1979

A Comparison of Cheddar Cheese Yields and Composition Using Conventional Bulk Set Cultures and Superstart Concentrated Cultures

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A COMPARISON OF CHEDDAR CHEESE YIELDS AND COMPOSITION USING CONVENTIONAL BULK SET CULTURES AND SUPERSTART CONCENTRATED CULTURES

BY

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A thesis submitted
in partial fulfillment of the requirements
for the degree of Master of Science,
Major in Dairy Science,
South Dakota State University

1979

A COMPARISON OF CHEDDAR CHEESE YIELDS
AND COMPOSITION USING CONVENTIONAL BULK SET
CULTURES AND SUPERSTART CONCENTRATED CULTURES

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ACKNOWLEDGMENTS

Sincere appreciation and gratitude are extended to Dr. Kenneth R. Spurgeon for his professional advice and constructive comments throughout the duration of my graduate program.

Special thanks are extended to Dr. John G. Parsons, Dr. James H. Martin, and Dr. Roscoe J. Baker for their advice during the initial proposal of this study.

Gratitude is expressed to the Marschall Division, Miles Laboratories, Inc. for their donation and constructive counsel to this study.

The assistance and expertise of Dr. W. Lee Tucker in the statistical analysis and Dr. Royce J. Emerick in atomic absorption spectrophotometry are gratefully acknowledged.

Recognition in due Mr. Shirley Seas and workers Curt Rich and Blaine Miller for their assistance during the manufacture of cheddar cheese.

Many thanks are extended to the Dairy Science graduate students and staff for the good times outside of academics.

Utmost gratitude is afforded Marlys Moberg for her standards of excellence in typing this thesis and for her patience during the final corrections of this manuscript.

Humble appreciation and thanks are given to my parents for teaching me the value of hard work and for their financial support through my college years.

To my dear wife, Deb, for her encouragement and enthusiasm, I dedicate this thesis.

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INTRODUCTION

The cheese industry has become by far the largest user of milk for manufacturing. In 1978, cheese production utilized a fourth of the total market supply of milk, up from less than an eighth in 1960 (4). Rising consumer incomes and changing lifestyles and eating habits have increased cheese consumption and sales by 60% since 1960 (21). In the last ten years, annual per capita consumption of cured cheese has increased from 11.6 lb to 17.1 lb (45). Economists state that the cheese market will continue to expand through the 1980's (7, 21, 68).

Manufacturing cultured dairy products can be a very profitable business, or sustained losses can occur. Over the past two decades, retail cheese prices have increased faster than prices of other foods and dairy products; while consumption has doubled. However, rising labor, raw material, and equipment costs have forced cheese producers into a very narrow profit margin.

Maximizing product yields often makes the difference whether a manufacturer-processor is successful. And since yields and profits can be synonymous, it is imperative that maximum yields are obtained. However, in recent years, cheesemakers have observed a gradual decrease in product yields (81).

One of the primary reasons cheese yields have been steadily on the decline is the change in the predominant breed of cow (67). Years ago, Jersey and Guernsey numbers were higher than now. These breeds traditionally produce milk with higher solids-not-fat to total solids ratios than Holstein milk (50). Thus, more protein was available for cheesemaking on a unit volume basis. Yee (81) stated that since 1957 the solids

content of milk has decreased, due mostly to increased breeding emphasis on high milk production and increase in numbers of the Holstein breed. Consequently, the current lower solids milk is resulting in less than 9 to 10% cheese yields that were common twenty years ago (2).

In order to obtain the best yield and quality of cheddar cheese, the optimum casein-to-fat ratio in milk should be at least .70 parts casein to 1.00 parts fat (32). In South Dakota, the actual ratio is approximately .62, with total protein levels as low as 2.80% (81).

Commercial cheesemaking studies have indicated a possible increase in yield when using direct-to-the-vat concentrated cultures (44). Supporting this is the fact that the whey generally contains a lower level of solids when these cultures are used. The reason for a possible increase in yield may be higher pH during ripening, renneting, and cooking of the cheese curd prior to drawing the whey. At higher pH, calcium salts and associated compounds are more insoluble, resulting in less acid soluble material being drawn off with the whey (57).

However, the benefits claimed for Superstart cultures have not been substantiated under controlled conditions. Therefore, one objective of this research was to determine yield differences, if any, when using Superstart concentrated cultures vs conventional bulk set cultures. Another objective was to evaluate and compare compositional and organoleptic characteristics in cheese manufactured using both types of starter cultures.

LITERATURE REVIEW

Cheddar cheese is a concentrated dairy product made from whole milk. Casein, the principal milk protein, is coagulated following addition of the proteolytic enzyme rennin and inoculation with lactic acid producing bacteria. A jelly-like curd of milk solids is formed which is cut into small cube shaped pieces. The curd particles shrink and exude moisture and the water-soluble constituents of milk. At a desirable level of acidity, the whey is drawn off and the curd particles fuse together.

Cheddar cheese is one of the oldest and most prominent varieties of cheese manufactured. It now comprises 44% of the U.S. cheese market (45). It originated in the county of Somerset, England. The name "cheddar" is taken from the town of Cheddar in that county where the cheese was first manufactured.

Starter Cultures, Importance and Function

Of the various ingredients that go into a cheese vat, none is more important than the cheese culture (14). This culture is appropriately called "starter" because it initiates (starts) most of the reactions and changes that take place in the vat during the manufacture of cheese and during the ripening period as well (75).

To fully appreciate these attributes, it is necessary to understand the overall functions of the starter in the manufacture and ripening of cheddar cheese. The starter must perform two important functions, a) acid production in the vat at a rapid but uniform rate and b) developement of flavor (19, 38, 60).

The need for carefully regulated acid production is better

appreciated by evaluating the role of acidity in the successive steps of cheddar cheese manufacture. Initial acid production in the vat is necessary to activate rennet for the coagulation of the cheese milk. Acid formation in milk releases free calcium ions from the bound state which are necessary for the rennet to form an efficient clotting of the milk (76). Acid also weakens the dispersed phase of colloidal casein by neutralizing the electrical charges or zeta potential (76). Further acid production is needed following cutting for the expulsion of whey from the curd cubes (20). Beyond this point, continued acid production during matting and cheddaring aids in the developement of desirable body and texture characteristics (79).

The second important function of the starter is the role it plays in developing the characteristic flavor of the cheddar cheese. Freshly made cheese regardless of the variety has only a mildly acidic flavor due to the lactic acid produced during manufacture. Full flavor developes during the curing process when enzymes and microorganisms break down the essentially flavorless major cheese components fat, protein, and carbohydrate into smaller flavorful compounds (42). Microorganisms, mostly from the starter, multiply and die during the cheese curing period (36). Flavor compounds are formed as a result of microbial metabolic processes to derive energy for growth and from the activities of enzymes which are excreted from the living cells or released from the dead cells (34). More than 200 potential flavor contributing compounds have been identified in cheese. These include a variety of fatty acids, amino acids, organic acids, ketones, esters, aldehydes, alcohols, sulfides and amines (33, 34, 53, 72).

Simply, the starter culture to a large degree determines the final body, texture, and flavor the cheese will have when it reaches the consumer. The bacteria in the starter culture should be vigorous, active, and metabolically competitive to carry out these functions.

Starter Cultures, Preparation and Problems

One cannot produce a high score cheese without normal starter activity in the cheese vat. This is especially crucial in the manufacture of cheddar cheese (28).

Years ago, the cheddar cheese manufacturer attempted to control acid and flavor developement in cheese by keeping back clean-flavored sour milk, buttermilk, or whey to be used as a starter (60). The starter was propagated in whole milk taken directly off the route truck (58).

Applied bacteriology in the last 60 years has made rapid progress in the identification, isolation, selection, propagation, and preservation of pure lactic cultures (16).

