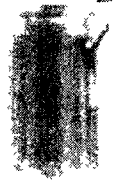
Dairy Proteins

Prepared by the
Wisconsin Center for Dairy Research and the
Wisconsin Milk Marketing Board



Dairy Proteins

This document, prepared by the Wisconsin Center for Dairy Research and the Wisconsin Milk Marketing Board, is intended to help clarify the present dairy protein issue. It can also be used as a resource for commonly used dairy terms, an illustration of the "flow" of milk to its components, and technical information regarding the use of dairy proteins and other milk components. If you have further questions, please contact Rusty Bishop [(608)265-3696], Matt Mathison [(608)836-8820], or Karen Smith [(608)265-9605].

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Cheese Milk Protein Review

This document, developed by WMMB and CDR, is intended to provide background information on the various dairy ingredients used in the cheesemaking process, with a focus on the key dairy protein ingredients.

Typical raw milk arriving at the cheese plant has the following average composition:

3.30% protein (3.0% true protein composed of 80% casein and 20% whey protein)
3.65% fat
4.75% lactose (milk sugar)
0.65% minerals (calcium, etc)
87.75% water

Raw milk for cheesemaking is often standardized to a specific casein and fat composition (referred to as the casein to fat ratio). The exact ratio depends on the cheese being manufactured. Standardization often involves the addition of protein to the cheese milk. **The various sources of this additional protein have created significant controversy with the U.S. dairy industry.**

There are two key benefits from the standardization of cheese milk with protein.

- *It improves the consistency of the finished cheese composition.*
- From an economic perspective, vat efficiency is increased; meaning more total cheese is produced per vat due to the addition of more cheese milk solids, resulting in more cheese throughput per day for the plant.

Why is protein (casein) so important in cheesemaking?
Casein coagulates in the presence of rennet/acid to form the cheese curd. Coagulated casein forms a three-dimensional lattice or backbone structure, which then entraps fat, water, minerals and starter cultures and results in cheese curd formation. As the casein coagulates, whey begins to separate from the curd. The amount of casein at the beginning of the cheesemaking process **is the single biggest factor** affecting cheese yield.

The only permitted ingredients for cheese and cheese products that are covered by the Food and Drug Administration's Standards of Identity regulations (21 CFR Part 133, Subpart B), are milk (liquid or milk powder), non-fat milk (condensed skimmilk or non-fat dry milk) and cream. Cheeses which have a U.S. standard of identity include Cheddar, Mozzarella, Colby, process cheese, process cheese food, process cheese spread, etc. (There are 88 standardized cheese varieties in the U.S.) Cheese types not covered under the specific Standards of Identity included in the CFR are allowed to use additional food-grade ingredients; however, protein and fat must still be from a dairy source. Dairy protein products such as milk protein concentrate (MPC) therefore, are permitted in cheeses that do not have a specific Standard of Identity. These non-standardized cheeses include Feta, Ricotta, "pizza cheese," process cheese product, Brie. Butterkase, Camembert, Comte, Danbo, Fontina, Havarti, Jarlsberg, Manchego, Mascarpone, Port Salut, quark, Queso Blanco, Queso Fresco, Raclette, St. Paulin, Stilton, Stravecchio, Tilsiter, Yogurt cheese, etc.

Condensed skimmilk and non-fat dry milk (NFDM) both have been traditionally added to milk for cheese manufacture for the sole purpose of increasing the amount of casein in the cheese milk. Because only water is removed during condensing and drying of milk, the compositions of the solids or nonwater portion of either milks are identical. The majority of the solids in the milks are lactose (50%). Casein is approximately 28% of the solids. Minerals (15%) and whey proteins (7%) are the remaining components.

The cheesemaker is actually adding lactose at a greater rate than the casein they want when they use NFDM or condensed skimmilk to fortify cheese milk. The additional lactose must be

removed from the curd when the whey is drained to prevent serious quality problems in the final cheese. Whey proteins will not remain in the curd and also drain into the whey. Therefore, a cheesemaker adding NFDM or condensed skimmilk to the cheesemilk is adding a lot more of the components that they do not want (lactose and whey proteins) compared to the amount of casein that they do desire in the cheesemilk. **Even though the actual casein content is low in these dairy products, they are still widely used in cheese manufacturing.**

What is the issue with MPC?
Membrane filtration technology is being used to produce liquid ultrafiltered (UF) milk. Membrane filtration systems separate milk components according to size. Small molecules such as lactose and minerals pass through the filter while large molecules such as proteins are held back. The removal of lactose and minerals causes the concentration of protein to increase in UF milk. A chart of the "Relative Milk Component Sizes in Comparison with Membrane Pore Size Ranges" is in the Appendix of the paper titled "Background on Milk Protein Products" by Karen Smith, Wisconsin Center for Dairy Research.

