The final pH of the curd was 5.18. Their cheese was nearly identical with Cheddar cheese but had a crumbly body and an atypical acid flavor.

Deane and Hammond (11) used D-glucoco-delta-lactone and meso-lactide as the only source of acid for Cottage cheese manufacture. They selected acidulants which best met the following characteristics; i) non-toxic; ii) not reactive with milk constituents tc form toxic products or affect the nutritive value of milk; iii) soluble in milk; iv) produced acid at a reasonable rate; v) did not alter curd properties; vi) did not impart unnatural flavors to the cheese; vii) readily available and inexpensive. D-glucono-delta-lactone, which hydrolysed to form a D-gluconic acid, was most soluble; but had the disadvantages of a slow rate of hydrolysis and high cost. Meso-lactide hydrolysed to lactyl-lactic acid, but had to be highly purified and finely divided to dissolve fast enough for practical use.

Cottage cheese was manufactured by using either the lactone or lactide as the sole acidulant. The lactone required 15 hr at 20C to coagulate milk, while the lactide took 2 hr at 25C. Coagulation times were reduced by raising the temperature, but setting the milk at temperatures above 37C, produced a stringy curd that was subject to matting. Calcium chloride was added to aid whey expulsion and curd formation. Cottage cheese produced by this method had a bland flavor. These results were confirmed by Hammond and Deane (27) in pilot plant trials and a patent for the process was issued in 1961.

D-glucono-delta-lactone has also been used in the manufacture of Cheddar cheese. Lactone Cheddar cheese curd made with a milling pH of 5.8 was difficult to distinguish from normal curd, but bitter and fermented flavors developed during curing (13). By adding selected

species of Lactobacilli and 10 ppm manganese to the cheese milk, a good flavored cheese was made which ripened faster than normal.

A similar process (without added manganese or bacteria, but with the addition of citric acid and starter distillate) has been employed to produce a sour cream-like product (12).

Organic or inorganic acidification: As early as 1909 substitution of hydrochloric acid for bacterial fermentation in Cottage cheese making was attempted by Van Slyke and Publow (59) with no success. Hucker and Marquardt (30) reported the manufacture of satisfactory Cheddar cheese from raw milk by using lactic acid in place of starter. Their success may have been due in part to the initial population of natural flora in the milk.

Tretsven (56) mentioned that direct addition of acid for Cottage cheese making seemed neither practical nor commercially feasible.

Sammis (49) observed that the quantity of any acid required to curdle milk varies markedly with the temperature. Acid required to coagulate a given sample of milk was less at high temperature than at low temperature. Spiess and Hollis (54) in a modification of a continuous cheese making procedure, stipulated that addition of acid to a stream of milk at 0 to 4.4C to a pH of 4.4 to 4.8 was possible, but no experimental evidence was given.

As early as 1954 Ernstrom (20) noted that concentrated lactic or hydrochloric acid could be added to skimmilk below 4C without causing localized coagulation. Further experiments showed that good Cottage cheese curd could be made by adding concentrated acid to cold skimmilk at 4C or less, agitating immediately to insure complete mixing,

and warming the acidified skimmilk with electrical resistance while maintaining it in a quiescent condition.

McNurlin (39) produced a good quality Cottage cheese curd by adding concentrated acid to cold skimmilk at a temperature of 4C, and warming it in a quiescent state by electrical resistance heating. He obtained a firm curd between pH 4.6 - 4.7. In making direct acid cheese, curd firmness is of utmost importance. While the pH at setting is probably the single most important factor, setting temperature, setting time, solids concentration, and presence of absence of rennet all influenced curd firmness.

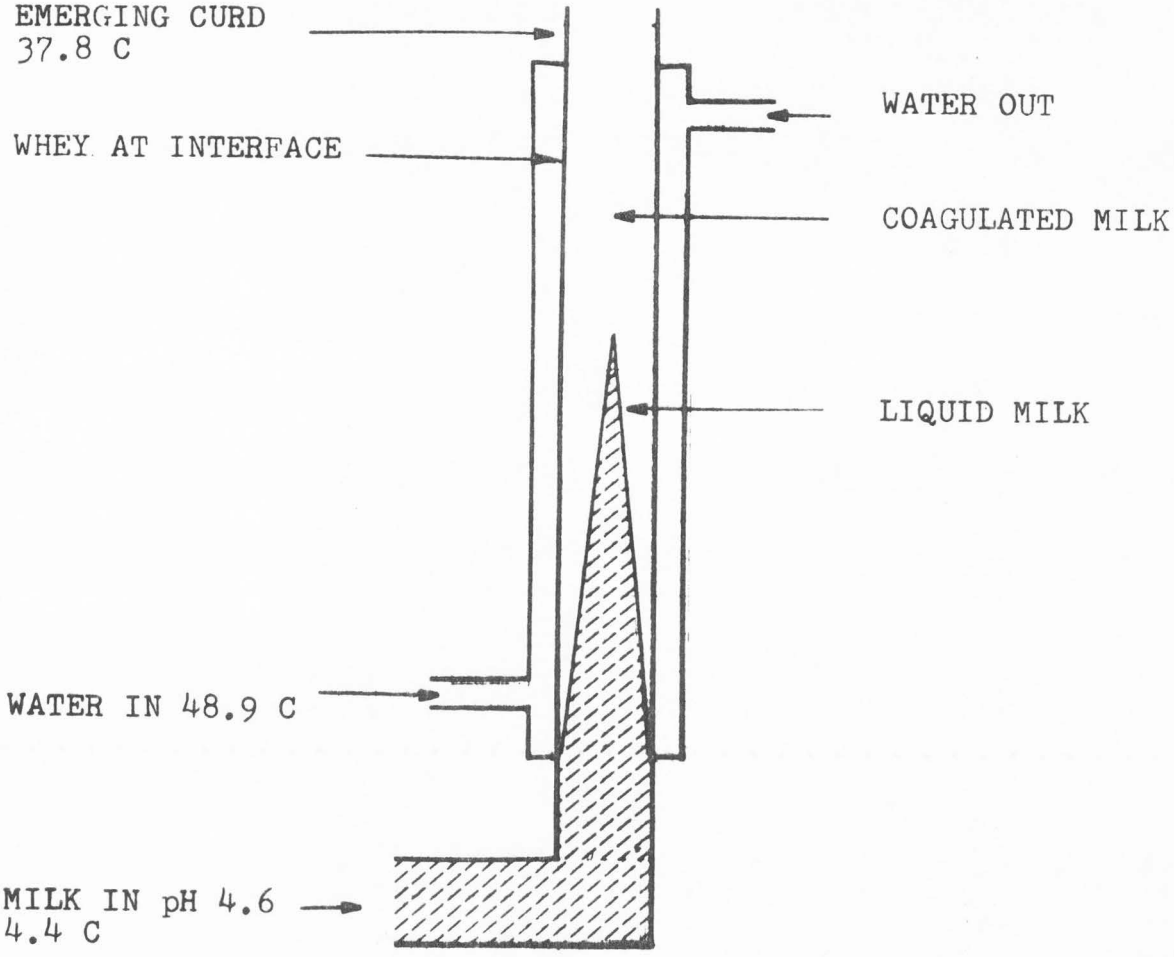
McNurlin (40) studied the properties of direct acid curd between pH 4.5 - 5.0 and indicated that curd firmness increased with decreasing pH, increasing setting temperature, and with time at the setting temperature. The use of 1 ml of rennet per 1,000 lb. of skimmilk improved the body of the finished curd. Increasing solids-not-fat in the skimmilk produced a firmer curd and improved the yield, but greatly increased the coagulation time.

