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Evaluation of Yield and Quality of Cheddar Cheese Manufactured from Milk with Added Whey Protein Concentrate

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EVALUATION OF YIELD AND QUALITY OF CHEDDAR CHEESE MANUFACTURED FROM MILK WITH ADDED WHEY PROTEIN CONCENTRATE

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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To my family and friends, this thesis is dedicated.

KAB

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Introduction

Large quantities of whey are produced as a by-product from the manufacture of cheese or casein. The United States has an annual cheese production of about 2.2 billion kg. The cheese industry has also experienced a steady increase in cheese production of about 6% a year (44). In the process, nearly 18.1 billion kg of whey are produced. Whey was once a discarded product of little value to the cheese producers. With the advent of laws and regulations governing the disposal of whey, whey became a problem that had few solutions. Even today, with the high cost of disposal and the need to reduce environmental pollution, only about 60% of the whey produced in the United States is processed (72).

Concentrating and drying whey eliminates water for easier handling of the product, and increases keeping quality. By far, the single largest use of whey solids is in the form of dry whey. Dry whey powders are used as commodity ingredients mostly in human food applications (65). Use of whey proteins has been limited because of poor physical and functional properties of the commercial products. Within the last 10 years, the efficient and economical removal of the water from whey by membrane filtration has become accepted in the dairy industry.

Research results have indicated some advantages for the use of ultrafiltration (UF) for removal of some of the milk serum before cheese manufacture. These include increased productivity and improved cheese yields. The largest use of membrane techniques in the dairy industry is to fractionate whey. Most research indicates that whey protein concentrates (WPC) produced by UF have superior functional properties over conventional heat coagulated wheys. The present commercial market for WPC is small, but considerable evidence indicates that more product formulation work is needed to move WPC into the general marketplace. The purpose of this research was to determine if reconstituted WPC could be used as an additive to milk for cheese making to increase yields.

Literature Review

Milk quality is determined by the proportions and properties of individual constituents, together, with the physical, organoleptic, and microbiological characteristics of the milk. Many dairy manufacturing processes are designed to alter the physical properties of milk. Included are manufacturing processes such as cheese making, cream separation, churning, drying, casein manufacture, and various types of fermentation. All are desirable and have provided man with a means of food preservation during surplus periods. The composition of milk exerts an important role in the manufacture of cheese.

Milk Composition

The average composition of bovine milk is 87% water, 4% fat, 3.3% protein, 5% lactose, and .7% ash (2). Water is quantitatively the most abundant component of bovine milk. The water content of milk can range from 82 to 90% (2). The physical properties of milk are those of water modified by the presence of the other constituents.

Fat

Fractionation of milk fat into its different constituents has received attention over the years (49,57). Milk fat is a mixture of triglycerides, diglycerides, monoglycerides, phospholipids, sterols, sterol esters, free fatty acids, and hydrocarbons. Triglycerides comprise up to 97 to 98% of the fat (36). The lipid content of Cheddar-type cheese has been reported to contribute more to the development of flavor than any other component of the cheese (50).

Protein

Milk proteins have recently been reviewed (6,37) and nomenclatures have been summarized in successive reports by a committee of the American Dairy Science Association (14,30,52,63,66). Casein is the principal protein in milk, accounting for about 80% of the total milk protein. Casein accounts for almost all of the protein of cheese. It is present in micellar complexes with calcium and inorganic phosphate. The caseins were defined originally as those phospho-proteins that precipitate from raw skim milk by acidification to pH 4.6 at 20°C (30). Presently, it has been recommended that caseins be identified according to homology of their amino acid sequences into the four categories: alpha_{s1}-, alpha_{s2}-, beta-, and kappa- caseins (14).

Kappa-casein differs from alpha_{s} and beta caseins in that it contains a bound carbohydrate and is cross-linked by disulfide groups (33). It contains a $\text{phenylalanine}_{105}$-$\text{methionine}_{106}$ peptidyl bond that is sensitive to attack by the enzyme, rennin (15). The hydrolytic cleavage of the phenylalanine-methionine linkage results in a loss of stability of casein micelles. This is the primary enzymatic phase of milk coagulation. In the secondary or nonenzymatic phase, the resulting para-kappa casein, in the presence of Ca^{++}, precipitates and forms a smooth gel. The network of precipated casein, or coagulum, produced by rennet mechanically traps most of the fat, insoluble salts, and a small quantity of the lactose and soluble whey proteins of milk.

Whey proteins are those that are soluble at pH 4.6 and 20°C. Thus, whey proteins are not normally included in the cheese structure. They are compact, globular proteins ranging in molecular weight from 16,000 to 5,000,000 (52). The whey proteins are stable to acid but sensitive to heat denaturation. The major components of this fraction are: beta-lactoglobulin, alpha-lactalbumin, serum albumin, immunoglobulins, and proteose-peptones.

The nonprotein nitrogen fraction of milk comprises about 5% of the total nitrogen (56), but in recent years amounts from 2.8 to 10% have been reported (8). Non-protein nitrogen is any compound that contains nitrogen, but is not present in the polypeptide form of protein. Examples are urea, ammonia, salts of ammonia, uric acid, creatine, and orotic acid.

Milk Sugar

Lactose is the predominant carbohydrate of milk ranging from 3.5 to 6.0%. It typically accounts for up to 40% of the total solids content (2). Lactose comprises about 70% of the solids in cheese whey and thus whey is the major raw material for lactose production. In 1984, the Whey Products Institute (65) reported that 43.15 million kg of lactose were produced from whey in the United States.

Vitamins

Vitamins are organic compounds that are required in small amounts for satisfactory body maintenance. Milk contains vitamins A, D, E, and K which are fat soluble. Both skim and low fat milks are required to be fortified with 2000 International units of vitamin A per quart and optionally with 400 International units of vitamin D per quart (2). Milk is usually considered a poor source of vitamin C, but some manufacturers have a vitamin C fortified milk available. Milk is a fairly good to excellent source of the B complex vitamins supplying from 0.8 to 10.4 mg/l of fluid whole milk (23).

Enzymes

A large number of enzymatic activities have been detected in milk and some milk enzymes have been isolated in pure form. Shahani et al. (55) reported that 20 milk enzymes have been isolated in pure form. Most enzymes present in milk serve no known function.

Minerals

A large number of elements are present in milk. The major minerals found in relatively large amounts in bovine milk are calcium, phosphorus, sodium, magnesium, chlorides, and potassium. Milk is usually considered a poor source of iron, copper, iodine, and flourine (31). Many trace minerals in microgram amounts or less are also present.

Gases

The gases, carbon dioxide, nitrogen, and oxygen are also present in bovine milk as it comes from the udder. The percent of each change upon contact with air (2).

Cheese

Cheese is a food of high nutritive value, often containing up to 10 times the amount of fat and protein found in the original milk. Most Cheddar cheese is made from pasteurized whole milk. If made from raw milk the cheese must be aged at least 60 days at temperatures not less than 1.7°C (19). This will insure the destruction of pathogens that might be present in raw milk cheese.

Curd formation can be initiated by adding cultures of bacteria and rennet to the milk. The cultures may be single or multiple strains of bacteria, usually from the genera Lactobacillus or Streptococcus. Proper control of acid production by starter bacteria is essential to avoid either acid flavor or lack of flavor in Cheddar cheese. An essential role for these bacteria in the development of flavor has been established (51). An acid environment also aids the action of the pepsin in the rennet, aids in moisture expulsion, protects against the growth of undesirable bacteria, and influences changes in the curd during cheddaring (67).

Cheddar cheese is defined under the federal standards of identity and must contain a minimum fat content of 50% by weight of the solids and a maximum moisture content of 39% by weight (19). The typical composition of Cheddar cheese is 37% moisture, 32% fat, 22% protein, 1.6% salt, and 3.7% ash (33).

Whey

Whey is the liquid remaining after removal of casein and fat from milk in the processes of cheese or casein manufacture. It is considered to be the most burdensome by-product of the dairy industry. The disadvantages of whey are its high volume, low total solids, and high biological oxygen demand (BOD). The Environmental Protection Agency forbids the disposal of whey into lakes and rivers, and disposal through the municipal sewage system is costly (32).