UF milk is becoming more common as a standardizing agent for cheese milk. Farms in the southwest United States, chiefly the New Mexico area, produce most of this UF milk. Product is shipped as a liquid from the southwest for incorporation in cheese milk in other parts of the country. UF milk from the New Mexico area typically has approximately 17.5% total solids. Casein is about 51% of these solids as compared to condensed skimmilk or NFDM which has 28% casein. The higher level of casein in UF milk as compared to condensed skimmilk or NFDM means the cheesemaker can put more of the protein that will become cheese curd (casein) into the cheese vat and less of components that they do not desire (lactose and minerals) with UF milk. **The sources of these dairy solids in UF milks are U.S. dairy farmers.**

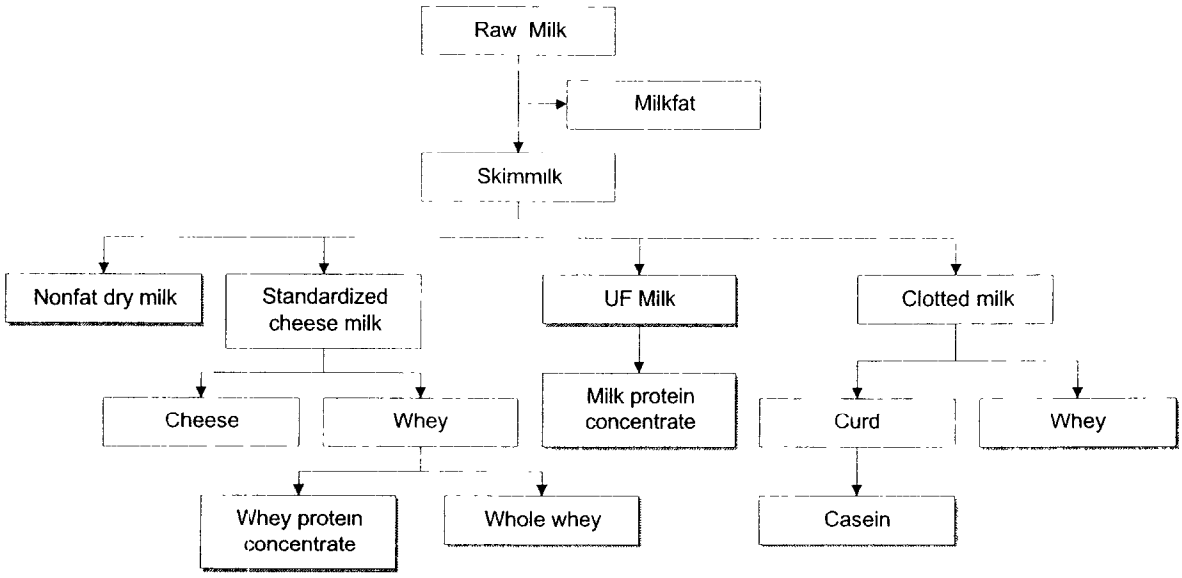
While liquid UF milk has found its way into cheese vats in Wisconsin and other States because of their shortage of milk for manufacture into cheese, it is the dry version of this product, known as MPC, that is at the center of the current controversy. UF milk is dried into MPC to extend the shelf life of the product and allow for easier distribution and storage. MPCs typically range from 42 to 80% protein with corresponding casein contents of 33.6 to 64%. Since there is little MPC presently is produced domestically, the source of these dairy solids has mainly been foreign dairy producers.

From a purely technological standpoint, the ideal dairy ingredient for standardizing cheese milk would be casein itself, since casein is the protein that forms the cheese matrix. However, commercially available forms of casein are either quite insoluble or do not react with rennet/acid and, therefore, these forms of casein are hard to incorporate into either cheese milk or curd. This type of casein is not widely used anywhere in the world for natural cheese production.

Because commercial casein products are unsuitable, the best dairy ingredient for standardizing cheese milk would be UF milk in either a liquid or dry form (MPC). Condensed skim milk and NFDM with the lowest casein and highest lactose contents of all the products discussed would be the least desirable dairy ingredients for standardizing cheese milk.

Since this issue extends beyond simple technology aspects, much more discussion will be needed before the U.S. dairy industry can agree upon a clear direction. More detailed information concerning dairy proteins is available in the attached document titled "Background on Milk Proteins" by Karen Smith, Wisconsin Center for Dairy Research.

Basic Flows and Definitions of Milk Products



Casein – Casein is one of two major groups of protein present in milk. The action of rennet on casein during the manufacture of cheese results in the separating of milk into curds and whey. Casein forms the cheese while the whey proteins go into the whey stream.

Milk protein concentrate (MPC) – Milk protein concentrates are produced by ultrafiltration (UF) of milk. The product in liquid form is generally referred to as UF milk while the dry form is known as MPC. This product contains unaltered forms of both casein and whey protein. The level of protein, lactose and mineral present vary depending on the degree of protein concentration.

Nonfat dry milk (NFDM) – Nonfat dry milk or skimmilk powder is skimmilk with the water removed. The composition of the original skimmilk is not altered.

Skimmilk – Milk that has had the fat removed. The dry form of skimmilk is known as nonfat dry milk.

