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A Process Incorporating Ultrafiltration Concentrated Whey Solids Into Cheese For Increased Cheese Yield

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A PROCESS INCORPORATING ULTRAFILTRATION CONCENTRATED WHEY SOLIDS INTO CHEESE FOR INCREASED CHEESE YIELD

by

Rodney Jay Brown

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of

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Rodney Jay Brown

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ABSTRACT

A Process Incorporating Ultrafiltration Concentrated Whey Solids Into Cheese For Increased Cheese Yield

by

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Utah State University, 1977

Major Professor: C. Anthon Ernstrom
Department: Nutrition and Food Science

A process which incorporates whey solids, primarily protein, into cheese to increase cheese yield and eliminate whey handling problems was evaluated. Whey was concentrated by ultrafiltration to levels of 9.8 to 20.3 percent total solids (4.3 to 7.1 percent protein), heated at 70 C for 30 minutes and added to cheese milk with the coagulating enzyme.

Increase in cheese yield, on the basis of 39 percent moisture, for 10 pairs of samples was 4.0 ± 2.8 (S.D.) percent. This increase was significant at alpha less than 0.001. Moisture and protein content increased while fat content decreased. Setting time and pH also decreased. Body/texture evaluation showed no change, but flavor scores decreased. Specific defects responsible for changes in flavor and body/texture were identified.

(54 pages)

INTRODUCTION

Manufacture of cheese results in separation of the various constituents of milk into cheese and whey. The weight ratio of cheese to whey for Cheddar cheese is approximately 1:9. Due to the high percentage of water in whey and the difficulty and expense of separating solids, whey has traditionally been a problem for cheese manufacturers (46). Increasing environmental concern and new demands for protein have increased the emphasis toward use of whey solids rather than their disposal.

In 1970, annual whey production in the United States was 22 billion pounds (2). For the period 1960 through 1969, total U.S. milk production dropped from 123 to 116 billion pounds annually. During the same period annual per capita cheese consumption increased from 8.2 to 10.4 pounds (1,30). The future outlook is for increasing cheese consumption, resulting in still more whey (74).

The biological oxygen demand (BOD) of one year's whey production in the U.S. has been equated with the wastes from a population of 10 million people. Disposing of this large amount of whey is a major problem (6). In 1970, one third of the U.S. whey production was used for animal feed. Whey disposal by other means was unprofitable for cheese manufacturers (2). Drying was the best

alternative, allowing manufacturers to barely cover disposal costs. The average size of cheese plants was increasing, but most plants were too small to justify drying their own whey (32). Only ten percent of the 700 cheese plants in the U.S. in 1971 were large enough to economically consider a whey drying plant (6).

The objective of this study was to evaluate a process in which some of the solids found in whey are incorporated into cheese during manufacture without adversely affecting cheese quality. An increase in cheese yield and elimination of some of the whey handling problems were anticipated. Cheddar cheese was used and is implied wherever cheese is mentioned, but results could be applied to most types of cheese.

REVIEW OF LITERATURE

Cheese Making

The components of milk may be divided into two groups according to their behavior in cheese making. Table 1 shows an average separation of constituents into cheese and whey (83). As milk is coagulated by enzymes used in cheese making a clot is formed by the casein micelles. Most of the fat in the milk, some lactose and some whey proteins are trapped in the curd (18). Most of the whey proteins, lactose and water plus slight amounts of casein and fat are separated from the curd as whey. Whey contains half the solids of milk but is more than 90 percent water (46).

The Whey Proteins

The present milk price structure favors the value of protein as opposed to fat more than ever before (81). The most valuable constituents of whey are the whey proteins. Most efforts to recover whey solids have been centered on this group of proteins (53,61,88).

The whey proteins as a group are sometimes called lactalbumin or serum protein, although both names are

Table 1. Milk constituents and their distribution in cheese (83)

Constituent	Milk (lbs)	Cheese (lbs)	Whey (lbs)
Water	87.0	3.90	83.10
Lactose	5.1	0.20	4.90
Fat	4.0	3.70	0.30
Casein	2.5	2.40	0.10
Whey Protein	0.7	0.05	0.65
Mineral	0.7	0.35	0.35
Total	100.0	10.60	89.40

misleading (51,76). They are a mixture of one fraction soluble in concentrated salt solutions (consisting of alpha-lactalbumin and beta-lactoglobulin) and a second fraction insoluble in such solutions (consisting of enzymes, milk serum albumins, immunoglobulins, pseudoglobulins, euglobulins and other proteins found in very small amounts in whey). Table 2 shows the relative concentrations in milk of the most important milk proteins along with some of their properties (38,44).

Nutritional Value Of Whey Proteins

The whey proteins have long been known to be nutritionally superior to most other proteins, including casein (66,84). Using relative growth rates of rats as an index, four common proteins were rated as follows; combined alpha-lactalbumin and beta-lactoglobulin 100, casein 70, soy protein 34 and wheat gluten 22 (31). In another study whey protein concentrate (WPC) fed to young rats at a ten percent level over a twelve week period produced a 24 percent greater weight gain than casein fed at the same level. Protein efficiency ratios (PER) were 3.1 for the WPC diet and 2.5 for the casein diet. Approximate percentages of protein converted to body protein were 100 percent for WPC and 75 percent for casein (87).

Table 2. Some properties of principle milk proteins and their concentrations in milk (38)

Protein	Approximate Concentration (gm/liter)	Groups Per Mole (-SH)	Groups Per Mole (-S-S-)	Molecular Weight (daltons X 10^{-4})	pI
Casein					
α_{s1} -Casein	13.7	0	0	3.0	4.1
κ-Casein	3.7	0	1	2.0	3.7
β-Casein	6.2	0	0	2.41	4.5
γ-Casein	1.2	0	0	3.0	5.8-6.0
Whey Proteins					
β-Lactoglobulin	3.0	1	2	1.83	5.3
α-Lactalbumin	0.7	0	4	1.42	5.1
Immunoglobulin	0.6			16.0	5.6-6.0
Bovine Serum Albumin	0.3	0.7	17	6.9	4.7

The daily amino acid requirements of a man weighing 70 kg may be met with either 28.4 gm of whole milk protein or 14.5 gm of the salt soluble fraction of whey protein, 68 percent less by weight. These amounts are below the recommended daily allowance (RDA) for protein because of the high PER of these proteins (86).