The types of bacteria commonly found in cheese starters belong to the lactic group of the genus Streptococcus. This group comprises the species Streptococcus lactis, Streptococcus cremoris, and Streptococcus diacetilactis. Some commercial mixtures also contain microorganisms belonging to the genus Leuconostoc, namely L. citrovorum and L. dextranicum.

In the late 1800's the first commercially produced starter culture was marketed in the form of 4-ounce mother cultures. These cultures were inoculated from a master culture and shipped in liquid form in glass containers. In warm months the culture would be over-ripened by the time the customer received it, and often the culture would have

coagulated (78). This manner for preparing starters for cheese manufacture had several disadvantages. The most important of these was the need for several subcultures and periods of incubation in order to prepare the large quantities of bulk starter required for inoculation of the milk in the cheese vat (39).

The next developement was dried cultures, which became available to the industry in 1930. They were dried in streams of warm air in vacuum chambers and lacked good viability due to the conditions of drying (78). Twelve years later the process of lyophilization or freeze drying was developed wherein the culture is frozen in a thin film and dried under high vacuum at the freezing temperatures (10). The freeze-dried cultures are used to inoculate a pilot or mother culture. However, only 20% to 80% of the bacteria cells survive drying and these are usually the least desirable strains (12). Moreover, changes occur continually after drying and during storage (63).

The introduction of frozen non-concentrated, 1 ml vial cultures in the early 1960's was a revolutionary change in culture handling. It was found if the culture were frozen in liquid nitrogen, the culture maintained good activity and strain balance. Also the protease system of the culture bacteria remained undisturbed (35, 40).

In 1967, five years after the developement of liquid nitrogen cultures, concentrated frozen cultures became available (57). These cultures are produced by growing them in a special medium, neutralizing the lactic acid and concentrating the cultures by centrifugation and are appropriately called bulk set concentrates. Just 70 ml of starter concentrate is sufficient to inoculate 1135 liters of starter medium

The cultures are packed in specially lacquered ring-pull cans and quickly frozen in liquid nitrogen to preserve viability (78).

As more cheese is produced to meet demand, millions more pounds of fluid starter culture must also be prepared. Each day cheese plants must produce up to several hundred liters of liquid starter culture to inoculate cheese vats at a rate of 37.85 liters (10 gallons) per 37.85 liters (1000 gallons) of milk (5). However hygienic the conditions, such continuous reproduction of cultures within the plant itself increases the chance of contamination by undesirable bacteria and bacteriophage.

In an attempt to reduce the hazards of manipulating bacterial cultures under plant conditions, a concentrated starter for direct vat inoculation was developed. The "Superstart" concentrated starter was introduced in 1973 by Miles Laboratories, Marschall Division. These cultures are packaged in 260 ml (8.8 oz) cans for the direct inoculation of 2270 kg (5000 lb) of cheese milk (3).

Factors Affecting Cheese Yields

Starter Cultures

Many agree that the key to maximizing product yields is the proper selection of an active starter culture (67). Uniform acid developement during the manufacture of cheddar cheese activates the rennet and improves the efficiency of coagulation (74). Therefore, more solids are retained in the cheese curd or coagulum. Also, the starter culture directly affects the flavor and body and texture of the finished product which may in turn affect the amount of marketable cheese a manufacturer produces.

Milk clotting which follows rennet addition is not well understood. Much of the problem arises from confusion over the structure of caseinate micelles in milk and the relationship of that structure to known facts about clotting. As the stabilizing power of κ-casein is destroyed by enzyme action, the caseinate micelles in milk become progressively more susceptible to clotting in the presence of calcium ions. A clot will not form in the absence of calcium. Pyne found that the calcium requirements for coagulation were affected by the presence of other ions such as magnesium and strontium (76).

In a comparison of the use of conventional bulk starter with direct-to-the-vat cultures when manufacturing cheddar cheese, the principle difference was found to be the degree of acid development at the different stages of manufacture (57) (This was verified in this study {Table 1}). When using Superstart cultures little or no acid development is seen until packing and cheddaring. Thus, at higher pH during the set, it is possible more calcium and associated compounds remain insoluble and held in the micelle, forming a better clot and increasing product yields. Thompson (57) performed preliminary yield comparisons of Superstart vs conventional cultures. He stated that a possible increase of 2 to 3 lb of cheese per 1000 lb of milk could be realized by using Superstart cultures. However, the details of these findings were never published, and no other comparative yield studies have been undertaken.

During cheesemaking, starter bacteria encounter several conditions which are adverse to their growth and function. These involve physical, chemical, and biological stresses which the starter bacteria must overcome.

TABLE 1. Typical changes in acidity during cheese manufacture[a,b].

Process Stage	Bulk Set[c]	Superstart[c]
Before starter	.165	.165
Starter addition	.170	.165
Rennet addition	.175	.165
Cutting	.120	.090
Drain whey	.145	.115
Cheddar begin	.220	.180
Milling	.500	.500

[a]Acidity expressed as percent lactic acid.

[b]Values are means of eight replications performed in this study.

[c]Culture type.

Although the cheese milk usually is heat treated before processing, this treatment is mainly intended to destroy coliforms, psychrotrophs, yeasts, and other heat-sensitive flora (56). The heat treatment by no means eliminates other heat-resistant flora, such as sporeformers, certain mesophiles, thermodurics, thermophiles, bacterial-, yeast-, and mold-spores. Thus, the starter flora must compete with these other microorganisms if the milk is heavily contaminated. Further contamination from the atmosphere, equipment, and personnel occurs during the manufacturing process. It is obvious that the entire microbiological environment in the cheese vat is competitive. In line with this, it has been demonstrated that certain lactic acid bacteria produce inhibitors for other lactic acid bacteria. Strains of S. cremoris were found to produce a compound, diplococcin, which is inhibitory to other strains of S. cremoris (52).

During the coagulation of the milk, the starter bacteria are held immobile in the thickening curd (75). They must be able to grow in this location to establish conditions favorable for further growth. As the cooking of the curd continues, the starter bacteria are subjected to temperatures of up to 40 C (104 F). The starter organisms must therefore be heat tolerant to perform their functions. As the cheesemaking process continues, there also is an increase in acidity. The starter flora should be capable of withstanding this increased acidity. After the curd is salted, salt tolerance will determine the numbers of viable starter bacteria in the fresh unripened cheese (31).

Finally, bacteriophages pose a serious challenge to starter flora during cheese manufacture (29). These tadpole-shaped viruses attach

themselves to the bacteria, penetrate, and in minutes burst the bacterial cell. The destruction of starter organisms in this way is termed phage-lysis (24). Other bacterial inhibitors, such as antibiotics and cleaning agents, also are important. Since it is easier to police improper usage of antibiotics and cleaning agents, the main cause of starter failure is bacteriophage, which is responsible for as many as 80% of the cases (14).

A successful culture program for cheese manufacture does not end with acquisition of starter cultures from a reputable culture supplier. Most of the problems with starters arise from improper storage, propagation, and handling of the cultures in the cheese plants (13).

Milk Composition

Milk, the starting material for making cheese, is known to vary in chemical composition with a number of factors, the most prominent of which is the breed of cow (11). Generally, the color breeds produce milk of higher solids content. The fat is in the form of small even sized globules very suitable for cheesemaking (11). The milk solids are divided between the curd and the whey and it is the balance between two of the major constituents, namely the fat and the casein, which determines the yield of cheese. Concentrations of these components may also be affected by mastitis, stage of lactation, unusual feeding practices, and seasonal variations (30, 62).

The microenvironment of the milk can also affect cheese yields. Modern milk production including tank collection of the milk often involves one or two day storage before it is received at the cheese plant, where it can again be held for 24 h or more before processing. During this storage over 2 to 3 days at low temperatures, phychrotropic

bacteria can develope (29). These "low temperature" bacteria can degrade casein so that it is not incorporated into the cheese (51).

