Dried Dairy Ingredients

Types of milk, whey and permeate • Dried dairy ingredients • Dairy ingredients from milk • Dairy ingredients from whey

Wisconsin Center for Dairy Research

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This document, prepared by the Wisconsin Center for Dairy Research and funded by Wisconsin Milk Marketing Board and Dairy Management, Inc., is intended to help clarify how milk and whey are converted into dried dairy ingredients. The document includes commonly used dairy terms, manufacturing and processing technology, and applicable technical information. When citing this information as a reference, please credit the Wisconsin Center for Dairy Research, the document name and date of the publication.

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Table of Contents

Introduction

The Dried Dairy Ingredient Handbook is designed to be an easy to use, quick source of information on the wide range of ingredients that can be made from milk and whey. The Handbook is intended only as a guide to dairy ingredients. Product manufacturing methods, composition and specifications will vary between producers. The guide describes what is typical for products.

Some ingredients can be made from either milk or whey but they have been included in the section under the starting material most typically used.

Information on products is given in several different formats reflecting the varied ways information on dry dairy products is conveyed. Graphs of product composition are on a total solids basis thereby allowing a quick comparison of components. Tables of product composition include moisture thereby reflecting what a customer would typically see for a bag of dry product. The table of typical composition and characteristics gives composition information in a format similar to the product composition table but protein is given on a dry basis.

Regulations for US dairy products often are distributed throughout several agencies. It may be necessary to consult several sources to obtain complete information on regulations and standards for a given product.

Standards and specifications also may vary between government agencies and trade groups. It is important to check for regulations governing your particular product as well as for any changes in regulations/standards.

I would like to thank the people in industry and at CDR that contributed to and reviewed the document. Their assistance was invaluable. I would like to give special thanks Tim Hogensen for all of his time and patience in producing this handbook.

Types of Milk, Whey and Permeate

Milk

- Whole
- Skim
- Buttermilk (from butter manufacture)

Whey

Resulting from

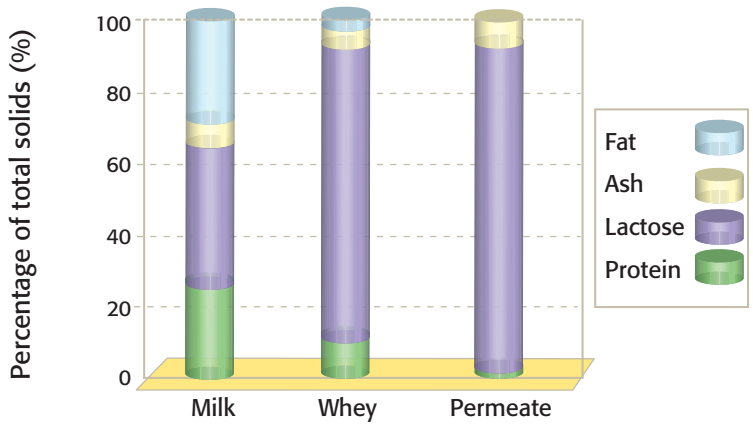
- Cheese manufacture
  - Sweet
  - Acid
  - Salty
- Casein production
  - Sweet
  - Acid

Permeate

Resulting from

- Milk
- Cheese manufacture
  - Sweet whey
  - Acid whey
- Casein manufacture
  - Sweet whey
  - Acid whey

Milk, whey and permeate composition



General composition of milk, whey and permeate

Component	Milk	Sweet whey	Whey permeate
	---------- % ----------		
Total solids	12.5	6.5	5.5
Protein	3.5	0.8	< 0.1
Lactose	4.8	4.9	4.9
Ash	0.7	0.5	0.5
Fat	3.5	0.3	0.0

Dried Dairy Ingredients

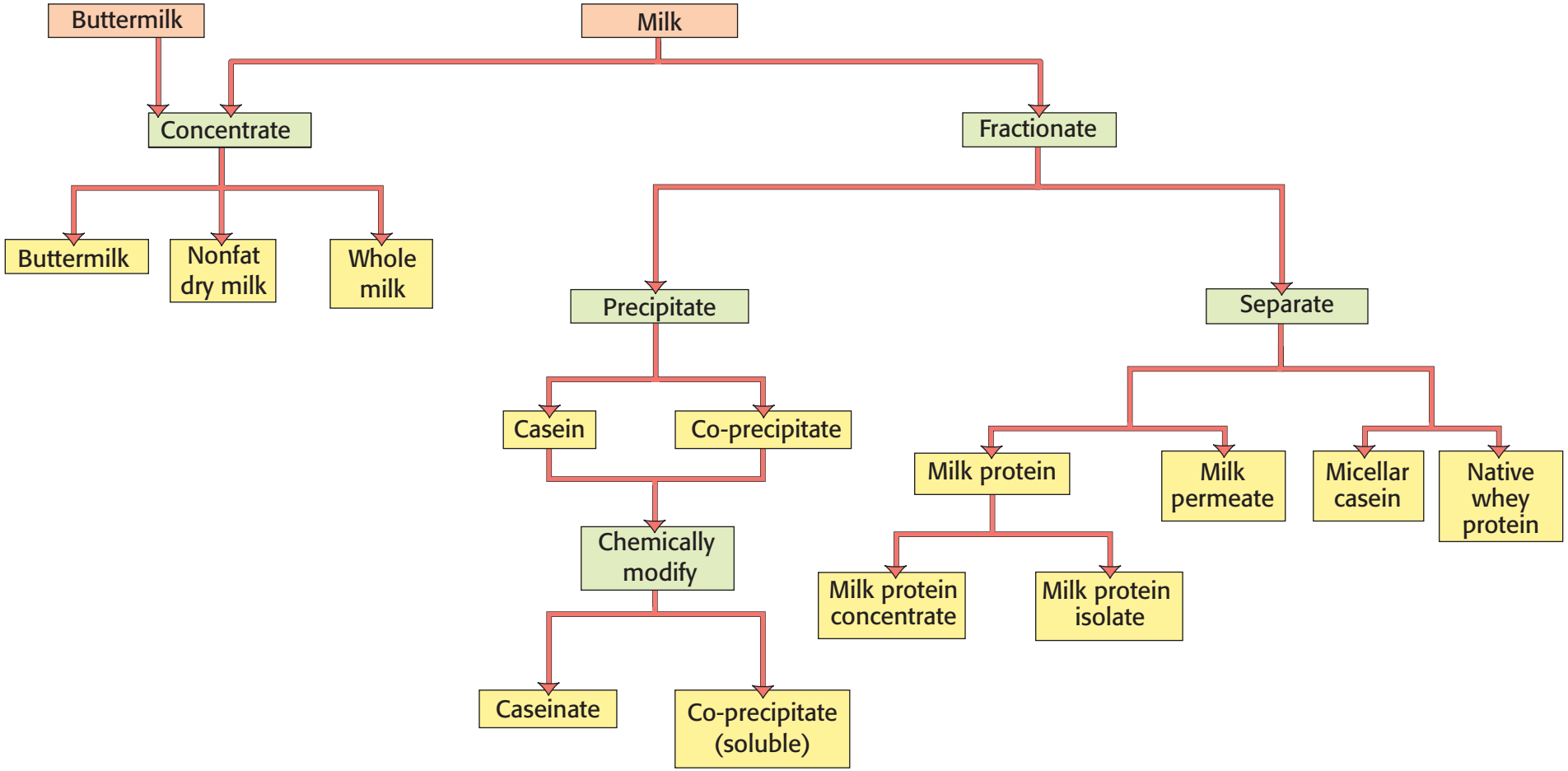
Milk based

- Milk powder
  - Nonfat dry milk (NFDM, NDM)
    - Low heat
    - Medium heat
    - High heat
  - Whole milk
  - Buttermilk
- Casein
  - Acid
  - Rennet
- Caseinate
  - Potassium
  - Calcium
  - Sodium
- Co-precipitate
  - Acid
  - Medium calcium
  - High calcium
- Milk protein concentrate (MPC)
  - 42 to 85
- Milk protein isolate (MPI)
- Permeate (milk)
- Micellar casein
- Native whey protein

Whey based

- Whey
  - Sweet
  - Acid
- Demineralized (reduced minerals) whey
  - 25 to 90%
- Reduced lactose whey
- Lactalbumin
- Whey protein concentrate (WPC)
  - 34 to 80
- Whey protein isolate (WPI)
- Lactose hydrolyzed whey
- Protein hydrolyzed whey
- Lactose
  - Food
  - Pharmaceutical
- Individual proteins
  - Lactoferrin
  - Lactoperoxidase
  - Glycomacropeptide (GMP)
- Permeate (whey)
- Dairy minerals
- Miscellaneous ingredients

Manufacturing Dairy Ingredients from Milk



Milk Powder

Milk powders are skim milk, whole milk or buttermilk with only water removed. All of the original constituents except water are present in their original ratios.

Note: The terms nonfat dry milk and skim milk powder are often used interchangeably but they are defined by two different sets of regulations and authorities. Nonfat dry milk is defined by FDA/USDA and skim milk powder is defined by Codex Allimentarius. Dry whole milk and whole milk powder also are used interchangeably but again are defined by two different sets of regulations and authorities. FDA/USDA defines and regulates dry whole milk while Codex Allimentarius defines and regulates whole milk powder.

Heat treatment of nonfat dry milk

- Nonfat dry milk (NFDM, NDM), also known as skim milk powder (SMP), may receive a heat treatment in addition to pasteurization.
- The heat treatment alters the functional properties of NFDM. Whey protein nitrogen index (WPNI) is a measure of the amount of heat treatment the powder has received. Whey proteins are denatured or altered by heat. The test measures the amount of undenatured whey protein present in the powder. Lower levels of undenatured whey protein in the powder indicate exposure to higher temperatures.
- WPNI does not indicate the heat stability of the powder.
- Low heat powder will have $< 25\%$ of the whey protein denatured while $> 81\%$ of the whey proteins are denatured in high heat powder.

Type of dryer used

- Milk powder functionality is affected by the type of dryer used.
- Majority of milk powder is produced by spray drying which is a less severe process than roller drying.
- Roller drying is relatively uncommon because of the amount of protein denaturation that results. Roller dried product will have a flaked appearance, browner color and more cooked flavor as compared to sprayed dried powder.

Final form of powder

- Agglomeration is used to increase particle size and is a step in the instantizing process.
- Instantizing improves the ability of powder to disperse and dissolve quickly. Lecithin may be added to whole milk or buttermilk powder to improve the ability of higher fat products to go into solution.
- Agglomeration and instantizing do not improve powder solubility. Rather they increase the rate of powder dispersing and dissolving. Powder that is insoluble will not be made soluble if agglomerated or instantized.
- Agglomerated/instantized powder will have a shorter shelf life as compared to ordinary powder because of the additional heat used during processing.

- Types
  - Nonfat
  - Whole
  - Buttermilk

- Grades
  - Extra grade
  - Standard grade
  - Grade not assignable

- Pre-heat treatments (nonfat)
  - Low heat
  - Medium heat
  - High heat

- Dryer used
  - Roller
  - Spray

- Final form
  - Ordinary (non-agglomerated, non-instant)
  - Agglomerated
  - Instantized

- Regulations
  - Nonfat dry milk
    21 CFR 131.125 (2007)

    United States Standards for Grades of Nonfat Dry Milk (Spray Process)
    USDA, AMS - Dairy Division, February 2, 2001

    United States Standards for Grades of Nonfat Dry Milk (Roller Process)
    USDA, AMS - Dairy Division, May 18, 1984

    United States Standards for Grades of Instant Nonfat Dry Milk
    USDA, AMS - Dairy Division, February 2, 2001

  - Skim milk powder
    Codex Stan 207-1999

  - Dry whole milk
    21 CFR 101.4 (b)(4) (2007)

    United States Standards for Grades of Dry Whole Milk
    USDA, AMS - Dairy Division, April 13, 2001

  - Whole milk powder
    Codex Stan 207-1999

  - Buttermilk
    21 CFR 101.4 (b)(6) (2007)

    United States Standards for Grades of Dry Buttermilk and Dry Buttermilk Product
    USDA, AMS - Dairy Division, February 2, 2001

Milk Powder Definitions
(summarized from Code of Federal Regulations)

Non fat dry milk (NFDM, NDM) is the product obtained by removal of water only from pasteurized skim milk. It contains not more than 5% by weight moisture, and not more than 1.5% by weight milk fat unless otherwise indicated. Product also may be known as skim milk powder (SMP).

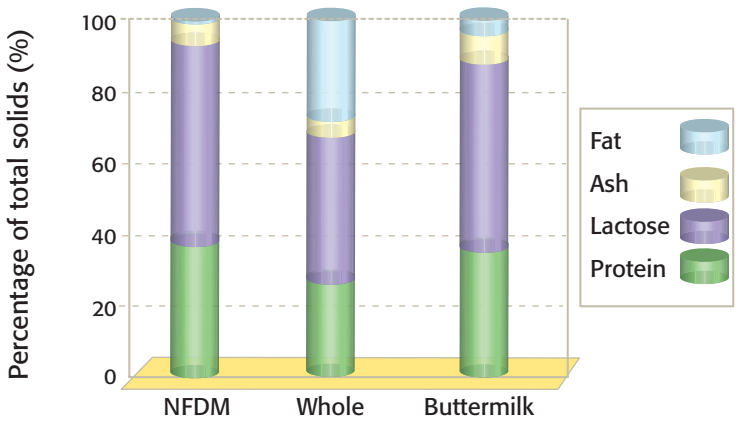
Dry whole milk (DWM) is the product resulting from the removal of water from pasteurized milk and contains by weight not less than 26%, but less than 40% milk fat and not more than 5% by weight of moisture. It contains lactose, milk proteins, milk fat and milk minerals in the same proportions as the milk from which it was made.

Dry buttermilk (DBM) is obtained by removing water from liquid buttermilk derived from the churning of butter. It shall contain not less than 4.5% milkfat and not more than 5% moisture. It shall have a protein content of not less than 30%.

The phospholipid and total lipid content of dried buttermilk is higher than NFDM. It may not contain or be derived from, skim milk powder, dry whey or products other than buttermilk, and contains no added preservative, neutralizing agent or other chemicals.

Dry buttermilk product (DBP) shall contain not less than 4.5% milkfat and not more than 5% moisture. Dry buttermilk product contains less than 30% protein and the label should specify the minimum protein content.

Milk powder composition



General composition of milk powders

Component	Skim	Whole	Buttermilk
	---------- % ----------		
Total protein	36.0	26.0	34.0
Lactose	51.0	37.0	48.5
Ash	8.2	6.0	8.5
Fat	0.8	27.0	5.0
Moisture	4.0	4.0	4.0

Classification of nonfat dry milk*

Category	Typical processing treatment		WPNI (mg/g undenatured whey protein)
	Temp (C)	Time (minutes)	
Low-heat	70	2	> 6.0
Medium-heat	70 - 78	20	1.51 - 5.99
High-heat	88	30	< 1.50

* USDA Dairy Standards for grades of nonfat dry milk (spray process)

Specifications for US Grades of nonfat dry milk (spray)*

Component	Extra	Standard	Instant extra
	---------- not greater than ----------		
Milkfat	1.25%	1.5%	1.25%
Moisture	4.0%	5.0%	4.5%
Titratable acidity	0.15%	0.17%	0.15%
Solubility index	1.2 ml**	2.0 ml***	1.0 ml
Scorched particles	15.0 mg	22.5 mg	15 mg
Bacteria	10,000/g	75,000/g	10,000/g
Coliforms	10/g	10/g	10/g

* USDA Dairy Standards for grades of nonfat dry milk (spray process)
** Except high heat not greater than 2.0
*** Except high heat not greater than 2.5

Specifications for US Grades of nonfat dry milk (roller)*

Component	Extra	Standard
	------ not greater than ------	
Milkfat	1.25%	1.5%
Moisture	4.0%	5.0%
Titratable acidity	0.15%	0.17%
Solubility index	15.0 ml	15.0 ml
Scorched particles	22.5 mg	32.5 mg
Bacteria	50,000/g	100,000/g
Coliforms	10/g	10/g

* USDA Dairy Standards for grades of nonfat dry milk (roller process)

Specifications for US Grades of dry whole milk (spray)*

Component	Extra	Standard
Milkfat	≮ 26% but < 40%	≮ 26% but < 40%
	---------- not greater than ----------	
Moisture**	4.5%	5.0%
Titratable acidity	0.15%	0.17%
Solubility index	1.0 ml	1.5 ml
Scorched particles	15.0 mg	22.5 mg
Bacteria	10,000/g	50,000/g
Coliforms	10/g	10/g

* USDA Dairy Standards for grades of dry whole milk
** As determined by weight of moisture on a milk solids-not-fat basis

Specifications for US Grades of dry whole milk (roller)*

Component	Extra	Standard
Milkfat	≮ 26% but < 40%	≮ 26% but < 40%
	---------- not greater than ----------	
Moisture**	4.5%	5.0%
Titratable acidity	0.15%	0.17%
Solubility index	15.0 ml	15.0 ml
Scorched particles	22.5 mg	32.5 mg
Bacteria	10,000/g	50,000/g
Coliforms	10/g	10/g

* USDA Dairy Standards for grades of dry whole milk
** As determined by weight of moisture on a milk solids-not-fat basis

Specifications for US Grades of dry buttermilk (spray)*

Component	Extra		Standard	
	not less than	not greater than	not less than	not greater than
Milkfat	4.5%		4.5%	
Protein	30.0%		30.0%	
Moisture		4.0%		5.0%
Titratable acidity	0.10%	0.18%	0.10%	0.20%
Solubility index		1.25 ml		2.0 ml
Scorched particles		15.0 mg		22.5 mg
Bacteria		20,000/g		75,000/g
Coliforms		10/g		10/g

* USDA Dairy Standards for grades of dry buttermilk and dry buttermilk product

Specifications for US Grades of dry buttermilk product (spray)*

Component	Extra		Standard	
	not less than	not greater than	not less than	not greater than
Milkfat	4.5%		4.5%	
Protein		30.0%		30.0%
Moisture		4.0%		5.0%
Titratable acidity	0.10%	0.18%	0.10%	0.20%
Solubility index		1.25 ml		2.0 ml
Scorched particles		15.0 mg		22.5 mg
Bacteria		20,000/g		75,000/g
Coliforms		10/g		10/g

* USDA Dairy Standards for grades of dry buttermilk and dry buttermilk product

Specifications for US Grades of dry buttermilk (roller)*

Component	Extra		Standard	
	not less than	not greater than	not less than	not greater than
Milkfat	4.5%		4.5%	
Protein	30.0%		30.0%	
Moisture		4.0%		5.0%
Titratable acidity	0.10%	0.18%	0.10%	0.20%
Solubility index		15.0 ml		15.0 ml
Scorched particles		22.5 mg		32.5 mg
Bacteria		20,000/g		75,000/g
Coliforms		10/g		10/g

* USDA Dairy Standards for grades of dry buttermilk and dry buttermilk product

Specifications for US Grades of dry buttermilk product (roller)*

Component	Extra		Standard	
	not less than	not greater than	not less than	not greater than
Milkfat	4.5%		4.5%	
Protein		30.0%		30.0%
Moisture		4.0%		5.0%
Titratable acidity	0.10%	0.18%	0.10%	0.20%
Solubility index		15.0 ml		15.0 ml
Scorched particles		22.5 mg		32.5 mg
Bacteria		20,000/g		75,000/g
Coliforms		10/g		10/g

* USDA Dairy Standards for grades of dry buttermilk and dry buttermilk product

Skimmed Milk Powder (SMP)

Skimmed milk powder is defined by Codex Alimentarius. The Codex Alimentarius Commission was created in 1963 by FAO and WHO to develop food standards, guidelines and related texts such as codes of practice under the Joint FAO/WHO Food Standards Programme. The main purposes of this Programme are protecting health of the consumers and ensuring fair trade practices in the food trade, and promoting coordination of all food standards work undertaken by international governmental and non-governmental organizations.