Another asset of whey proteins is their value in supplementing other proteins. They have high levels of the sulfur containing amino acids with tyrosine as the limiting amino acid. Casein is low in the sulfur containing amino acids and high in tyrosine (13). By combining casein with the whey proteins the limiting amino acids of each protein are supplied by the other protein and the overall protein value is enhanced (63).

Whey Protein Heat Denaturation

Heat denaturation of protein is any change in the native protein structure caused by heat and generally results in a less soluble protein due to unfolding of the molecule to expose more hydrophobic groups. Each protein included in the whey protein group follows a separate course of denaturation (82). Each is affected by temperature, solids in the solution, pH and time of heating (64). Heating affects beta-lactoglobulin in a two step process, denaturation and aggregation, which may then

be followed by coagulation (77,42). Beta-lactoglobulin also interacts with kappa-casein to form a complex (16,78,79). Once heated, beta-lactoglobulin reacts with kappa-casein at room temperature (86,90). Evidence has also been found for a complex between alpha-lactalbumin and beta-lactoglobulin (37).

Near maximum denaturation of whey proteins in milk is reached after 30 minutes at 90 C . Denaturation is readily accomplished in pure whey protein solutions with no other milk solids present (41).

Ultrafiltration And Reverse Osmosis

The use of cellulose acetate membranes for the desalinization of water was reported in 1959 (75). By 1960 improvements in the process made membrane filtration feasible as an industrial process. Separation of the components of whey was a natural application (25,43,47,50). No heat or phase change is needed so no heat damage or denaturation occurs. Components of a solution can be separated by size and costs are low (34,67). Small plants can afford membrane processing equipment where other processes are too costly (14,15,32,45).

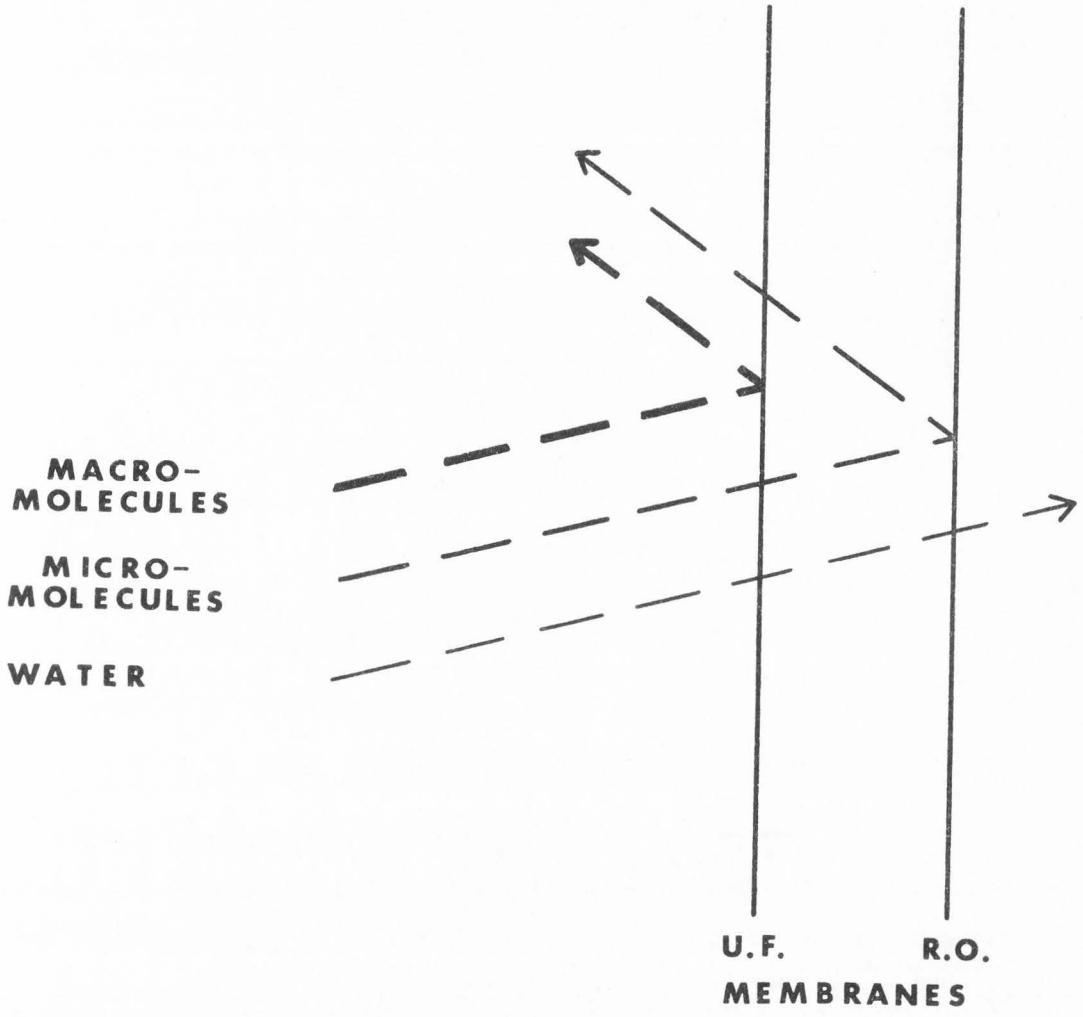
Membrane processing is divided into two similar but different processes, ultrafiltration (UF) and reverse

osmosis (RO). Figure 1 illustrates both processes (19,58,60). Pore sizes of membranes may be varied, thus varying the cut off size of molecules passing through the membrane. Pressures used range from a low of 50 psig for UF to 600 psig for RO (49). To prevent damage to cellulose acetate membranes a backing of porous material is used.

