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The Effects of Rancid Milk on Cheddar Cheese

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THE EFFECTS OF RANCID MILK ON CHEDDAR CHEESE

BY

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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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INTRODUCTION

One of the most serious defects of fluid milk is hydrolytic rancidity. Although not a new problem, recent practices in the dairy industry have increased its incidence. On the farm, the use of pipeline milking and transferring systems, in conjunction with bulk cooling and storage, involves excessive agitation and foaming of the raw milk. Both agitation and foaming enhance the development of rancidity. Additional agitation occurs when milk is pumped into storage silos, and pumped about the plant for processing. Dairy processing facilities are becoming more centralized. Hence, raw milk must be transported longer distances to the dairy plants. Also, milk is often collected from the farm on alternate days. This results in longer time intervals between milking and processing, hence there is more time for rancidity to develop. Consequently, milk is frequently near to having rancid flavor by the time it reaches the dairy plant (77).

The rapidly growing cheese industry in the United States now utilizes a quarter of the nation's milk supply (53). Over 1.8 billion kg of cheese were sold in 1980, which is a 53% increase from 10 years earlier (53). Per capita sales of American cheese (primarily cheddar) rose from 3.1 kg to 4.1 kg in the same 10 year period (53).

Since both cheddar cheese production and the incidence of rancid milk is increasing, it must be concluded that increasing amounts of cheddar cheese are being manufactured from rancid milk. This raises the questions of how great is the frequency and what are the types of defects in cheddar cheese due to rancid milk. Deleterious results may

include flavor and body defects, lowered yields, and undesired compositional changes.

The objectives of this study were to determine the effects of milk rancidity on the yields, composition, curing, and organoleptic quality of cheddar cheese manufactured from rancid milk. Since these factors are involved in the per unit cost of making the product, as well as affecting acceptability of cheese by consumers, an additional objective was to provide managers in the cheese industry with information concerning necessity of a higher quality milk supply. The managers can then make proper decisions to assure better quality, such as education of patrons, drivers, and plant workers, and the use of penalties or premiums in payment based on the degree of rancidity in farm milk.

LITERATURE REVIEW

Lipase, lipolysis, and rancidity

Lipolysis is the hydrolysis of glycerides resulting in the release of free fatty acids (FFA) and glycerol. In fresh, normal milk, about .10 to .44% of the total weight of milk lipids are FFA, probably left over from the metabolic pool (45). The presence of more than .44% of the milk lipids as FFA in milk is termed hydrolytic rancidity.

Lipolysis is catalyzed by the enzyme lipase, a type of esterase. Jensen (36) defined lipases as enzymes acting on emulsified glyceride molecules separated by an interface. Chandan et al. (10) reported values of lipase activity in milk from 1.0 to 1.7 units per ml (a unit is equal to the microequivalent of FFA liberated per minute). However, lipase is inactive in freshly drawn milk unless some physical or thermal manipulation has been applied to it (67).

Tarassuk and Frankel (73) concluded all cows' milk contains at least two types of lipase; viz., membrane lipase and plasma lipase. Membrane lipase is irreversibly adsorbed onto the surface of the fat-globule membranes upon the cooling of freshly drawn milk. Plasma lipase, which is associated with the casein micelle, remains in the plasma upon initial cooling (73).

Five different lipase fractions were reported by Downey and Andrews (20). However, Richter and Randolph (65) theorized different fractions of lipase could be due to the interaction of a single low molecular weight milk lipase with various milk proteins, or by self-polymerization of the enzyme. A lipoprotein lipase has been isolated

by Korn (42). Jensen (36) suggested this lipoprotein lipase is the same as membrane lipase.

Membrane lipase is associated with spontaneous rancidity. Spontaneous rancidity may occur when membrane lipase is activated upon the initial cooling of susceptible freshly drawn milk (73).

About one cow in five produces milk susceptible to spontaneous rancidity (67). Cows may have a tendency to produce "spontaneous" milk when they are fed a ration of dry feed deficient of green forage (12), are in late lactation (13, 19, 23), mastitic (18, 26) or shortly before estrous (83).

Tarassuk and Henderson (74) found by mixing one part milk from susceptible cows with four or more parts "normal" milk within 1 h after milking, spontaneous rancidity did not occur. Since about one cow in five produces "spontaneous" milk, the problem will usually automatically be alleviated by mixing these cows' milk with that of their herdmates (67).

Of more concern to the dairy industry is induced, or nonspontaneous, rancidity. Induced rancidity is caused by plasma lipase, which is inactive in milk unless the fat globule membrane is disrupted by an activation treatment (73). These activation treatments include agitation, foaming, and thermal shocking (67).

Any agitation of warm raw milk appears to increase the rate of lipolysis (67). Cold milk is much less susceptible (30). Homogenization of warm raw milk, a violent form of agitation, will cause milk to become rancid very quickly (79). Homogenization promotes

lipolysis by recoating new fat globules with casein to which plasma lipase is bound and by greatly increasing the surface area of the fat globules. This increase in surface area explains why pasteurized, homogenized milk contaminated with raw milk becomes rancid so quickly (36).

Other forms of agitation, such as shaking raw milk (44) and excessive pumping (67) will accelerate lipolysis. In general, the more severe the agitation and the higher the temperature (up to 40°C) the greater the amount of induced lipolysis (18).

Foaming as a result of agitation greatly promotes lipolysis. Tarassuk and Frankel (72) concluded foaming promotes lipolysis by providing greatly increased surface area, concentrating the enzyme at the air-liquid interface, "activating" substrate by denaturing surface materials on the fat globules, and providing for more intimate contact between the enzyme and its substrate.

Temperature manipulation, or thermal shocking, will activate plasma lipase. Krukovsky and Herrington (43) first demonstrated this effect by heating previously cooled milk at 5°C to 30°C then recooling to 10°C. The temperature attained is more important than the length of time the milk stays at that temperature (43). Alternate freezing and thawing will also activate lipase (5, 67).

The most practical means of inactivating milk lipase is by heat treatment. Hetrick and Tracy (31) observed a semi-log relationship between the holding temperature and the time required to inactivate lipase, similar to alkaline phosphatase inactivation. They

concluded a treatment of 58.3°C for 30 min was sufficient to destroy lipase. At 85°C, inactivation time was the same for alkaline phosphatase and milk lipase, but at 63°C inactivation time for phosphatase was three times longer than for lipase (31).

Harper and Gould (28) heated milk in a tubular heater for 1.5 sec and held it for 17.6 sec. Heating milk to 60°C did not inactivate lipase, 85% of lipase activity was reported at 71°C, and slight residual activity occurred at 88°C. Inactivation of lipase was affected by factors such as homogenization, fat level, solids-not-fat levels, and minerals. They also raised the possibility of lipase reactivation subsequent to heat treatment (28).

Wallander and Swanson (82) reported complete inactivation of lipase did not occur at 85°C for 30 min. They concluded the minimal time-temperature relationship for complete inhibition of lipase was unknown (82). However, pasteurization is generally sufficient to nearly inactivate the lipase enzyme (4, 11, 35).

The quality of the raw milk is an important factor in whether or not the milk will be prone to lipolysis. Some bacteria, primarily psychrotrophs, produce heat stable lipase that will survive pasteurization (46, 69). Also, lipolytic bacteria have been isolated from pasteurized milk (47). The incidence of rancid milk in the United States milk supply is unknown (64). Bandler (5) reported there has been an increase of rancidity in the New York State milk supply since 1975. The principle causes are a) pipeline air leaks, b) pipeline risers, c) excessive foaming, and d) freeze-on in bulk tanks (5).

