5-1951

Use of DK Cheese Starter in Manufacture of Commercial Cheddar Cheese

Carl Anthon Ernstrom
Utah State University

USE OF DK CHEESE STARTER IN MANUFACTURE

OF COMMERCIAL CHEDDAR CHEESE

by

Carl Anthon Ernstrom

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

of

MASTER OF SCIENCE

in

Dairy Manufacturing

1951

UTAH STATE AGRICULTURAL COLLEGE
Logan, Utah

ACKNOWLEDGEMENT

I wish to express appreciation to Professor A. J. Morris for his able assistance in directing this research problem, and for his help in the periodic scoring of the cheese. I also acknowledge the valuable suggestions given from time to time by Professor Paul B. Larsen, and wish to thank him for his help in scoring and grading the cheese.

I wish to thank Mr. David O. Williamson and the Animal Husbandry Department at Utah State Agricultural College for the use of their equipment and laboratory where much of the analytical work of this project was done.

TABLE OF CONTENTS

TABLE OF CONTENTS (concluded)

INTRODUCTION

Importance of project

Several months' curing time is needed to give cheddar cheese the desirable flavor demanded by the market. The exact length of time required for curing depends upon the flavor intensity desired, but the curing process is always costly and time-consuming.

The practice of making cheddar cheese from pasteurized milk is now common throughout the industry. Many progressive cheese factories are pasteurizing their milk and enjoying the consequent benefits from a higher quality product. Although pasteurization has eliminated many of the quality problems in cheesemaking, it has resulted in even slower curing cheese.

Much of the cheese research now being carried on is concerned with finding means to shorten the normal curing period of cheddar cheese. A method of reducing the curing period without adversely affecting the quality of the product would be invaluable to the cheddar cheese industry.

DK cheese starter

The curing of cheddar cheese is made possible by the symbiotic growth of microorganisms in the cheese curd, the action of enzymes present in the milk, and the enzymes in rennet which are added to the milk. Many workers (2) (33) (39) have expressed the thought that the rate of ripening of cheese may be influenced by specific microorganisms. Dahlberg and Kosikowsky (14) have isolated a particular strain of Streptococcus faecalis which, when used in cheese starter, is reported to hasten the development of good cheddar flavor in cheese that naturally tends to cure rather slowly. DK cheese starter is a culture of this reputedly successful strain of S. faecalis.

Purpose of investigation

Dahlberg and Kosikowsky (14) reported that fine highly flavored cheddar cheese was produced, and that a two-month reduction in curing time was obtained when DK cheese starter was combined with commercial lactic acid starter in cheese making.

Vanderbeek (50) experimented with cheese starter containing a strain of S. faecalis which may or may not have been the same strain employed in DK starter. He found that S. faecalis starter did not reduce the normal curing period, and that a bitter flavor developed in all the cheese in which S. faecalis had been used.

The purpose of this investigation is to use DK cheese starter in combination with commercial lactic acid starter to make cheddar cheese. The ultimate object of this work is to gather evidence for the cheese industry showing the advantages or disadvantages of the use of DK cheese starter in quality cheddar cheese production.

Scope of problem

DK cheese starter was used to make cheddar cheese in the exact manner prescribed by its advocates. Control cheese was made with commercial cheese starter and used as a basis for comparison. Any pronounced differences in the manufacture of the cheese as a result of the starter were recorded. Efforts were made to determine the effect of DK cheese starter on the rate of curing and the quality of the resulting cheese.

All of the cheese was made in the College Creamery at Utah State Agricultural College during December 1949.

REVIEW OF LITERATURE

Flavor development in cheese made from pasteurized milk

Wilster (55) estimates that half of all the cheddar cheese produced in the United States is made from pasteurized milk. He further believes that eventually all cheese factories manufacturing cheddar cheese will pasteurize their milk. Many of the difficulties encountered in large scale cheese production from raw milk have been eliminated by pasteurization. A higher quality more uniform product has been the result. Van Slyke and Price (51) and Wilster (55), however, report that in spite of all the advantages gained by pasteurization of cheese milk, slower curing cheese is produced which does not develop typical cheddar flavor to the same degree as cheese made from raw milk. Pette (39) also found that cheese made from pasteurized milk does not develop good flavor. He attributed it to the weakening of rod-shaped lactic acid bacteria, and probably intestinal bacteria that were accidentally present in milk.

Many experiments have been performed in an effort to determine the organism or group of organisms responsible for the more rapid flavor production in raw milk cheese. This work has been done with the view of artificially inoculating the flavor-producing organisms of raw milk cheese into the pasteurized milk cheese in order to increase its rate of ripening and flavor development. With the exception of certain lactobacilli (33) and to a limited extent a micrococci

(2), no bacteria have been found that have materially aided in the development of good cheddar cheese flavor.

Curing temperature

The part played by curing temperatures on the flavor production in cheddar cheese has been widely demonstrated. Extensive experiments conducted by Sanders *et al.* (41) on the effect of curing temperatures on the rate of curing and development of flavor in cheddar cheese showed that cheese cured at 60° F. ripened faster and developed more flavor than cheese cured at 50° F. However, high quality milk was essential in making cheese for rapid curing at 60° F. Wilson *et al.* (54) reported that if cheese is destined as a result of some inherent defect in the making process to have a score below 92, it will have a relatively higher score if it is cured at 34° F. than if it is cured at 50° F. The same authors found that cheese made from milk of good quality and by good cheesemaking methods can be cured at temperatures as high as 50° F. with reasonable certainty of developing a clean and characteristic cheddar flavor. Cheese made from bacteriologically poor milk or by poor methods should be cured at 34° F. in order to suppress the defects as much as possible.

Streptococcus faecalis cheese starter

Dahlberg and Kosikowsky (14) recently isolated a strain of *Streptococcus faecalis* from human stools which showed promise as a cheese starter organism, and which, they believed, might increase the flavor development of cheddar cheese. They found *Streptococcus faecalis* to have characteristics of special significance in cheese. It grows well at 106° F. in the cheese vat and at 50° F. in the curing room. Proper strains ferment lactose rapidly enough to be used as a cheese starter. The organism grows well at both the pH and salt concentrations found in cheese. It is not proteolytic and grows under the anaerobic conditions found in cheese. Cheesemaking experiments conducted by Dahlberg and Kosikowsky (14) in which the newly isolated strain of Streptococcus faecalis was used in the starter showed that S. faecalis starter used in combination with regular commercial lactic starter hastened the ripening of cheddar cheese. They reported that well ripened cheese of medium flavor intensity was produced in 4.5 months at 50° F. and in 2.5 months at 60° F. when S. faecalis was used with commercial lactic starter. When commercial lactic starter was used alone, 2 to 2.5 additional months of curing time were required to develop the same flavor intensity.

Kosikowsky and Dahlberg (32) continued their investigation to learn whether the improved rate of ripening they obtained by using S. faecalis starter might be due to the growth and survival of the organism in the curing cheese. They found that S. faecalis was able to grow and survive in cheddar cheese in large numbers for a considerable period of time, both at 50° F. and 60° F. The highest number of enterococci were present in the curd just prior to salting. The numbers decreased slowly during the curing period, but considerable numbers were still present at the end of 180 days. It is well known that the S. lactis organisms of commercial cheese starter do not survive very long in the cheese during the curing process. Dahlberg and Kosikowsky (15) reported that the growth of S. faecalis in cheddar cheese resulted in a marked increase in the amount of tyramine in the cheese, and that there was a direct semilogarithmic relationship between the tyramine content and flavor intensity. The tyramine itself was not credited with providing the flavor, but served as a measure of the bacterial activity which did produce the desired flavor. A mixture of commercial starter and S. faecalis starter produced larger amounts of tyramine and more flavor in the resulting cheese than was obtained when either of the starters were used alone. The same authors indicated that the flavor intensity was directly related to the increase in titratable acidity, and in a general way related to the water soluble nitrogen content. Additional studies by Dahlberg and Kosikowsky (16) showed that cheddar cheese containing S. faecalis developed more tyramine and cheddar flavor as the ripening temperatures were increased from 40° F. to 60° F. They also reported that cheese made with S. faecalis starter maintained its flavor for a longer period of time without becoming over cured at warm temperatures than did cheese made with ordinary lactic starter alone.

The use of S. faecalis starter under ordinary commercial conditions was demonstrated by Dahlberg and Kosikowsky (17) in the manufacture of cheddar and stirred curd cheese. The cheese was made in large vats from milk from a wide variety of sources. The use of S. faecalis starter under such conditions improved the flavor development of the cheese little if at all over the cheese made with commercial starter alone. They concluded that cheese made from pasteurized milk which naturally contained bacteria that ripened the cheese especially well was improved slightly or not at all by the use of S. faecalis starter.

Vanderbeek (50), working with a strain of S. faecalis in cheese starter, found that a combination of S. faecalis and commercial starter produced a higher titratable acidity at milling than did commercial starter alone. He found that the highest flavor scores were produced by the control cheese in which only commercial lactic starter was used. The use of S. faecalis resulted in poorer quality cheese due to high acid and bitter flavors. Bitterness was by far the most objectionable criticism. The same author found no correlation between the soluble nitrogen content of cheese made with commercial starter alone, and that to which S. faecalis had been added. He concluded that the strain of S. faecalis which he used as a cheese starter did not reduce the curing time or increase the development of cheddar flavor. It is very likely that the strain of S. faecalis used by Vanderbeek (50) was different from the one found successful by Dahlberg and Kosikowsky (14). Deane et al. (18) found that they were able to make better quality cheddar cheese when pure S. lactis was used as the only starter organism.

Comparison of Streptococcus faecalis to Streptococcus lactis

The distinction between Streptococcus lactis and the fecal streptococci has not always been clear. Ayers and Johnson (6) reported in 1924 that very great similarities existed between S. lactis and S. faecalis. In 1929 Demeter (19) stated that the organism known as S. lactis may represent at most only a strain of the fecal streptococci which frequently assume a stabilized or habitat form in milk. On the basis of physiological, nutritive, and serological characteristics; Gunsalus et al. (24) found S. lactis R, which was being used for the assay of folic acid, to be S. faecalis.

The nomenclature of the fecal streptococci has also been indefinite. Chapman (11) stated that early American workers referred to the enterococcus as Streptococcus faecalis. English, German, and recent Americans refer to it as the enterococcus. In French literature it is known as Micrococcus ovalis. Kendall and Haner (30) also referred to this organism as Micrococcus ovalis.

The most recent system of classification by Breed et al. (9) divides the streptococci into five major groups: the pyogenic group, the viridans group, the lactic group, the enterococcus group, and the strict anarobes. Streptococcus faecalis is classified as a species of the enterococcus group. Table 1, compiled from the same system of classification, lists the outstanding differences between Streptococcus lactis and Streptococcus faecalis. Seeleman and Nottbohm (43) and Sherman and Stark (47) have reported similar findings. Seeleman and Nottbohm (43), however, added that S. faecalis did not produce acid in milk as rapidly as S. lactis. They found that S. faecalis acidulated milk in two to six days while S. lactis acidulated it in twenty hours.

Niven and Sherman (37) placed Streptococcus faecalis,

Table 1. Characteristic differences between S. lactis and S. faecalis.

Characteristic	S. lactis	S. faecalis
Morphology	Spheres, many cells enlongated in direction of chain. 0.5 to 1.0 micron. Mostly in pairs and short chains, with some cultures long chains. Gram positive.	Sphere, ovals, of variable size, usually occurring in pairs and sometimes short chains in fluid media. Gram positive.
Temperature	Growth at 10° C. or below, and at 40° C. but not at 45° C. Some strains survive 60° C. for 30 min.	Optimum 37° C. May grow at 5° C. and below. Grows at 10° C. and 45° C. Seldom grows at 50° C. Survives 62.8° C. for 30 min.
Chemical tolerance	Growth with 2 percent and 4 percent NaCl but not with 6.5 percent. Final pH in broth 4.5 to 4.0. No growth at pH 9.6 but grows at pH 9.2 tolerates 0.01, 0.1, and 0.3 percent methylene blue. Bile neither lyses or inhibits growth.	Tolerates 2 percent 4 percent, and 6.5 percent NaCl. Final pH in glucose broth 4.4 to 4.0. Grows at pH 9.6. Tolerates 0.01, and 0.1 percent methylene blue. Bile does not lyse or inhibit growth.
Litmus milk	Acid, complete reduction of litmus before curdling. Young cultures entirely reduced with narrow red band at top which widens with aging. No digestion and no gas produced, but whey may be expressed.	Acid, usually reduction of litmus before curdling. No digestion of clot.
Source	Milk and milk products.	Human feces and intestinal contents. Inflammatory exudates; blood stream in sub acute endocarditis. Milk and cheese.

Table 1. (concluded)

Characteristic	S. lactis	S. faecalis
Acid from raffinose	-	±
Acid from inulin	-	-
Acid from glycerol	-	±
Acid from sorbitol	-	±
Acid from manitol	±	+
Acid from salicin	±	+

Streptococcus zymogenes, *Streptococcus liquifaciens*, and *Streptococcus durans* in the same group on the basis of serological properties. This group constitutes the enterococcus group of streptococci classified by Breed *et al*. (9). Seeleman and Nottbohm (43) found that biochemical and serological differences existed between *S. lactis* and the enterococcus group of organisms. Niven and Sherman (37) report that they have found the nutritive requirements of *S. lactis* to be different from those of the enterococcus group with respect to vitamins and amino acids. Niven (36) reported similar findings.

Characteristics of *Streptococcus faecalis*

The normal habitat of *S. faecalis* is the intestinal tract of man and animals. Chapman (11) studied 909 strains of which 80 percent were taken from human intestinal matter. Only 18.5 percent of other streptococcus organisms were taken from this source.

An outstanding characteristic of *S. faecalis* is its extreme hardiness. Sherman, Mauer, and Stark (45) studied 434 cultures of *S. faecalis* and found the organism able to grow at 10° C. and 45° C., and to survive 62.8° C. for 30 minutes. Growth also took place in 6.5 percent sodium chloride solutions. Chapman (11) found that *S. faecalis* would grow in 20 percent bile in peptone water, and would grow within the pH range of 4 to 11. The same author found that 94.7 percent of the *S. faecalis* organisms studied were resistant to solutions of 1:500,000 merthiolate, 1:2,500 phenol, 1:5,000 basic fuchsin, 1:50,000 hexylresorcinol, and 1 percent sodium carbonate.

The morphology of *S. faecalis* was studied by Knaysi (31). He found that when grown on meat infusion agar, the cells approach an ellipsoidal form, changing from flattened to ellipsoidal to enlongated ellipsoid during their growth. They pass through the sperical phase, but are seldom encountered as strict spheres. The size of the cells vary from 0.84u in width to from 0.7 to 1.2u in length. There is great regularity shown in form, length, width, and growth of the organisms from the time the new cells are formed until subsequent cell division occurs. The width of the cells remain quite constant at all times. Sherman *et al.* (45) found *S. faecalis* to grow mostly in pairs and to a less extent in short chains.

S. faecalis does not produce gas from the fermentation of carbohydrates under normal conditions. According to

Frosbisher (21) however, synergism may occur in which gas is produced when S. faecalis grows in the presence of several other organisms. With Escherichia coli, gas is produced from saccharose, with Salmonella paratyphi and Proteus vulgaris gas is produced from both saccharose and lactose, and with Klebsiella pneumoniae gas is produced from lactose.

Although numerous investigators (11) (9) (25) (14) have definitely established the intestinal tract of man and animals as the normal habitat of S. faecalis, the organism is frequently found in milk and milk products. White and Sherman (52) examined 192 samples of raw milk and 19 samples of pasteurized milk for the presence of enterococci. It was found that organisms of this group constituted 0.4 and 0.1 percent respectively of the total bacterial population. Milks which had high total bacterial counts had significantly lower percentages of enterococci, although the actual numbers were higher. It was also found that there was a large variation in the numbers and percentages of enterococci in the different samples of milk examined.

Tittsler et al. (49) investigated the bacterial flora of cheddar cheese made from raw and pasteurized milk. They found that after the cheese was one month old the flora of pasteurized milk cheese consisted almost entirely of enterococci and a few diversified types. Ary (4) found S. faecalis to be the only streptococcus found in ripe Hungarian emmental cheese.