Codex definitions and specifications for SMP differ from US standards for NFDM. Whole milk powder and partly skimmed milk powder also are defined by Codex.

An important difference between Codex and US standards is the adjustment of protein levels. Codex allows the protein content of milk powder to be adjusted through the addition of milk retentate, milk permeate or lactose. The protein content of SMP typically is lower than the protein content of NFDM.

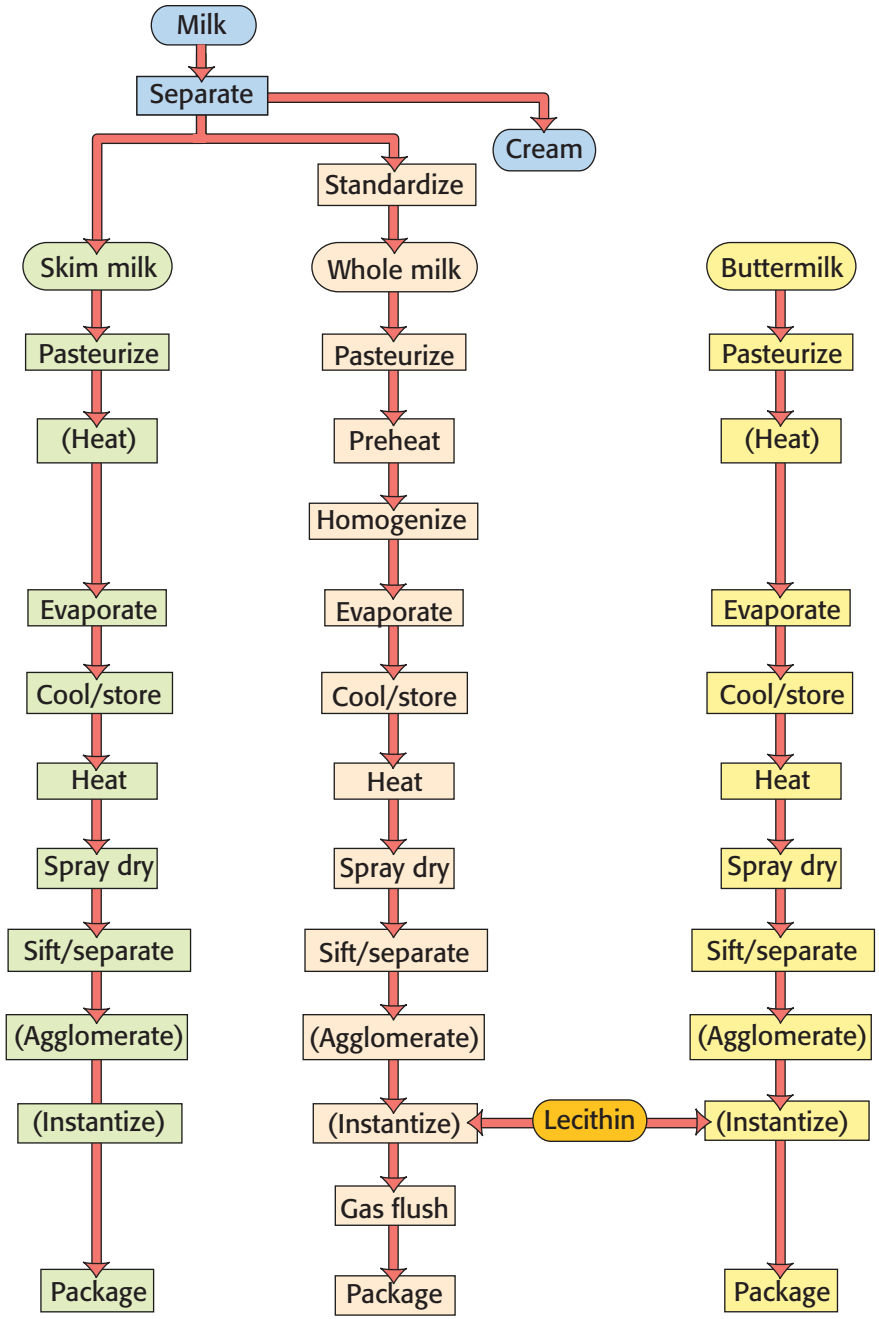
Codex specifications for milk powders*

Component	Skimmed	Partly skimmed	Whole
Milkfat	< 1.5%	≮ 1.5% but < 26%	≮ 26% but < 42%
Protein**	> 34%	> 34%	> 34%
	---------- not greater than ----------		
Moisture	5%	5%	5%
Titratable acidity	0.18%	0.18%	0.18%
Solubility index	1.0 ml	1.0 ml	1.0 ml
Scorched particles	15.0 mg	15.0 mg	15.0 mg

* Codex Stan 207-1999

** Milk protein as determined on a milk solids-not-fat basis

Manufacture of Milk Powder



Typical composition and characteristics

Nonfat dry milk

- Typical composition

Protein (db)	37.3%
Moisture	3.5%
Lactose	51%
Fat	1%
Ash	8.5%

- Storage
  - <27 C, <65% rh
  - 12–18 months
  - 6–12 months (instant)
- Characteristics
  - Color: white to light cream
  - Flavor: clean, dairy
  - TA <0.14%
  - Solubility index

Instant	1.0 ml
Low heat spray	1.2 ml
High heat spray	2.0 ml
Roller dried	15.0 ml

  - Scorch particle content

Spray dried	<15 mg
Roller dried	<22.5 mg

Whole milk

- Typical composition

Protein (db)	26.8%
Moisture	3%
Lactose	38%
Fat	27%
Ash	6%

- Storage
  - <27 C, <65% rh
  - 6–9 months
  - Shelf life very dependent on storage conditions
- Characteristics
  - Color: white to light cream
  - Flavor: clean, dairy
  - TA <0.15%
  - Solubility index

Spray dried	1.25 ml
Roller dried	15.0 ml

  - Scorch particle content

Spray dried	<15 mg
Roller dried	<22.5 mg

Buttermilk

- Typical composition

Protein (db)	34.4%
Moisture	4%
Lactose	48%
Fat	6.5%
Ash	8.5%

- Storage
  - <27 C, <65% rh
  - 6–9 months
  - Shelf life very dependent on storage conditions
- Characteristics
  - Color: uniform cream to dark
  - Flavor: clean, dairy
  - TA 0.10 – 0.18%
  - Solubility index

Spray dried	1.25 ml
Roller dried	15.0 ml

  - Scorch particle content

Spray dried	<15 mg
Roller dried	<22.5 mg

Casein

Casein is the major protein present in milk. Approximately 80% of the protein in milk is casein while whey proteins account for the remaining 20%.

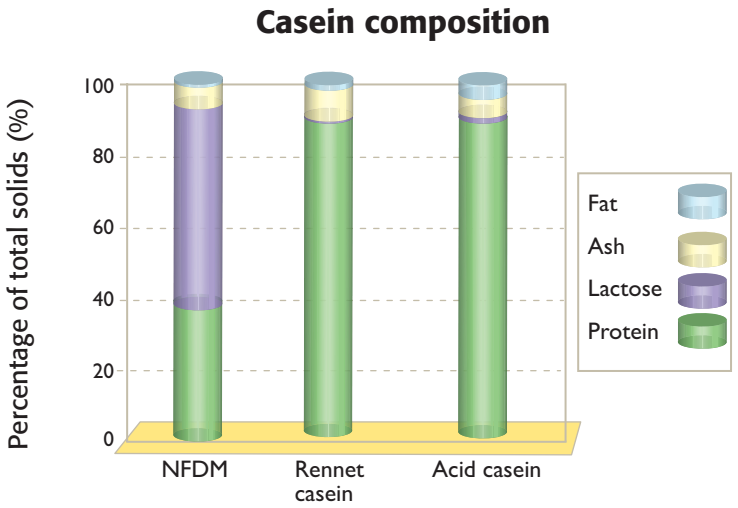
Commercial casein is prepared from pasteurized skim milk. Acid or rennet is used to coagulate the casein. A washing step is included to remove impurities such as lactose and minerals and thereby increase shelf life of the product. The functional properties of the resulting casein will depend on the coagulation method used.

Casein isolated by coagulation is in a not native or non-micellar form and is not soluble. Additional treatments are required to convert the casein into caseinates which are soluble.

- Types
  - Mineral acids
    - Hydrochloric
    - Sulfuric
    - Orthophosphoric
  - Organic acids
    - Lactic
      - Produced by starter culture
      - Addition of lactic acid
    - Acetic
    - Citric
  - Rennet
- Dryer
  - Roller
  - Spray

- Regulations
  - Acid casein
    United States Standards for Grades of Edible Dry Casein (Acid)
    USDA, AMS - Dairy Division, July 20, 1968

    Codex Stan A-18-1995 Rev 1-2001
  - Rennet casein
    Codex Stan A-18-1995 Rev 1-2001



General composition of casein

Component	Rennet	Acid
	---------- % ----------	
Protein	80.5	86.5
Lactose	0.5	0.5
Ash	8	2
Fat	1	1
Moisture	10	10
pH	7	5

Specifications for US Grades of acid casein*

Component	Extra	Standard
	---------- not less than ----------	
Protein (db)	95%	90%
	---------- not greater than ----------	
Milkfat	1.5	2.0
Moisture	10%	12%
Titratable acidity	0.20%	0.27%
Scorched particles	15 mg	22.5 mg
Bacteria	30,000/g	100,000/g
Coliforms	none/0.1g	2/0.1g

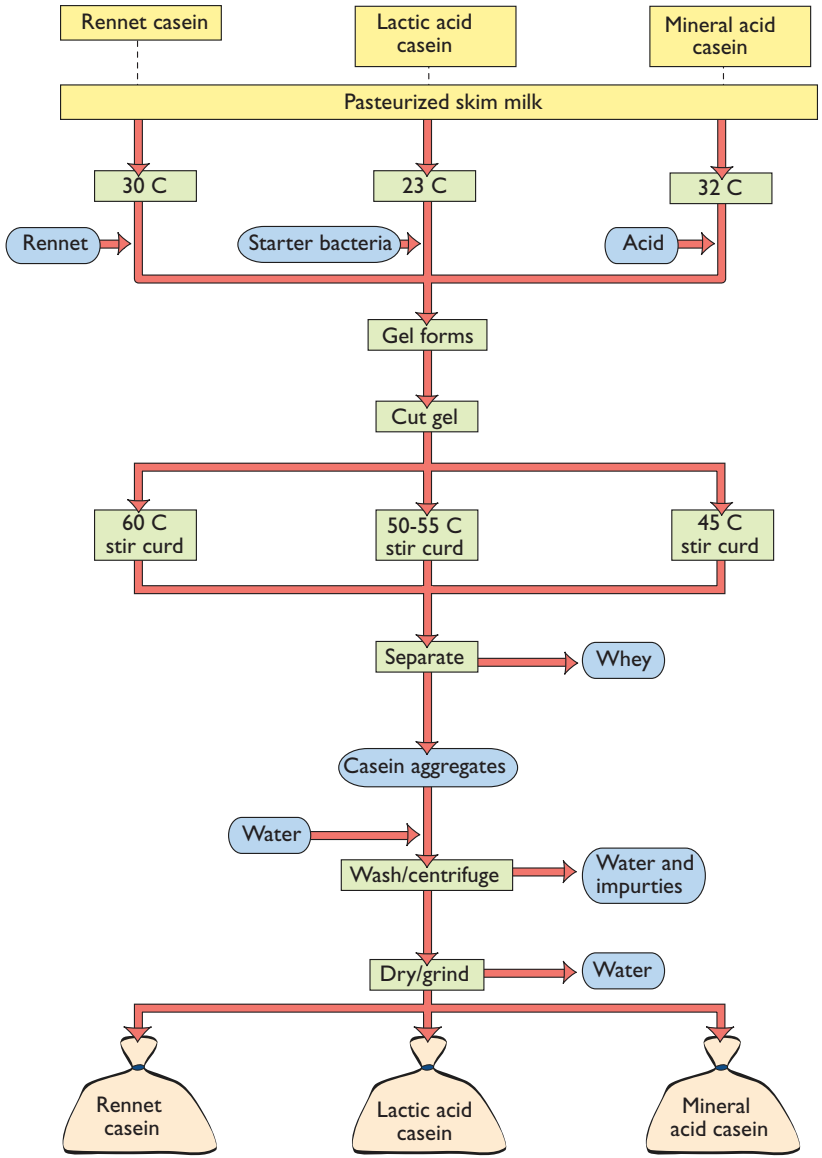
* USDA Dairy Standards for grades of casein (acid)

Codex specifications for casein products*

Component	Rennet		Acid	
	not less than	not greater than	not less than	not greater than
Milkfat		2.0%		2.0%
Protein (db)	84.0%		90.0%	
Casein in protein	95.0%		95.0%	
Moisture		12.0%		12.0%
Lactose**		1.0%		1.0%
Ash	7.5%			2.5%
Titratable acidity				0.27%
Scorched particles		15 mg		22,5 mg

* Codex Stan A-18 1995 Rev 1-2001
** Expressed in anhydrous form

Manufacture of Casein



Typical composition and characteristics

Rennet casein

- Typical composition

Protein (db)	90%
Moisture	10%
Lactose	0.5%
Fat	1%
Ash	8%

- Characteristics
  - Color: white to cream
  - Flavor: bland
  - pH 7
- Storage
  - <26 C, <65% rh
  - 12 months

Acid casein

- Typical composition

Protein (db)	90%
Moisture	10%
Lactose	0.5%
Fat	2%
Ash	2.5%

- Characteristics
  - Color: white to cream
  - Flavor: bland
  - pH 4.6
- Storage
  - <26 C, <65% rh
  - 18 months

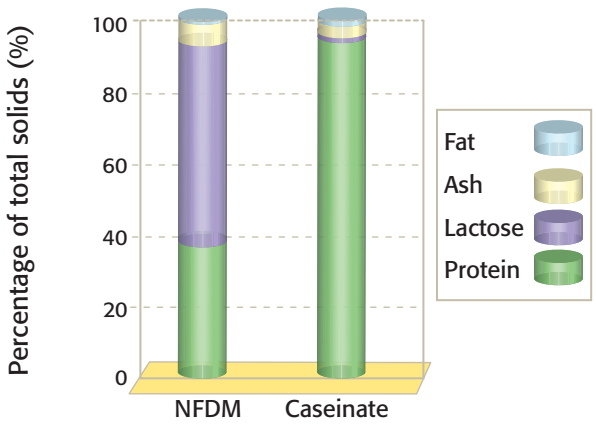
Caseinate

Acid or rennet casein is insoluble in water but they may be treated with alkali to make a caseinate which is soluble. The exact alkali used will determine the functional properties of the resulting caseinate.

- Types
  - Alkali used
    - Sodium hydroxide or carbonate
    - Potassium hydroxide
    - Calcium hydroxide
    - Ammonium hydroxide
  - Dryer used
    - Roller dryer
    - Spray dryer
    - Extruded

- Regulations
  - Codex Stan A-18-1995 Rev 1-2001

Caseinate composition



General composition of caseinate

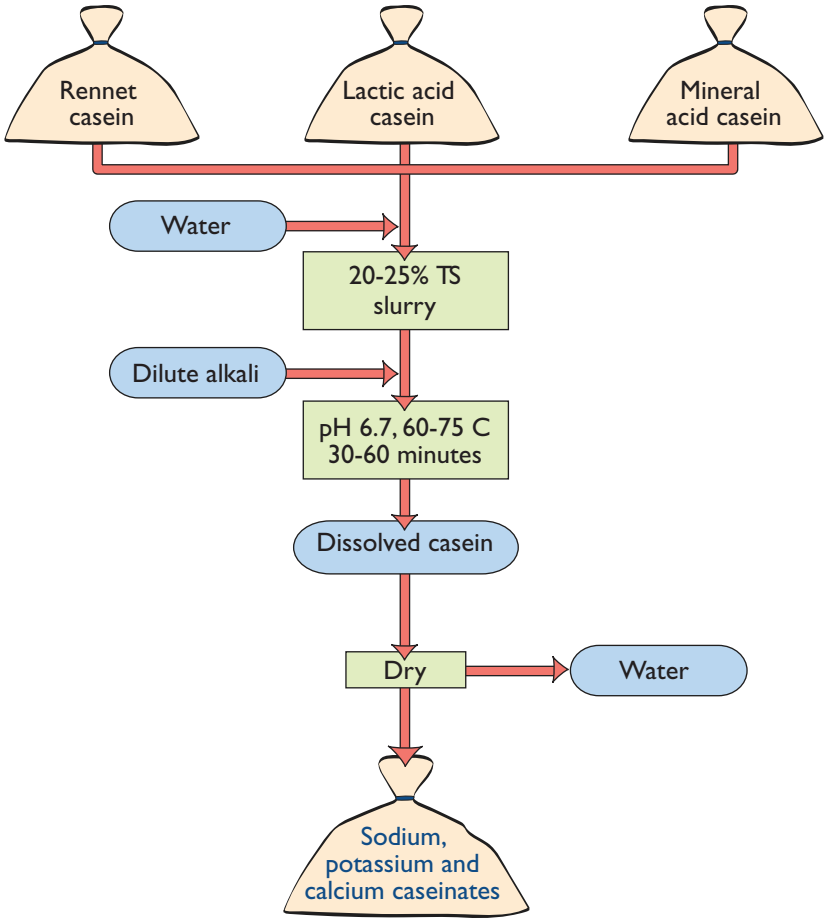
Component	Caseinate type		
	Potassium	Calcium	Sodium
	---------- % ----------		
Protein	88	88	88
Lactose	0.3	0.3	0.3
Ash	4.7	4.7	4.7
Fat	1.5	1.5	1.5
Calcium	0.2	1	0.2
Moisture	5.5	5.5	5.5
pH	6.5-7.0	6.5-7.0	6.5-7.0
Solubility	99	95	99

Codex specifications for caseinate*

Component	Caseinate	
	not less than	not greater than
Milkfat		2.0%
Protein (db)	88.0%	
Casein in protein	95.0%	
Moisture		8.0%
Lactose**		1.0%
Scorched particles spray roller		 22.5 mg 81.5 mg
pH		8.0

* Codex Stan A-18-1995 Rev 1-2001
** Expressed in anhydrous form

Manufacture of Caseinate



Typical composition and characteristics

Potassium caseinate

- Typical composition

Protein (db)	92%
Moisture	6%
Lactose	<1%
Fat	2%
Ash	5%
Potassium	1.5%
Calcium	0.2%

- Characteristics
  - Color: white to cream
  - Flavor: bland
  - pH 6-7
- Storage
  - <25 C, <65% rh
  - 12-24 months

Calcium Caseinate

- Typical composition

Protein (db)	91%
Moisture	6%
Lactose	<1%
Fat	1.5%
Ash	5%
Calcium	1.2%

- Characteristics
  - Color: white to cream
  - Flavor: bland
  - pH 6.6-7
- Storage
  - <25 C, <65% rh
  - 12-24 months

Sodium caseinate

- Typical composition

Protein (db)	92%
Moisture	6%
Lactose	<1%
Fat	1.5%
Ash	5%
Sodium	1.2%
Calcium	0.2%

- Characteristics
  - Color: white to cream
  - Flavor: bland
  - pH 6.6-7
- Storage
  - <26 C, <65% rh
  - 12 months

Ammonium caseinate

- Typical composition

Protein (db)	91%
Moisture	6%
Lactose	1%
Fat	1.5%
Ash	5%

- Characteristics
  - Color: white to cream
  - Flavor: bland
  - pH 5.7-6.7
- Storage
  - <25 C, <65% rh

Co-precipitate

Co-precipitates consist of casein and whey protein complexes. Heat is used to cause the whey proteins and casein to interact. Acid or calcium salts then are used to precipitate the protein complexes.