An outstanding example of the effects of air agitation and foaming is "pipeline milker rancidity" (71). Milk as it leaves the cow is at a temperature where activation by agitation occurs most readily (when the milk fat is liquid) (18). About 6 times as much rancid milk has been reported from pipeline milkers as from comparable non-pipeline systems (38).

Foaming and churning is the result of excessive air admittance from claws, teat cups, cracks in the milk hose, and loose line joints, especially in the presence of risers and with low milk flow. Excessive agitation is brought about by air leaks, obstructions, elbows, tees, valves, long pipelines, risers, and continuous operation of centrifugal pumps with low milk flow (12, 18).

Risers, vertical sections of pipeline where milk is raised under vacuum, are a special problem. In a study by Kelley and Dunkley (39), little rancidity was detected in milk passed through a horizontal line. An increase of rancidity in pipelines with a riser was detected and was approximately proportional to the lift. Rancidity was greater with a riser with elbows and in-line filters. Flooded pumps produced much less rancidity than "starved" pumps (39).

Weigh jars are a significant cause of rancidity. Pillay et al. (60) observed pipeline milking systems employing weigh jars induced more lipolysis than around-the-barn installations and parlors without weigh jars. The latter system produced the least lipolysis. Weigh jars in parlor milking systems apparently have a greater effect

on lipolysis than the longer lines and greater number of elbows and other fittings generally encountered in around-the-barn installations (60).

Activation can occur by several ways in the bulk tank. Foaming can occur from milk splashing into the bulk tank or from over-agitation by the agitator, especially with small amounts of milk (18). A bulk tank with inadequate or poorly functioning refrigeration equipment may allow cold milk from previous milkings to be heated to a critical temperature (30°C) by the warm new milk. When recooled, this may cause thermal activation, as will freeze-on (18, 39).

The trend towards every-other-day (EOD) pickup of milk and EOD processing at the plant, as well as increasing distances milk is transported to centralized dairy plants, has greatly increased the storage time. Storage of raw milk has been shown to result in increased levels of FFA (18, 32, 37, 71) and allows for increases in psychrotrophic bacteria which are likely to promote lipolysis (18, 32, 46).

Hydrolytic rancidity has several effects on dairy products. They include a) varied fat tests, b) decreased surface tension, c) inhibited rennet action, d) inhibited bacterial growth, and e) rancid flavor.

Lipolysis has been shown to decrease the fat test by the Babcock method on milk samples (50). Increased lipolysis was noted in samples preserved with mercuric chloride (50). In a study by Grappin and Jeunet (25), with 3.5% fat milk, one milliequivalent FFA

increased the fat test by 0.004% for the Gerber method and an infrared instrument with fat measurement at 3.4 micron. The same increase in FFA decreased the fat test by 0.004% for the Roese-Gottlieb method, by 0.031% by the Milko-tester, and by 0.021% by an infrared instrument with fat measurement at 5.7 micron (25).

Lipolysis causes a decrease in the surface tension of milk (9, 21). This is attributable to the fact that FFA, especially their salts, and mono- and di-glycerides are good surface-active agents which decrease surface tension (67). Mono- and di-glycerides as well as slightly rancid milk or cream have been shown to effectively inhibit foaming of skim milk and whey (8).

Fat hydrolysis may completely inhibit rennet action. Tarassuk and Richardson (75) demonstrated long chain FFA in cheesemilk inhibited rennet activity. However, raising the temperature of the milk to the melting point of the FFA involved (42°C to 44°C) and cooling will restore normal coagulation. Adding calcium chloride is also effective (75).

Rancidity inhibits the growth of bacteria, particularly Streptococcus lactis, commonly used in cheddar cheese starter culture, as reported by Tarassuk and Smith (76). The researchers concluded the starter inhibition was due to decreased surface tension. Inhibition could be overcome by increasing the starter concentration (76). Costilow and Speck (14, 15) also observed inhibition of S. lactis and other bacteria by milk rancidity but ruled out decreased surface tension as the cause. The concluded inhibition was due to the toxic effects of

certain individual FFA (14, 15).

Contrary to the inhibitory effects of FFA generally found in cheesemaking, Deeth and Fitz-Gerald made cheddar cheese from very rancid milk with an acid degree value (ADV) of up to 4.4 with no apparent effects on the cheesemaking process (17). Acid degree value is defined as the milliliters of 1 N potassium hydroxide necessary to neutralize the FFA in 100 g of fat (3), with an ADV of 1.0 being borderline rancid (49).

The most serious effect of lipolysis is rancid flavor, also called lipolyzed flavor (18). Bandler (4) described rancid flavor as characterized by a sharp, unclean, astringent taste that lingers as an unpleasant after taste. ADV can be roughly correlated with rancid flavor in milk (41). Correlation of ADV with flavor is shown in Table 1.

TABLE 1. Comparison of milk acid degree value (ADV) with flavor (49).

ADV range	Description of milk
0.4-0.8	Normal, pleasing taste
0.9-1.1	Borderline milk, rancid bitter taste can be detected
1.2-1.5	Unsaleable for Grade A milk, soapy taste
1.6-16.0	Unusable for fluid milk purposes

Scanlan et al. (66) found even-numbered carbon FFA from four to twelve carbons long [called the volatile fatty acids (VFA)] were

responsible for rancid flavor in milk. No single VFA exerted a dominant influence on flavor, rather a blend of the VFA gave characteristic rancid flavor. Long chain FFA contributed little if any flavor (66).

Proper flavor in cheddar cheese depends on lipolysis, mostly from the action of the lipase of the cheese bacterial flora (55). Milk lipase surviving pasteurization is unimportant in cheesemaking, as it is inactive at the pH of cheesemaking and in the final product (59, 69). High plate counts of raw milk (20 million per ml) result in two to three times more FFA in the final cheese due to heat stable bacterial lipase not destroyed during pasteurization (46).

Cheddar cheese flavor is a blend of numerous compounds arising from the action of bacteria on milk constituents, such as lipolysis, proteolysis, fermentation, and β-oxidation (48). Aroma is due to a blend of volatile components, especially VFA's including acetic acid (57). Flavor is due to volatiles and water-soluble compounds such as salts, amino acids, and peptides (52). Silverman and Kosikowski (68) emphasized the apparent interdependence of amino acids and FFA for the formation of typical cheddar flavor.

Bills and Day (7) determined the FFA composition of cheddar cheese. Acetic acid was the major FFA, the product of bacterial metabolism. The rest of the FFA were due to lipolysis. Rancid cheeses were found to have approximately the same amount of acetic acid, but 10 times the concentration of other FFA (7). Too much lipolysis results in a rancid cheese, too little gives a bland cheese (55). Long chain FFA may exist as salts at the pH of cheese and may contribute a

soapy flavor to rancid cheese (7). In general, cheddar cheese flavor is due to a mixture of components; proper flavor is due to the proper "component balance" (48).

Conflicting theories exist as to the effect of rancidity of cheesemilk on the flavors of the final product. Peterson et al. (59) observed that of the FFA contributed by the milk, starter, and rennet, only acetic and butyric acids were carried over into the cheese in significant amounts, yet nearly all of the acetic and butyric acids could be recovered from the whey at the time of draining. However, studies comparing the ADV of milk with the ADV of raw milk cheddar cheese (33) and pasteurized milk cheddar cheese (17) showed an increase of cheese fat ADV with increasing milkfat ADV. Rancid milk resulted in rancid and unclean flavors in raw milk cheddar cheese (34) and bitter and unclean flavors in pasteurized milk cheddar cheese (17).