Gale (22) observed that washed suspensions of stock S. faecalis were able to decarboxylate 1 (-) tyrosine to form tyramine. The amino acid, tyrosine, is quite abundant in ripened cheese and was isolated and identified as such by Dorn and Dahlberg (20). Gale (22) noted that the decarboxylase involved in the reaction was optically active at pH 5, and that cultures grown at 27° C. had the same decarboxylase activity as those grown at 37° C. Cultures grown in carbohydrate media at pH 7 had little activity. The activity was increased 30 to 40 fold by lowering the pH to 5. Of the seven strains of S. faecalis studied, six of them decarboxylated tyrosine. These active strains appeared to be the more rapid acid producing strains. The tyrosine decarboxylase was strictly specific and affected no other amino acids. The specificity of the decarboxylase was emphasized by Hanke and Koesler (25) who found that microorganisms that produce histamine do not decarboxylate tyrosine and tyramine producers do not decarboxylate histidine.

Physiological effects of tyramine

It is readily seen that the physiological effect of tyramine is an important consideration in the use of S. faecalis as a cheese starter. Heilbron and Bunbury (27) described tyramine (2-p hydroxyphenylethylamine) as the chief pressor base found in some extracts of mature cheese and putrified animal tissue. Hawk et al. (26) states that tyramine is closely related to adrenaline both in structure and action. It is a vasoconstrictor and elevates blood pressure. Tyramine was reported by Abell (1) to have caused arteriolar constriction when doses of 1.5 mg. were injected into rabbits. The constriction became maximal in 0.8 to 1.5

minutes. Tyramine usually did not cause constriction of the venules. No response of capillaries was observed. Hoshimoto (28) observed that intravenous injection of tyramine -HCl in rabbits resulted in transitory dilation and subsequent constriction of renal blood vessels when the dose was 20 mg. or more. Initial constriction when the dose was small and either constriction or dilation when the dose was medium. The fate of tyramine in the tissues of the body was suggested by the work of Bernheim and Bernheim (8) in 1944. They found that tyramine was readily metabolized by tissues in vitro. Heart, skelatal, and possibly smooth muscle of the rat is able to deaminate tyramine and can presumable break the hydroxyphenyl ring. Kidney and liver are only able to deaminate it.

Toxicity of Streptococcus faecalis

Two outbreaks of food poisoning attributed to cheese were reported to the U. S. Public Health Service within the year March 1925 to February 1926. Linden et al. (34) described the suspected causative organism as being very similar to the ordinary cheese starter organism except that it produced only 0.5 to 0.6 percent acid in milk calculated as lactic acid. Using the same organism, Sherman, Smiley, and Niven (46) were able to cause diarrhea in cats. They later identified the organism as S. faecalis. Rantz and Kirby (40) state that enterococci have been demonstrated to cause otitis media, endocarditis, and infections of the abdomen and urinary tract. Buchbinder, Osler, and Steffen (10) found S. faecalis to be present most frequently and in overwhelming numbers in canned evaporated milk implicated in an outbreak of gastro enteritis. Osler, Buchbinder and Steffen (38) were able to produce acute mild intestinal or gastric disturbances or both in man with young cultures of enterococci. They had no success with cultures incubated for 20 hours. They concluded that their results tended to confirm the etiological role of _S. faecalis_ in naturally occurring outbreaks of food poisoning. Sherman _et al_. (44) found _S. faecalis_ to be responsible for a rare type of food poisoning from cheese and other food products. Six cases of food poisoning were investigated in which _S. faecalis_ was implicated. Sherman _et al_. (44) pointed out that _S. faecalis_ and a few related varieties of the enterococcus group were the only ones which could cause this trouble, and that their results indicated that the poison substance might be tyramine formed by the decarboxylation of tyrosine by _S. faecalis_. Five of the seven strains of _S. faecalis_ investigated by Gale (23) were capable of forming ornithine by the liberation of ammonium carbonate from arginine. Gale also noted the symbiotic effect of _Escherichia coli_ and _S. faecalis_ on arginine. At pH 5.5, which is near the pH of cheddar cheese, _S. faecalis_ converted the arginine to ornithine. The _E. coli_ then decarboxylated the ornithine to form putrescine. Putrescine, however, is reported by Hawk _et al_. (26) and Johnston (29) to be non-toxic.

Dack _et al_. (12) conducted 52 feeding tests on 37 volunteers to determine the safety of using the DK strain of _S. faecalis_ as a starter culture for cheese. Cheese made with the starter strain and containing large numbers of viable organisms as well as appreciable quantities of tyramine, had no unfavorable effect on human volunteers. When tyramine mono-chloride was fed in 0.3 or 1 gram amounts in one pint of milk to human volunteers, no rise in blood pressure or any other ill effect was noticed. The same authors found that cultures of S. faecalis grown in milk for 4.25 to 4.5 hours had no effect when fed to human volunteers. Neither was any ill effect noticed when 40 to 370 billion viable enterococci were fed to the volunteers. The only ill effects noted during the feeding tests occurred in 2 or 3 volunteers who were fed a milk culture containing a strain of Streptococcus liquifaciens recently isolated from an outbreak of food poisoning. Dack et al. concluded that there was no evidence to show that tyramine is toxic to man when taken by mouth in the doses indicated. They further concluded that the strain of S. faecalis used in DK cheese starter was without ill effect when taken by mouth.

MATERIALS AND PROCEDURE

Materials

Hansen's lactic ferment culture containing the organisms *Streptococcus lactis*, *Leuconostoc dextranicum*, and *Leuconostoc citrovorum* was used as the commercial cheese starter in this experiment. The mother culture was carried in grade A whole milk which had been treated in an autoclave to a temperature of 240° F. for 10 minutes. Good activity was maintained by transferring the culture daily using a one percent inoculum. The cultures were then incubated at a temperature of 70° F. for 14 to 15 hours. Bulk starter was prepared in one gallon metal ice cream cans using the same quality milk, method of sterilization, percent inoculum, and temperature of incubation as was used in the preparation of the mother cultures. The starter usually developed an acidity of about 0.80 percent and possessed a smooth texture and a pleasing flavor typical of good lactic starter.

A culture of DK cheese starter was obtained from the Department of Dairy Industry, Cornell University. The mother culture was propagated in milk which had been treated in an autoclave to a temperature of 240° F. for 10 minutes. The mother starters were transferred daily to insure maximum activity, and carried in the manner recommended by Dahlberg (13). The cultures were inoculated with a one percent inoculum and incubated at a temperature of 88° F. for 15 to 16 hours. The bulk starter was prepared in gallon metal ice cream cans using the same procedure as was used in preparation of the mother culture. The DK starter possessed a rather soft granular curd with a pronounced chemical type flavor which was not at all typical of the flavor of good commercial lactic starter.

The milk used in these experiments was of good quality and was a part of the regular supply of the Utah State Agricultural College Creamery. It was standardized to 3.5 percent fat with freshly separated skim milk and pasteurized at 143° F. for 30 minutes. The milk was then cooled to 40° F. and held overnight in the pasteurizing vat. The following morning it was heated to 88° F. and pumped into three cheese vats, each holding 500 pounds of milk. Samples of milk for bacterial counts were taken before the milk was pumped into the cheese vats. None of the counts exceeded 30,000 per cc as determined by the standard plate count authorized by the American Public Health Association (3).

Method of Manufacture

Strict uniformity was maintained among all batches of cheese by the use of Wilson's (53) clock method of cheese manufacture as outlined in figure 1.

Hansen's cheese rennet was used in all batches at the rate of 4 oz. per 1000 pounds of milk. Salt was added to the curd at the rate of 2.75 pounds per 1000 pounds of milk.

The cheese was manufactured in three vats using a different starter combination in each. The first vat of milk was inoculated with 0.75 percent lactic starter; the second with 0.53 percent lactic plus 0.53 percent DK; and the third

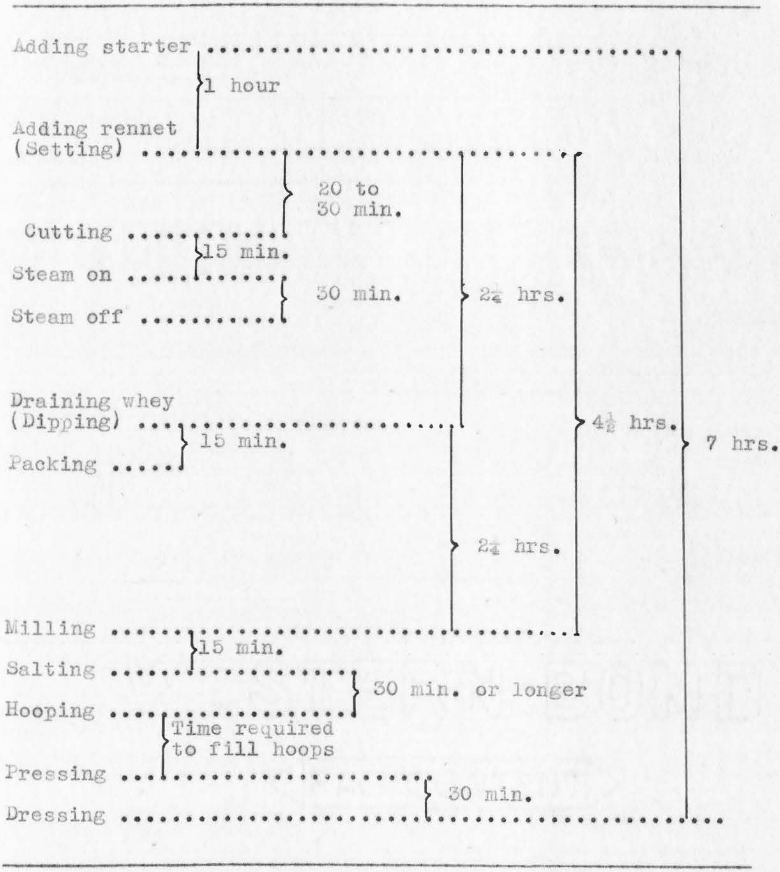


Figure 1. Time intervals between steps in the manufacture of cheddar cheese

with 0.75 percent lactic plus 0.375 percent DK starter.

During the manufacture of the cheese, the rate of acid development in each of the three vats of cheese was carefully noted. The acid development was measured by determination of the titratable acidity expressed as percent lactic acid, and the pH as determined by the Beckman pH meter with a calomel and glass electrode. The titratable acidity of the milk was measured before adding the starter and at the time of adding the rennet. The titratable acidity and pH of the whey were taken at the time of cutting the curd, draining the whey, and milling the curd. Any noticeable differences between the appearance of the curd during cheddaring which may have been due to the starter combination were noticed and recorded.

Forty-three pounds of curd from each vat were placed in two 20-pound square hoops. The curd was pressed for a minimum of 30 minutes before being removed from the press for dressing. The curd in each hoop was cut into four 5-pound loaves which were then individually wrapped in rayon cheese cloths. The loaves were replaced in the hoops and pressed overnight.

Upon removal from the press, the loaves were marked and the surfaces allowed to dry. When the surface of the cheese was sufficiently dry, the loaves were paraffined and placed in the curing rooms. Four loaves from each vat were placed in a curing room at 50° F., and the remaining four were cured at 60° F.

Eight separate trials consisting of three vats of cheese each were made in the manner described.

Methods of analysis

Analysis of the cheese took place when the product was 10, 30, 60, 90, and 120 days old.

Samples were taken for analysis by drawing several triers of cheese from the end of the loaves in such a manner that the plugs were evenly spaced and the trier penetrated to the center of the cheese. Both ends of the loaves were used for sampling, and a new loaf was used for each periodic analysis. The trier holes were filled with paraffin after the sampling was completed.

The pH of the cheese was determined by a Beckman pH meter. The sample was ground to a smooth paste with a mortar and pestle and placed in contact with the electrodes of the meter.

Moisture content was determined with a Brabender Semi-Automatic Moisture Tester. The cups were heated in the oven to 130° C. and brought to a uniform weight by the addition of clean dry quartz sand. Ten grams of cheese were quickly weighed into the cooled cups, which were then replaced in the machine and dried at 130° C. At the end of 80 minutes the percent moisture was read directly from the scale on the moisture tester. Each sample was run in duplicate.

The percent fat in the cheese was determined by a modified Babcock method as recommended by Wilster (56), with the exception that acid having a specific gravity of 1.84 was used, and the test bottles were not placed in boiling water.

At the time of each periodic analysis the cheese was judged and scored for flavor, body, and texture. The standards on the score card of the American Dairy Science Association outlined by Nelson and Trout (35) were adhered to by the judges. The judging was done by two expert dairy products judges from the staff of the Dairy Department at Utah State Agricultural College.

The total nitrogen content of the cheese was determined in duplicate by the official Kjeldahl Gunning method of the Association of Official Agricultural Chemists (5) with the boric acid modification suggested by Scales and Harrison (42). The titration was carried out with 1/14 normal sulfuric acid using a mixed indicator of methyl red and bromcresol green. The total nitrogen content was expressed as milligrams of nitrogen per gram of cheese.

The soluble nitrogen fraction was extracted from the cheese according to the procedure outlined by Sommer (48). The filtering process was modified according to the suggestions of Babel (7) with further modifications necessary in order to obtain a clear filtrate. A pad of non absorbent cotton in addition to an extra layer of filter paper was placed in a Buchner funnel along with some filter cell. A suction flask was used to speed the filtering process. The filtrate was made up to 500 ml. in a volumetric flask. A 50 ml. aliquot portion of the filtrate was placed in a Kjeldahl flask and the nitrogen content determined by the same procedure used in the determination of total nitrogen. Soluble nitrogen determinations were run in duplicate and the results reported as percent of total nitrogen.

RESULTS AND DISCUSSION

Titratable acidity of bulk starters

A comparison of the titratable acidity of each batch of commercial lactic and DK bulk starter used in this experiment is presented in Table 2.

The bulk starter made with commercial lactic starter culture developed a higher titratable acidity in every case than did the bulk starter made with DK starter culture. The commercial lactic starter was incubated for 14 to 15 hours, and the DK starter was incubated for 15 to 16 hours. The average titratable acidity of the commercial lactic bulk starter was 0.816 calculated as percent lactic acid as compared to 0.660 percent for the DK bulk starter. The results of this phase of the experiment tend to substantiate the fact that the organisms of commercial lactic starter produce acid more rapidly in milk than *S. faecalis*.

Changes in acidity during manufacture of cheese

The acid development during the manufacture of the cheese was determined by measuring the pH and titratable acidity of the whey at cutting, dipping, and milling.

The average results obtained for each starter combination are presented in tables 3, 4, and 4a, and are shown graphically in figures 2, 3, and 4.

The results at the time of cutting the curd showed that there was no variation in pH, and practically no variation in titratable acidity due to the difference in starters.

Table 2. The titratable acidity of 8 trials of commercial lactic and DK bulk starters incubated for 14 to 15 and 15 to 16 hours respectively.

Trial	Commercial lactic starter	DK starter
A	0.79	0.60
B	0.79	0.60
C	0.81	0.67
D	0.81	0.63
E	0.87	0.68
F	0.79	0.72
G	0.80	0.68
H	0.87	0.70
Avg.	0.816	0.660

At the time of dipping there was still very little variation in acidity due to the starters used, however, the inoculation of 0.53 percent DK plus 0.53 percent lactic starter showed a slightly lower titratable acidity than the other two starter combinations. There were marked differences, however, between the amounts of acid produced by the three starter combinations at the time of milling the curd. Both the titratable acidity and pH showed the greatest amount of milling acid to be produced by the inoculation of 0.75 percent lactic plus 0.375 percent DK starter. The commercial lactic starter was a little lower in acid production, and the inoculation of 0.53 percent lactic plus 0.53 percent DK starter produced a considerably lower acidity at milling than did either of the other two starter combinations.

Table 3. Average titratable acidity and pH values obtained at 3 stages in manufacture of 24 lots of cheddar cheese with DK and commercial lactic starter.