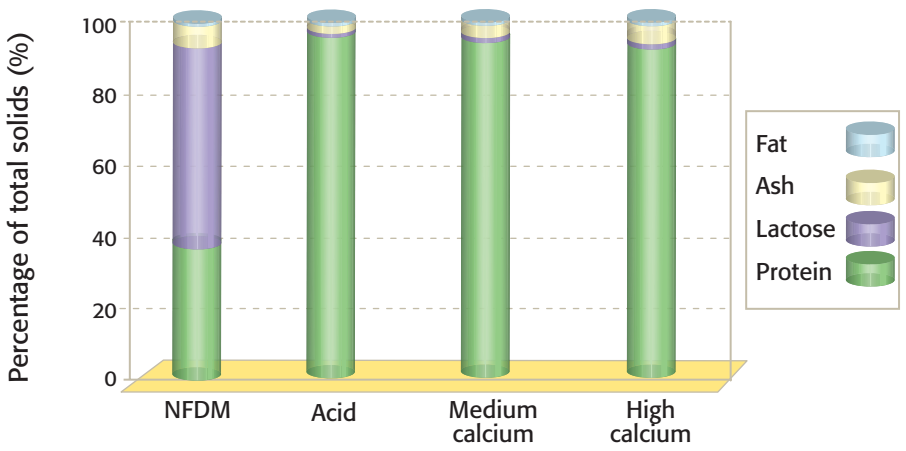
Co-precipitates are classified according to their calcium content. The pH when the proteins coagulate determines the calcium content of the co-precipitate.

Co-precipitates are insoluble unless modified by alkali in a process similar to the conversion of casein into caseinates. Low and medium calcium co-precipitates can be converted into very soluble products. High calcium co-precipitates may not be converted into a completely soluble product. Functional properties of the soluble co-precipitate will depend on the calcium content.

Co-precipitates typically are not produced in the United States. Products similar to soluble co-precipitates produced outside of the United States include total milk protein (TMP™), soluble lacto-protein and milk proteinate.

- Types
  - Acid
  - Medium calcium
  - High calcium
- Regulations
  - None, product not defined

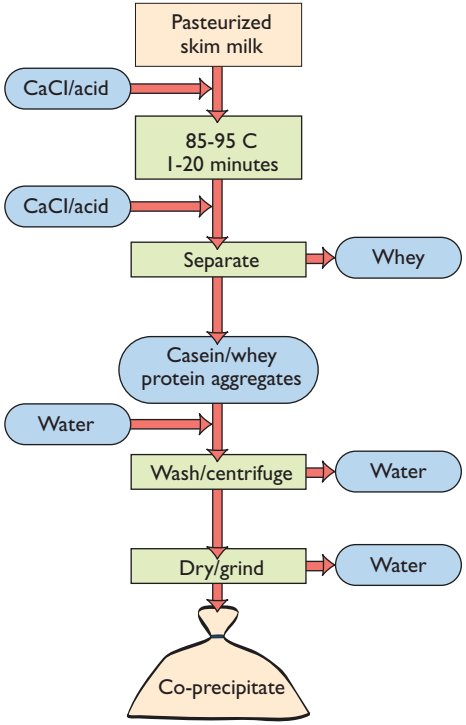
Co-precipitate composition



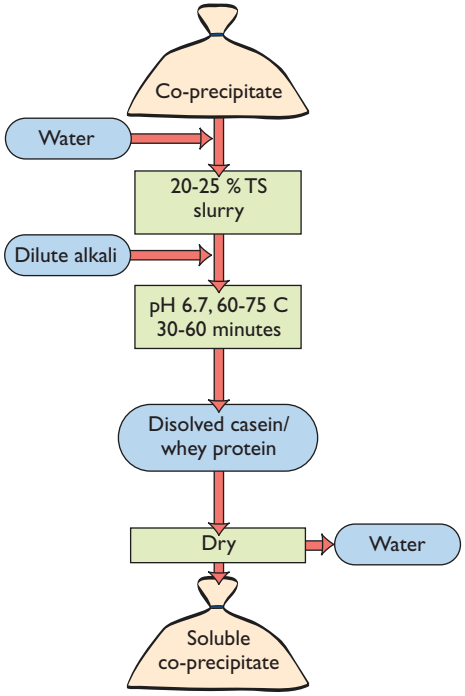
General composition of co-precipitate

Component	Co-precipitate type		
	Acid	Medium calcium	High calcium
	---------- % ----------		
Protein	86.7	85.6	81.7
Lactose	0.5	0.5	0.5
Ash	2.4	3.7	7.7
Fat	0.9	0.7	0.6
Moisture	9.5	9.5	9.5
Calcium	0.54	1.13	2.81
pH	5.4-5.8	5.6-6.2	6.5-7.2

Manufacture of Co-precipitate



Manufacture of Soluble Co-precipitate



Typical composition and characteristic

Not available

Milk Protein Concentrate (MPC)

Milk protein concentrates are not defined. For the purposes of this handbook, however, the following definitions will be used:

UF milk – liquid milk that has a portion of the lactose and mineral removed. The ratio of casein to whey protein is relatively unchanged from the original milk.

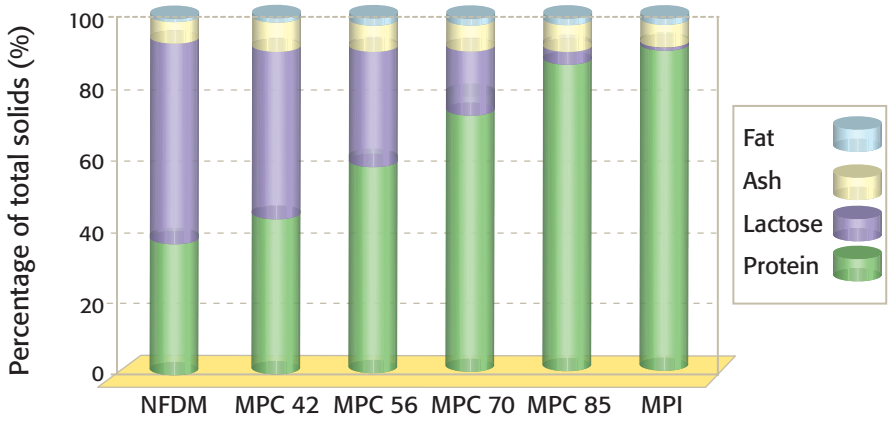
Milk protein concentrate (MPC) – the dry form of UF milk. MPCs typically range from 42 to 85% protein (dry basis). An MPC having 90% protein is referred to as a milk protein isolate (MPI).

MPCs are produced by a pressure driven process using semipermeable membranes known as ultrafiltration (UF). Lactose and minerals are removed by UF until the desired protein content is reached. The portion that remains, that is, the concentrated protein fraction, is referred to as retentate, while the lactose and mineral stream is known as permeate.

Proteins are not denatured by the UF process, therefore, MPCs are very soluble. Skim or whole milk may be used; however, MPCs typically are produced with skim milk.

- Regulations
  - None, product not defined

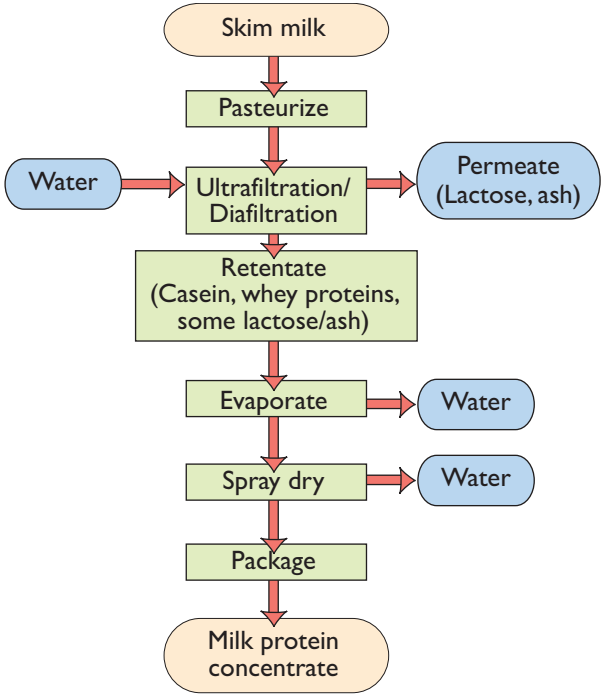
MPC composition



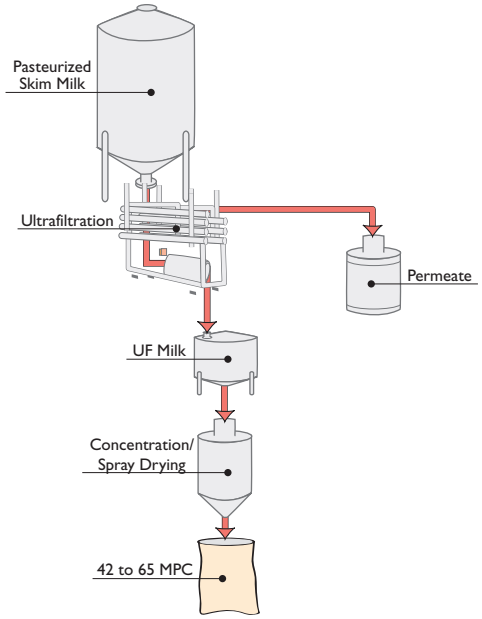
General composition of MPC

Component	MPC 42	MPC 56	MPC 70	MPC 85	MPI
	%				
Protein	40.6	54.4	68.3	83.1	87.1
Lactose	45.5	31.7	18.2	3.5	0.5
Ash	7.9	7.6	7.3	6.9	5.9
Fat	0.9	1.2	1.2	1.5	1.5
Moisture	5	5	5	5	5

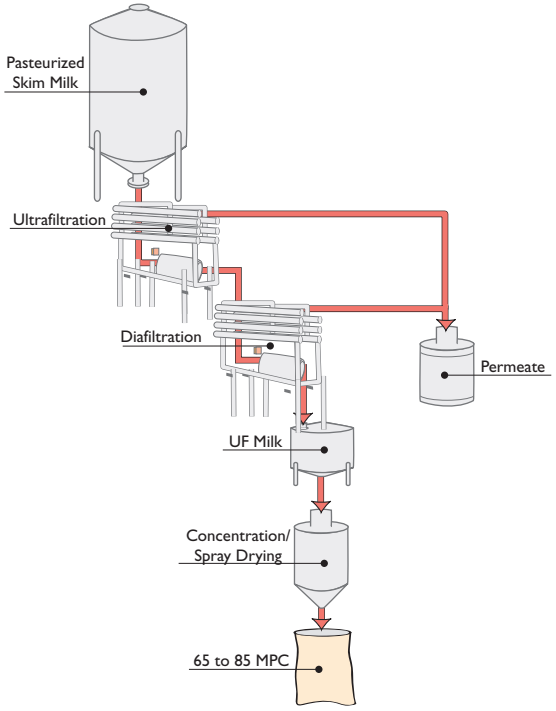
Manufacture of MPC



Manufacture of MPC 42 to 65



Manufacture of MPC 65 to 85



Typical composition and characteristics

MPC 42

- Typical composition

Protein (db)	42%
Moisture	5%
Lactose	46%
Fat	1%
Ash	8%

- Characteristics
  - Color: white to light cream
  - Flavor: clean, dairy
  - pH (5% solution) 6.5
- Storage
  - < 25 C, <65% rh
  - 12-18 months

MPC 70

- Typical composition

Protein (db)	70%
Moisture	5%
Lactose	17%
Fat	1.4%
Ash	7%

- Characteristics
  - Color: white to light cream
  - Flavor: clean, dairy
  - pH (5% solution) 6.5
- Storage
  - < 25 C, <65% rh
  - 12-18 months

MPC 85

- Typical composition

Protein (db)	85%
Moisture	5%
Lactose	3%
Fat	1.5%
Ash	7%

- Characteristics
  - Color: white to light cream
  - Flavor: clean, dairy
  - pH (5% solution) 6.5
- Storage
  - < 25 C, <65% rh
  - 12-18 months

MPI

- Typical composition

Protein (db)	90%
Moisture	5%
Lactose	<1%
Fat	1.5%
Ash	6%

- Characteristics
  - Color: white to light cream
  - Flavor: clean, dairy
  - pH (5% solution) 6.5
- Storage
  - < 25 C, <65% rh
  - 12 months

Milk Permeate

Milk permeate is not defined. For purposes of this handbook, however, the following definition will be used:

Milk permeate - portion of the milk that crosses or permeates the UF membrane. Milk permeate contains lactose, minerals and nonprotein nitrogen (NPN). True protein typically is not present although some manufacturers include small molecular weight compounds that contain nitrogen as part of the protein content.

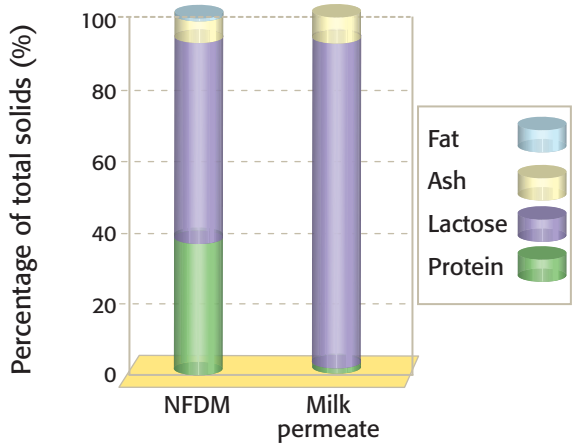
Milk permeate is a by product of MPC production.

Small molecular weight compounds such as galactose and lactic acid that are produced during cheese production are not present in milk permeate as compared to permeate produced from whey.

Manufacturers often do not distinguish permeate from milk as opposed to whey and unless listed otherwise it should be assumed that permeate is from whey rather than milk.

- Regulations
  - See permeate (whey)

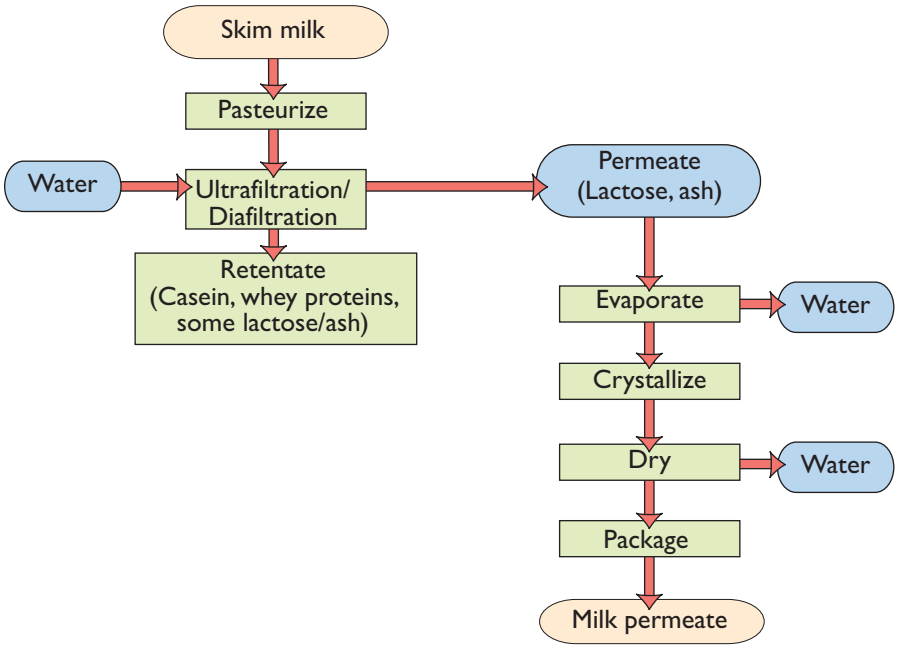
Milk permeate composition



General composition of milk permeate

Component	Milk permeate
	------ % -------
Protein	<1
Lactose	82
Ash	9
Fat	<1
Moisture	4
NPN	4

Manufacture of Milk Permeate



Typical composition and characteristics

Not available, see whey permeate

Microfiltered (MF) milk

Microfiltered milk is not defined. For the purposes of this handbook, however, the following definitions will be used:

Microfiltered (MF) milk – liquid milk that has a portion of the whey protein, lactose and mineral removed. The ratio of casein to whey proteins is altered such that a greater portion of casein is present than in typical milk.

Micellar casein – the dry form of MF milk.

Another term for micellar casein may be native phosphocasein.

MF milk is produced by a pressure driven process using semipermeable membranes known as microfiltration (MF). Whey proteins, lactose and minerals are removed until the desired casein content is reached. The portion that remains, that is, the concentrated casein fraction, is referred to as retentate, while the whey protein, lactose and mineral stream is known as the permeate. Because whey proteins are removed the ratio of casein to whey protein is altered from that found in milk.

Casein is present in milk in the form of micelles. The MF process does not alter the structure of the micelles; therefore, MF milk with micellar casein is very soluble.