Cheddar cheese

Cheddar cheese is a concentrated dairy product made from whole milk. Cheddar is a hard, close-textured, bacterial ripened variety of cheese that requires several months of curing at low temperature to develop characteristic flavor. It is obtained from the warm pressed curd obtained from the action of rennet and lactic acid bacteria on whole milk. Freshly made cheddar cheese has a firm, elastic body with a mild flavor. Bacterial enzymes reduce firmness and increase flavor by hydrolyzing fat into FFA and protein into various water-soluble compounds (27).

Factors affecting yields of cheese

Milk, the starting material for cheese, has an important effect on the quality and yields of cheese. Milk composition is affected by numerous factors such as breed of cow, stage of lactation, feed, and season of year. Seasonal variations in fat and casein levels result in lower yields during the spring and summer and highest cheese yields between the months of October and December. Mastitis can severely decrease cheese yields (56). Antibiotics in the milk are inhibitory to the starter culture (40).

Cheesemilk is often pasteurized to destroy pathogenic and defect-producing organisms. Raw milk cheese cures faster and has a stronger flavor but is more likely to suffer from flavor and body defects, and has been linked to food-borne-disease outbreaks (63). The use of pasteurized milk for cheddar cheese has been shown to improve uniformity, flavor and texture, storage, and yields (61). Excessive heat treatments results in inferior cheese (63, 69). Some manufacturers have decided on the use of sub-pasteurization heat treatments to kill defect-producing bacteria while retaining some of the bacteria and enzymes in raw milk (63).

The influences of homogenization include lower fat losses in whey, higher cheese yields, lower shrinkage losses during ripening and storage, and reduced fat leakages of cheese stored at elevated temperatures (58).

A good quality starter culture is essential for the manufacture of a good quality cheddar cheese. The bacteria normally used

are Streptococcus lactis and/or Streptococcus cremoris. The most important function of starters is to rapidly produce lactic acid by fermenting lactose. Lactic acid is necessary to a) favor curdling of milk by rennet, b) influence shrinking of curd and assist in whey expulsion, c) mat the curd, d) activate pepsin in cheese, and e) inhibit growth of defect producers. These bacteria also are necessary for proper body and flavor (51).

Addition of calcium chloride to cheesemilk stimulates coagulation by rennet. Price (62) observed that the addition of 0.1% calcium chloride to cheesemilk reduced the amount of rennet needed, increased the rate of whey expulsion from the cheese curds, and increased yields by increasing fat retention.

Physical abuse of the cheesemilk can result in disruption of fat globules and subsequent loss of fat in the whey and lower yields (34, 56). Poor cutting or rough handling of the curd can result in loss of casein into the whey. Other factors that affect yields include a) amount of salt added, b) efficiency of separation of whey, c) length of ripening, and d) temperature and humidity during ripening (84).

MATERIALS AND METHODS

Cheddar cheese was made from pasteurized milk with three levels of hydrolytic rancidity. Each type was replicated five times for a total of 15 lots of cheese.

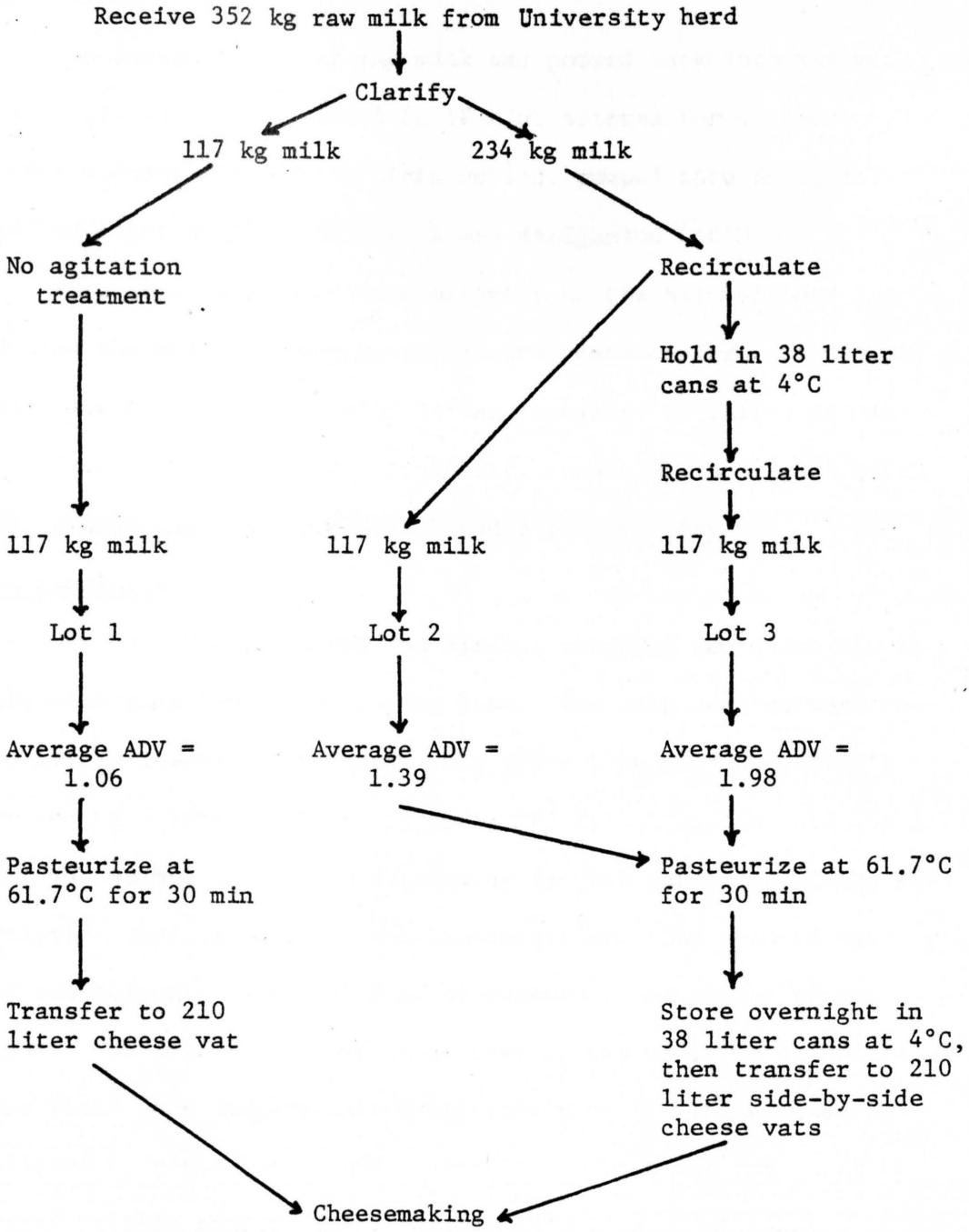
Milk preparation

Fresh whole raw milk was obtained from the South Dakota State University (SDSU) dairy herd each week. The milk (352 kg) was clarified in the SDSU Dairy Processing Laboratory (a semi-commercial dairy processing and research facility). One third of the milk (117 kg) was pasteurized forthwith at 61.7°C for 30 min, to preclude further rancidity development, then it was cooled to 32°C and made into cheddar cheese the same day. This milk was used as control and designated Lot 1.