More recently, Ernstrom (20) stated that satisfactory curd was produced with lactic acid, citric acid, phosphoric acid, acetic acid, hydrochloric acid, and sulfuric acid. Sulfuric acid, however, was unsatisfactory because it must be added in very dilute form to prevent generation of heat. He suggested the use of hydrochloric acid because it was least expensive. Two patents were issued to Ernstrom (19,22) for making Cottage cheese curd by direct acidification of milk at low temperature.

Even though electrical resistance heating for curd formation (18,24,39,40) proved to be unsuitable for practical use, a successful continuous curd former was designed by C.P. division St. Regis (20). The operating principle of the curd former is illustrated diagrammatically in Figure 1.

Ernstrom's second patent (22) involved a process whereby the milk was fortified to a high percentage solids-not-fat (14 - 16% SNF). Sufficient water-soluble, non-toxic acid was added to the cold milk with agitation at a temperature of 2 - 10C in order to reduce the pH to 4.5 - 4.7. The acidified milk was then warmed to 32 - 52C without agitation. This was accomplished by a tube type heat exchanger which controlled the flow in such a way as to prevent turbulence. The milk adjacent to the walls of the tube was first coagulated and some whey was expelled to form a lubricating film between the coagulum and the wall of the tube. This allowed the product to slip up the tube without agitation. As the curd emerged from the top of the curd former it was cut to the desired size by a rotating knife. Then the curd was fed directly into a continuous cooker (43 to 71C) that cooked the curd in a relatively few min. The moisture content of the finished curd was adjusted by holding the hot drained curd for 10 - 90 sec. The curd was then washed and drained in a normal fashion prior to creaming.

Recent modifications of the curd forming and processing equipment have led to another patent (60). The new machine eliminated the air bubbles in the curd by deaerating the milk prior to processing. Subsequent operations were carried out in a closed system to prevent air from reentering the milk. Another feature of this machine was


EMERGING CURD
37.8 C
WHEY AT INTERFACE
WATER OUT
COAGULATED MILK
LIQUID MILK
WATER IN 48.9 C
MILK IN pH 4.6
4.4 C

that it had a provision for periodically reversing the flow of coagulating milk to prevent sticking in the coagulation tubes.

Fox and Ernstrom (25) reported that the prolonged contact (up to 7 min) of acid and milk prior to coagulation significantly reduced the firmness of newly coagulated curd made by direct acidification.

According to Gerson (26) Vitex Laboratories has developed and introduced a new batch process for producing direct acid Cottage cheese. Their process was based on a modification of the Hammond and Deane patent. Skimmilk was placed in a cheese vat and acidified with a special food grade acidulant. It was then heated to 27C and inoculated with D-glucono-delta-lactone. The vat was allowed a setting period of one hr. The curd was then cut, cooked and washed, as is done in culture processes. It was claimed that the end product was indistinguishable in flavor, wholesomeness and texture from good quality cultured Cottage cheese. The following benefits were listed: (i) increased shelf-life, (ii) improved cheese consistency, (iii) reduced production time with commensurate increased return, (iv) elimination of fermentation failures, increased profits from increased yields and (v) customer satisfaction.

More recently, Born and Muck (5) reported that consumer acceptance ratings of the continuous direct acid product were slightly, but not significantly, lower than for conventional Cottage cheese manufactured in their plant. In a consumer survey conducted in February 1968, and involving 649 persons, the direct acid Cottage cheese received a rating of 6.62 and the cultured Cottage cheese 6.91 on a Hedonic scale of 1 to 9 where a score 7.0 meant "like moderately." The general conclusion

was that statistically there was no real difference between direct acid Cottage cheese and conventional Cottage cheese.

The characteristic stretchiness and elasticity of rennet curd made from milk acidified to pH 5.6 led Breene et al. (8) to investigate the possibility of making Pizza cheese. This cheese is usually used when less than one month old. The lack of curing time eliminates the potential problem of undesirable fermentations of lactose left in the curd. Their original procedure (8) called for either whole milk or part skimmilk to be acidified to pH 5.6. It was then set with 100 ml rennet per 1000 lb. of milk. The curd was cut with 6.35 mm knives, stirred until sufficient whey was expelled, heated in hot water and molded by hand into 1½ to 2 lb. spheres. The cheese was then brined salted for 18 to 22 hr. Initial trials on this variety of cheese were conducted by acidifying the milk to pH 5.4. This pH was selected because it had been reported (33) that Pizza cheese made by conventional methods would not stretch if cut above pH 5.4. However, this procedure resulted in excessive fat losses in the whey, and in a curd that toughened to such a degree that it could not be cut and stretched properly. Although some fat leakage during baking is desirable, the whole milk cheese exhibited what was termed excessive leakage. This defect was corrected by single stage homogenization at 500 psi. A pressure of 1000 psi was also tried, but cheese made from this milk was criticized for insufficient fat loss, as it resulted in a baked pizza with a dried-out appearance. The cheese made by direct acidification from a milk homogenized at 500 psi took only about one half the time required for a conventional operation, and appeared to be adaptable to mechanization.

Ernstrom (21) modified the above procedure and showed that setting and cutting the curd in a conventional manner was not required. Rennet was added to acidified milk at 35C while the agitator was operating. This caused the production of small, irregular curd particles which later formed larger aggregates. Agitation helped to expell the whey at a faster rate. Larson et al. (35,36) compared the two methods of making direct-acid Pizza cheese and found that the moisture content was lower at all stages of manufacture with the stirred-curd method. Fat and total solids recovery were not significantly altered by using the continuous agitation method (21,47). Non-fat-solids recovery was slightly increased by the use of phosphoric acid instead of hydrochloric or lacric acids (47).

Shehata and Olson (51) developed a direct acid method for the production of Blue cheese curd that was similar in body and texture to curd made by traditional methods. It was essential to use 0.5% lactic starter culture to control undesirable fermentations and aid in flavor development of the cheese during ripening. Curd formed with hydrochloric acid or phosphoric acid was firmer and lower in moisture than that made with lactic or citric acids (50,52).

Calcium levels were significantly higher in Blue and Pizza cheese made with phosphoric acid; Blue cheese made with citric acid had the lowest calcium level (50).