	Cutting		Dipping		Milling	
Starters	T.A.*	pH	T.A.*	pH	T.A.*	pH
.75% lactic	.118	6.40	.141	6.16	.422	5.63
.53% lactic plus .53% DK	.118	6.40	.138	6.16	.360	5.70
.75% lactic plus .375% DK	.119	6.40	.141	6.19	.440	5.57

* Titratable acidity

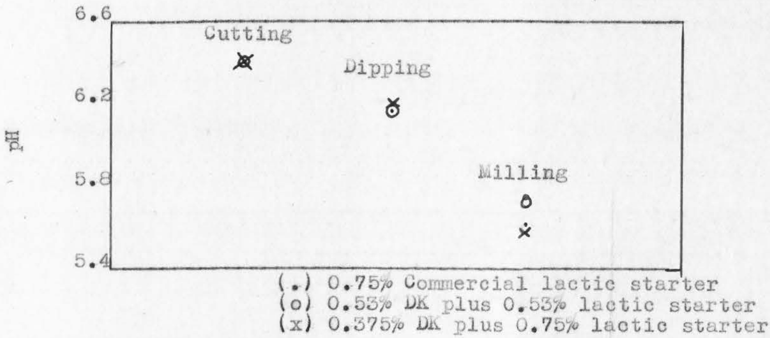


Figure 2. Relationship of the pH of the whey at 3 stages in manufacture of 24 batches of cheddar cheese with 3 starter combinations containing DK and commercial lactic starter.

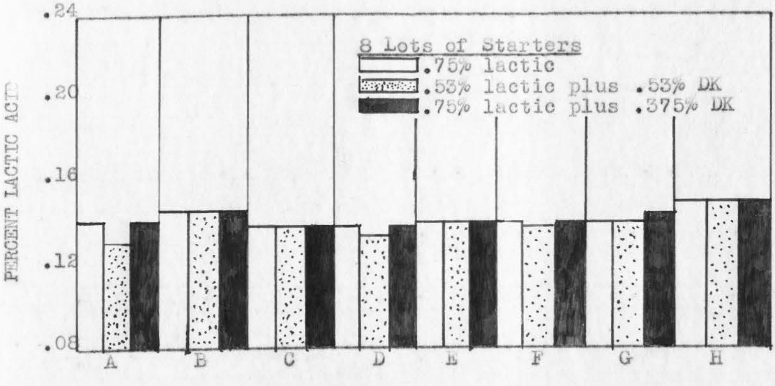


Figure 3. A comparison of the titratable acidity at dipping of 24 lots of cheddar cheese made with DK and commercial lactic starter.

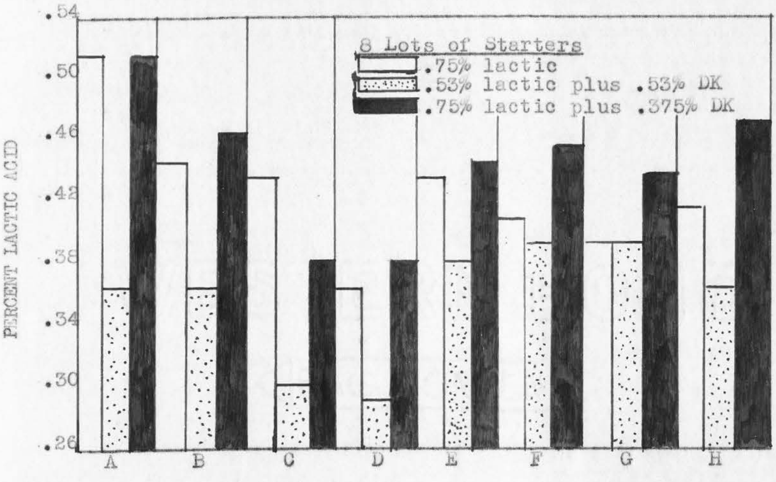


Figure 4. A comparison of the titratable acidity at milling of 24 lots of cheddar cheese made with DK and commercial lactic starter.

Table 4. Analysis of variance of the titratable acidity during 3 stages in the manufacture of 24 batches of cheddar cheese made with DK and commercial lactic starter.

Sources of Variation	Degrees of Freedom	Mean Square	"F" factor
3 Between starters	2	5209.75	16.053**
8 Between trials	7	1498.18	4.614**
Error (a)	14	324.50	
3 Stages	2	622162.65	1057.632**
9 Stages by starters	4	4446.50	7.559**
Error (b)		588.26	

** Highly Significant

Table 4a. Significance* of the difference between the mean titratable acidity values obtained for 2 DK starter combinations and commercial lactic starter in the manufacture of 24 batches of cheddar cheese.

Starter	Mean Value	Difference from control
1- Control	226.0	
2-	205.2	21.7**
3-	233.3	6.4 NS

* Least Significant Difference
15.480 at p = 0.01
11.654 at p = 0.05

** Highly Significant
NS No Significance

1- 8 lots 0.75% commercial lactic starter
2- 8 lots 0.53% DK plus 0.53% commercial lactic starter
3- 8 lots 0.375% DK plus 0.75% commercial lactic starter

Statistically, as shown in table 4a, there was a highly significant difference between the acid production of the straight commercial lactic starter and the mixture of 0.53 percent commercial lactic plus 0.53 percent DK starter throughout the cheesemaking process. The heavy inoculation of DK starter tended to retard the development of acid. Where 0.375 percent DK starter was used with 0.75 percent commercial lactic starter there was a slight increase in acid development over the 0.75 percent commercial lactic starter, but the increase was not significant.

The difference in acid production between trials was barely highly significant. This variation may have been due to variations in the starter activity from day to day.

The results tend to show that at the time of cutting the curd there was no difference in the acid production of the 3 starter combinations used. However, as the process continued the rate of acid production by the 0.75 percent lactic plus 0.375 percent DK starter was slightly greater than the 0.75 percent lactic starter, and the combination of 0.53 percent lactic plus 0.53 percent DK starter showed a significantly lower rate of acid production than 0.75 percent lactic starter.

Appearance of curd during cheddaring

During the cheddaring process the curd made from milk containing the greatest concentration of DK cheese starter showed marked differences in texture and matting properties from the curd made from milk inoculated with lactic starter only.

The curd made with the heavy inoculation of DK starter matted less readily and had a harder more granular consistency.

There was more difficulty encountered in the rapid expulsion of whey, and the slabs of cheese curd did not flatten and produce the same degree of elasticity as the curd made with lactic starter alone. Cutting into the curd prior to milling revealed slightly more openness and less healing qualities in the heavily inoculated DK curd than in the straight lactic curd. There seemed to be no detectable difference in the nature of the curd made with 0.75 percent lactic plus 0.375 percent DK starter and that made with 0.75 percent lactic starter alone.

The slabs of curd containing the 0.75 percent commercial lactic starter inoculation and those containing the 0.75 percent lactic plus 0.375 percent DK starter inoculation cheddared more rapidly and became more pliable than the curd made with 0.53 percent DK starter plus 0.53 percent lactic starter.

The differences in the appearance of the curd during cheddaring were probably due to the variation in the acid production between dipping and milling. The development of good matting and pliability in cheddar cheese curd during the cheddaring process is dependent upon the rate of acid production in the curd particles.

In all cases a clear whey was expelled during the cheddaring process until very shortly before milling time. There were no differences observed in the clarity of the expelled whey as a result of the starter combinations.

<u>pH changes during ripening of cheese</u>

All the cheese showed a gradual increase in pH throughout the curing period of 120 days. As may be seen from figure 5, there were no noticeable differences in the pH changes during the curing period at 50° F. as a result of the starter combinations used. The rises in pH were relatively constant among all three lots of cheese.

The pH changes in the cheese cured at 60° F. are illustrated in figure 6. The same trend of increasing pH values for all the cheese is again evident. However, when cured at 60° F. both lots of cheese containing DK starter showed a slightly greater increase in pH toward the end of the curing period than did the cheese made with straight commercial lactic starter.

The cheese cured at 60° F. exhibited a more rapid increase in pH throughout the curing period, and a definitely higher pH at the end of 120 days than the cheese cured at 50° F.

Changes in percent fat during ripening of cheese

The results of periodic fat analysis of the cheese are shown graphically in figures 7 and 8.

All of the cheese showed a gradual increase in percent fat as the curing period progressed. The differences in percent fat of the cheese as a result of the starter combinations used in this experiment were too slight to be of any importance. Average variations were less than 0.5 percent, and the modified Babcock test used to determine the fat content of the cheese is accurate only to the nearest 0.5 percent.

It may be seen by comparison of figures 5 and 6 that there was a more rapid increase in percent fat in the cheese cured at 60° F. than in the cheese cured at 50° F. This condition was probably a result of the increased loss of moisture at the higher curing temperature.

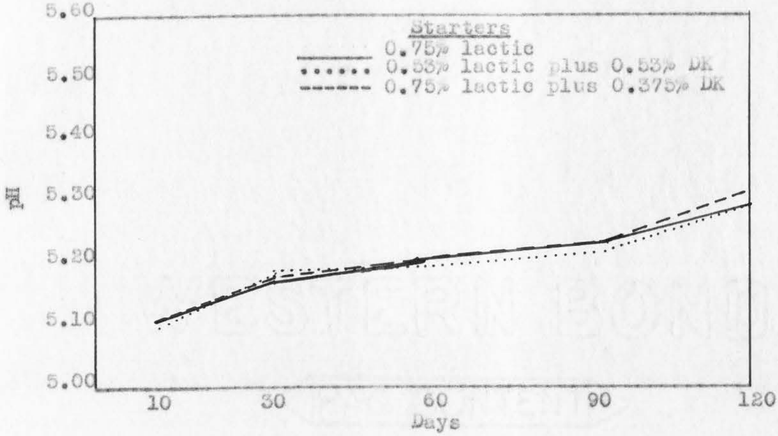


Figure 5. Changes in pH of cheddar cheese made with combinations of DK and commercial lactic starter and cured for a period of 120 days at 50° F.

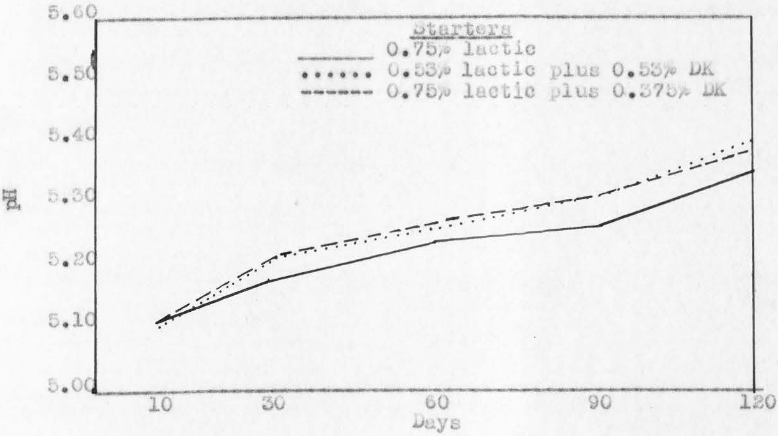


Figure 6. Changes in pH of cheddar cheese made with combinations of DK and commercial lactic starter and cured for a period of 120 days at 60° F.

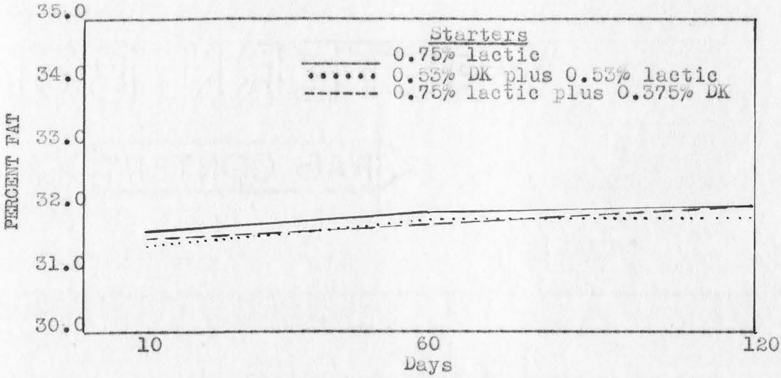


Figure 7. Changes in fat content of cheddar cheese made with combinations of DK and lactic starter, and cured for 120 days at 50° F.

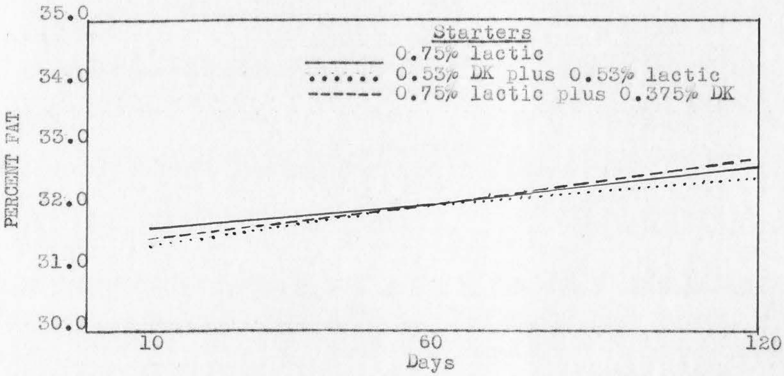


Figure 8. Changes in fat content of cheddar cheese made with combinations of DK and lactic starter, and cured for 120 days at 60° F.

Changes in moisture content of cheese during ripening

The moisture content of all the cheese gradually decreased throughout the entire 120 day ripening period. The rates of decrease in moisture of cheese representing each starter combination and each curing temperature are illustrated in figures 9 and 10. The results obtained from this phase of the experiment indicate that any differences between the moisture content of the cheese throughout the curing period at 50° F. or 60° F. as a result of the starters used, are small enough to be unimportant. It may be easily seen, however, that a considerably greater moisture loss was encountered throughout the ripening period when the cheese was cured at 60° F. than when it was cured at 50° F.

Results of scoring cheese for flavor

The results of periodic scoring of the cheese at 10, 30, 60, 90, and 120 days definitely showed the superiority of the cheese made with 0.75 percent commercial lactic starter as far as flavor is concerned. Table 5 shows the overall average flavor score of the cheese made with straight lactic starter and cured at 50° F. to be 39.6. Cheese cured at the same temperature but made with 0.53 percent lactic plus 0.53 percent DK starter had an average flavor score of 38.8 while the cheese made with 0.75 percent lactic plus 0.375 percent DK starter had an average flavor score of 39.3. Throughout the entire curing period at 50° F., the cheese made with straight commercial lactic starter maintained the highest flavor scores, and the cheese made with the greatest concentration of DK starter had the lowest flavor scores.

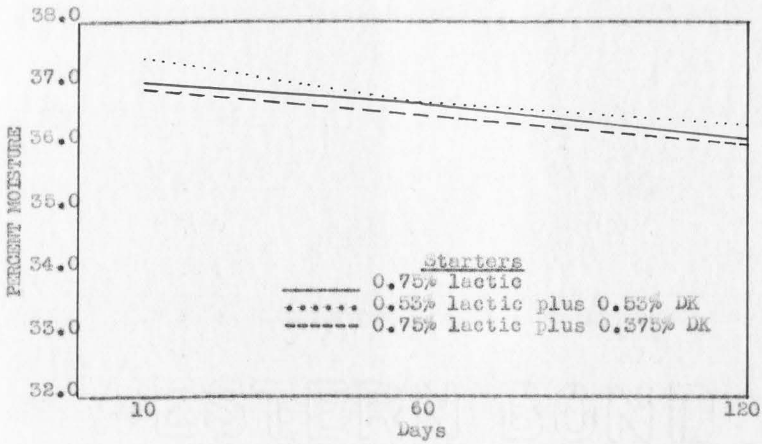


Figure 9. Changes in moisture content of cheddar cheese made with combinations of lactic and DK cheese starter and cured for 120 days at 50° F.