The remaining 234 kg of milk were placed in a 380 liter stainless steel pasteurization vat. The milk was heated to 30°C and recirculated to develop rancidity. Recirculation was accomplished by pumping milk from the bottom of the vat using a centrifugal sanitary pump and returning the milk into the top of vat. This resulted in considerable foaming.

Recirculation was continued for 10 to 15 min, after which the milk was mechanically stirred by a paddle agitator for approximately 4 h. Half of this milk was pumped out of the vat into 38 liter cans and temporarily stored at 4°C. The 117 kg of milk still in the vat was pasteurized, cooled to 4°C by passing through a plate cooler, pumped into cans, and stored overnight at 4°C. This milk was

Figure 1. Flow chart for preparation of milk used in cheesemaking.


Receive 352 kg raw milk from University herd
Clarify
117 kg milk
234 kg milk
No agitation treatment
Recirculate
Hold in 38 liter cans at 4°C
Recirculate
117 kg milk
117 kg milk
117 kg milk
Lot 1
Lot 2
Lot 3
Average ADV = 1.06
Average ADV = 1.39
Average ADV = 1.98
Pasteurize at 61.7°C for 30 min
Pasteurize at 61.7°C for 30 min
Transfer to 210 liter cheese vat
Store overnight in 38 liter cans at 4°C, then transfer to 210 liter side-by-side cheese vats
Cheesemaking

designated Lot 2.

The remaining 117 kg raw milk was poured back into the vat. It was recirculated again for 5 to 10 min, stirred for an hour, pasteurized, cooled to 4°C by plate cooler, pumped into cans, and stored overnight at 4°C. This milk was designated Lot 3.

Some water was added inadvertently to the milk of Lots 2 and 3 when the milk was pumped through the plate cooler. To get all the milk out of the plate cooler it was necessary to follow it with water. Some mixing occurred unavoidably, resulting in diluted milk. Cheddar cheese was made from Lots 2 and 3 the next day.

Cheese manufacture

Cheddar cheese was made in similar properly sanitized 210 l side-by-side stainless steel cheese vats. The milk weights were recorded before the milk was poured into vats. The milk was at 32°C before adding starter culture. Superstart[1] frozen concentrate cheese culture was warmed in the can by placing in cool water containing 200 ppm chloride sanitizer to prevent contamination. The culture was thawed sufficiently to allow 20 ml of culture to be pippetted for each vat. The culture was one or another of two mixtures of several strains which were commercially designated M or L. The cheesemilk was allowed to ripen for 45 min. Acid development was monitored by pH and titratable acidity (TA). During this time, 8 ml annatto coloring[1] (30 ml per 450 kg milk) diluted five fold with cold water, and

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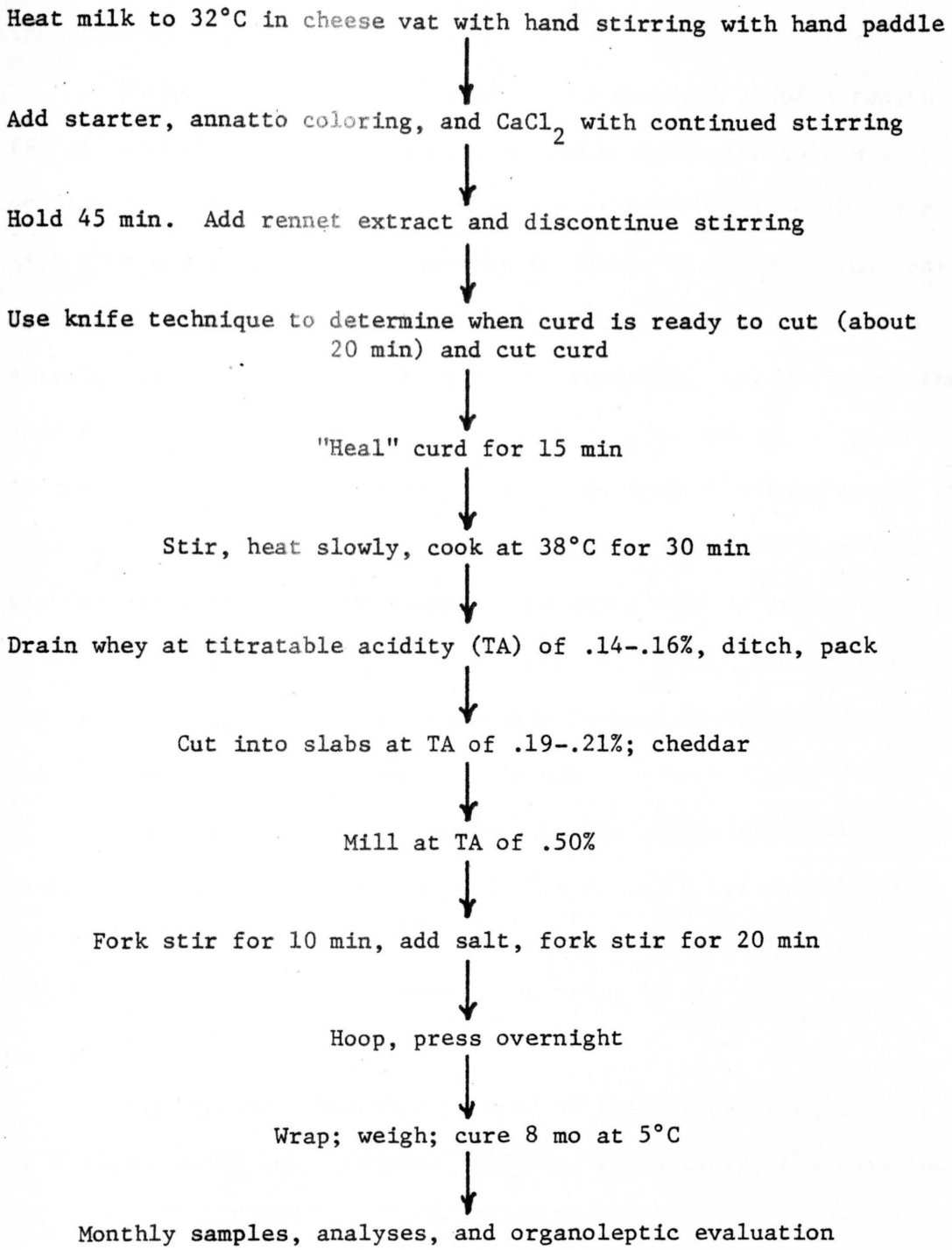
[1]Marshall Dairy Ingredients Division, Miles Laboratories, Inc. P.O. Box 592, Madison, WI 53701.

Figure 2. Flow chart for cheesemaking.


Heat milk to 32°C in cheese vat with hand stirring with hand paddle
Add starter, annatto coloring, and $CaCl_2$ with continued stirring
Hold 45 min. Add rennet extract and discontinue stirring
Use knife technique to determine when curd is ready to cut (about 20 min) and cut curd
"Heal" curd for 15 min
Stir, heat slowly, cook at 38°C for 30 min
Drain whey at titratable acidity (TA) of .14-.16%, ditch, pack
Cut into slabs at TA of .19-.21%; cheddar
Mill at TA of .50%
Fork stir for 10 min, add salt, fork stir for 20 min
Hoop, press overnight
Wrap; weigh; cure 8 mo at 5°C
Monthly samples, analyses, and organoleptic evaluation

2.7 g calcium chloride (11 g per 450 kg) dissolved in hot water were incorporated into the milk.