Higher pressures are required for RO than for UF because of the high osmotic pressure created by a concentration of solids on the flow side and a film of water on the permeate side of the membrane. As whey becomes more concentrated, osmotic pressure across the membrane increases.

Osmotic pressure is decreased greatly in UF by small molecules passing through the membrane freely in either direction. But, because of this, the possibility of 100 percent separation of lactose and protein in whey is eliminated . Better separation can be attained by UF concentration followed by addition of water to the concentrate, then repeated concentration. Protein levels of 60 to 70 percent with protein to lactose ratios (P/L) of 20:1 are possible using this procedure (19,49,59,68). Permeation rates in UF are not pressure dependant above ca. 150 psig, and lower pressures favor removal of a

Figure 1. Ultrafiltration (UF) and Reverse Osmosis (RO)


MACRO-
MOLECULES
MICRO-
MOLECULES
WATER
U.F.
R.O.
MEMBRANES

greater percentage of lactose from the whey. Permeation rates decrease as concentration increases, partly due to a coating of the feed side of the membrane with protein (20,55,72,73).

Increasing the whey temperature causes an increase in permeation rates by as much as 20 percent for an increase from 25 C to 30 C or 55 percent for an increase from 25 C to 45 C (59). To protect the membranes and for microbiological reasons a concentration temperature of 18 C to 24 C is recommended for cellulose acetate membranes. Early concerns of membrane destruction by heat have been overcome with better cellulose acetate membranes and with membranes made of other materials (19,29). Whey fits in the center of the 3 to 8 pH range recommended for most membranes.

By concentrating cottage cheese whey with UF to collect protein, then concentrating the UF permeate with RO to collect lactose, BOD has been lowered from 35,000 mg/liter in raw whey to 1,000 mg/liter in the RO permeate. This is a reduction in BOD in the waste stream of 97 percent (26).

A full plant project at Crowley Milk Company in Albany, New York supported by United States Department Of Agriculture (USDA) has furnished much practical operating and economic information on membrane whey processing (26,34,35,89). It was preceded by a pilot plant study at

Saint Albans, Vermont (48). Many other countries also have research in UF and RO technology (28,36,39,52, 53,62,65,71).

Whey Protein As A Cheese Ingredient

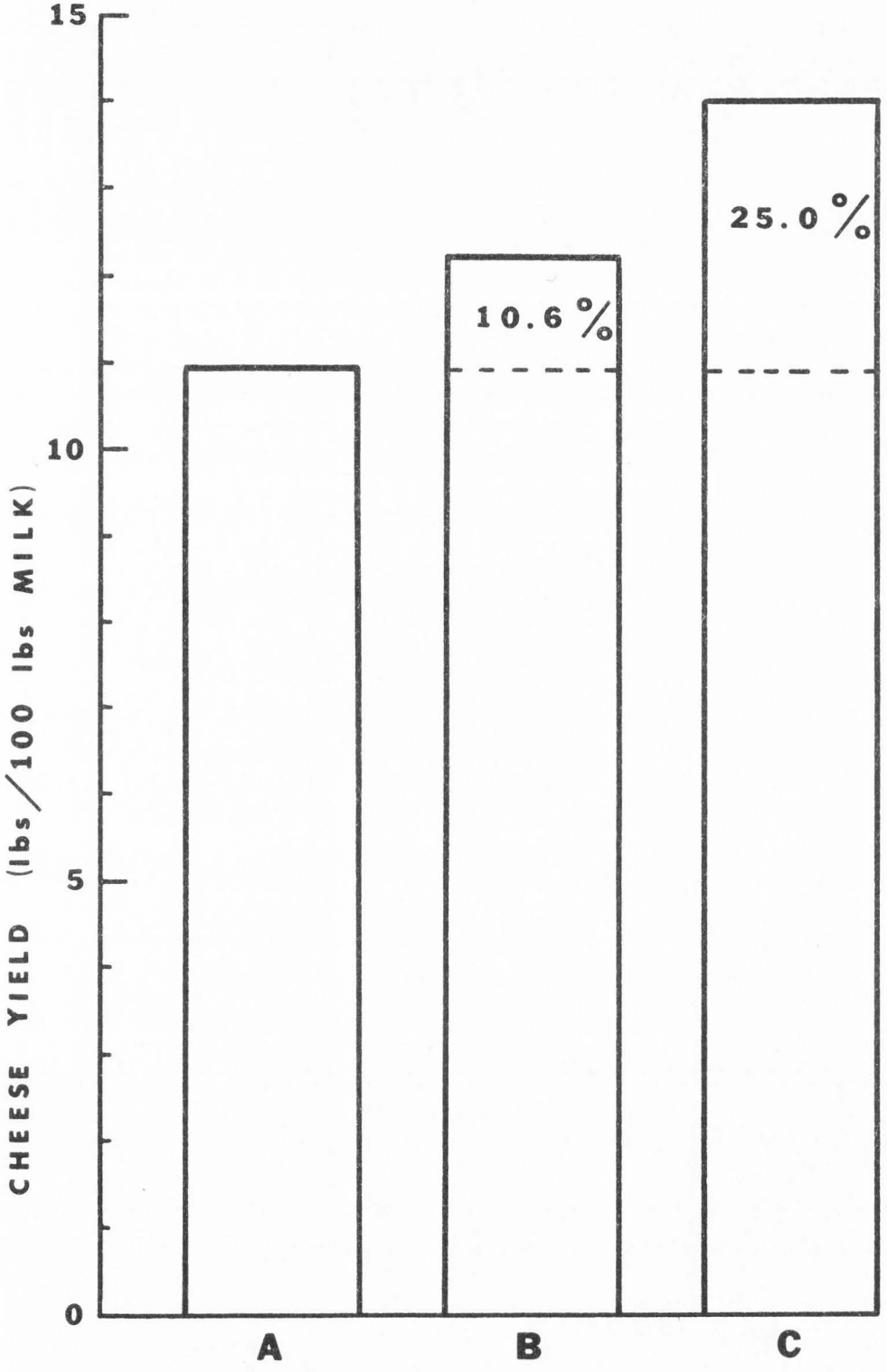
Whey is very perishable, making its storage and transportation difficult (21,46). Efforts have been made to make use of whey at the cheese plant where it is produced to avoid some of these problems. Incorporating whey solids into cheese has been attempted by various processes to prevent the disposal problem, increase cheese yield and improve protein value of the cheese.