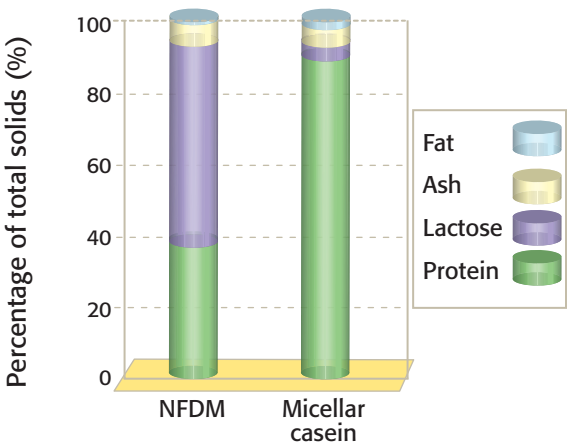
MF milk typically is produced from skim milk.

The permeate produced by the MF process has a very different composition from UF permeate.

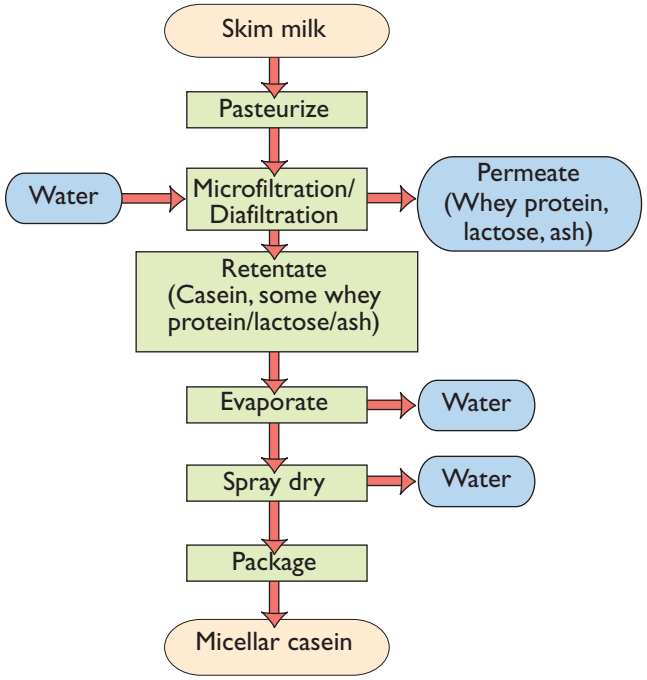
Native whey proteins are a byproduct of this process.

- Regulations
  - None, product not defined

Micellar casein composition



Manufacture of Micellar Casein



Typical composition and characteristics

Micellar Casein # 1

- Typical composition

Protein (db)	86%
Moisture	5%
Lactose	4%
Fat	1%
Ash	8%
Casein to total protein	92%

- Characteristics
  - Color: white to light cream
  - Flavor: clean, dairy
  - Solubility 99%
  - pH (10% solution) 6.5
- Storage
  - < 25 C, <65% rh
  - 24 months

Micellar Casein # 2

- Typical composition

Protein (db)	89%
Moisture	5%
Lactose	<0.5%
Fat	2%
Ash	8%
Casein to total protein	na

- Characteristics
  - Color: white to light cream
  - Flavor: clean, dairy
  - Solubility 99%
  - pH (10% solution) 7.1
- Storage
  - < 25 C, <65% rh

Native Whey Protein

Native whey proteins are not defined. For the purposes of this handbook, however, the following definition will be used:

Native whey protein – whey proteins that have been removed from milk by the process of MF/UF. Native whey proteins have not been through the cheese making process.

Other terms for native whey proteins may include serum proteins and ideal whey although none of these terms have a standard definition.

Native whey proteins are a by product of micellar casein production.

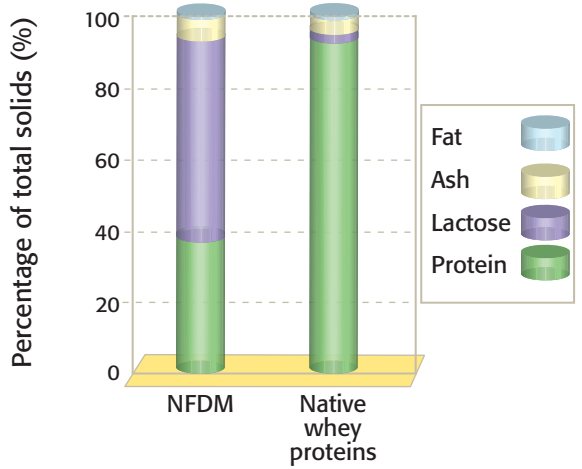
Native whey proteins may be concentrated by UF, through removal of lactose and minerals, to any desired protein level.

- Regulations
  - None, product not defined

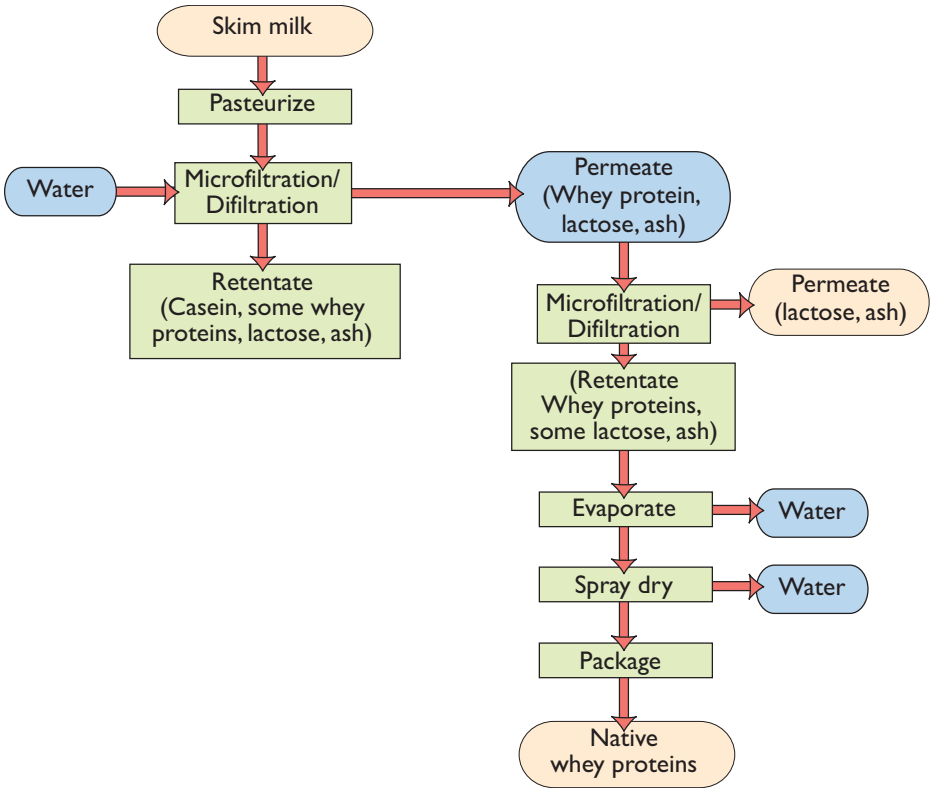
Presence of components in cheese whey versus MF permeate whey

Component	Cheese whey	MF permeate whey
Starter cultures	Yes	No
Rennet	Yes	No
Glycomacropeptide	Yes	No
Pasteurization steps	2	1
Fat/phospholipids	Yes	Negligible
pH	<6.5	6.6

Native whey protein composition



Manufacture of Native Whey Protein



Typical composition and characteristics

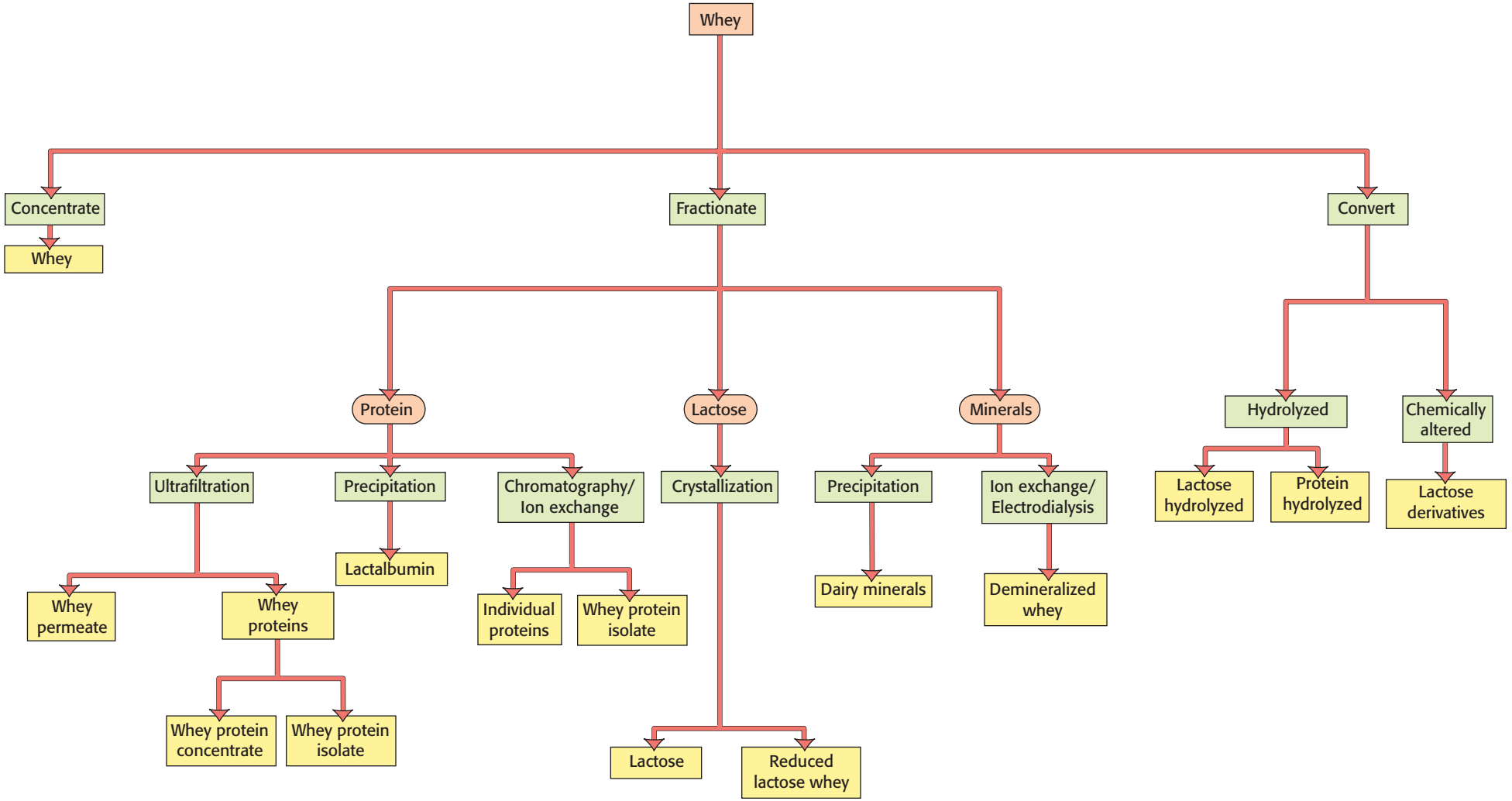
Native whey protein

- Typical composition

Protein (db)	92%
Moisture	5%
Lactose	2%
Fat	0.5%
Ash	3%

- Characteristics
  - Color: white to light cream
  - Flavor: clean, dairy
  - Solubility 99%
  - pH (10% solution) 6.0
- Storage
  - Not available

Manufacturing Dairy Ingredients from Whey



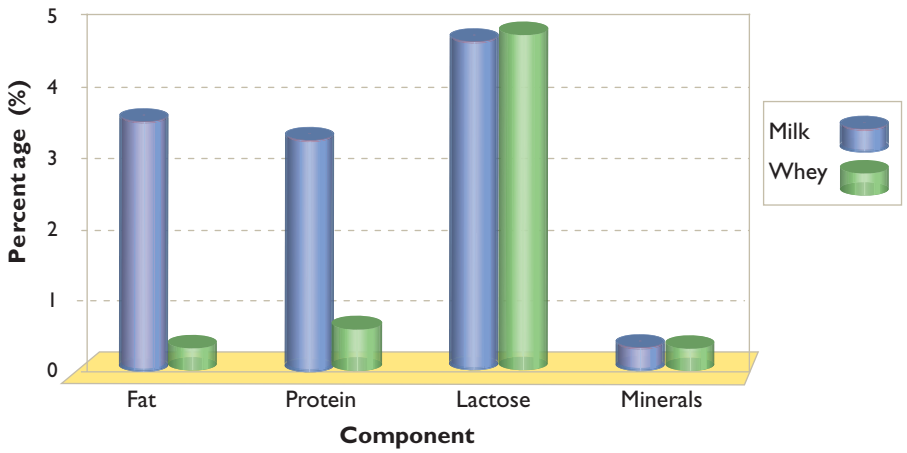
Whey

Cheesemaking and whey production

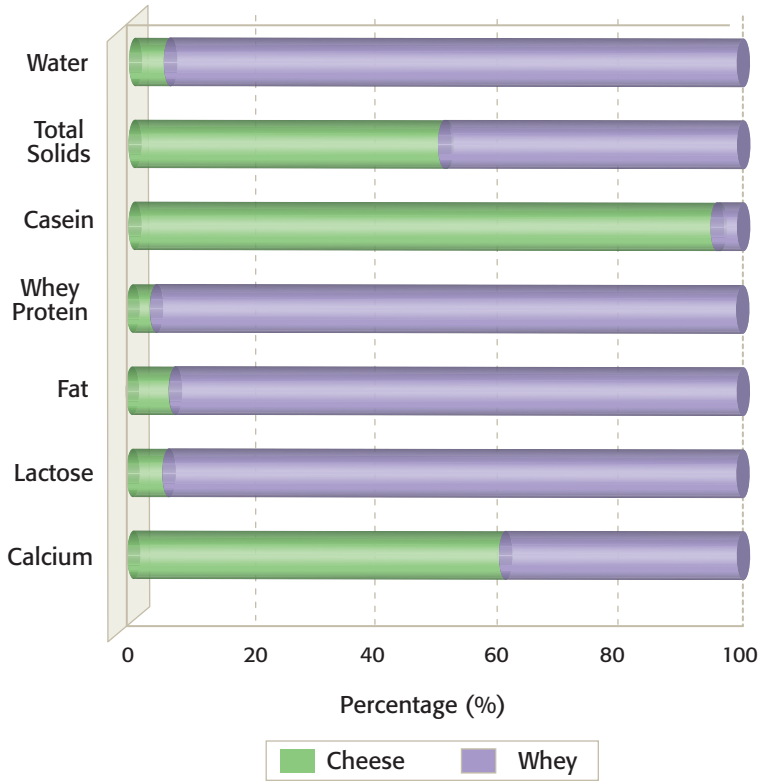
- Whey is a byproduct of cheese manufacture. Approximately 9 pounds of whey are produced for every 1 pound of cheese.
- Cheese may be produced through use of enzymes, such as rennet, that clot casein or addition of acid to lower the pH of the milk so that casein will precipitate. Some types of cheese use both methods to clot the casein.
- Whey drawn from curd that is clotted by rennet only will have a higher pH and is considered to be sweet whey.
- Whey drawn from curd that has formed through the use of acid (with or without added rennet) will have a lower pH and is referred to as acid whey.

- Fermented whey – sweet whey that has a lower pH due to the action of cheese starter culture. Fermented whey is not typically produced but rather results from undesired continued acid production by starter cultures.
- Sweet whey cheeses – most cheese types including Cheddar, Mozzarella, Swiss and Brick.
- Acid whey cheeses – Cottage, ricotta, quark and cream cheese and industrial casein made by acid coagulation

Composition of milk and whey



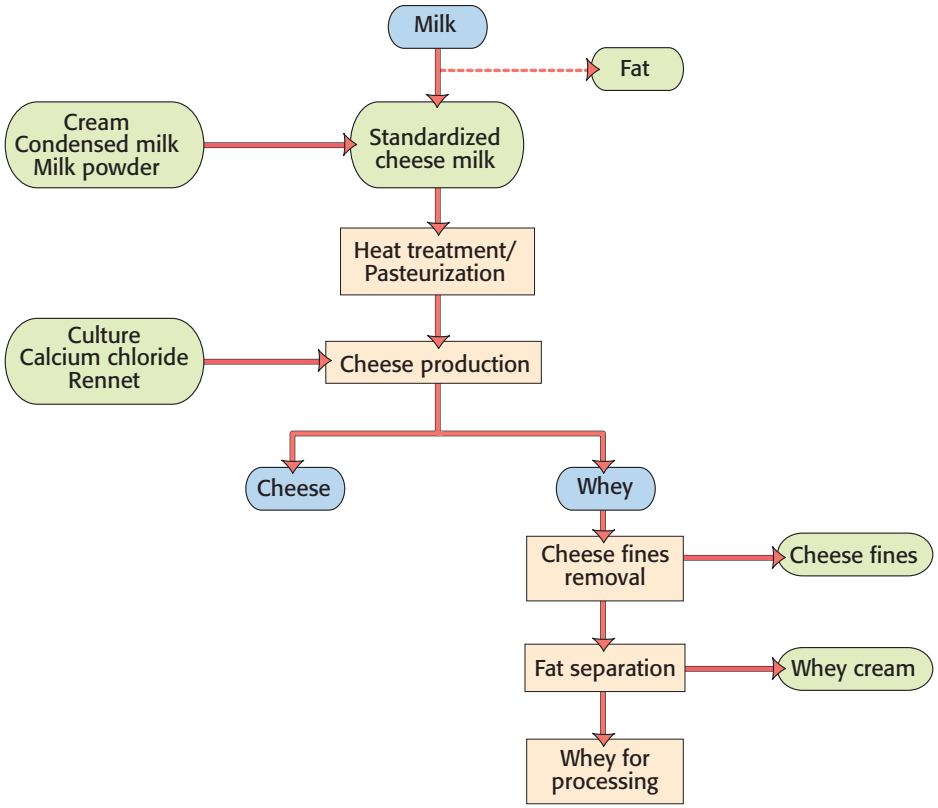
Distribution of milk components during cheese manufacture



Comparison of milk and sweet and acid whey

Component	Milk	Sweet whey	Acid whey
	---------- % ----------		
Total solids	12.5	6.5	6.5
Protein	3.5	0.8	0.7
Lactose	4.8	4.8	4.4
Ash	0.7	0.5	0.6
Fat	3.5	0.3	0.3
Lactic acid	––	0.1	0.5
	---------- mg/100 g ----------		
Calcium	120	45	103
Phosphorous	9	45	78

Production of Whey for Processing



Compositional differences

- The composition of the resulting sweet and acid whey will differ because of the pH when the whey is removed from cheese curds and the use of rennet.
- Sweet whey will contain glycomacropeptide (GMP). Rennet cleaves κ–casein thereby producing a protein fragment known as GMP. Glycomacropeptide can be 20% of the protein in sweet whey and it is not present in acid whey unless rennet is used. GMP is also know as casein macropeptide (CMP).
- Acid whey will have higher levels of calcium than sweet whey. Calcium phosphate is more soluble at lower pHs therefore the lower pH of acid whey will draw more calcium from the cheese curd into the whey than sweet whey.
- Sweet or acid whey that was produced from cheese where the pH was reduced by microbial cultures will contain byproducts of the fermentations such as galactose and lactic acid. Whey produced from cheese that used direct addition of acid will contain the acid used rather than fermentation byproducts. Acids typically used include: glucono–δ–lactone, lactic, sulfuric, phosphoric, hydrochloric and citric.
- Fermented whey will not have higher calcium levels but will contain by products of starter culture fermentations.