Other problems related to milk composition include natural inhibitors and antibiotics. Heavy feeding with new clover, turnips, or silage may result in the reduction of the fermenting capabilities of the milk (52). Certain fatty acids may be produced which inhibit bacterial growth. Also, the presence of lactenin, lactoperoxidase and agglutinins may inhibit the proper growth of starter organisms (16, 66).

Mastitis therapy continues to result in the occurrence of inhibitory antibotics in the milk supply (62). Lactic acid bacteria vary in their resistance to antibiotics but generally 0.5-1.0 I.U. of penicillin per ml is sufficient to inhibit starter growth (52).

Heat Treatment of Milk

Cheddar cheese has been traditionally manufactured from raw milk. Pathogenic bacteria which present a public risk do not normally proliferate appreciably during the manufacture of cheddar cheese due to the unfavorable acid and saline environment. However outbreaks of food poisoning have occasionally been traced to the consumption of cheddar cheese (64). Therefore today much of the whole milk used to manufacture cheese is pasteurized. Studies have shown that excessive heat treatment can degrade the protein resulting in inferior, slow curing cheese (43). Others have reported higher cheese yields when using pasteurized milk (54). Nevertheless, many cheesemakers are reluctant to use pasteurized milk and believe the best, full-mature cheddar cheese flavors can only be produced from raw milk. Still, the use of pasteurized milk for cheese manufacture is widespread (18).

Homogenization of Cheesemilk

The influence of homogenization on the suitability of milk for cheesemaking has recently been reviewed (76). In addition to reducing fat losses into the whey and fat leakage from mature cheese, there is some evidence of improved body and decreased flavor defects in cheddar cheese. These advantages are at least partially offset by increased manufacturing costs. Some have reported that homogenization reduces coagulation time and increases curd "viscosity" and yield (76).

Miscellaneous Manufacturing Variables

Loss of potential cheese yield can occur at any stage of cheese manufacturing. Physical abuse of the milk can disrupt the fat globules with subsequent loss of fat into the whey resulting in lower yields (51). Cutting prior to the optimum time causes disruption of the fragile curd and results in curd breakage and solids loss into the whey. Carelessness during the cutting process can also result in decreased curd yields due to excessive curd breakage (50). Knives must be in good condition with no missing wires. The coagulum should be cut slowly and without overlap to minimize solids passage into the whey.

Abrasion of curd particles being stirred during cooking can result in "curd fines" and yield loss. Milling cheddared blocks exposes fresh curd surfaces and consequently fat globules. These globules can be eroded depending on temperature and method of handling. Other factors that can affect yield include, 1) addition of coagulant and calcium chloride, 2) proper setting and control of incubation temperature, 3) uniform cooking schedule, 4) draining, 5) pressing, and 6) curing (8, 55, 67).

Methods of calculating cheddar cheese yields

When considering yields of cultured dairy products many factors must be considered. However product yields do have predictable, theoretical maximums. Extensive research in the early 1900's demonstrated that in the conversion of milk to cheese curd, a partition of milk constituents occurs that is greatly dependent upon the characteristics of each component (49). Casein, which exists as a suspension of spheres or micelles in milk, aggregates during milk clotting to form a network that entraps some of the water and most of the milk fat. After formation, the protein network begins to shrink and expel liquid whey. The whey being expelled from the curd carries with it any water-soluble component including lactose, whey proteins, soluble salts, non-protein nitrogenous compounds and peptides. Fat globules are held within the protein network because of their size and weak chemical bonding with the protein (50). Average fat losses during manufacture amount to 7% of the original milk fat. It is also assumed that 4% of the original casein is lost.

The above discussion indicates the importance of casein and fat in determining cheese yields. A direct linear relationship has been demonstrated between these components and yield of cheddar cheese (49). This led to the developement of the following formulas for predicting yield (49).

Formula A

$$\text{Yield} = 0.93F + \frac{0.907\ P}{1.00 - MNFS}$$

Formula B

$$\text{Yield} = 0.93F + \frac{1.163\ C}{1.00 - MNFS}$$

Formula C

$$MNFS = \frac{\text{\% moisture in cheese}}{100 - \text{\% moisture in cheese} - \text{\% fat in cheese}}$$

Where:

Yield = lb 37% moisture cheese per 100 lb milk.

F = % milk fat.

P = % milk protein.

C = % milk casein.

MNFS = lb water per lb of nonfat cheese solids.

The fat content of milk for yield calculation can be accurately measured and is easily obtainable. However casein analysis is time consuming since it requires analysis for total protein, precipitation of casein, filtration, and analysis for the non casein protein (81). Casein can also be estimated by assuming that casein constitutes a fixed percentage (80%) of the total milk protein, or by using the following formula based upon a correlation with the fat content of milk (49).

$$\text{\% casein} = (\text{\% fat} \times 0.4) + 1.0$$

It is assumed in the above yield formulas that a constant amount of casein (0.1%) is lost during cheese manufacture. This loss is equal to 4% of the casein if the total amount of casein in the milk is 2.5%.

In spite of these limitations, the cheese yield formulas can accurately predict cheese yields, and can be used to evaluate the performance of a cheese plant in recovering milk solids in cheese (51).

MATERIALS AND METHODS

Cheddar cheese was manufactured using Superstart[1] direct-to-the vat cultures and conventional bulk set starter. Each type was replicated eight times using an industrial make procedure suggested by Marschall Division, Miles Laboratories[1].

Fresh whole milk was used to manufacture cheddar cheese two consecutive days of each week: one day cheese was made using Superstart cultures, the next day bulk set cultures were used. The order of starter use (Superstart, Bulk Set) was chosen at random to preclude bias which may have occurred due to overnight storage of milk (25). This manufacturing schedule was followed over 8 wk.

Each week, milk (2550 kg) (5622 lb) was obtained from the South Dakota State University (SDSU) Dairy Production and Research Unit. The milk was immediately pasteurized by the batch method: 63 C (145 F) for 30 min. Half (1275 kg) of the milk was cooled by cold water jacket to 1 C (33 F) and held overnight. The other half (1275 kg) was cooled to 31 C (88 F) and pumped directly into a 1250 liter (330 gal) vat in the SDSU Dairy Products Laboratory.

Superstart and Bulk Set cultures were obtained from Marschall Division, Miles Laboratories. All cultures were made from identical lactic acid culture strains, commercially designated MD. These cultures were held in a mechanical freezer at -196 C (-410 F). Bulk Set cultures are commercially packaged in 70 ml cans for the inoculation of 378.5