Increase of cheese yield has been the prime factor in encouraging the use of whey proteins in cheese. By adding a small amount of solids, a large increase in cheese yield is realized. This is due to the large percentage of free water in cheese. Each gram of protein also "binds" 0.1 to 0.5 gm of water (5,79). A formula used commonly to estimate cheese yield from milk composition is:

$$\text{LBS PER CHEESE (100 LBS) MILK} = \frac{(.93(\%\ \text{FAT})+(\%\ \text{CASEIN})-0.1)1.09}{1.0-\text{DECIMAL}\ \%\ \text{WATER IN CHEESE}}$$

Using this formula, Figure 2 illustrates the increase possible in cheese yield by adding solids to the cheese milk (83). All cheese is assumed to be 39 percent

Figure 2. Possible Cheese Yields From Milk of Three Different Compositions: A-4.0% Fat, 2.5% Casein, 0.7% Whey Protein; B-same as A but with the Whey Protein calculated as Casein; C-same as B but with 1.1% Fat added; percents represent increase over A.


15
10
5
0
CHEESE YIELD (lbs/100 lbs MILK)
10.6 %
25.0 %
A
B
C

moisture. Addition of fat is desirable to keep the protein to fat ratio constant in the cheese and to take advantage of the low cost of fat relative to cheese. By adding 1.1 pounds of fat an increase of 3.1 pounds of cheese may be achieved. This assumes that the whey proteins can be made to remain in the cheese.

Heating the milk to a high temperature to denature the whey proteins is one way of keeping them in the cheese. Gains in yield of 10 percent for cottage cheese and 15 to 20 percent for Twarog cheese are reported using heat treatments of 80 C to 95 C for 30 minutes. Costs of heating all of the cheese milk are high and whey is still produced as a by product (17,40).

Other methods claiming substantial increase in cheese yield concentrate the milk by vacuum before cheese making. This is done below heat denaturation temperatures and inclusion of whey protein in cheese is due to high concentration and physical hinderance. Gains in yield are low and whey produced is similar in quantity and composition to regular cheese whey except that it has lower moisture content (7,24,69).

A more recent process is the concentration of skim milk by UF followed by the addition of cream to make highly concentrated milk from which cheese is then made. Whole milk cannot be concentrated effectively by UF due to clogging of the membranes by fat. Whey protein is trapped

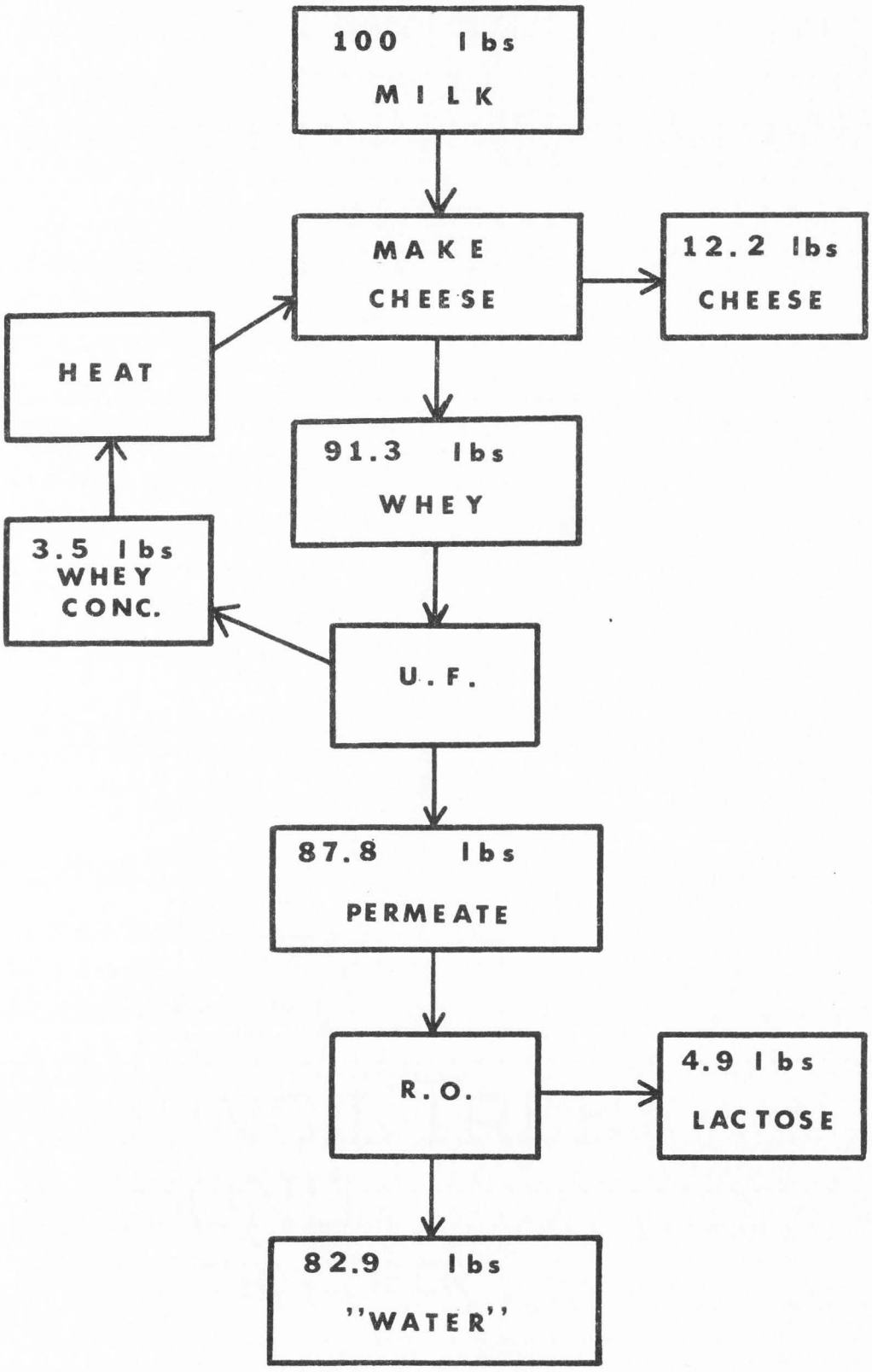
in the curd and whey production is very slight or absent, depending on the level of concentration of the milk. The process is suitable for all types of cheese, with greater consistency in the cheese produced and increased yield. A disadvantage is the necessity of separating the fat, concentrating the skim milk, then recombining before cheese making (8,20,22,56,57).

