1984

The Manufacture of Cheddar Cheese Using Vacuum Concentrated Milks

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THE MANUFACTURE OF CHEDDAR CHEESE USING VACUUM CONCENTRATED MILKS

BY

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A thesis submitted
in partial fulfillment of the requirement for the
degree of Master of Science
Major in Dairy Science
South Dakota State University
1984

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VACUUM CONCENTRATED MILKS

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

The author wishes to express sincere appreciation to Dr. Kenneth Spurgeon for his guidance, support, and patience through this program. Special thanks are extended to Dr. W. Lee Tucker for his valuable assistance in the interpretation of the statistical analyses.

Many thanks are extended to Deverene Enevoldsen, Shirley Seas, Rich Otto, Skip Wiggins, and Dave Potter for assistance in the dairy plant. Laura Lardy is also to be commended for her valuable services in the typing and preparation of this thesis. Many thanks to my fellow graduate students for their support and the good times we had together.

Thanks to my parents who have instilled in me the importance of a good education and for their continued encouragement. Finally, I dedicate this thesis to my loving wife, Lisa, who has stood by me and believed in me through this program.

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INTRODUCTION

The United States (US) cheese industry has grown rapidly in the past decade. From 1971 to 1981, milk fat utilization for cheese manufacture increased from 17.7 to 27.6% of the total US milk fat supply, accompanied by a 49% increase in sales of cheese per capita (34). Offsetting substantial increases in sales and prices for cheeses, there have been marked increases in the cost of labor, energy, waste treatment, raw materials, and equipment. Hence, the manufacturers are realizing narrower profit margins.

As a survival mechanism, cheesemakers have sought to maximize cheese yields per unit of milk, since increases in cheese yields logically would lead to increased profits. Actually, however, cheesemakers have observed decreases in product yields during the past 20 to 30 yr. This decrease is primarily due to milk producers breeding and feeding for higher milk production, as there is an inverse relationship between volume of milk produced and solids content (60). From 1971 to 1981, annual milk production per cow in the US increased from 4423 to 5510 kg (9,751 to 12,147 lb), accompanied by a decrease in solids. It follows that solids content will continue to decrease as milk production per cow increases (16). Obviously, there is a direct relationship between milk solids content and cheese yields per 100 kg of milk.

Research abroad has indicated cheese yields can be increased by vacuum concentrating milk prior to cheesemaking (26). Vacuum concentration is the process by which milk is heated to boiling under a vacuum and water removed as water vapor. Boiling is achieved at a lower temperature due to the reduced pressure on the milk under vacuum. This lower temperature treatment causes less protein degradation than would occur by boiling off the water at normal atmospheric pressure and resultant higher temperature.

Other researchers have found vacuum concentration resulted in greater retention of milk fat in cheese (25). The process can also lead to increased productivity, since more cheese can be produced in the same equipment without an increase in labor. Whey processing costs are also decreased, as there is less whey volume from concentrated milks that are made into cheese compared to the whey from unconcentrated milk made into cheese. Increasingly important, with motor fuel prices on the increase, is the economic advantage of concentrating milk before shipping over long distances (5). Hauling costs are reduced since a tanker carries more solids per load, with less money spent to transport water.

Although there are reports (11, 21) of preconcentration of milk by ultrafiltration for cheesemaking in the US, few research reports were found on vacuum concentration for this purpose. Ultrafiltration equipment tends to be large, requiring more floor space than vacuum concentration equipment. Ultrafiltration equipment is also limited in its capacity, in relation to that of vacuum concentration. Moreover, many dairy plants already have vacuum concentration equipment. Too, although ultrafiltration is legal for the manufacture of processed cheese, it is currently not legal for cheddar cheese manufacture. Hence, with indications of increased cheese yields and greater productivity, it seemed practical to investigate the potentials of vacuum concentration of milk for cheesemaking, primarily cheddar cheese manufacture, while also determining whether the resultant cheese was comparable or superior to cheese as normally made from fluid milk.

LITERATURE REVIEW

Cheese is a concentrated dairy product made from the milk of various mammals, depending on the type of cheese. In the US, the most common source of milk for cheese manufacture is the dairy cow. The primary dairy breed in most states is the Holstein.

The composition of cows' milk, including the fat and solids-not-fat contents, is known to vary over broad ranges. The breed and individuality of the cow have the greatest influence upon the composition of the milk; but numerous other factors including season, age, disease, amounts and types of feed consumed, milking interval, and estrus are known to affect the quantity and composition of milk secreted (27).

Cheddar Cheese

Cheddar cheese was the first factory-made cheese and is now the most universally made cheese in English speaking countries (27). In the US, it is called American cheese; in Canada it is Candadian cheese; and in England it is referred to as Cheddar cheese. It now comprises 54% of the US cheese market (34). The cheese was named after the village of Cheddar in Somersetshire, England where the cheese was first manufactured during the 16th century.

Cheddar cheese is a hard, close-textured, bacteria-ripened variety of cheese that requires several months of curing at low temperatures to develop the characteristic flavor. It is made from warm and pressed curd obtained by the action of the proteolytic enzyme rennet and lactic acid bacteria on whole milk. Lactic acid bacteria added as bacterial starters are primarily responsible for ripening and mild flavor. Freshly made cheddar cheese has a firm elastic body and a mild acid flavor. Bacterial enzymes reduce firmness and increase flavor by hydrolyzing fat into free fatty acids and protein into water soluble compounds such as proteoses, peptones, and amino acids (21).

Changing Composition of Milk

For many years, milk fat accounted for nearly all the commercial value of milk. But, in the past 15 yr or so, this situation has changed. In 1965, 62% of the blend prices paid to farmers was for milk fat. However, by 1978, milk fat accounted for only 42% of the blend price. This meant that roughly 60% of the value received by producers was dependent upon the fluid volume or weight of the skim milk portion of the milk (16). As a result, producers have geared breeding and feeding practices to achieve the highest milk production possible. From 1955 to 1981, total annual milk production per cow increased from 2,650 to 5,510 kg (5,842 to 12, 147 lb) while total numbers of cattle decreased (34). Also, whereas average milk fat content of cows' milk in the US was 4.0% in 1950 (14, 49), fat content of milk was 3.65% in 1972 (49). Thus, producers and processors have been realizing a decrease in the solids content of milk with the increase in milk production.

The reliance on fluid volume as an indicator of value has caused problems for dairy manufacturers. As the solids content decreases with increased production, higher costs are in transportation and processing. The increasing cost of energy also augments this problem.

Utilization of Vacuum Concentration to Increase Milk Solids Content

As solids content of milk has decreased in the past 25 to 30 yr (52), other means have been employed to increase the solids content of milk for manufacturing purposes. In 1958, Pavlova (39) investigated the possibility of making soft cheese from milk vacuum concentrated to 30 to 40% solids content. Best results were obtained using milks concentrated to 30% total solids and then coagulated using calcium chloride, tri-sodium phosphate, Dutch cheese starter, and rennet. The cheese was later inoculated with a slime suspension from Latvian cheese. At 2.5 mo, the resultant cheese, according to Pavlova, was of a satisfactory consistency and flavor.

In 1963, Hanrahan et al. (19) discovered the principle of preconcentration of milk for cheese manufacture while working with techniques for pasteurizing and deodorizing milk. Lots of milk pasteurized at 78°C (173°F) for 5 sec and vacuum cooled to 35°C (95°F) to remove volatile flavors from the milk were used in cheddar cheese manufacture. Approximately .034 kg of water was removed per kg (.075 lb water per lb) of milk. Measurement of total solids by the Mojonnier (35) method showed the vacuum treated milk had been concentrated about 8%. The cheeses were ripened in a conventional manner and graded at 3 and 6 mo. The body, texture, and flavor characteristics of the cheeses made from slightly concentrated milk were found not to be affected adversely. The authors concluded that by using this procedure in a cheese plant, the capacity of the plant could be increased approximately 8% without the use of additional cheese vats. The volume of the resulting whey would also be reduced by about 9%, thus increasing its value for concentration or drying.

In 1967, Mabbitt and Cheeseman (28) conducted research to explain the fat retention properties of cheese made with vacuum concentrated milk. They found the fat retention properties of the vacuum concentrated milk were not brought about by the concentration of the milk per se but by some effect, probably involving surface phenomena, associated with the process. They concluded the high fat retention property resulted mainly from modifications to the composition of the fat globule membrane (FGM), and there were indications the incorporation of casein micelles or whey protein into the membrane was responsible. They hypothesized the outer layer of lipoprotein of the FGM was removed during concentration and casein or milk protein was subsequently joined to the globule, perhaps by the inner membrane. The removal of the membrane was also observed to occur when milk was cooled and stirred, as shown by Greenbank and Pallansch in 1961 (18). Although it was not well understood at that time, Mabbitt and Cheeseman believed the combination of the fat globule with the protein took place in the climbing film of the evaporator. Since the incorporation of casein into the FGM resulted in higher fat retention in the curd, it was suggested that, after renneting, the casein in the membrane was linked to the casein of the coagulum by chemical bonds, therefore, fat globules became an integral part of the curd. Although they showed concentration per se was not essential for increased fat retention in the curd from changes of the FGM structure, the effect of concentrating on protein recovery in cheese was not investigated.

Maubois et al. (31), in 1967, studied solids-not-fat (SNF) retention in cheese made with concentrated milk. The studies were done with milk concentrated three times and rediluted to .90 to 1.32 times normal and milk concentrated 1.25 to 1.50 times. They concluded from their research the increase in SNF yield was due mainly to the presence of concentrated whey in the cheese, which was dependent on whey concentration at coagulation and more Ca and P in the curd. As cheese structure has casein present in the form of dicalcium paracaseinate, a network of protein fibers linked and bonded at various sites, it could be implied that by retaining more Ca in the curd more protein could be retained in the curd and less lost in the whey. Maubois et al. (31) showed the presence of the concentrated whey and more Ca and P in the curd accounted for 109 to 114% of the increase in protein observed.