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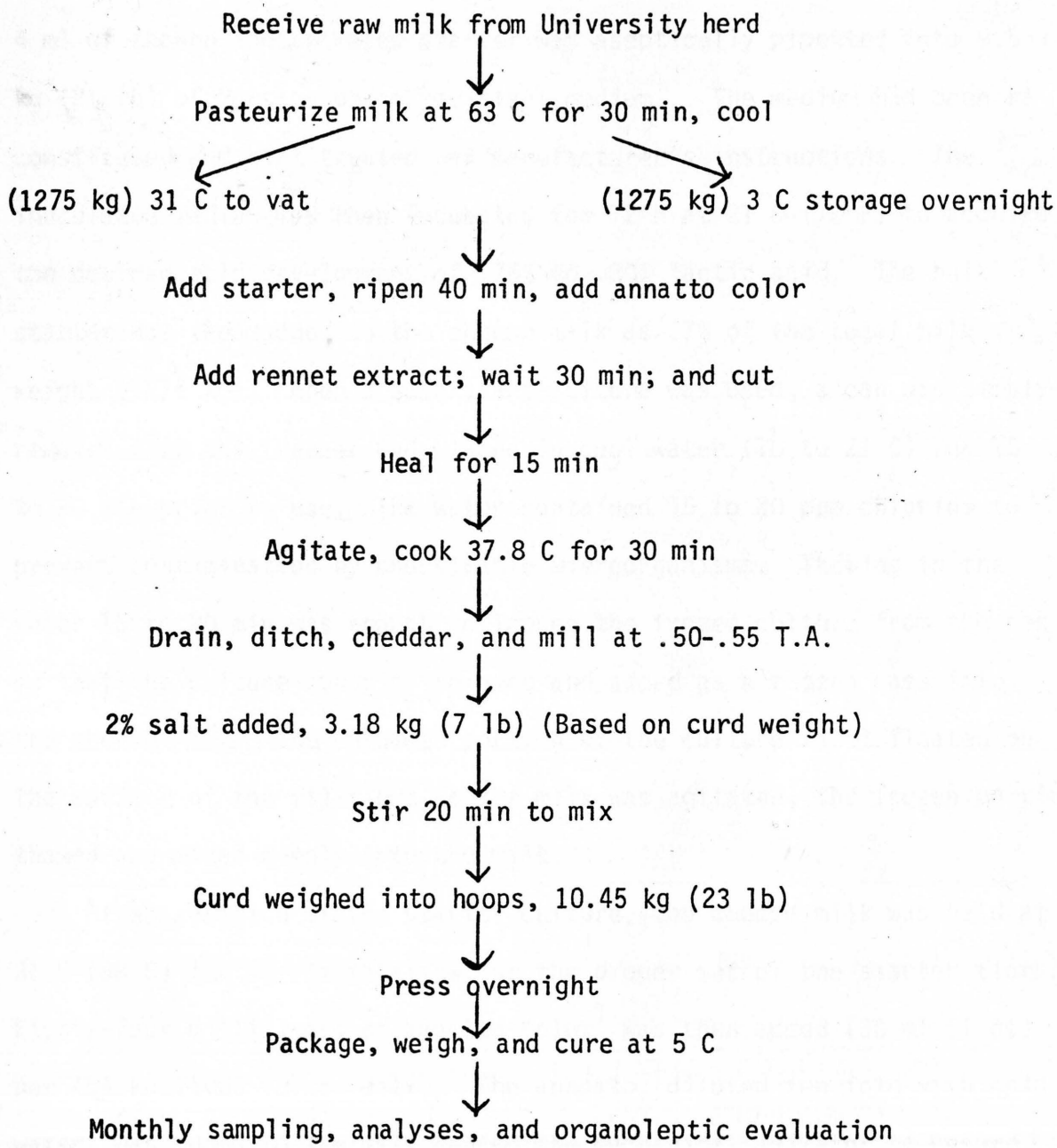
[1]Marschall Dairy Ingredients Division, Miles Laboratories, Inc., P. O. Box 592, Madison, WI 53701.

FIG. 1. Flow diagram of cheese manufacture.


Receive raw milk from University herd
Pasteurize milk at 63 C for 30 min, cool
(1275 kg) 31 C to vat
(1275 kg) 3 C storage overnight
Add starter, ripen 40 min, add annatto color
Add rennet extract; wait 30 min; and cut
Heal for 15 min
Agitate, cook 37.8 C for 30 min
Drain, ditch, cheddar, and mill at .50-.55 T.A.
2% salt added, 3.18 kg (7 lb) (Based on curd weight)
Stir 20 min to mix
Curd weighed into hoops, 10.45 kg (23 lb)
Press overnight
Package, weigh, and cure at 5 C
Monthly sampling, analyses, and organoleptic evaluation

liters (100 gal) of starter media. Working with much smaller amounts, 4 ml of thawed concentrated starter was aseptically pipetted into 9.5 kg (21 lb) of Marstar phage resistant medium[1]. The medium had been reconstituted and heat treated per manufacturer's instructions. The inoculated medium was then incubated for 12 h at 21 C (70 F) to acquire the desired acid development of .75% to .80% lactic acid. The bulk starter was then added to the cheese milk as .7% of the total milk weight (1275 kg). When a Superstart culture was used, a can was simply removed from the freezer and placed in cool water (10 to 21 C) for 15 to 20 min prior to use. The water contained 15 to 20 ppm chlorine to prevent contamination by undesirable microorganisms. Thawing in the water 15 to 20 min was enough to loosen the frozen culture from the can so that the culture could be removed and added as a frozen mass into the cheese milk. The unthawed portion of the culture first floated on the surface of the milk; but as the milk was agitated, the frozen portion thawed and mixed evenly into the milk.

After addition of the starter culture, the cheese milk was held at 31 C (88 F) for 40 min to allow for the proper set of the starter flora. Eighty-four milliliters of annatto color[1] was then added (30 ml {1 oz} per 454 kg {1000 lb} of milk). The annatto, diluted ten fold with cold water, was added to the milk behind the mechanical agitator to ensure adequate incorporation into the milk.

Two hundred eighty-nine milliliters of rennet extract[1] (100%

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[1]Marschall Dairy Ingredients Division, Miles Laboratories, Inc., P. O. Box 592, Madison, WI 53701.

strength) (105 ml {3.5 oz} per 454 kg {1000 lb} of milk), diluted with twenty times its volume of cold water, was added to the milk behind the mechanical agitator and mixed into the milk for 2 min. The currents in the vat were stilled by manually reversing the agitators and the milk let stand for a period of 30 min. A test to ensure proper coagulation was performed using a knife technique whereby a slice is made in the coagulum. The knife is then inserted perpendicularly at one end of the slice and lifted gradually. If the coagulum falls away from the slice uniformly on both sides, the vat is ready to be cut.

The curd was cut using .93 cm stainless steel wire knives which had been sanitized in 200 parts per million chlorine solution. To cut the curd, two knives (vertical, horizontal) were drawn through the curd to the end of the vat. The horizontal knife was removed from the vat and the vertical knife was given a half-turn (180^{o}), then the horizontal knife was inserted back into the vat on the opposite side from the first pass. Both knives were now in a reversed position. Each knife was drawn back through the curd and carefully removed. The vertical knife was then used to cut the curd crosswise throughout the length of the vat to form uniform cubes of curd.

The curd was allowed to "heal" for 15 min after cutting. Then, with mechanical stirring the cooking process began. The temperature was increased slowly at the rate of 0.55 C (1 F) for each 4 min interval for the first 20 min, then increased so that desired cook temperature 38 C (101 F) was reached in 30 min. Cooking and agitation continued for 30 min not to exceed a maximum temperature of 38.9 C (102 F).

Upon completion of the cooking process, curd was manually pushed to the rear of the vat using mechanical agitation paddles. Whey was drawn down to a level with the top of the curd. When the titratable acidity reached .14% to .15% lactic acid, the remainder of the whey was drawn off. Acidity developed to .16% to .17% lactic acid by the time all the whey was drawn from the vat. Immediately the curd cubes begin to pack together. After 15 min and further whey removal, the packed mass of curd was cut into slabs of 20 cm (8 in) width and turned every 10 to 15 min. After two turns the cheddar blocks were piled two high by cutting each block in half and placing the front portion on top of the back portion. The blocks were turned every 10 min, next going three high, then four high. The blocks were turned continuously at four high until a desired titratable acidity of .50% lactic acid was reached. During the experimental manufacture of cheddar cheese throughout this research, a milling acidity range .50% to .55% lactic acid was established.

Cheese was milled into strips finger size, 1.6 cm (5/8 in) width and 6 cm (2.5 in) length. Following milling, cheese was manually and mechanically forked for 10 min before salting. Salt was added in two applications as 2% of curd weight, 3.1 kg (7 lb) total. Mechanical forking was continued for 20 min after final salting to aid in salt distribution and absorption and whey expulsion. Fresh salted curds were then weighed into Wilson rectangular hoops, 10.5 kg (23 lb) per hoop. The hoops were placed in a simple spring horizontal cheese press until the next morning. The cheese was carefully removed from the

hoops and wrapped in a cry-o-vac film and a waxed paper covering the heat sealed. Wrapped cheese blocks were weighed to determine total fresh cheese recovered from the total milk weight. Cheese was then placed in a forced air curing room at 7.2 C (45 F) for 9 mo.