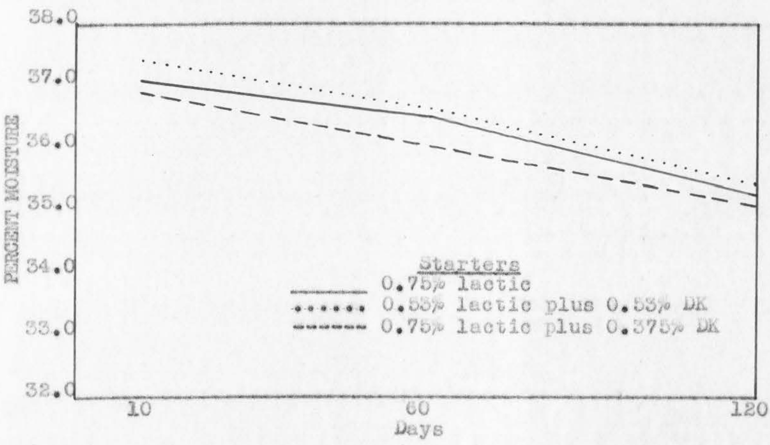


Figure 10. Changes in moisture content of cheddar cheese made with combinations of lactic and DK cheese starter and cured for 120 days at 60° F.

Table 5. Average periodic flavor scores of 8 batches of cheddar cheese made with 3 combinations of lactic and DK starter and cured at 50° F.

Days	0.75% Lactic starter	0.53% Lactic plus 0.53% DK starter	0.75% Lactic plus 0.375% DK starter
10	39.6	39.0	39.4
30	39.1	38.4	39.1
60	39.6	38.9	39.1
90	39.9	38.8	39.2
120	39.8	38.8	39.5
Avg.	39.6	38.8	39.3

Table 6. Average periodic flavor scores of 8 batches of cheddar cheese made with 3 combinations of lactic and DK starter and cured at 60° F.

Days	0.75% Lactic starter	0.53% Lactic plus 0.53% DK starter	0.75% Lactic plus 0.375% DK starter
10	39.6	39.0	39.4
30	39.1	38.6	38.8
60	38.8	38.6	38.0
90	38.0	37.7	38.3
120	38.8	37.5	37.9
Avg.	38.9	38.3	38.5

The relationship between the flavor scores of the cheese made with each combination of starter are shown graphically in figures 11 and 12.

It is of interest to note that when cured at 50° F., the cheese made with pure lactic starter improved in flavor as it became older while the cheese containing DK starter gradually decreased or remained constant in flavor quality. It is also important to notice the rapid decrease in the flavor scores of all the cheese cured at 60° F. as compared to the cheese cured at 50° F. This tends to substantiate the fact that any tendency for cheese to develop off flavors is greatly assisted by any increase in curing temperature.

Flavor criticisms of the cheese

Flavor criticisms were rendered forty times during five monthly scorings on cheese representing each starter combination and each curing temperature. With very few minor exceptions, the only flavor criticisms encountered in all batches of cheese were slight acid, high acid, fruity, weed, and rancid. Figures 13 and 14 illustrate the number of each of these off flavors found in cheese representing each starter combination and each curing temperature.

When cured at 50° F. the major flavor criticism encountered in the cheese made with straight lactic starter was slight acid. This criticism was encountered nine times followed by high acid, fruity, and weed which occurred twice each and rancid which was found once. At the same curing temperature the cheese containing the heavy inoculation of DK starter was criticized 17 times for being weedy, 8 times for being

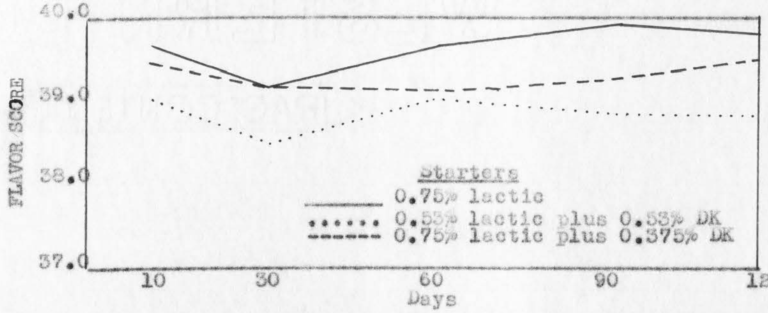


Figure 11. A comparison of average monthly flavor scores of cheddar cheese made with 3 combinations of lactic and DK starter and cured at 50° F.

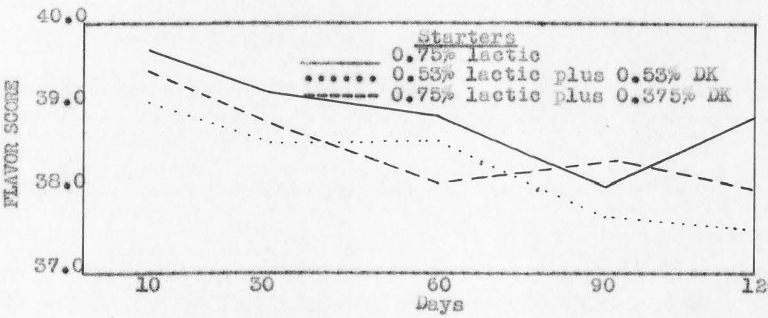


Figure 12. A comparison of average monthly flavor scores of cheddar cheese made with 3 combinations of lactic and DK starter and cured at 50° F.

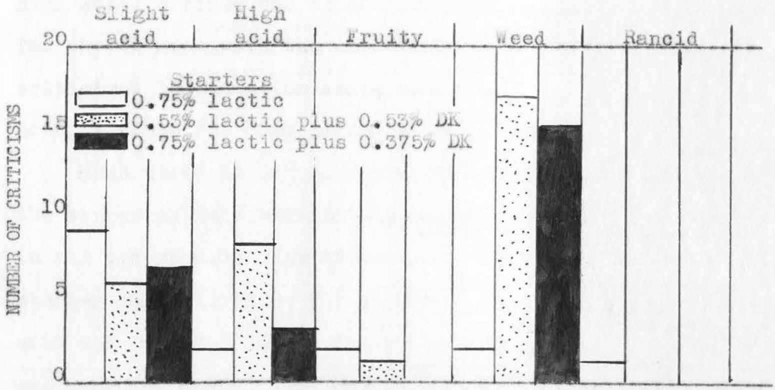


Figure 13. Flavor criticisms encountered in 5 scorings of cheddar cheese made with 3 combinations of DK and lactic starter and cured at 50° F.

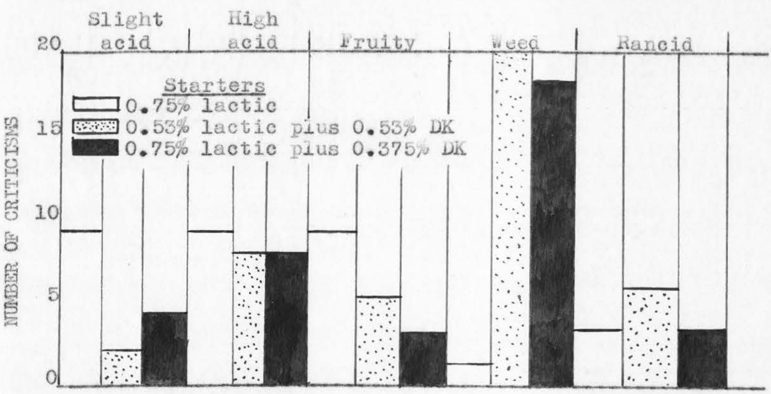


Figure 14. Flavor criticisms encountered in 5 scorings of cheddar cheese made with 3 combinations of DK and lactic starter and cured at 60° F.

high acid, 6 times for slight acid and once for being fruity. The cheese made with the light inoculation of DK starter was criticized 15 times for being weedy, 8 times for being slight acid, 3 times for high acid, and none for rancid or fruity.

When cured at 60° F. there was a noticeable increase in the number of more undesirable flavor criticisms encountered in all the cheese. The cheese made with 0.75 percent lactic starter was criticized 9 times each for being slight acid, high acid and fruity. It was rancid in 3 instances and a weed flavor was detected once. The cheese made with 0.53 percent lactic plus 0.53 percent DK starter was criticized 20 times for being weedy, 8 times for being high acid, 6 times for being rancid, 5 times for being fruity, and twice for being slight acid. The cheese containing 0.75 percent lactic plus 0.375 percent DK starter was weedy in 17 instances, high acid in 7, slight acid in 5, and fruity and rancid in 3 each.

The presence of a bitter flavor in the cheese made with starter containing S. faecalis was conspicuous by its absence in view of the findings of Vanderbeek (50). It seems quite probable that the strain of S. faecalis used by the above author which produced a bitter flavor in cheese was different from the one in DK cheese starter.

A flavor idenified as weed was found to be present in many instances in the cheese made with DK starter. Some difficulty was encountered by the judges in the proper description of this flavor as it is not a flavor ordinarily met in cheese grading. The same flavor was detected in the DK starter itself, and was described as a chemical type flavor in the starter. One prominent authority on cheese grading described it as a type of unclean flavor.

The weed flavor was not present in all the cheese made with either concentration of DK starter. It may be that there are factors which operate in the presence of the DK strain of S. faecalis, and are necessary to either produce or prevent the chemical breakdown of the cheese constituents responsible for producing this off flavor.

A Chi-square analysis of the occurrence of weed flavor in cheese cured at both 50° F. and 60° F. was made and tabulated in tables 7 and 7a. Eight lots of cheese made with commercial lactic starter were compared with 16 lots of cheese containing the two concentrations of DK starter to determine the significance of the weed flavor in the DK cheese. The cheese cured at 50° F. showed a highly significant difference at 30 days, no significant difference at 60 days, a highly significant difference at 90 days, and a significant difference at 120 days. The cheese cured at 60° F. showed no significant difference at 30 days and a highly significant difference at 60, 90, and 120 days.

High acid flavor was detected in cheese cured at 50° F. only twice where the cheese was made with commercial lactic starter, whereas this criticism was met 8 times in the cheese made with the heavy inoculation of DK starter. The cheese made with the small inoculation of DK starter did not develop high acid flavors to the same extent as that made with the heavy inoculation. The occurrence of high acid flavors in heavily inoculated DK cheese cured at 50° F. may be a result

Table 7. Chi-square analysis of weed flavor detected in cheese cured at 50° F.

30 days

Starter		No weed		Weed	Total
(1)	x	8.00	x	0.00	8.00
	m	5.00	m	3.00	
	x-m	3.00	x-m	3.00	
(2)&(3)	x	7.00	x	9.00	16.00
	m	10.00	m	6.00	
	x-m	-3.00	x-m	3.00	
Total		15.00		9.00	24.00

$X^2 = S \frac{(x-m)^2}{m} = 12.70$**

60 days

Starter		No weed		Weed	Total
(1)	x	6.00	x	2.00	8.00
	m	5.33	m	2.66	
	x-m	0.67	x-m	.34	
(2)&(3)	x	10.00	x	6.00	16.00
	m	10.66	m	5.33	
	x-m	-0.66	x-m	0.67	
Total		16.00		8.00	24.00

$X^2 = S \frac{(x-m)^2}{m} = 0.24$ N.S.

(1) 8 lots 0.75% lactic starter
(2) 8 lots 0.53% DK plus 0.53% lactic starter
(3) 8 lots 0.375% DK plus 0.75% lactic starter

x Observed values
m Expected values calculated from border totals
N.S. Not significant
* Significant
** Highly significant

Table 7. (concluded)

90 days			
Starter	No weed	Weed	Total
(1)	x 8.00 m 5.33 x-m 2.67	x 0.00 m 2.66 x-m -2.66	8.00
(2)&(3)	x 8.00 m 1.06 x-m 6.94	x 8.00 m 5.33 x-m 2.67	16.00
Total	16.00	8.00	24.00

$X^2 = S \frac{(x-m)^2}{m} = 50.78$ **

120 days			
Starter	No weed	Weed	Total
(1)	x 8.00 m 6.00 x-m 2.00	x 0.00 m 2.00 x-m -2.00	8.00
(2)&(3)	x 10.00 m 12.00 x-m -2.00	x 6.00 m 4.00 x-m 2.00	16.00
Total	18.00	6.00	24.00

$X^2 = S \frac{(x-m)^2}{m} = 3.99$ *

(1) 8 lots 0.75% lactic starter
(2) 8 lots 0.53% DK plus 0.53% lactic starter
(3) 8 lots 0.375% DK plus 0.75% lactic starter

x Observed value
m Expected values calculated from border totals
N.S. Not significant
* Significant
** Highly significant

Table 7a. Chi-square analysis of weed flavor detected in cheese cured at 60° F.

30 days			
Starter	No weed	Weed	Total
(1)	x 7.00 m 5.00 x-m 2.00	x 1.00 m 3.00 x-m -2.00	8.00
(2)&(3)	x 8.00 m 10.00 x-m -2.00	x 8.00 m 6.00 x-m 2.00	16.00
Total	15.00	9.00	24.00

$X^2 = S\,\frac{(x-m)^2}{m} = 3.20$ N.S.

60 days			
Starter	No weed	Weed	Total
(1)	x 8.00 m 5.00 x-m 3.00	x 0.00 m 3.00 x-m -3.00	8.00
(2)&(3)	x 7.00 m 10.00 x-m -3.00	x 9.00 m 6.00 x-m 3.00	16.00
Total	15.00	9.00	24.00

$X^2 = S\,\frac{(x-m)^2}{m} = 7.20^{**}$

(1) 8 lots 0.75% lactic starter
(2) 8 lots 0.53% DK plus 0.53% lactic starter
(3) 8 lots 0.375% DK plus 0.75% lactic starter

x Observed value
m Expected values calculated from border totals
N.S. Not significant
* Significant
** Highly significant

Table 7a. (concluded)

90 days			
Starter	No weed	Weed	Total
(1)	x 8.00 m 5.00 x-m 3.00	x 0.00 m 3.00 x-m -3.00	8.00
(2)&(3)	x 7.00 m 10.00 x-m -3.00	x 9.00 m 6.00 x-m 3.00	16.00
Total	15.00	9.00	24.00

$X^2 = S\ (\frac{x-m}{m})^2 = 7.20^{**}$

120 days			
Starter	No weed	Weed	Total
(1)	x 8.00 m 5.00 x-m 3.00	x 0.00 m 3.00 x-m -3.00	8.00
(2)&(3)	x 7.00 m 10.00 x-m -3.00	x 9.00 m 6.00 x-m 3.00	16.00
Total	15.00	9.00	24.00

$X^2 = S\ (\frac{x-m}{m})^2 = 7.20^{**}$

(1) 8 lots 0.75% lactic starter
(2) 8 lots 0.53% DK plus 0.53% lactic starter
(3) 8 lots 0.375% DK plus 0.75% lactic starter

x Observed value
m Expected values calculated from border totals
N.S. Not significant
* Significant
** Highly significant

of the ability of S. faecalis to continue to produce acid under conditions unfavorable to regular lactic starter organisms.

The raising of the curing temperature to 60° F. resulted in a marked increase in high acid, fruity, and rancid flavors in nearly all the cheese. However, there was no increase in the number of high acid criticisms encountered in the heavily inoculated DK cheese when the curing temperature was raised to 60° F. There was little difference in the number of these three flavors detected as a result of the starter combination when the higher curing temperature was used.

Relationship between milling acidity and weed flavor in cheese made with DK starter

It is evident from the fact that weed flavor did not appear in all cheese made with DK starter that some other factor in addition to the mere presence of S. faecalis must be playing a part in the development of this off flavor.

It is common knowledge that the amount and rate of acid production during the cheddaring process plays an important role in controlling the flavor and body of the resulting cheese. It was suggested that a check be made to see if there was any correlation between the titratable acidity at the time of milling the curd, and the subsequent occurrence of weed flavor in cheese made with DK starter. The results of this investigation are presented in tables 7 and 8.

When cheese made with the heavy inoculation of DK starter developed a milling acidity of 0.38 percent lactic acid or over, and was cured at 50° F., a weed flavor was detected in 15 out of 20 samples. When the milling acidity was 0.36

percent lactic acid or less, a weed flavor was found in only one out of 20 samples. When cured at 60° F., 15 out of 20 samples were criticized for being weedy when the milling acidity was 0.38 percent or over, while only 5 out of 20 samples were weedy when the milling acidity did not exceed 0.36 percent.