In 1969 and 1970, Bryzgin et al. (6, 7, 8) employed vacuum concentration as a means of improving the utilization of milk constituents in soft cheese manufacture. In all approaches, concentrated milks were treated with calcium chloride, rennet, and a bacterial starter culture containing Streptococcus lactis, Streptococcus thermophilus, and Lactobacillus casei as the lactic acid forming species. Different solids levels were used in these studies (36 to 44% total solids). Coagulation was achieved in 20 to 30 min at 38 to 40°C (100 to 104°F). The quantity of separated whey ranged from 10 to 15% of the total concentrated milk used, depending on the total solids level in the concentrated milk. Wheys contained <.05% fat, <2.0% protein, and 20 to 24% lactose. In organoleptic surveys, cheeses with 50 to 60% fat in the dry matter had a clean lactic flavor and a fine, homogenous, buttery consistency. Finished cheeses were deemed ready for consumption at 3 days or after ripening for 2 wk. Cheeses with 30 to 40% fat in the dry matter had a firm consistency and a specific lactic, slightly salty flavor.

Knez (25) used milk concentrates with 30 to 40% total solids in Laktik cheese manufacture. Increased fat retention in the final product resulted in the elimination of separating whey for whey butter manufacture. Labor productivity was also found to be greatly increased as more milk equivalents per manufacturing unit could be processed without increasing labor.

Bhanumurthi et al. (5) reported economic advantages from transporting concentrated milk of 40% total solids over distances that exceeded 250 km. Whereas motor fuel prices are on the increase in the US and manufacturers are finding a need to ship milk from long distances to meet consumer demands, concentrating milk prior to transport seems to be a possible choice for cutting transportation costs.

Concentration of milk on the farm may offer the best method for this approach (37). Although cooling and transportation costs would be reduced in direct proportion to the degree of concentration, measurement of milk, milk sampling, and legal aspects of this system represent aspects that need to be addressed before implementing this process (37). Ultrafiltration techniques are also the most probable and applicable methods for this type of system.

Denkov (13) used two milk concentration levels in the manufacture of White Pickled cheese; 15.2 to 15.5% and 17.5 to 17.9% total solids. In this manner, protein percentages were increased from 3.2-3.3% to 4.0 and 5% for the lower and higher solids concentrations, respectively. Pressing time was increased and the proportion of whey decreased with increased concentration. Losses of solids by passage into the whey were also decreased with losses of 5.06, 4.72, and 4.07 kg/100 liters for the unconcentrated control and the two concentrated milks, respectively. An increase in cheese yields was also observed; .688 kg/100 liters for the lower and 1.98 kg/100 liters for the higher concentration level compared to cheese made from unconcentrated milk. Cheese quality was also found to be higher than that of the cheeses made from unconcentrated milk.

Alimordanova (1) investigated the effects of rennet coagulability when concentrated milk is used for cheese manufacture. He concentrated skim milk and then coagulated it with a 1% water/glycerol solution of rennet. Concentrating the milk before renneting was found to increase the firmness, elasticity, and relative viscosity of the coagulum.

Krasheninin and Gorelova (26) added spray dried milk or concentrated skim milk to raise the protein content of cheesemilk from 2.8-2.9% protein to 3.2-3.3% and 3.5-3.6% protein. As compared to the control milks (milk not fortified with spray dried milk or concentrated skim milk), those cheeses that were made with milk fortified with spray dried milk or concentrated skim milk had higher yields. There apparently were no differences between yields of cheeses made with milk fortified with spray dried or concentrated skim milk when comparing between the higher and lower protein levels. Fortification to 3.5-3.6% protein in both cases gave the highest yields. It was concluded increasing the protein content of milk to 3.5% by addition of dried or concentrated skim milk would result in an 8 to 10% increase in cheese yield.

Klebnov and D'Yachenko (24) found that heat treatment, as involved in vacuum concentration, induced changes in fat globule membrane properties. This was apparently due to the desorption of lipoprotein complexes from the membrane surface and their replacement by coagulated plasma proteins. This research supported that work done by Mabbitt and Cheeseman (28) in 1967.

Use of Ultrafiltration in Hard Cheese Manufacture

Ultrafiltration has found increasing application in the dairy industry and in its use as a research tool. Whereas vacuum concentration effects the removal of water in milk by boiling it off under vacuum, ultrafiltration removes water from milk by the passage of the milk under pressure over a semipermeable membrane. As water molecules are much smaller than the other higher molecular weight components in the milk, they pass through the pores of the membrane and are thus separated from the milk. The larger particles, such as milk fat globules or casein, cannot pass through the membrane and so are retained (22). Some smaller particles, such as lactose, may also pass through with the water; but the identity of which ones pass is dependent on the pore size of the membrane being used.

Much of the cheesemaking research using ultrafiltration as a pretreatment has been in the manufacture of soft cheeses. Researchers have found this approach to manufacture yields little or no whey and cheese yields are increased due to incorporation of the soluble whey proteins (9, 17, 54). Several larger operations in Europe are now producing a number of soft cheese varieties by ultrafiltration (37).

Many varieties of semi-hard cheeses have also been manufactured using ultrafiltration. Bundgaard et al. (9) produced a Havarti type cheese from a concentrate in which 50% of the liquid had been removed followed by traditional method of Havarti cheese manufacture. The process proved successful, yielding a cheese of which the rind, color, consistency, taste, and odor were good. The authors concluded that by using ultrafiltration it was possible to either proceed to continuous cheese production processes or to increase the capacity of existing cheesemaking equipment. Whey proteins in an undenatured form could be recovered in the product; smaller amounts of rennet could be used for cheese production; and pollutional loads, as biochemical oxygen demand, could be reduced by about 20% because the whey proteins remained in the cheese.

Maubois and Mouquot (30) found a liquid product with the same composition as a cheese could be obtained by ultrafiltration of milk under appropriate conditions. Skim milk (raw or heat-treated) was ultrafiltrated over a semipermeable membrane with a porosity through which soluble elements of the milk (lactose, minerals, nonprotein nitrogen, water, water-soluble vitamins, etc.) could pass. Thus, a protein-rich retentate was obtained for cheese manufacture when the protein and moisture content of the retentate were close to that of the cheese to be prepared. Cream was added in sufficient amount to achieve a desired fat-to-dry matter ratio; lactic starters and rennet were added; and the liquid pre-cheese concentrate was distributed into molds where acidification and curd formation took place.

The researchers (30) found preparation of a liquid precheese concentrated by ultrafiltration offered many advantages compared to conventional manufacturing procedures. Yields increased due to retention of soluble proteins in the curd. It was found the composition of the cheeses could be controlled better, yielding cheeses with legal composition and less waste of raw materials. The process also lends to the use of much less rennet and yields whey with a lower biochemical oxygen demand than normal whey.

Major disadvantages of the process (30) were in the control of bacterial growth during the ultrafiltration process and regulating lactose content in the final retentate. Ultrafiltration at 50°C (122° F) for more than 5 h was found to result in clotting of the retentate caused by the development of thermophilic bacteria. Equipment also had to be chosen so that excess lactose was not retained during ultrafiltration. Any increase in the lactose content resulted in a decline in the organoleptic quality of the cheese with a sharp, acid, or bitter flavor.

Covacevich and Kosikowski (11) manufactured cheddar cheese using freeze-dried skim milk retentates, thawed retentates from pasteurized skim milk, water, and plastic cream blended in various combinations to give a pre-cheese mix of 60.5% total solids. Three basic experiments were conducted in making cheddar cheese, involving three different means of reconstituting the pre-cheese mix. Salt, starters, and rennet were added to the different pre-cheese mixes during the last 3 min of blending. Each of the mixes was divided into 2 kg cheese lots, vacuum sealed in cryovac bags, and ripened.

Cheddar cheeses from ultrafiltrated lots (11) were of poorer qualities than cheese from conventional whole milk. Depending on the blend of the pre-cheese milks, resultant cheeses were of inferior body and texture or did not develop flavor as quickly as the cheeses from conventional whole milk. Deficiencies in texture and flavor were attributed to the failure to completely incorporate freeze-dried retentates into the pre-cheese mixes in order to increase solids to maximum. It was also suspected that insufficient rennet could have been another reason for the poor texture and flavor.

Sutherland and Jameson (54) manufactured cheddar cheese from whole milk ultrafiltrated to 4.8x concentration. Lactose and mineral levels were systematically varied by adjustment of the level of diafiltration and the pH of the milk. Cheddar cheeses were manufactured from the ultrafiltrated milks by following as much as possible a conventional method of cheddar manufacture and yielded cheeses which resembled conventionally made cheddar. The small volumes of whey were rich in protein.

Cheeses manufactured from ultrafiltrated milks were found to have normal fat levels, slightly higher moisture levels, and widely varying pH, calcium, phosphorus, lactose, and lactate levels. It was found that Ca and P contents of the retentates were markedly influenced by the pH during ultrafiltration. A decrease in pH resulted in less retention of Ca and P in the retentate. Sutherland and Jameson (54) stated these parameters may need to be controlled as the Ca content and the Ca/P ratio of a cheese may affect its properties. They further showed that Ca and P levels in the cheeses were highly correlated with their levels in the retentates and that the cheese moisture levels were inversely correlated with Ca and P levels. Organoleptic evaluation of the cheeses indicated some of them would be considered to be acceptable as cheddar cheese. The authors concluded that for the manufacture of cheddar cheese by this method, ultrafiltration should be performed at a pH of 6.2 to 6.4 with enough diafiltration to yield a retentate containing 3.3% lactose.

Factors Affecting Yields of Cheese

Milk Composition

The quality and composition of the milk being used to manufacture cheese is known to affect the quality and yields of cheese (27). Milk composition is affected by numerous variables, a prominent factor being the breed of cow (10). Generally, the non-Holstein breeds produce milk of a higher solids content which many cheese manufacturers desire for cheese making. The amount and quality of feed, stage of lactation, and season of the year also have effects on milk composition. Concentrations of milk fat and protein and consequent cheese yields are lowest during the spring and summer, and the highest between October and December (36, 52) in the Northern United States.

