Dried Dairy Ingredients

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

May 15, 2008
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

General composition of milk, whey and permeate

<table>
<thead>
<tr>
<th>Component</th>
<th>Milk</th>
<th>Sweet whey</th>
<th>Whey permeate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids</td>
<td>12.5%</td>
<td>6.5%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Protein</td>
<td>3.5%</td>
<td>0.8%</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Lactose</td>
<td>4.8%</td>
<td>4.9%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Ash</td>
<td>0.7%</td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Fat</td>
<td>3.5%</td>
<td>0.3%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
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

- Buttermilk
- Nonfat dry milk
- Whole milk
- Precipitate
- Co-precipitate
- Casein
- Chemically modify
- Caseinate
- Co-precipitate (soluble)
- Milk protein concentrate
- Milk protein isolate
- Milk protein
- Milk permeate
- Micellar casein
- Native whey protein
- Separate
- Concentrate
- 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 Alimentarius. 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 Alimentarius defines and regulates whole milk powder.

Heat treatment of nonfat dry milk
- Nonfat dry milk (NFDN, 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**
    - 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**
    - United States Standards for Grades of Dry Whole Milk
      - USDA, AMS - Dairy Division, April 13, 2001
  - **Whole milk powder**
    - Codex Stan 207-1999
  - **Buttermilk**
    - 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.

<table>
<thead>
<tr>
<th>Component</th>
<th>Skim</th>
<th>Whole</th>
<th>Buttermilk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total protein</td>
<td>36.0</td>
<td>26.0</td>
<td>34.0</td>
</tr>
<tr>
<td>Lactose</td>
<td>51.0</td>
<td>37.0</td>
<td>48.5</td>
</tr>
<tr>
<td>Ash</td>
<td>8.2</td>
<td>6.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Fat</td>
<td>0.8</td>
<td>27.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Moisture</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>
### Classification of nonfat dry milk

<table>
<thead>
<tr>
<th>Category</th>
<th>Typical processing treatment</th>
<th>WPNI (mg/g undenatured whey protein)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temp (°C)</td>
<td>Time (minutes)</td>
</tr>
<tr>
<td>Low-heat</td>
<td>70</td>
<td>2</td>
</tr>
<tr>
<td>Medium-heat</td>
<td>70 - 78</td>
<td>20</td>
</tr>
<tr>
<td>High-heat</td>
<td>88</td>
<td>30</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Extra</th>
<th>Standard</th>
<th>Instant extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>1.25%</td>
<td>1.5%</td>
<td>1.25%</td>
</tr>
<tr>
<td>Moisture</td>
<td>4.0%</td>
<td>5.0%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Titratable acidity</td>
<td>0.15%</td>
<td>0.17%</td>
<td>0.15%</td>
</tr>
<tr>
<td>Solubility index</td>
<td>1.2 ml**</td>
<td>2.0 ml***</td>
<td>1.0 ml</td>
</tr>
<tr>
<td>Scorched particles</td>
<td>15.0 mg</td>
<td>22.5 mg</td>
<td>15 mg</td>
</tr>
<tr>
<td>Bacteria</td>
<td>10,000/g</td>
<td>75,000/g</td>
<td>10,000/g</td>
</tr>
<tr>
<td>Coliforms</td>
<td>10/g</td>
<td>10/g</td>
<td>10/g</td>
</tr>
</tbody>
</table>

* * 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 dry whole milk (spray)*

<table>
<thead>
<tr>
<th>Component</th>
<th>Extra</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>&lt; 26% but &lt; 40%</td>
<td>&lt; 26% but &lt; 40%</td>
</tr>
<tr>
<td>Moisture**</td>
<td>4.5%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Titratable acidity</td>
<td>0.15%</td>
<td>0.17%</td>
</tr>
<tr>
<td>Solubility index</td>
<td>1.0 ml</td>
<td>1.5 ml</td>
</tr>
<tr>
<td>Scorched particles</td>
<td>15.0 mg</td>
<td>22.5 mg</td>
</tr>
<tr>
<td>Bacteria</td>
<td>10,000/g</td>
<td>50,000/g</td>
</tr>
<tr>
<td>Coliforms</td>
<td>10/g</td>
<td>10/g</td>
</tr>
</tbody>
</table>