Cheese made with the light inoculation of DK starter plus the full amount of lactic starter developed a higher milling acidity without the subsequent appearance of weed flavor than the cheese made with the heavy inoculation of DK starter. At the 50° F. curing temperature, weed flavors were detected in only 3 out of 20 samples where the milling acidity did not exceed 0.44 percent lactic acid. When the milling acidity was over 0.44 percent lactic acid weed flavors were detected in 12 out of the 20 samples. Where the light inoculation of DK starter and 60° F. curing temperature was used, the relationship between the milling acidity and occurrence of weed flavor was not so distinct. It is possible that the more frequent and more intense off flavors produced at the higher curing temperature tended to obscure the relationship, especially where the weed flavor tended to be slight.

It is impossible to say upon the basis of this experiment, that high milling acidities plus DK starter produce a weed flavor in the resulting cheese. More work would be necessary in order to prove or disprove this point. However, this phase of the experiment seems to indicate that where DK starter is used in cheesemaking, there may be a maximum milling acidity above which there is a tendency for weedy flavors to develop

Table 7. Relationship between milling acidity and frequency of occurrence of weed flavor in cheese made with 0.53% lactic plus 0.53% DK starter and cured at 50° F. and 60° F.

Lot	Titratable acidity at milling	Number* of weed criticisms cured at 50° F.	cured at 60° F.
A	.360	1	0
B	.360	0	2
C	.320	0	2
D	.290	0	1
E	.380	3	4
F	.390	5	4
G	.390	4	3
H	.390	4	4

* 5 possible

Table 8. Relationship between milling acidity and frequency of occurrence of weed flavor in cheese made with 0.75% lactic plus 0.375% DK starter and cured at 50° F. and 60° F.

Lot	Titratable acidity at milling	Number* of weed criticisms cured at 50° F.	cured at 60° F.
A	.510	3	2
B	.460	2	0
C	.380	0	0
D	.380	0	0
E	.440	1	4
F	.450	3	4
G	.430	2	4
H	.470	4	3

* 5 possible

in the resulting cheese. It seems also that the maximum milling acidity may be in inverse relationship to the concentration of DK starter used.

Scoring the cheese for body and texture

Samples of cheese representing each starter combination and each curing temperature were scored for body and texture when the cheese was 10, 30, 60, 90, and 120 days old. The average scores for each period, and the overall average scores of cheese representing each starter combination are shown in tables 9 and 10. The relationship between the average body and texture scores of cheese representing each of the three combinations of starter are illustrated in figures 15 and 16. Figure 15 illustrates the relative scores of cheese cured at 50° F., and figure 16 illustrates the relative scores when cured at 60° F.

The data obtained from this part of the experiment indicates that DK cheese starter, in the concentrations used in this problem, has no effect on the body and texture scores of the resulting cheese. The average scores of the cheese from each starter were close enough to be well within the range of experimental error.

It may be seen from the data presented in tables 9 and 10 and figures 15 and 16 that the body and texture scores of the cheese cured at 50° F. averaged approximately one-half point higher than the cheese cured at 60° F. The main criticisms encountered at the 50° F. curing temperature were slight curdy, slight open, and slight sweet fermentation. In addition to these same criticisms, much of the cheese cured

Table 9. Average periodic body and texture scores of 8 batches of cheddar cheese made with 3 combinations of lactic and DK starter and cured at 50° F.

Days	0.75% lactic starter	0.53% lactic plus 0.53% DK starter	0.75% lactic plus 0.375% DK starter
10	29.4	29.5	29.6
30	29.2	29.8	29.2
60	29.0	29.1	29.0
90	29.9	29.7	29.9
120	30.0	29.8	30.0
Avg.	29.5	29.6	29.5

Table 10. Average periodic body and texture scores of 8 batches of cheddar cheese made with 3 combinations of lactic and DK starter and cured at 60° F.

Days	0.75% lactic starter	0.53% lactic plus 0.53% DK starter	0.75% lactic plus 0.375% DK starter
10	29.4	29.5	29.6
30	29.1	28.6	28.9
60	28.6	28.7	28.3
90	29.2	29.0	29.1
120	29.2	28.6	28.8
Avg.	29.1	28.9	28.9

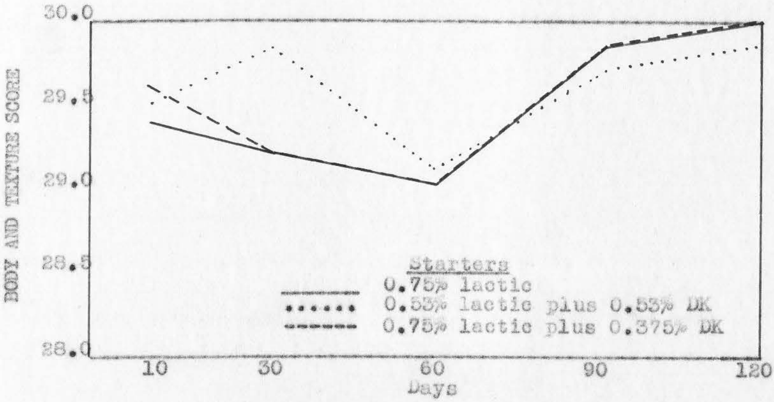


Figure 15. Relationship between average periodic body and texture scores of cheddar cheese made with 3 different combinations of lactic and DK starter and cured at 50° F.

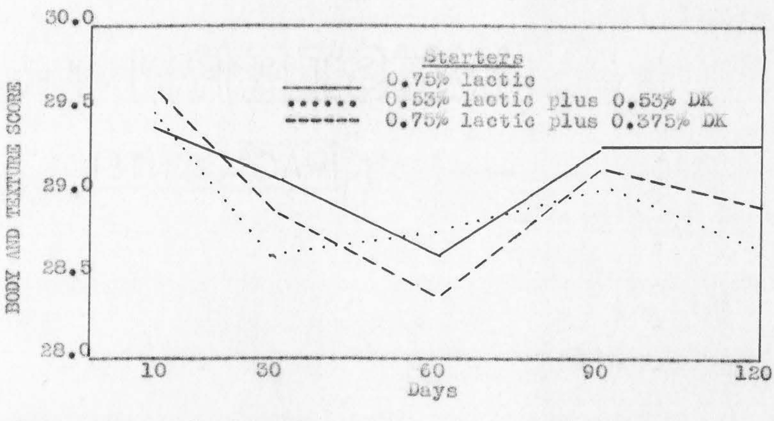


Figure 16. Relationship between average periodic body and texture scores of cheddar cheese made with 3 different combinations of lactic and DK starter and cured at 60° F.

at 60° F. was found to be mealy.

Water soluble nitrogen development during curing of cheese

When the cheese was 30, 60, 90, and 120 days old it was analyzed for water soluble nitrogen to see if there was any variation in the rate of protein breakdown as a result of the starter combinations used in this experiment. When the cheese was 60 and 90 days old it was analyzed for its total nitrogen content, and the soluble nitrogen was calculated as percent of total nitrogen.

The average percentages of water soluble nitrogen at monthly intervals during the curing of cheese made with each combination of starter and cured at each curing temperature are shown in tables 11 and 12. The same results are illustrated graphically in figures 17 and 18.

There was a gradual increase in the water soluble nitrogen of all the cheese throughout the entire curing period. However, the period from 30 to 60 days showed the most rapid increase in soluble nitrogen.

Using soluble nitrogen as an index, DK cheese starter had little or no effect on the rate of protein breakdown of the cheese in this experiment. This condition held true regardless of whether the curing temperature of the cheese was 50° F. or 60° F.

Statistically, as shown in tables 13 and 13a there was no significance between the soluble nitrogen of the cheese as a result of the starter combinations.

A comparison of figure 17 and figure 18 shows that a very marked increase in the rate of soluble nitrogen

Table 11. Average periodic soluble nitrogen content* of cheddar cheese made with 3 combinations of lactic and DK cheese starter and cured at 50° F.

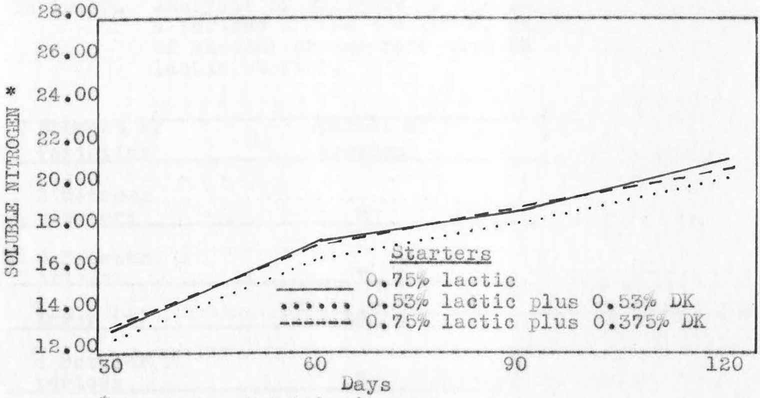
Days	0.75% lactic starter	0.53% lactic plus 0.53% DK starter	0.75% lactic plus 0.375% DK starter
30	12.88	12.79	13.23
60	17.11	16.62	16.98
90	18.54	18.15	18.57
120	20.76	20.06	20.43
Avg.	17.32	16.75	17.30

* percent of total nitrogen

Table 12. Average periodic soluble nitrogen content* of cheddar cheese made with 3 combinations of lactic and DK cheese starter and cured at 60° F.

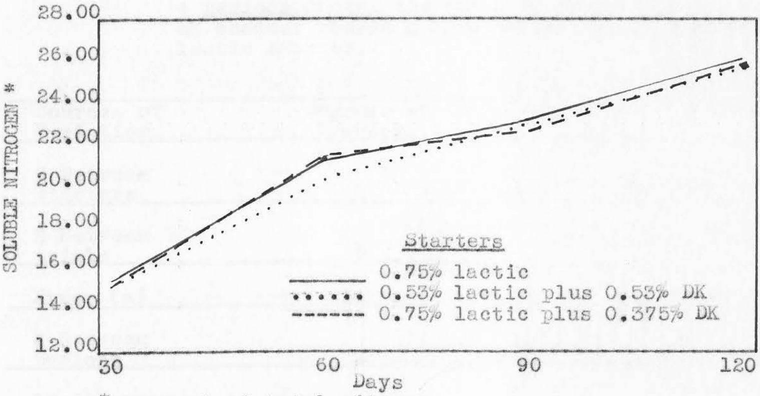
Days	0.75% lactic starter	0.53% lactic plus 0.53% DK starter	0.75% lactic plus 0.375% DK starter
30	15.17	14.91	14.91
60	21.11	20.35	21.16
90	23.15	22.74	22.69
120	26.17	25.50	25.71
Avg.	21.40	20.88	21.12

* percent of total nitrogen



* percent of total nitrogen

Figure 17. Comparison of the rate of development of soluble nitrogen during the 50° F. curing of cheddar cheese made with 3 combinations of DK and lactic starter.



* percent of total nitrogen

Figure 18. Comparison of the rate of development of soluble nitrogen during the curing at 60° F. of cheddar cheese made with 3 combinations of DK and lactic starter.

Table 13. Analysis of variance of the soluble nitrogen at 4 periods during the 50° F. curing of 24 batches of cheddar cheese made with DK and commercial lactic starter.

Sources of Variation	Degrees of Freedom	"F" factor
3 Between starters	2	1.532 NS
8 Between trials	7	1.639 NS
Error (a)	14	
4 Between periods	3	752.695 **
12 Starters by periods	6	.514 NS
Error (b)	63	

NS No Significance
** Highly Significant

Table 13 a. Analysis of variance of the soluble nitrogen at 4 periods during the 60° F. curing of 24 batches of cheddar cheese made with DK and commercial lactic starter.

Sources of Variation	Degrees of Freedom	"F" factor
3 Between starters	2	.98 NS
8 Between trials	7	3.72 *
Error (a)	14	
4 Between periods	3	782.80 **
12 Starters by periods	6	24.10 **
Error (b)	63	

NS No Significance
** Highly Significant

development was achieved by raising the curing temperature from 50° F. to 60° F.

The results tend to indicate that DK cheese starter, in the concentrations used in this experiment, had no effect on the rate of soluble nitrogen production in cheddar cheese which was cured at 50° F. or 60° F.

CONCLUSION

Studies on the effect of DK cheese starter on the rate of ripening and flavor development in cheddar cheese indicate that no advantage is gained by the use of this starter culture in cheddar cheesemaking under the conditions of this experiment. No effect on protein breakdown, rate of cheddar flavor development, or composition could be detected as a result of the use of DK cheese starter.

The occurrence of a flavor described as weed or weed like in the cheese made with DK starter is of interest. This flavor was described by one prominent cheese judge as unclean. Another labeled it as oily weed. The term unclean seemed a little severe because the flavor was really not that bad. No attempt was made by the judges of the cheese in this experiment to coin a new flavor criticism, but the flavor was there, and the term weed or weed like was suggested for use with reference to the flavor in question until more agreement is reached on this problem. DK cheese starter seemed to be necessary for the production of weed flavor. However, the starter was apparently unable to produce the flavor unless a certain critical milling acidity was reached. This critical milling acidity seemed to be in inverse relationship to the concentration of DK starter used.

There are many strains of <u>Streptococcus</u> <u>faecalis</u>. Because the strain used in this experiment was found to be of no benefit in cheesemaking does not mean that others do not exist which may be the answer to the cheese ripening problem.

SUMMARY

1. Because of the time-consuming nature of normal cheese curing and the slow rate of flavor development reported in cheese made from pasteurized milk, studies were conducted during the winter and spring of 1950 at Logan Utah on the effect of a specific strain of Streptococcus faecalis on the rate of ripening and flavor development in cheddar cheese made from pasteurized milk. The culture of S. faecalis used in the experiment was known as DK cheese starter, and was obtained from the Dairy Industry Department at Cornell University.

2. Eight lots of cheddar cheese were manufactured, each consisting of three vats of cheese. The first vat of cheese was inoculated with 0.75 percent commercial lactic starter, the second with 0.53 percent commercial lactic plus 0.53 percent DK starter, and the third with 0.75 percent lactic plus 0.375 percent DK starter. Half of the cheese from each vat was cured at 60° F. and half was cured at 50° F.

3. The average titratable acidity developed by eight lots of commercial lactic bulk starter during 14 to 15 hours incubation was 0.816 calculated as percent lactic acid. The average titratable acidity developed by eight lots of DK bulk starter after 15 to 16 hours incubation was 0.660 calculated as percent lactic acid. The results tend to confirm the fact that the organisms of commercial lactic starter produce acid more rapidly in milk than S. faecalis.

4. A comparison of the three combinations of starter used in

this experiment was made on the basis of their relative acid producing ability throughout the cheesemaking process. The results show that at the time of cutting the curd there was no difference in the acid production of the three starter combinations. However, as the process continued the rate of acid production by the 0.75 percent lactic plus 0.375 percent DK starter became slightly greater than the 0.75 percent lactic starter. The combination of 0.53 percent lactic plus 0.53 percent DK starter showed a significantly lower rate of acid production than the 0.75 percent lactic starter. The greatest differences were observed at the time of milling the curd at which time the relative titratable acidities were as follows: 0.75 percent lactic plus 0.375 percent DK starter was 0.440 percent lactic acid, 0.75 percent lactic starter was 0.422 percent lactic acid, and 0.53 percent lactic plus 0.53 percent DK starter was 0.360 percent lactic acid.

5. The cheese made with the heavy inoculation of DK starter cheddared less readily and had a more granular consistency during the cheddaring process than the cheese made with commercial lactic starter or with the light inoculation of DK starter.

6. There were no significant differences as a result of the starter combinations used in this experiment on changes in pH of the cheese throughout ripening, changes in fat content of the cheese throughout ripening, or changes in moisture content of the cheese throughout ripening.

7. The results of scoring the cheese for flavor definitely showed the superiority of cheese made with 0.75 percent lactic starter over the cheese made with either concentration of

DK starter. When cured at 50° F. the flavor scores averaged 39.6, 39.3, and 38.8 on cheese made with 0.75 percent lactic, 0.53 percent lactic plus 0.53 percent DK, and 0.75 percent lactic plus 0.385 percent DK starter respectively. When cured at 60° F. the flavor scores averaged 38.9, 38.5, and 38.3 on cheese made with lactic, light DK, and heavy DK starter inoculations.