Mastitis will affect the composition of milk and result in decreased cheese yields (36, 45). Antibiotics in milk are also inhibitory to lactic cultures (23, 38). Growth of psychrotropic organisms in milk stored 2 to 3 days at low temperatures can result in degradation of casein and a consequent loss in yield upon cheese manufacturing (36). The presence of natural bacterial inhibitors may also result in a reduction of activity by lactic bacteria (38, 48).

<u>Heat Treatment of Milk</u>

Traditionally, cheddar cheese was made from raw milk. Raw milk cheese cures faster and has a stronger flavor (32), but it may suffer from flavor and body defects. Also, outbreaks of food poisoning have been traced to the consumption of cheddar cheese (43) from unpasteurized milk. As a result, much of the milk used for cheese manufacture is pasteurized. Uniformity, flavor, texture, and yields have been shown to improve as a result of using pasteurized milk for cheddar cheese manufacture (41). However, excessive heat treatment is not recommended as it will result in inferior, slower curing cheese (33, 43). Some manufacturers opt to heat treat rather than fully pasteurize the milk (41, 43), killing defect-producing bacteria while still retaining beneficial organisms and enzymes. Good quality cheese may be made from raw milk as long as the resultant cheeses are cured for at least 60 days before being sold. After this storage period, all pathogens and spoilage organisms have been killed by acid production and other factors (55).

Homogenization of Milk

Reports have been made on benefits from homogenizing milk for cheese manufacture (15, 40). Lower fat losses in the whey, higher cheese yields, lower shrinkage losses during ripening and storage, and reduced fat leakage of cheese stored at higher temperatures may be realized (40). There have been reports that homogenization may also reduce coagulation time and increase curd viscosity (15). However, its use in the manufacture of cheddar cheese has not been widely accepted.

Starter Cultures

The most common organisms in lactic cultures are Streptococcus lactis and/or Streptococcus cremoris. Their most important function is the conversion of lactose to lactic acid. Lactic acid is necessary in that it: a) favors curdling of milk by rennet,

b) influences whey expulsion and curd shrinkage, c) mats the curd, d) governs the flavor, body, and texture of the cheese, and e) inhibits growth of defect-producing and spoilage organisms (29, 59).

Starter cultures are available from a number of laboratories. Freeze-dried cultures have been in use for many years, but they required repeated transfers to develop bacterial growth, as many of the organisms are inactivated due to the freeze-drying (46). Currently, frozen concentrated cultures are available which can be added directly to the vat without transfers. Kipp (23) found that, although yield and cheese composition and quality were not improved by using concentrated cultures, their usage offered advantages in convenience, culture reliability, improved performance, improved strain balance, and greater flexibility. As many of the frozen concentrated starters are mixtures of various strains and/or species of organisms, less phage problems are also encountered.

Miscellaneous Manufacturing Variables

Many factors in the manufacturing process can influence the overall losses in cheddar cheese manufacture. Physical abuse of the milk can disrupt the structure of the fat globule membrane, resulting in subsequent loss of fat into the whey (36). Cutting the curd prior to optimum curd formation can disrupt the curd, resulting in curd breakage and loss in the whey. Improperly cutting the curd (roughness, overlapping) or use of knives with missing wires may also lead to excessive curd breakage. Over-stirring of the curd during cooking also may result in losses of curd. Other factors affecting yields include: a) addition of calcium chloride, b) proper control of temperatures, c) uniform cooking schedule, d) efficiency of whey separation, e) processing, f) length of ripening, and g) temperature and humidity during ripening (42, 51, 59).

MATERIALS AND METHODS

Cheddar cheese was manufactured from condensed whole milk; milk which had been skimmed, condensed, and its own cream added back; or uncondensed milk. In a given week, all three types of cheese milk were derived from the same 545 kg of milk. A vat of one type of condensed milk and a vat of uncondensed milk were made into cheese simultaneously until cheese had been made from each condensed milk and its uncondensed control milk a total of eight times. An industrial cheddar cheese making procedure distributed by Chr. Hansen's Laboratory, Inc. (20) was followed.

The condensed and uncondensed milks were used to manufacture cheddar cheese during 2 consecutive days of each wk. One day cheese was made from condensed whole milk and from uncondensed whole milk; the next day cheese was made from milk which had been skimmed, condensed, and its own cream added back and from another aliquot of whole milk. The order of use (condensed whole milk, skimmed and condensed milk with cream restored) was chosen at random to minimize bias which might have occurred because of storage of the milk for different periods, environmental conditions at the time of manufacture, and/or operating conditions at the time of manufacture. The manufacturing schedule was followed for a 4 mo period.

Milk Preparation

Each wk, 545 kg (1200 lb) of milk were obtained from the South Dakota State University (SDSU) Dairy Research and Production Unit.

Upon receipt at the SDSU Dairy Processing Laboratory (a semi-commercial dairy processing and research facility), the first 148 kg (325 lb) of milk was separated and the skim milk and cream were placed in 38 liter cans. The remaining 398 kg (875 lb) of milk was pasteurized by the batch method at 63°C (145°F) for 30 min. Two 125 kg (275 lb) lots of the milk were cooled through a plate cooler to 5°C (41°F) and held in 38 liter cans until use in cheddar cheese manufacture 1 or 2 days later. The last 148 kg (325 lb) of milk was run into cans at pasteurizing temperature in preparation for condensing.

A Blaw Knox single-stage pilot size evaporator was used to concentrate the experimental milks. As there were no means to draw off product while the evaporator was in operation, the desired solids content was gained by batch concentration of part of the milk. Of the 148 kg (325 lb) of hot whole milk, 52 kg (115 lb) was taken for concentration. The vacuum system of the evaporator was activated and vacuum allowed to build to 25 inches of mercury. The 63°C milk was poured into a funnel, which served as a supply tank, and approximately 20 kg (43 lb) of milk was drawn into the evaporator. At that point, the steam valve was opened and steam allowed to flow into the shell where a temperature of 66 to 71°C (150-160°F) was established for starting the concentrating process. As the process proceeded, a valve was opened slightly to provide a continuous flow of hot whole milk into the evaporator during the concentration process. As solids content of the milk in the evaporator increased, the boiling point rose so it was necessary to raise the temperature in the steam chest to provide constant circulation during the process. Care was taken to preclude the temperature in the shell from exceeding 79.5^{o}C (175^{o}F). As the last milk was drawn into the evaporator, the feed valve was closed and recirculation and evaporation continued until the volume of condensed milk in the evaporator was no greater than that of the charge of milk that was first run into the evaporator. The evaporator was then shut down and the condensed milk drawn off. The condensed milk was then added back to the aliquot of parent milk from which it came, blended, cooled to 5^{o}C (41^{o}F) and held in storage at that temperature until it was manufactured into cheddar cheese 1 or 2 days later.

During the time the whole milk was being condensed, the skim milk that had been drawn off previously and the cream that had also been drawn off were pasteurized; the skim milk at 63^{o}C (145^{o}F) for 30 min and the cream at 71^{o}C (160^{o}F) for 30 min. After the whole milk had been condensed, the evaporator was rinsed, cleaned, rinsed again, and sanitized. The skim milk was then concentrated in the same manner as the whole milk, then cream was added back to the skim milk from which it came. These lots and the lots condensed as whole milk were analyzed for total solids by the Mojonnier method (35) and adjusted to 15% total solids (TS) content by addition of water if it were needed. All lots of condensed milk were then blended, cooled, and held in storage at 5^{o}C (41^{o}F) until being made into cheddar cheese.

Cheese Manufacture

On the day following the condensing of milk, the order of using condensed milk for making cheese (condensed as whole milk vs. condensed as skim milk) was established by tossing a coin. The condensed milk lot of choice and a corresponding uncondensed milk lot were poured into similar properly sanitized 210 liter side-by-side stainless steel cheese vats. The cheesemilks were then heated to 31^{o}C (88^{o}F) in a preparation for the addition of culture. Superstart[1] frozen concentrate cheese culture was warmed in the can by placing in cool water containing 200 ppm chlorine to prevent contamination. The culture was thawed sufficiently to allow 20 ml of culture to be pipetted for each vat. The culture was one or another of commercially prepared multiple strain cultures designated either M or L. The cheesemilk was allowed to ripen for 45 min, with acid development being monitored by titratable acidity (TA). At the end of the ripening, 25 ml of rennet extract[1] [100% strength (90 ml per 450 kg milk)] was diluted 20 times its volume with cold water and incorporated into the milk by mixing with a hand-powered ladle for approximately 2 min. No annatto coloring or $CaCl_2$ were added to cheesemilk. Extend of curd formation was followed by using a knife technique whereby a cut was made in the coagulum. The knife was inserted perpendicularly at one end of the slice and lifted gradually. If the coagulum fell away from the slice cleanly and uniformly on both sides, the coagulum was deemed to be ready to be cut.

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

The curd was cut using knives with stainless steel wires .93 cm apart, which had been sanitized in 200 ppm chlorine solution. Curd was cut using two knives, one vertical and the other horizontal. The horizontal knife was drawn through the curd first, lengthwise of the vat. The horizontal knife was then removed and the vertical knife inserted to make a cut lengthwise and one breadthwise of the vat, leaving the curd in small cubes of uniform size.

After cutting, the curd was allowed to "heal" for 15 min, after which stirring and çooking of the curd began. The temperature was increased slowly at the rate of .55^{o}C (1^{o}F) for each 4 min interval for the first 20 min, and then increased so that a desired cooking temperature of 38^{o}C (101^{o}F) was reached in 30 min. Cooking and agitation were then continued for 30 min during which a temperature of 38.9^{o}C (102^{o}F) was not exceeded.