Since whey is a well balanced source of essential amino acids and important milk minerals and vitamins its disposal by any means is unacceptable to those concerned with the conservation of food energy. The nutritional superiority of whey proteins have been well established (11,20,41,68). The protein efficiency ratio (PER) of whey protein is 3.1 compared to 2.5 for casein. Yet, only about 60% of the total quantity of whey produced in the United States is processed (72).

The two major types of whey are acid and sweet whey produced from cottage cheese and Cheddar type cheeses, respectively. The typical composition of fluid sweet whey is 6.35% total solids, 93.7% water, 0.5% fat, 0.8% total protein, 4.85% lactose, and 0.5% ash, and that of acid whey is 6.5, 93.5, 0.04, 0.75, 4.9, and 0.8%, respectively. Acid wheys are more corrosive to equipment than sweet wheys, because of their low pH, and are usually neutralized.

Mavropoulou and Kosikowski (40) reported on the composition, solubility, and stability of acid and sweet whey powders. Acid whey powders possessed the lowest levels of amino acids and thus contained a lower total protein content than sweet wheys. Protein values were 11% and 13% for acid and sweet whey. Acid whey powders contained approximately 35% more calcium and higher percentages of other minerals than sweet whey powders. This is probably due to minerals being more soluble at lower pH values and therefore would not be trapped in the cheese curd. Sodium, potassium, and most phospholipids, and vitamin contents did not differ between the two powders. In general, acid whey powders are more stable during storage at room temperature than the sweet whey powders.

Whey Availability

In 1984, the Whey Products Institute (65) reported the following figures for the production of whey and whey products used as food and feed (in thousands of pounds): concentrated whey solids, 132,324; dry whey, 894,173; reduced lactose whey, 60,050; reduced minerals whey, 26,034; whey protein concentrate, 95,124; lactose, 120,188; and whey solids in wet blends, 132,964; giving a total of 1,460,821 thousand pounds, or 662,617 thousand kg. The major use of whey is in the dry form as a supplement for human food. All of the previous whey products, except concentrated whey solids, dry whey, and WPC have decreased in production since 1981 (65). Even though extraction processes for producing WPC have been available to the dairy industry for years (45,72), they have been slow in gaining industry acceptance. In 1982, only 8% of the total whey solids were fractionated as WPC (71). However, in the past 5 years the production of WPC have increased about 700% (72).

Whey Protein Concentrates

In 1976, Morr (45) indicated that WPC's were commercially available or potentially available, and that these new products were without enough commercial end uses to avoid surpluses. Similarly, in 1982, the New York State Energy Research and Development

Authority (71) concluded that the present market for WPC was small, but could be greatly increased.

The legal definition of WPC is: the substance obtained by the removal of sufficient nonprotein constituents from whey so that the resulting product contains not less than 25% protein. As with liquid whey, WPC can be used as a fluid, concentrate or in a dry product form (18).

There are six processes that can be used separately or in sequence to produce WPC's. They are: ultrafiltration, heat coagulation, electrodialysis, poly-phosphate precipitation, gel filtration, and ion exchange (71,72). Morr et al. (45) found wide compositional differences among WPC prepared by a given process and even wider differences in the composition of WPC from different processes. Whey protein concentrates can contain from 15 to 81% protein, 12 to 86% lactose, 1 to 18% minerals, and 1 to 9% fat (10).

Ultrafiltration is probably the most appropriate and widely used process for the manufacture of WPC's. In UF, the separation of macromolecules from low molecular weight solvents is possible. The whey is circulated over a semi-permeable membrane which allows water, dissolved mineral salts, and lactose to pass through, while the protein becomes concentrated. The WPC's can contain from 30 to 70% protein, but the high lactose to protein ratio in whey makes it difficult to prepare WPC by UF with more than 50 to 60% protein (10).

In general, protein concentrated by UF remains undenatured and exhibits good solubility over a wide range of pH, good whippability, and good emulsification properties (25,28,47,60). Thompson and Reyes (60) modified WPC by succinylation and found that all functional properties except whippability were improved.

Feed and Food Uses of Whey and WPC's

Whey and WPC's are becoming important ingredients in many food and animal products because of their potential value for improving nutritional quality and functional characteristics (25,26,42,61,62). A basic review by Schingoethe (54) on the use of whey proteins in dairy cattle rations concluded that ruminants can consume up to 29% of their intake of dry matter as liquid whey with good results. Muller (48) reported on the manufacture of calf milk replacers in which 50% of the solids-not-fat were derived from skim milk and the other 50% from Cheddar cheese WPC.

Wingerd (68) found that the addition of WPC to corn meal, wheat flour or rice would about double the protein efficiency of these cereal grains. Similarly, Forsum (21) proposed the use of WPC as a supplement to maize, rice, and potatoes.

Holsinger (26) found that whey protein enriched orange juice was more acceptable with a better flavor and smoother body than that of a control juice. Zall (72) stated that 39 million kg of WPC could be incorporated into the market as beverage fortifiers.

Broome et al. (4) found that yogurt could be manufactured with no taste or textural problems from skim milk in which liquid WPC replaced upto 25% of the milk volume. They also found that the rate and acid production of the organisms used were stimulated by the presence of WPC. The same stimulation did not occur in factory trials. Other researchers (24,29) found similar results when whey was added to yogurt.

Ice cream is also a suitable product into which whey and WPC's can be incorporated (62,70,72). Economically, WPC may replace most if not all, of the milk-solids-not-fat in ice cream and some of the stablilzer (72). Presently only 25% of the milk-solids-not-fat may be replaced with whey solids(17). Thompson et al. (62) used succinylated WPC as a substitute for nonfat dry milk in ice cream mixes and instant puddings. The modified WPC acceptably replaced up to 10% of the milk solids in both products. Higher levels decreased acceptability and flavor scores.

Spurgeon and Seas (59) reported that Dulce de Leche, a sweetened condensed milk product, was improved by the addition of whey solids. Amounts of up to 8% whey solids produced a product that was smoother in texture and had a better overall flavor than control lots. However, when dry whey was added at 15% of the total solids an objectionable whey flavor was produced.

Processing Techniques to Increase Cheese Yields

The casein and fat contents of milk determine its theoretical cheese yield. To obtain increased yields and meet legal requirements, standardization of milk to the optimum fat-to-casein ratio is practiced. The best yield and quality of Cheddar cheese comes from milk that contains one part fat to 0.7 parts casein (33,67). Standardizing milk for cheese making will usually eliminate variation in the cheese composition and variation in body, texture, and quality of the cheese. Since cheese yield is one of the most economically important aspects of cheese manufacturing, many methods have been employed to increase cheese yields. Several have indirectly incorporated whey proteins into the cheese structure (34,53).

Vacuum Concentration of Milk

Manufacturing cheese from pre-concentrated milk can increase cheese yields (3,38,53) and decrease the volume of whey produced (38). Mabbit and Cheeseman (53) speculated that increased yields obtained using pre-concentrated milks were a result of casein micelles, or whey proteins, interacting with the milk fat globule membrane, causing fats to be retained and an increase in the amount of whey solids that were incorporated into the cheese curd.

Precheeses

Most research on membrane filtration of milk for cheese manufacture has evaluated the use of UF techniques to concentrate the milk (7,16,34,35,39). Ultrafiltration techniques can be used to obtain a liquid/solid product known as pre-cheese. The milk in this form has to be reconstituted with fat and water. The mixture is then usually homogenized to incorporate starter and rennet into the slurry. This process has been successful in the preparation of soft cheeses of the camembert type (39). Cheddar cheese made by this procedure was crumbly and corky in body and lacked typical Cheddar cheese flavor (9).

Retentate Supplementation

Kosikowski et al. (34,35) manufactured cottage and Cheddar cheese from milks supplemented with skim and whole milk retentates to 1.7:1 total protein concentration. Experimental Cheddar cheeses manufactured by this procedure displayed increased yields and better textural and flavor qualities than control cheeses. Total solids, total protein and ash losses in whey were reduced. Similarly, cottage cheese yields were increased and an optimum cottage cheese was obtained from retentate-supplemented skim milks. Kosikowski indicated that the biggest advantage of retentate supplementation is the retention of whey proteins in the cheese.

Heat Treatment of Cheese Milk

Cottage cheese yields were increased by heating milk to high temperatures (12,64). Others (12,13) have shown increased yields of cottage cheese as a result of heating and storing milk. Melachouris et al. (43) indicated that excessive heat treatments of milk will result in an inferior, slow curing cheese.