Whey processing

- Cheese maker typically removes cheese fines and whey cream from the whey before it is processed.
- Cheese fines are small pieces of cheese that were not captured in the curd. Cheese fines consist of coagulated casein and are not soluble, therefore their presence in whey is not desired.
- Whey cream consists of small fat globules that were not trapped within the cheese matrix. These fat globules can cause off flavors during storrage of whey based prowders; therefore, it is important that as much of the whey cream be removed as possible.
- The majority of whey is produced from pasteurized milk. Regardless of whether the whey came from raw or pasteurized milk, all whey must be pasteurized before it may be further processed into a dairy ingredient.

Optional steps

- Bleaching – benzoyl or hydrogen peroxide may be added to reduce the yellow/orange color of whey resulting from the use of annatto color during cheese manufacture.
- Neutralizing – addition of caustic to increase the pH of the whey. Neutralizing typically would be used only for acid or fermented whey.
- Crystallization – concentrated whey is allowed to cool so that lactose crystallizes. Crystallized lactose is less hygroscopic than lactose in glass form. The majority of whey powder produced in the US has a crystallization step so that the resulting powder is nonhygroscopic.

Type of dryer used

- Whey powder functionality is affected by the type of dryer used.
- Majority of whey powder is produced by spray drying which is a less severe process than roller drying.
- Roller drying is relatively uncommon because of the amount of protein denaturation that results. Roller dried product will have a flaked appearance, browner color and more cooked flavor as compared to sprayed dried powder.

Final form of powder

- Agglomeration is used to increase particle size and is a step in the instantizing process.
- Instantizing improves the ability of powder to disperse and dissolve quickly.
- Agglomeration and instantizing do not improve powder solubility. Rather they increase the rate of powder dispersing and dissolving. Powder that is insoluble will not be made soluble if agglomerated or instantized.
- Agglomerated/instantized powder will have a shorter shelf life as compared to ordinary powder because of the additional heat used during processing.

Assumptions used in this booklet when describing whey for further processing

- Cheese fines removed
- Whey cream removed
- Whey has been pasteurized

- Types
  - Sweet whey
  - Acid whey

- Grade
  - Extra
  - Grade not assignable

- Dryer used
  - Roller
  - Spray

- Final form
  - Ordinary, hygroscopic
  - Ordinary, non hygroscopic
    (non-agglomerated, non-instant)
  - Agglomerated
  - Instantized

- Regulations
  - Liquid whey
    21 CFR 184.1979 (2007)
  - Concentrated whey
    21 CFR 184.1979 (2007)
  - Dry whey
    21 CFR 184.1979 (2007)

    United States Standards for Dry Whey
    USDA, AMS - Dairy Division, December 14, 2000

    Codex Stan A-15-1995, Rev 1-2003, Amd 2006

Whey Definitions

(summarized from Code of Federal Regulations)

Whey is the liquid obtained by separating the coagulum from milk, cream, or skim milk in cheese making. Acidity may be adjusted with safe and suitable pH adjusting ingredients.

Sweet whey is whey that has an insignificant conversion of lactose to lactic acid. Maximum TA of not greater than 0.16% and alkalinity of ash not greater than 225 ml of 0.1 HCl.

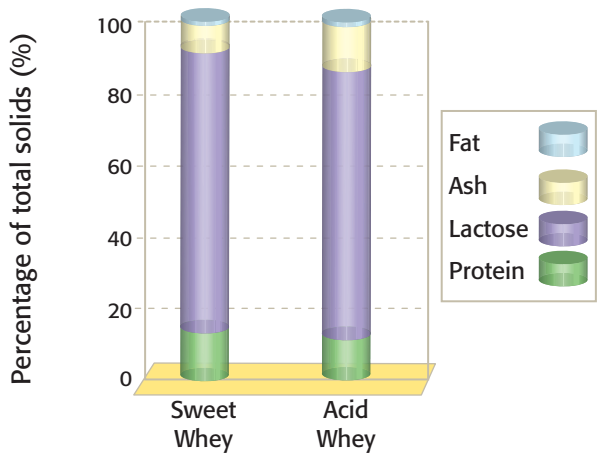
Concentrated whey is whey where a portion of the water has been removed leaving all other constituents in the same relative proportions.

Dry whey is fresh whey that has been pasteurized and contains all constituents, except water, in the same proportions as found in the original whey. Preservatives are not permitted.

Dry sweet whey shall not have greater than 0.16 percent titratable acidity on a reconstituted basis.

Dry acid whey shall have greater than 0.35 percent titratable acidity on a reconstituted basis.

Sweet and acid whey composition



General composition of whey powders

Component	Sweet whey	Acid whey
	---------- % ----------	
Protein	12.5	12.0
Lactose	73	70
Ash	8.5	12
Fat	1	1
Moisture	5	5

CFR specifications for dry whey*

Component	Not less than	Not greater than
	---------- % ----------	
Milkfat	0.2	2
Protein	10	15
Lactose	61	75
Ash	7	14
Moisture	1	8

* 21 CFR 184.1979 (2007)

USDA specifications for US Grades of dry whey*

Component	Extra	
	not less than	not greater than
Milkfat		1.5%
Moisture		5.0%
Titratable acidity sweet (dry) acid (dry)	 0.35%	 0.16%
Scorch		15.0 mg
Bacteria		30,000
Coliform		10
Optional test requirements		
Protein	11%	
Alkalinity of ash (sweet)		225 ml/100 g (0.1 N NaOH)

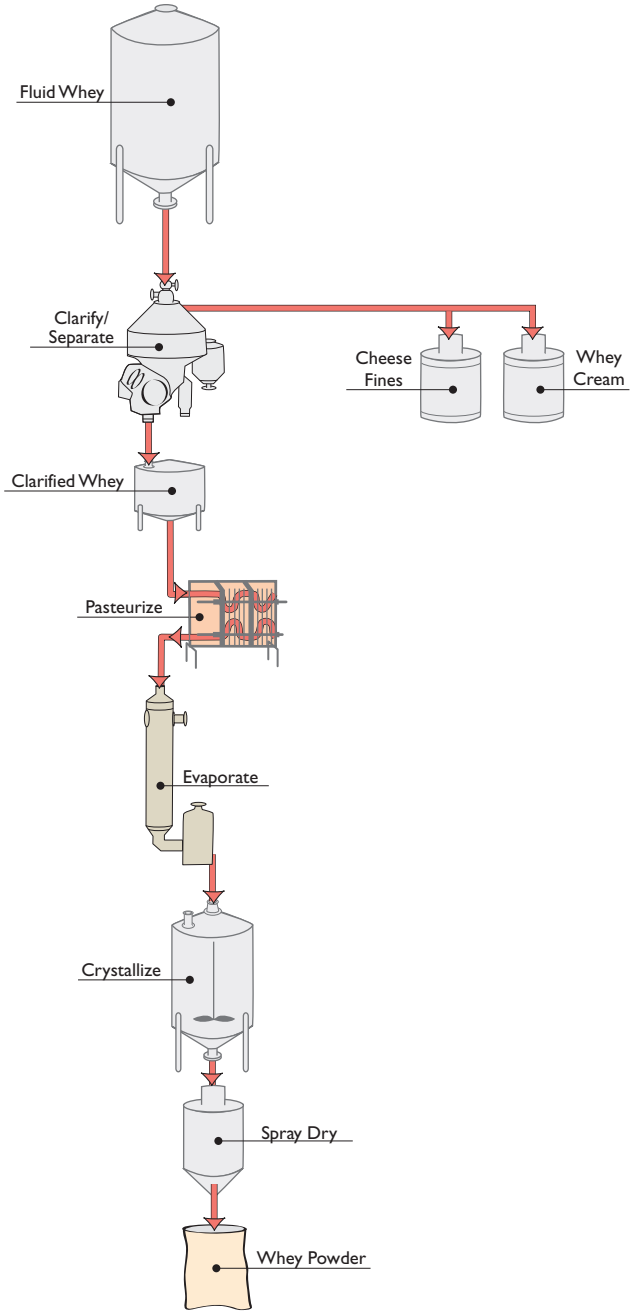
* United States Standards for Dry Whey
USDA, AMS - Dairy Division, December 14, 2000

Codex specifications for whey powders*

Component	Sweet		Acid	
	not less than	not greater than	not less than	not greater than
Protein	10.0%		7.0%	
Moisture		5.0%		4.5%
Ash		9.5%		15.0%
Titratable acidity or pH	5.1	0.35%	0.35% 5.1	

* Codex Stan A-15-1995, Rev 1-2003, Amd 2006

Manufacture of Sweet and Acid Whey



Typical composition and characteristics

Sweet whey

- Typical composition

Protein (db)	13%
Moisture	5%
Lactose	73%
Fat	1%
Ash	8%

- Characteristics
  - Color: off white to cream
  - Flavor: whey, slight salty
  - pH 5.7 - 6.0
- Storage
  - < 27 C, <65% rh
  - 6 - 12 months

Acid whey

- Typical composition

Protein (db)	13%
Moisture	5%
Lactose	70%
Fat	1%
Ash	12%

- Characteristics
  - Color: off white to cream
  - Flavor: whey, slight salty
  - pH 4.5
  - TA 0.35 - 0.44%
- Storage
  - < 27 C, <65% rh
  - 6 - 12 months

Demineralized or Reduced Minerals Whey

Processes such as precipitation, ion exchange, electrodialysis and membrane filtration may be used to remove the minerals. Membrane filtration, ion exchange and electrodialysis do not denature proteins thereby preserving protein solubility in demineralized whey produced by such methods. The exact process used will determine the mineral profile of the final product. Demineralized whey often will have a less salty flavor because of the removal of minerals.

Demineralized or reduced minerals whey - Whey with a portion of the minerals removed. The dry product cannot contain more than 7% ash. Acidity may be adjusted with safe and suitable pH adjusting ingredients.

CFR requires product to be listed as reduced minerals whey.

Types

- 25, 50 and 90% demineralization is typical

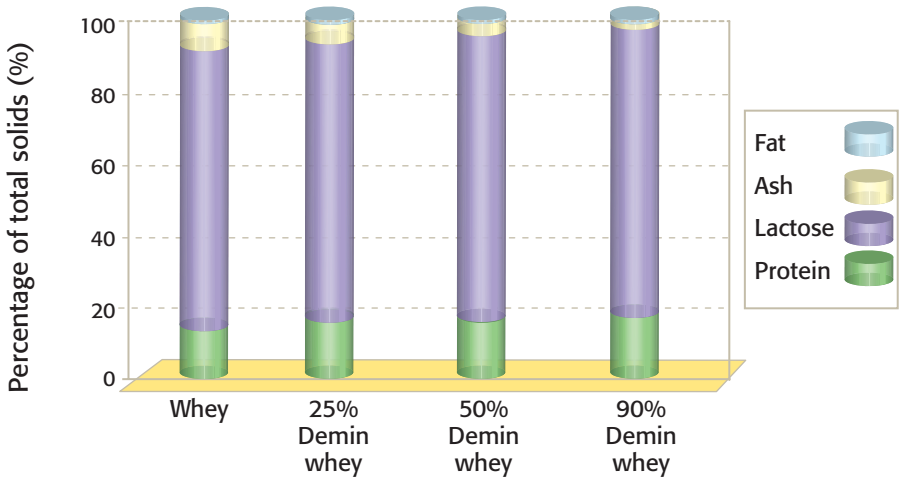
- Regulations
  - 21 CFR 184.1979 (2007)

Composition of demineralized whey *

Component	Whey	25% Demin	50% Demin	90% Demin
	grams			
Water	10	10	10	10
Fat	2.5	2.5	2.5	2.5
Protein	30	30	30	30
Lactose	186	186	186	186
Ash	21	17	11	2
Total	250	245	239	230
	%			
Ash in whey	8.6	7.0	4.6	0.9

* Values are in grams to illustrate the effect of mineral reduction on composition

Demineralized whey composition



General composition of demineralized whey

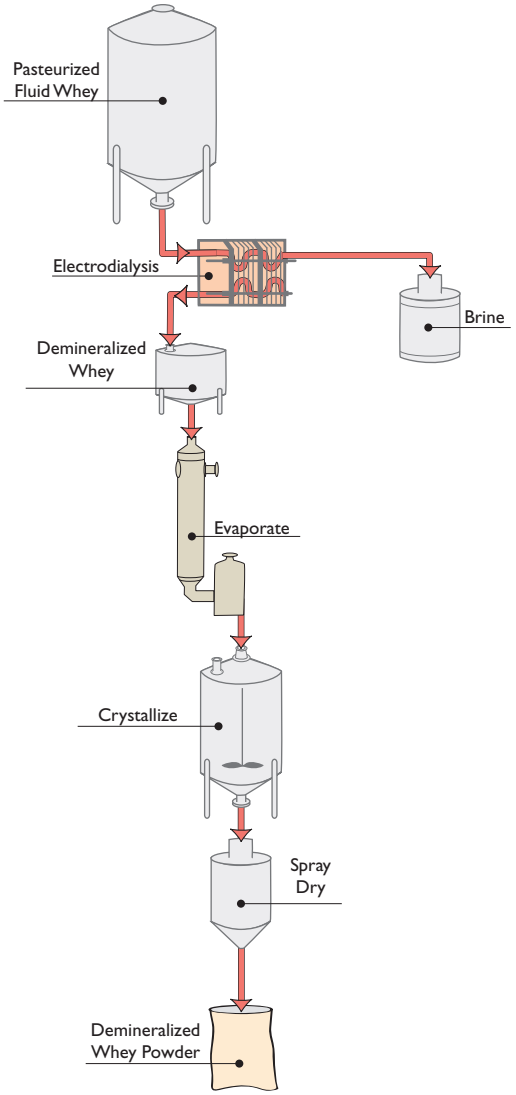
Component	25% Demin	50% Demin	90% Demin
	%		
Protein	12	13	13
Lactose	77	78	80
Ash	5	3	1
Fat	1	1	1
Moisture	5	5	5

CFR specifications for reduced minerals whey*

Component	Not less than	Not greater than
	%	
Milkfat	1	4
Protein	10	24
Lactose		85
Ash		7
Moisture	1	6

* 21 CFR 184.1979 (2007)

Manufacture of Demineralized Whey



Typical composition and characteristics

25% demineralized whey

- Typical composition

Protein (db)	11.4%
Moisture	5%
Lactose	78%
Fat	1%
Ash	5%

- Characteristics
  - Color: white to cream
  - Flavor: less salty whey flavor
- Storage
  - < 27 C, <75% rh
  - 24 months

50% demineralized whey

- Typical composition

Protein (db)	11.5%
Moisture	5%
Lactose	80%
Fat	1%
Ash	3%

- Characteristics
  - Color: white to cream
  - Flavor: not salty whey flavor
  - pH 6.0 – 6.5
- Storage
  - < 27 C, <75% rh
  - 24 months

90% demineralized whey

- Typical composition

Protein (db)	13.7%
Moisture	5%
Lactose	80%
Fat	1%
Ash	1%

- Characteristics
  - Color: white to cream
  - Flavor: not salty whey flavor
  - pH 6.7
- Storage
  - < 27 C, <75% rh
  - 24 months

Reduced Lactose Whey

Reduced lactose whey is produced by removing a portion of the lactose in the whey. Crystalline lactose is a byproduct. The mineral components of the whey are not altered.

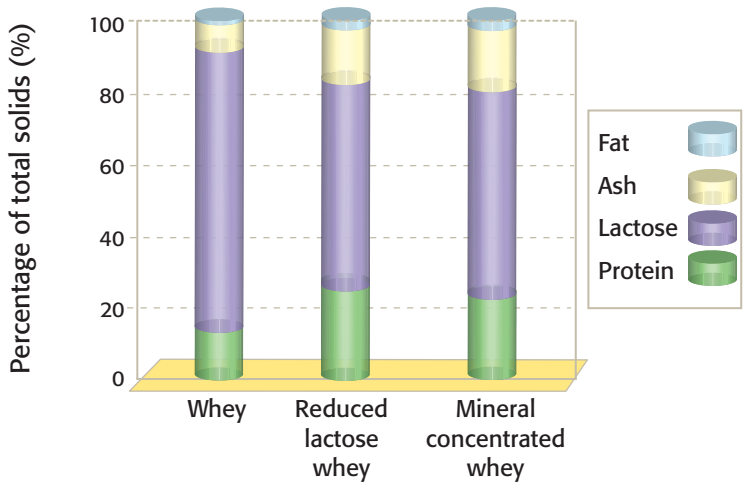
Reduced lactose whey differs from whey protein concentrate (WPC) in that the minerals are not removed while production of WPCs involves removal of both lactose and minerals.

Because only lactose is removed, lactose reduced whey may also be referred to as mineral concentrated whey or fractionated whey.

Reduced lactose whey - Lactose content of the final dry product cannot exceed 60%. Acidity may be adjusted with safe and suitable pH adjusting ingredients.