Twenty-seven milliliters of rennet extract[1] [100% strength (90 ml per 450 kg milk)] were diluted twenty-fold with cold water and incorporated by hand mixing into the milk after ripening. The milk then was allowed to sit quietly for about 20 min to permit coagulation. Proper coagulation was tested using a knife technique. A knife was used to make a slice in the coagulum. The knife was then inserted perpendicularly at one end of the slice and lifted gradually. If the coagulum fell away from the slice uniformly on both sides, the curd was ready to cut. The curd was cut using two stainless steel wire knives (vertical, horizontal) with wires 0.64 cm apart. The two knives were passed, each in turn, lengthwise through the curd; then the vertical knife was passed crosswise to form uniform cubes of curd. The curd was allowed to "heal" for 15 min.

The curd and whey were carefully hand agitated, while the temperature was slowly increased at the rate of .55°C for each 4 min interval for 20 min. The rate of heating was then increased so the desired cooking temperature (38°C) was reached 30 min after heating commenced.

The curd and whey were stirred at this temperature until a TA of 0.14% to 0.16% was attained. The whey was drained, the curd packed

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

and ditched, then allowed to mat until the TA reached .19% to 0.21%. The curd was cut into eight slabs which were turned over every 10 min. After two turns, the slabs were stacked two high, turned twice and stacked three high, turned and stacked four high. Cheddaring continued until a minimal TA of 0.50% was attained. The curd was hand milled into strips approximately 2 cm by 2 cm by 6 cm. The curd was forked for 10 min, then 300 g of salt (2.5% of expected yield) was sprinkled onto the curd in two portions, and the curd forked for an additional 20 min.

The curd from each vat was packed into a single sanitized Wilson rectangular hoop and pressed overnight. The blocks were wrapped in a Cry-O-Vac film and a wax paper covering and heat sealed. The blocks were weighed and stored for 8 mo at 5°C.

Sampling

Milk samples were obtained before pasteurization by dipping a sanitized beaker into the pasteurization vat while the agitator was turning. Pasteurized milk samples were obtained the same way from the cheese vat before starter was added while the milk was being stirred by hand. Whey was sampled from the drain spout early in the whey draining process. The covering of the cheese block was marked into 10 sections which were randomly assigned for initial and monthly sampling. Nine plugs were taken with a cheese trier each month and the plug holes filled with warm cheese wax. All samples were stored in 530 ml Whirlpak plastic bags under refrigeration at 4°C. In cases where analyses were delayed, samples were frozen and held at -10°C.

Compositional analyses

Total protein in milk, whey, and cheese was determined by the Kjeldahl procedure of the Association of Official Analytical Chemists (AOAC) (2). Water soluble nitrogen of cheese as a measure of protein degradation during ripening was determined by a modification of the method of Vakaleris and Price (81). Upon precipitation and filteration, duplicate 25 ml aliquots were taken and water soluble nitrogen was determined by the Kjeldahl method (2).

Total solids and fat of milk, whey, and cheese were determined by the Mojonnier method (54). Solids-not-fat were calculated as the difference between total solids and fat for all samples. Ash contents of all samples were determined by the AOAC method (2) using Vycor[2] crucibles.

Lactic acid content of cheese was determined by the procedure of Harper and Randolph (29). The Marquardt test as described by Atherton and Newlander (3) was used to ascertain salt in cheese.

Cheese pH was measured using the procedure described in Standard Methods for the Examination of Dairy Products (1). The cheese was chopped finely, the electrodes of the pH meter were immersed in the cheese, and the pH read directly.

Rancidity of milk was expressed as acid degree value (ADV) using a modification published by Atherton and Newlander (3) of the test of Thomas et al. (78). ADV of cheese was determined by the method of Dulley and Grieve (22). Five grams of cheese and 37.5 ml of 2%

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[2] Corning Glass Works. 80 Houthon Park, Corning, NY 14830.

sodium citrate at 50°C to 60°C were blended in an Osterizer blender at high speed for 3 min. The resulting slurry was transferred to a Babcock cream test bottle and the procedure for milk was followed.

Bacteriological quality of each milk was determined before and after pasteurization. Duplicate platings of various dilutions were made for Standard Plate Count, coliforms, and psychrotrophs as directed by Standard Methods for Examination of Dairy Products (1).

Organoleptic evaluation

A judging panel 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[1] score card. Organoleptic evaluations were performed on cheese from one month to eight months old. All samples were displayed randomly to prevent knowledge of sample identity during evaluation.

Expression of yield

Yield data were computed three ways: a) kg of 63% total solids cheese per 100 kg milk, b) kg of 63% total solids cheese per kg milk solids, and c) percent recovery of milk solids. The first method is commonly used but does not take into consideration differences in the total solids content of milk as the other two methods.

Statistical analysis

Statistical analysis of the data utilized least squares analysis of variance for a randomized complete block experiment with a three

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[1]ADSA-DFISA = American Dairy Science Association-Dairy and Food Industries Supply Association.

factor (replication, treatment, and month) experimental design (70). The main effects of treatment and time were tested by their 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

Cheesemilk composition

Research has shown that cheese yields are closely associated with milk composition (16). The average compositions of the milks used for cheddar cheese manufacture in this study are listed in Table 2. The average composition of Lot 1 milk, the control, was 11.60% total solids, 3.12% fat, 8.48% solids-not-fat (SNF), 2.95% total protein, and .63% ash. Milk used was from July and early August, when milk solids characteristically are at a seasonal low in this climate (87). A survey of the South Dakota milk supply by Yee (87) showed July milk with a composition of 11.67% totals solids, 3.48% fat, 8.19% SNF, 2.99% total proteins, and .68% ash. Therefore, milk used for this study had lower total solids, fat, protein, and ash, but higher SNF than reported (87). Since Federal and South Dakota standards require 3.25% fat and 8.25% SNF in milk, Lot 1 milk did not meet minimum fat requirements (80).

As mentioned earlier, some water was inadvertently added to Lot 2 and Lot 3 milks, resulting in lower levels of milk constituents. A summary of statistical analysis of milk compositions (Table 3) shows a significant difference ($P<.05$) among the total solids of the three lots of milk, although differences among other milk components were not significant.

The acid degree values (ADV) of milks used are listed in Table 4. Average ADV for the milk were 1.06, 1.39, and 1.98 for Lots 1, 2, and 3, respectively. Even the control, Lot 1, demonstrated a rather

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

Composition	Lot 1 (ADV = 1.06)[b]	Lot 2 (ADV = 1.39)[b]	Lot 3 (ADV = 1.98)[b]	Overall Mean	Overall SE[c]
	(%)				
Total solids	11.60	10.09	10.67	10.78	.27
Fat	3.12	2.52	2.69	2.78	.18
Solids-not-fat	8.48	7.56	7.97	8.00	.28
Total protein	2.94	2.80	2.85	2.97	.04
Ash	.63	.57	.59	.60	.03

[a]Values are means of five replications.

[b]ADV (acid degree value) is milliliters of 1 N KOH needed to neutralize the free fatty acids in 100 g fat.

[c]Standard error.

TABLE 3. Summary of analysis of variance of percentages of components in milk used for cheddar cheese manufacture.