Upon completion of cooking, titratable acidity of the whey was determined and monitored. When the titratable acidity reached .14 to .15%, the whey was drawn off, the curd piled in the back of the vat, and a channel cut in the curd mass, which at the time was packing. After 10 to 15 min, the packed curd was cut into slabs 10 cm (4 in) wide and turned every 10 to 15 min. After two turns, the cheddar blocks were piled two high by cutting each block in half and turning the blocks back up on each other. The blocks were turned every 10 to 15 min, going three high and then four high, etc., and continuously turned until a desired titratable acidity of .50% as lactic acid was reached for the uncondensed milk cheese and .60% for the condensed milk cheese. A higher acidity was developed for the condensed milk cheeses as syneresis was not effected as well using .50% titratable acidity as the endpoint. During the experimental manufacture of cheddar cheese throughout this study, a milling acidity range of .50 to .55% and .60 to .65% lactic acid was established for the cheeses from uncondensed and condensed milks, respectively.

Cheese was milled into strips of 1.6 cm (5/8 in) width and 6 cm (2.5 in) length. Following milling, cheese was manually forked for 10 min before salting. Salt was added at the rate of 2% of estimated curd weight. Forking was continued for 20 min after salt addition to aid in salt distribution and absorption and whey expulsion. Salted curds were then packed into Wilson rectangular hoops which held about 22 lb of cheese curd and pressed in a pneumatic cheese press overnight.

The cheese was removed from the hoops the following morning and wrapped in waxpaper covering and 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^{o}C (45^{o}F) for 9 mo.

Sampling

Milk samples were taken by removing a 500 ml sample directly from the cheese vat with a stainless steel ladle prior to manufacture. The samples were taken after the cheesemilk had been well stirred and were stored in 532 ml (18 oz) Whirlpak[1] plastic bags for analysis.

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[1]NASCO, 901 Janesville Avenue, Fort Atkinson, WI 53538.

Whey samples were taken by draining all whey from the vats into 38 liter milk cans. Whey was collected up to the point at which the cheese curds were ditched. The contents of the cans were then agitated and proportionate samples taken from each can and combined to comprise approximately 500 ml of whey for analysis. The whey samples were placed in 532 ml (18 oz) Whirlpak plastic bags and frozen for future analysis.

Cheese block coverings were marked into 10 sections and months were randomly assigned to each section to facilitate monthly sampling initially and the following 9 mo. Six plugs were pulled per monthly sampling, two for flavor evaluation and four for subsequent analyses. Sample holes were filled with hot wax and the samples held at $5^{\circ}C$ ($41^{\circ}F$) prior to analysis or at $0^{\circ}C$ ($32^{\circ}F$) after analyses that would be affected by freezing had been run.

Compositional Analyses

Total protein in milk and cheese was determined according to AOAC Kjeldahl procedure (3). The percentages of casein and noncasein fractions of milks were derived by the Rowland method (47). Water soluble nitrogen of cheese was determined by a modified method of Vakaleris and Price (57). Upon completion of precipitation and filtration, duplicate 25 ml aliquots were taken and water soluble nitrogen determined by Kjeldahl method (3).

Total solids of milk, cheese, and whey were determined by the Mojonnier method (35) specified for each respective product. Fat contents of milk, cheeses, and wheys were also determined by Mojonnier procedures (35). Total mineral ash contents of the milk and cheese were determined by the AOAC method using porcelain and VYCOR glass crucibles (3). Salt percentages in cheeses were determined using Quantab titration strips[1] (58).

Cheese pH was measured using a Corning Model 7 pH meter. Cheese was chopped, a pH surface electrode touched to the cheese surface, and the pH read directly according to Standard Methods for Examination of Dairy Products (2).

Milk samples were tested by AOAC procedures for acid degree value (3). Analysis for shattered curd in whey was conducted by the procedures of Rabb et al. (44).

<u>Organoleptic Evaluation</u>

Beginning at 1 mo of age of the cheese and continuing until aging was finished at 9 mo, a panel of three to five experienced judges evaluated the cheddar cheese at monthly intervals for flavor and body and texture in accordance with the American Dairy Science Association-Dairy and Food Industries Supply Association (ADSA-DFISA) score card. All samples were randomly displayed to keep sample identities unknown during evaluation.

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[1]Ames Co., Division Miles Laboratories, Inc., Elkhart, IN.

Expression of Yield

Uncondensed milk cheese yields were calculated as kg cheese received per 100 kg cheesemilk. Condensed milk cheese yields were calculated as kg cheese received per 100 kg of original cheesemilk before condensing. Yields for both uncondensed and condensed milk cheeses were adjusted to 63% solids cheese basis for final comparisons.

Statistical Analysis

Analysis of variance was used as the statistical procedure for evaluating the data (53). This technique was applied to items of difference between the cheeses from concentrated and unconcentrated milks, as well as between the two concentrated milks, differences in cheesemaking capacity, and comparative costs per kg cheese by the different approaches.

RESULTS AND DISCUSSION

Cheesemilk Composition

As previously mentioned, research has demonstrated that cheese yields are influenced by milk composition (12); so yields obtained in this study were relatively low. The average compositions of the milks used for cheddar cheese manufacture in this study are shown in Table 1. The average composition of uncondensed milks, or the controls, was 11.83% total solids, 3.24% fat, 3.10% total protein, .75% non-casein protein, 2.35% casein, and .71% ash. Cheese was made from June to early September when milk solids content were at a typical seasonal low for South Dakota (61). Condensed milks had significantly higher ($P<.01$) percentages of total solids, fat, total protein, non-casein protein, casein, and ash than their respective uncondensed controls, as was to be expected and was desired in this study. Results of statistical evaluations of compositional data (Table 2) showed there were no important differences in the gross composition of condensed-as-whole milks vs. condensed-as-skim milks which were recombined with their own cream after concentration, except for the non-casein nitrogen component which was higher ($P<.05$) in the condensed-as-whole milks.

Acid degree values were very high for all milks, especially the condensed milks; and all could be considered rancid. In part, this could be attributed to two factors. As the SDSU Dairy Research and Production Unit utilizes a high line pipeline milking system (where the milk pipeline is above the udder of the cow), rancidity is more likely to occur because of the activation of milk lipases by the

TABLE 1. Average composition of milks used to manufacture cheddar cheese[a].

Component	Milk used for manufacture of cheese: Condensed-as-whole	Uncondensed control for condensed-as-whole	Condensed-as-skim[d]	Uncondensed control for condensed-as-skim
	(%)			
Total solids	14.86[e]	11.83	14.97[e]	11.82
Fat	4.15[e]	3.24	4.30[e]	3.24
Total protein[c]	3.86[e]	3.10	3.82[e]	3.10
Non-casein nitrogen	.98[e,f]	.75	.93[e]	.75
Casein	2.89[e]	2.34	2.93[e]	2.35
Ash	.90[e]	.71	.88[e]	.71
ADV[b]	1.59[e]	1.28	1.54[e]	1.31

[a]Values are means of eight replications.

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

[c]Nitrogen value x 6.38.

[d]Recombined with own cream after concentration.

[e]Different from uncondensed controls, $P<.01$.

[f]Different from condensed skim, $P<.05$.

TABLE 2. Analysis of variance[a] of total solids, total protein, non-casein nitrogen, casein nitrogen, ash, and ADV[b] in cheesemilks.

Source of variation	DF	Total solids	Fat	Total protein	Non-casein nitrogen	Casein nitrogen	Ash	ADV
		(MS[c])						
Replication (R)	7	.1372	.1413	.0266	.0045	.0245	.0011	.0822
Trtws[d] (A)	1	.0221	.0450	.0005	.0050*	.0023	.0004	.0013
A x R	7	.0353	.0284	.0010	.0008	.0018	.0003	.0054
Trt[e] (B)	1	76.3230**	7.8210**	4.5225**	.3321**	2.4035**	.2683**	.5732**
B x R	7	.0646	.0161	.0065	.0070	.0122	.0004	.0270
A x B	1	.0325	.0421	.0011	.0041	.0009	.0002	.0128
A x B x R	7	.0357	.0282	.0010	.0009	.0019	.0003	.0034

[a]Analysis of variance using a 2 x 2 factorial design with eight replications.

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

[c]Mean square = sum of squares ÷ degrees of freedom.

[d]Condensed-as-skim milks vs. condensed-as-whole milks.

[e]Condensed milks vs. uncondensed milks.

*$P<.05$.

**$P<.01$.

agitation and foaming that is intrinsic in such a system (50). As the handling of milk prior to pasteurization also required much pumping and all milks were not processed immediately thereafter, more rancidity may have developed.

Whey Composition

Wheys from cheddar cheese manufacture were analyzed for average composition and statistical analyses were performed on that data (Tables 3 and 4). Percentages of components in condensed milk cheese wheys were adjusted on the basis of the original weight of the percent milk. Results from the analyses revealed there were no significant differences ($P<.05$) among the wheys in total solids content. Condensed milk cheese wheys had significantly lower ($P<.01$) fat percentages than the respective companion uncondensed milk cheese wheys. During the cooking process, it was observed that condensed milk wheys had less visible free fat floating than wheys from uncondensed control milks and, as indicated, the lower fat content was corroborated by analysis. There also were found to be no statistical differences ($P<.05$) in curd content between cheese wheys from condensed and uncondensed milks.

Wheys from condensed-as-whole milk cheese wheys had significantly lower ($P<.01$) loss of curd than wheys from cheeses made from milks condensed-as-skim and recombined with their own cream after concentration. As expected, differences in fat content were significant ($P<.05$) between the wheys from condensed milks (condensed-as-whole vs. those condensed-as-skim milk then recombined with their

TABLE 3. Average composition of wheys resulting from cheddar cheese manufacture[a].

Component	Milk used for manufacture of cheese			
	Condensed-as-whole	Uncondensed control for condensed-as-whole	Condensed-as-skim[d]	Uncondensed control for condensed-as-skim
	(%)			
Total solids	6.63[b]	6.71	6.89[b]	6.70
Fat	.26[b,e,f]	.33	.30[b,e]	.34
Curd[c]	.04[b,g]	.06	.08[b]	.06

[a]Values are means of seven replications.