* 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)*

<table>
<thead>
<tr>
<th>Component</th>
<th>Extra</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>&lt; 26% but &lt; 40%</td>
<td>&lt; 26% but &lt; 40%</td>
</tr>
<tr>
<td>Moisture**</td>
<td>4.5%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Titratable acidity</td>
<td>0.15%</td>
<td>0.17%</td>
</tr>
<tr>
<td>Solubility index</td>
<td>15.0 ml</td>
<td>15.0 ml</td>
</tr>
<tr>
<td>Scorched particles</td>
<td>22.5 mg</td>
<td>32.5 mg</td>
</tr>
<tr>
<td>Bacteria</td>
<td>10,000/g</td>
<td>50,000/g</td>
</tr>
<tr>
<td>Coliforms</td>
<td>10/g</td>
<td>10/g</td>
</tr>
</tbody>
</table>

* 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)*

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

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

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

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

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

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

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

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

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

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

* 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*

<table>
<thead>
<tr>
<th>Component</th>
<th>Skimmed</th>
<th>Partly skimmed</th>
<th>Whole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>&lt; 1.5%</td>
<td>≤ 1.5% but &lt; 26%</td>
<td>≤ 26% but &lt; 42%</td>
</tr>
<tr>
<td>Protein**</td>
<td>&gt; 34%</td>
<td>&gt; 34%</td>
<td>&gt; 34%</td>
</tr>
<tr>
<td>Moisture</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Titratable acidity</td>
<td>0.18%</td>
<td>0.18%</td>
<td>0.18%</td>
</tr>
<tr>
<td>Solubility index</td>
<td>1.0 ml</td>
<td>1.0 ml</td>
<td>1.0 ml</td>
</tr>
<tr>
<td>Scorched particles</td>
<td>15.0 mg</td>
<td>15.0 mg</td>
<td>15.0 mg</td>
</tr>
</tbody>
</table>

* Codex Stan 207-1999

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

![Casein composition graph](image-url)
### General composition of casein

<table>
<thead>
<tr>
<th>Component</th>
<th>Rennet</th>
<th>Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>80.5%</td>
<td>86.5%</td>
</tr>
<tr>
<td>Lactose</td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Ash</td>
<td>8%</td>
<td>2%</td>
</tr>
<tr>
<td>Fat</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Moisture</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>pH</td>
<td>7%</td>
<td>5%</td>
</tr>
</tbody>
</table>

### Codex specifications for casein products*

<table>
<thead>
<tr>
<th>Component</th>
<th>Rennet</th>
<th>Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>2.0%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Protein (db)</td>
<td>84.0%</td>
<td>90.0%</td>
</tr>
<tr>
<td>Casein in protein</td>
<td>95.0%</td>
<td>95.0%</td>
</tr>
<tr>
<td>Moisture</td>
<td>12.0%</td>
<td>12.0%</td>
</tr>
<tr>
<td>Lactose**</td>
<td>1.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Ash</td>
<td>7.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Titratable acidity</td>
<td>0.27%</td>
<td></td>
</tr>
<tr>
<td>Scorched particles</td>
<td>15 mg</td>
<td>22.5 mg</td>
</tr>
</tbody>
</table>

** Expressed in anhydrous form

### Specifications for US Grades of acid casein*

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

* USDA Dairy Standards for grades of casein (acid)
### Manufacture of Casein

- **Rennet casein**
  - Pasteurized skim milk
  - 30°C
  - Rennet
  - 32°C
  - Lactic acid casein
  - 23°C
  - Starter bacteria
  - 30°C
  - Acid
  - 60°C
  - Stir curd
  - 50-55°C
  - Cut gel
  - Separate
  - Gel forms
  - Wash/centrifuge
  - Water
  - Dry/grind

- **Lactic acid casein**
  - Mineral acid casein
  - 32°C
  - Acid
  - 45°C
  - Stir curd
  - Cut gel
  - Separate
  - Gel forms
  - Wash/centrifuge
  - Water
  - Dry/grind