Factor	Components					
	Total solids	Fat	Solids-not-fat	Total protein	Ash	ADV[a]
Cheesemilk rancidity	*	NS	NS	NS	NS	**

[a]ADV (acid degree value) is milliliters of 1 N KOH needed to neutralize the free fatty acids in 100 g fat.

*Significant ($P<.05$).

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

NS = Not significant.

TABLE 4. Acid Degree Value (ADV) of pasteurized milk used for cheddar cheese manufacture.[a]

Replication	Lot 1	Lot 2	Lot 3	Mean	SE[b]
1	.98	1.46	2.34		
2	1.12	1.41	2.26		
3	1.11	1.49	1.92		
4	1.04	1.24	1.64		
5	1.04	1.37	1.76		
Mean	1.06	1.39	1.98	1.48	.08

[a]ADV is the milliliters of 1 N KOH needed to neutralize the free fatty acids in 100 g fat.

[b]Standard error.

high ADV, considered to be borderline rancid (49). This is typical of milk from a high line pipeline milking system (where the milk pipeline is above the udder of the cow) such as the system used in the milking parlor at the SDSU Dairy Research Unit (24). Agitation by recirculation and the resultant foaming resulted in the higher ADV for milks of Lot 2 and 3. Differences in rancidity among lots of milk are shown to be highly significant ($P<.01$) in Table 3.

Bacteriological quality of raw and pasteurized milks used in cheesemaking is shown in Table 5. Psychrotrophs in the raw milk were at acceptable levels, the highest count being 3130 colonies/ml. There are no South Dakota standards for Standard Plate Count (SPC) or coliforms in pasteurized manufacturing grade milk. However, five of the pasteurized milks failed to meet Grade A requirements for SPC (maximum 20,000 colonies/ml) and nine failed to meet coliform standards (less than 10 colonies/ml). This may have been due to recontamination during handling of milk after pasteurization, for the milk from the Dairy Research Unit is Grade A milk.

Three of the milks used (Replication 1, Lots 2 and 3; and Replication 5, Lot 2) had greatly elevated SPC and coliform counts. Difficulties in operating the plate cooler resulted in milk not being cooled sufficiently after heat treatment. The milks were too warm when they were stored in the cooler overnight. As a result, coliforms from a spot in the plate cooler, which did not clean by cleaning-in-place recirculation cleaning, and surviving bacteria were able to grow overnight. This produced defects in the cheeses made from this milk,

TABLE 5. Bacteriological quality of milks used for cheddar cheese manufacture.

Replication	Lot 1	Lot 2	Lot 3
	Standard Plate Count		
	------- colonies per ml pasteurized milk --------		
1	3.00×10^3	2.06×10^6	1.47×10^6
2	1.30×10^3	1.85×10^3	1.50×10^3
3	2.95×10^4	1.25×10^3	2.25×10^3
4	1.80×10^3	3.24×10^5	7.40×10^3
5	1.00×10^3	$>3.00 \times 10^6$	8.00×10^3
	Coliforms		
	------- colonies per ml pasteurized milk --------		
1	$<1.00 \times 10^1$	$>3.00 \times 10^4$	$>3.00 \times 10^4$
2	$<1.00 \times 10^1$	$<1.00 \times 10^1$	$<1.00 \times 10^1$
3	4.50×10^1	$<1.00 \times 10^1$	6.00×10^1
4	2.00×10^1	9.00×10^1	1.00×10^2
5	$<1.00 \times 10^1$	$>3.00 \times 10^4$	1.50×10^3
	Psychrotrophs		
---- colonies per ml raw milks prior to rancidity development --------			
1	9.95×10^2		
2	2.48×10^3		
3	2.50×10^1		
4	3.13×10^3		
5	1.05×10^2		

which are discussed later.

Cheddar cheese composition

Tables 6 and 7 show the average composition of cheddar cheeses produced in this study, while Table 8 contains a listing of monthly protein values, followed by a summary of statistical analysis of cheese composition (Table 9). Since moisture levels of finished cheese will vary from vat to vat, more meaningful comparisons of yields and composition of cheddar cheese is accomplished by adjusting all constituents except total solids to a basis of 63% solids cheese. For comparing yields, amount of cheese must be adjusted to equivalent amount of 63% solids cheese.

The average total solids of all cheese was 61.81% (Table 6), which was legal by Federal and South Dakota requirements for cheddar cheese (80). There were no significant differences between total solids of cheeses from milk of varying degrees of rancidity. However, fat content of cheese declined considerably with increasing rancidity of cheesemilk ($P<.01$); but since total solids of all cheeses were about the same, values for SNF, protein, and ash increased ($P<.01$) as fat percentage decreased. Vigorous agitation of raw milk to induce rancidity also had a churning effect (34), rupturing the fat globule membranes which led to loss of fat in the whey (56). Visible free fat floated on the top of they whey during cheesemaking and was removed with the last of the whey. Presumably as a result, fat content for Lot 3 cheese was 29.58% and SNF was 33.52%. Since Federal and South Dakota laws require 50% of the total solids of cheddar cheese to be

TABLE 6. Average composition of fresh (0 mo) cheddar cheeses.[a,b]

Component	Lot 1	Lot 2	Lot 3	Overall Mean	Overall SE[c]
	(%)				
Total solids	61.87	61.30	61.35	61.50	.42
Fat	34.31	32.67	29.81	32.26	.36
Solids-not-fat	28.69	30.33	33.39	30.80	.34
Total protein[d]	25.03	26.05	27.95	26.34	.44
Ash	3.64	3.92	4.18	3.91	.06
Salt	1.50	1.67	1.64	1.60	.06
Lactic acid	1.27	1.17	1.07	1.17	.11

[a]All values are means of five replications.

[b]All values except total solids are adjusted to a basis of 63% solids cheese.

[c]Standard error.

[d]Nitrogen value x 6.38.

TABLE 7. Average composition of aged (8 mo) cheddar cheeses.[a,b]

Component	Lot 1	Lot 2	Lot 3	Overall Mean	Overall SE[c]
	(%)				
Total solids	62.57	62.37	61.42	62.12	.44
Fat	33.87	32.56	29.35	31.92	.21
Solids-not-fat	29.13	30.44	33.65	31.08	.21
Total protein[d]	25.74	27.04	28.61	27.13	.28
Ash	3.49	3.66	4.05	3.73	.09

[a]All values are means of five replications.

[b]All values except total solids are adjusted to a basis of 63% solids cheese.

[c]Standard error.

[d]Nitrogen value x 6.38.

TABLE 8. Average monthly protein values of cheddar cheeses.[a,b]

Age in month	Lot 1	Lot 2	Lot 3	Overall Mean	Overall SE[c]
	(%)				
0	25.03	26.05	27.95	26.34	.44
1	26.19	27.94	29.14	27.76	.29
2	25.91	27.66	29.16	27.58	.22
3	25.87	27.35	29.02	27.41	.20
4	25.76	27.30	29.34	27.46	.13
5	26.28	27.98	29.91	28.06	.20
6	26.17	27.59	29.64	27.80	.14
7	26.05	27.51	29.20	27.59	.20
8	25.74	27.04	28.61	27.13	.28

[a]Monthly values are means of five replications; Protein was computed as nitrogen x 6.38.

[b]All values adjusted to a basis of 63% solids cheese.

[c]Standard error.

TABLE 9. Summary of analysis of statistical effects of cheesemilk rancidity and age at analysis on the composition of cheddar cheeses.