Standardized Cheese Milk - Milk that has had the fat and protein content adjusted such that the cheese produced from this milk will have the appropriate composition.

Whey – Whey is a byproduct of cheese manufacture. There are two general types of whey – acid and sweet. Acid whey is produced from cheeses such as cottage and cream. Sweet whey is from cheeses such as Cheddar and mozzarella. Whey contains whey proteins, lactose, minerals and a small amount of fat.

Whey protein concentrate (WPC) – Whey protein concentrates are produced by ultrafiltration of whey. They can be in liquid or dry form and have a protein content typically ranging from 34 to less than 90%. When the protein concentration exceeds 90% the product is known as a whey protein isolate (WPI).

Whole dry whey – Whey that has had the water removed. The composition of the whey has not been altered.

Background on Milk Protein Products

Karen E. Smith, Ph.D.
Wisconsin Center for Dairy Research
August, 2001

Milk Constituents

Milk consists of fat, proteins, lactose and minerals.

Fat - The fat portion generally is removed before milk is processed into milk protein products and therefore the fat component is not a great concern.

Proteins – Milk contains many types of proteins; however, they can be grouped into two general categories -- casein* and whey proteins*. When milk is made into cheese, casein* remains in the cheese while the whey proteins* go into the whey* stream.

Caseins* are about 80% of the proteins in milk. Casein* will precipitate (i.e. join together and fall out of solution) when treated with rennet or acid.

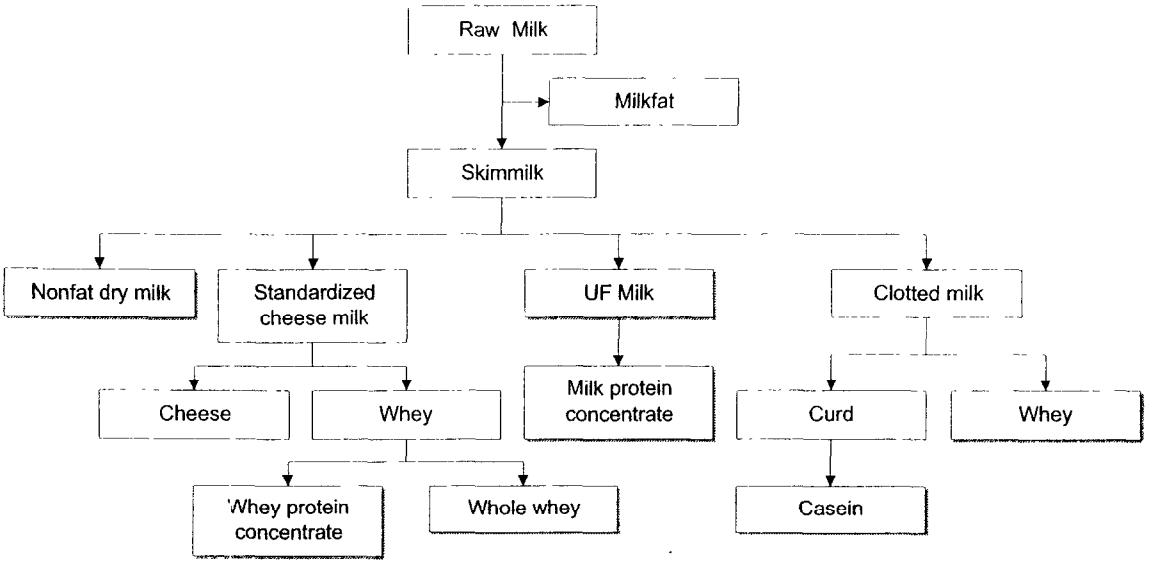
Whey proteins* are approximately 20% of the proteins in milk. These proteins are soluble unless they are denatured by exposure to high temperatures. A denatured protein has an irreversible change in its structure that causes the protein to precipitate. A precipitated protein is not soluble in water.

Lactose - Lactose or milk sugar is a carbohydrate found only in milk. Lactose is a disaccharide; that is, it is made up of two sugar molecules, glucose and galactose. Bacteria added during cheese manufacture break lactose into glucose and galactose and they then convert the glucose to lactic acid. It is the lactic acid that is responsible for the acid flavor in cheese. When milk products are heated to high temperatures the lactose can interact with proteins and cause a brown color in the milk.

Minerals – Minerals are also known as milk salts or ash. The major salts are calcium, sodium, potassium and magnesium, which combine with phosphates, chlorides and citrates in milk.

General Milk Protein Manufacturing Processes

The following is a general outline of the processes involved in the manufacture of milk protein products. Appendix II and III have outlines that provide greater detail of these processes.



* Terms marked by asterisks are defined in the glossary.

Skimmilk Powder Manufacturing Process

Skimmilk powder or nonfat dry milk* (NFDM) is essentially skimmilk* with the water removed. Skimmilk* is pasteurized to eliminate pathogens and then dried on either a roller or spray dryer. The milk can be given a heat treatment before drying. This heat treatment denatures the whey proteins* and gives the NFDMs different functional properties. The amount of denaturation is given by the Whey Protein Nitrogen Index (WPNI). NFDM* is categorized according to its WPNI as low, medium or high heat powder.