### 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**

### General composition of caseinate

<table>
<thead>
<tr>
<th>Component</th>
<th>Caseinate type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium</td>
<td>%</td>
</tr>
<tr>
<td>Calcium</td>
<td>%</td>
</tr>
<tr>
<td>Sodium</td>
<td>%</td>
</tr>
<tr>
<td>Protein</td>
<td>88</td>
</tr>
<tr>
<td>Lactose</td>
<td>0.3</td>
</tr>
<tr>
<td>Ash</td>
<td>4.7</td>
</tr>
<tr>
<td>Fat</td>
<td>1.5</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.2</td>
</tr>
<tr>
<td>Moisture</td>
<td>5.5</td>
</tr>
<tr>
<td>pH</td>
<td>6.5-7.0</td>
</tr>
<tr>
<td>Solubility</td>
<td>99</td>
</tr>
</tbody>
</table>

### Caseinate composition

- **NFDM**
- **Caseinate**

### Codex specifications for caseinate*

<table>
<thead>
<tr>
<th>Component</th>
<th>Caseinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>not less than 2.0%</td>
</tr>
<tr>
<td>Protein (db)</td>
<td>88.0%</td>
</tr>
<tr>
<td>Casein in protein</td>
<td>95.0%</td>
</tr>
<tr>
<td>Moisture</td>
<td>8.0%</td>
</tr>
<tr>
<td>Lactose**</td>
<td>1.0%</td>
</tr>
<tr>
<td>Scorched particles</td>
<td>22.5 mg</td>
</tr>
<tr>
<td>Spray roller</td>
<td>81.5 mg</td>
</tr>
<tr>
<td>pH</td>
<td>8.0</td>
</tr>
</tbody>
</table>


** Expressed in anhydrous form
**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 (TMPTM), soluble lacto-protein and milk proteinate.

- **Types**
  - Acid
  - Medium calcium
  - High calcium

- **Regulations**
  - None, product not defined

<table>
<thead>
<tr>
<th>Component</th>
<th>Acid</th>
<th>Medium calcium</th>
<th>High calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>86.7</td>
<td>85.6</td>
<td>81.7</td>
</tr>
<tr>
<td>Lactose</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Ash</td>
<td>2.4</td>
<td>3.7</td>
<td>7.7</td>
</tr>
<tr>
<td>Fat</td>
<td>0.9</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Moisture</td>
<td>9.5</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.54</td>
<td>1.13</td>
<td>2.81</td>
</tr>
<tr>
<td>pH</td>
<td>5.4-5.8</td>
<td>5.6-6.2</td>
<td>6.5-7.2</td>
</tr>
</tbody>
</table>
**Manufacture of Co-precipitate**

- Pasteurized skim milk
- CaCl/acid
- 85-95 C, 1-20 minutes
- Separate
- Water
- Casein/whey protein aggregates
- Wash/centrifuge
- Water
- Dry grind
- Co-precipitate

**Manufacture of Soluble Co-precipitate**

- Water
- Co-precipitate
- Water
- 20-25 % TS slurry
- Dilute alkali
- pH 6.7, 60-75 C, 30-60 minutes
- Disolved casein/whey protein
- Dry
- 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

### General composition of MPC

<table>
<thead>
<tr>
<th>Component</th>
<th>MPC 42</th>
<th>MPC 56</th>
<th>MPC 70</th>
<th>MPC 85</th>
<th>MPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>40.6</td>
<td>54.4</td>
<td>68.3</td>
<td>83.1</td>
<td>87.1</td>
</tr>
<tr>
<td>Lactose</td>
<td>45.5</td>
<td>31.7</td>
<td>18.2</td>
<td>3.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Ash</td>
<td>7.9</td>
<td>7.6</td>
<td>7.3</td>
<td>6.9</td>
<td>5.9</td>
</tr>
<tr>
<td>Fat</td>
<td>0.9</td>
<td>1.2</td>
<td>1.2</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Moisture</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

### Manufacture of MPC

1. Skim milk
2. Pasteurize
3. Ultrafiltration/Diafiltration
4. Retentate (Casein, whey proteins, some lactose/ash)
5. Evaporate
6. Spray dry
7. Package
8. Milk protein concentrate
9. Water
Manufacture of MPC 42 to 65