Pre-acidification of skimmilk for Cottage cheese making. The use of chemical acidulants in combination with starter was studied by Baker and Stoll (4). This combination was used to study the curd forming properties and acid producing ability of lactic starter in acidified milk. Hydrochloric acid (2N) was added to reconstituted spray-dried

skimmilk (10% T.S.) at 5C to obtain a pH value of 6.40 to 4.70. Lactic starter (5%) was then added and the milk warmed to 31C, and held until it coagulated (pH 4.70). A single strain culture (E8) and mixed strain multiple type culture (H5) were compared in acidified skimmilk each against unacidified skimmilk controls containing the respective cultures. A 25% reduction in time to reach pH 4.70 was observed by acidification of the skimmilk to pH 6.0 and 5.75. Acidification to pH 5.0 yielded a 50% reduction in time but produced a shattered curd on cutting. No significant reduction in time was noticed when acidified to pH 5.50. A weaker curd was produced with cultures (E8) and H5 than when the milk was acidified to pH 5.90 or below. The only exceptions were at pH 5.50 and 5.60 with H5 culture, where curd tension was not different from the control.

Bristol and Martin (9) prepared a non-coagulated exponential-phase culture (EPC) by inoculating skimmilk with 0.5% commercial starter culture and incubating it at 21C for 15 hr or 35C for 5 hr. Preacidified skimmilk was prepared by adding sufficient (i) citric acid, (ii) phosphoric acid or (iii) a commercial mixture of the 2 acids to produce acidities approximating those of EPC ($\lesssim$0.6% titratable acidity). The time required for manufacturing Cottage cheese by the conventional short set procedure was compared with that using EPC and preacidified skimmilk. High acid coagulated (control) starters were inoculated into the skimmilk at 6% and EPC starters at 25%. In comparison with the conventional procedure, EPC starters decreased the setting time by 35% in skimmilk without pre-acidification, and by 44, 45 and 52% respectively in skimmilk preacidified with (iii), (ii) and (i). Curd from experiments with EPC and skimmilk pre-acidified

with (ii) or (iii) compared favorably with the control in physical appearance and aroma, but pre-acidification with (i) resulted in less firm curd.

Effect of adding salts to Cottage cheese milk.

Knaysi and Nelson (32) reported a 5% increase in yield of Cheddar cheese when they added 0.1% $CaCl_2$ to the milk. This was attributed to a more complete precipitation of the soluble solids.

During World War II Mulder and Radema (43) tried to process milk into a nutritious, and palatable product of good keeping quality without using much heat. They tried to make some of the Dutch varieties of cheese at 20C. First they used large amounts of rennet, but even when 8 times the normal quantity of rennet was used syneresis of the curd proceded too slowly for cheese making.

Curdling and syneresis improved when calcium chloride was added to the milk, and a normal amount of rennet was used. Curd obtained in this way had a good appearance, but syneresis was still very slow.

Hydrochloric acid strongly accelerated curdling and syneresis. However, when a large quantity of HCl was used the curd particles were not smooth but flaky and frayed. Calcium chloride produced a fine curd, but did not accelerate syneresis sufficiently. Even though hydrochloric acid accelerated syneresis, the curd was abnormal. A combination of HCl and $CaCl_2$ succeeded in curdling the milk at 20C with the aid of a normal quantity of rennet or less. The syneresis was satisfactory, and the curd had a good appearance and was sufficiently firm.

Ovchinnikov and Vedyashkin (46) revealed that the consistency of Dutch cheese depended upon the amount of CaO combined with the protein. They reported that the pH had no direct effect.

Emmons et al. (17) showed that anhydrous $CaCl_2$, when used at the rate of 0.02% and 0.05% of the skimmilk, was not beneficial in the manufacture of Cottage cheese from pasteurized skimmilk.

Similar observations were made by Thurston and Gould (55) and Henson and Miller (29)

Medved et al. (41) concluded from their experiment that the addition of 0.12 or 0.36% sodium hexametaphosphate to milk, which was then made into Cottage cheese and kept in frozen storage for 8 weeks; did not result in an improved flavor or texture of the thawed cheese when compared with the control cheese.

Ashworth and Nebe (2) obtained more rapid curd tension increase than the control by the addition of either $CaCl_2$ or NaH_2PO_4 to the milk.

Flickinger and Stimpson (23) revealed a method of treating Cottage cheese curd with such additives as citrates or phosphates to ensure that the curd had a uniform texture. This was particularly important if sour products such as pineapple, citrus fruit or cultured cream were used as ingredients, as this led to the hardening of the curd. Disodium phosphate, sodium citrate, potassium citrate or their combination were added to act as sequestering agents as well as buffers. The addition was at a rate of 0.1 to 1.1% of the drained Cottage cheese.

According to Bosworth and Van Slyke, (6) addition of sodium citrate made curd softer. The same report was made by Knaysi (31).

Mumm (44) reported that citrates and phosphates favored the hydration of milk proteins and that calcium salts depressed it when reaction was on the alkaline side of pH 4.7. Similar observations were made by Sommer (53).

Proteolysis by Streptococcus lactis.

A study of the proteolytic acitivity of a number of S. lactis cultures isolated from various dairy products was carried out in milk by Anderegg and Hammer (1). They showed that certain cultures of S. lactis demonstrated a definite proteolytic activity in milk, while others did not. They also noticed that when there was an increase in soluble nitrogen during the growth of S. lactis in milk, there was usually an increase in the amino nitrogen. They failed to show an increase in soluble nitrogen when sterile lactic acid was added to milk in quantities comparable to those developed by S. lactis. This suggested that the protein decomposition with that organism was due to an enzyme from the bacteria. Streptococcus lactis caused a rapid increase in both soluble nitrogen, tyrosine and tryptophane during the first 24 hr, followed by a smaller but gradual increase during the rest of the experimental period (72 to 90 hr). Considerably more soluble nitrogen, tyrosine and tryptophane were produced when the reaction was controlled at pH 6.0 to 7.5 than when comparable samples were grown without controlled pH (58).

Morgan and Nelson (42) reported a marked increase in leucine, isoleucine, valine, threonine, arginine, methionine, histidine, tryptophane, tyrosine and phenylalanine in tungstic acid and lactic acid filtrates of skimmilk after incubation with S. lactis for 15 days at 21C.

Williamson and Speck (61) revealed that the proteinase system of the streptococci appeared to be adaptive, since cells grown in a medium containing only casein as a nitrogeneous source possessed

greater proteolytic activity than when grown in a medium fortified with simpler nitrogenous compounds contained in pancreas extract.

Williamson et al. (62) showed that S. lactis could produce an extracellular proteolytic enzyme(s). The two closely related lactic streptococci, S. lactis and S. cremoris, were the predominant species in dairy starter cultures. They were believed to be the sources of proteinases important in the hydrolysis of milk proteins during the manufacture of cultured milk products.

Zalashko and Mochalova (63) examined 220 strains of S. lactis, S. diacetilactis and S. paracitrovorous for proteolytic activity and divided them into strong, medium and weak categories. Mixed starters prepared within each category from 2 - 6 strains were tested for persistence of proteolytic activity on subculture, and for usefulness in manufacture of Dutch-type Brick cheese. They concluded that strong starters maintain their activity longer and produce better cheese than weak starters.