Sampling

Milk samples were taken by compositing five 1000 ml samples taken directly from the cheese vat prior to manufacture. Duplicate 200 ml aliquots were taken for analyses and preserved frozen in 532 ml (18 oz) Whirlpak[1] plastic bags. Total milk weight in the cheese vat was determined by reading a dipstick, assuming that 1 gal milk equals 3.91 kg (8.61 lb). Whey samples were taken by compositing ten 1000 ml samples taken during several intervals during the whey drainage. Duplicate 200 ml aliquots were taken for analyses and preserved frozen in 532 ml (18 oz) Whirlpak plastic bags.

The fifth cheese block in the press was designated for analyses. This block was near the center of the press and was taken repeatedly to preclude any bias due to hoop location in the press. The covering of the cheese blocks were marked off into ten sections and months were randomly assigned to each section to facilitate monthly sampling initially and the following 9 mo. Nine plugs were pulled per monthly sampling, one for bacteriological review, two for flavor evaluation, and seven for subsequent analyses. All cheese samples used for analyses were chopped in a 500 ml Waring blender and preserved frozen in 532 ml

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[1]Nasco, Fort Atkinson, Wisconsin 53538.

(18 oz) Whirlpak plastic bags.

Compositional Analyses

Total protein in the milk, cheese, and whey was determined according to the A.O.A.C. Kjeldahl procedure (6). Casein and whey protein fractions were derived by the Rowland method (65). Water soluble nitrogen of cheese was determined by a modified method of Vakaleris and Price (73). Upon precipitation and filtration, duplicate 25 ml aliquots were taken and water soluble nitrogen determined by Kjeldahl method (6).

Total solids of milk, cheese, and whey were determined by the Mojonnier method as described by Newlander and Atherton (47). Fat content of milk and whey was determined by Mojonnier procedure (6). Cheese fat was determined by A.O.A.C. Babcock extraction (6). Solids-not-fat values were calculated as the difference between total solids and fat for all samples. Total mineral ash content of milk, cheese, and whey was determined by the A.O.A.C. method using porcelain crucibles. Lactic acid content of cheese was determined by Harper and Randolph procedure (22).

Cheese pH was measured using a Leeds-Northrup expanded scale pH meter. The cheese was chopped finely, then the electrode was immersed directly into the cheese and the pH read directly, according to Standard Methods for the Examination of Dairy Products (1).

Milk and whey samples were protein precipitated with 10% trichloracetic acid and appropriately diluted to determine phosphorus content by Morrison procedure (46). Cheese samples were ashed by A.O.A.C. method, solubilized with concentrated sulfuric acid and appropriately

diluted for mineral determination (17). Again, phosphorus was determined by the Morrison method (46).

Atomic absorption spectrophotometry[1] for calcium, magnesium, sodium, and potassium was performed on milk and whey following acid precipitation. Cheese samples were ashed and solubilized as explained. Dilutions were prepared using .5% lanthanum solution for calcium and magnesium, and using distilled water for sodium and potassium determinations. Lanthanum is used to prevent the interference of phosphorus.

Bacteriological quality of milks used for cheddar cheese manufacture was assessed by plating for total count of standard plate, coliform and psychrophiles. Duplicate platings of appropriate dilutions (1:1, 1:10, 1:100, 1:1000, 1:10,000) of raw and pasteurized milks were performed.

Organoleptic Evaluation

A judging panel consisting of three to four experienced judges evaluated the cheddar cheese at monthly intervals for flavor and body and texture defects in accordance with the ADSA-DFISA score card. Organoleptic evaluation was performed on cheese 30 days to 9 mo old. All samples were displayed randomly to prevent knowledge of sample identity during evaluation.

Expression of Yield

Yield data were calculated as kg 63% solids cheese received per 100 kg cheese milk. Yield from cheese made with bulk set starter was

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[1]Perkin-Elmer model 303 atomic absorption spectrophotometer, with model SCRIB digital concentration read out, Perkin-Elmer, Norwalk, Connecticut 06850.

also calculated as kg 63% solids cheese received per 100 kg cheese milk plus .7 kg starter media.

Statistical Analysis

Statistical analysis of the data utilized least squares analysis of variance for a randomized block experiment with a three factor (replication, treatment, and month) design experiment (69). The main effects of treatment and time were tested by the respective main effect and replication interaction. The remainder was used as the error term to test the interaction of treatment and time.

RESULTS AND DISCUSSION

Cheese Milk Composition

As previously discussed, research has demonstrated that yield of cheddar cheese is closely associated and influenced by milk composition (15). To ensure a legitimate comparison of yields, it is crucial that that compositions of milks used for each starter culture type be statistically identical. Therefore, it was necessary to collect milk samples from each vat and appropriate analyses performed.

Average composition of the eight milks used in this study are listed in Table 2. Fresh whole milk contained 3.35% fat, 8.63% SNF, 2.98% total protein, 2.29% casein, and 4.99% lactose by difference. These values are relatively low and are typical of much of the milk supply in South Dakota (81). The milks used for cheddar cheese manufacture were obtained during June and July which may account for some of the total solids depression. Casein content for fresh whole milk was considerably lower than historically reported (27). These values are reflective of the low cheese yields seen in this study.

The major minerals of the milks used in this study are also listed in Table 2. The average composition of respective milk minerals compares closely with reported values (70). Calcium levels were slightly higher than reported while potassium levels were slightly lower.

Statistical information in Table 3 demonstrates that the gross composition of the Superstart and Bulk Set cheese milks were not significantly different ($P<.01$). The table also indicates a highly significant difference ($P<.01$) in milk composition between weeks. This

TABLE 2. Average composition of milks used to manufacture cheddar cheese.[a]

Component	Superstart	Bulk Set	Overall Mean	Overall SE[b]
	%			
Total solids	11.97	11.99	11.98	.04
Fat	3.33	3.38	3.35	.03
Solids-not-fat	8.64	8.61	8.63	.06
Total protein	2.99	2.97	2.98	.02
Casein protein	2.29	2.26	2.28	.04
Lactose	5.00	4.98	4.99	.07
Ash	.65	.66	.65	.008
	mg/100 ml			
Phosphorus	93.2	95.5	94.4	1.6
Calcium	146.0	137.6	141.8	4.9
Magnesium	12.5	13.6	13.1	0.5
Potassium	94.2	94.1	94.2	4.4
Sodium	52.9	55.9	54.4	2.8

[a]Values are means of eight replications.

[b]Standard error.

TABLE 3. Statistical analysis of components of milk used for cheddar cheese manufacture.

Factor	Component											
	Total solids	Fat	SNF	Total protein	Casein protein	Lactose	Ash	P	Ca	Mg	Na	K
Treatment	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Week (replication)	**	N.S.	**	**	**	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* Significant ($P<.05$).

** Highly significant ($P<.01$).

N.S. = Not significant.

TABLE 4. Bacteriological quality of pasteurized milk used for cheddar cheese manufacture.[a,b]

Week	SPC		Coliform		Psychrotrophs
	Superstart	Bulk Set	Superstart	Bulk Set	Raw milk
1	580	130	28	8	1350
2	140	20,000	4	6	670
3	430	660	32	3	10
4	2,900	320	12	10	4900
5	1,300	270	12	21	10
6	2,000	950	4	1	320
7	10,200	8,500	1	1	10
8	5,800	6,500	4	1	10

[a]Bacteria counts are expressed as colonies/ml.