The major components of milk are heat labile and can be changed physically and/or chemically by heat treating milk. Harper (22) summarized the effect of heat on the major components of milk. He noted that many of the changes in heated milk arise from changes in the whey proteins or through heat-induced interaction of the proteins. Heated whey proteins apparently bind to casein micelles and account for some of the increase in cheese yield of heated milk. Researchers (13,22,46,58) stated that more than one mechanism is involved in the inclusion of proteins with micelles. The types of interactions that are probably responsible for milk protein associations are disulfide bridging, calcium linkages, and hydrophobic bonds.

Jablonka et al. (27) showed that pre-heat treated milk had a marked effect on the protein content of whey. Treatments of 70°C for 10 min decreased the protein content of whey by 27% and decreased the volume of settled heat-precipitated whey by 50 to 70%. Dzurec and Zall (13) postulated that the heat treatment of milk caused increased cheese yields by the inclusion of more whey proteins and soluble casein being associated with casein micelles. They showed that casein content increased from control milks to heat treated and stored milks, and that the mean whey protein fraction decreased.

Whey Addition to Cheese

Whey proteins in the undenatured state are highly water soluble. The denaturation of whey proteins changes their configuration by exposing sulfhydryl groups and therefore allows them to readily aggregate. Denatured whey proteins can be used as an addition to the milk for cheesemaking (1,5).

Wingfield (69) added dry whey at the time of hooping and unexpectedly found that protein values were significantly lower in cheeses with added whey solids. An open sticky cheese was produced that had a weak body and a mottled appearance. The dry whey did not go readily into solution or mix with the salted curd.

Brown and Ernstrom (5) manufactured Cheddar cheeses using whey concentrated by UF to between 9.8 and 20.3% solids and then heated the liquid concentrate at 75°C for 30 min. Whey for the first vat of experimental cheese was collected from a vat of control cheese made for that purpose. Succeeding vats used the whey from the previous vats of cheese and this allowed for a cumulative effect of whey concentration from vat to vat. Cheeses were ripened and evaluated at 2 months. Experimental and control cheeses (5) did not differ significantly in any specific flavor or body/texture defects, except acid. Cheeses with added WPC were lower in fat than control cheeses and had higher moisture contents. The average yields of experimental cheeses were 4% over that of controls.

Abrahamsen (1) manufactured Norwegian Saint Paulin cheese with added liquid WPC. Sweet whey was ultrafiltered and contained

14% total solids and 8.75% protein. The concentrate was heat treated at 2 different temperatures: 81°C and 95°C for 15 sec. Milk was fortified at 3 levels (2.5, 5.0, and 10.0% by weight of the milk) with the concentrated whey. Cheeses manufactured from fortified milk had higher yields (1). Whey protein concentrate additions that were heat treated at 81°C increased cheese yields from 1.0% to 11%. Whey protein concentrated heat treated at 95°C increased cheese yields from 9 to 17% over the control cheeses. Abrahamsen (1) reported some of this could be attributed to the higher moisture content of the cheese. The bodies of the experimental cheeses were reported as loose and doughy. All experimental cheeses exhibited a sour off-flavor.

References for Introduction and Literature Review

1 Abrahamsen, R. K. 1979. Cheesemaking from milk fortified with whey protein concentrate. Milchwissenschaft 34:65.

2 Atherton, H. V., and J. A. Newlander. 1977. Chemistry and testing of dairy products. 4th ed. AVI Publishing Co., Inc., Westport, CT.

3 Bemis, C. A. 1984. Manufacture of Cheddar cheese using vacuum concentrated milks. M. S. Thesis, South Dakota State University, Brookings.

4 Broome, M. C., N. Willman, H. Roginski, and M. W. Hickey. 1982. The use of cheese whey protein concentrate in the manufacture of skim milk yogurt. Aust. J. Dairy Technol. 37:139.

5 Brown, R. J., and C. A. Ernstrom. 1982. Incorporation of ultrafiltration concentrated whey solids into Cheddar cheese for increased yield. J. Dairy Sci. 65:2391.

6 Brunner, J. R. 1981. Cow milk proteins: Twenty-five years of progress. J. Dairy Sci. 64:1038.

7 Bush, C. S., C. A. Garoutte, C. H. Amundson, and N. F. Olson. 1983. Manufacture of Colby and brick cheeses from ultrafiltration milks. J. Dairy Sci. 66:415.

8 Cerebulis, J., and H. M. Farrell, Jr. 1975. Composition of milks of dairy cattle. I. Protein, lactose, and fat contents and distribution of protein fraction. J. Dairy Sci. 58:817.

9 Covacevich, H. R., and F. V. Kowsikowski. 1978. Mozzarella and Cheddar cheese manufacture by ultrafiltration principles. J. Dairy Sci. 61:701.

10 Delaney, R. A. M. 1976. Composition, properties and uses of whey protein concentrate. J. Soc. Dairy Tech. 29:91.

11 Demott, B. J. 1972. Nutritional value of casein and whey protein. Food Prod. Dev. 6:88.

12 Dzurec, D. J., and R. R. Zall. 1981. Effect of on farm heating and storage of milk on cottage cheese yield. J. Dairy Sci. 65:2296.

13 Dzurec, D. J., and R. R. Zall. 1985. Effect of heating, cooling, and storing milk on casein and whey proteins. J. Dairy Sci. 68:273.

14 Eigel, W, N., J. E. Butler, C. A. Ernstrom, H. M. Farrell, Jr., V. R. Harwalker, R. Jenness, and R. McL. Whitney. 1984. Nomenclature of the proteins of cows milk: Fifth revision. J. Dairy Sci. 67:1599.

15 Ernstrom, C. A. 1974. Milk clotting enzymes and their action. Page 662 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 Ernstrom, C. A., B. J. Sutherland, and G. W. Jameson. 1980. Cheese base for processing. A high yield product from whole milk by ultrafiltration principles. J. Dairy Sci. 63:228.

17 Food and Drug Administration. 1983. Code Fed. Reg. 21 CFR. part 135.110. U. S. Govt. Publ., Washington, DC.

18 Food and Drug Administration. 1983. Code Fed. Reg. 48(15): 2743. U. S. Govt. Publ., Washington, DC.

19 Food and Drug Administration. 1981. Code Fed. Reg. 46(172): 44434. U. S. Govt. Publ., Washington, DC.

20 Forsum, E. 1974. Nutritional value of whey protein concentrates and their fractions. J. Dairy Sci. 57:665.

21 Forsum, E. 1975. Use of a whey protein concentrate as a supplement to maize, rice, and potatoes: A chemical and biological evaluation using growing rats. J. Nutr. 105:147.

22 Harper, W. J., and C. W. Hall. 1981. Dairy technology and engineering. AVI Publishing Co., Inc. Westport, CT.

23 Hartman, A. M., and L. P. Dryden. 1974. The vitamins in milk and milk products. Page 325 in Fundamentals of dairy chemistry. 2nd ed. B. H. Webb, A. H. Johnson, and J. A. Alford, ed. AVI Publ. Co., Inc., Westport, CT.

24 Hartman, G. H. 1975. The use of whey in manufacture of yogurt. Cult. Dairy Prod. J. 10(2)6.

25 Hidalgo, J. and E. Gamper. 1977. Solubility and heat stability of whey protein concentrates. J. Dairy Sci. 60:1515.

26 Holsinger, V. H., J. P. Posati, and E. D. DeVilbiss. 1974. Whey beverages: A review. J. Dairy Sci. 57:849.

27 Jablonka, M. S., J. T. Vu, and P. A. Munro. 1984. Effect of milk preheat treatment and bovine serum albumin addition on the settling characteristics of heat precipitated whey protein. N. Z. J. Dairy Sci. Technol. 19:99.

28 Jelen, P. 1973. Whipping studies of partially delactosed whey. J. Dairy Sci. 56:1505.

29 Jelen, P., and H. Horbal. 1974. Utilization of cottage cheese whey in yogurt manufacture. J. Dairy Sci. 57:584 (abstr.).

30 Jenness, R., B. L. Larson, T. L. McMeekin, A. M. Swanson, C. H. Whitnah, and R. McL. Whitney. 1956. Nomenclature of the proteins of bovine milk. J. Dairy Sci. 39:536.