Using a different concept, whole whey has been heat treated to partially denature the whey protein and mixed with milk for cheese making (11,23,27). A similar process uses heat and acid to precipitate the protein from whole whey. The precipitated protein is then separated by centrifugation and added to the cheese milk (9,10,70). Both of these methods produce a more uniform cheese and increase yield. Whey produced is then recycled in the following batch of cheese. Heating of all whey produced is expensive enough to make these procedures impractical.

A final method, and the one evaluated by this study, is suggested by combining the merits of each of the others. Whey is concentrated by UF following which the concentrate is heated to partially denature the protein without precipitating it and added to cheese milk before the enzyme coagulation. Whey produced is concentrated for the next batch of cheese and the cycle repeats. Permeate from the UF step may be concentrated by RO to produce lactose. Net whey production is eliminated. Only a small

volume of whey concentrate is heated rather than the whole volume of whey produced. Figure 3 shows an example of the process. In this study only the UF portion of the process was evaluated. No effort was made to concentrate lactose from the permeate nor was fat added or other measures taken to achieve maximum yields. Some of these possibilities are mentioned in Appendix B.

Figure 3. Schematic of Procedure


100 lbs
MILK
MAKE
CHEESE
12.2 lbs
CHEESE
HEAT
91.3 lbs
WHEY
3.5 lbs
WHEY
CONC.
U.F.
87.8 lbs
PERMEATE
R.O.
4.9 lbs
LACTOSE
82.9 lbs
''WATER''

METHODS AND PROCEDURES

Facilities And Milk Source

Cheese was made in the dairy products laboratory at Utah State University between December 16, 1972 and April 6, 1973. Analyses were done in the food science laboratory at Utah State University between December 16, 1972 and May 16, 1973. Milk was obtained from the Utah State University dairy farm.

Cheese Making

Ten batches of experimental cheese were made, each of which used 250 pounds of milk pasteurized at 63 C for 30 minutes. Control batches of the same size were made simultaneously. Table 3 shows the cheese making procedure used, which is taken from the procedure of Davis (12). Each control batch was identical to its experimental counterpart except that whey concentrate was added to the experimental batches only.

Starter strains were rotated so that the same strain was used again after six batches of cheese. The blends used in the order used were DPL 4642A, DPL 4643, DPL 4644, DPL 4645, DPL 4646 and DPL 4641. All starters were obtained as freeze dried samples from Dairy Products

Table 3. Cheese Making Procedure

Operation	Time	Temperature (C)	Titratable Acidity (%)	Comment
Add Starter	9:00 AM	30.0	.16	Stir
Add Color	9:30	30.5	.16	Stir
Add Rennet	9:45	31.1	.165	Add Concentrate
Coagulation	10:00	31.1		
Cutting	10:15	31.1	.10	
Steam On	10:30	31.1	.10	Schedule Below, Stir
Steam Off	11:00	38.8	.105	Stir
Start Dipping	12:00 Noon	38.8	.12	Stir
End Dipping	12:15	38.8	.14	Stir
Pack	12:30	38.0	.17	
Pile 2 high	1:15	35.6	.25	
Pile 3 high	1:45	34.0	.30	
Mill	2:15	32.5	.40	pH 5.4
Salt	2:35	31.5		
Hoop & Press	3:15	31.0		
Dress	4:05			

Minutes from Steam On	0	5	10	15	20	25	30
Temperature (C)	31.1	31.8	32.7	34	35	36.6	38.8