Vahora and Ernstrom (57) observed that S. lactis produced extracellular proteinase activity. They also noted that during the growth of lactic organisms at a controlled pH, of 6.2 more proteolytic activity was produced than when the pH was not controlled.

Proteolysis and curd firmness.

Heinemann (28) observed that starter in the manufacture of Cottage cheese significantly affected firmness of the curd at the time of cutting. Curd firmness was believed to reflect the relative degree of proteolysis caused by organisms in the cultures. Emmons et al. (15) discounted proteolytic activity as an important factor

when they found a close relationship between pH and curd strength produced by 17 cultures. A relationship between titratable acidity of whey and curd strength did not correlate closely, and this was explained by a varied production of weakly ionized acids such as carbonic and acetic acids by different cultures.

Williamson and Speck (61) offered no explanation for their results in which they observed no direct relationship between proteolytic activity of cultures and curd strength; they concluded that acid production and curd strength were independent properties produced by cultures and did not appear to have any direct relationship; but they did show a close correlation between titratable acidity and pH.

EXPERIMENTAL

Bacterial culutres.

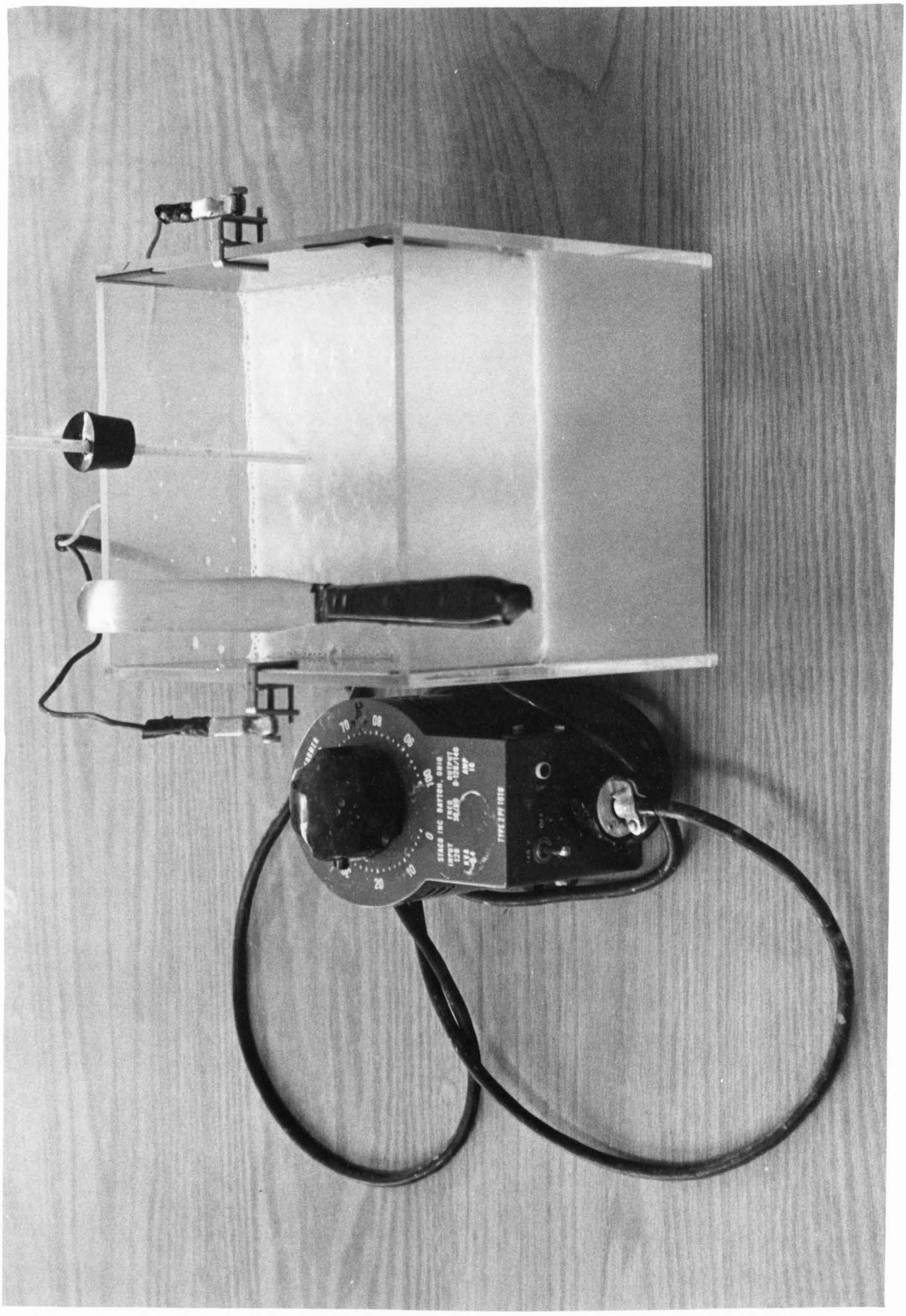
Non-sludging strains of Streptococcus lactis (strain C_2) and Streptococcus cremoris (strain AM_2) were employed as starter organisms. S. lactis (strain C_2) was used in partially cultured and conventional Cottage cheese making. Cultures were maintained in sterile skimmilk. Transfers were made every two weeks, incubated 14 to 16 hr at 21C and stored at 4C. Fresh starters were used for making cultured and partially cultured cheese.

Manufacturing procedure.

Raw skimmilk from Utah State University Dairy Products Laboratory was pasteurized at 63C for 30 min.

(i) Direct acid curd. The method described by Ernstrom (20) was used for cheese making. The curd was formed by cooling the skimmilk to 4C, acidifying to pH 4.6 with concentrated HCl. Approximately 5 to 7 liters of the cold acidified skimmilk was placed in plastic coagulation containers 21 by 21 cm^2 and 23 cm high. These were fitted with stainless steel electrodes at opposite sides which were connected to 110 - volt alternating current. The coagulation container is pictured in Figure 2. The acidified skimmilk was warmed electrically, without agitation, to setting temperature of 32C. The curd was cut with 6.35 mm knives after ten min at the setting temperature (39). It was then cooked to 62C in 120 min, washed and drained. The curd was washed twice

Figure 2. Apparatus for warming acidified skimmilk by electrical resistance without agitation.



with water at 20C and 8C respectively, and kept in contact with each wash water for 10 min. The last wash water was acidified to pH 5.0 with hydrochloric acid.

(ii) Cultured Cottage cheese. The short-set method for Cottage cheese making as described by Emmons and Tuckey (18) was modified to include heating the curd and whey in a plastic box by electrical resistance heating as described by Ernstrom (20). The skimmilk at 32C was set with 5% starter and 1 ml rennet per 1,000 lb. of skimmilk. The curd was cut at the A-C end point (16), and was cooked and washed as described in (i).