[b]Pasteurized Grade A milk must contain <20,000 SPC and <10 Coliform.

is due to total solids and total protein concentration fluctuations. Such fluctuations were expected.

The results of bacteriological examination are summarized in Table 4. The milks used for cheddar cheese manufacture were of high quality and the Standard Plate Count conformed to Grade A standards. Five of the sixteen milks contained coliform counts exceeding the 10 colonies/ml limit. The phychrotroph concentration of raw milk was also within acceptable limits, the highest count being 4900 colonies/ml.

Cheddar Cheese Composition

The average composition of cheddar cheese produced in this study is summarized in Tables 5 and 6, followed by a summary of statistical analysis of cheese composition in Table 7. The total solids content of Superstart cheese was found to be significantly higher ($P<.05$) than Bulk Set cheese. This may be due to more uniform acid development in the curd during cheddaring when using Superstart cultures, resulting in better control of whey expulsion and product moisture levels. Average total solids for all cheeses was 62.79% which is legal for cheddar cheese by Federal and South Dakota standards (71). When manufacturing cheddar cheese, moisture levels in the finished product are not consistent from vat to vat. Therefore, a more precise comparison of composition and yields are possible by adjusting all components except total solids to a 63% total solids basis. Solids and moisture levels were determined on fresh cheese and at monthly intervals up to 9 mo of age.

The fat content of Bulk Set and Superstart cheeses at 0 mo averaged

TABLE 5. Average composition of fresh (0 month) cheddar cheeses[a].

Component	Starter used		Overall	
	Superstart	Bulk Set	Mean	SE[c]
	---------- %[b] ----------			
Total solids	63.34	62.54	62.94	.28
Fat	31.53	31.86	31.68	.27
Solids not fat	31.81	30.68	31.26	.45
Total protein	24.18	24.00	24.09	.27
Ash	3.74	3.76	3.75	.07
	---------- mg/100 g ----------			
Phosphorus	353.8	360.5	357.2	8.2
Calcium	568.1	585.5	578.9	10.5
Magnesium	35.4	35.1	35.2	1.1
Sodium	578.4	556.9	567.7	32.1
Potassium	87.9	88.6	88.2	6.6

[a]Values are means of eight replications.

[b]Percentages for all cheese components except total solids are adjusted to basis of 63% solids in the cheese.

[c]Standard error.

TABLE 6. Average composition of aged (9 month) cheddar cheeses[a].

Component	Starter used		Overall	
	Superstart	Bulk Set	Mean	SE[c]
	% [b]			
Total solids	63.43	62.47	62.95	.45
Fat	31.08	31.33	31.19	.25
Solids not fat	32.35	31.14	31.77	.61
Total protein	23.78	23.92	23.85	.49
Ash	3.61	3.58	3.59	.07
	mg/100 g			
Phosphorus	355.2	358.4	356.8	5.4
Calcium	552.0	593.8	572.9	13.2
Magnesium	32.8	36.8	34.8	1.3
Sodium	680.7	670.0	675.2	21.9
Potassium	89.2	89.7	89.5	2.7

[a]Values are means of eight replications.

[b]Percentages for all cheese components except total solids are adjusted to basis of 63% solids in the cheese.

[c]Standard error.

TABLE 7. Statistical analysis of effects of starter culture and age at analysis on the composition of cheddar cheeses.

Factor	Component %							
	Total solids	Fat	Total protein	Soluble nitrogen	Lactic acid	Ash	Calcium	pH
Starter culture	**	*	N.S.	**	*	N.S.	*	**
Age in months	**	**	N.S.	**	**	**	N.S.	**
Starter x month interaction	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* Significant ($P<.05$).

** Highly significant ($P<.01$).

N.S. = not significant.

31.86% and 31.53%, respectively. This difference between treatments was statistically significant ($P<.05$). It is possible that due to greater acid content during manufacture when using bulk set cultures, the rennet was more thoroughly activated and a more efficient clot formed. This may result in a less fragile curd and a reduction of fat losses to the whey. During the 9 mo curing period, hydrolysis of lipids by lipases originating from microorganisms, rennet, and milk contribute substantially to the flavor of cheddar cheese (77). The resultant compounds are not measurable by the method used to determine fat which results in lower fat levels in the 9 mo cheese than in the 0 mo cheese.

Levels of total protein, ash, phosphorus, magnesium, sodium, and potassium were not significantly different in cheese made with the culture types. Total protein decreased slightly for both treatments at 9 mo of age compared to the levels in fresh cheese. This may be explained by formation and release of volatile ammonia or the inherent variability and limits of accuracy of the test procedure used. Ash also decreased for both treatments at 9 mo of age. Wingfield (80) also incurred this change and no explainable reason for this decrease is apparent. Bulk Set cheese contained significantly ($P<.05$) more calcium than Superstart cheese in both 0 and 9 mo samplings. These findings do not agree with the composition of wheys, in which Bulk Set whey was found to contain more calcium.

Salt was added at a constant rate for all cheeses, and no analyses were performed to determine total NaCl concentration. However, levels of sodium in cheese made from the culture types were not significantly

different. A 16% increase in measured sodium was seen in 9 mo old cheeses compared to 0 mo values. No reason has been established for this increase occurring after the 9 mo curing period.

Table 8 summarizes the pH changes occurring in the curing cheeses. The pH of typical cheddar cheese is approximately 5.0 2 days after manufacture but increases during curing due to alkaline products liberated during protein hydrolysis (76). Superstart cheese maintained consistently higher pH levels throughout curing as shown in Table 8.

The difference in pH levels between cheeses was highly significant ($P<.01$). This may be due to a more active microflora in the Superstart cheese, resulting in greater lactic acid destruction and formation of less highly dissociated acids including acetic and carbonic acids. It would also tend to indicate more extensive proteolysis and liberation of more alkaline products.

The levels of lactic acid production in the cheeses during the first 180 days of curing are summarized in Table 9. The utilization by the starter bacteria of the lactose in cheese is very rapid and it has been reported that most of the lactose fermentation occurs within the first few days of curing (41, 77). Glycolysis of lactose to lactic acid requires numerous enzymatic steps. Production of lactic acid is essential for proper flavor, ripening, and inhibition of spoilage-type microorganisms in cheese (79). Although milling acidities were identical for both treatments, the bulk starter cheese contained significantly ($P<.05$) higher levels of lactic acid. The rate of protein breakdown and lactose release from the casein complex may have been more conducive to bacterial

TABLE 8. Average monthly pH levels of cheddar cheeses[a].

Month	Starter used		Overall	
	Superstart	Bulk Set	Mean	SE[b]
	---------- % ----------			
0	5.04	5.02	5.03	.02
1	5.06	5.07	5.06	.02
2	5.11	5.09	5.10	.02
3	5.25	5.22	5.24	.02
4	5.38	5.34	5.36	.02
5	5.32	5.32	5.32	.02
6	5.41	5.38	5.39	.02
7	5.42	5.36	5.39	.02
8	5.52	5.42	5.47	.02
9	5.57	5.50	5.53	.02

[a]Values are means of eight replications.

[b]Standard error.

TABLE 9. Average monthly lactic acid levels of cheddar cheeses[a,b].