Pasteurized Skim Milk → Ultrafiltration → UF Milk → Concentration/Spray Drying → 42 to 65 MPC

Manufacture of MPC 65 to 85

Pasteurized Skim Milk → Ultrafiltration → UF Milk → Concentration/Spray Drying → Permeate → Diafiltration → 65 to 85 MPC

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)

| Component | Milk permeate % | Percentable Solids
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>&lt;1</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Lactose</td>
<td>82</td>
<td>70-85</td>
</tr>
<tr>
<td>Ash</td>
<td>9</td>
<td>3.5-5.5</td>
</tr>
<tr>
<td>Fat</td>
<td>&lt;1</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Moisture</td>
<td>4</td>
<td>1-3</td>
</tr>
<tr>
<td>NPN</td>
<td>4</td>
<td>1-3</td>
</tr>
</tbody>
</table>

Milk permeate composition

<table>
<thead>
<tr>
<th>Percentage of total solids (%)</th>
<th>NDFM</th>
<th>Milk permeate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80</td>
<td>60</td>
</tr>
<tr>
<td>Fat</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Ash</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Lactose</td>
<td>100</td>
<td>82</td>
</tr>
<tr>
<td>Protein</td>
<td>80</td>
<td>60</td>
</tr>
</tbody>
</table>

Typical composition and characteristics
Not available, see whey permeate

Manufacture of Milk Permeate

[Diagram of milk permeate production process]
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**

![Micellar casein composition](chart.png)
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 byproduct 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**

<table>
<thead>
<tr>
<th>Component</th>
<th>Cheese whey</th>
<th>MF permeate whey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starter cultures</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Rennet</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Glycomacropeptide</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Pasteurization steps</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Fat/phospholipids</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td>pH</td>
<td>&lt;6.5</td>
<td>6.6</td>
</tr>
</tbody>
</table>

![Native whey protein composition graph]
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 → Concentrate → Whey protein concentrate, Whey protein isolate → Ultrafiltration → Whey permeate, Lactalbumin → Precipitation → Whey proteins, Individual proteins, Whey protein isolate → Chromatography/Ion exchange → Lactalbumin, Lactose → Crystallization → Lactose → Precipitation → Lactose → Ion exchange/Electrodialysis → Dairy minerals, Demineralized whey → Minerals → Hydrolyzed → Lactose, Protein hydrolyzed → Lactose derivatives → Convert → Hydrolized, Chemically altered

Whey protein concentrate → Reduced lactose 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

<table>
<thead>
<tr>
<th>Component</th>
<th>Milk</th>
<th>Sweet whey</th>
<th>Acid whey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>3.5</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Protein</td>
<td>4.8</td>
<td>4.8</td>
<td>4.4</td>
</tr>
<tr>
<td>Lactose</td>
<td>0.7</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Ash</td>
<td>3.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>–</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Calcium</td>
<td>120</td>
<td>45</td>
<td>103</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>9</td>
<td>45</td>
<td>78</td>
</tr>
</tbody>
</table>

Comparison of milk and sweet and acid whey

<table>
<thead>
<tr>
<th>Component</th>
<th>Milk</th>
<th>Sweet whey</th>
<th>Acid whey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids</td>
<td>12.5</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Protein</td>
<td>3.5</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Lactose</td>
<td>4.8</td>
<td>4.8</td>
<td>4.4</td>
</tr>
<tr>
<td>Ash</td>
<td>0.7</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Fat</td>
<td>3.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>–</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Calcium</td>
<td>120</td>
<td>45</td>
<td>103</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>9</td>
<td>45</td>
<td>78</td>
</tr>
</tbody>
</table>
**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 known 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 byproducts 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 storage of whey based powders; 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
- Concentrated whey
- Dry whey