31 Johnson, A. H. 1974. The composition of milk. Page 1 in Fundamentals of dairy chemistry. 2nd ed. B. H. Webb, A. H. Johnson, and J. A. Alford, ed. AVI Publ. Co., Inc., Westport, CT.

32 Kosikowski, F. V. 1979. Whey utilization and whey products. J. Dairy Sci. 62:1149.

33 Kosikowski, F. V. 1982. Cheese and fermented milk foods. 2nd. ed. Edwards Brothers, Inc., Ann Arbor, MI.

34 Kosikowski, F. V., A. R. Masters, and V. V. Mistry. 1984. Cheddar cheese from retentate-supplemented whole milk. J. Dairy Sci. 68:548.

35 Kosikowski, F. V., A. R. Masters, and V. V. Mistry. 1984. Cottage cheese from retentate-supplemented skim milk. J. Dairy Sci. 68:541.

36 Kurtz, F. E. 1974. The lipids of milk: Composition and properties. Page 125 in Fundamentals of dairy chemistry. 2nd ed. B. H. Webb, A. H. Johnson, and J. A. Alford, ed. AVI Publ. Co., Inc., Westport, CT.

37 Lyster, R. L. J. 1972. Reviews of the progress of dairy science. Section C. Chemistry of milk proteins. J. Dairy Res. 39:279.

38 Mabbit, L. A., and G. C. Cheeseman. 1967. The effect of concentrating milk on the fat retention property of cheese curd. J. Dairy Res. 34:73.

39 Maubois, J. L., and G. Mocquot. 1975. Applications of membrane ultrafiltration to preparation of various types of cheese. J. Dairy Sci. 58:1001.

40 Mavropoulou, I. P., and F. V. Kosikowski. 1973. Composition solubility, and stability of whey powders. J. Dairy Sci. 56:1128.

41 Mavropoulou, I. P., and F. V. Kosikowski. 1973. Free amino acids and soluble peptides of whey powders. J. Dairy Sci. 56:1135.

42 McDonough, F. E., R. E. Hargrove, W. A. Mattingly, L. P. Posati, and J. A. Alford. 1974. Composition and properties of whey protein concentrates from ultrafiltration. J. Dairy Sci. 57:1438.

43 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.

44 Milk Industry Foundation. 1984. Milk Facts. Washington D. C.

45 Morr, C. V. 1976. Whey protein concentrates: An update. Food Technol. 39(3):18.

46 Morr, C. V., and R. V. Josephson. 1968. Effect of calcium, N-Ethylmaleimide and casein upon heat induced whey protein aggregation J. Dairy Sci. 51:1349.

47 Morr, C. V., P. E. Swenson, and R. L. Richter. 1973. Functional properties of whey protein concentrates. J. Food Sci. 38:324.

48 Muller, L. L., 1979. Observations on the economics of whey utilization. N. Z. J. Dairy Sci. Technol. 14:121.

49 Norris, R., I. K. Gray, A. K. R. McDowell, and R. M. Dolby. 1971. The chemical composition and physical properties of fractions of milk fat obtained by a commercial fractionation process. J. Dairy Res. 38:179.

50 Ohren, J. A., and S. L. Tuckey. 1969. Relation of flavor development in Cheddar cheese to chemical changes in the fat of the cheese. J. Dairy Sci. 52:598.

51 Reiter, B., and M. E. Sharpe. 1971. Relationship of the microflora to the flavor of Cheddar cheese. J. Appl. Bact. 34:63.

52 Rose, D., J. R. Brunner, E. B. Kalan, B. L. Larson, P. Melnychyn, H. E. Swaisgood, and D. F. Waugh. 1970. Nomenclature of the proteins of cows milk. Third revision. J. Dairy Sci. 53:1.

53 Sandfort, P. 1983. Preconcentrated cheese-milk by evaporation. Dairy Rec. 84(11):16.

54 Schingoethe, D. J. 1976. Whey utilization in animal feeding: A summary and evaluation. J. Dairy Sci. 59:556.

55 Shahani, K. M., W. J. Harper, R. G. Jensen, R. M. Parry, Jr., and C. A. Zittle. 1973. Enzymes in bovine milk: A review. J. Dairy Sci. 56:531.

56 Shahani, K. M., and H. H. Sommer. 1951. The protein and non-protein nitrogen fractions in milk II. Their content in fresh raw skim milk. J. Dairy Sci. 34:1010.

57 Sherbon, J. W. 1974. Crystallization and fractionation of milk fat. J. Am. Oil Chem. Soc. 51:22.

58 Smits, P., and J. H. Van Brouwershaven. 1980. Heat-induced association beta-lactoglobulin and casein micelles. J. Dairy Res. 47:313.

59 Spurgeon, K. R., and S. W. Seas. 1974. Dulce de leche: A new use for whey. Cult. Dairy Prod. J. 9(2):15.

60 Thompson, L. U., and E. S. Reyes. 1980. Modification of heat coagulated whey protein concentrates by succinylation. J. Dairy Sci. 63:715.

61 Thompson, L. U., D. J. Reniers, and L. M. Baker. 1982. Succinylated whey protein concentrates in meat patties and wieners. J. Dairy Sci. 65:1715.

62 Thompson, L. U., D. J. Reniers, and M. Siu. 1983. Succinylated whey protein concentrates in ice cream and instant puddings. J. Dairy Sci. 66:1630.

63 Thompson, M. P., N. P. Tarassuk, R. Jenness, H. A. Lillevik, U. S. Ashworth, and D. Rose. 1965. Nomenclature of the proteins of cows milk: Second revision. J. Dairy Sci. 48:159.

64 Vakaleris, D. J. 1962. A method for making cottage cheese. U. S. Pat. 3,039,879.

65 Whey Products Institute. 1985. Whey products: A survey of utilization and production trends for 1984. Bulletin No. 25.

66 Whitney, R. McL., J. R. Brunner, K. E. Ebner, H. M. Farrell, Jr., R. V. Josephson, C. V. Morr, and H. E. Swaisgood. 1976. Nomenclature of the proteins of cows milk: Fourth revision. J. Dairy Sci. 59:795.

67 Wilster, G. H. 1980. Practical cheese making 13th ed. OSU Bookstores, Corvallis, OR.

68 Wingerd, W. H. 1971. Lactalbumin as a food ingredient. J. Dairy Sci. 54:1234.

69 Wingfield, J. M. 1978. The effects of added dry whey on yield and acceptability of Cheddar cheese. M. S. thesis, South Dakota State University, Brookings.

70 Zall, R. R. 1976. Uses for demineralized whey protein. Am. Dairy Review 38(10):34.

71 Zall, R. R. 1982. Whey protein concentrate market enhancement. ERDA Report 82-29. New York State Energy Research and Development Authority, Albany, NY.

72 Zall, R. R. 1984. Trends in whey fractionation and utilization. A global perspective. J. Dairy Sci. 67:2621.

Evaluation of Yield and Quality of Cheddar Cheese Manufactured from Milk with Added Whey Protein Concentrate

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ABSTRACT

Cheddar cheese was produced from whole milk with blends of whey protein concentrates (WPC) added. Two WPC powders containing 35% or 55% protein were each reconstituted to a 15% (w/w) solution and heat treated at 70^{O}C for 15 min. Addition of the denatured WPC solution to the milk was at 5 or 10% by weight of the milk. Addition of reconstituted partially denatured WPC increased cheese yields from 1.4 TO 6.2% above those of the control on a 63% solids basis. The only significant (P<.05) increase in yield was from the 55% WPC solution at 10% replacement by weight of the milk. The correlation coefficient between percent denaturation in the WPC and yield in this cheese was 0.62. Experimental cheeses decreased in fat and total solids contents and increased in total nitrogen, ash, and salt. Fat reduction varied from 4.3% to 18.2% below the control cheeses and, similarly, total solids

decreased from 1.7 to 8.9% below the control cheeses. Total nitrogen values of experimental cheeses increased from 0.73 to 5.64% above the control. Cheeses were evaluated organoleptically; more flavor defects were associated with increased levels of WPC in the experimental cheeses. The most common criticism of the experimental cheeses was an atypical (unclean) cheese flavor.