Factor	Component				
	Total solids	Fat	Solids-not-fat	Total protein	Ash
Cheesemilk rancidity	NS	**	**	**	**
Age of cheese	*	NS	NS	**	NS
Rancidity x age interaction	NS	NS	NS	NS	NS

*Significant (P<.05).

**Highly significant (P<.01).

NS = Not significant.

milkfat, cheese from Lot 3 milks was, on the average, illegal (80).

Total solids of the cheeses increased significantly with age ($P<.05$) (Table 7) due to loss of moisture by evaporation during curing and to water becoming part of the end products of protein hydrolysis. There was a highly significant increase ($P<.01$) in total protein as measured by total nitrogen x 6.38 as the cheese aged (Tables 8 and 9). Improved analytical technique of the author with practice may have resulted in more complete recovery of nitrogen during testing. Increases in total solids are commonly noted during cheese ripening; Wingfield (85) also observed a slight increase in both total solids and of nitrogen calculated on the basis of 63% solids cheese. Hydrolytic cleavage of proteins occurs during ripening, with the release of proteosis and peptides which may in turn form esters with the FFA also released. The author has found no explanation, however, for an actual increase in the amount of nitrogen present.

Fat and ash content decreased slightly with age but not to a significant extent (Table 9). Kipp (40) and Wingfield (85) also reported slight decreases of fat and ash with age. Fat content decrease was attributed to lipolysis during curing (40, 85) with release of glycerol and some FFA which are not measurable by the Mojonnier method of fat determination used in this study (3). Also, short chain fatty acids are readily volatile and so likely were lost from the sample to the atmosphere. No reason was given for decrease in ash (40, 85). These workers noted the complex changes in cheese minerals and their release from or combining with other constituents. The author

speculates that as a result of these changes less carbonate stays in the ash as curing progresses.

Salt was added to cheese curds at the rate of 2.5% of expected yield (10 kg cheese per 100 kg milk). Average salt content for all cheddar cheese was 1.60%. Average lactic acid content for all cheese was 1.17%. There were no significant differences in salt or lactic acid content of cheese as rancidity of the cheesemilks varied.

As cheese ages, acid and enzymes hydrolyze casein into water-soluble nitrogen compounds (WSN) (6). By monitoring the amount of nitrogen in these compounds, the rate of cheese ripening can be gauged. Average monthly WSN levels in the cheese made for this study are summarized in Table 10, with a summary of statistical analysis in Table 11. No significant differences in WSN occurred amongst the various cheeses, irrespective of rancidity of parent milk (Table 11). WSN values, which compared closely with those found by Kipp (40) and Wingfield (85), increased with age as expected ($P<.01$) (40, 81, 85) as protein was hydrolyzed into water soluble compounds during curing. WSN levels were greatly elevated in the three cheeses (Replication 1, Lots 2 and 3; and Replication 5, Lot 2) with milk having high levels of coliforms.

Table 12 shows monthly pH values of the cheeses; results of statistical analysis are summarized in Table 11. The pH of cheddar cheese will increase with age, as alkaline products are released by proteolysis (86). Milk used in the cheese had a significant effect ($P<.05$) on pH. The higher pH's for cheese from milk Lots 2 and 3 were probably due to their higher protein content; milk proteins have a

TABLE 10. Average monthly water soluble nitrogen values for cheddar cheeses.[a,b]

Age in months	Lot 1	Lot 2	Lot 3	Overall Mean	Overall SE[c]
	(%)				
0	.36	.48	.43	.42	.03
1	.49	.60	.58	.56	.03
2	.60	.72	.71	.68	.04
3	.71	.88	.82	.80	.05
4	.82	1.01	.94	.93	.05
5	.86	1.08	1.02	.98	.06
6	.95	1.17	1.06	1.06	.06
7	.98	1.24	1.20	1.14	.07
8	1.15	1.31	1.21	1.23	.07

[a]Monthly values are means of five replications.

[b]All values adjusted to a basis of 63% solids cheese.

[c]Standard error.

TABLE 11. Summary of statistical analysis of effects of cheesemilk rancidity and age at time of analysis on water soluble nitroten, pH, and acid degree value (ADV) of cheddar cheeses.[a]

Factor	Component		
	Water soluble nitrogen	pH	ADV
Cheesemilk rancidity	NS	*	**
Age of cheese	**	**	*
Rancidity x age interaction	**	NS	NS

[a]ADV is milliliters of 1 N KOH needed to neutralize the free fatty acids in 100 g fat.

*Significant (P<.05).

**Highly significant (P<.01).

NS = Not significant.

TABLE 12. Average monthly pH values for cheddar cheeses.[a]

Age in months	Lot 1	Lot 2	Lot 3	Overall	
				Mean	SE[b]
0	5.18	5.22	5.25	5.21	.04
1	5.14	5.18	5.19	5.17	.03
2	5.24	5.32	5.35	5.30	.03
3	5.27	5.33	5.35	5.32	.04
4	5.24	5.33	5.36	5.31	.03
5	5.24	5.32	5.33	5.30	.03
6	5.27	5.37	5.40	5.35	.02
7	5.40	5.52	5.48	5.47	.04
8	5.39	5.51	5.48	5.46	.07

[a]Monthly values are means of five replications.

[b]Standard error.

buffering effect. pH increased with age as expected ($P<.01$).

ADV's were determined monthly on the cheddar cheese. Results (Table 13) upon statistical analysis (Table 11) indicated ADV cheddar cheese reflected the ADV of the cheesemilk. ADV increased with fat hydrolysis of milk ($P<.01$); that is, increasing rancidity of the cheesemilk resulted in higher ADV of the cheese. These results were in agreement with studies by Hylnka and Hood (33) and Deeth and Fitz-Gerald (17). Therefore, it appears that the FFA in milk is at least partially retained by the cheese. This is in disagreement with findings by Peterson et al. (59), who concluded FFA in milk were for most part lost in the whey.

As mentioned earlier, fat is lipolyzed during cheese ripening. This resulted in an increase in ADV of cheese with age ($P<0.5$), in agreement with earlier studies (17, 34).

Whey composition

Average composition of wheys resulting from cheddar cheese manufacture (Table 14) were also subjected to statistical analysis (Table 15). Levels of all whey constituents were similar among wheys from all milks as the wheys were sampled. Unfortunately, truly representative whey samples were not taken, that is, by collecting all the whey during the draining of a given batch, blending, and taking an aliquot. Rather, the wheys were sampled directly from the drain spout. Total solids of wheys followed the same trend as total solids of parent milks, but the differences were not significant.

It had been expected to find higher fat contents in wheys from

TABLE 13. Average monthly Acid Degree Value (ADV) of cheddar cheeses.[a,b]

Age in months	Lot 1	Lot 2	Lot 3	Overall Mean	Overall SE[c]
0	1.32	1.78	3.13	2.07	.35
1	1.36	1.90	2.65	1.97	.10
2	1.36	1.97	2.76	2.03	.12
3	1.34	1.96	2.70	2.00	.10
4	1.42	2.11	3.26	2.26	.31
5	1.45	2.09	2.80	2.11	.10
6	1.48	2.14	2.88	2.17	.11
7	1.50	2.20	2.96	2.22	.11
8	1.66	2.34	3.04	2.35	.13

[a]All values are means of five replications.

[b]ADV is the milliliters of 1 N KOH needed to neutralize the free fatty acids in 100 g fat.

[c]Standard error.