(iii) Partial culturing and direct acidification. Pasteurized skimmilk was inoculated with 5% starter at 32C and allowed to reach pH 6.0 or 5.5 then cooled to 4C within 10 - 12 min by circulating salt brine (-1C) through cooling coils immersed in the milk. This apparatus is shown in Figure 3. The cold milk was then acidified to pH 4.6 with concentrated HCl, and Cottage cheese curd made as described in (i).

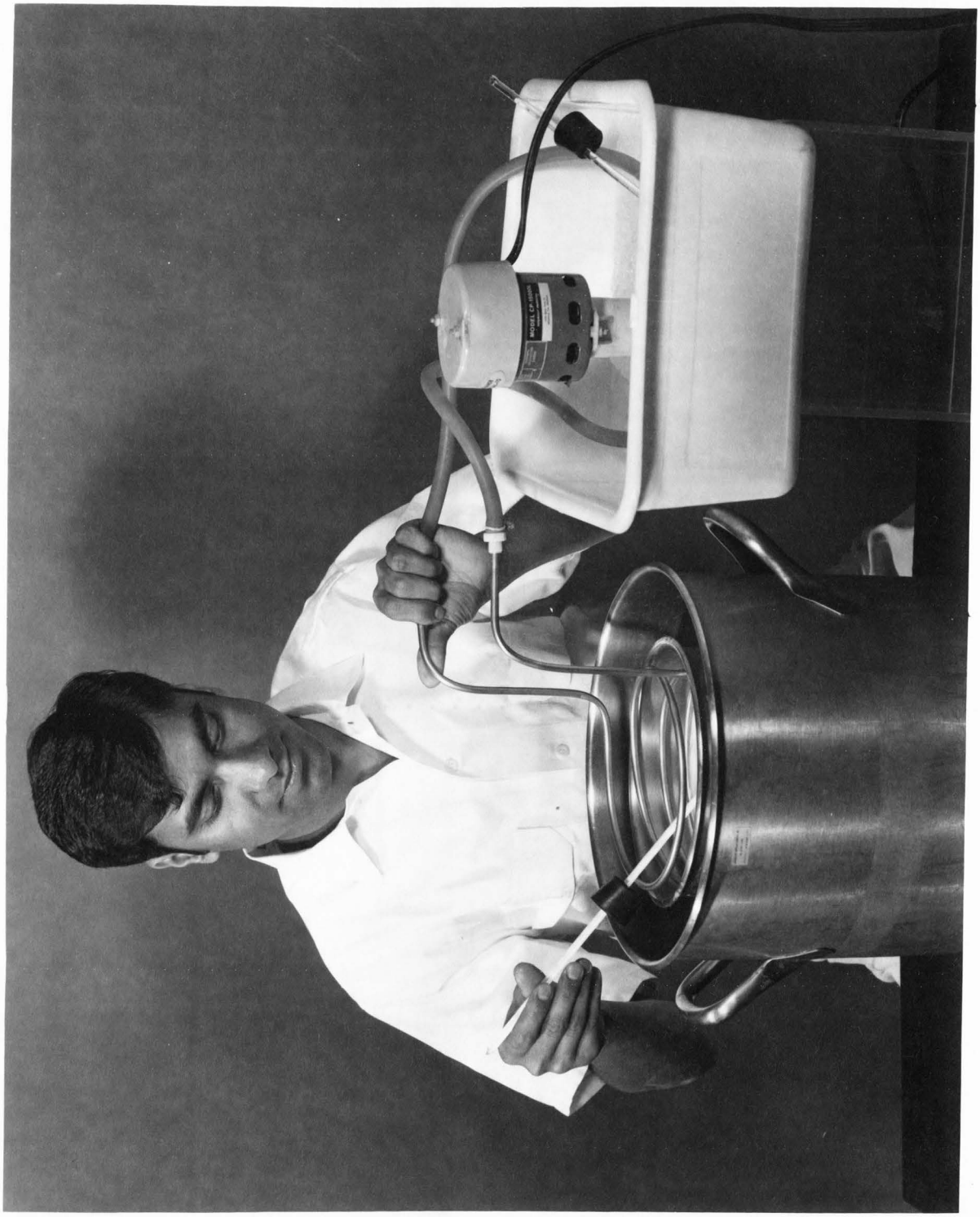
Pasteurized skimmilk was divided into 4 lots. The first lot was made into direct acid curd. The second and third lots were made into curd by partial culturing to pH 6.0 and 5.5 respectively as described in (iii). The fourth (culture control) lot was made into Cottage cheese as described in (ii).

Measuring proteolytic activity.

Proteolysis in skimmilk during culturing was measured by a modification of the method of Cowman and Speck (10).

Skimmilk was inoculated with 5% culture at 32C $\pm$ 1C. After 0, $\frac{1}{2}$, 1, 2, 3, 4 and 5 hr of incubation, at 4.0 ml sample was removed and

Figure 3. Cooling of partially cultured skimmilk by circulating salt brine (-1C) through cooling coils immersed in the milk.


MODEL CP-1000

transferred to 4.0 ml of a 4% trichloroacetic acid solution. This mixture was shaken and allowed to stand for 10 min, then filtered through washed Whatman No. 42 filter paper. To 1.0 ml of the trichloroacetic acid filtrate was added 7.0 ml of 7.5% Na_2CO_3 solution and 1.0 ml of 1:3 dilution (v/v) of Folin Ciocalteau Reagent (Fischer Scientific Co., Fair-Lawn, New Jersey). The tubes were allowed to stand 2 min for color development. The color was measured spectrophotometrically at 650 nm in a Coleman Universal Spectrophotometer. A blank reading was taken at 0 hr of incubation.

Moisture analysis.

Moisture in Cottage cheese was determined by the A.O.A.C. method (3) for determining the moisture content of soft cheese.

Cream dressing.

Cream dressing was prepared according to Manus (38).