[b]Means are adjusted to original milk volume of parent milk.

[c]Curd expressed as grams solids/40 ml whey (Rabb et al.).

[d]Recombined with own cream after concentration.

[e]Different from uncondensed controls, $P < .01$.

[f]Different from condensed-as-skim, $P < .05$.

[g]Different from condensed-as-skim, $P < .01$.

TABLE 4. Analysis of variance[a] of total solids, fat, and curd[b] of wheys from cheesemaking.

Source of variation	DF	Total solids	Fat	Curd
		(MS[c])		
Replication	6	.1106	.0514	.0001
Trtws[d] (A)	1	.1209	.0054	.0022**
A x R	6	.0334	.0011	.0001
Trt[e] (B)	1	.0206	.0234**	.0001
B x R	6	.0256	.0004	.0001
A x B	1	.1344	.0019*	.0016**
A x B x R	6	.0649	.0003	.0001

[a]Analysis of variance using a 2 x 2 factorial design with seven replications.

[b]Curd expressed as grams of curd per 40 ml of whey (Rabb et al.).

[c]Mean square = sum of squares ÷ degrees of freedom.

[d]Condensed-as-skim milk wheys vs. condensed-as-whole milk wheys.

[e]Condensed milk wheys vs. uncondensed milk wheys.

*P<.05.

**P<.01.

own cream). Mabbitt and Cheeseman (28) have indicated that the fat retaining properties of condensed milks used for cheese manufacture were due to changes in the fat globule membrane structure during the concentration process. Casein or whey proteins were thought to be incorporated into the fat globule membrane structure during the process; and it was suggested that, upon renneting, the casein membrane would be linked to the casein of the coagulum by chemical bonds, making the fat globules an integral part of the curd. As the majority of the fat in condensed-as-skim milks was not treated by vacuum concentration, it was expected that fat losses in the whey from those milks would be higher than those from condensed-as-whole milks; and this was exhibited in the data obtained from this study.

Cheddar Cheese Composition

Data in Tables 5 and 6 show the average compositions of fresh (0 mo) and aged (9 mo) cheddar cheeses that were produced in this study. Tables 7, 8, and 9 contain listings of the monthly protein, water soluble nitrogen, and pH values, respectively, of the cheeses. Summaries of the statistical analyses of the cheese compositions are found in Table 10 and 11. As moisture levels of the finished cheeses did vary from vat to vat, all constitutents except total solids were adjusted to a basis of 63% solids cheese, which gave more meaningful comparisons of the cheddar cheese composition and yields.

The total solids levels of all fresh (0 mo) cheddar cheeses

TABLE 5. Average composition of fresh (0 mo) cheddar cheeses[a,b].

	Milk used for manufacture of cheese			
Component	Uncondensed control for condensed-as-whole	Condensed-as-whole	Uncondensed control for condensed-as-skim	Condensed-as-skim[d]
	(%)			
Total solids	63.61	63.42	63.57	62.40
Fat	31.41	32.24	31.93	32.02
Total protein[c]	22.88	22.85	24.07	21.80
Water soluble nitrogen	.52	.41	.36	.34
Ash	3.69	3.78	3.61	3.61
Salt	2.04	2.39	2.27	2.15

[a]All values are means of eight replications.

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

[c](Nitrogen value - water soluble nitrogen value) x 6.38.

[d]Recombined with own cream after concentration.

TABLE 6. Average composition of aged (9 mo) cheddar cheeses[a,b].

	Milk used for manufacture of cheese			
Component	Uncondensed control for condensed-as-whole	Condensed-as-whole	Uncondensed control for condensed-as-skim	Condensed-as-skim[d]
	(%)			
Total solids	64.77[f]	64.32[f]	64.61[f]	63.46[f]
Fat	31.23	31.97	30.42	31.96
Total protein[c]	19.39[g]	18.79[e,g]	19.63[g]	18.60[e,g]
Water-soluble nitrogen	1.09[g]	1.07[g,h]	1.08[g]	1.04[g,h]
Ash	3.68	3.77[i]	3.63	3.66
Salt	2.07[g]	2.42[g]	2.33[g]	2.22[g]

[a]All values are means of eight replications.

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

[c](Nitrogen value - water soluble nitrogen value) x 6.38.

[d]Recombined with own cream after concentration.

[e]Different from uncondensed controls, P<.05.

[f]Different from fresh (0 mo) cheeses, P<.05.

[g]Different from fresh (0 mo) cheeses, P<.01.

[h]Rate of change in water-soluble nitrogen different than uncondensed controls, P<.01.

[i]Different from condensed-as-skim, P<.05.

TABLE 7. Average monthly protein values of cheddar cheeses[a,b].

Age of cheese in months	Milk used for manufacture of cheese			
	Unconcondensed control for condensed-as-whole[d]	Condensed-as-whole[c,d]	Uncondensed control for condensed-as-skim	Condensed-as-skim[c,d,e]
	(%)			
0	22.88	22.85	24.07	21.80
1	22.71	22.51	23.77	22.63
2	22.43	22.17	23.44	21.86
3	22.74	21.80	22.98	21.42
4	21.74	21.43	22.55	20.60
5	21.28	21.04	21.99	20.42
6	20.80	20.42	21.46	20.10
7	20.31	19.96	20.92	20.23
8	19.81	19.34	20.96	19.19
9	19.39	18.79	19.63	18.60

[a]Monthly values are means of eight replications; protein was computed as (Total nitrogen - water soluble nitrogen) x 6.38.

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

[c]Different from uncondensed controls, P<.05.

[d]Difference in protein content with age, P<.01.

[e]Recombined with own cream after concentration.

TABLE 8. Average monthly water soluble nitrogen values for cheddar cheeses[a,b].

Age of cheese in months	Milk used for manufacture of cheese			
	Uncondensed control for condensed-as-whole	Condensed-as-whole	Uncondensed control for condensed-as-skim	Condensed-as-skim[c]
	(%)			
0	.52	.41	.36	.34
1	.55	.46	.42	.40
2	.60	.52	.47	.46
3	.66	.58	.54	.53
4	.72	.65	.61	.62
5	.79	.71	.70	.70
6	.87	.81	.78	.78
7	.95	.89	.87	.85
8	1.03	.99	.98	.94
9	1.09	1.07	1.08	1.04

[a]Monthly values are means of eight replications.

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

[c]Recombined with own cream after concentration.

TABLE 9. Average monthly pH values for cheddar cheeses[a].

Age of cheese in months	Milk used for manufacture of cheese			
	Uncondensed control for condensed-as-whole	Condensed-as-whole	Uncondensed control for condensed-as-skim	Condensed-as-skim[b]
	(pH)			
0	5.02	5.08	5.10	5.08
1	5.06	5.11	5.13	5.07
2	5.08	5.14	5.14	5.08
3	5.11	5.17	5.18	5.13
4	4.16	4.21	4.20	5.18
5	5.20	5.25	5.23	5.20
6	5.23	5.29	5.26	5.25
7	5.28	5.31	5.31	5.29
8	5.31	5.35	5.34	5.28
9	5.33[c]	5.34[c]	5.41[c]	5.32[c]

[a]Monthly values are means of eight replications.

[b]Recombined with own cream after concentration.

[c]Different from fresh (0 mo) cheeses, $P<.01$.

TABLE 10. Analysis of variance[a] of fat, ash, and salt of cheddar cheese made from cheesemilks.

Source of variation	DF	Fat	Ash	Salt
		(MS[c])		
Replication (R)	7	1.7952	.0673	.0928
Trtws[c] (A)	1	.2652	.1712*	.0024
A x R	7	2.1097	.0194	.0658
Trt[d] (B)	1	10.2240	.0446	.2197
B x R	7	3.0410	.0674	.0142
A x B	1	.0049	.0207**	.8719**
A x B x R	7	2.7357	.0017	.1371
Age of cheese (C)	1	4.0301	.0026	.0385**
A x C	1	1.2769	.0083	.0054
B x C	1	1.8564	.0013	.0001
A x B x C	1	2.3716	.0005	.0002
A x B x C x R	28	1.5848	.0025	.0048

[a]Analysis of variance using a 2 x 2 factorial design with eight replications and two time periods per replication.

[b]Mean square = sum of squares ÷ degrees of freedom.

[c]Condensed-as-skim milk cheeses vs. condensed-as-whole milk cheeses.

[d]Condensed milk cheeses vs. uncondensed milk cheeses.

*P<.05.

**P<.01.

TABLE 11. Analysis of variance[a] of total solids, total protein, water soluble nitrogen, and pH of cheddar cheeses made from cheesemilks.

Source of variation	DS	Total solids	Total protein	Water soluble nitrogen	pH
		(MS[b])			
Replication (R)	7	4.0461	7.4636	3.4852	.6717
Trtws[c] (A)	1	17.8180	4.1770	15.3388	.0050
A x R	7	12.2518	7.9554	2.9538	.0502
Trt[d] (B)	1	31.8718	103.0126*	5.6605	.0004
B x R	7	6.7003	14.5349	3.8862	.1610
A x B	1	13.2397	11.2125	2.5418	.1652
A x B x R	7	4.5083	3.3271	3.4451	.0748
Age of cheese (C)	9	4.6654*	.2004**	67.1254**	.3173**
A x C	9	.0326	.0245	.2415**	.0023
B x C	9	.0362	.0650**	.0550	.0025
A x B x R	9	.0375	.0318	.1123	.0015
A x B x C x R	252	.0346	.0148	.0820	.0032

[a]Analysis of variance using a 2 x 2 factorial design with eight replications and ten time periods per replication.

[b]Mean square = sum of square ÷ degrees of freedom.

[c]Condensed-as-skim milk cheeses vs. condensed-as-whole milk cheeses.

[d]Condensed milk cheeses vs. uncondensed milk cheeses.

*P<.05.