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


---

**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.
Dried Dairy Ingredients

USDA specifications for US Grades of dry whey*

<table>
<thead>
<tr>
<th>Component</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>not less than</td>
</tr>
<tr>
<td>Milkfat</td>
<td>1.5%</td>
</tr>
<tr>
<td>Moisture</td>
<td>5.0%</td>
</tr>
<tr>
<td>Titratable acidity</td>
<td></td>
</tr>
<tr>
<td>sweet (dry)</td>
<td>0.35%</td>
</tr>
<tr>
<td>acid (dry)</td>
<td>0.16%</td>
</tr>
<tr>
<td>Scorch</td>
<td>15.0 mg</td>
</tr>
<tr>
<td>Bacteria</td>
<td>30,000</td>
</tr>
<tr>
<td>Coliform</td>
<td>10</td>
</tr>
</tbody>
</table>

Optional test requirements

<table>
<thead>
<tr>
<th>Component</th>
<th>Extra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>11%</td>
</tr>
<tr>
<td>Alkalinity of ash (sweet)</td>
<td>225 ml/100 g (0.1 N NaOH)</td>
</tr>
</tbody>
</table>

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

Codex specifications for whey powders*

<table>
<thead>
<tr>
<th>Component</th>
<th>Sweet</th>
<th>Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>not less than</td>
<td>not greater than</td>
</tr>
<tr>
<td>Protein</td>
<td>10.0%</td>
<td>7.0%</td>
</tr>
<tr>
<td>Moisture</td>
<td>5.0%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Ash</td>
<td>9.5%</td>
<td>15.0%</td>
</tr>
<tr>
<td>Titratable acidity or pH</td>
<td>0.35%</td>
<td>0.35%</td>
</tr>
</tbody>
</table>


General composition of whey powders

<table>
<thead>
<tr>
<th>Component</th>
<th>Sweet whey</th>
<th>Acid whey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>12.5%</td>
<td>12.0%</td>
</tr>
<tr>
<td>Lactose</td>
<td>73%</td>
<td>70%</td>
</tr>
<tr>
<td>Ash</td>
<td>8.5%</td>
<td>12%</td>
</tr>
<tr>
<td>Fat</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Moisture</td>
<td>5%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Sweet and acid whey composition

<table>
<thead>
<tr>
<th>Component</th>
<th>Sweet whey</th>
<th>Acid whey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>12.5%</td>
<td>12.0%</td>
</tr>
<tr>
<td>Lactose</td>
<td>73%</td>
<td>70%</td>
</tr>
<tr>
<td>Ash</td>
<td>8.5%</td>
<td>12%</td>
</tr>
<tr>
<td>Fat</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Moisture</td>
<td>5%</td>
<td>5%</td>
</tr>
</tbody>
</table>

CFR specifications for dry whey*

<table>
<thead>
<tr>
<th>Component</th>
<th>Not less than</th>
<th>Not greater than</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>0.2%</td>
<td>2%</td>
</tr>
<tr>
<td>Protein</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>Lactose</td>
<td>61%</td>
<td>75%</td>
</tr>
<tr>
<td>Ash</td>
<td>7%</td>
<td>14%</td>
</tr>
<tr>
<td>Moisture</td>
<td>1%</td>
<td>8%</td>
</tr>
</tbody>
</table>

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

Diagram shows the process from fluid whey to whey powder through clarifying, separating, pasteurizing, evaporating, crystallizing, and spray drying.
**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**


**Composition of demineralized whey** *

<table>
<thead>
<tr>
<th>Component</th>
<th>Whey</th>
<th>25% Demin</th>
<th>50% Demin</th>
<th>90% Demin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Fat</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Protein</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Lactose</td>
<td>186</td>
<td>186</td>
<td>186</td>
<td>186</td>
</tr>
<tr>
<td>Ash</td>
<td>21</td>
<td>17</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>250</td>
<td>245</td>
<td>239</td>
<td>230</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>25% Demin</th>
<th>50% Demin</th>
<th>90% Demin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash in whey</td>
<td>8.6</td>
<td>7.0</td>
<td>4.6</td>
</tr>
</tbody>
</table>

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

**CFR specifications for reduced minerals whey** *

<table>
<thead>
<tr>
<th>Component</th>
<th>Not less than</th>
<th>Not greater than</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Protein</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>Lactose</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