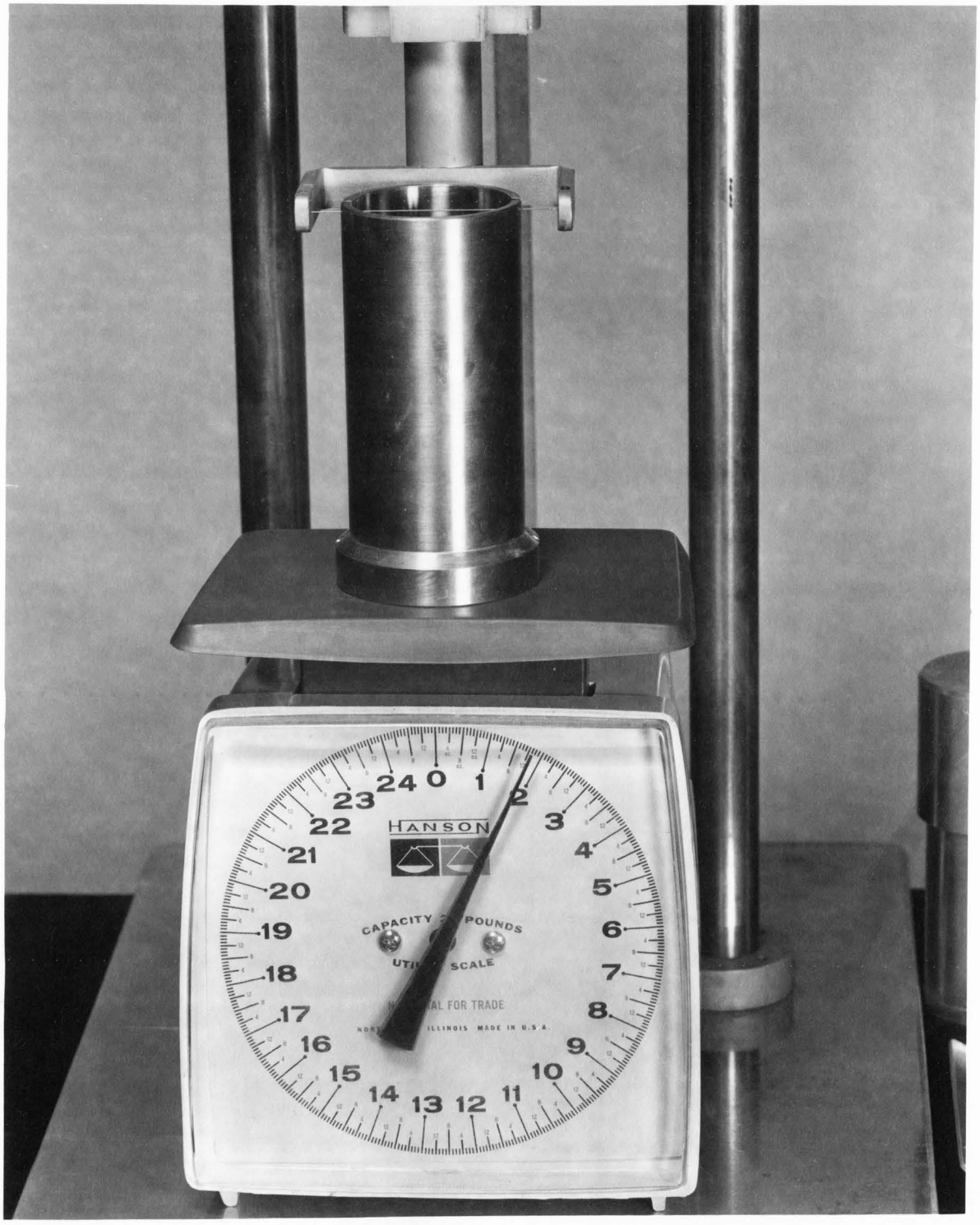
Curd firmness.

Curd firmness was measured according to the method of Emmons and Price (14). Curd was packed into a 5.08 cm stainless slotted cylinder closed at the bottom (see Figure 4). The slots were covered while a 5 lb. weight pressed the curd for approximately 10 sec to pack it firmly. Free whey, but not curd, could escape via the covered slots. The cylinder was placed on a scale, and a wire cutter was driven through the curd at a rate of 0.338 cm/sec so it did not touch the container. Curd firmness was measured in grams.

Organoleptic evaluation of cheese.

After the curd was creamed and allowed to stand for 24 hr,

Figure 4. Curd tension meter showing stainless steel slotted cylinder and wire cutter.


HANSON
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14
15
16
17
18
19
20
21
22
23
24

its body and texture was evaluated by five separate graders on a 5 point scale in which, 1. represented superior, 2. excellent, 3. satisfactory, 4. objectionable, and 5. unsaleable. Average scores of the five judges were reported for each treatment. Analysis of variance of the results of the scores was carried out according to the complete randomized design as described by Ostle (45).

RESULTS

Effect of added salts on body and texture.

In preliminary experiments calcium chloride, disodium phosphate or sodium citrate were added to skimmilk at concentrations of 0.02, 0.05, 0.10, 0.15, and 0.20% prior to the manufacture of direct acid Cottage cheese curd. Each salt was run in triplicate at all concentrations, and compared with direct acid curd made with no added salts. The curd was evaluated by two judges who criticized it by comments only without attempting to show quantitative relationships. Results are given in Table 1.

Table 1. Effect of added salts on body and texture criticisms of direct acid Cottage cheese.

Concentration	Salt added		
	$CaCl_2$	Na_2HPO_2	Na_3Citrate
(% w/v)			
0.00	Sl. firm Smooth	Sl. firm Smooth	Sl. firm Smooth
0.02	Mealy Soft	Sl. mealy Soft	Sl. mealy Soft
0.05	Sl. firm Smooth	Sl. mealy Soft	Sl. mealy Soft
0.10	Firm Smooth	Mealy Soft	Mealy Soft
0.15	Sl. firm Smooth	Very mealy Soft	Very mealy Soft
0.20	Sl. mealy Soft	Extremely mealy	Extremely mealy

Addition of 0.10% $CaCl_2$ to Cottage cheese milk appeared to produce a slight improvement in the body and texture of direct acid Cottage cheese. However, it was not as good as Cottage cheese made by conventional starter culture methods. Addition of disodium phosphate and sodium citrate adversely affected the body and texture. It was concluded that addition of salts to skimmilk offered little hope of improving the body and texture of direct acid Cottage cheese.