Milk Protein Concentrate Manufacturing Process

Milk protein concentrate (MPC) is produced from skim milk by a series of processes that include ultrafiltration* (UF), evaporation and drying. Ultrafiltration* determines the composition of the MPC while evaporation and drying are used to remove only water. The product also is pasteurized to eliminate potential pathogens in raw milk.

The first step in the manufacture of MPC* typically is UF* of the skim milk. UF* is a sieving process that separates milk components according to their size. There are two clear groups of compounds based on size in milk. Minerals and lactose are smaller in size while proteins, including casein* and whey proteins*, are much larger. It is this large difference between the size of the two groups of components that allows milk to be separated efficiently by UF*. The relationship between size of milk components and UF* is illustrated in a chart titled "Relative Milk Component Sizes in Comparison with Membrane Pore Size Ranges" which can be found in the attached appendix.

During UF*, milk passes across a membrane that resembles a piece of thin plastic. Some of the lactose, minerals and water will cross through the membrane and become the permeate* stream. Casein* and whey proteins* because of their large size will not be able to pass through the membrane. The proteins along with the lactose and minerals that did not go into the permeate* stream will become the retentate* stream. The concentration of protein in the retentate* stream will increase as more lactose and minerals are removed in the permeate* stream. A diafiltration (DF) or washing step is required to get protein concentration greater than 65% in the final dried product. Diafiltration involves adding water to the retentate* as it is being ultrafiltered to reduce product viscosity and further remove lactose and minerals.

UF* can be done over a range of temperatures; however, for microbiological reasons UF* of milk typically is done either cold (41° F) or hot (115° F). The temperature of the process affects the economics of producing MPC* but does not affect the final product composition.

Following UF*, the retentate* may be evaporated to increase the total solids in the processing stream which improves dryer performance. Because milk proteins are sensitive to damage by heating, falling film tubular evaporators typically are used.

The retentate* then is spray dried. Dryer designs such as tall form, spray bed and stage dryers are considered appropriate for drying MPC*. These types of dryers are designed to minimize the temperature exposure of the MPC* during drying so that important functional properties such as solubility are retained.

Whey Protein Concentrate* Manufacturing Process

Whey* is a byproduct of cheese manufacture. Rennet, an enzyme that clots milk, or acid is added to milk thereby causing casein* to join together. The milk then separates into curds and whey*. The whey* is drained from the curds (casein*) and becomes the starting material for WPCs*.

The production of whey protein concentrate* (WPC*) is very similar to the methods used to make MPC*. Ultrafiltration*, evaporation and drying are used to manufacture WPCs* with 34 to 80%

protein in the dry product. Additional processing steps are needed to make whey protein isolates which have greater than 90% protein. As with MPC*, UF* determines the composition of the WPC* while evaporation and drying are used to remove water only.

Casein* Manufacturing Process

Commercial casein* is made from skim milk by one of two methods – precipitation by acid or coagulation by rennet. Fat, whey proteins*, lactose and minerals must be removed from the casein* through washing with water to improve the quality of the final casein* product. The product is dried to improve keeping quality.

Commercial casein* products:

1. Precipitation by acid – Acid casein*
2. Coagulation by rennet – Rennet casein*

There are also two other types of commercially available casein* products of note:

1. Co-precipitates*
2. Caseinates*

Casein* – Casein* is manufactured by adding either acid or rennet to skimmilk*. Addition of acid or rennet to milk will cause casein* to join together and separate from the other components. This separation is exactly what happens during cheese manufacture where the casein* portion is referred to as curds and the remaining milk components are known as whey*. The casein* then is separated from the whey* and the casein* washed and dried.

Co-precipitate* – Calcium chloride or dilute acid is added to skim milk and the mixture then is heated to precipitate both casein* and whey proteins*. The precipitated proteins then are washed and dried to produce an insoluble protein mixture. The proteins can be treated with neutralizers to make a co-precipitate* that is more soluble in water.

Caseinate* – Caseinate* is produced by neutralizing acid/rennet casein* with alkali and then drying the resulting product. The alkali treatments makes caseinate* more soluble in water than casein*.

Composition and Functionality of Milk Protein Products

Skimmilk* powder

Skimmilk* powder or NFDM* has approximately 3.2% moisture, 0.8% fat, 36% protein, 52% lactose and 8% ash. Both casein* and whey proteins* are present.

The amount of heat used to produce NFDM* affects solubility of the protein with high heat powder slightly less soluble than low heat powder.

Whey protein concentrate*

Whey protein concentrates* average 4% moisture. They have protein contents ranging form 34 to 80%. Casein* is not present. As the protein levels increase, the percentage of lactose decreases. Minerals range from 4 to 7%.

WPCs are soluble in water because of the processes used in their manufacture.