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

General composition of reduced lactose whey

<table>
<thead>
<tr>
<th>Component</th>
<th>Reduced lactose</th>
<th>Mineral concentrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>23 %</td>
<td>22 %</td>
</tr>
<tr>
<td>Lactose</td>
<td>56 %</td>
<td>56 %</td>
</tr>
<tr>
<td>Ash</td>
<td>16 %</td>
<td>17 %</td>
</tr>
<tr>
<td>Fat</td>
<td>2 %</td>
<td>2 %</td>
</tr>
<tr>
<td>Moisture</td>
<td>3 %</td>
<td>3 %</td>
</tr>
</tbody>
</table>

Reduced lactose whey composition

![Bar graph showing the composition of whey, reduced lactose whey, and mineral concentrated whey.]

CFR specifications for reduced lactose whey*

<table>
<thead>
<tr>
<th>Component</th>
<th>Not less than</th>
<th>Not greater than</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>1 %</td>
<td>4 %</td>
</tr>
<tr>
<td>Protein</td>
<td>16 %</td>
<td>24 %</td>
</tr>
<tr>
<td>Lactose</td>
<td>60 %</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>11 %</td>
<td>27 %</td>
</tr>
<tr>
<td>Moisture</td>
<td>1 %</td>
<td>6 %</td>
</tr>
</tbody>
</table>

**Manufacture of Reduced Lactose Whey**

**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

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

### General composition of lactalbumin

<table>
<thead>
<tr>
<th>Component</th>
<th>Lactalbumin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>85</td>
</tr>
<tr>
<td>Lactose</td>
<td>6</td>
</tr>
<tr>
<td>Ash</td>
<td>3</td>
</tr>
<tr>
<td>Fat</td>
<td>2</td>
</tr>
<tr>
<td>Moisture</td>
<td>4</td>
</tr>
</tbody>
</table>
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). Ultrafiltration 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

### General composition of whey protein concentrate

<table>
<thead>
<tr>
<th>Component</th>
<th>WPC 34</th>
<th>WPC 55</th>
<th>WPC 80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>33</td>
<td>53</td>
<td>77</td>
</tr>
<tr>
<td>Lactose</td>
<td>52</td>
<td>31</td>
<td>9</td>
</tr>
<tr>
<td>Ash</td>
<td>7</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Fat</td>
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<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Moisture</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

### CFR specifications for whey protein concentrate*

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<thead>
<tr>
<th>Component</th>
<th>Not less than</th>
<th>Not greater than</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Protein</td>
<td>25</td>
<td>–</td>
</tr>
<tr>
<td>Lactose</td>
<td>–</td>
<td>60</td>
</tr>
<tr>
<td>Ash</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Moisture</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

**Manufacture of WPC 34 to 50**

**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

<table>
<thead>
<tr>
<th>Percentage of total solids (%)</th>
<th>Whey</th>
<th>WPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Ash</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Lactose</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>Protein</td>
<td>80</td>
<td>40</td>
</tr>
</tbody>
</table>

General composition of whey protein isolate

<table>
<thead>
<tr>
<th>Component</th>
<th>WPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>89</td>
</tr>
<tr>
<td>Lactose</td>
<td>2</td>
</tr>
<tr>
<td>Ash</td>
<td>3</td>
</tr>
<tr>
<td>Fat</td>
<td>1</td>
</tr>
<tr>
<td>Moisture</td>
<td>5</td>
</tr>
</tbody>
</table>

FDA specifications for whey protein isolate*

<table>
<thead>
<tr>
<th>Component</th>
<th>Not less than</th>
<th>Not greater than</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Protein</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Lactose</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Ash</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Moisture</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

* FDA GRAS Notice No. 37 (2000)
**Manufacture of WPI**

**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

### General composition of individual whey proteins

<table>
<thead>
<tr>
<th>Component</th>
<th>α-lactalbumin</th>
<th>Lactoferrin</th>
<th>Lactoperoxidase</th>
<th>GMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>90</td>
<td>94</td>
<td>92</td>
<td>86</td>
</tr>
<tr>
<td>Lactose</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Ash</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Fat</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Moisture</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
**Manufacture of individual whey proteins**