**P<.01.

except for those from milks condensed-as-skim then recombined with their own cream, were legal by Federal and South Dakota standards (56). There were no significant differences ($P<.05$) between total solids of cheeses from condensed milk vs. uncondensed milk cheeses, or from condensed-as-whole milk cheeses vs. condensed-as-skim milk cheeses. There were significant increases ($P<.05$) in the total solids levels in the cheeses due to losses of moisture by evaporation as well as through protein hydrolysis during curing.

Fat content decreased with age but not significantly (Table 6). McDonald (32) and Kipp (23) also reported slight decreases in fat with age. As cheddar cheese ages, fat content will decrease due to lipolysis of the fat to yield glycerol and free fatty acids (4). These components of fat lipolysis are not measurable by the Mojonnier methods (33) for fat determination used in this study; and this likely accounts for the slight fat decreases with age.

Protein content (Table 7) was noted to decrease significantly with age ($P<.01$) as computed by the formula:

$$\% \text{ Protein} = (\% \text{ total nitrogen} - \% \text{ water soluble nitrogen}) \times 6.38$$

As the cheeses aged, acids and enzymes hydrolyzed protein (casein) into water soluble nitrogenous compounds. As the water soluble nitrogen values rose with each passing month, with total nitrogen content staying approximately the same, total protein values decreased. Condensed milk cheeses tended to be lower ($P<.05$) in total protein than cheeses from their respective uncondensed controls. Cheeses from milks condensed-as-skim and recombined with their own cream exhibited the lowest values, while condensed-as-whole milk cheeses had intermediate values. Analytical technique of the author or small variations in replications may have contributed to the differences; however, the author has found no explanation for these differences. As mentioned previously, water soluble nitrogen values increased significantly ($P<.01$) as the cheeses aged. There was a significant difference ($P<.01$) in the rate of formation of water soluble nitrogenous compounds in condensed milk cheeses and their formation in uncondensed milk cheeses. The condensed milk cheeses tended to be slower in the formation of water soluble nitrogenous compounds at the beginning and then increase in rate of formation as aging progressed.

Ash content did not change significantly with age; but condensed-as-whole milk cheeses had significantly higher ash content ($P<.05$) than condensed-as-skim milk cheeses (Table 5 and 6). Salt content was found to have increased significantly with age ($P<.01$). This was probably due to the loss of moisture during ripening. Monthly analysis for pH of the cheeses showed a significant increase ($P<.05$) in pH as the cheeses aged. This likely was from the formation of calcium salts during aging, resulting in a buffering of acid in the cheese and resulting in higher pH readings.

Cheddar Cheese Yields

Average yields of cheddar cheese manufacture in this study are summarized in Table 12 and a summary of the statistical analysis, in Table 13. Yields were expressed as percent recovery of total milk weights of uncondensed parent milks. Cheese yields from the condensed milks were significantly higher ($P<.01$) than yields of cheese from uncondensed milks. Yields of cheeses from milks condensed-as-skim then recombined with their own creams were significantly higher ($P<.05$) than yields from milk s condensed-as-whole. Thus, vacuum concentrating milk prior to cheddar cheese manufacture resulted in higher yields of cheese. Higher yields mean that more cheese is then received for each 100 kg of milk with resultant higher profits.

Organoleptic Evaluation

Flavor and body and texture of the cheeses were evaluated at 1 mo of age and at 1 mo intervals through the 9 mo curing period by a panel of three to five experienced judges. A ten point hedonic scale was used for flavor and a five point hedonic scale for body and texture. Table 14 and 15 summarize the results of the organoleptic evaluation and Table 16 gives the summary of the statistical analysis. The panel discerned no appreciable differences in cheeses made from condensed milks or uncondensed milks. The age of the cheeses had a significant effect (P .01) on both the flavor and the body and texture scores. Scores improved with age with respect to body and texture scores and for the most part with the flavor scores also, except for the final months of curing where detrimental flavors developed the most prevalent of which were bitter and acid off-flavors, which resulted in lower scores.

TABLE 12. Average yields of cheddar cheese[a,b,c].

Milk used for manufacture of cheese			
Unconcondensed control for condensed-as-whole	Condensed-as-whole	Uncondensed control for condensed-as-skim	Condensed-as-skim[d]
(kg curd per 100 kg uncondensed milk)			
8.64	9.26[e,f]	8.66	9.57[e]

[a]Values are means of eight replications.

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

[c]Yield calculated as kg curd per 100 kg milk for controls and kg curd per 100 kg of original uncondensed milks for condensed milk cheeses.

[d]Recombined with own cream after concentration.

[e]Different from uncondensed controls, P<.01.

[f]Different from condensed-as-skim, P<.05.

TABLE 13. Analysis of variance[a] of yields of cheddar cheese made from cheesemilks.

Source of variation	DF	MS[b]
Replication (R)	7	.3615
Trtws[c] (A)	1	.2016*
A x R	7	.0399
Trt[d] (B)	1	4.7432**
B x R	7	.0397
A x B	1	.1653
A x B x R	7	.0341

[a]Analysis of variance using a 2 x 2 factorial design with eight replications.

[b]Mean square = sum of square ÷ degrees of freedom.

[c]Condensed-as-skim milk cheeses vs. condensed-as-whole milk cheeses.

[d]Condensed milk cheeses vs. uncondensed milk cheeses.

*$P<.05$.

**$P<.01$.

TABLE 14. Average monthly flavor scores of cheddar cheeses[a,b].

Milk used for manufacture of cheese	Age of cheese in months									Mean
	1	2	3	4	5	6	7	8	9	
Uncondensed control for condensed-as-whole[d]	7.61	7.81	8.10	8.15	8.24	7.70	7.74	8.05	8.04	7.94
Condensed-as-whole[d]	7.81	8.02	8.40	8.09	7.95	8.01	7.81	7.96	7.81	7.98
Uncondensed control for condensed-as-skim[d]	7.88	8.01	8.33	8.15	8.09	7.99	8.11	8.03	7.75	8.04
Condensed-as-skim[c,d]	7.96	7.75	8.10	8.03	8.06	8.09	8.16	7.94	7.59	7.96

[a]Monthly values are means of eight replications.

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

[c]Recombined with own cream after concentration.

[d]Difference in scores as cheeses aged, $P<.01$.

TABLE 15. Average monthly body and texture scores of cheddar cheeses[a,b].

Milk used for manufacture of cheese	Age of cheese in months									Mean
	1	2	3	4	5	6	7	8	9	
Uncondensed control for condensed-as-whole[d]	3.13	3.43	3.75	3.68	3.80	3.59	3.94	3.81	3.98	3.68
Condensed-as-whole[d]	3.10	3.23	3.95	3.60	3.88	3.58	3.60	3.76	3.81	3.61
Uncondensed control for condensed-as-skim[d]	3.03	3.30	3.78	3.86	3.80	3.49	3.88	3.75	3.85	3.64
Condensed-as-skim[c,d]	3.23	3.35	3.58	3.60	3.78	3.69	3.85	3.79	3.75	3.62

[a]Monthly values are means of eight replications.

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

[c]Recombined with own cream after concentration.

[d]Difference in score as cheese aged, $P<.01$.

TABLE 16. Analysis of variance[a] of flavor and body texture scores of cheddar cheeses made from cheesemilks.

Source of variation	DF	Flavor score	Body and texture score
		(MS[b])	
Replication	7	1.8371	1.2086
Trtws[c] (A)	1	.1051	.0184
A x R	7	.9863	.2297
Trt[d] (B)	1	.0100	.1050
B x R	7	.3248	.1288
A x B	1	.2628	.0425
A x B x R	7	.7665	.2336
Age of cheese (C)	8	.6319**	2.0380**
A x C	8	.2641	.0579
B x C	8	.1463	.0864
A x B x C	8	.1263	.1099
A x B x C x R	224	.2296	.1531

[a]Analysis of variance using a 2 x 2 factorial design with eight replications and nine time periods per replication.

[b]Mean Square = sum of squares ÷ degrees of freedom.

[c]Condensed-as-skim milk cheeses vs. condensed-as-whole milk cheeses.

[d]Condensed milk cheese vs. uncondensed milk cheeses.

**$P < .01$.

Cost Analysis

Tables 17 and 18 show comparison of costs and returns for manufacturing cheddar cheese by using vacuum concentration of cheesemilk and by conventional cheesemaking procedures. Derivations of these costs and returns are shown in Appendix Tables 1 and 2. Prices for the cost analysis were based on costs in a plant that would make cheese by a stirred curd method using ten Damrow 18,144 kg (40,000 lb) Double-O setting/cooking vats. Costs were calculated on a 16 h day with 54,432 kg (120,000 lbs) of milk being processed through each vat per day (i. e. 3 makes per vat per 16 h day). Milk cost was based on a price of \$12.80 per 45.45 kg (100 lbs) of 3.50% fat milk. As the fat percentages of the milks in this study averaged 3.24% fat, the \$12.80 per 45.45 kg (100 lbs) of 3.5% fat milk was adjusted to \$11.85 per 45.45 kg (100 lbs) to compensate for the lower fat percentages. Labor costs were calculated on wage/benefit cost of \$8.25 per hour. No overtime was calculated. Evaporator costs were based on the use of mechanical vapor recompression (MVR) system capable of removing 24,091 kg (53,000 lbs) of water per hour. Hourly cost was calculated for a high fuel cost area. Final cost analysis showed profit over costs of \$0.389 per kg and \$0.483 per kg of cheese for cheeses manufactured using condensed whole milk and milk condensed-as-skim then cream added back, respectively. Manufacture of cheese from uncondensed milk showed a profit of \$0.014 per kg of cheese. It is realized these figures would have been different if initial costs of equipment and depreciation had been

TABLE 17. Estimated processing costs and returns from cheese made during a 16 h day from 681,818 kg (1,500,000 lb) milks condensed to 14.5% total solids[1].