TABLE 14. Average composition of wheys resulting from the manufacture of cheddar cheeses.[a]

Component	Lot 1	Lot 2	Lot 3	Overall Mean	Overall SE[c]
	(%)				
Total solids	6.25	6.15	6.30	6.32	.15
Fat	.27	.26	.24	.25	.01
Solids-not-fat	6.25	5.89	6.07	6.07	.15
Total protein	.81	.81	.79	.80	.03
Ash	.55	.56	.53	.55	.02

[a]Values are means of five replications.

[b]Standard error.

TABLE 15. Summary of statistical analysis of percentages of components in wheys resulting from manufacture of cheddar cheeses.

Factor	Components				
	Total solids	Fat	Solids-not-fat	Total protein	Ash
Cheesemilk rancidity	NS	NS	NS	NS	NS

*Significant (P<.05).

**Highly significant (P<.01).

NS = Not significant.

Lots 2 and 3 milks, as fat churned during agitation was not incorporated into the cheese; rather, it was lost in the whey. However, the fat composition of the whey failed to reflect this. This is because of the method of sampling. As noted above, whey was sampled early in the draining procedure directly from the drain spout. Most of the fat remained floating on the top of the whey and was not drained until after the whey had been sampled.

Cheddar cheese yields

Yields of cheddar cheese were calculated three ways. Average yields of cheese and results of statistical analysis are listed in Table 16 and 17. Yields of cheddar cheese were 9.24, 8.29, and 7.87 kg of 63% solids cheese per 100 kg milk for Lots 1, 2, and 3, respectively; which demonstrated a highly significant difference ($P<.01$) between cheeses of different parent milk rancidity. However, this is misleading because of differences in the total solids of the cheesemilks. When yield was calculated as kilograms 63% solids curd per kilogram milk solids or as percent recovery of milk solids, there were no significant differences in yields of cheese from milks of different rancidities. This was true despite differences in the fat content of the cheese.

Organoleptic evaluation

A panel of three to four experienced judges evaluated the cheeses over an 8 mo period. Flavor and body and texture were evaluated montly starting at 1 mo. A ten point hedonic scale was used for flavor and a five point hedonic scale was used for body and texture. Tables 18, 19, and 20 summarize the results of organoleptic evaluation

TABLE 16. Average yields of cheddar cheese using three methods of calculating yield.[a]

Yield calculation method	Lot 1	Lot 2	Lot 3	Overall Mean	Overall SE[b]
Kg curd per 100 kg milk[c]	9.24	8.29	7.87	8.47	.16
Kg curd per kg milk solids[c]	.797	.827	.738	.788	.02
Recovery of milk solids (%)	48.29	49.37	47.41	47.41	1.39

[a]Values are means of five replications.

[b]Standard error.

[c]Values are adjusted to a basis of 63% solids curd.

TABLE 17. Summary of statistical analysis of effects of cheesemilk rancidity of cheddar cheese yields.

Factor	kg 63% solids curd per 100 kg milk	kg 63% solids curd per kg milk solids	Percent recovery of milk solids
Cheesemilk rancidity	**	NS	NS

*Significant (P<.05).

**Highly significant (P<.01).

NS = Not significant.

TABLE 18. Average monthly flavor scores of cheddar cheeses.[a,b]

	Age of cheese in months								
	1	2	3	4	5	6	7	8	Mean
Lot 1	8.5	8.9	8.8	9.1	9.0	8.5	8.1	8.5	8.7
Lot 2	7.3	7.7	7.6	6.8	7.6	7.4	8.1	7.5	7.5
Lot 3	7.5	7.7	8.1	8.2	7.7	7.8	7.8	7.9	7.8

[a]Monthly values are means of five replications.

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

TABLE 19. Average monthly body and texture scores of cheddar cheeses.[a,b]

	Age of cheese in months								
	1	2	3	4	5	6	7	8	Mean
Lot 1	3.9	4.5	4.3	4.7	4.2	4.6	4.7	4.7	4.5
Lot 2	3.3	3.7	3.8	4.2	3.9	3.6	3.9	3.7	3.8
Lot 2	3.0	3.5	3.8	4.0	4.0	3.6	3.7	3.7	3.7

[a]Monthly values are means of five replications.

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

TABLE 20. Summary of statistical analysis of effects of cheesemilk rancidity and age of cheese on cheddar cheese flavor and body and texture.

Factor	Flavor	Body and Texture
Cheesemilk rancidity	**	*
Age of cheese	NS	**
Rancidity x age interaction	*	NS

*Significant (P<.05).

**Highly significant (P<.01).

NS = Not significant.

and statistical analyses.

Average flavor scores for Lots 1, 2, and 3 were 8.6, 7.6, and 7.8 respectively. Differences in flavor between cheeses from milk with various degrees of rancidity were highly significant ($P<.01$). Flavor should improve with curing, but age differences were not significant. Some of the decreases in flavor scores were due to deleterious effects of coliform contamination in some cheese from Lots 2 and 3 milk resulting in excessive proteolysis as reflected in higher WSN levels. However, it was felt cheese fat acidity (as measured by ADV) was also a contributing factor to less desirable flavor. High ADV of cheese has been shown to lower the grade of cheddar cheese (17, 33); and bitter, rancid, and unclean flavors are attributable to milk rancidity (17, 34). Deeth and Fitz-Gerald (17) reported the threshold of flavor defects to be at about ADV in cheese of 3.0, which is around the levels of Lot 3 cheddar cheese.

Body scores demonstrated significant differences with type of parent milk ($P<.05$), with lower scores for cheeses made from rancid milk. However, this was probably due to lower fat content in those cheeses and to gassiness from coliforms. Body improved with age ($P<.01$) as the elastic nature of fresh cheese was reduced by hydrolysis of fat and protein to simpler compounds.

SUMMARY AND CONCLUSIONS

Cheddar cheese was made from milk with three levels of rancidity. Rancidity was induced by agitation and foaming from recirculation. Different levels of rancidity were produced by differing the recirculation time.

Observations and conclusions were as follows:

1. Water added to some of the more rancid cheesemilks resulted in lower total solids of those milks. Cheddar cheese yields, when calculated as kilograms of 63% solids cheese from 100 kg milk, decreased with increasing rancidity of the cheesemilk. However, when methods of calculating yields took into account the total solids content of the milk, no significant differences were observed.

2. Bacterial contamination of milk, especially coliforms, increased proteolysis of some cheese, as evidenced by greater water soluble nitrogen (WSN) values during curing. Coliform contamination also caused marked bitterness and gassiness which lowered flavor and body scores of affected cheese.

3. Vigorous agitation of raw milk to induce rancidity churned fat from the milk; and that fat was not retained by the cheese. Fat content of cheese decreased and solids-not-fat, protein, and ash content increased with increased time of recirculation and resultant increase in milk rancidity. No differences in whey composition including fat content were observed; this was because of improper sampling technique. Lower fat content in the cheeses may have resulted in lower body scores; while higher protein content increased pH of cheese

due to the buffering effect of protein.

4. Proteolysis during ripening was indicated by increased WSN and pH with age; and lipolysis was denoted by increased Acid Degree Value (ADV) with age. Flavor scores failed to show significant increase with age due to other factors; however, body scores did improve.

5. Increasing levels of milk rancidity, as measured by ADV, resulted in increasing ADV of cheddar cheese. Therefore, it appeared free fatty acids in milk are at least partially retained by the cheese. This was believed to be a contributory factor in lower flavor scores for rancid-milk cheddar cheese.

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