8. A flavor described as weed or weed like was the most common flavor criticism of cheese made with DK starter. This flavor was detected in 61 of 128 samples of cheese made with DK starter. It was detected in only 3 out of 64 samples of cheese made with commercial lactic starter. The weed flavor seemed to occur in the cheese made with DK starter only when the acidity at milling exceeded a certain maximum which was apparently in inverse relationship to the concentration of DK starter used. There was no bitterness encountered in any of the cheese made with DK cheese starter.

9. The data obtained in this experiment indicated that DK cheese starter, in the concentrations used in this problem, has no effect on the body and texture scores of the resulting cheese.

10. On the basis of the rate of soluble nitrogen developed during cheese curing, DK cheese starter in the concentration used in this experiment did not increase the rate of ripening of cheddar cheese when cured at either 50° F. or 60° F.

11. The curing of the experimental cheese at 60° F. resulted in a more rapid moisture loss, a greater rise in pH, and a greater increase in percent fat, than when it was cured at 50° F. The cheese cured at 60° F. had an average of .7 point

lower flavor score and a .5 point lower body and texture score than the cheese cured at 50° F. When the curing temperature was raised from 50° F. to 60° F. there was a noticeable increase in the number of undesirable flavor criticisms encountered in the cheese regardless of the starter used.

LITERATURE CITED

(1) Abell, Richard G. Reaction of peripheral blood vessels to angiotonin, renin, and other pressor agents. Jour. Exptl. Med. 75: 305-314. 1942.

(2) Alford, John A. and Fraxier, W. C. Effect of micrococci on the development of flavor when added to cheddar cheese made from pasteurized milk. Jour. of Dairy Science 33 (2): 115-120. 1950.

(3) American Public Health Assn. Standard methods for the examination of dairy products. 9th ed. New York: A. P. H. A., 1948.

(4) Ary, I. Adatok a hazai erett emmentali sajtok csiratartalmahoz. The bacterial content of ripe Hungarian emmental cheese. Thesis. Royal Hungarian Univ. 1941. Abstracted in Biological Abstracts 15: 22339. 1941.

(5) Assn. of Official Agr. Chemists. Official and tentative methods of analysis. 6th ed. Washington D. C. A. O. A. C. 1945.

(6) Ayers, S. H. and Johnson, W. T. Jr. Relation of Streptococcus faecalis to Streptococcus lactis. Jour. of Infectious Disease 34: 49-53. 1924.

(7) Babel, F. J. Effect of calcium chloride and reduced amounts of rennet on protein degradation in cheddar cheese. Nat. Butter and Cheese Jour. 39 (5): 42-43. 1948.

(8) Bernheim, F. and Bernheim, Mary. The metabolism of tyramine, l(-) tyrosine, and phenol by rat tissues in vitro. Jour. of Biological Chem. 153: 369-374. 1944.

(9) Breed, R. S., Murray, E. G., and Hitchens, P. Bergey's manual of determinative bacteriology. 6th ed. Baltimore: Williams and Wilkins Co. 1948.

(10) Buchbinder, L., Osler, A. G., and Steffen, G. I. Study of canned evaporated milk implicated in an outbreak of gastro enteritis. Public Health Reports 63: 109-118. 1948.

(11) Chapman, G. H. Studies of streptococci; resistance of enterococci. Jour. of Bact. 32 (1): 41-46. 1936.

(12) Dack, G. M., Niven, C. F. Jr., Kirsner, J. B., and Marshall, Homer. Feeding tests on human volunteers with enterococci and tyramine. Jour. of Infectious Disease 85 (2): 131-138. 1949. Abstracted in Biological Abstracts 24 (1): 1950.

(13) Dahlberg, A. C. DK cheese starter: general statement. Unpublished report. Cornell Univ. Ithaca: 1949.

(14) Dahlberg, A. C. and Kosikowsky, F. V. The development of flavor in American cheddar cheese made from pasteurized milk with Streptococcus faecalis starter. Jour. of Dairy Science 31 (4): 275-284. 1948.

(15) -------- The relationship of the amount of tyramine and the numbers of Streptococcus faecalis to the intensity of flavor in American cheddar cheese. Jour. of Dairy Science 31 (4): 305-314. 1948.

(16) -------- The influence of temperature of ripening on the tyramine content and flavor of American cheddar cheese. Jour. of Dairy Science 32 (4): 316-321. 1949.

(17) -------- The bacterial count, tyramine content, and quality score of commercial American cheddar and stirred curd cheese made with Streptococcus faecalis starter. Jour. of Dairy Science 32 (7): 1949.

(18) Deane, D. P., Anderson, T. G., and Dahle, C. D. Use of pure cultures in the manufacture of cheddar cheese. National Butter and Cheese Jour. 36 (1): 28-30. 1945.

(19) Demeter, K. J. Studies on lactic acid streptococci on Streptococcus lactis L and its relation to the fecal streptococci. Milchwirtschoftliche Forshungen 8: 201. 1929. Abstracted in Jour. of Bact. 17 (1): 32-33. 1929.

(20) Dorn, F. L. and Dahlberg, A. C. Identification of white particles found in ripened cheddar cheese. Jour. of Dairy Science 25: 31-36. 1942.

(21) Frobisher, M. Jr. Fundamentals of bacteriology 3rd ed. Philadelphia: W. B. Saunders Co. 1945.

(22) Gale, E. F. The production of amines by bacteria. The production of tyramine by Streptococcus faecalis. Biochem. Journal 34: 846-852. 1940.

(23) -------- The production of amines by bacteria. The production of putrescine from l(+) arginine by Bacterium coli in symbiosis with Streptococcus faecalis. Biochemical Journal 34 (1): 853-857. 1940.

(24) Gunsalus, I. C., Niven, C. F. Jr., and Sherman, J. M. The identification of Streptococcus lactis R as a strain of Streptococcus faecalis. Jour. of Bact. 48:611. 1944.

(25) Hanke, M. T. and Koesler, K. K. Studies in proteinogenous amines. The faculty of normal intestinal bacteria to form toxic amines. Jour. of Biological Chem. 59: 835-853. 1924.

(26) Hawk, P. B., Oser, B. L., and Summerson, W. H. Practical physiological chemistry 12th ed. Philadelphia: The Blakiston Co. 1947.

(27) Heilbron, D. S. O. and Brunbury, H. M. Dictionary of organic compounds. New York: Oxford University Press. 1938.

(28) Hoshimoto, Atsuhide. Action of tyramine on renal blood vessels and total urine. Nagoya Igakkai Zasshi 55: 721-752. 1942. Abstracted in Chem. Abstracts 42 (1): 685a. 1948.

(29) Johnston, O. R. The toxic affect of amines. Jour. of Infectious Disease 42: 473-484. 1928.

(30) Kendall, I. A. and Haner, R. C. Micrococcus ovalis. Studies in bacterial metabolism. Jour. of Infectious Disease 35: 67. 1924.

(31) Knaysi, Georges. A morphological study of Streptococcus faecalis. Jour. of Bact. 42: 575-586. 1941.

(32) Kosikowsky, F. V. and Dahlberg, A. C. The growth and survival of Streptococcus faecalis in pasteurized milk American cheddar cheese. Jour. of Dairy Science 31 (4): 285-293. 1948.

(33) Lane, C. B. and Hammer, B. W. The effect of Lactobacillus casei on the nitrogenous decomposition and flavor development in cheddar cheese made from pasteurized milk. Iowa Agr. Exp. Sta. Research Bul. 190: 339-376. 1935.

(34) Linden, B. A., Turner, W. R., and Thom, C. Food poisoning from a Streptococcus in cheese. Pub. Health Reports 41: 1647-1652. 1926.

(35) Nelson, J. A. and Trout, G. M. Judging dairy products 2nd ed. Olsen Pub. Co. Milwaukee: 1948.

(36) Niven, C. F. Nutrition of S. lactis. Jour. of Bact. 47: 343. 1944.

(37) Niven, C. F. and Sherman, J. M. Nutrition of enterococci. Jour. of Bact. 47: 335. 1944.

(38) Osler, A. G., Buchbinder, L., and Steffen, G. I. Experimental enterococcal food poisoning in man. Proc. Soc. Exptl. Biol. and Med. 67: 456-459. 1948.

(39) Pette, J. W. De ryping van kaas unit gepasteuriseerde melk. (The ripening of cheese from pasteurized milk.) Landbouwk Tijdschr 1947 706-708: 1947. Abstracted in Biol. Abstracts 22 (10): 24869. 1948.

(40) Rantz, L. A. and Kirby, W. M. M. Enterococci infections. Archives of Internal Med. 71 (4): 516-528. 1943. Abstracted in Biol. Abstracts 17: 22016. 1943.

(41) Sanders, George P., Tittsler, R. P., and Walter, H. E. The rapid ripening of cheddar cheese made from pasteurized milk. Jour. of Milk Technology 9: 171-172. 1946. Abstracted in Biological Abstracts 21: 20278. 1947.

(42) Scales, F. M. and Harrison, A. P. Boric acid modification of the Kjeldahl method for crop and soil analysis. The Jour. of Industrial and Chemical Engineering 12 (4): 350-352. 1920.

(43) Seeleman, M. and Nottbohm H. Untersuchungen uber die Unterscheidung des <u>Str. lactis</u> non den Enterokokken. Ein Beitrag zur serologischen Gruppendifferenzierung. Zentralbl Bakt. I Abt. Orig. 146 (4): 142-154. 1940. Abstracted in Biological Abstracts 16: 9985. 1942.

(44) Sherman, J. M., Gunsalus, I. C., and Bellamy, W. D. Streptococcus food poisoning. 57th Annual Report. N. Y. State Agr. Expt. Sta. Cornell Ithaca, N. Y. 116. 1944.

(45) Sherman, J. M., Mauer, J. C., and Stark, P. <u>Streptococcus faecalis</u>. Jour. of Bact. 33. 275-282. 1937.

(46) Sherman, J. M., Smiley, K. L., and Niven, C. F. Jr. The identity of a streptococcus associated with food poisoning from cheese. Jour. of Dairy Science 26 (4): 321-324. 1943.

(47) Sherman, J. M. and Stark, P. The differentiation of <u>S. lactis</u> from <u>S. faecalis</u>. Jour. of Dairy Science 17: 525. 1934.

(48) Sommer, H. H. Laboratory manual supplement of dairy chemistry. Madison: Author, 1948.

(49) Tittsler, R. P., Geib, D. S., Sanders, G. P., Walter, A. E., Sager, O. S., and Lochry, H. R. The effect of quality and pasteurization of milk on the bacterial flora and quality of cheddar cheese. Jour. of Bact. 51 (5): 590. 1946.

(50) Vanderbeek, J. L. The use of Streptococcus faecalis in commercial cheddar cheese making. M. S. Thesis. Logan, Utah: U. S. A. C. 1949.

(51) Van Slyke, L. L. and Price, W. V. Cheese. 2nd ed. New York: Orange Judd Publ. Co. 1949.

(52) White, J. C. and Sherman, J. M. Occurrance of enterococci in milk. Jour. of Bact. 48: 262. 1944.

(53) Wilson, H. L. Making American cheddar cheese of uniformly good quality. U. S. Dept. Agr. B. D. I. M. 947: Nov. 1942.

(54) Wilson, H. L., Hall, S. A., and Johnson, W. T. Jr. Relationship of curing temperatures to quality of American cheddar cheese. Jour. of Dairy Science 24 (2): 169-177. 1941.

(55) Wilster, G. H. Practical cheddar cheese manufacture and cheese technology. 6th ed. Corvallis, Ore. O. S. C. Cooperative Assn. 1949.

APPENDIX

Table 14. Changes in pH and titratable acidity during manufacture of eight batches of cheddar cheese made with 0.75 percent commercial lactic starter.

Batch	Cutting		Dipping		Milling	
	T.A.*	pH	T.A.*	pH	T.A.*	pH
A	0.115	6.40	0.140	6.04	0.510	5.42
B	0.120	6.42	0.145	6.03	0.440	5.60
C	0.115	6.30	0.135	6.15	0.430	5.67
D	0.115	6.40	0.135	6.25	0.360	5.85
E	0.120	6.25	0.140	6.18	0.430	5.70
F	0.120	6.45	0.140	6.23	0.405	5.70
G	0.115	6.50	0.140	6.23	0.390	5.65
H	0.125	6.45	0.150	6.20	0.410	5.62
Average	0.118	6.40	0.141	6.16	0.422	5.63

* Titratable acidity

Table 15. Changes in pH and titratable acidity during manufacture of eight batches of cheddar cheese made with 0.53 percent commercial lactic starter plus 0.53 percent DK starter.

Batch	Cutting		Dipping		Milling	
	T.A.*	pH	T.A.*	pH	T.A.*	pH
A	0.110	6.55	0.130	5.98	0.360	5.70
B	0.120	6.28	0.145	6.10	0.360	5.70
C	0.115	6.32	0.135	6.25	0.320	5.72
D	0.115	6.44	0.130	6.15	0.290	5.96
E	0.120	6.23	0.140	6.12	0.380	5.71
F	0.120	6.45	0.135	6.23	0.390	5.62
G	0.115	6.50	0.140	6.20	0.390	5.61
H	0.125	6.42	0.150	6.18	0.390	5.54
Average	0.118	6.40	0.138	6.16	0.360	5.70

* Titratable acidity

Table 16. Changes in pH and titratable acidity during manufacture of eight batches of cheddar cheese made with 0.75 percent commercial lactic starter plus 0.375 percent DK starter.

Batch	Cutting		Dipping		Milling	
	T.A.*	pH	T.A.*	pH	T.A.*	pH
A	0.115	6.50	0.140	6.08	0.510	5.45
B	0.120	6.32	0.145	6.03	0.460	5.55
C	0.120	6.34	0.135	6.10	0.380	5.65
D	0.115	6.43	0.135	6.30	0.380	5.71
E	0.120	6.24	0.140	6.12	0.440	5.70
F	0.120	6.45	0.140	6.23	0.450	5.55
G	0.115	6.49	0.145	6.27	0.430	5.61
H	0.125	6.40	0.150	6.19	0.470	5.34
Average	0.119	6.40	0.141	6.19	0.440	5.57

* Titratable acidity

Table 17. Periodic pH values of 8 lots of cheddar cheese made with 0.75% commercial lactic starter and cured at 50° F.

Lot	Days				
	10	30	60	90	120
A	5.11	5.18	5.18	5.19	5.20
B	5.13	5.17	5.20	5.22	5.25
C	5.04	5.08	5.13	5.15	5.20
D	5.12	5.22	5.21	5.25	5.37
E	5.06	5.18	5.21	5.23	5.30
F	5.10	5.11	5.22	5.26	5.32
G	5.16	5.22	5.20	5.30	5.38
H	5.07	5.10	5.21	5.24	5.30
Average	5.10	5.16	5.20	5.23	5.29

Table 18. Periodic pH values of 8 lots of cheddar cheese made with 0.53% commercial lactic plus 0.53% DK starter and cured at 50° F.

Lot	Days				
	10	30	60	90	120
A	5.20	5.28	5.29	5.30	5.35
B	5.20	5.23	5.25	5.25	5.32
C	5.05	5.18	5.13	5.20	5.22
D	5.07	5.27	5.22	5.28	5.40
E	5.00	5.16	5.17	5.22	5.25
F	5.07	5.10	5.12	5.12	5.26
G	5.12	5.22	5.25	5.25	5.35
H	5.00	5.05	5.10	5.16	5.20
Average	5.09	5.18	5.19	5.22	5.29

Table 19. Periodic pH values of 8 lots of cheddar cheese made with 0.75% commercial lactic plus 0.375% DK starter and cured at 50° F.