Month	Starter used		Overall	
	Superstart	Bulk Set	Mean	SE[c]
	%			
0	1.06	1.13	1.09	.07
1	1.32	1.32	1.32	.06
2	1.33	1.36	1.35	.06
3	1.35	1.39	1.37	.06
6	1.35	1.39	1.37	.05

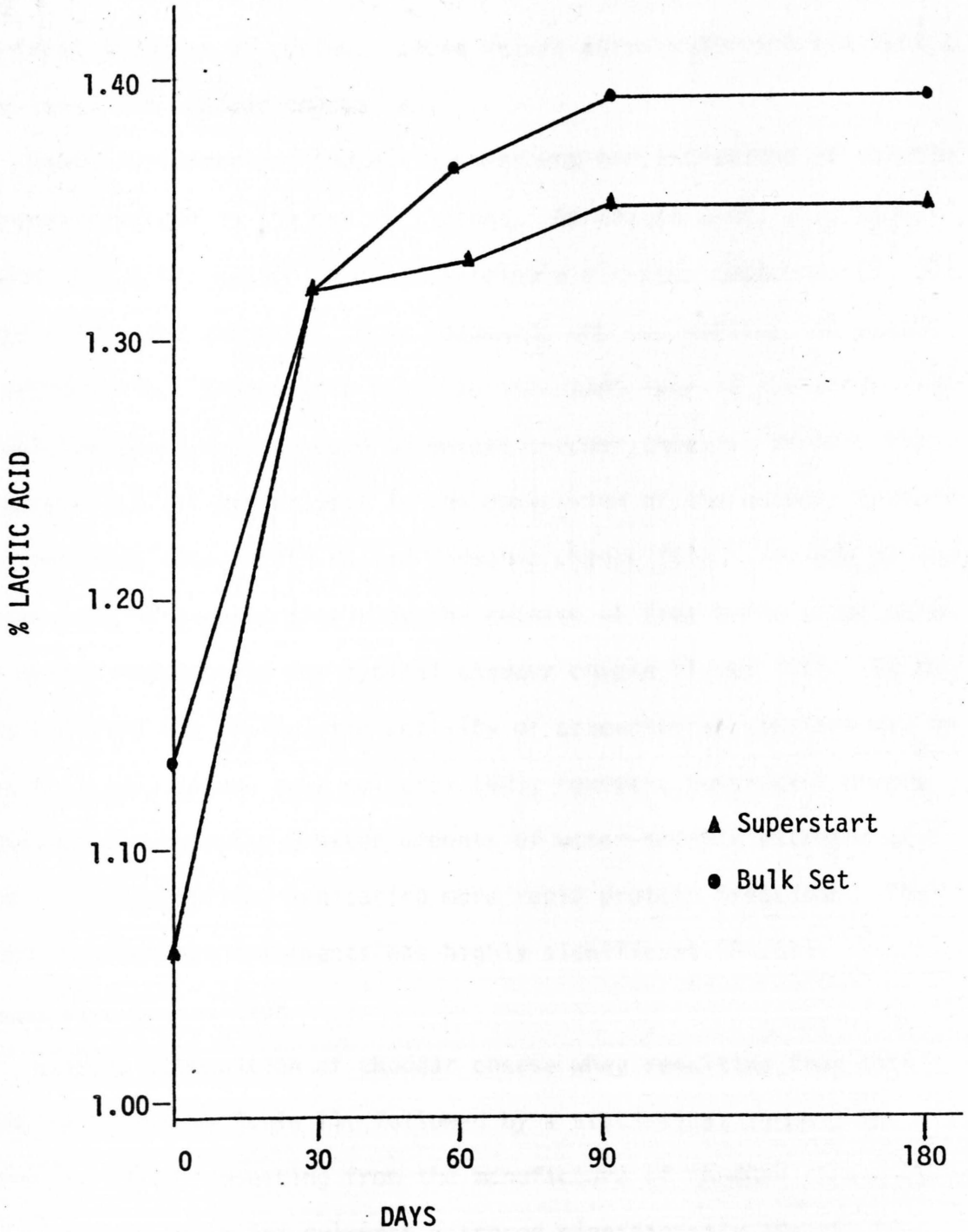
[a]Values are means of eight replications.

[b]Values are adjusted to basis of 63% solids in the cheese.

[c]Standard error.

FIG. 2. Average lactic acid values of cheddar cheeses at various ages[a].

[a]Values are means of eight replications.


1.40
1.30
1.20
1.10
1.00
% LACTIC ACID
0
30
60
90
180
DAYS
Superstart
Bulk Set

fermentation in the bulk starter cheese. The microflora in these cheeses may not have been as active in the destruction of lactic acid. Figure 2 grahpically illustrates the rate of lactic acid production for the first 180 days of curing. These values agree with reported lactic acid levels in cheddar cheese (23).

Table 10 summarizes the average percent concentrations of soluble nitrogen produced in the curing cheeses. As cheese ages, acid and enzymes hydrolyze casein into water-soluble nitrogen compounds (9, 37). By measuring the amount of these compounds one can monitor the extent of proteolysis. Proteolysis plays an important role in the conversion of calcium paracaseinate curd to mature cheddar cheese. Perhaps the primary result of proteolysis is the conversion of the rubbery texture of green curd into smooth-bodied finished cheese (61). Protein decomposition also influences flavor by the release of free amino acids which are partly responsible for typical cheddar cheese flavor (48). It has been reported the proteolytic activity of concentrated starters may be less than traditional bulk cultures (40); however, Superstart cheese contained consistently greater amounts of water-soluble nitrogen at each monthly sampling, indicating more rapid protein breakdown. The difference between treatments was highly significant ($P<.01$).

Cheese Whey Composition

Average composition of cheddar cheese whey resulting from this study is listed in Table 11, followed by a statistical summary in Table 12. Wheys resulting from the manufacture of cheddar cheese using Superstart and Bulk Set cultures differed significantly ($P<.05$) in

TABLE 10. Average monthly water-soluble nitrogen levels of cheddar cheeses[a,b]

Month	Starter used		Overall	
	Superstart	Bulk Set	Mean	SE[c]
	%			
0	.35	.34	.34	.01
1	.52	.47	.49	.03
2	.60	.58	.59	.03
3	.70	.66	.68	.03
4	.77	.72	.75	.03
5	.82	.76	.79	.04
6	.90	.85	.88	.04
7	.95	.91	.93	.04
8	1.03	.96	.99	.04
9	1.10	1.04	1.07	.04

[a]Values are means of eight replications.

[b]Values are adjusted to basis of 63% solids in the cheese.

[c]Standard error.

total protein, ash, phosphorus, and sodium. Higher protein levels in bulk starter whey may be explained by the fact that casein contained in the starter, although held fast in the coagulum initially, separates to a large extent during the cheesemaking in the form of fine particles. The small particles are sometimes noticeable in the whey (26). Bulk Set whey contained 24% more calcium, 7.5% more phosphorus, and 7.4% more sodium. This seems to indicate that the lower acid levels during Superstart manufacture may in fact render the calcium salts and associated compounds more insoluble and retain them in the curd, as reported by Thompson (57).

Cheddar Cheese Yields

Average yields of cheddar cheese produced in this study are summarized in Tables 13 and 14 followed by a statistical summary in Table 15. Yields are expressed by two methods for Bulk Set starter cheese. One method expresses yield as percent recovery of cheese from total milk weight. The second method expresses yield as percent cheese recovered from total fluid weight in the cheese vat which includes milk plus starter media. Superstart yields averaged 9.40% compared to Bulk Set yields of 9.43% and 9.49%. It has been reported that starter media added to a vat of cheese milk is not retained in the cheese curd and does not contribute to cheese yields (26). The findings of this study and others (59) are not in agreement with this theory. Contrary to the theoretical basis for this study, lower acid levels when using Superstart cultures may be detrimental to yields by insufficient rennet activation necessary for the formation of an efficient clot. Least

TABLE 11. Average composition of whey resulting from cheddar cheese manufacture[a].

Component	Starter used		Overall	
	Superstart	Bulk Set	Mean	SE[b]
	%			
Total solids	6.69	6.75	6.72	.03
Fat	.28	.26	.27	.02
Solids not fat	6.41	6.49	6.45	.03
Total protein	.81	.82	.82	.005
Lactose	5.11	5.16	5.13	.04
Ash	.49	.51	.50	.006
	mg/100 ml			
Phosphorus	53.3	57.6	55.4	1.2
Calcium	70.2	92.4	81.3	8.5
Magnesium	10.3	10.2	10.2	0.4
Sodium	50.2	54.2	52.2	.01
Potassium	101.0	102.8	101.9	3.2

[a]Values are means of eight replications.