Introduction

The cheese manufacturing industry has considerable interest in developing applications to use WPC. Zall (24) reported that the production of WPC in the United States increased 700% over the past 5 years. The Food and Drug Adminstration (9) lists whey protein concentrate as the substance obtained by the removal of nonprotein constituents from whey so that the resulting product contains not less than 25% protein. As with whey, WPC can be used as a fluid, concentrate, or can be dried to a powder.

Ultrafiltration (UF) has become the most common process for producing WPC. Other procedures are heat coagulation, electrodialysis, polyphosphate precipitation, gel filtration and ion exchange (24). Results of most research have indicated that WPC produced by membrane techniques have superior functional properties over conventional heat coagulated wheys (7,12,14,19).

The UF of milk for cheese manufacture has has been studied (6,8,10,11). Ultrafiltered and denatured liquid WPC has been used as an additive to milk for cheese making (1,5). Whey concentrated by UF to between 9.8 and 20.3% solids was used directly in the traditional manufacture of Cheddar cheese (5). Return of denatured liquid WPC to cheese milk increased average yield by 4%. Experimental and control cheeses did not differ significantly in any flavor or body-texture defects except acid. Abrahamsen (1) manufactured Saint Paulin cheese with added liquid WPC containing 14% total solids and 8.75% protein. The cheeses manufactured from fortified milk had increases in yield from 1 to 17% above the controls. Some of the increase in yield was attributed to the higher moisture content of the experimental cheeses. All experimental cheeses exhibited a loose and doughy body and some cheeses had a sour off-flavor.

No papers throughout the literature describing the use of reconstituted WPC as an additive to the milk for cheese making were found. The objectives of this study were to evaluate the yield, composition, and flavor of Cheddar cheese manufactured from milks with added, reconstituted, partially denatured WPC solutions.

Materials and Methods

Milk and Whey Protein Concentrates

Whole milk for Cheddar cheese manufacture was obtained from the South Dakota State University (SDSU) dairy farm and pasteurized at 63°C for 30 min. Two WPC powders for incorporation into the cheese (First District Association Cooperative, Litchfield, MN.) consisted of 35% and 55% protein and were each reconstituted to a 15% (w/w) solution. They were heat-treated at 70°C for 15 min to partially denature the whey proteins, which was promptly followed by cold water jacket cooling to 31°C. Addition to the milk of the heat-treated WPC was at 5 or 10% by weight of the milk.

Cheese Manufacture

A control and 4 experimental Cheddar cheeses were manufactured using the conventional method of Wilster (21), with the exception that denatured whey proteins were incorporated into the experimental cheeses. The 5 cheeses consisted of a control (no WPC addition), two 35% protein WPC additions at 5 and 10% by weight of the milk, and two 55% protein WPC additions at similar replacement levels. All experimental cheeses have been abbreviated as 35-5, 35-10, 55-5, or 55-10, indicating the percent protein in the WPC powder and the percent addition by weight to the milk, respectively. All cheeses were replicated eight times.

Yields were based on weight of cheddar cheese computed to 63% solids (see Appendix). Cheddar cheeses were made in pilot scale 210 liter stainless steel vats. Milk lots of 181 kg, with 0.02% $CaCl_2$ by weight of the milk were inoculated at 32°C with 33 ml thawed, direct-set, commercial frozen concentrated Superstart starter (Marschall Foods Division, Miles Laboratories, Madison WI 53701) and ripened for 30 min at 32° C. Twelve ml of annatto color (Marschall Foods Division, Miles Laboratories, Madison WI 53701) was added 15 min into the ripening period. Whey protein concentrate solutions were added to the milk during the last 5 min of ripening. Thirty ml single strength rennet extract (Marschall Foods Division, Miles Laboratories, Madison WI 53701) was added to the ripened milks. After 30 min at 32°C the curd was cut with 0.93 cm stainless steel wire knives and allowed to heal for 15 min. Then curds were brought up to 38°C in 30 min for the control cheeses, 40 min for 35-5 and 55-5 cheeses, and 50 min for 35-10 and 55-10 cheeses, and stirred for an additional 30, 40, and 50 min, respectively. Following whey removal, the curds were cheddared, milled, salted (2% by weight of the curd), and pressed overnight in 9-kg rectangular hoops. Two 9-kg cheese blocks were obtained and one was cut into eighths, wrapped in Cry-O-Vac bags (All Craft Mfg. Co. Inc., Cambridge, MA 02139) and sealed with wax. The other block was wrapped in a Cry-O-Vac film and waxed paper and heat sealed. All cheeses were stored at 7°C for 6 months.

Sampling and Analyses

Cheese milks, Cheddar cheeses, cheese wheys, and WPC's were analyzed in duplicate for fat and total solids according to Mojonnier procedure (13); ash and total protein were determined by the Association of Official Analytical Chemists (AOAC) methods (2). Nitrogen distributions in milks were determined by the Rowland method (17). Nitrogen distribution and extent of denaturation in WPC powder and WPC heat-treated solutions were determined by a procedure described by Wyeth (22). Water-soluble nitrogen of cheeses were determined by a modified method of Vakaleris and Price (20). Upon precipitation, 25 ml aliquots were removed and water soluble nitrogen was determined by the Kjeldahl method (2). Salt contents in cheeses were determined by AOAC procedure (2). The pH was obtained with a Corning Model 7 pH meter (Corning Medical, Medfield, MA 02052) and an Orion needle combination pH electrode (Orion Research Inc. Cambridge MA 02139); and titratable acidity, with 0.10 N NaOH and phenolphthalein (3).

Sensory Evaluation

Flavor and body/texture of Cheddar cheeses were evaluated by a panel of five qualified cheese graders. Samples were coded and graded at one, three, and six month intervals using a 1 to 10 scale to indicate flavor acceptability and a 1 to 5 scale for body acceptability, with 1 being unacceptable in both cases. Defect characterizations were those outlined in the official American Dairy Science Association-Dairy and Food Industries Supply Association score card for Cheddar cheese (15).

Statistical Analysis

The data were evaluated statistically using the analysis of variance procedure from Statistical Analysis System (SAS Institute Inc., Cary, NC 27511). The mean values of variables of treatments were compared by the Waller-Duncan K-ratio test (18).

Results and Discussion

Milk Composition

The mean compositional values of whole milks used for cheese manufacture are shown Table 1. Milk was obtained from May to August 1984, a time of the year when many milk components were at a typical seasonal low for South Dakota milk (23). With lower total solids, fat, and casein in the milk, cheese yield would be expected to be lower than at other times of the year.

Whey Protein Concentrate Composition

Compositional values of the two WPC powders used in this study are listed (Table 2). The protein differentiation into individual nitrogen components indicated no denatured whey protein nitrogen was present. This was evidence that the powders were not temperature abused during processing. The values were within typical composition ranges of ultrafiltered (UF) WPC powders (7).

The WPC reconstituted to 15% (w/w) total solids, contained 5.0 or 7.8% total protein for the 35% WPC and 55% WPC solutions, respectively (Table 3). The extent of denaturation in reconstituted solutions is summarized and large standard deviations for percent denaturation indicated that several of the WPC solutions were inadequately denatured (Table 3). It was found that the extent of denaturation could not be controlled accurately using a time-temperature relationship. The extent of denaturation in whey solutions is dependant upon temperature, time, pH, and concentration (16). Whey proteins not adequately denatured would be soluble and drain out at the end of the cook period. If added in the undenatured state whey proteins will not be incorporated into the cheese structure and will dilute the milk. Whey proteins heated to the extent of coagulation will precipitate out of solution and settle to the bottom of the cheese vat and therefore, would not be incorporated into the cheese curd.

Cheese Composition and Yields

Table 4 shows mean composition values of the control and experimental Cheddar cheeses. Cheese with added whey solids had decreased fat and total solids and increased moisture, total nitrogen, ash, salt, and yield of curd obtained (Table 4). These changes were relatively large and the experimental cheeses did not meet legal moisture requirements.

Addition of denatured WPC increased cheese yields from 1.4% to 6.2% above the control on a 63% solids basis. The 35-5 and 55-5 experimental cheeses had similar increases in yield of about 1.4%. The 35-10 cheeses exhibited a yield increase of 2.0% over the controls. The 55-10 cheeses gave the only significant increase in yield ($P<.05$) (Table 4). The correlation coefficient (r) between percent denaturation and yield in the 55-10 cheeses was 0.62. Cheese yields (Table 4) in other experimental cheeses only increased slightly with the addition of WPC and thus, correlations between percent denaturation and yields were not applicable.