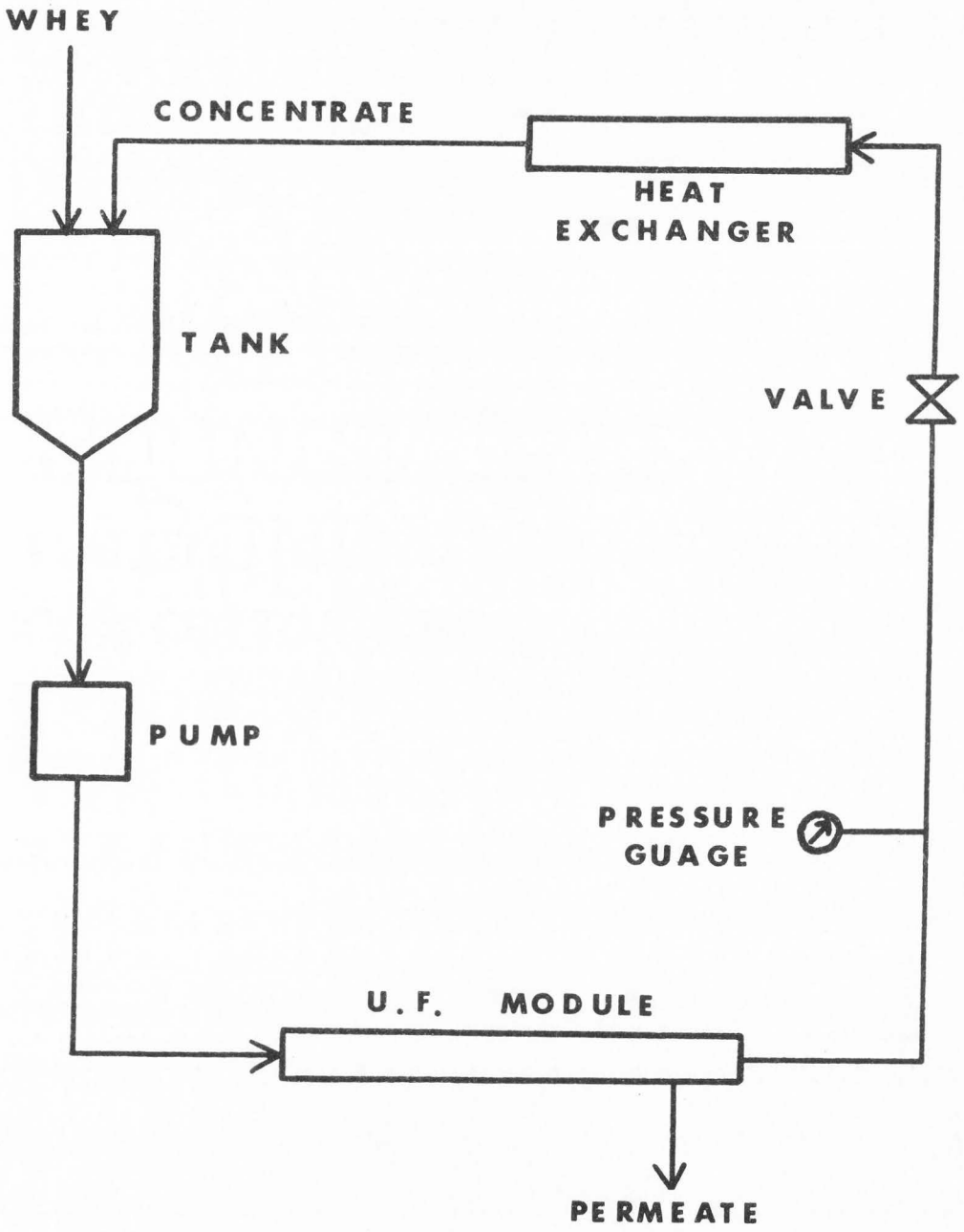
Laboratory, San Francisco, California. The dry starter was incubated in reconstituted non-fat dry milk until titratable acidity reached ca. .70 percent (ca. 16 hours incubation) before use. Amount of starter used varied from 1.0 to 1.75 percent, but experimental and control batches were always equal.

Rennet and cheese coloring used were commercial preparations. Double strength cheese coloring was used at 3 ml per 100 pounds of milk. Rennet was used at 9 ml per 100 pounds of milk. Salt was added at .3 pounds per 100 pounds of milk.

Concentration And Partial Denaturation Of Whey

Following separation of fat, whey concentration was accomplished using a Calgon-Havens tubular ultrafiltration membrane model 215 and Robbins and Myers pump model SRM-156-B-20. A one phase counter flow heat exchanger was used to keep whey temperature at ca. 20 C during concentration. Figure 4 shows the concentration system used. A pressure of ca. 120 psig was used during concentration and was controlled by a valve for back pressure. When the desired concentration was reached the concentrate was collected.

Figure 4. Ultrafiltration System Used For Whey Concentration


WHEY
CONCENTRATE
HEAT
EXCHANGER
TANK
VALVE
PUMP
PRESSURE
GUAGE
U. F. MODULE
PERMEATE

Concentrated whey was then given a heat treatment of 75 C for 30 minutes to partially denature the protein. This was done by submerging a can containing the concentrate in a boiling water bath and stirring to reach 75 C quickly. Cooling was by the same method in a cold water bath. Choice of heat treatment and concentration level was based on preliminary experiments which are discussed in Appendix A.

Whey concentrate for the first batch of experimental cheese was obtained from a batch of control cheese made for that purpose. Subsequent batches used the whey from control and experimental cheese. Concentrate equivalent to that obtained from one batch of cheese of the same size was added to each batch of experimental cheese immediately before rennet addition and at the temperature of the cheese milk at that time (ca. 31 C).

Milk Analysis

Analysis for fat in milk was by the Babcock method. Total solids analysis in milk was done by steaming followed by vacuum drying (4).

Whey Concentrate Analysis

Total solids analysis for whey concentrate was done by the same method as for milk. Protein was determined by the micro-Kjeldahl method using 6.38 as the factor and mercuric sulfate catalyst (4,33). Ash was determined by the standard AOAC method (3). Lactose was determined by the phenol sulfuric acid method as modified by Verhey (54,85).

Cheese Analysis

Cheese fat was determined by the Babcock method for cream. Moisture was determined by vacuum drying. Cheese pH was measured with a quinhydrone electrode with the samples prepared as for fat determination (4).

Measurement of protein was by the micro-Kjeldahl method with some slight modifications. A solution of 25 gm cheese, 10 gm sodium citrate and 300 ml water was blended in a Waring blender. Water was then added to bring the solution volumetricly to 500 ml. Samples from this solution were then analyzed by the same method as was used for whey concentrate.

Flavor Evaluation

Flavor was evaluated by a panel of three qualified cheese graders. Age of cheese at time of evaluation was 51 ± 7 days. Each sample of experimental cheese was evaluated on the same day as its control. Table 4 shows the flavor criticisms looked for and their importance in a total of 40 possible points for perfect cheese.

Body/Texture Evaluation

Body/texture was evaluated by the same judges and at the same times as flavor evaluation. Table 5 shows the criticisms and their relative importance of a total of 30 possible points.

Cheese Yield

At hooping all cheese curd was weighed. One hoop was weighed and pressed of each batch of cheese and weighed again after pressing and wrapping. Total yield from each batch was then calculated from the total weight of curd and the weight of pressed cheese per pound of curd.