Milk Protein Concentrate*

MPCs* can be produced with protein contents ranging from 42 to greater than 80%. As the protein content increases, the lactose content decreases. Because some of the calcium is bound to casein*, the concentration of calcium remains fairly constant in MPCs*. Both casein* and whey proteins* are present. All of the proteins in skimmilk* remain in a MPC*; therefore, the biological protein value does not change for MPCs* versus skimmilk*.

The processes used to make MPC* do not damage the proteins; therefore, MPC* behavior is similar to milk when MPC* is used as an ingredient. The ability of a milk protein product to dissolve in water is one of its most important functional properties. Because MPC* production processes do not alter the proteins this product has good solubility.

Acid/Rennet casein*

Acid casein* has 10 to 12% moisture. Fat and minerals are less than 4% and lactose is absent. It is approximately 90 to 95% protein which is all in the form of casein* (whey proteins* are not present).

Moisture varies from 12 to 13% and fat and minerals make up approximately 8.5% of rennet casein*. There is approximately 89% protein in rennet casein* that is all in the form of casein* (whey proteins* are not present). Lactose is absent.

The processes used to make acid and rennet casein* make the products insoluble in water. Neither acid or rennet casein* will react further with rennet. Acid/rennet casein* in general does not react with other components and therefore acid/rennet casein* does not have a lot of functional properties.

Caseinate*

Caseinate* have approximately 3.8% moisture and 91% protein (all in the form of casein*). There is 0.1% lactose and approximately 3.7% ash in caseinates*. These products are usually salts of sodium or calcium.

The neutralization process makes caseinates* soluble; however, the protein will not react further with acid or rennet.

Co-precipitates*

Unlike acid and rennet casein*, co-precipitates* contain whey proteins*. Calcium may be present in greater amounts because of the use of calcium chloride in the production process. Small amounts of lactose (0.5%) also are present. Co-precipitates* have approximately 5 to 10% moisture and 89 to 94% protein.

Co-precipitates* are insoluble unless they are treated with neutralizers in process similar to that used for caseinates*. Because whey proteins* are denatured during production of co-precipitates*, this product may remain incompletely soluble despite treatment with neutralizers.

Appendix I

Glossary

Acid casein – Acid casein is produced by the addition of acid to milk. Acid casein has 10 to12% moisture. Fat and minerals are less than 4% and lactose is absent. It has approximately 90 to 95% protein all in the form of casein. The pH of acid casein ranges from 4.6 to 5.4. This product is insoluble in water.

Acid casein is the major casein product of world markets. It is used as an additive for glazing high quality paper and in the production of paints and cosmetics. Lactic acid casein is favored for food uses by New Zealand and Australia.

Casein – Casein is one of two major groups of protein present in milk. The action of rennet on casein during the manufacture of cheese results in the separating of milk into curds and whey. Casein forms the cheese while the whey proteins go into the whey stream.

Caseinate – Caseinates are produced by dissolving casein in dilute alkali. Caseinates have approximately 3.8% moisture and 91% protein. The protein is in the form of casein. There is 0.1% lactose and approximately 3.7% ash. Caseinates are usually salts of sodium or calcium and have a pH of 6.5 to 7.0. These products are soluble in water.

Caseinates are used in the food industry. Some examples of their use include emulsifiers in cured meats, and as milk and cream substitutes.

Co-precipitate – Dilute acid and or calcium chloride are added to heated skim milk to form coprecipitates. Co-precipitates contain both casein and whey proteins. Calcium may be present in greater amounts because of the use of calcium chloride in the production process. Small amounts of lactose (0.5%) also are present. Co-precipitates have approximately 9.5% moisture. The pH varies with the method of manufacture. These products are insoluble in water. Co-precipitates are used in food products.

Milk protein concentrate (MPC) – Milk protein concentrates are produced by ultrafiltration (UF) of milk. The product in liquid form is generally referred to as UF milk while the dry form is known as MPC. This product contains unaltered forms of both casein and whey protein. The level of protein, lactose and mineral present vary depending on the degree of protein concentration.

Nonfat dry milk (NFDM) – Nonfat dry milk or skimmilk powder is skimmilk with the water removed. The composition of the original skimmilk is not altered.

Permeate – The portion of the processing stream that permeates or crosses the membrane during ultrafiltration. This stream contains compounds that are small enough to go through the pores of the membrane.

Rennet casein – Rennet casein is produced by the addition of rennet to milk. Casein is the only protein present in the final product. Moisture varies from 12 to 13%. Rennet casein contains approximately 1.5% fat and 7.5% mineral. Lactose is absent. Rennet casein is insoluble in water.

Rennet casein is used to produce materials similar to plastics. There is some use of this product in processed cheese.

Retentate – The portion of the processing stream that is retained by the membrane during ultrafiltration. This stream contains compounds that are too large to pass through the pores of the membrane.

Skimmilk – Milk that has had the fat removed. The dry form of skimmilk is known as nonfat dry milk.

Standardized Cheese Milk – Milk that has had the fat and protein content adjusted such that the cheese produced from this milk will have the appropriate composition.