Total nitrogen content of all experimental cheeses increased with WPC addition (Table 4). The increase in total nitrogen content was similar for the 35-5 and 55-5; and 35-10 and 55-10 cheeses being 2.2% and 3.4% above the control cheeses. The protein content of the whey solutions, whether it was the 35 or 55% protein WPC solution, had no influence on the amount of additional nitrogen being incorporated into the cheeses. Differences ($P<.05$) in water-soluble nitrogen occurred between the treatments, at day zero the 55-10 cheeses exhibited the only increase water-soluble nitrogen values (Table 5). As time progressed the 35-10, 55-5, and 55-10 water-soluble nitrogen values differed from the control cheeses. The amount of water-soluble nitrogen increased (P<.05) as time progressed for all cheeses.

The increase in the moisture content in the cheeses varied between 2.6% for the 35-5 cheese and 12.4% for the 55-10 cheese above the control. An increase in moisture content was expected, since whey protein concentrates have good water binding capacity. Berlin et al. (4) reported that 35% and 55% WPC's could bind 0.91 and 1.09 g water per gram of solids, respectively. The only attempt to reduce moisture content was a longer cook period for the experimental cheeses.

Cheese Ripening

Ripening causes chemical and physical changes to occur in cheese. The principal components which undergo change are protein, carbohydrates, and fats. Ripening can be monitored by following the hydrolysis of casein into water-soluble compounds. No differences (P<.05) in soluble nitrogen values occurred between the control and experimental cheeses (Table 5). As expected, the water soluble-nitrogen values increased as time progressed. To determine the true protein values of Cheddar cheese (Table 5), water-soluble nitrogen must be subtracted from the total nitrogen, and protein calculated from this adjusted nitrogen value. Protein contents of all cheeses were different (P<.05) over time.

Cheese Whey Composition

Total solids, total protein, and fat content of the cheese wheys increased ($P<.05$) in all experimental cheese wheys and ash contents increased ($P<.05$) in the 35-10 and 55-10 cheese wheys (Table 6).

Sensory Evaluation of Cheddar Cheeses

Mean scores for flavor and body/texture of the cheeses are shown in Table 7. Overall flavor and body/texture scores of control cheeses were higher than those of all experimental cheeses. Cheese flavor and body/texture scores showed a general increase in acceptability from the one month to the three month period, but; from the three month to the six month aging period only, the control and 35-10 cheeses exhibited increased acceptability. The most common flavor defect for experimental cheeses was an atypical or unclean cheese flavor. This could possibly have been from the high moisture in the experimental cheeses. The most common flavor defect of control cheeses was flat, lacks flavor. Some of the experimental cheeses were slightly sticky; and a few of the 35-10 and 55-10 cheeses were graded as pasty, due to their high moisture contents.

Conclusion

The addition of WPC to milk for cheese manufacture markedly affected composition and yield of the experimental cheeses as well as sensory qualities. All experimental cheeses decreased in fat and total solids and did not meet legal composition requirements. Cheeses did increase in total nitrogen, ash, and salt content. Yields increased in all experimental cheeses, with the 55-10 cheeses exhibiting the only significant (P<.05) increase. In this study no attempt was made to standardize the milk composition. Production techniques such as cutting, cooking, and milk standardization could possibly be modified to obtain satisfactory cheese composition and moisture content.

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References

1 Abrahamsen, R. K. 1979. Cheesemaking from milk fortified with whey protein concentrate. Milchwissenschaft 34:65.

2 Association of Offical Analytical Chemists. 1980. Offical methods of analysis. 13th ed. AOAC, Washington, DC.

3 Atherton, H. V., and J. A. Newlander. 1977. Chemistry and testing of dairy products. 4th ed. AVI Publ. Co., Inc., Westport, CT.

4 Berlin E., P. G. Kilman, B. A. Anderson, and M. J. Pallansch. 1973. Water binding in whey protein concentrates. J. Dairy Sci. 56:984

5 Brown, R. J., and C. A. Ernstrom. 1982. Incorporation of ultrafiltration concentrated whey solids into Cheddar cheese for increased yield. J. Dairy Sci. 65:2391.

6 Bush, C. S., C. A. Garoutte, C. H. Amundson, and N. F. Olson. 1983. Manufacture of Colby and brick cheeses from ultrafiltration milks. J. Dairy Sci. 66:415.

7 Delaney, R. A. M. 1976. Composition, properties and uses of whey protein concentrate. J. Soc. Dairy Tech. 29:91.

8 Ernstrom, C. A., B. J. Sutherland, and G. W. Jameson. 1980. Cheese base for processing. A high yield product from whole milk by ultrafiltration principles. J. Dairy Sci. 63:228.

9 Food and Drug Administration. 1981. Code Fed. Reg. 46(172): 44434. U. S. Govt. Publ., Washington, DC.

10 Kosikowski, F. V., A. R. Masters, and V. V. Mistry. 1984. Cheddar cheese from retentate-supplemented whole milk. J. Dairy Sci. 68:548.

11 Maubois, J. L., and G. Mocquot. 1975. Applications of membrane ultrafiltration to preparation of various types of cheese. J. Dairy Sci. 58:1001.

12 McDonough, F. E., R. E. Hargrove, W. A. Mattingly, L. P. Posati, and J. A. Alford. 1974. Composition and properties of whey protein concentrates from ultrafiltration. J. Dairy Sci. 57:1438.

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

14 Morr, C. V., P. E. Swenson, and R. L. Richter. 1973. Functional properties of whey protein concentrates. J. Food Sci. 38:324.

15 Nelson, J. A., and G. M. Trout. 1964. Judging dairy products 4th ed. AVI Publ. Co., Inc., Westport, CT.

16 Nielsen, M. A., S. T. Coulter, C. V. Morr, and J. R. Rosenau. 1973. Four factor response surface experimental design for evaluating the role of processing variables upon protein denaturation in heated whey systems. J. Dairy Sci. 56:76.

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

18 Steel, R. G. D., and Torrie, J. H. 1980. Principles and procedures of statistics: A biometrical approach. 2nd ed. McGraw-Hill Book Co., New York, NY.

19 Thompson, L. U., and E. S. Reyes. 1980. Modification of heat coagulated whey protein concentrates by succinylation. J. Dairy Sci. 63:715.

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

21 Wilster, G. H. 1980. Practical Cheese making 13th ed. OSU Bookstores, Corvallis, OR.

22 Wyeth, T. C. 1972. Chemical analysis of whey powders. J. Society Dairy Tech. 25:136.

23 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.

24 Zall, R. R. 1984. Trends in whey fractionation and utilization, A global perspective. J. Dairy Sci. 67:2621.

TABLE 1. Composition of milks used to manufacture Cheddar cheeses[1].

Component	Mean	SD
	-------%	-------
Total solids	11.75	.10
Fat	3.19	.16
Solids-not-fat	8.56	.12
Total protein	3.00	.05
TN[2]	.47	.008
CN[3]	.36	.006
WPN[4]	.08	.002
NPN[5]	.03	.003
Lactose	4.91	.15
Ash	.65	.04

[1]Means of eight replicates.
[2]TN= Total nitrogen.
[3]CN= Casein nitrogen.
[4]WPN = Whey protein nitrogen.
[5]NPN = Non-protein nitrogen.

TABLE 2. Composition of whey protein concentrate powders.

Component	35% protein	55% protein
	--------- %	---------
Total solids	95.57	95.23
Moisture	4.43	4.77
Fat	5.19	7.04
Lactose	46.82	27.80
Total protein	37.43	55.56
TN[1]	5.87	8.71
DWPN[2]+ CN[3]	0.00	0.00
UDWPN[4]	3.55	4.95
PPN[5]+ GMPN[6]+ NPN[7]	2.32	3.76
Ash	6.13	4.83

[1] TN = Total nitrogen
[2] DWPN = Denatured whey protein nitrogen
[3] CN = Casein nitrogen
[4] UDWPN = Undenatured whey protein nitrogen
[5] PPN = Proteose-peptone nitrogen
[6] GMPN = Glycomacro peptide nitrogen
[7] NPN = Non-protein nitrogen

TABLE 3. Whey protein (WP) and denatured whey protein nitrogen (DWPN)in reconstituted partially denatured whey protein concentrate solutions[1].