Lot	Days				
	10	30	60	90	120
A	5.14	5.29	5.22	5.23	5.30
B	5.13	5.28	5.28	5.30	5.32
C	5.03	5.15	5.21	5.24	5.25
D	5.09	5.23	5.28	5.26	5.39
E	5.08	5.15	5.16	5.20	5.31
F	5.12	5.10	5.12	5.20	5.29
G	5.12	5.15	5.25	5.30	5.40
H	5.07	5.04	5.10	5.13	5.23
Average	5.10	5.17	5.20	5.23	5.31

Table 20. Periodic pH values of 8 lots of cheddar cheese made with 0.75% commercial lactic starter and cured at 60° F.

Lot	Days				
	10	30	60	90	120
A	5.11	5.20	5.20	5.20	5.31
B	5.13	5.18	5.21	5.40	5.40
C	5.04	5.10	5.19	5.21	5.28
D	5.12	5.21	5.26	5.30	5.48
E	5.06	5.20	5.31	5.25	5.32
F	5.10	5.15	5.15	5.15	5.30
G	5.16	5.28	5.34	5.32	5.47
H	5.07	5.15	5.19	5.19	5.31
Average	5.10	5.18	5.23	5.25	5.36

Table 21. Periodic pH values of 8 lots of cheddar cheese made with 0.53% commercial lactic plus 0.53% DK starter and cured at 60° F.

Lot	Days				
	10	30	60	90	120
A	5.20	5.29	5.30	5.32	5.42
B	5.20	5.22	5.25	5.38	5.42
C	5.05	5.16	5.20	5.29	5.51
D	5.07	5.27	5.32	5.35	5.46
E	5.00	5.14	5.22	5.28	5.40
F	5.07	5.13	5.18	5.21	5.32
G	5.12	5.25	5.32	5.35	5.49
H	5.00	5.14	5.23	5.20	5.26
Average	5.09	5.20	5.25	5.30	5.41

Table 22. Periodic pH values of 8 lots of cheddar cheese made with 0.75% commercial lactic plus 0.375% DK starter and cured at 60° F.

Lot	Days				
	10	30	60	90	120
A	5.14	5.29	5.30	5.30	5.42
B	5.13	5.18	5.24	5.30	5.39
C	5.03	5.16	5.27	5.30	5.40
D	5.09	5.24	5.30	5.37	5.48
E	5.08	5.22	5.25	5.30	5.38
F	5.12	5.18	5.20	5.23	5.37
G	5.12	5.24	5.33	5.35	5.46
H	5.07	5.11	5.17	5.23	5.33
Average	5.10	5.20	5.26	5.30	5.40

Table 23. Periodic fat content of 8 lots of cheddar cheese made with 0.75% lactic starter and cured at 50° F.

Lot	Days		
	10	60	120
A	31.5*	31.5	32.0
B	32.0	32.0	32.0
C	32.0	32.5	32.5
D	31.0	31.0	31.0
E	31.0	31.5	31.5
F	31.0	31.5	31.5
G	31.0	31.5	31.5
H	32.5	33.0	33.0
Average	31.5	31.8	31.9

* Percent fat

Table 24. Periodic fat content of 8 lots of cheddar cheese made with 0.53% lactic plus 0.53% DK starter and cured at 50° F.

Lot	Days		
	10	60	120
A	31.5*	32.0	31.5
B	31.2	32.0	31.5
C	32.0	32.0	32.0
D	30.0	31.0	30.5
E	31.0	31.5	32.0
F	31.0	31.5	31.5
G	31.5	31.7	32.0
H	32.0	32.5	32.5
Average	31.3	31.7	31.7

* Percent fat

Table 25. Periodic fat content of 8 lots of cheddar cheese made with 0.75% lactic plus 0.375% DK starter and cured at 50° F.

Lot	Days		
	10	60	120
A	31.5*	31.5	31.5
B	31.0	31.0	31.5
C	32.0	32.0	32.5
D	31.0	31.0	31.5
E	31.5	31.5	32.0
F	31.0	31.5	32.0
G	31.5	32.0	32.0
H	32.0	32.5	32.0
Average	31.4	31.6	31.9

* Percent fat

Table 26. Periodic fat content of 8 lots of cheddar cheese made with 0.75% lactic starter and cured at 60° F.

Lot	Days		
	10	60	120
A	31.5*	31.8	32.5
B	32.0	32.5	32.0
C	32.0	33.0	34.0
D	31.0	31.0	31.5
E	31.0	31.5	32.5
F	31.0	31.0	32.5
G	31.0	32.0	32.0
H	32.5	32.5	33.5
Average	31.5	31.9	32.5

* Percent fat

Table 27. Periodic fat content of 8 lots of cheddar cheese made with 0.53% lactic plus 0.53% DK starter and cured at 60° F.

Lot	Days		
	10	60	120
A	31.5*	32.0	32.5
B	31.2	32.0	32.5
C	32.0	32.5	32.5
D	30.0	30.5	31.0
E	31.0	32.0	32.5
F	31.0	31.5	32.0
G	31.5	32.0	33.0
H	32.0	32.5	33.5
Average	31.3	31.9	32.4

* Percent fat

Table 28. Periodic fat content of 8 lots of cheddar cheese made with 0.75% lactic plus 0.375% DK starter and cured at 60° F.

Lot	Days		
	10	60	120
A	31.5*	32.0	32.5
B	31.0	32.0	32.5
C	32.0	32.5	33.5
D	31.0	31.0	31.5
E	31.5	32.0	32.0
F	31.0	31.5	32.0
G	31.5	32.0	32.5
H	32.0	32.5	33.0
Average	31.4	31.9	32.6

* Percent fat

Table 29. Periodic moisture percentage during curing of 8 lots of cheddar cheese made with 0.75% lactic starter and cured at 50° F.

Lot	Days		
	10	60	120
A	36.1*	36.1	35.7
B	36.2	35.8	35.3
C	37.1	36.3	36.1
D	37.7	37.1	36.3
E	38.0	37.3	36.6
F	38.0	37.7	37.2
G	36.8	36.5	35.9
H	36.2	36.3	36.0
Average	37.0	36.6	36.1

* Percent moisture

Table 30. Periodic moisture percentages during curing of 8 lots of cheddar cheese made with 0.53% lactic plus 0.53% DK starter and cured at 50° F.

Lot	Days		
	10	60	120
A	36.9*	36.0	35.8
B	36.7	36.2	35.5
C	37.8	36.8	36.8
D	38.3	37.5	37.5
E	37.4	36.5	36.2
F	37.7	37.3	36.6
G	36.5	35.9	35.9
H	37.1	36.4	36.2
Average	37.3	36.6	36.3

* Percent moisture

Table 31. Periodic moisture percentages during curing of 8 lots of cheddar cheese made with 0.75% lactic plus 0.375% DK starter and cured at 50° F.

Lot	Days		
	10	60	120
A	36.2*	35.7	35.4
B	36.2	36.2	35.1
C	36.6	36.6	35.9
D	37.5	37.1	36.6
E	37.3	36.5	36.1
F	37.6	36.7	36.3
G	36.3	35.6	35.3
H	36.5	36.4	36.2
Average	36.8	36.4	35.9

* Percent moisture

Table 32. Periodic moisture percentages during curing of 8 lots of cheddar cheese made with 0.75% lactic starter and cured at 60° F.

Lot	Days		
	10	60	120
A	36.1*	36.2	34.8
B	36.2	35.8	35.0
C	37.1	36.1	34.5
D	37.7	36.9	36.6
E	38.0	36.7	35.4
F	38.0	37.0	35.8
G	36.8	36.9	34.9
H	36.2	36.1	34.6
Average	37.0	36.5	35.2

* Percent moisture

Table 33. Periodic moisture percentages during curing of 8 lots of cheddar cheese made with 0.53% lactic plus 0.53% DK starter and cured at 60° F.

Lot	Days		
	10	60	120
A	36.9*	36.0	34.5
B	36.7	36.1	34.8
C	37.8	36.8	35.4
D	38.3	37.5	36.4
E	37.4	36.5	34.9
F	37.7	37.3	36.3
G	36.5	35.9	34.8
H	37.1	36.4	34.9
Average	37.3	36.6	35.3

* Percent moisture

Table 34. Periodic moisture percentages during curing of 8 lots of cheddar cheese made with 0.75% lactic plus 0.375% DK starter and cured at 60° F.

Lot	Days		
	10	60	120
A	36.2*	35.6	35.0
B	36.2	35.5	34.4
C	36.6	36.0	35.1
D	37.5	36.9	35.5
E	37.3	36.3	35.6
F	37.6	36.8	35.3
G	36.3	35.3	34.6
H	36.5	35.9	34.4
Average	36.8	36.0	35.0

* Percent moisture

Table 35. Periodic flavor scores and criticism of 8 lots of cheddar cheese made with 0.75% lactic starter and cured for 120 days at 50° F.

	10 day period		30 day period		60 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism	Flavor Score	Criticism
A	39.5	Sl. acid	39.0	Sl. acid	38.5	Weed
B	40.0		39.0	Sl. acid	38.5	High acid
C	39.0	Sl. acid	39.5	Sl. acid	40.0	
D	39.5	Sl. acid	39.0	Sl. Fermented	40.0	
E	40.0		39.5	Flat	40.0	
F	40.0		37.5	High acid	39.0	Weed
G	40.0		39.5	Sl. acid	40.0	
H	39.0	Sl. acid Sl. fruity	39.5	Sl. acid	39.0	Flat
Avg.	39.6		39.1		39.6	

	90 day period		120 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism
A	40.0		40.0	
B	40.0		40.0	
C	40.0		40.0	
D	40.0		40.0	
E	40.0		40.0	
F	39.0	Fruity	38.0	Sl. rancid
G	40.0		40.0	
H	40.0		40.0	
Avg.	39.9		39.8	

Table 36. Periodic flavor scores and criticism of 8 lots of cheddar cheese made with 0.53% lactic plus 0.53% DK starter and cured for 120 days at 50° F.

	10 day period		30 day period		60 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism	Flavor Score	Criticism
A	40.0		39.5	Sl. acid	38.0	Flat Weed
B	39.5	Sl. acid	39.5	Sl. acid	39.0	Flat
C	38.5	Sl. acid Foreign	38.0	High acid	39.0	Cooked
D	39.5	Sl. acid	39.0	Sl. acid	40.0	
E	40.0		38.0	High acid Weed	40.0	
F	38.0	High acid Weed	38.0	High acid Weed	38.0	Weed
G	38.0	Weed	38.0	High acid Weed	39.0	Feed
H	38.5	Fruity	37.5	High acid Weed	38.0	Weed
Avg.	39.0		38.4		38.9	

	90 day period		120 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism
A	40.0		40.0	
B	40.0		39.0	Fermented
C	40.0		40.0	
D	40.0		40.0	
E	38.0	High acid Weed	38.0	Weed
F	37.0	Weed	38.0	High acid Weed
G	38.0	Weed	38.5	Weed
H	37.0	Weed	37.0	Weed
Avg.	38.8		38.8	

Table 37. Periodic flavor scores and criticism of 8 lots of cheddar cheese made with 0.75% lactic plus 0.375% DK starter and cured at 50° F.

	10 day period		30 day period		60 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism	Flavor Score	Criticism
A	40.0		39.0	Sl. weed	38.5	Weed
B	40.0		39.0	Sl. acid Sl. weed	38.5	Weed
C	40.0		39.5	Sl. acid	38.0	High acid
D	40.0		39.5	Sl. acid	40.0	
E	39.0	Sl. acid	39.0	Sl. weed	40.0	
F	39.0	Sl. acid	39.5	Sl. weed	39.0	Sl. acid
G	38.5	Weed	39.0	Sl. acid Flat	40.0	
H	39.0	Sl. acid	38.0	High acid Weed	38.5	Weed
Avg.	39.4		39.1		39.1	

	90 day period		120 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism
A	39.0	Sl. weed	40.0	
B	40.0		40.0	
C	40.0		40.0	
D	40.0		40.0	
E	40.0		40.0	
F	37.0	Weed	38.0	Weed
G	39.0	Weed	40.0	
H	38.5	Weed High acid	38.0	Weed
Avg.	39.2		39.5	

Table 38. Periodic flavor scores and criticism of 8 lots of cheddar cheese made with 0.75% lactic starter and cured for 120 days at 60° F.

	10 day period		30 day period		60 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism	Flavor Score	Criticism
A	39.5	Sl. acid	39.0	Sl. weed	38.5	Fruity
B	40.0		39.5	Sl. acid	38.0	Fruity
C	39.0	Sl. acid	38.0	High acid	38.5	High acid
D	39.5	Sl. acid	39.5	Sl. acid	40.0	
E	40.0		40.0		39.0	Sl. acid
F	40.0		39.5	Sl. acid	37.5	Bitter Sl. rancid
G	40.0		39.0	Sl. acid	40.0	
H	39.0	Fruity Sl. acid	38.5	High acid	38.5	Cooked
Avg.	39.6		39.1		38.8	

	90 day period		120 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism
A	37.0	Fruity	37.5	Fruity
B	38.0	Fruity High acid	38.0	Fruity
C	38.0	Fruity High acid	36.5	Rancid
D	37.0	Rancid	40.0	
E	38.0	Fruity	40.0	
F	38.0	High acid	39.0	High acid
G	40.0		40.0	
H	38.0	High acid	39.0	High acid
Avg.	38.0		38.8	

Table 39. Periodic flavor scores and criticism of 8 lots of cheddar cheese made with 0.53% lactic plus 0.53% DK starter and cured at 60° F.

	10 day period		30 day period		60 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism	Flavor Score	Criticism
A	40.0		38.5	Fruity	39.0	Flat
B	39.5	Sl. acid	40.0		40.0	
C	38.5	High acid Fruity	38.0	High acid Sl. weed	37.0	Rancid
D	39.5	Sl. acid	39.0	Sl. weed	40.0	
E	40.0		39.0	Sl. weed	39.0	Weed
F	38.0	High acid Weed	38.5	High acid Sl. fruity	37.5	High acid Weed
G	38.0	Weed	38.5	Fruity	38.5	Weed
H	38.5	Fruity	37.0	Weed Unclean	38.0	Weed
Avg.	39.0		38.6		38.6	

	90 day period		120 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism
A	40.0		40.0	
B	39.0	Sl. weed	37.0	Weed
C	36.0	Rancid	37.0	Sl. rancid Weed
D	37.0	Rancid	36.0	Rancid
E	36.0	Rancid Weed	37.0	Weed
F	38.0	High acid Weed	37.0	Weed
G	38.5	Weed	40.0	
H	37.0	High acid Weed	36.0	High acid Weed
Avg.	37.7		37.5	

Table 40. Periodic flavor scores and criticism of 8 lots of cheddar cheese made with 0.75% lactic plus 0.375% DK starter, and cured for 120 days at 60° F.

	10 day period		30 day period		60 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism	Flavor Score	Criticism
A	40.0		38.5	Sl. weed Fruity	38.0	Weed
B	40.0		38.5	High acid	38.5	High acid
C	40.0		39.5	Sl. acid	37.0	Rancid
D	40.0		40.0		39.0	Sl. fruity
E	39.0	Sl. acid	38.5	Weed	38.5	High acid Weed
F	39.0	Sl. acid	38.5	Sl. weed High acid	37.0	Weed Sl. rancid
G	38.5	Weed	38.0	Weed High acid	38.0	Weed
H	39.0	Sl. acid	38.5	High acid	38.0	Weed
Avg.	39.4		38.8		38.0	

	90 day period		120 day period	
Lot	Flavor Score	Criticism	Flavor Score	Criticism
A	38.0	Weed	40.0	
B	39.0	High acid	37.5	High acid
C	38.0	Heated	38.0	Fruity
D	37.0	Rancid	40.0	
E	39.0	Sl. weed	37.0	Weed
F	38.5	Weed	37.0	Weed
G	40.0		37.0	Weed
H	37.0	High acid Weed	37.0	Weed
Avg.	38.3		37.9	

Table 41. Periodic body and texture scores and criticism of 8 lots of cheddar cheese made with 0.75% lactic starter and cured for 120 days at 50° F.