Ultrafiltration (UF) – Ultrafiltration uses semipermeable membranes to separate components based on their molecular weight. The portion of the processing stream that is retained by the membrane and contains the larger components is referred to as the retentate stream while the components that are smaller and cross the membrane are known as the permeate portion

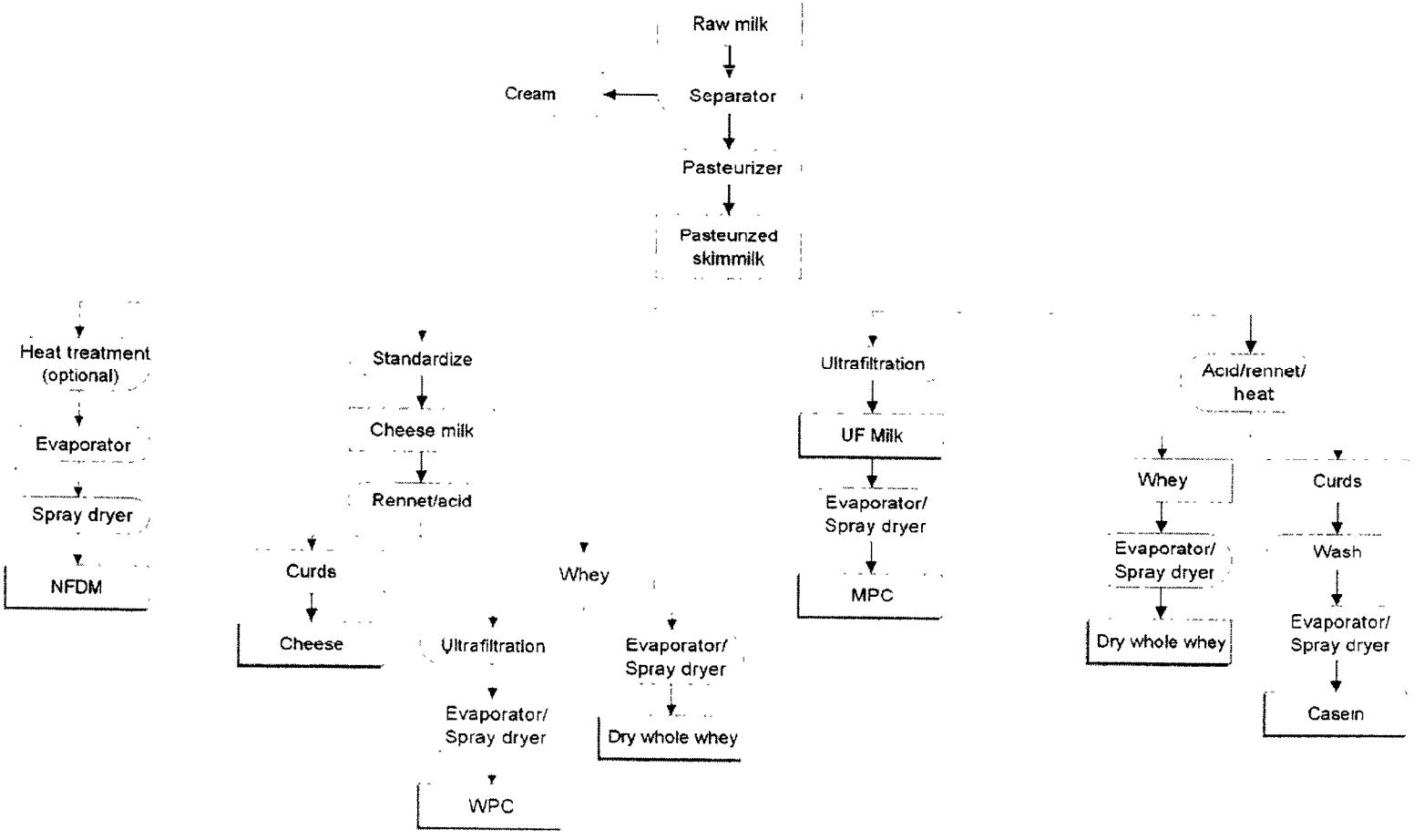
Whey – Whey is a byproduct of cheese manufacture. There are two general types of whey – acid and sweet. Acid whey is produced from cheeses such as cottage and cream. Sweet whey is from cheeses such as Cheddar and mozzarella. Whey contains whey proteins, lactose, minerals and a small amount of fat.

Whey proteins – Whey proteins are one of two major groups of protein present in milk.