Treatment	WP		DWPN	
	mean	SD	mean	SD
	-----%----		------%-----	
35-5	5.03[a]	.40	20.42[a]	5.2
35-10	4.96[a]	.13	18.44[a]	3.0
55-5	7.82[b]	.49	27.50[b]	11.3
55-10	7.73[b]	.48	28.99[b]	5.9

[a,b]Means in same column with same letter do not differ ($P<.05$).

[1]Means of eight replicates.

TABLE 4. Yield and composition of Cheddar cheeses[1].

Component	Day	Treatment: Control	35-5	35-10	55-5	55-10
Yield[2,3]		8.84a	8.98a	9.02a	8.95a	9.42b
pH	0	5.16a	5.18a	5.15a	5.12a	5.15a
pH	180	5.24ab	5.22ab	5.26a	5.28a	5.18b
		------	------	%	------	------
TS[4]	0	61.50a	60.45b	58.07c	58.72c	56.04d
TS	180	61.20a	60.40a	57.29b	58.54c	54.25d
Moisture	0	38.50a	39.55b	41.93c	41.28c	43.96d
Moisture	180	38.80a	39.60a	42.71c	41.46c	45.75d
Fat[3]	0	30.73a	29.41b	27.34c	28.10d	25.14e
Fat[3]	180	30.76a	29.52b	26.52c	27.84d	24.76e
TN[5,3]	0	4.06a	4.11ab	4.25b	4.13ab	4.15ab
TN[3]	180	4.02a	4.12b	4.15ab	4.15ab	4.15b
Ash[3]	0	3.81a	4.02b	4.66c	4.29d	4.49e
Salt[3]	0	2.18a	2.44b	2.99c	2.84c	2.90c

[a,b,c,d,e]Means in the same row with same letter do not differ (P<.05).

[1]Means of eight replicates.
[2]kg curd per 100 kg milk.
[3]Percentages adjusted to 63% solids in the cheese.
[4]TS = Total solids.
[5]TN = Total nitrogen.

TABLE 5. Protein and soluble nitrogen of Cheddar cheeses[1].

Component	Day	Control	35-5	35-10	55-5	55-10
		Treatment				
		%				
Protein	0	24.37a	24.63a	25.32a	24.53a	24.32a
SN[2]	0	.24a	.24a	.26a	.26a	.30b
Protein	90	21.59a	21.96a	21.69a	21.91a	21.41a
SN	90	.62a	.66ab	.71bc	.67bc	.72c
Protein	180	19.54ab	20.22a	19.22b	19.41b	19.03b
SN	180	.87a	.83a	.96bc	.92b	.98c

a,b,c Means in same row with same letter do not differ (P<.05).
[1]Means of eight replicates.
[2]SN = Soluble nitrogen.

TABLE 6. Composition of whey from Cheddar cheeses manufactured with reconstituted partially denatured whey protein concentrate[1].

	Treatment				
	Control	35-5	35-10	55-5	55-10
	%				
Total solids	6.78a	7.26b	7.69c	7.25b	7.61c
Fat	.29a	.37b	.49d	.44c	.53d
Total protein	.82a	1.00b	1.19c	1.14c	1.42d
Ash	.46a	.48ab	.53c	.47ab	.49b

[a,b,c]Means in same row with same letter do not differ (P<.05).
[1]Means of eight replicates.

TABLE 7. Sensory evaluation scores of Cheddar cheeses[1].

	Treatments				
	Control	35-5	35-10	55-5	55-10
1 month					
Flavor[2]	8.2a	8.0ab	7.6c	7.7bc	7.6c
Body/texture[3]	3.1ab	3.1ab	3.0b	3.0b	3.2a
3 month					
Flavor[2]	8.5a	8.2ab	7.6c	7.7bc	7.3c
Body/texture[3]	3.8a	3.8a	3.7a	3.6ab	3.3b
6 month					
Flavor[2]	8.6a	8.1b	7.7c	7.6c	6.9d
Body/texture[3]	4.1a	3.7b	3.5b	3.5b	2.8c

[a,b,c]Means in same row with same letter do not differ ($P<.05$).
[1]Means of eight replicates.
[2]Based on a 1 to 10 scale with 10 as very acceptable.
[3]Based on a 1 to 5 scale with 5 as very acceptable.

APPENDIX

Calculations Used

Yield of cheese is one of the most economically important aspects of cheese manufacturing. To alleviate any artifically high or low yields, or differences in cheese components, caused by moisture differences among cheeses all variables of cheese other than total solids were calculated on a standard basis using the following formulas:

Adjustment of components to a 63% solids level in cheese.

$$\frac{63}{\text{Total solids in cheese}} \text{ X Percent component}$$

kg curd per 100 kg milk on a 63% solids level in the cheese.

$$\frac{\text{kg cheese X \% total solids in cheese X 100}}{\text{63\% X kg milk used}}$$

Data obtained from Cheddar cheese manufacture

Milk Data*

REP	TS	FAT	PROT	TN	NCN	NPN	PN	CN	WPN	ASH
1	1169	314	300	47	11	03	44	36	08	64
2	1191	358	309	48	12	04	44	36	08	62
3	1180	316	301	47	12	03	44	35	08	70
4	1168	312	299	47	11	03	43	36	08	65
5	1176	309	303	48	11	03	44	36	08	58
6	1171	316	291	46	11	03	42	34	08	63
7	1160	313	299	47	11	03	43	36	08	68
8	1187	315	299	47	11	03	44	35	08	67

* Data are 2 digit decimals (i.e. 44 = .44)

REP = replicate

TS = total solids

PROT = protein

TN = total nitrogen

NCN = non-casein nitrogen

NPN = non-protein nitrogen

PN = protein nitrogen

CN = casein nitrogen

WPN = whey protein nitrogen

Whey Data*

TRT	REP	FAT	TS	PROTEIN	ASH
1	1	27	682	79	45
1	2	34	691	89	45
1	3	33	679	83	51
1	4	28	682	81	48
1	5	24	672	80	38
1	6	28	678	77	48
1	7	29	668	79	50
1	8	30	671	85	46
2	1	33	704	102	48
2	2	42	728	105	49
2	3	35	731	107	54
2	4	35	726	94	51
2	5	33	726	101	37
2	6	42	724	97	47
2	7	33	714	93	50
2	8	40	756	105	55
3	1	48	776	125	51
3	2	44	776	116	52
3	3	54	783	127	55
3	4	55	762	124	52
3	5	38	759	116	52
3	6	43	740	116	54

Whey Data*

TRT	REP	FAT	TS	PROTEIN	ASH
3	7	47	761	102	50
3	8	60	805	127	55
4	1	51	728	124	44
4	2	37	721	114	47
4	3	47	732	118	55
4	4	46	732	129	49
4	5	37	710	106	41
4	6	44	720	102	42
4	7	39	704	107	50
4	8	48	752	116	51
5	1	53	756	146	47
5	2	67	786	140	50
5	3	61	756	149	54
5	4	45	748	151	51
5	5	44	753	142	44
5	6	43	748	132	46
5	7	53	744	130	53
5	8	60	798	150	51

* Data are 2 digit decimals (i.e. 44 = .44)

TRT = treatment

REP = replicate

TS = total solids

Cheese Data*

CRT	YLD	FAT	TS	TN	SN	PROT	ASH	SLT	PH	FL	BD	WN	DWN
111	893	3140	6288	418	024	2514	391	224	510				
121	878	3080	6146	387	021	2335	398	211	515				
131	896	2950	6003	396	023	2380	394	234	530				
141	895	3172	6315	399	025	2386	353	171	510				
151	880	3050	6160	413	024	2482	386	228	522				
161	883	3043	6089	394	024	2361	366	231	510				
171	885	3065	6109	379	024	2265	373	212	510				
181	862	3084	6091	386	024	2310	387	231	510				
211	917	2953	6068	415	024	2494	394	249	510			534	1720
221	918	2860	6198	394	021	2380	430	209	550			568	2011
231	905	2843	5959	388	023	2329	418	236	530			510	2347
241	922	3097	6169	394	028	2335	369	245	510			587	1413
251	884	2952	6077	411	023	2475	414	285	510			536	1639
261	873	2944	6034	392	024	2348	414	251	510			510	2716
271	923	2970	5997	386	025	2303	373	216	510			510	1683
281	846	2908	5852	376	024	2246	407	258	510			448	2807
311	910	2983	5596	401	025	2399	478	329	510			516	1786
321	885	2809	5994	408	022	2463	497	252	540			542	2125
331	895	2546	5590	382	024	2284	473	232	510			515	1344
341	915	2670	5877	390	027	2316	444	295	515			534	2239
351	900	2741	5766	383	025	2284	451	319	510			519	2099
361	917	2785	5962	395	026	2354	446	338	510			500	1611