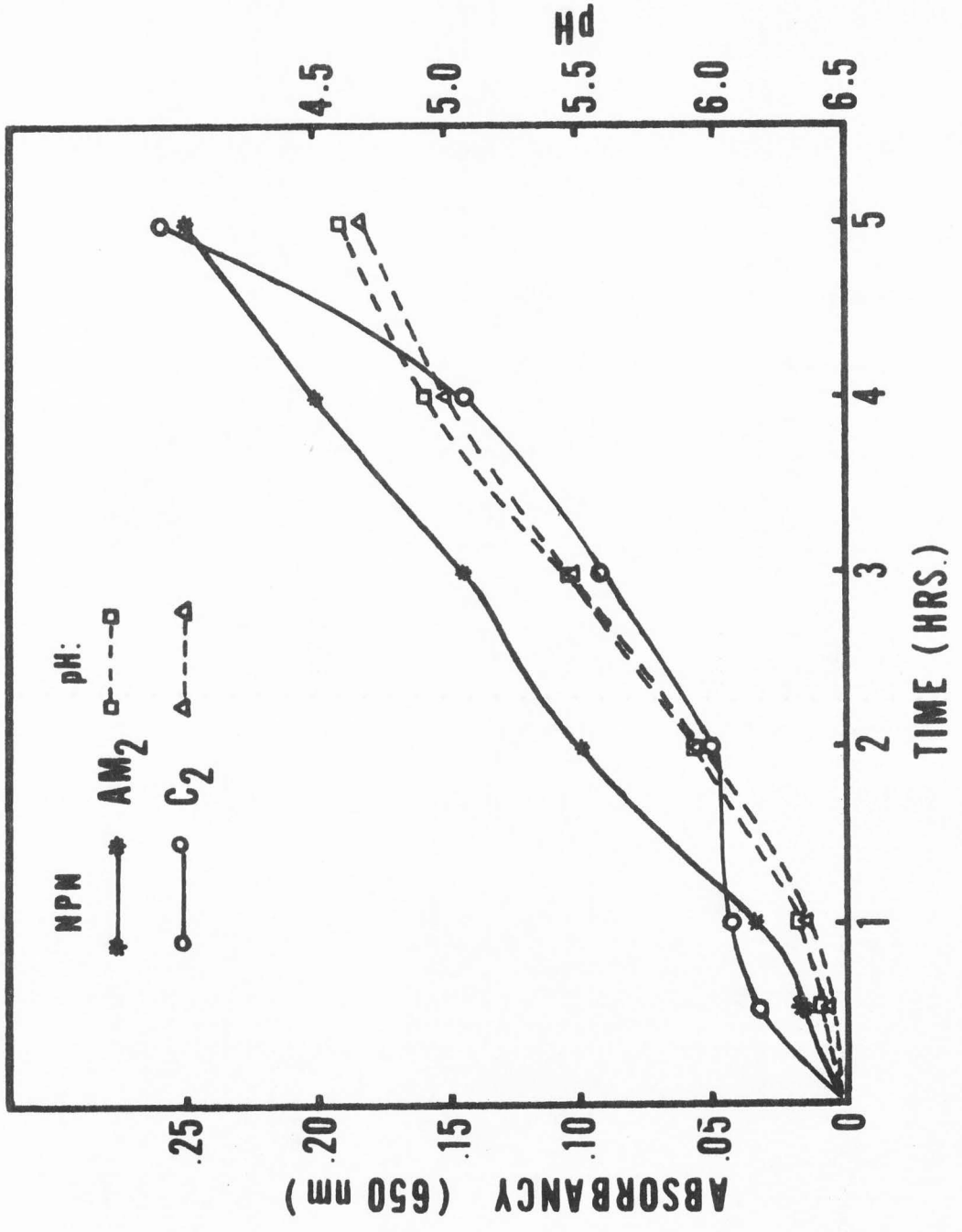
Effect of acid species on properties of direct acid curd.

Lactic acid (85% strength) was used to make Cottage cheese curd by direct acidification, and was compared with concentrated HCl and the culture process. Curd made with lactic acid was more mealy than HCl curd. Neither was as good as curd made by the culture process.

Effect of starter cultures on NPN increase during setting of Cottage Cheese.

The extent of proteolysis during the setting of Cottage cheese milk with two strains of lactic streptococci (AM_2, C_2) is shown in Figure 5. The pH changes during setting are also shown. It is evident that proteolysis was measurable in Cottage cheese milk during setting, and could possibly contribute to the body and texture of Cottage cheese curd. Rennet, pepsin, and bromelain were diluted to concentrations that would approximately duplicate the proteolytic results shown in Figure 5. However, when used to pretreat skimmilk prior to making direct acid Cottage cheese, these enzymes had no noticeable effect, or they produced a tough leathery curd.

Figure 5. Effect of growth of Streptococcus lactis (C_2) and Streptococcus cremoris (AM_2) on the release of non-protein nitrogen and change of pH in skimmilk at 32C.


ABSORBANCY (650 nm)
.25
.20
.15
.10
.05
0
TIME (HRS.)
1
2
3
4
5
pH
4.5
5.0
5.5
6.0
6.5
NPN
pH:
AM2
C2

Effect of preculturing skimmilk on the body and texture of Cottage cheese.

The effect of preculturing skimmilk prior to making direct acid Cottage cheese on the average moisture content of the uncreamed curd is shown in Figure 6. Marks at the top of each bar represent standard deviations. Average moisture retention in the curd increased with increasing growth of the culture in the milk. Average firmness measurements of the drained, uncreamed curd are illustrated in Figure 7. It was apparent that growth of lactic organisms in the milk substantially increased the firmness of the finished curd.

Average body and texture scores of the finished creamed Cottage cheese are given in Table 2. Results of the analysis of variance of the grading are given in Table 3.

Figure 6. Effect of partial culturing on the moisture content of uncreamed direct acid Cottage cheese. 1- Direct acid, 2- Cultured to pH 6.0 prior to direct acidification, 3- Cultured pH 5.5 prior to direct acidification, 4- Culture control.

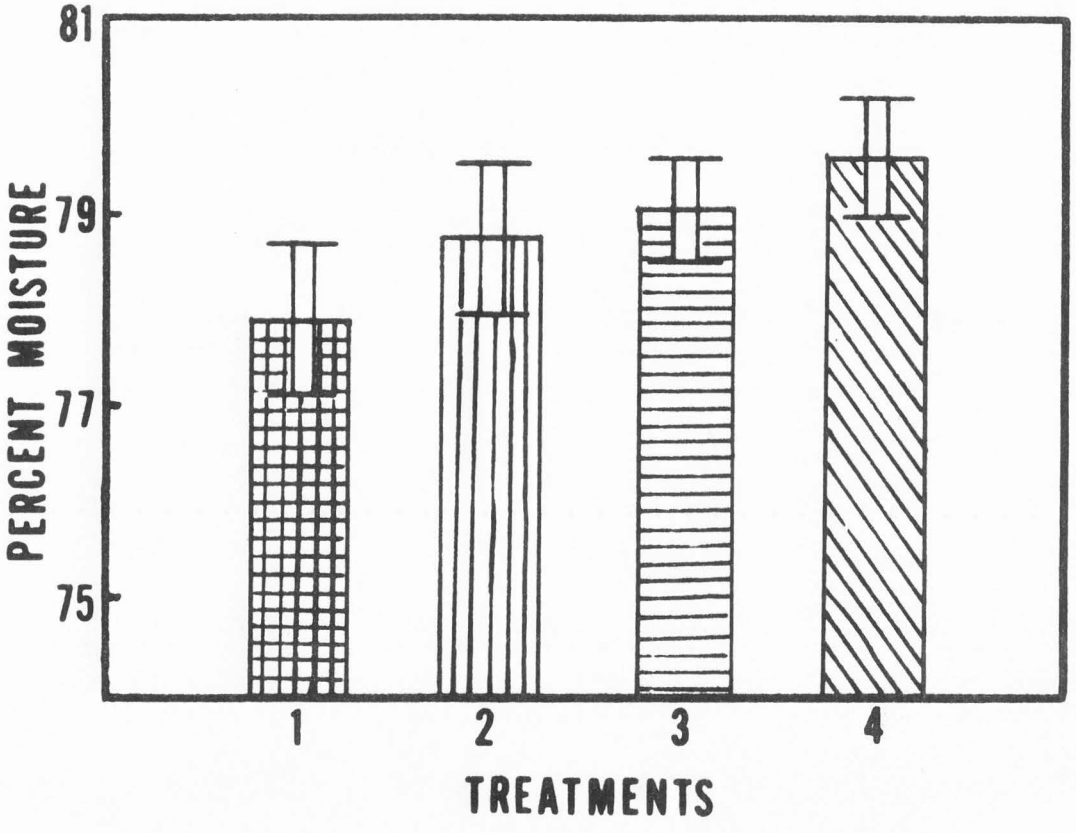

81
79
77
75
PERCENT MOISTURE
1
2
3
4
TREATMENTS

Figure 7. Effect of partial culturing on the firmness of uncreamed direct acid Cottage cheese. 1- Direct acid, 2- Cultured to pH 6.0 prior to direct acidification, 3- Cultured to pH 5.5 prior to direct acidification, 4- Culture control.