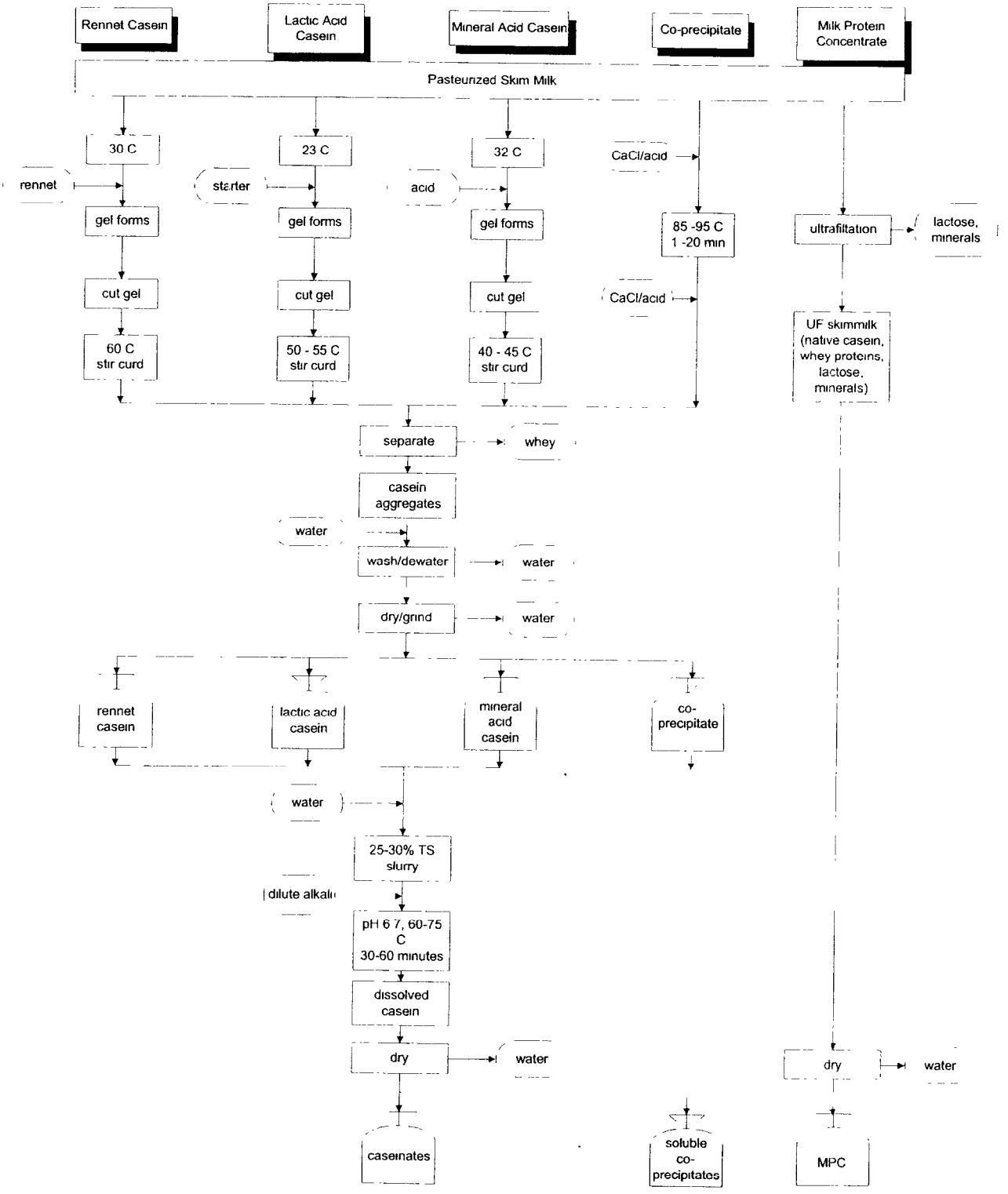
Whey protein concentrate (WPC) – Whey protein concentrates are produced by ultrafiltration of whey. They can be in liquid or dry form and have a protein content typically ranging from 34 to less than 90%. When the protein concentration exceeds 90% the product is known as a whey protein isolate (WPI).

Whole dry whey – Whey that has had the water removed. The composition of the whey has not been altered.

Appendix II. Outline of processes used to produce milk protein products



Appendix III. General outline for the manufacture of casein and milk protein concentrates



Appendix IV

Composition of some milk protein concentrates (MPC).

Component	Skim milk (%)	MPC 42 (%)	MPC 56 (%)	MPC 70 (%)	MPC 80 (%)
Moisture	3.2	3.5	3.8	4.2	3.9
Fat	0.8	1.0	1.2	1.4	1.8
Protein	36.0	42.0	56.0	70.0	82.8
Lactose	52.0	46.0	31.0	16.2	4.1
Ash	8.0	7.5	8.0	8.2	7.4