Cheese Data*

CRT	YLD	FAT	TS	TN	SN	PROT	ASH	SLT	PH	FL	BD	WN	DWN
371	940	2689	5869	382	028	2258	468	314	512			504	1726
381	854	2654	5803	394	033	2303	473	317	515			518	1826
411	891	2773	5744	348	026	2054	455	282	510			821	3704
421	888	2845	5904	372	024	2220	413	238	540			868	4079
431	888	2724	5770	398	023	2392	443	248	510			763	2577
441	860	2827	5834	387	023	2322	442	316	520			911	0321
451	893	2837	5918	404	028	2399	424	311	500			766	3032
461	939	2864	5962	386	024	2310	405	309	500			794	3135
471	912	2757	5912	384	026	2284	403	274	510			788	2631
481	887	2851	5927	397	035	2310	448	292	510			828	2519
511	930	2497	5442	384	028	2271	492	338	510			828	2241
521	932	2518	5813	391	024	2341	414	242	540			874	3112
531	996	2521	5739	357	026	2112	481	302	500			745	3599
541	933	2574	5455	361	029	2118	401	258	515			874	2285
551	922	2566	5619	367	029	2156	458	328	510			800	2097
561	959	2573	5637	361	027	2131	437	307	515			753	3209
571	939	2445	5525	367	029	2156	433	254	520			765	3307
581	927	2420	5605	363	046	2022	476	289	510			822	3342
112					040				510	82	28		
122					034				515	86	32		
132					039				530	80	32		
142					051				510	80	32		
152					048				520	82	32		

Cheese Data*

CRT	YLD	FAT	TS	TN	SN	PROT	ASH	SLT	PH	FL	BD	WN	DWN
162					043				505	78	28		
172					041				510	84	32		
182					038				510	80	32		
212					042				510	82	28		
222					038				510	84	30		
232					038				530	80	30		
242					056				510	80	32		
252					053				520	84	32		
262					046				505	76	32		
272					048				510	84	32		
282					045				500	70	30		
312					046				510	76	28		
322					038				540	78	28		
332					048				510	82	32		
342					055				510	76	30		
352					052				540	80	30		
362					050				501	78	28		
372					049				510	74	30		
382					049				500	68	30		
412					045				510	76	28		
422					039				540	80	30		
432					037				510	82	30		

Cheese Data*

CRT	YLD	FAT	TS	TN	SN	PROT	ASH	SLT	PH	FL	BD	WN	DWN
442					055				500	80	30		
452					059				500	80	32		
462					048				505	72	32		
472					049				500	74	28		
482					041				510	74	28		
512					048				510	78	28		
522					041				540	82	32		
532					041				510	78	34		
542					058				500	78	36		
552					058				500	78	34		
562					053				510	76	30		
572					055				500	74	28		
582					046				500	68	32		
113			6288	410	055	2265			520	80	34		
123			6146	400	053	2214			530	84	36		
133			6003	376	075	1920			530	88	40		
143			6315	394	054	2169			515	86	38		
153			6160	398	061	2150			520	86	42		
163			6089	389	068	2048			512	82	36		
173			6109	389	065	2067			508	86	38		
183			6091	382	063	2035			522	88	38		
213			6068	384	060	2067			520	84	30		

Cheese Data*

CRT	YLD	FAT	TS	TN	SN	PROT	ASH	SLT	PH	FL	BD	WN	DWN
223			6198	402	056	2207			520	82	38		
233			5959	400	073	2086			530	84	40		
243			6169	395	058	2150			510	90	42		
253			6077	409	068	2176			520	78	40		
263			6034	396	069	2086			510	80	36		
273			5997	389	067	2054			500	82	42		
283			5852	391	073	2029			512	72	34		
313			5596	367	060	1959			520	86	36		
323			5994	398	053	2201			540	72	33		
333			5590	400	081	2035			520	78	34		
343			5877	382	062	2042			518	74	40		
353			5766	384	075	1971			540	78	44		
363			5962	381	077	1940			512	80	42		
373			5869	376	070	1952			505	72	34		
383			5803	372	076	1888			510	72	36		
413			5744	385	061	2067			530	86	32		
423			5904	391	060	2112			538	78	38		
433			5770	392	063	2099			530	78	40		
443			5834	383	056	2086			528	76	38		
453			5918	407	080	2086			515	74	36		
463			5962	384	073	1984			512	82	38		
473			5912	372	068	1940			500	68	32		

Cheese Data*

CRT	YLD	FAT	TS	TN	SN	PROT	ASH	SLT	PH	FL	BD	WN	DWN
483			5927	379	072	1959			530	76	34		
513			5442	363	062	1920			520	86	32		
523			5813	387	061	2074			530	78	40		
533			5739	363	066	1895			525	68	34		
543			5455	364	065	1908			510	74	36		
553			5619	376	078	1901			505	74	36		
563			5637	372	079	1869			512	70	34		
573			5525	352	076	1761			505	72	30		
583			5605	379	080	1908			510	60	24		
114		3114	6302	357	073	1812			525	84	40		
124		3101	6190	391	075	2016			540	86	40		
134		2894	5880	371	094	1767			540	88	36		
144		3169	6195	393	098	1882			530	80	44		
154		3090	6164	407	090	2022			515	86	40		
164		3094	6121	379	088	1856			505	88	44		
174		3028	6016	385	089	1888			520	88	42		
184		3117	6094	392	088	1940			520	90	44		
214		2870	6046	363	059	1940			525	84	36		
224		2900	6005	384	076	1965			550	80	38		
234		2940	6010	369	092	1767			542	85	36		
244		3103	6090	395	103	1863			515	80	42		
254		3033	6159	416	072	2195			510	81	36		

Cheese Data*

CRT	YLD	FAT	TS	TN	SN	PROT	ASH	SLT	PH	FL	BD	WN	DWN
264		2964	6091	395	080	2010			510	78	34		
274		2939	5977	382	094	1837			510	84	42		
284		2864	5938	391	088	1933			512	78	34		
314		2490	5517	337	085	1608			525	76	28		
324		2721	5912	375	075	1914			560	78	32		
334		2595	5662	365	097	1710			530	76	36		
344		2692	5697	389	110	1780			520	78	38		
354		2754	5876	398	094	1940			520	78	34		
364		2762	5830	375	104	1729			520	76	40		
374		2627	5708	370	100	1723			515	74	36		
384		2571	5627	351	102	1589			520	78	38		
414		2640	5692	347	082	1691			528	78	34		
424		2809	5772	368	081	1831			545	70	32		
434		2780	5881	374	094	1786			550	76	36		
444		2752	5828	360	100	1659			522	72	36		
454		2823	5960	400	093	1959			518	76	34		
464		2829	5922	394	098	1888			518	84	38		
474		2818	5897	374	100	1748			510	72	32		
484		2820	5875	384	091	1869			532	82	38		
514		2355	5278	322	084	1518			520	76	24		
524		2478	5622	367	083	1812			540	64	30		
534		2460	5348	345	103	1544			525	62	28		

Cheese Data*

CRT	YLD	FAT	TS	TN	SN	PROT	ASH	SLT	PH	FL	BD	WN	DWN
544		2588	5458	350	111	1525			510	66	30		
554		2589	5650	382	094	1837			522	72	34		
564		2548	5464	360	106	1621			510	78	36		
574		2393	5256	353	106	1576			510	66	24		
584		2393	5321	365	101	1684			505	70	24		

* Data are 2 digit decimals (i.e. 44 = .44)

CRT = cheese/replicate/time

YLD = yield

TS = total solids

TN = total nitrogen

SN = soluble nitrogen

PROT = protein

SLT = salt

FL = flavor

BD = body

WN = whey nitrogen

DWN = denatured whey nitrogen