<table>
<thead>
<tr>
<th><strong>Lactoferrin</strong></th>
<th><strong>Characteristics</strong></th>
<th><strong>Storage</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical composition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (db)</td>
<td>99%</td>
<td>&lt; 27 C, &lt;65% rh</td>
</tr>
<tr>
<td>Lactoferrin*</td>
<td>96%</td>
<td>12 months</td>
</tr>
<tr>
<td>Moisture</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Lactose</td>
<td>na</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>na</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td><strong>Typical composition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (db)</td>
<td>98%</td>
<td></td>
</tr>
<tr>
<td>Lactalbumin*</td>
<td>91%</td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Lactose</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td><strong>Typical composition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (db)</td>
<td>97%</td>
<td></td>
</tr>
<tr>
<td>Lactoperoxidase*</td>
<td>na%</td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Lactose</td>
<td>na</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>na</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td><strong>Typical composition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (db)</td>
<td>92%</td>
<td></td>
</tr>
<tr>
<td>Glycomacropeptide (GMP)</td>
<td>96%</td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Lactose</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>6%</td>
<td></td>
</tr>
</tbody>
</table>

* Given as a percentage of total protein
**Permeate (Whey)**

Permeate is a byproduct 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 multiplies 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**

<table>
<thead>
<tr>
<th>Component</th>
<th>Permeate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>nil</td>
</tr>
<tr>
<td>Ash</td>
<td>9</td>
</tr>
<tr>
<td>Lactose</td>
<td>84</td>
</tr>
<tr>
<td>Protein*</td>
<td>3</td>
</tr>
</tbody>
</table>

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

**General composition of permeate**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage of total solids (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>na na</td>
</tr>
<tr>
<td>Protein</td>
<td>10</td>
</tr>
<tr>
<td>Lactose</td>
<td>59</td>
</tr>
<tr>
<td>Ash</td>
<td>27</td>
</tr>
<tr>
<td>Moisture</td>
<td>6</td>
</tr>
</tbody>
</table>

*FDA specifications for permeate *

<table>
<thead>
<tr>
<th>Component</th>
<th>Not less than</th>
<th>Not greater than</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milkfat</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Protein</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Lactose</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>Moisture</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

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

\[
\text{Lactose + water} = \alpha\text{-lactose monohydrate crystal}
\]

\[
\begin{align*}
342 & \quad + \quad 18 \quad = \quad 360 \\
95\% & \quad + \quad 5\% \quad = \quad 100\%
\end{align*}
\]

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 understimation 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 than 1% 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:

<table>
<thead>
<tr>
<th>Bound</th>
<th>Free</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>0.3%</td>
<td>5.3%</td>
</tr>
</tbody>
</table>

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 evaporation, 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)
  - Food Chemical Codex (FCC)
- Edible refined
  - None, product not defined
- Pharmaceutical

Dried Dairy Ingredients
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

<table>
<thead>
<tr>
<th>Component</th>
<th>Industrial/fermentation</th>
<th>Edible (food)</th>
<th>Edible refined</th>
<th>Pharmaceutical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total protein</td>
<td>1.0</td>
<td>&lt; 0.10</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>Lactose</td>
<td>98.0</td>
<td>99.0</td>
<td>99.5</td>
<td>99.85</td>
</tr>
<tr>
<td>Ash</td>
<td>0.45</td>
<td>0.20</td>
<td>0.20</td>
<td>0.03</td>
</tr>
<tr>
<td>Fat</td>
<td>0.20</td>
<td>&lt; 0.10</td>
<td>nil</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Specifications for US food grade lactose

<table>
<thead>
<tr>
<th>Component</th>
<th>CFR</th>
<th>FCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactose (db)</td>
<td>98.0%</td>
<td>98.0%</td>
</tr>
<tr>
<td>Sulfated ash (db)</td>
<td>0.3%</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td></td>
<td>0.3%</td>
</tr>
<tr>
<td>Total moisture</td>
<td>6.0%</td>
<td></td>
</tr>
<tr>
<td>Monohydrate</td>
<td>4.5%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Spray dried</td>
<td>4.5%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Anhydrous</td>
<td></td>
<td>1.0%</td>
</tr>
<tr>
<td>pH (10% solution)</td>
<td>4.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Specifications for US pharmaceutical lactose*