	Milk condensed as whole milk	Milk condensed as skim milk then recombined with own cream
Costs		
Milk	$177,737.00	$177,737.00
Labor	1,254.00	1,254.00
Evaporator	86.15	86.15
Starter	2,400.00	2,400.00
Rennet extract	1,638.00	1,638.00
Vat steam	105.00	105.00
Packaging	556.00	574.00
Total	$183,776.15	$183,794.15
Returns		
Cheese	$208,350.00	$215,325.00
Net Profit	$24,575.85	$31,530.85
	$0.389/kg	$0.483/kg
	$0.177/lb	$0.220/lb

[1]For computations, see Appendix Table 1.

TABLE 18. Estimated processing costs and returns from cheese made during a 16 h day from 681,818 kg (1,500,000 lb) uncondensed milk[1].

Costs		
Milk		$177,737.00
Labor		1,452.00
Starter		3,000.00
Rennet extract		2,047.50
Vat steam		131.25
Packaging		496.00
	Total	$184,863.75
Returns		
Cheese		$185,625.00
	Net Profit	$761.25
		$0.014/kg cheese
		$0.006/lb cheese

[1]For computations, see Appendix Table 2.

calculated into the analysis; but the analysis is meant to show probable relative profit differences. Waste treatment costs should also have been considered; they would be less in making cheese from condensed milk with less fluid volume of waste to process. Water evaporated from the milk can be utilized in equipment washing and in boilers and so has value. As this water is virtually free from minerals, losses of energy caused by boiler scale buildup would be less and also result in cost savings in energy. It is also realized the yields from this study do not necessarily reflect those obtained in industry; it was felt their use here for purposes of comparison of the different manufacturing approaches was justified since they reflected differentials that likely would occur with the substrates and attendant procedures studied.

SUMMARY AND CONCLUSIONS

Cheddar cheeses were manufactured from condensed whole milks and milks which were condensed as skim then their cream added back. The cheeses were compared with cheddar cheeses made from uncondensed whole milk based on results of chemical analyses, organoleptic evaluations, and yield determinations.

Condensed cheesemilks exhibited higher acid degree values than whole cheesemilks. This would indicate that more lipolysis or rancidity was induced in the condensing process.

Condensed milk wheys had lower fat contents than did wheys from cheeses made from uncondensed milk at the same time. Lower curd and fat losses were sustained via condensed-as-whole milk cheese wheys than in condensed-as-skim milk cheese wheys.

Overall, compositions of the cheeses manufacturing during the study were similar except total protein contents were lower in condensed milk cheeses. The rate of formation of water soluble nitrogenous compounds also differed between condensed and uncondensed milk cheeses in that condensed milk cheeses tended to form water soluble nitrogenous compounds more slowly at the beginning then increase in rate of formation as aging processed. Yields were higher when cheeses were made with condensed milk. All cheeses were similar in flavor, body, and texture as indicated by results of organoleptic evaluations.

Cost analysis indicated economic advantages resulted from the use of condensed milk for cheese manufacture. Labor, starter, and coagulant costs were less; as a further advantage, more milk solids were processed per vat if the milk were first condensed. It is realized that yield data generated in the study do not reflect those yields obtained in industry and that many costs relative to the operation of cheese plant were not calculated in the analysis. However, results of the cost analysis indicated there were economic benefits from using condensed milk for cheddar cheese manufacture.

REFERENCES

1 Alimordanova, M. K. 1974. Rennet coagulability of concentrated milk. Sernopererabatyvavshchayor i Pishchevaya Promyshlennost. No. 3, 144-148, 157. As cited in Dairy Sci. Abstr. 38(12):8264.

2 American Public Health Association. 1978. Standard methods for the examination of dairy products. 14th ed. APHA, Washington, DC.

3 Association of Official Analytical Chemists. 1980. Official methods of analysis. 13th ed. AOAC, Washington, DC.

4 Bassett, H. J., K. R. Spurgeon, and A. M. Swanson. 1951. A study of changes in cheese protein during ripening. J. Dairy Sci. 34:475.

5 Bhanumurthi, J. L., T. S. Sudersanam, M. R. Srinivasan, and O. Samlick. 1972. Application of the technique of preconcentration for long distance transport of rural milk. Indian Dairyman 24(12): 329-332. As cited in Dairy Sci. Abstr. 35(10):3893.

6 Bryzgin, M. I., T. V. Popova, and A. M. Shlygina. 1969. Ripening of soft cheese made from concentrated milk. Moloch. Prom. 30(5): 8-11. As cited in Dairy Sci. Abstr. 32(3):1013.

7 Bryzgin, M. I., T. V. Popova, and A. M. Shalygina. 1970. A protein dairy product from slightly concentrated milk. XVIII International Dairy Congress Vol 1E, Brief Communications.

8 Bryzgin, M. I., A. M. Shlygina, T. V. Popova, and P. V. Vasil'ev. 1969. Method for the manufacutre of a protein milk product. USSR Patent 235-538. As cited in Dairy Sci. Abstr. 32(1):55.

9 Bundgaard, A. G., Olsen, O. J., and R. G. Madsen. 1972. Ultrafiltration and hyperfiltration of skim milk for production of various dairy products. Dairy Industries. 37:539.

10 Chapman, H. R. 1974. The effect the chemical quality of milk has on cheese quality. Dairy Industries 39:329.

11 Covachevich, H. R., and F. V. Kosikowski. 1978. Mozzarella and cheddar cheese manufacture by ultrafiltration principles. J. Dairy Sci. 61:701.

12 Custer, E. W. 1977. The yield and quality of cheddar cheese. I. The effect of high and low solids milk. J. Dairy Sci. 60(Suppl. 1):55. (Abstr.)

13 Denkov, T. S. 1973. Study of syneresis in manufacture of white pickled cheese from partly concentrated cows' milk. Izvestiga, Nauchmoizsledovatelski Institut po Mlechna Promishlenost. 7:81-90. As cited in Dairy Sci. Abstr. 36(11):568.

14 Eckles, C. H., W. B. Combs, and H. Macy. 1951. Milk and milk products. 4th ed. McGraw-Hill Book Co., Inc., New York.

15 Ernstrom, C. A. 1978. Milk clotting enzymes and cheese chemistry - Part I. Milk-clotting enzymes and their actions. Page 730 in Fundamentals of dairy chemistry. 2nd ed. B. H. Webb, A. H. Johnson, and J. A. Alford, ed. AVI Publ. Co., Inc., Westport, CT.

16 Fif, C. L., and J. B. Curr. 1981. Component pricing . . . lessons from the butterfat experience. Hoard's Dairyman 125(6):457.

17 Flueler, O., and Z. Puhan. 1977. Ultrafiltration in the manufacture of quarg. Schweizerische Milchzeitung 103(47):339-340. As cited in Dairy Sci. Abstr. 39(11):6229.

18 Greenback, G. R., and M. J. Pallansch. 1961. Migration of phosphatides in processing dairy products. J. Dairy Sci. 44:1597.

19 Hanrahan, F. P., H. E. Walter, A. M. Sadler, and R. P. Tittsler. 1963. Modified equipment for pasteurizing and deodorizing market milk for pasteurizing, deodorizing, and slightly concentrating cheese milk. J. Dairy Sci. 46(1):69-72.

20 Hansen's, CHR Laboratory, Inc. 1979. Cheesemaking Chart. 9015 W. Maple St. Milwaukee, WI 53214.

21 Hargrove, R. E., and J. A. Alford. 1974. Composition of milk products. Page 38 in Fundamentals of dairy chemistry. 2nd ed. B. H. Webb, A. H. Johnson, and J. A. Alford, ed. AVI Publ. Co., Inc., Westport, CT.

22 Harper, W. J., and D. A. Seiberling. 1981. General processes for manufactured products. Page 185 in Dairy technology and engineering. W. J. Harper and C. W. Hall, ed. AVI Publ. Co., Inc., Westport, CT.

23 Kipp, W. J. 1979. A comparison of cheddar cheese yields and composition using conventional bulk set cultures and superstart concentreated cultures. M.S. Thesis, South Dakota State University, Brookings.

24 Klebnov, G. I., and P. F. D'Yachenko. 1972. Structural characteristics of the milk fat globule membrane. Prikladnaya Biokhimiya i Mikrobidagiya. 8(5):625-629. As cited in Dairy Sci. Abstr. 35(6): 2307.

25 Knez, V. 1971. New types of cheese. Vyz. Sidu. 26(10):150. As cited in Dairy Sci. Abstr. 34(2):632.

26 Krasheninin, P. F., and N. F. Gorelova. 1977. Utilization of major milk constituents in the manufacture of Rossiiskii cheese. Trudy, Usesoyuznyi Navchnoissledovated'skii Institut Maslodel'noi i Syrodel'noi Promyshlennosti. No. 21:21-26, 105-106. As cited in Dairy Sci. Abstracts. 41(12):7561.

27 Lampert, L. M. 1975. Modern dairy products. 3rd edition. Chemical Publishing Company, Inc., New York.

28 Mabbitt, L. A., and G. C. Cheeseman. 1967. The effect of concentrating milk on the fat retention property of cheese curd. J. Dairy Res. 34(1):73-83.

29 Marth, E. H. 1963. Microbial and chemical aspects of cheddar cheese ripening: A review. J. Dairy Sci. 48:869.

30 Maubois, J. L., and G. Mocquot. 1975. Application of membrane ultrafiltration to preparation of various types of cheeses. J. Dairy Sci. 58:1001.

31 Maubois, J. L., G. Macquot, and E. Blane-Patin. 1967. Effect of milk concentration on cheese dry matter after rennet coagulation. Annul. Technol. Agric. 16(4):287-299.

32 McDonald, S. T. 1982. The effects of rancid milk on cheddar cheese. M.S. Thesis, South Dakota State University, Brookings.

33 Melachouris, N. P., and S. L. Tuckey. 1966. Changes of the proteins in cheddar cheese made from milk heated at different temperatures. J. Dairy Sci. 49:800.