- Regulations
  - 21 CFR 184.1979 (2007)

Reduced lactose whey composition



General composition of reduced lactose whey

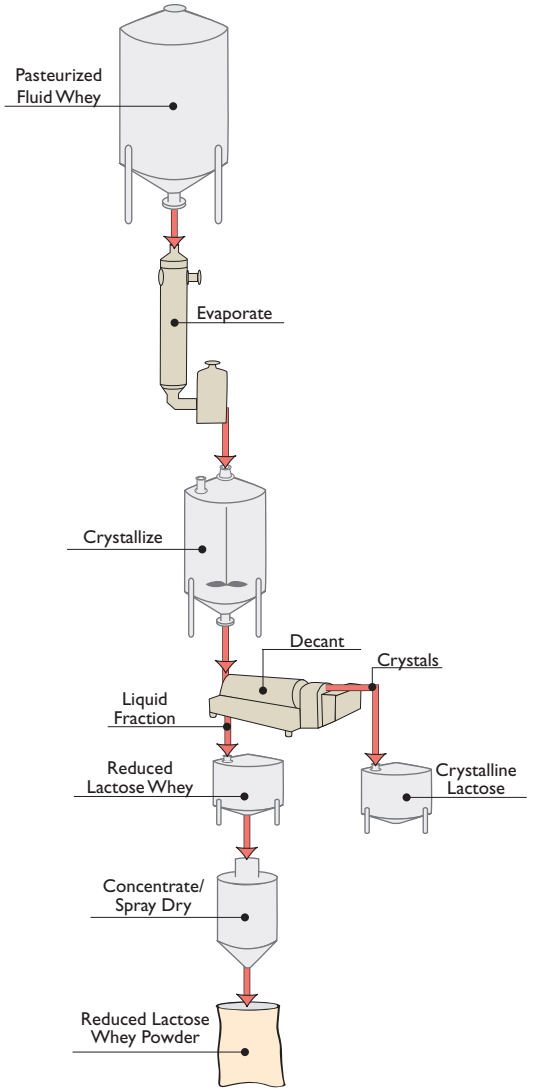
Component	Reduced lactose	Mineral concentrated
	---------- % ----------	
Protein	23	22
Lactose	56	56
Ash	16	17
Fat	2	2
Moisture	3	3

CFR specifications for reduced lactose whey*

Component	Not less than	Not greater than
	---------- % ----------	
Milkfat	1	4
Protein	16	24
Lactose		60
Ash	11	27
Moisture	1	6

* 21 CFR 184.1979 (2007)

Manufacture of Reduced Lactose Whey



Typical composition and characteristics

Reduced lactose whey*

- Typical composition

Protein (db)	24%
Moisture	4%
Lactose	56%
Fat	2%
Ash	15%

- Characteristics
  - Color: cream to dark cream
  - Flavor: typical whey
- Storage
  - < 27 C, <65% rh
  - 12 months

Mineral concentrated whey*

- Typical composition

Protein (db)	21.3%
Moisture	3%
Lactose	56%
Fat	2%
Ash	17%

- Characteristics
  - Color: cream to dark cream
  - Flavor: typical whey
- Storage
  - < 27 C, <65% rh
  - 12 months

*Exact composition depends on specifications

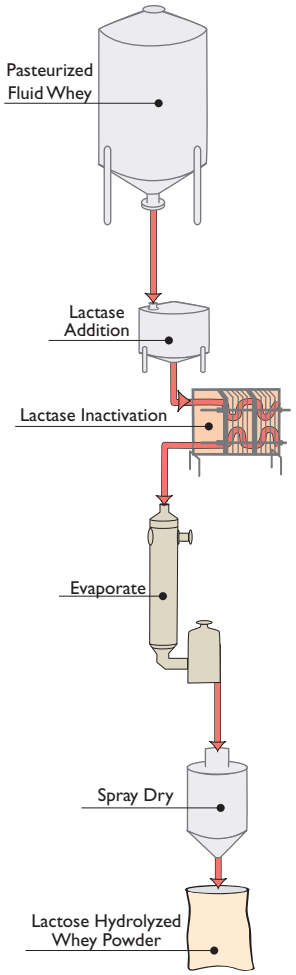
Lactose Hydrolyzed Whey

Lactose hydrolyzed whey is produced by hydrolyzing a portion of the lactose to glucose and galactose by addition of lactase enzyme. The product will have increased sweetness and decreased tendency for lactose crystallization as compared to whey. The amount of lactose converted to glucose and galactose depends on product specifications.

Lactose hydrolyzed whey is difficult to dry and the powder may tend to become sticky with storage.

- Regulations
  - None, product not defined

Manufacture of Lactose Hydrolyzed Whey



Typical composition and characteristics

Not available

Protein Hydrolyzed Whey

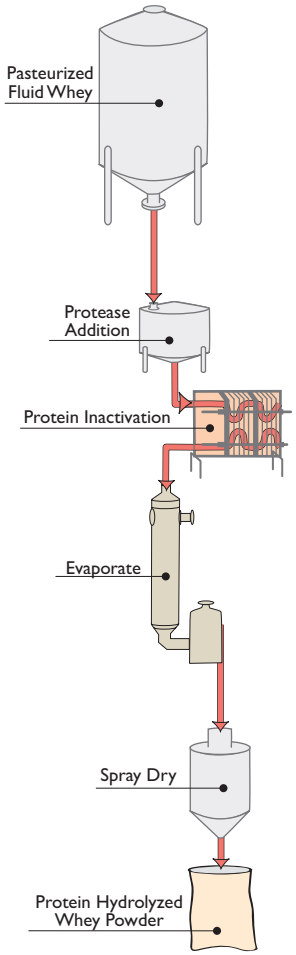
Protein hydrolyzed whey has a portion of the whey protein hydrolyzed into smaller fragments. Enzymes such as trypsin, chymotrypsin, etc. are used.

There is considerable variation in the product profile. The specific enzymes used, sequence of enzymes, reaction time, reaction temperature, etc are all important and can affect the type of protein fragments produced.

Manufacturers currently are using whey protein concentrates (WPC) as starting material to produce protein hydrolyzed products with higher protein contents.

- Regulations
  - None, product not defined

Manufacture of Protein Hydrolyzed Whey



Typical composition and characteristics

Not available

Lactalbumin

Lactalbumin is produced by precipitating whey proteins. Heat and pH changes may be used to denature the whey proteins so that they aggregate and separate from the other whey constituents.

Lactalbumin is different from α-lactalbumin

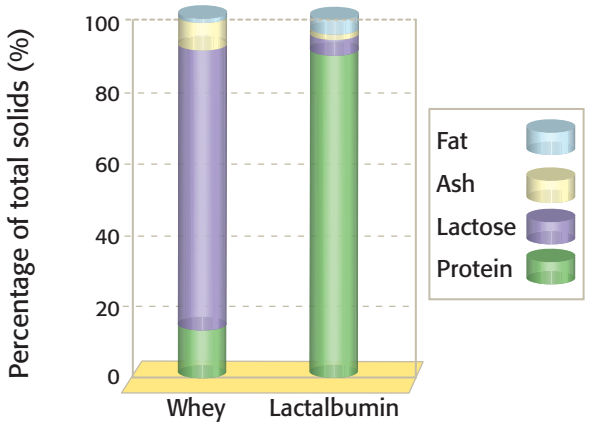
Proteins are not soluble because they have been denatured.

Although some products in the US are referred to as lactalbumin these products are different in composition and functionality than the product described here. Lactalbumin in this form is typically a European product and is not produced in US.

- Final product composition and functionality depends on:
  - Temperature/holding time
  - pH
  - Whey type
  - Calcium concentration
  - Dryer used

- Regulations
  - None, product not defined

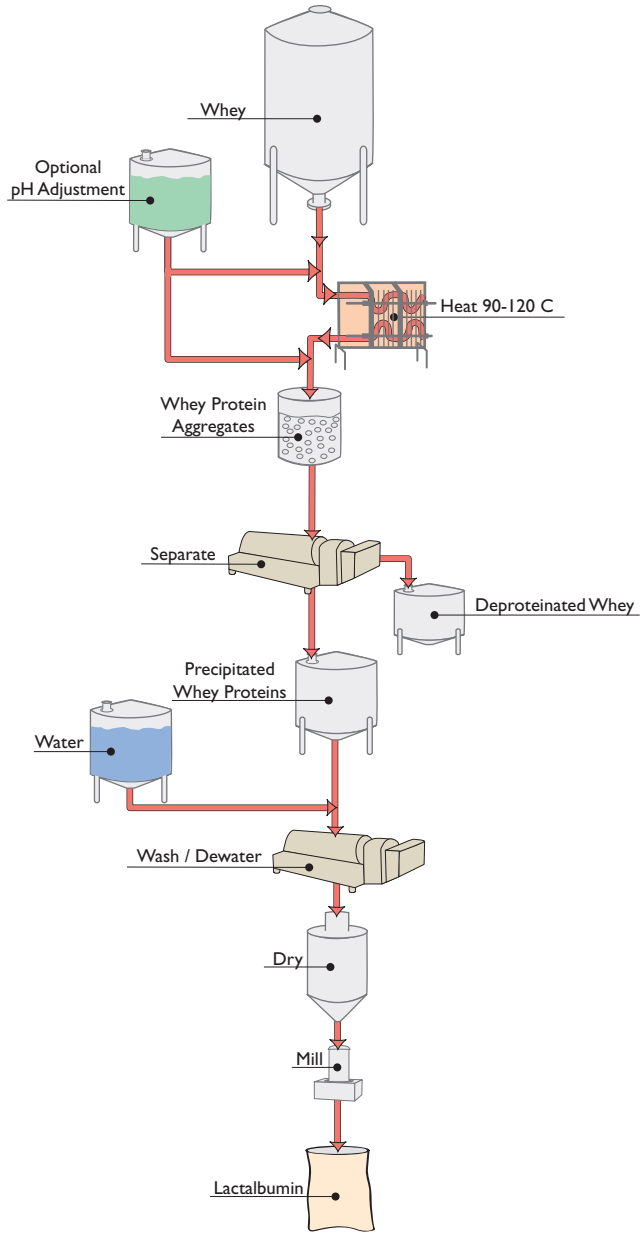
Lactalbumin composition



General composition of lactalbumin

Component	Lactalbumin
	--------- % ---------
Protein	85
Lactose	6
Ash	3
Fat	2
Moisture	4

Manufacture of lactalbumin



Typical composition and characteristics

Lactalbumin

- Typical composition

Protein (db)	89%
Moisture	4%
Lactose	5%
Fat	2%
Ash	3%

- Characteristics
  not available
- Storage
  not available

Whey Protein Concentrate (WPC)

Produced by a pressure driven process known as ultrafiltration (UF). Ultrafilteration uses semipermeable membranes.

Lactose and minerals are removed until desired protein content is reached. By product of this process is permeate. Higher protein WPCs require the use of water, in a process known as diafiltration (DF), to remove greater amounts of lactose and ash.

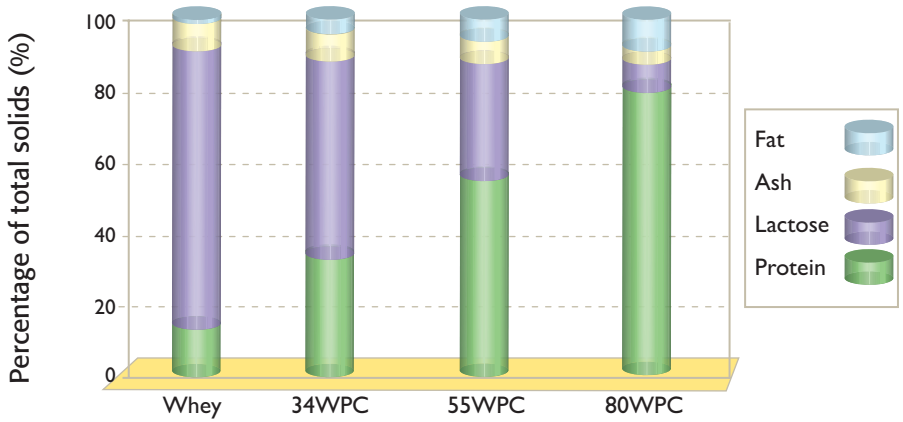
Proteins are not denatured by the UF process therefore WPCs can be very soluble.

Sweet or acid whey may be used, however, WPCs typically are produced from sweet whey.

Whey protein concentrates - Lactose, minerals and nonprotein nitrogen compounds are removed thereby concentrating the protein fraction. The final dry product must contain at least 25% protein.

- Regulations
  - 21 CFR 184.1979 (2007)

Whey protein concentrate composition



General composition of whey protein concentrate

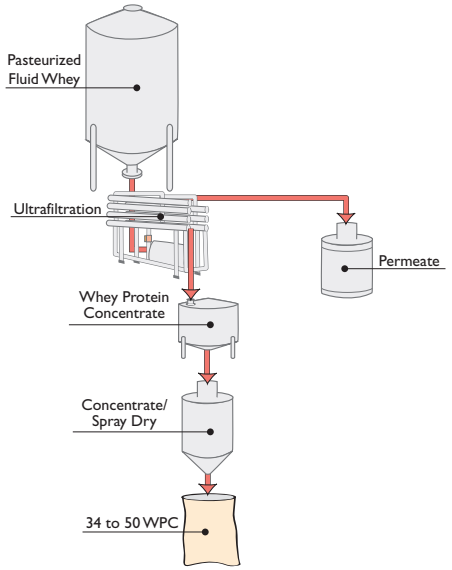
Component	WPC 34	WPC 55	WPC 80
	%		
Protein	33	53	77
Lactose	52	31	9
Ash	7	6	4
Fat	4	6	6
Moisture	4	4	4

CFR specifications for whey protein concentrate*

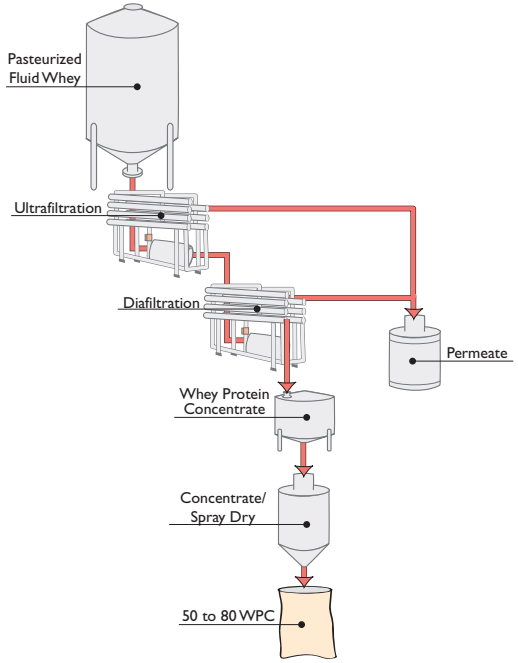
Component	Not less than	Not greater than
	%	
Milkfat	1	10
Protein	25	–
Lactose	–	60
Ash	2	15
Moisture	1	6

* 21 CFR 184.1979 (2007)

Manufacture of WPC 34 to 50



Manufacture of WPC 50 to 80



Typical composition and characteristics

WPC 34

- Typical composition

Protein (db)	34%
Moisture	4%
Lactose	52%
Fat	4%
Ash	7%

- Characteristics
  - Color: white to light cream
  - Flavor: bland, clean
  - pH 6.0-6.7
- Storage
  - < 27 C, <65% rh
  - 9-12 months

WPC 55

- Typical composition

Protein (db)	55%
Moisture	4%
Lactose	31%
Fat	6%
Ash	6%

- Characteristics
  - Color: white to light cream
  - Flavor: bland, clean
  - pH 6.0-6.7
- Storage
  - < 27 C, <65% rh
  - 9-12 months

WPC 80

- Typical composition

Protein (db)	80%
Moisture	4%
Lactose	9%
Fat	6%
Ash	4%

- Characteristics
  - Color: white to light cream
  - Flavor: bland, clean
  - pH 6.0-6.7
- Storage
  - < 27 C, <65% rh
  - 9-12 months

Whey Protein Isolate (WPI)

Whey protein concentrates with protein contents on a dry basis greater than 90% are referred to as whey protein isolates (WPI).

WPIs are produced by one of two methods:

- MF/UF
- Ion exchange

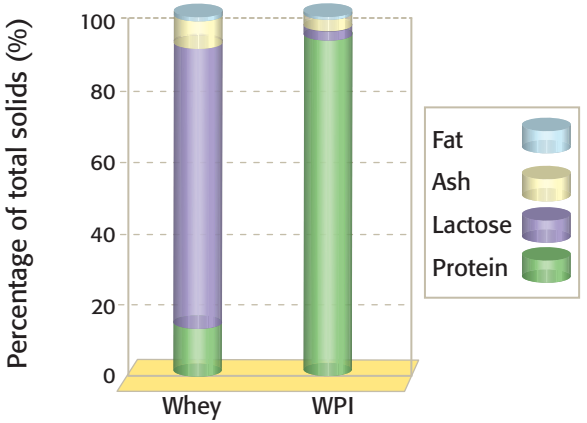
Protein composition of the WPI will depend on the method used. The greatest difference is the presence of glycomacropeptide (GMP). GMP is a protein fragment resulting from the action of rennet on casein during cheesemaking. The ion exchange process does not capture GMP and therefore GMP is absent from WPI produced by ion exchange unless it is added back. MF/UF process retains GMP so that it is present in the resulting WPI.

Reports in the literature indicate the ratio of specific whey proteins also may differ between MF/UF and ion exchange produced WPIs. The producer of the specific WPI should be contacted for further information should the precise protein profile be important to the end user.

- Types
  - Process used
    - MF/UF
    - Ion exchange
  - Final form
    - Ordinary (non-agglomerated, non-instantized)
    - Instantized

- Regulations
  - FDA GRAS Notice No. 37 (2000)

Whey protein isolate composition



General composition of whey protein isolate

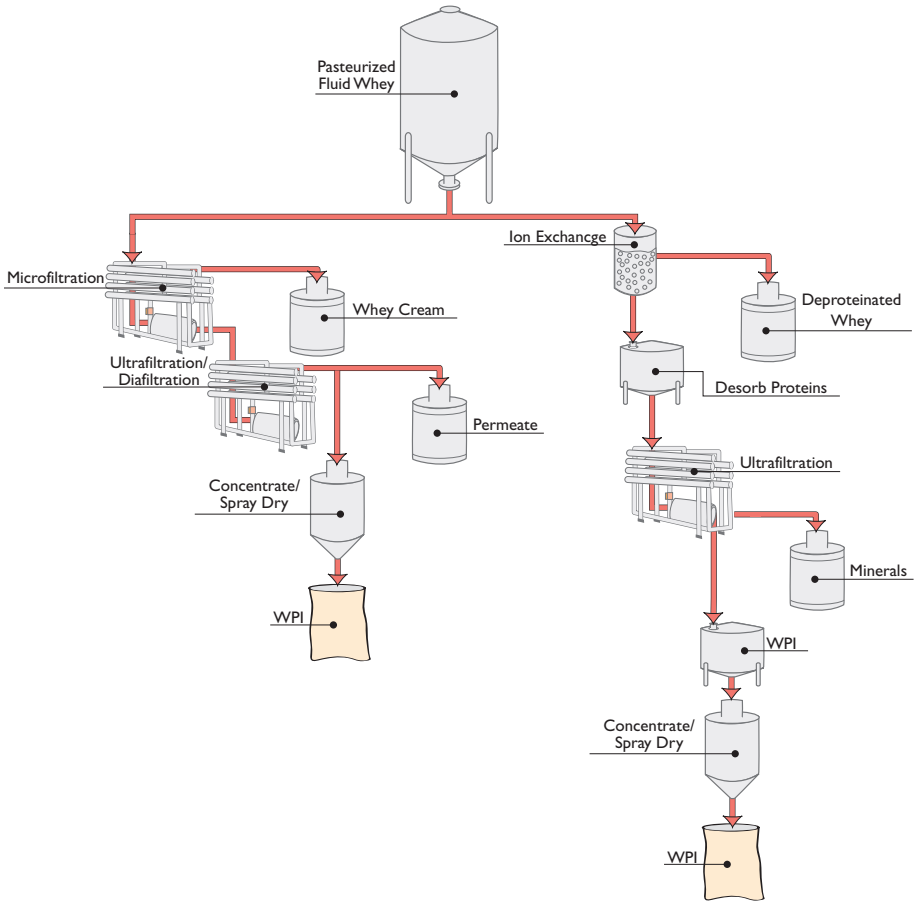
Component	WPI
	----- % -----
Protein	89
Lactose	2
Ash	3
Fat	1
Moisture	5

FDA specifications for whey protein isolate*

Component	Not less than	Not greater than
	---------- % ----------	
Milkfat	na	na
Protein	90	
Lactose		6
Ash		6
Moisture		6

* FDA GRAS Notice No. 37 (2000)

Manufacture of WPI



Typical composition and characteristics

Whey Protein Isolate (WPI)

- Typical composition

Protein (db)	93%
Moisture	1%
Lactose	3%
Fat	1%
Ash	5%

- Characteristics
  - Color: white to cream
  - Flavor: bland, clean
- Storage
  - < 27 C, <65% rh
  - 12 months

Whey Protein Isolate (WPI) - Instantized

- Typical composition*

Protein (db)	93%
Moisture	5%
Lactose	3%
Fat	1%
Ash	2%

- Characteristics
  - Color: off white to cream
  - Flavor: bland, clean
- Storage
  - < 27 C, <65% rh
  - 12 months

* Composition does not include soy lecithin (<1.5%) added to instantized product.