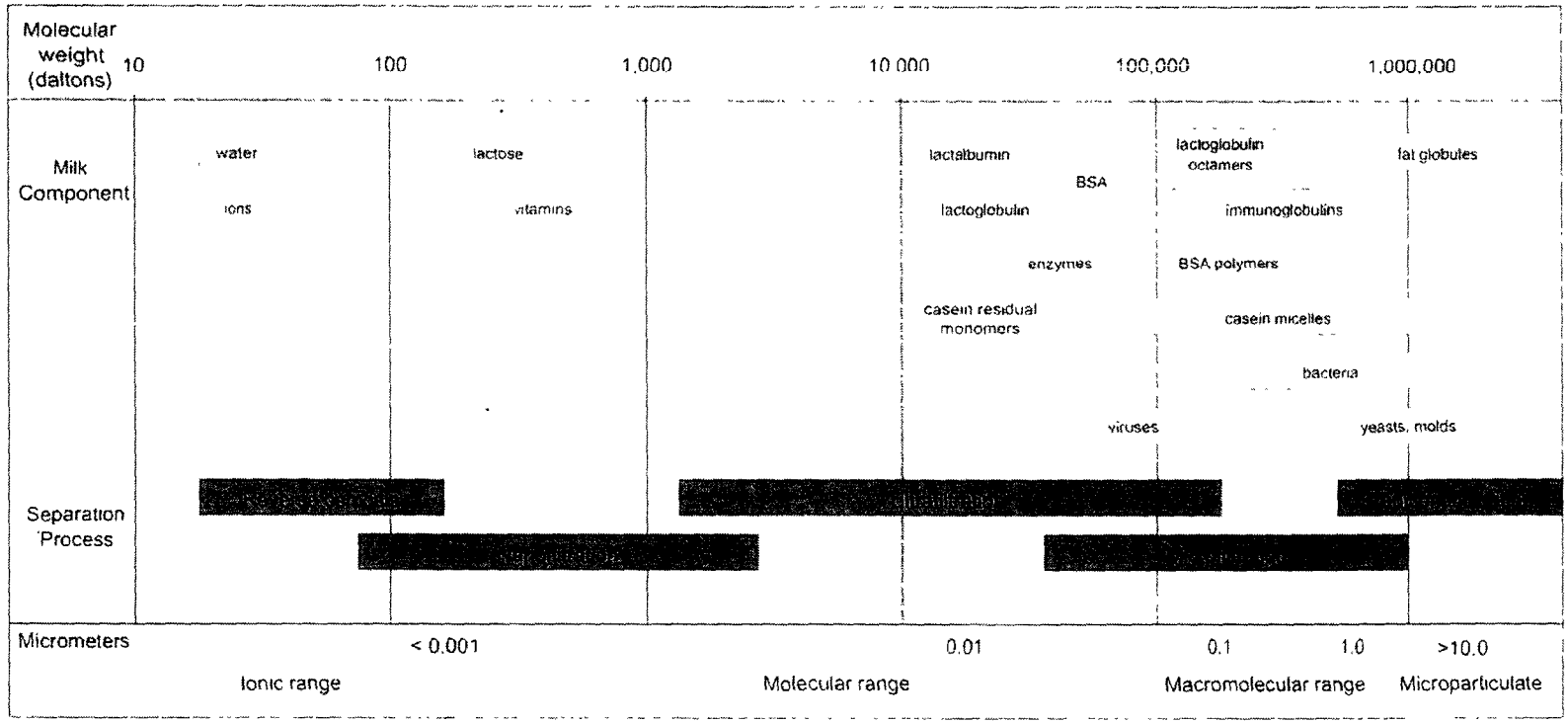
Percentage composition of commercial casein and caseinate products.

Component	Rennet Casein	Acid Casein	Sodium Caseinate	Calcium Caseinate	Co-Precipitate
Protein	89	95	94	93.5	89-94
Ash (max)	7.5	2.2	4.0	4.5	4.5
Sodium	0.02	0.1	1.3	0.05	-
Calcium	3.0	0.08	0.1	1.5	-
Phosphorous	1.5	0.9	0.8	0.8	-
Lactose (max)	-	0.2	0.2	0 2	1 5
Fat (max)	1.5	1.5	1.5	1.5	1.5
Moisture (max)	12	10	4.0	4.0	5.0
pH	7	-	6.6	6.8	6.8

Composition of some whey protein concentrates (WPC).

Component	Sweet whey (%)	Acid whey (%)	WPC 34 (%)	WPC 50 (%)	WPC 80 (%)
Moisture	4.5	4.5	4.0	4.0	4.0
Fat	1.0	0.5	3.0	4.0	5.0
Protein	12.0	12.0	35.0	50.0	80.0
Lactose	73.0	68.0	51.0	35.0	4.0
Ash	8.0	11.0	6.0	7.0	4.0

Relative Milk Component Sizes in Comparison with Membrane Pore Size Ranges



PROCESS	Reverse Osmosis (RO)	Nanofiltration (NF)	Ultrafiltration (UF)	Microfiltration (MF)
OPERATING PRESSURE	200 - 1,200 psig	150 - 400 psig	30 - 150 psig	20 - 100 psig
RETENTATE	All total solids of stream	Total solids of stream except for monovalent ions	Proteins and fats	Fat, very large proteins and particles
PERMEATE	Water only	Monovalent ions	Minerals, NPN and lactose	Lactose, minerals and all proteins
SEPARATION METHOD	Ability of compound to mimic tetrahedral structure of water determines ability to permeate	Diffusion and flow through pores controlled by mass transfer, diffusion characteristics and charge	Shape, charge, flexibility, molecular weight determine ability to cross membrane	Size determines ability to cross membrane