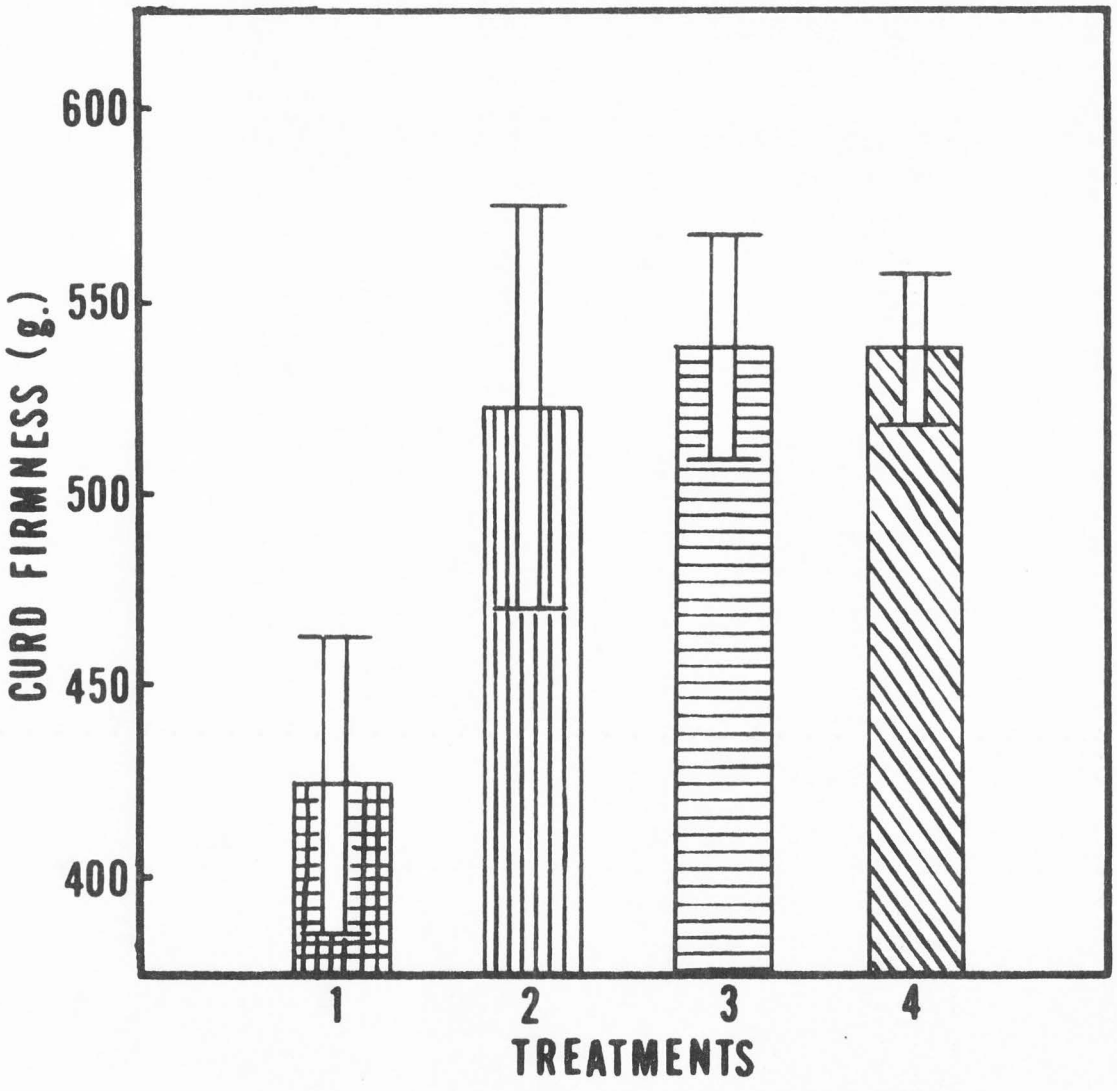

600
550
500
450
400
CURD FIRMNESS (g.)
1
2
3
4
TREATMENTS

Table 2. Effect of partial culturing on average body and texture scores[+] of creamed direct acid Cottage cheese.

TREATMENTS			
1	2	3	4
3.70	3.11	2.80	2.88

—— Not significant at 0.01 level

___ Significant at 0.01 level

+ 1, Superior; 2, Excellent; 3, Satisfactory; 4, Objectionable; 5, Unsaleable.

Table 3. Analysis of variance of the average body and texture scores of creamed direct acid Cottage cheese.

Source	df	SS	MS	F
Replicates	9(r-1)	2.65	0.294	1.26
Treatments	3(t-1)	25.12	8.37	*35.62
Judges	4(j-1)	6.60	1.65	* 7.02
Judges X Treat.	12(j-1)(t-1)	13.88	1.16	4.94
Error	171(r-1(tj-1)	40.13	0.235	
Total	199(rtj-1)	88.38		

* Significant at 0.01 level.

DISCUSSION AND CONCLUSIONS

Addition of calcium chloride, disodium phosphate, and sodium citrate to Cottage cheese milk did not increase curd firmness of direct acid Cottage cheese. It appeared that addition of 0.10% $CaCl_2$ slightly improved the body and texture of direct acid Cottage cheese. However, it was not as good as cheese made by the culture process. Disodium phosphate or sodium citrate when added in increasing amounts adversely affected the body and texture of the direct acid Cottage cheese.

Cottage cheese made with lactic acid was more mealy than curd made with hydrochloric acid. Neither was as good as curd made with starter organisms.

Lactic streptococci produce protease enzymes. Further evidence has suggested that the proteolytic acitvity of the starter organisms was responsible for the increase in soluble nitrogen in the milk. The increase in in non-protein nitrogen and pH was correlated with the length of incubation time. This soluble nitrogen must have arisen from the action of protease enzymes on milk proteins.

Culturing pasteurized skimmilk to pH 6.0 prior to direct acid manufacture of Cottage cheese significantly improved the body and texture of the creamed Cottage cheese. An additional significant improvement was achieved by culturing the milk to pH 5.5 before chemical acidification. No further advantage was gained by complete manufacture of curd by the culture process.

The most frequent criticisms of Cottage cheese made completely by direct acidification were mealy and soft. The most frequent comments by the judges about the cheese cultured to pH 5.5 and that made entirely by the culture process were firm and smooth.

This study has shown that the factors associated with the growth of lactic streptococci in skimmilk prior to the manufacture of direct acid Cottage cheese can significantly improve the body and texture of the cheese, and that once these factors have affected the milk, higher quality Cottage cheese can be made by the direct acid process. These factors also increased the moisture holding capacity and the firmness of the finished uncreamed Cottage cheese.

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