Some evaluations are meaningful only if moisture content is constant. In these cases total solids were determined and results adjusted to 39 percent moisture.

Table 4. Flavor Scoring Guide

Criticism	Intensity of Defect		
	Slight	Definite	Pronounced
Acid	39	37	35
Bitter	39	37	34
Feed	39	38	36
Fermented/Fruity	38	36	35
Flat	39.5	38.5	37
Garlic/Onion	36	34	31
Heated	39	38	37
Moldy	37	35	33
Rancid	36	34	31
Sulfide	39	37	34
Unclean	38	36	35
Whey Taint	38	37	35
Yeasty	36	34	31

Table 5. Body/Texture Scoring Guide

Criticism	Intensity of Defect		
	Slight	Definite	Pronounced
Corky	29	28	27
Crumbly	28	27	26
Curdy	29	28	27
Gassy	28	27	25
Mealy	28	27	25
Open	29.5	28	27
Pasty	28	27	25
Short	29.5	28	27
Weak	29	28	26

Setting Time

Time from addition of rennet to firm set was recorded as setting time. Firm set was determined by free breaking of the curd when cut with the tip of a thermometer.

RESULTS

Milk

Milk used for cheese making was 3.6 ± 0.05, standard deviation (S.D.), percent fat and 12.7 ± 0.1 (S.D.) percent total solids. It was pasteurized before dividing into experimental and control vats for cheese making.

Whey Concentrate

Whey concentrate added to the experimental cheese varied over a range of 9.8 to 20.3 percent solids with a mean of 16.1 ± 3.3 (S.D.). Protein content ranged from 4.3 to 7.1 percent with a mean of 6.4 ± 0.8 (S.D.) percent. Mean ash content was .79 ± .11 (S.D.) percent over a range of .6 to .9 percent. Lactose content ranged from 6.0 to 12.0 percent with a mean of 9.43 ± 2.03 (S.D.) percent. All four measures increased from one sample to the next, indicating a cumulative effect.

Cheese

Characteristics of experimental and control cheese are compared in Table 6. In order to make both by the

Table 6. Properties of Experimental Cheese vs. Controls[1]

Characteristic	Experimental Mean	Experimental S.D.	Control Mean	Control S.D.	Significance of Difference[2]
Yield[3] (lbs)	11.33	0.29	10.88	0.25	**
Moisture (%)	41.0	1.1	39.0	1.4	**
Protein[3] (%)	20.81	1.19	20.18	1.05	n.s.
Fat[3] (%)	31.5	0.8	31.8	0.7	*
pH	5.1	0.1	5.2	0.2	**
Setting Time (Min)	13.7	5.2	19.2	2.9	*
Flavor (Score)	37.2	1.4	38.8	1.2	**
Body/Texture (Score)	28.4	1.4	28.7	1.4	n.s.

1. Based on 100 pounds of milk

2. Significance was tested by Analysis of Variance (completely randomized block design, batches as blocks)
   ** Significant at alpha=.01
   * Significant at alpha=.05
   n.s. Not Significant at alpha=.05

3. Adjusted to 39% Moisture for comparison

same procedure, measures were not taken to control moisture. Where necessary for comparison, adjustment has been made on the table.

Difference between experimental and control cheese was not significant at the alpha=.05 level for any of the specific flavor or body/texture defects using analysis of variance in completely randomized block design with batches as blocks. Table 7 shows each defect and its frequency of occurance.

Analysis of variance among judges' scores for both flavor and body/texture failed to show significant differences at alpha=.05. The correlation coefficient between pH as measured by pH meter and acid defect in flavor was -0.84 with a probability of 0.0001. A regression with flavor score as the dependent variable and incidence of flavor defects (Table 7) as independent variables and a similar regression for body/texture were both significant at alpha=.01 with R^2=.95.

Table 7. Specific Defects For Which Samples Were Criticized

	Percent of Samples Criticized	
	Experimental	Control
Flavor		
Acid	90	43
Bitter	17	3
Fermented/Fruity	3	0
Flat	3	27
Sulfide	3	0
Unclean	17	0
Whey Taint	13	3
Yeasty	3	3
Body/Texture		
Crumbly	3	0
Curdy	3	23
Gassy	13	27
Open	83	67
Pasty	10	0
Weak	17	3

DISCUSSION AND CONCLUSIONS

The objective of this study was to determine whether a practical process incorporating whey protein into cheese could be used to increase cheese yield without adversely affecting quality. Information was also obtained suggesting other benefits from the process.

Increase in yield was very significant (Table 6), averaging 4.0 $\pm$ 2.8 (S.D.) percent. Maximum increase for any pair was 8.9 percent on 39 percent moisture basis. By controlling concentration and heat treatment of the concentrate this level or higher could be consistently obtained.

There was no significant difference in body/texture scores (Table 6) between experimental and control cheese nor was there significant incidence of any one criticism (Table 7). Control cheese was more curdy and gassy while experimental cheese was more crumbly, open, pasty and weak but none of these differences were significant. Partial explanation of these slight differences is given by noting that use of whey proteins in cheese foods and spreads in other studies gave a softer bodied product (80). Higher moisture content also contributes to the pasty and weak defects and decreases curdiness. Openness shows a resistance to binding in the press, presumably due to the whey proteins.

Less gassiness in experimental cheese is due to faster growth of starter organisms. Lower pH in the cheese (Table 6) is a sign of accelerated starter organism growth which was noted in the experimental cheese. Probable causes of this accelerated growth are high free nitrogen and lactose levels from the heated whey concentrate and the higher moisture level.

Flavor scores were significantly different (Table 6) but individual flavor defects noted (Table 7) did not vary significantly when they were analysed stistically. Acid, bitter, sulfide, unclean and whey taint were criticisms more prominent in the experimental cheese. Flat was the only criticism more common to the controls. Acid defect is related to the starter culture growth already explained. The other four defects could all be grouped together as strong flavors not easily distinguished from each other by the judges. They give a distinct contrast to the flat defect of the control cheese. This suggests a possible speeding up of the aging process in the experimental cheese. This also correlates well with the defects noted in body/texture.