Individual Whey Proteins

Individual proteins are produced by ion exchange/chromatographic methods. The desired protein typically is captured on special "beads" or membranes while the remainder of the whey proteins proceeds unhindered through the vessel. Special solutions are then used to release the captured proteins. These products typically have very high purity of the desired proteins as compared to products that have increased concentrations of a particular protein or group of proteins.

α-lactalbumin – makes up approximately 20 – 25% of the whey proteins. Denatures at 144F (62C). Binds calcium which stabilizes it against denaturation.

Lactoferrin - is an iron binding protein. Present at 30 – 100 mg/L in whey. Lactoferrin is not denatured by standard pasteurization (72C for 15 seconds).

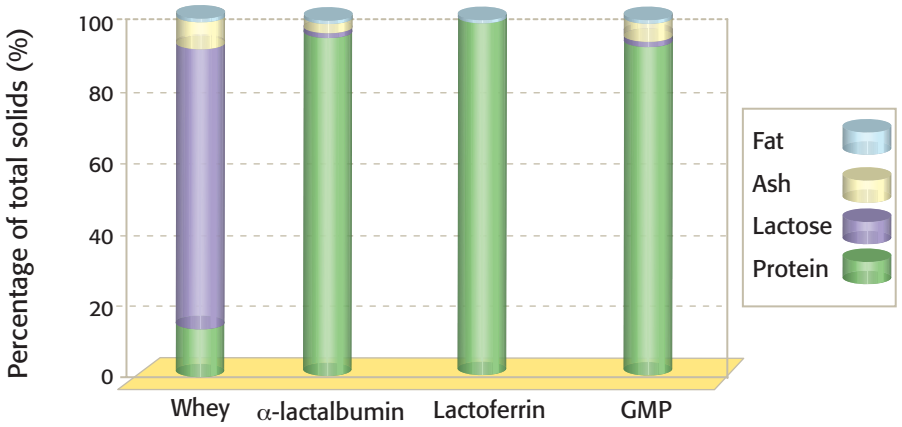
Lactoperoxidase – is an enzyme with antimicrobial ability. It is present in whey at approximately 1 – 30 mg/L and is considered to be relatively heat resistant.

Glycomacropeptide (GMP) – is a peptide that is also known as casein macropeptide (CMP). The peptide is formed when rennet clips off a piece of κ-casein during cheese manufacture. GMP therefore is present only in whey that is produced using rennet.

- Types
  - α-lactalbumin
  - Lactoferrin
  - Lactoperoxidase
  - Glycomacropeptide (GMP)

- Regulations
  - Lactoferrin
    FDA GRAS Notice No. 42 (2001)
  - Other proteins
    None, products not defined

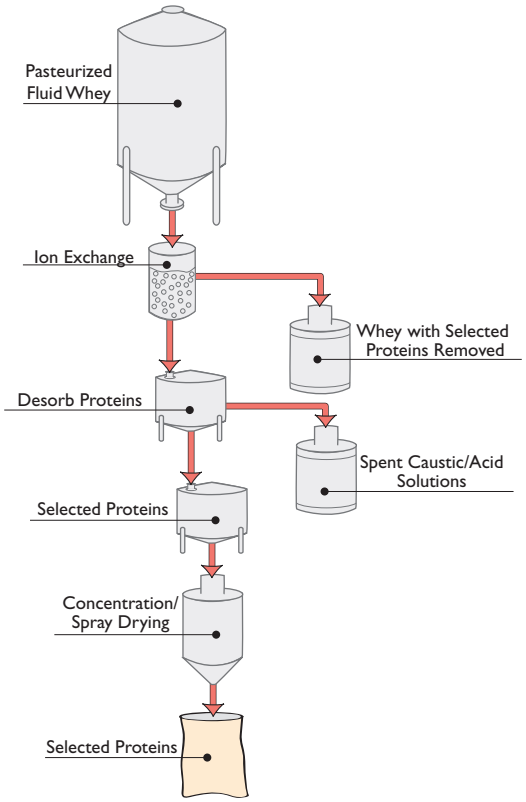
Individual whey protein composition



General composition of individual whey proteins

Component	α–lactalbumin	Lactoferrin	Lactoperoxidase	GMP
	%			
Protein	90	94	92	86
Lactose	1	0	0	1
Ash	3	1	3	6
Fat	1	0	0	1
Moisture	5	5	5	6

Manufacture of individual whey proteins



Typical composition and characteristics

α-lactalbumin

- Typical composition

Protein (db)	98%
Lactalbumin*	91%
Moisture	5%
Lactose	1%
Fat	1%
Ash	3%

- Characteristics
  - Color: light cream
  - Flavor: bland, clean
  - pH 7
  - Solubility: fully soluble
- Storage
  - < 27 C, <65% rh
  - 12 months

Lactoferrin

- Typical composition

Protein (db)	99%
Lactoferrin*	96%
Moisture	5%
Lactose	na
Fat	na
Ash	1%

- Characteristics
  - Color: light red
  - Flavor: na
  - pH 6-7
  - Solubility: 99%
- Storage
  - < 25 C, <65% rh
  - time period - na

Lactoperoxidase

- Typical composition

Protein (db)	97%
Lactoperoxidase*	na%
Moisture	5%
Lactose	na
Fat	na
Ash	3%

- Characteristics
  - Color: green/brown
  - Flavor: na
  - pH 7
  - Solubility: fully soluble
- Storage
  - 2-8 C, na rh
  - 6 months

Glycomacropeptide (GMP)

- Typical composition

Protein (db)	92%
GMP*	96%
Moisture	6%
Lactose	1%
Fat	1%
Ash	6%

- Characteristics
  - Color: light cream
  - Flavor: bland, clean
  - pH na
  - Solubility: na
- Storage
  - < 27 C, <65% rh
  - 12 months

* Given as a percentage of total protein

Permeate (Whey)

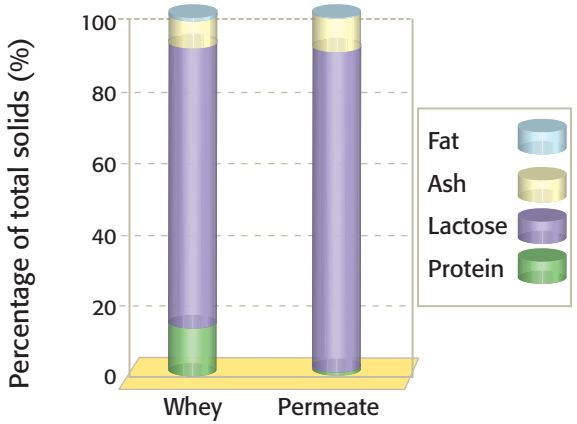
Permeate is a by product of whey protein concentrate (WPC) or ultrafiltered (UF) milk production. Permeate actually is a term used to cover a family of products that have a minimum of 59% lactose, and a maximum of 10% protein and 27% ash. Manufacturers in the United States use the terms "dairy product solids", "de-proteinized whey", "modified whey", "reduced protein whey" or "permeate" on the label.

Milk and sweet, acid, casein and rennet wheys may be used as starting materials. Composition of permeate will vary somewhat depending on the original material used. Sweet whey and milk are the most common starting materials for permeate production in the United States.

Permeate may contain a maximum of 10% protein according to product definition. Permeate typically has only trace amounts of protein, however, commercial specifications often list protein at 3.5 to 5%. The discrepancy is due to the method used to test for protein. The industry tests for total nitrogen and then multiples the result by 6.38 to convert the result into a protein value. The nitrogen found by testing often actually is nonprotein nitrogen (NPN) rather than true protein. Examples of NPN compounds typically found in milk and whey include: urea; creatine; creatinine; uric acid; orotic acid; and ammonia. The net result of listing nitrogen as protein rather than NPN is an overestimation of the protein and underestimation of the lactose content of the powder, It should be noted that there are manufactures of permeate who add protein to permeate to assist with drying.

- Types
  - Milk
  - Whey
- Regulations
  - FDA GRAS Notice No. 37 (2000)
  - FDA GRP 1G0371

Permeate composition



General composition of permeate

Component	Permeate
	----- % -----
Protein*	3
Lactose	84
Ash	9
Fat	nil
Moisture	4

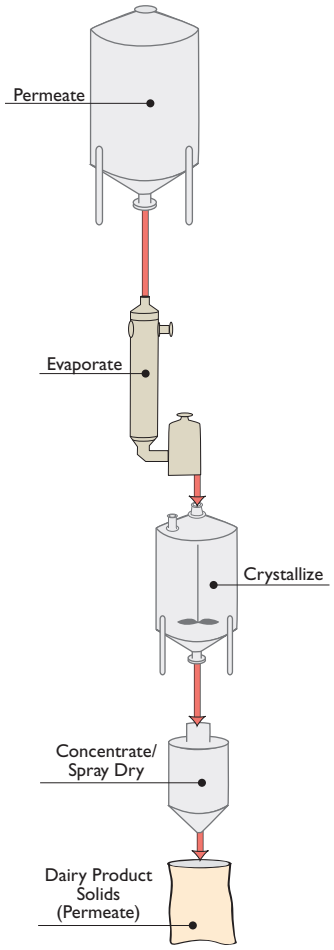
* Non protein nitrogen included in this value. May or may not contain true protein.

FDA specifications for permeate *

Component	Not less than	Not greater than
	---------- % ----------	
Milkfat	na	na
Protein		10
Lactose	59	
Ash		27
Moisture		6

* FDA GRAS Notice No. 37 (2000) and FDA GRP No. 1G0371

Manufacture of permeate



Typical composition and characteristics

Permeate

- Typical composition

Protein (db)*	3%
Moisture	4%
Lactose	85%
Fat	< 0.1%
Ash	9%

- Characteristics
  - Color: white to cream
  - Flavor: bland, clean
- Storage
  - < 25 C, <65% rh
  - 12 months

* Non protein nitrogen included in this value. May or may not contain true protein.

Lactose

Lactose can be produced from either whey or permeate although permeate is the more common starting material. Whey or permeate is concentrated until the solubility of lactose is exceeded and lactose crystals form. The crystals then are washed to remove impurities and dried.

Lactose is a disaccharide, that is, a carbohydrate made up of two sugar molecules. The monosaccharides or sugar molecules that comprise lactose are glucose and galactose. The chemical name for lactose is 4-O-β-galactopyranosyl-D-glucopyranose.

Lactose crystals

- Although lactose can exist in a number of different forms, when dried it typically is present as:
  - Alpha-lactose monohydrate crystals (α–lactose monohydrate crystals)
  - Beta-lactose crystals (β–lactose crystals)
  - Amorphous (glass) mixture of uncrystallized alpha (α) and beta (β) lactose

Alpha-lactose monohydrate crystals – formed when lactose crystallizes at temperatures <93.5 C (200 F). The α-lactose monohydrate form has one molecule of water as part of its structure. The molecule of water is bound to the lactose crystal and is also known as the water of crystallization. Alpha-lactose crystals often appear as prisms or tomahawk shapes. The crystals are very hard and can have a "sandy" or even glass-like mouthfeel.

Beta-lactose crystals – formed when lactose crystallizes at temperatures >93.5 C (200 F). The β form does not have water associated with its structure.

Amorphous (glass) – formed when a lactose solution is dried rapidly such as by spray drying or freeze drying. The amorphous form is very hygroscopic and will readily absorb water to form α–lactose monohydrate crystals. Lumps can develop in the product if enough crystals form. The amorphous form is typical in products such as nonfat dry milk.

- Several other forms of lactose can be produced under special conditions.

Stable anhydrous α-lactose – produced at temperatures between 100 and 190 C (212 and 374 F) with a water vapor pressure of 6 to 80 cm mercury. Typically crystallized **α-lactose monohydrate is sprayed onto a drum dryer to produce stable anhydrous α-lactose.** Stable anhydrous α-lactose is relatively nonhygroscopic.

Hygroscopic (unstable) anhydrous α-lactose – is produced by heating α-hydrate lactose at temperatures above 100 C (212 F) under vacuum. Hygroscopic (unstable) anhydrous α-lactose is stable in dry air but will readily absorb moisture under typical atmospheric conditions.

Lactose and water

- Lactose as a commercial product typically is in the form of α-lactose monohydrate. Beta-lactose was produced many years ago but is no longer commercially available except in the form of anhydrous lactose. Mixtures of α-lactose and β-lactose also are available.

- Moisture specifications reflect the fact that water can be present in two different forms in lactose.
  - **Bound** – water that is part of the crystal structure of α-lactose.
  - **Free** – water that is not associated with the lactose crystal.
  - **Total moisture** – free and bound water.

◉ The molecular weight of lactose is 342. The molecular weight of water is 18. Added together the molecular weight of α-lactose monohydrate crystal becomes 360. Therefore there is 5% moisture in an α-lactose monohydrate crystal due to bound water.

Lactose + water = α-lactose monohydrate crystal
342 + 18 = 360
95% + 5% = 100%

◉ The calculation for moisture in commercial lactose is based on the assumption that 100% of the lactose present is in the form of α-lactose monohydrate. In many cases this is a good assumption, however, in certain lactose products where significant amounts of β-lactose, stable anhydrous α-lactose or amorphous lactose may be present the assumption can lead to an underestimation of the free moisture content depending on the method of moisture analysis used. Free moisture content is important because it has a large affect on product shelf life.

◉ Loss on drying refers to the free moisture content of lactose. The greater the loss on drying the more free moisture is present.

◉ The Karl Fischer test for moisture indicates both bound and free moisture in lactose.

◉ Free moisture must be less than 1% according to standards of identity. Because a free moisture of more than1% would lead to quality issues, free moisture in crystalline lactose typically is less than 0.5%. The type of lactose affects the amount of free moisture typically present. Spray dried lactose would have a free moisture of not more than 1% while anhydrous lactose would have a free moisture of not more than 0.5%.

◉ An example of moisture in lactose would be:

Bound	Free	Total
5%	0.3%	5.3%

Commercial lactose products

Industrial, fermentation lactose is not defined. The product essentially is lactose that does not meet the specifications for edible (food) or pharmaceutical lactose.

Edible (food) lactose is produced by evaporating, crystallizing, refining and then drying. The majority of lactose is dried on a flash dryer although spray and roller dryers also may be used. Only the lactose crystals are dried.

Although the product consists of primarily of α-lactose monohydrate some lactose will be in the amorphous form. The exact ratios of α-lactose monohydrate to amorphous lactose depend on the method of production; however, it is possible that 3 to 5% of the lactose is in the amorphous form. Typically more than 90% of the lactose is in the α-monohydrate form.

Edible refined sprayed dried lactose is not defined but lies between edible and pharmaceutical lactose in composition and functionality. The product is produced by evaporating, crystallizing, refining, reevaporating, recrystallizing and then spray drying. The lactose crystals and the mother liquor (the liquid from which the lactose crystallizes) are sprayed dried together. Edible refined lactose is a mixture of α-lactose monohydrate and amorphous lactose.

Pharmaceutical lactose is produced by redissolving, refining and then filtering edible lactose crystals. The lactose then is evaporated, recrystallized and dried. There are three forms of pharmaceutical lactose: spray dried; crystalline; and anhydrous. The anhydrous type is drum (roller) dried and is primarily β–lactose.

Lactose also may be known as milk sugar.

Regulations

- Industrial, fermentation
  - None, product not defined
- Edible (Food)
  - 21 CFR 168.122 (2007)
  - Food Chemical Codex (FCC)
- Edible refined
  - None, product not defined
- Pharmaceutical

Lactose Definitions

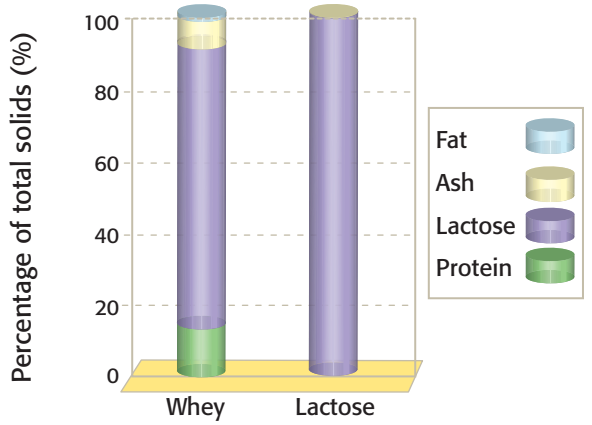
Lactose (CFR) – the carbohydrate normally obtained from whey. It may be anhydrous or contain one molecule of water of crystallization or be a mixture of both forms.

Lactose (FCC) – occurs as a white to creamy white, crystalline powder. It is normally obtained from whey. It may be anhydrous, contain one molecule of water of hydration, or contain a mixture of both forms if it has been prepared by a spray-drying process.

Anhydrous lactose (NF) – is primarily β–lactose or a mixture of α- and β–lactose.

Lactose monohydrate (NF) – is a natural disaccharide obtained from milk, which consists of one glucose and one galactose moiety. (Note – lactose monohydrate may be modified as to its physical characteristics. It may contain varying proportions of amorphous lactose.)