[b]Standard error.

TABLE 12. Statistical analysis of components of wheys resulting from manufacture of cheddar cheese.

Factor	Component										
	Total solids	Fat	SNF	Total protein	Lactose	Ash	P	Ca	Mg	Na	K
Treatment	N.S.	N.S.	N.S.	*	N.S.	*	*	N.S.	N.S.	*	N.S.
Week (replication)	*	**	*	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* Significant ($P<.05$).

** Highly significant ($P<.01$).

N.S. = Not significant.

TABLE 13. Yields of cheddar cheese expressed as percent recovery from total milk weight[a].

Replication	Starter used	
	Superstart	Bulk Set
	%	
1	9.25	9.28
2	9.41	9.70
3	9.36	9.49
4	9.55	9.71
5	9.44	9.43
6	9.49	9.21
7	9.16	9.60
8	9.54	9.53
Mean $\overline{X}$	9.40	9.49
SE[b]	.05	.06

[a]Values are adjusted to a basis of 63% solids in the cheese.

[b]Standard error.

TABLE 14. Yields of cheddar cheese expressed as percent recovery from total milk plus starter weight[a].

Replication	Superstart	Bulk Set
	%	
1	9.25	9.21
2	9.41	9.63
3	9.36	9.43
4	9.55	9.64
5	9.44	9.36
6	9.49	9.15
7	9.16	9.53
8	9.54	9.45
Mean $\overline{X}$	9.40	9.43
SE[b]	.05	.06

[a]Values are adjusted to a basis of 63% solids in the cheese.

[b]Standard error.

TABLE 15. Statistical analysis of effects of starter culture on cheddar cheese yields.

Factor	Yield	
	% recovered from total milk wt	% recovered from total milk plus starter wt
Superstart or bulk set culture	N.S.	N.S.

* Significant (P<.05).

**Highly significant (P<.01).

N.S. = Not significant.

squares analysis of variance was used to analyze the data. It was determined there were no significant differences in yields of cheddar cheese when using Superstart concentrated starters and conventional bulk starter.

The efficiency of conversion of milk to cheese curd can be evaluated using accepted formulas used to predict yields. Surveys of cheese yield and the casein and fat contents of milk were used to develop the following formula for predicting yield of cheddar cheese (49).

$$\text{lb cheese/100 lb milk} = \frac{(0.93F + C - 0.1)\ 1.09}{1.00 - W}$$

In which:

F = % milk fat = 3.35%.

C = % milk casein = 2.27%

W = lb water in 1 lb cheese = .37 lb.

Substituting the values determined in this study, predicted yields should approximate 9.18%. Overall yields for all cheeses was 9.43% which indicates excellent solids retention and curd strength during cheesemaking.

Organoleptic Evaluation

A panel of three to four experienced judges evaluated the cheeses over a 9 mo period. Flavor and body and texture of the cheese was evaluated at 1 mo of age and continued through the 9 mo. A ten point hedonic scale was used for flavor and a five point scale for body and texture. Tables 16 and 17 summarize the results of organoleptic evaluation. The panel determined there was no detectable difference in cheese made from Superstart or Bulk Set cultures. Average flavor and

body and texture scores for both treatments was 8.9 and 4.2, respectively. The age of the cheese judged had a highly significant effect ($P<.01$) on flavor scores. The cheese appeared to exhibit the most desirable flavor at 4 mo of age. Age of cheese had no effect on scores of body and texture. A summary of statistical analysis for flavor and body and texture is shown in Table 18.

TABLE 16. Flavor score of manufactured cheddar cheeses[a,b].

	Month									
	1	2	3	4	5	6	7	8	9	Mean $\bar{X}$
Superstart	9.2	9.0	9.4	9.2	8.9	8.6	8.5	8.6	9.1	8.9
Bulk Set	9.2	9.0	9.0	9.2	8.8	8.7	8.7	8.7	9.0	8.9

[a]Based on a hedonic scale with 10 as perfect score.

[b]Monthly values are means of eight replications.

TABLE 17. Body and texture score of manufactured cheddar cheeses[a,b].

	Month									
	1	2	3	4	5	6	7	8	9	Mean $\bar{X}$
Superstart	4.2	4.1	4.3	4.1	4.2	4.3	4.3	4.3	4.3	4.2
Bulk Set	4.1	4.2	4.1	4.3	4.4	4.3	4.2	4.2	4.3	4.2

[a]Based on a hedonic scale with 5 as perfect score.

[b]Monthly values are means of eight replications.

TABLE 18. Statistical analysis of treatment effects on cheddar cheese flavor and body and texture.

Factor	Flavor[a]	Body and Texture[b]
Starter culture	N.S.	N.S.
Age of cheese	**	N.S. (P = .06)
Starter X age interaction	N.S.	N.S.

[a]Based on a hedonic scale with 10 as a perfect score.

[b]Based on a hedonic scale with 5 as a perfect score.

* Significant (P<.05).

**Highly significant (P<.01).

N.S. = Not significant.

SUMMARY

The objectives of this research were to compare cheddar cheese yields when using conventional bulk starter and Superstart concentrated starters. Another objective was to evaluate composition and organoleptic characteristics of cheese made from both culture types.

Fresh whole milk was used to manufacture cheddar cheese two consecutive days of each week for a total of sixteen vats with eight replications with each culture. All cheeses were cured at 5 C for 9 months. Sampling, analyses, and organoleptic evaluations were done on fresh cheese and at monthly intervals.

Weights were accurately taken to ascertain crude yield information. Composition analyses performed on the milks, cheese, and wheys included: total solids, fat, total nitrogen, ash, phosphorus, calcium, magnesium, potassium, and sodium. Nitrogen fractions in the milks were determined by measuring levels of non-casein and non-protein nitrogen. Solids-not-fat, casein protein, and lactose were derived by difference. Cheese was also analyzed for pH, soluble nitrogen, and lactic acid. Flavor and body and texture of the cheese were evaluated by a panel of judges on a monthly basis for 9 mo. Yields of cheddar cheese were expressed as percent cheese (adjusted to 63% solids in the cheese) recovered from total milk weight.

Using least squares analysis of variance to test the data, no significant differences ($P<.05$) existed between cheddar cheese yields when conventional bulk starter or Superstart concentrated cultures were used. Result of organoleptic evaluation indicated there were no detectable differences in flavor and body and texture of cheeses

made with either of the two starter culture types. Compositional characteristics of cheeses made using the respective starter cultures were almost identical; but significant differences were seen in the chemical changes occurring during curing.

Although yield and cheese composition and quality were not improved when using Superstart concentrated cultures, this culture type does offer other advantages (44, 57):

1) Convenience - No starter preparation is necessary prior to the manufacture of cheese.
2) Culture reliability - Cultures are pretested for activity.
3) Improved daily performance - Cultures result in more uniform acid development from day to day.
4) Improved strain balance - The strain balance in the culture remains constant. Strain balance can change when the culture is transferred in milk.
5) Greater flexibility - The cheesemaker is able to use several different strains of cultures on the same day for producing different styles and types of cheese.

Once a skilled art, cheesemaking now depends more and more on scientific technology. Any company manufacturing cultured products must exercise not only sound management practices as they relate to marketing, sales, and product development; but also utilize and maximize all the best known technologies in manufacturing practices and equipment designs. Much of the United States' output of cheese depends on mechanized methods developed through cooperation between industry

and research universities. It is important therefore, to review, periodically, technology and procedures as they relate to equipment changes and innovative processing techniques.

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