As expected, percent protein was slightly higher and percent fat was significantly lower in the experimental cheese (Table 7). Possibility of obtaining cheese with no change in composition is discussed in Appendix B.

Significant decrease in setting time is noted for the experimental cheese (Table 6). Similar results were found in preliminary work (Appendix A). This effect is partially due to concentration of residual milk clotting enzyme in the whey concentrate.

This work shows clearly that the process studied is practical. Further study is needed to find optimums which will produce larger yields of high quality cheese. Some suggestions for this work are found in Appendix B.

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APPENDIXES

APPENDIX A

Preliminary Experiments

As a starting point for this study some experiments were conducted to determine how much whey concentrate could be added to cheese milk, what the concentration should be and what heat treatment should be used.

In the first experiment, whey concentrate was spun to separate the solids. More than 5.0 ml of whey were required to obtain 1.0 ml of solids. The solids were then mixed with milk at room temperature. The mixture was heated to 30 C and rennet added. Up to 1.0 ml of solids could be added to 10.0 ml of milk and the milk reacted normally to rennet. At 1.3 ml solids to 10.0 ml milk the clot formed at 30 C before rennet was added. Above 2.0 ml solids to 10.0 ml milk the clot formed at room temperature without rennet.

From this experiment it was concluded that all of the whey from a batch of cheese could be concentrated and added to the next batch of cheese without changing the curd formation appreciably. The concentration of rennet from whey in the whey concentrate combined with the high solids concentration accounts for clot formation in the absence of added rennet.

The next step was to determine how much the whey should be concentrated and to what temperature it should be heated for partial denaturation. A heating time of 30 minutes was chosen for convenience. Five protein concentrates were prepared ranging from 1.3 to 2.1 percent protein. An equal amount of milk was added to each of the concentrates which had been heated earlier to 40 or 60 C or not heated. The mixture was warmed to 31 C and rennet was added. The temperature was then raised to 38 C and held for 0.5 hour. Whey and curd were then separated and analyzed for protein content along with the milk and concentrate samples. Duplicates were run on each treatment.

Analysis of variance of this data was carried out with percentage of total protein from both milk and whey concentrate ultimately found in the curd as the dependant variable. Treatment as a whole, temperature alone and protein concentration in the whey concentrate all showed significance at alpha=0.0005. The regression formula for these same variables with an alpha level of less than 0.0001 based on this experiment is:

DECIMAL % PROTEIN IN CURD	= .524 +	.083	% PROTEIN IN CONCENTRATE	+ .001	TEMPERATURE (C) TREATMENT OF CONCENTRATE

From this the determination was made to use the highest levels of whey concentration and heat treatment possible.

A further observation was that the whey concentrate texture varied with both heat treatment and degree of concentration. Low heat treatment and high concentration gave a light, fluffy texture. The opposite extremes produced a course, sandy texture.

Using this information, batches of cheese were made by the procedure found in the methods and procedures section using whey concentrate of ca. 5 percent protein heated to 60, 75 and 90 C for 30 minutes. The amount of concentrate used was that amount obtained from one batch of cheese. A problem was encountered when 90 C treated concentrate was added to the milk. It was course textured and settled in the bottom of the vat. The 75 C treatment did not cause this problem.

It was determined to use a concentrate of as high protein content as could be produced conveniently and a heat treatment of 75 C for 30 minutes. The regression formula estimates that ca. 100 percent of the protein from both milk and whey concentrate would be expected in the curd if the concentrate has 5.0 percent protein and these treatments are used. This estimate is extrapolated beyond the range of the regression data, but served as a good estimate. The temperature and concentration values used were not the optimums, but served well for the purposes of this study.

APPENDIX B

Suggestions For Further Work

The making of cheese is a complex interaction of many variables which does not allow changing one variable without affecting others. Moisture, pH, temperature and many other variables must all be in proper balance and the various steps in the process (Table 3) must be carried out at the proper times. The results of this study show that many factors are affected by addition of heated whey concentrate to cheese milk. The aim of further research on this process should be to balance these factors, maintaining quality while increasing cheese yields.

Restrictions are imposed upon cheese composition by consumers as well as by government. In order to make whey added cheese fit the approved standards and to further improve yields, additional work needs to be done. Adding fat to the cheese milk (from whey plus additional fat from elsewhere) should be studied to allow increased yield while maintaining proper fat content. Dry stirring the curd or some other treatment could be used to control moisture in the final product. Control of moisture throughout the process may also need attention.

Timing of the various steps may need adjustments to accomplish such goals as proper pH and moisture. Speeding up of acid production, and therefore of the whole process, appears to be possible when whey concentrate is added. Leaving some lactose in the whey concentrate may speed up acid production even more. Concentration of all the lactose separately may be more desirable.

The concentration level should also be studied to put as much of the whey protein as possible into the cheese. This is especially true if whey is being concentrated from every batch of cheese for use in the next. Heat treatment of the concentrate may be handled better in a plate pasteurizer than by the batch method used thus far. Time and temperature values would need to be established for this. Studies of concentrate pH at the time of heating could also be helpful in obtaining a partially denatured protein concentrate of the proper texture.

The possible reuse of coagulating enzyme should be considered in any heat treatment of the concentrate. Possibly changing from rennin to an enzyme more heat stable and more predominant in whey would be helpful.

Production of cheese which resembles traditional cheese in every way and increasing yield may not be as important as studying increase in protein content or improvement of amino acid balance or some other characteristic. Application of the process to cheese other

than Cheddar and the problems which may be peculiar to each variety of cheese is another area for possible research.

The list given here is not complete, but does point out some of the areas where further research was suggested during this study. As some of these areas are investigated more will appear.

VITA

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Candidate for the Degree of

Master of Science

Thesis: A Process Incorporating Ultrafiltration Concentrated Whey Solids Into Cheese For Increased Cheese Yield

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