34 Milk Industry Foundation. 1981. Milk Facts. Washington, DC.

35 Mojonnier Brothers Co. 1925. Instruction manual for setting up and operating the Mojonnier milk tester. Bull. No. 101. Mojonnier Brothers Co., Chicago, IL.

36 Olson, N. F. 1978. Properties of milk and their relation to cheese yield. Dairy Ice Cream Field. 161(1):66.

37 Olson, N. F. 1981. Ultrafiltration of cheese milk: Taking a second look. Dairy Field 164(11):133.

38 Overby, A. J. 1969. Starter problems. Danish Dairy Industry 5:47.

39 Pavlova, A. 1958. Making cheese from concentrated milk. Mol. Prom. 19(3):33-34. As cited in Dairy Sci. Abstr. 20(7):561.

40 Peters, I. I. 1964. Homogenized milk in cheesemaking. Dairy Sci. Abstr. 26(10):457-461.

41 Price, W. V. 1927. Cheddar cheese from pasteurized milk. J. Dairy Sci. 10:155.

42 Price, V. W. 1927. Concerning the addition of calcium chloride to milk for cheesemaking. J. Dairy Sci. 10:373.

43 Price, W. V., and A. O. Call. 1969. Cheddar cheese: Comparison of effects of raw and heated milk on quality and ripening. J. Milk Food Technol. 32:304.

44 Rabb, J. R., Jr., B. L. Liska, and C. E. Parmelee. 1964. A simple method for estimating curd fines in cottage cheese whey. J. Dairy Sci. 47:92.

45 Rennich, R. 1966. Effect of mastitis on cheese yields. M.S. Thesis, South Dakota State University, Brookings.

46 Richardson, G. H., and H. E. Calbert. 1959. A storage study of a lyophilized and frozen lactic culture. J. Dairy Sci. 42:907. (Abstr.)

47 Rowland, S. J. 1938. The determination of the nitrogen distribution in milk. J. Dairy Res. 9:42.

48 Sandine, W. E. 1977. New techniques in handling lactic cultures to enhance their performance. J. Dairy Sci. 60:822.

49 Schultz, L. H. 1974. Changes in nutritional value of milk mediated by the cow. J. Dairy Sci. 57:729.

50 Schwartz, D. O. 1974. Lipolysis and rancidity. Page 220 in Fundamentals of dairy chemistry. 2nd ed. B. H. Webb, A. H. Johnson, and J. A. Alford, ed. AVI Publ. Co., Inc., Westport, CT.

51 Sellaro, R. L. 1977. Maximizing cultured product yields: The success factor. Dairy Ice Cream Field. 160(12):68F.

52 Spurgeon, K. R., J.-J. Yee, and J. H. Martin. 1981. Selection of milk for maximum yield of cheese and other dairy products. Cultured Dairy Prod. J. 16(3):5.

53 Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc. New York.

54 Sutherland, B. J., and G. W. Jameson. 1981. Composition of hard cheese manufactured by ultrafiltration. Aust. J. Dairy Technol. 36:136.

55 Tuckey, S. L., M. E. Stiles, Z. J. Ordal, and L. D. Witter. 1964. Relation of cheesemaking operations to survival and growth of Staphylococcus aureus in different varieties of cheese. J. Dairy Sci. 47:604.

56 United States Department of Agriculture. 1980. Federal and state standards for the composition of milk products (and certain non-milkfat products). Agric. Handbood 51, USDA, Washington, DC.

57 Vakaleris, D. G., and W. V. Price. 1959. A rapid spectrophotometric method for measuring cheese ripening. J. Dairy Sci. 42:264.

58 Werf, L., J. Vander, and H. A. Free. 1974. Collaborative study of the use of a convenient salt measuring titrator for monitoring salt concentration in meat, fish, and cheese. J. AOAC 54(3):587-589.

59 Wilster, G. H. 1974. Practical cheesemaking. 12th ed. Oregon State Univ. Book Stores, Inc., Oregon State Univ., Corvallis.

60 Yee, J. J. and K. R. Spurgeon. 1978. Seasonal and regional differences in the composition of cows' milk in South Dakota. South Dakota Agric. Exp. Sta. Tech. Bull. 46.

APPENDIX

APPENDIX TABLE 1. Computation of estimated processing costs and returns from cheese made during a 16 h day from 681,818 kg (1,500,000 lb) of milks condensed to 14.75% total solids.

Costs

1) Milk 681,818 kg (1,500,000 lb) @ $11.85 per 45.45 kg (100 lb)	$177,737.00
2) Labor 5 men for 10 vats	
1 man at the evaporator (1st shift)	
1 man at the draining tables	
1 man packaging	
2 men cooler	
10 men first shift; 9 men second shift	
19 men at 8 h each = 152 men-h/16 h day; 152 x $8.25/h =	1,254.00
3) Evaporator - run 5.66 h daily @ $15.22/h	86.15
4) Starter - Superstart; 1 can per 2,268 kg (5,000 lb) milk; 240 cans per day @ $10	2,400.00
5) Rennet extract - 3.64 liters/vat x 30 vats @ $15.00 per liter	1,638.00
6) Steam for vats - $3.50 for 454 kg (1,000 lb) steam; 454 kg (1,000 lb) steam per vat; 30 vats	105.00
7) Packaging in 227 kg (500 lb) barrels;	
278 barrels for condensed as whole milk cheese @ $2.00	556.00
287 barrels for condensed as skim milk cheese @ $2.00	574.00
TOTALS - Cheese from milk condensed as whole	$183,776.15
Cheese from milk condensed as skim	$183,794.15

Returns

Cheese from milk condensed as whole milk (9.26% yield) / 63,136 kg (138,900 lb) cheese @ $3.30/kg ($1.50/lb) =	$208,350.00
Cheese from milk condensed as skim then recombined with own cream (9.57% yield) / 65,250 (143,550 lb) cheese @ $3.30/kg ($1.50/lb) =	$215,325.00

Net Profits

Cheese from milk condensed as whole milk, net profit	$\frac{24,573.85}{63,136}$ =	$0.389/kg cheese $0.177/lb cheese =	$24,575.85
Cheese from milk condensed as skim milk then recombined with own cream, net profit	$\frac{31,530.85}{65,250}$ =	$0.483/kg cheese $0.220/lb cheese =	$31,530.85

APPENDIX TABLE 2. Computation of estimated processing costs and returns from cheese made from 681,818 kg (1,500,000 lb) uncondensed milk in a 16 h day.

Costs	
1) Milk - 681,818 kg (1,500,000 lb) @ \$11.85 per 45.45 kg (100 lb)	\$177,737.00
2) Labor - 7 men for 13 vats 1 man at draining table 1 man packaging 2 men cooler 11 men x 2 shifts = 22 men 22 men at 8 h each = 176 man-h/16 h day; 176 x \$8.25/h =	1,452.00
3) Starter - Superstart; 1 can per 2,268 kg (5,000 lb) milk; 300 cans/day @ \$10.00	3,000.00
4) Rennet extract - 3.65 liters/vat x 37.5 vats @ \$15.00/liter	2,047.50
5) Steam for vats - \$3.50 for 454 kg (1,000 lb) steam; 454 kg (1,000 lb) steam/vat; 37.5 vats	131.25
6) Packaging in 227 kg (500 lb) barrels; 248 barrels @ \$2.00/barrel	496.00
TOTAL	\$184,863.75
Returns (8.25% yield)	
56,133 kg (123,750 lb) cheese @ \$3.30/kg (\$1.50/lb) =	\$185,625.00
Net Profit	
\$761.25 ÷ 56,133 kg cheese	\$0.014/kg cheese \$0.006/lb cheese

Appendix Figure 1. American Dairy Science Association cheddar cheese score card.

CONTEST

DATE _______ ADSA CHEDDAR CHEESE SCORE CARD DISA ______ CONTESTANT NO. ___

PERFECT SCORE	CRITICISMS	Sample No. 1	2	3	4	5	6	7	8	9	10	TOTAL GRADE
FLAVOR	CONTESTANT SCORE →											
NO CRITICISM 10 NORMAL RANGE 1-10	GRADE SCORE											
	GRADE CRITICISM											
	ACID											
	BITTER											
	FEED											
	FERMENTED/FRUITY											
	FLAT/LACKS FLAVOR											
	GARLIC/ONION											
	HEATED											
	MOLDY											
	RANCID											
	SULFIDE											
	UNCLEAN											
	WHEY TAINT											
	YEASTY											
BODY AND TEXTURE	CONTESTANT SCORE →											
NO CRITICISM 5 NORMAL RANGE 1-5	GRADE SCORE											
	GRADE CRITICISM											
	CORKY											
	CRUMBLY											
	CURDY											
	GASSY											
	MEALY											
	OPEN											
	PASTY											
	SHORT											
	WEAK											
COLOR	ALLOWED PERFECT IN CONTEST →	X	X	X	X	X	X	X	X	X	X	
FINISH	ALLOWED PERFECT IN CONTEST	X	X	X	X	X	X	X	X	X	X	
TOTAL	TOTAL SCORE OF EACH SAMPLE →											
	TOTAL GRADE PER SAMPLE											

FINAL GRADE ______

RANK ______

TEAM RANK

Code	Grade
1	
2	
3	
TOTAL	
RANK	

Appendix Figure 2. Suggested flavor and body and texture scores with designated intensities of flavor defects for cheddar cheese.

Defect	Intensity: Slight	Definite	Pronounced
Flavor			
Acid	9	7	5
Bitter	9	7	4
Feed	9	8	6
Fermented/fruity	8	6	5
Flat/lacks flavor	9	8	7
Garlic/onion	6	4	1
Heated	9	8	7
Moldy	7	5	3
Rancid	6	4	1
Sulfide	9	7	4
Unclean	8	6	5
Whey taint	8	7	5
Yeasty	6	4	1
Body and Texture			
Corky	4	3	3
Crumbly	4	3	3
Curdy	4	3	2
Gassy	3	2	1
Mealy	4	3	2
Open	4	3	2
Pasty	4	3	1
Short	4	3	2
Weak	4	3	2