Lactose composition



General composition of lactose

Component	Industrial/ fermentation	Edible (food)	Edible refined	Pharmaceutical
	%			
Total protein	1.0	< 0.10	nil	nil
Lactose	98.0	99.0	99.5	99.85
Ash	0.45	0.20	0.20	0.03
Fat	0.20	< 0.10	nil	0.0

Specifications for US food grade lactose

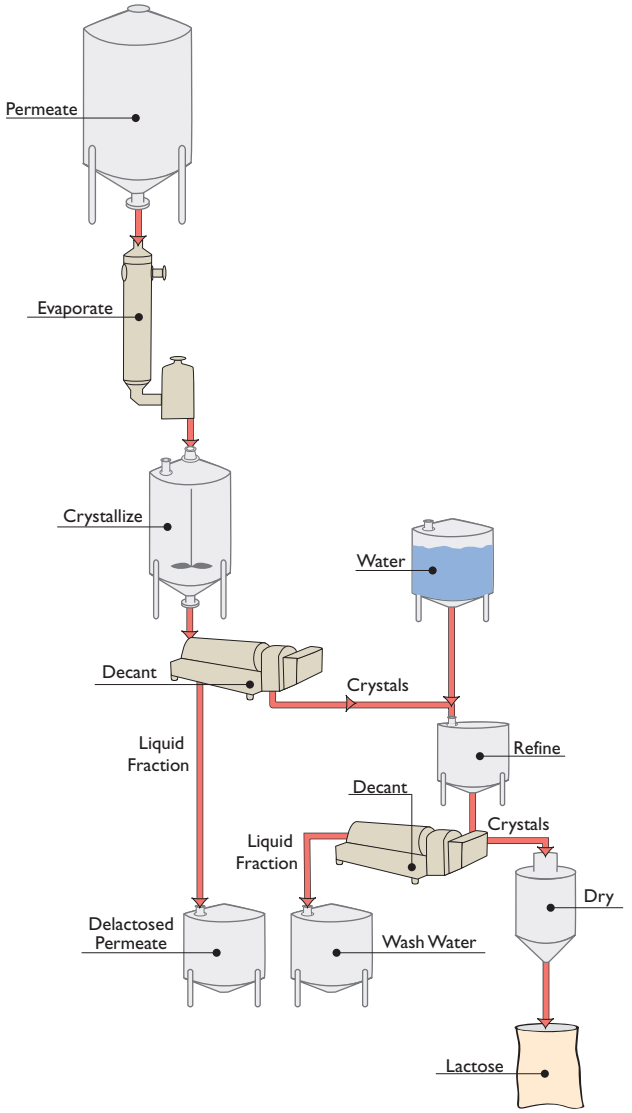
Component	CFR		FCC	
	not less than	not greater than	not less than	not greater than
Lactose (db)	98.0%		98.0%	100.5%
Sulfated ash (db)		0.3%		
Ash				0.3%
Total moisture		6.0%		
Monohydrate			4.5%	5.5%
Spray dryed			4.5%	5.5%
Anhydrous				1.0%
pH (10% solution)	4.5	7.5	4.5	7.5

Specifications for US pharmaceutical lactose*

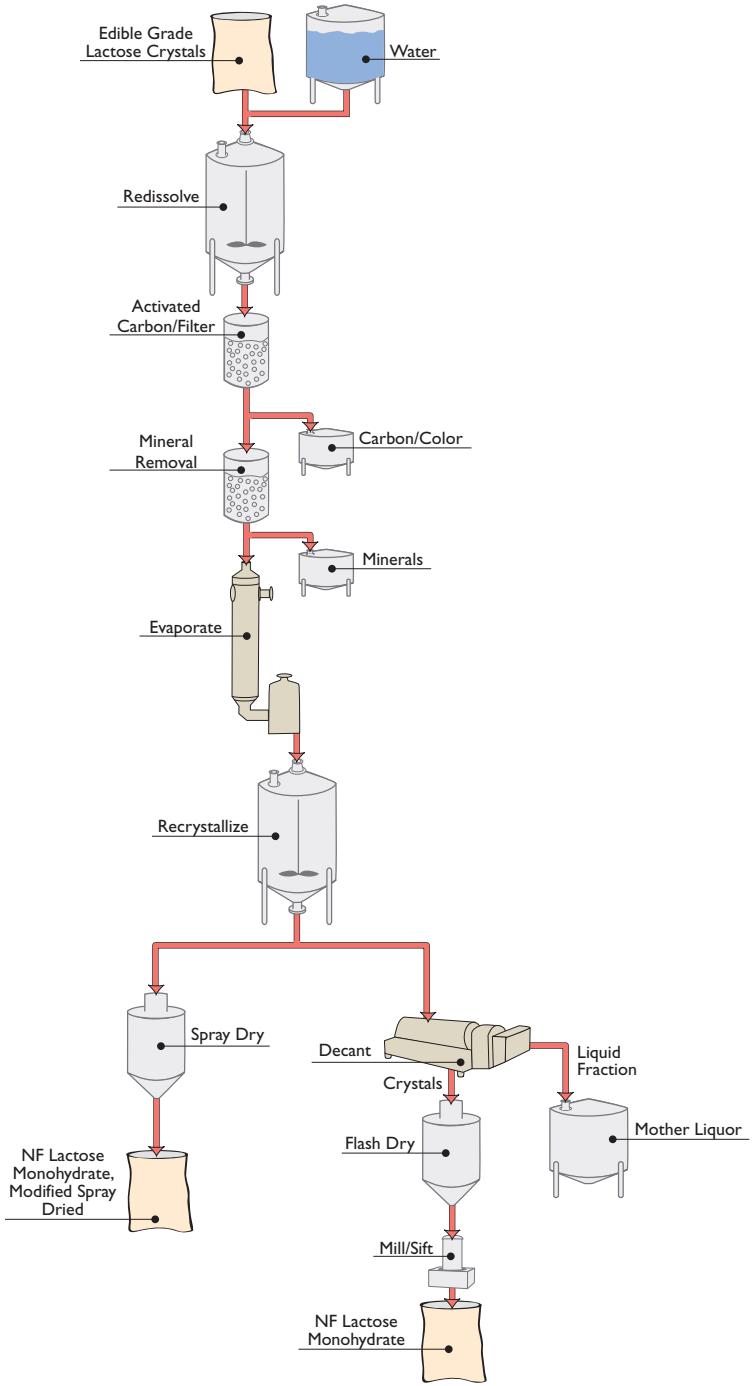
Component	Monohydrate		Anhydrous	
	not less than	not greater than	not less than	not greater than
Protein and light absorbing impurities 210 nm 300 nm		 0.25 au 0.07 au		 0.25 au 0.07 au
Ash		0.1%		0.1%
Total moisture	4.5%	5.5%		1.0%
Free moisture		0.5%**		0.5%
Acidity (0.1N NaOH)		0.4 ml		0.4 ml

* National Formulary
** Modified monohydrate ≯ 1.0%
(Spray dried monohydrate)

Manufacture of edible lactose



Manufacture of pharmaceutical lactose



Typical composition and characteristics

Edible (food) lactose

- Typical composition

Protein*	0.2%
Moisture	
total	4.6%
free	0.5%
Lactose**	99.0%
Fat	NA
Ash	0.3%

- Characteristics
  - Color: white to slight yellow
  - Flavor: clean, slight sweet
  - pH: 4.5 to 7.0
- Storage
  - < 25 C, <75% rh
  - 24 months

* Non protein nitrogen included in this value. May or may not contain true protein.
** Monohydrate

Refined edible lactose (spray dryed)

- Typical composition

Protein*	nil
Moisture	
total	5.0%
free	0.3%
Lactose**	99.5%
Fat	nil
Ash	0.2%

- Characteristics
  - Color: white
  - Flavor: clean, slight sweet
  - pH: 4.5 to 7.0
- Storage
  - < 25 C, <75% rh
  - 24 months

* Non protein nitrogen included in this value. May or may not contain true protein.
** May be combination of α-monhydrate and amorphous

Pharmceutical lactose (monohydrate)

- Typical composition

Protein and light absorbing impurities	
220 nm	0.03au
300 nm	0.01au
Moisture	
total	5.0%
free	0.3%
Lactose	99.9%
Fat	nil
Ash	0.02%

- Characteristics
  - Color: white
  - Flavor: bland, slight sweet
- Storage
  - < 25 C, <75% rh
  - 36 months

Dairy Minerals

Dairy minerals may be produced from either whey or permeate. There are several methods for producing dairy minerals; however, generally the whey or permeate is concentrated such that calcium phosphate precipitates. The precipitated calcium phosphate then is removed from the liquid and washed to remove impurities such as lactose and nonprotein nitrogen. The resulting product typically has at least 20% calcium along with other minerals found in milk or whey.

The ratio of calcium to phosphorous or phosphate in dairy minerals is considered important by many end users. Typically a ratio similar to the ratio of calcium to phosphorous in milk is desired. Care must be taken when considering the ratio as some manufacturers express the ratio as calcium (Ca)/phosphorous (P) while other use calcium (Ca)/phosphate (PO_4). A typical ratio for calcium to phosphorous would be 1.8. A ratio of 0.6 would be typical for calcium to phosphate.

Calcium in whey typically is present in the form of calcium phosphate. Other minerals also are present and depending on their concentration they are divided into major and minor elements.

- Major elements – calcium (Ca), sodium (Na), potassium (K), magnesium (Mg), chloride (Cl) and phosphorous (P)

- Minor elements – zinc (Zn), copper (Cu), iron (Fe) and others

The terms minerals, salts and ash often are used interchangeably; however, they are not equivalent terms.

Minerals – generally refers to elements other than carbon (C), hydrogen (H), oxygen (O) and nitrogen (N) that are found in dairy products.

Minerals typical in dairy products include calcium (Ca), magnesium (Mg), phosphorous (P), iron (Fe), potassium (K), sodium (Na) and zinc (Zn).

Milk salts – includes both inorganic and organic substances. Organic acids with a negative charge and amino acids with positive charges are included in this group. Mineral salts have a molecular weight of 300 or less.

Positively charged components (cations) include calcium (Ca), potassium (K), sodium (Na), magnesium (Mg) and amines.

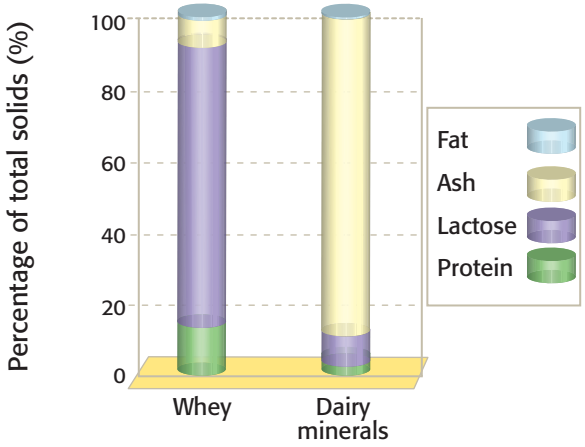
Negatively charged components (anions) include phosphate (PO_4), sulfate (SO_4), carbonate (CO_3), chloride (Cl^-), carboxylic acid and citrate.

Ash – is the residue that remains when milk/whey is heated to very high temperatures in a muffle oven. Organic acids are lost during ashing. Some minerals such as sulfur and phosphorous also may be lost. Other minerals may be converted to oxides, sulfates, phosphates, silicates and chlorides. In general, ash overestimates the concentration of minerals present since oxygen often is combined with minerals in the remaining ash.

Dairy minerals also may be referred to as whey mineral concentrate, milk mineral concentrate or milk calcium.

- Regulations
  - GRAS Notice No. 52 (2001)

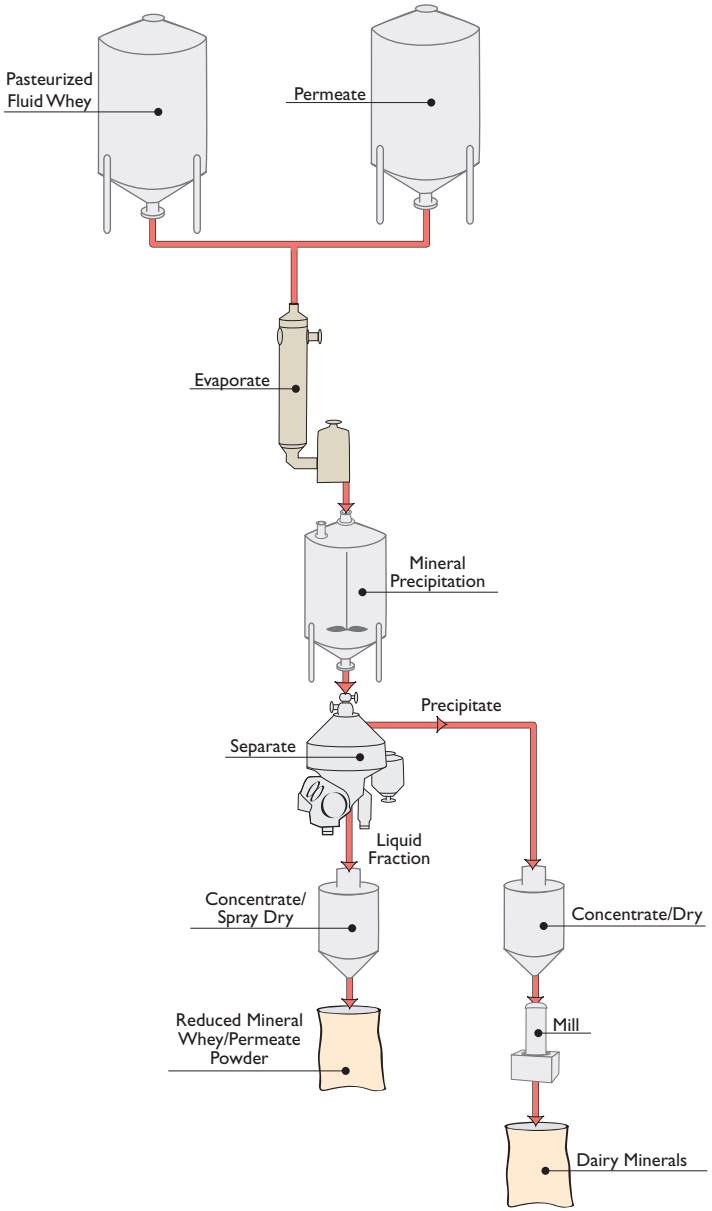
Dairy minerals composition



General composition of dairy minerals

Component	Dairy minerals
	----- % -----
Protein	5
Lactose	6
Ash	2
Fat	< 1
Moisture	6

Manufacture of dairy minerals



Typical composition and characteristics

Dairy minerals

- Typical composition

Protein (db)*	4.5%
Moisture	6%
Lactose	6%
Fat	< 0.1%
Ash	83%
Calcium	23%
Phosphorous (as PO_4)	40%
Ca:P	1.7

- Characteristics
  - Color: white to off white
  - Flavor: clean, salty
  - pH 6.5
  - Partical size:
    - coarse 95% < 100μm
    - fine 95% < 10μm
- Storage
  - < 25 C, <65% rh
  - 12 to 24 months

* Non protein nitrogen included in this value. May or may not contain true protein.

Websites

American Dairy Products Institute (ADPI)
www.adpi.org

Center for Dairy Research (CDR)
www.cdr.wisc.edu

Code of Federal Regulations (CFR)
www.gpoaccess.gov/cfr

CODEX Alimentarius
www.codexalimentarius.net

Dairy Management, Inc. (DMI)
www.innovatewithdairy.com

Food and Drug Administration (FDA)
www.fda.gov

Food and Drug Administration (FDA)
Center for Food Safety and Applied Nutrition (CFSAN)
www.cfsan.fda.gov

National Dairy Council (NDC)
www.nationaldairycouncil.org

US Dairy Export Council (USDEC)
www.usdec.org

US Department of Agriculture, Agricultural Marketing Service (USDA, AMS)
www.ams.usda.gov/dairy

Abbreviations

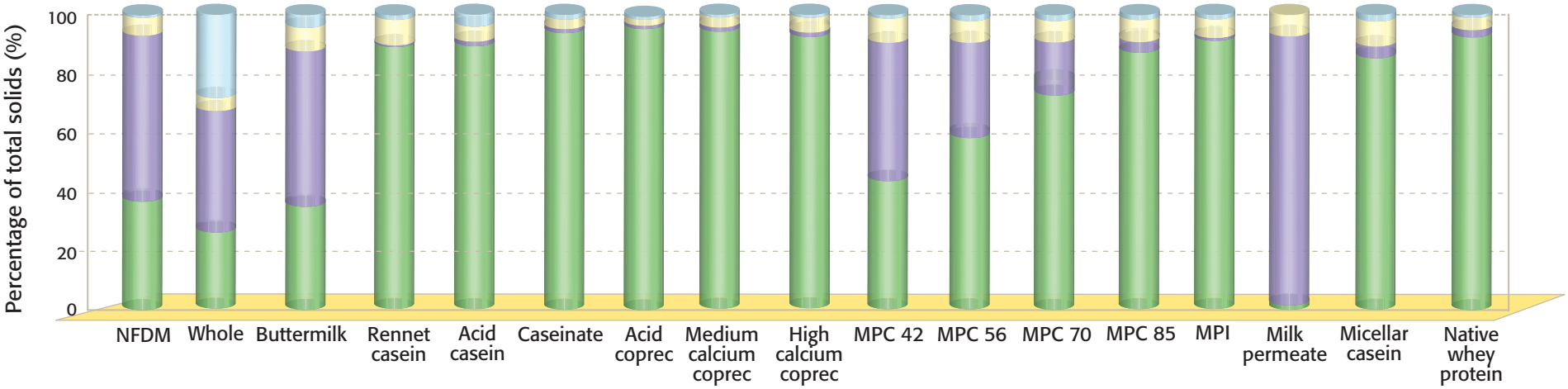
CFR	Code of Federal Regulations
CMP	Casein macro peptide
db	Dry basis
DBM	Dry buttermilk
DBP	Dry buttermilk product
DWM	Dry whole milk
FCC	Food Chemical Codex
FDA	Food and Drug Administration
GMP	Glycomacropeptide
GRAS	Generally recognized as safe
MF	Microfiltration
MPC	Milk protein concentrate
MPI	Milk protein isolate
na	Not available
NF	National Formulary
NDM	Nonfat dry milk
NFDM	Nonfat dry milk
NPN	Nonprotein nitrogen
rh	Relative humidity
SMP	Skim milk powder
TA	Titratable acidity
UF	Ultrafiltration
USDA	US Department of Agriculture
WPC	Whey protein concentrate
WPI	Whey protein isolate
WPNI	Whey protein nitrogen index

Symbols

α	Alpha
β	Beta
K	Kappa
>	Greater than
<	Less than
$\ngtr$	Not greater than
$\nless$	Not less than
μ	Micron
Ca	Calcium
CaCl	Calcium chloride
C	Carbon
CO_3	Carbonate
Cu	Copper
H	Hydrogen
Mg	Magnesium
N	Nitrogen
PO_4	Phosphate
P	Phosphorous
K	Potassium
O	Oxygen
Na	Sodium
SO_4	Sulfate
Zn	Zinc

Summary Graphs

Composition of dairy ingredients made from milk



Composition of dairy ingredients made from whey