	10 day period		30 day period		60 day period	
Lot	Score	Criticism	Score	Criticism	Score	Criticism
A	28.5	Curdy, Sl. open	29.5	Sl. curdy	29.0	Sl. sweet Ferment
B	30.0		29.0	Sl. curdy	28.5	Sl. mealy
C	30.0		29.5	Sl. open	29.0	Sl. sweet ferment
D	29.0	Open	29.5	Sl. curdy	29.0	Sl. sweet ferment
E	30.0		29.0	Sl. sweet ferment	29.0	Sl. sweet ferment
F	30.0		28.5	Sweet ferment	29.5	Sl. open
G	29.0	Curdy	29.0	Curdy, Sl. open	29.0	Sl. sweet ferment
H	29.0	Curdy	29.5	Sl. open	29.0	Open
Avg.	29.4		29.2		29.0	

	90 day period		120 day period	
Lot	Score	Criticism	Score	Criticism
A	29.5	Sl. open	30.0	
B	30.0		30.0	
C	30.0		30.0	
D	29.5	Sl. open	30.0	
E	30.0		30.0	
F	30.0		30.0	
G	30.0		30.0	
H	30.0		30.0	
Avg.	29.9		30.0	

Table 42. Periodic body and texture scores and criticisms of 8 lots of cheddar cheese made with 0.53% lactic plus 0.53% DK starter and cured for 120 days at 50° F.

	10 day period		30 day period		60 day period	
Lot	Score	Criticism	Score	Criticism	Score	Criticism
A	28.5	Curdy, Sl. open	29.0	Sl. curdy	28.5	Sweet ferment
B	29.5	Curdy	29.0	Sl. curdy, Sl. open	29.0	Open
C	29.5	Sl. sweet ferment	29.0	Sl. sweet ferment	30.0	
D	30.0		29.0	Open	29.0	Open
E	30.0		28.0	Sweet ferment	29.0	Sl. sweet ferment
F	30.0		29.0	Open	29.5	Sl. open
G	28.5	Curdy	29.0	Sl. open, Sl. curdy	29.5	Sl. curdy
H	30.0		29.0	Sl. curdy	28.5	Sl. open Sl. curdy
Avg.	29.5		28.9		29.1	

	90 day period		120 day period	
Lot	Score	Criticism	Score	Criticism
A	29.5	Sl. open	29.5	Sl. open
B	29.5	Sl. open	30.0	
C	30.0		30.0	
D	29.0	Open	29.0	Open
E	29.5	Sl. open	30.0	
F	30.0		30.0	
G	30.0		30.0	
H	30.0		30.0	
Avg.	29.7		29.8	

Table 43. Periodic body and texture scores and criticisms of 8 lots of cheddar cheese made with 0.75% lactic plus 0.375% DK starter and cured for 120 days at 50° F.

	10 day period		30 day period		60 day period	
Lot	Score	Criticism	Score	Criticism	Score	Criticism
A	30.0		29.0	Curdy	29.0	Curdy
B	29.5	Sl. curdy	29.0	Curdy	28.5	Sl. mealy
C	30.0		29.5	Sl. open	29.0	Sl. sweet ferment
D	30.0		29.5	Sl. open	29.0	Sl. sweet ferment
E	30.0		29.0	Sl. curdy, Sl. open	29.5	Sl. sweet ferment
F	30.0		29.5	Sl. curdy	29.0	Open
G	28.5	Curdy	29.0	Open	29.5	Sl. open
H	29.0	Curdy	29.0	Sl. curdy	29.0	Open
Avg.	29.6		29.2		29.0	

	90 day period		120 day period	
Lot	Score	Criticism	Score	Criticism
A	30.0		30.0	
B	30.0		30.0	
C	30.0		30.0	
D	30.0		30.0	
E	30.0		30.0	
F	29.5	Sl. open	30.0	
G	29.5	Sl. open	30.0	
H	30.0		30.0	
Avg.	29.9		30.0	

Table 44. Periodic body and texture scores and criticisms of cheddar cheese made with 0.75% lactic starter and cured for 120 days at 60° F.

	10 day period		30 day period		60 day period	
Lot	Score	Criticism	Score	Criticism	Score	Criticism
A	28.5	Curdy, Sl. open	28.0	Curdy, Open	29.0	Curdy
B	30.0		29.0	Sl. mealy	27.5	Mealy
C	30.0		28.5	Mealy	29.0	Open
D	29.0	Open	29.0	Sl. sweet ferment	29.5	Sl. open
E	30.0		30.0		29.0	Open
F	30.0		29.5	Sl. open	28.5	Open
G	29.0	Curdy	29.5	Sl. open	29.0	Open
H	29.0	Curdy	29.0	Sl. sweet ferment	27.5	Open, Mealy
Avg.	29.4		29.1		28.6	

	90 day period		120 day period	
Lot	Score	Criticism	Score	Criticism
A	29.5	Sl. open	29.0	Open
B	29.0	Open	29.0	Open
C	29.0	Sl. mealy	29.5	Sl. open
D	29.0	Open	29.5	Sl. open
E	29.5	Sl. open	29.5	Sl. sweet ferment
F	29.5	Sl. curdy	30.0	
G	29.5	Sl. open	29.0	Open
H	28.5	Open, Mealy	28.0	Mealy
Avg.	29.2		29.2	

Table 45. Periodic body and texture scores and criticisms of cheddar cheese made with 0.53% lactic plus 0.53% DK starter and cured for 120 days at 60° F.

	10 day period		30 day period		60 day period	
Lot	Score	Criticism	Score	Criticism	Score	Criticism
A	28.5	Curdy, Sl. open	28.0	Open	29.0	Open, Sl. curdy
B	29.5	Curdy	29.5	Sl. open	29.0	Open
C	29.5	Sl. sweet ferment	29.0	Open	29.0	Open
D	30.0		28.5	Sweet ferment	29.0	Open
E	30.0		28.5	Sweet ferment	29.0	Sl. sweet ferment
F	30.0		28.5	Sweet ferment	28.5	Mealy
G	28.5	Curdy	29.0	Open	29.0	Open
H	30.0		28.0	Mealy	27.0	Mealy Open
Avg.	29.5		28.6		28.7	

	90 day period		120 day period	
Lot	Score	Criticism	Score	Criticism
A	29.0	Open	29.0	Open
B	29.0	Open	29.0	Open
C	29.0	Mealy	28.0	Sl. mealy Open
D	29.0	Open	29.0	Open, Sl. Sw. ferment
E	28.5	Open	29.5	Sl. open
F	29.0	Curdy	28.0	Mealy
G	30.0		28.0	Open, Sl. Sw. ferment
H	28.5	Mealy, Open	28.0	Mealy
Avg.	29.0		28.6	

Table 46. Periodic body and texture scores and criticisms of cheddar cheese made with 0.75% lactic plus 0.375% DK starter and cured for 120 days at 60° F.

	10 day period		30 day period		60 day period	
Lot	Score	Criticism	Score	Criticism	Score	Criticism
A	30.0		29.0	Open	29.0	Open
B	29.5	Sl. curdy	29.0	Sl. mealy	28.0	Open, Mealy
C	30.0		29.5	Sl. open	29.0	Open
D	30.0		29.5	Sl. open	28.5	Open, Sw. ferment
E	30.0		28.5	Sweet ferment	28.5	Sweet ferment
F	30.0		29.0	Open	28.0	Mealy
G	28.5	Curdy	28.0	Sl. curdy Open	28.5	Sweet ferment
H	29.0	Curdy	28.5	Open	27.0	Mealy
Avg.	29.6		28.9		28.3	

	90 day period		120 day period	
Lot	Score	Criticism	Score	Criticism
A	29.0	Open	28.5	Open, Sl. Sw. ferment
B	29.0	Mealy	28.0	Mealy
C	29.0	Mealy	29.5	Sl. open
D	29.0	Mealy	29.0	Open
E	29.5	Sl. open	30.0	
F	29.0	Open	28.0	Mealy
G	29.5	Sl. open	29.5	Sl. sweet ferment
H	28.5	Open, Mealy	28.0	Mealy
Avg.	29.1		28.8	

Table 47. Total nitrogen, and soluble nitrogen as percent of total nitrogen at monthly intervals of 8 lots of cheddar cheese made with 0.75% lactic starter and cured at 50° F.

	30 day period		60 day period	
Lot	Total N.* Mgms./gm.	Soluble N. % of total N.	Total N. Mgms./gm.	Soluble N. % of total N.
A	41.3	12.85	41.3	16.49
B	41.6	13.56	41.6	16.87
C	39.8	12.46	39.8	17.53
D	41.2	13.45	41.2	17.98
E	41.0	14.05	41.0	17.00
F	39.5	12.38	39.5	17.50
G	41.5	12.79	41.5	17.26
H	39.8	11.48	39.8	16.28
Avg.	40.7	12.88	40.7	17.11

	90 day period		120 day period	
Lot	Total N. Mgms./gm.	Soluble N. % of total N.	Total N.** Mgms./gm.	Soluble N. % of total N.
A	40.9	18.77	40.9	21.48
B	41.0	18.07	41.0	20.12
C	39.4	18.43	39.4	20.32
D	40.0	18.83	40.0	20.68
E	41.4	17.99	41.4	20.09
F	39.7	18.45	39.7	21.58
G	41.5	19.69	41.5	22.35
H	40.3	18.07	40.3	19.50
Avg.	40.5	18.54	40.5	20.76

* Analysis at 60 days
** Analysis at 90 days

Table 48. Total nitrogen, and soluble nitrogen as percent of total nitrogen at monthly intervals of 8 lots of cheddar cheese made with 0.53% lactic plus 0.53% DK starter and cured at 50° F.

	30 day period		60 day period	
Lot	Total N.* Mgms./gm.	Soluble N. % of total N.	Total N. Mgms./gm.	Soluble N. % of total N.
A	41.2	11.82	41.2	16.28
B	40.7	12.95	40.7	15.83
C	38.6	13.24	38.6	16.79
D	41.1	13.89	41.1	17.12
E	41.3	11.69	41.3	15.99
F	40.4	12.92	40.4	16.25
G	40.6	12.73	40.6	17.28
H	39.5	13.08	39.5	17.40
Avg.	40.4	12.79	40.4	16.62

	90 day period		120 day period	
Lot	Total N. Mgms./gm.	Soluble N. % of total N.	Total N.** Mgms./gm.	Soluble N. % of total N.
A	38.8	17.82	38.8	19.67
B	39.7	18.45	39.7	20.03
C	37.8	18.51	37.8	20.07
D	39.1	18.32	39.1	20.33
E	41.2	17.33	41.2	19.53
F	40.3	17.72	40.3	20.07
G	41.3	19.03	41.3	21.35
H	40.6	18.04	40.6	19.41
Avg.	39.9	18.15	39.9	20.06

* Analysis at 60 days
** Analysis at 90 days

Table 49. Total nitrogen, and soluble nitrogen as percent of total nitrogen at monthly intervals of 8 lots of cheddar cheese made with 0.75% lactic plus 0.375% DK starter and cured at 50° F.

	30 day period		60 day period	
Lot	Total N.* Mgms./gm.	Soluble N. % of total N.	Total N. Mgms./gm.	Soluble N. % of total N.
A	42.3	12.84	42.3	16.98
B	42.3	13.85	42.3	16.78
C	39.9	14.24	39.9	17.48
D	41.5	14.24	41.5	17.55
E	41.4	12.17	41.4	16.02
F	40.7	11.94	40.7	16.13
G	41.3	12.71	41.3	17.49
H	40.1	12.84	40.1	17.45
Avg.	41.2	13.23	41.2	16.98

	90 day period		120 day period	
Lot	Total N. Mgms./gm.	Soluble N. % of total N.	Total N.** Mgms./gm.	Soluble N. % of total N.
A	39.8	18.98	39.8	21.36
B	41.9	18.96	41.9	19.75
C	38.0	19.28	38.0	21.77
D	41.4	19.14	41.4	19.86
E	41.7	17.77	41.7	19.62
F	41.1	16.27	41.1	19.90
G	42.8	18.27	42.8	20.50
H	40.8	19.87	40.8	20.66
Avg.	40.9	18.57	40.9	20.43

* Analysis at 60 days
** Analysis at 90 days

Table 50. Total nitrogen, and soluble nitrogen as percent of total nitrogen at monthly intervals of 8 lots of cheddar cheese made with 0.75% lactic starter and cured at 60° F.

	30 day period		60 day period	
Lot	Total N.* Mgms./gm.	Soluble N. % of total N.	Total N. Mgms./gm.	Soluble N. % of total N.
A	41.5	14.75	41.5	21.71
B	41.9	14.77	41.9	21.90
C	39.1	14.81	39.1	21.89
D	40.1	16.80	40.1	20.95
E	40.1	14.96	40.1	20.80
F	40.2	15.35	40.2	19.40
G	41.1	15.77	41.1	22.72
H	40.4	14.16	40.4	19.50
Avg.	40.6	15.17	40.6	21.11

	90 day period		120 day period	
Lot	Total N. Mgms./gm.	Soluble N. % of total N.	Total N.** Mgms./gm.	Soluble N. % of total N.
A	42.3	23.45	42.3	25.17
B	42.1	23.46	42.1	25.18
C	39.9	24.09	39.9	26.23
D	41.2	24.37	41.2	26.45
E	41.4	22.91	41.4	25.60
F	40.4	20.87	40.4	25.11
G	41.7	24.02	41.7	29.20
H	41.2	21.98	41.2	26.45
Avg.	41.3	23.15	41.3	26.17

* Analysis at 60 days
** Analysis at 90 days

Table 51. Total nitrogen, and soluble nitrogen as percent of total nitrogen at monthly intervals in 8 lots of cheddar cheese made with 0.53% lactic plus 0.53% DK starter and cured at 60° F.

	30 day period		60 day period	
Lot	Total N.* Mgms./gm.	Soluble N. % of total N.	Total N. Mgms./gm.	Soluble N. % of total N.
A	41.1	14.01	41.1	18.88
B	41.3	14.96	41.3	21.23
C	38.3	15.14	38.3	21.44
D	40.7	16.07	40.7	21.08
E	40.4	14.60	40.4	19.45
F	39.3	15.04	39.3	19.95
G	41.4	15.00	41.4	21.28
H	40.5	14.49	40.5	19.50
Avg.	40.4	14.91	40.4	20.35

	90 day period		120 day period	
Lot	Total N. Mgms./gm.	Soluble N. % of total N.	Total N.** Mgms./gm.	Soluble N. % of total N.
A	41.2	23.38	41.2	24.56
B	41.5	22.56	41.5	25.82
C	39.8	23.99	39.8	26.46
D	41.4	23.27	41.4	26.05
E	41.1	22.13	41.1	23.63
F	41.1	21.03	41.1	23.79
G	41.8	23.63	41.8	27.93
H	40.0	21.92	40.0	25.76
Avg.	41.0	22.74	41.0	25.50

* Analysis at 60 days
** Analysis at 90 days

Table 52. Total nitrogen, and soluble nitrogen as percent of total nitrogen at monthly intervals in 8 lots of cheddar cheese made with 0.75% lactic plus 0.375% DK starter and cured at 60° F.

	30 day period		60 day period	
Lot	Total N.* Mgms./gm.	Soluble N. % of total N.	Total N. Mgms./gm.	Soluble N. % of total N.
A	41.6	15.22	41.6	21.87
B	42.1	15.04	42.1	22.45
C	39.4	14.77	39.4	21.57
D	41.5	15.40	41.5	21.76
E	40.4	14.60	40.4	20.02
F	40.4	13.96	40.4	19.21
G	42.0	15.43	42.0	21.45
H	40.5	14.88	40.5	20.94
Avg.	41.0	14.91	41.0	21.16

	90 day period		120 day period	
Lot	Total N. Mgms./gm.	Soluble N. % of total N.	Total N.** Mgms./gm.	Soluble N. % of total N.
A	42.5	22.37	42.5	25.80
B	43.3	23.14	43.3	25.70
C	40.2	23.91	40.2	26.83
D	42.0	21.95	42.0	25.62
E	42.1	22.48	42.1	24.26
F	41.3	20.78	41.3	23.51
G	42.8	23.56	42.8	27.60
H	40.6	23.37	40.6	26.34
Avg.	41.9	22.69	41.9	25.71

* Analysis at 60 days
** Analysis at 90 days