<table>
<thead>
<tr>
<th>Component</th>
<th>Monohydrate</th>
<th>Anhydrous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein and light absorbing impurities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>210 nm</td>
<td>0.25 au</td>
<td>0.25 au</td>
</tr>
<tr>
<td>300 nm</td>
<td>0.07 au</td>
<td>0.07 au</td>
</tr>
<tr>
<td>Ash</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Total moisture</td>
<td>4.5%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Free moisture</td>
<td>0.5%**</td>
<td>0.5%</td>
</tr>
<tr>
<td>Acidity (0.1N NaOH)</td>
<td>0.4 ml</td>
<td>0.4 ml</td>
</tr>
</tbody>
</table>

* National Formulary
** Modified monohydrate ≥ 1.0%
(Spray dried monohydrate)
**Dried Dairy Ingredients**

**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.

**Edible (food) lactose**

Typical composition and 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.

**Refined edible lactose**

Typical composition and 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.

**Pharmaceutical lactose (monohydrate)**

Typical composition and 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 (PO₄). 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 (PO₄), sulfate (SO₄), carbonate (CO₃), 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

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage of total solids (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whey</td>
<td></td>
</tr>
<tr>
<td>Dairy minerals</td>
<td></td>
</tr>
</tbody>
</table>

- Fat: 100
- Ash: 80
- Lactose: 60
- Protein: 40
- Moisture: 20
- Fat: < 1

General composition of dairy minerals

<table>
<thead>
<tr>
<th>Component</th>
<th>Dairy minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>5%</td>
</tr>
<tr>
<td>Lactose</td>
<td>6%</td>
</tr>
<tr>
<td>Ash</td>
<td>2%</td>
</tr>
<tr>
<td>Fat</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Moisture</td>
<td>6%</td>
</tr>
</tbody>
</table>
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 PO₄): 40%
  - Ca:P: 1.7

- Characteristics
  - Color: white to off white
  - Flavor: clean, salty
  - pH: 6.5
  - Particle 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.
Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>CMP</td>
<td>Casein macro peptide</td>
</tr>
<tr>
<td>db</td>
<td>Dry basis</td>
</tr>
<tr>
<td>DBM</td>
<td>Dry buttermilk</td>
</tr>
<tr>
<td>DBP</td>
<td>Dry buttermilk product</td>
</tr>
<tr>
<td>DWM</td>
<td>Dry whole milk</td>
</tr>
<tr>
<td>FCC</td>
<td>Food Chemical Codex</td>
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<tr>
<td>FDA</td>
<td>Food and Drug Administration</td>
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<tr>
<td>GMP</td>
<td>Glycomacropeptide</td>
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<tr>
<td>GRAS</td>
<td>Generally recognized as safe</td>
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<tr>
<td>MF</td>
<td>Microfiltration</td>
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<tr>
<td>MPC</td>
<td>Milk protein concentrate</td>
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<tr>
<td>MPI</td>
<td>Milk protein isolate</td>
</tr>
<tr>
<td>na</td>
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<tr>
<td>NF</td>
<td>National Formulary</td>
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<tr>
<td>NDM</td>
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<tr>
<td>NFDM</td>
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<td>NPN</td>
<td>Nonprotein nitrogen</td>
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<tr>
<td>rh</td>
<td>Relative humidity</td>
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<td>SMP</td>
<td>Skim milk powder</td>
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<td>TA</td>
<td>Titratable acidity</td>
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<td>UF</td>
<td>Ultrafiltration</td>
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<td>USDA</td>
<td>US Department of Agriculture</td>
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<td>WPC</td>
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<td>Whey protein isolate</td>
</tr>
<tr>
<td>WPNI</td>
<td>Whey protein nitrogen index</td>
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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

Symbols

<table>
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<tr>
<th>Symbol</th>
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<td>α</td>
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<td>Beta</td>
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<td>Zn</td>
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Composition of dairy ingredients made from milk

Composition of dairy ingredients made from whey