U.S. Dairy Export Council®

REFERENCE MANUAL FOR U.S. MILK POWDERS

2005 REVISED EDITION

Since 1995, the U.S. Dairy Export Council has been committed to developing educational materials on U.S. dairy ingredients based on current scientific research. This manual is an update of the first two editions of the "Reference Manual for U.S. Milk Powders." We have again attempted to review the most current technical and scientific information available on the characteristics, functions and benefits of U.S. milk powders. Many USDEC members, U.S. suppliers, processors, industry experts, consultants, researchers, Dairy Management Inc. and USDEC staff have shared their knowledge and contributed their resources to this new volume. This is part of our effort to provide up-to-date information to potential customers, educators, health professionals, food scientists, food aid programs and other interested groups. We hope this new edition will continue to be a useful resource on U.S. milk powders.

Véronique Lagrange
Editor
U.S. Dairy Export Council

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The U.S. Dairy Export Council wishes to extend its appreciation to all the individuals, companies and associations who contributed to the development, review and production of this manual. In addition to the many experts in the field who cannot all be listed here the U.S. Dairy Export Council would like to recognize the contribution of its member companies (list available at www.usdec.org), the American Dairy Products Institute, the California Dairy Research Foundation, the Dairy Products Technology Center at California Polytechnic State University, Dairy Management Inc., Design Two Ltd. and the Wisconsin Center for Dairy Research.

ADPI
AMERICAN DAIRY PRODUCTS INSTITUTE

American Dairy Products Institute

The American Dairy Products Institute (ADPI) is the U.S. trade association of the processed dairy products industry. ADPI was established in 1986 by a merger of the American Dry Milk Institute and the Whey Products Institute. In 1987 the Evaporated Milk Association merged with ADPI.

Current Institute membership includes manufacturers of evaporated and dry milks, cheese and whey products, firms that provide supplies and services to processors, and many companies that utilize processed dairy products. The majority of ADPI's members are located in the U.S., but the Institute has many international members as well.

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DMI DAIRY MANAGEMENT INC.™

Dairy Management Inc.

Formed in 1995, Dairy Management Inc. is the domestic and international planning and management organization that builds demand on behalf of America's dairy farmers. DMI along with international, state and regional organizations manage the American Dairy Association, the National Dairy Council and the U.S. Dairy Export Council.

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U.S. *Dairy* Export Council

The U.S. Dairy Export Council (USDEC) is an independent membership organization that represents the interests of U.S. milk producers, cooperative dairy companies, dairy processors, export marketing and trading companies, and suppliers to the dairy industry. USDEC's members represent the vast majority of U.S. milk production and include companies with the widest varieties of dairy products available anywhere in the world.

A function of USDEC is to unify the U.S. dairy industry's international market development efforts, so that the United States can be a more responsive supplier to international markets. USDEC works with U.S. suppliers to help them maximize all of the benefits the industry has to offer: size, efficiency, consistency, high-quality products, product applications support, and state-of-the-art technology.

USDEC's activities fall into three broad categories: provide on-going service to trade partners; bring potential buyers and sellers together to facilitate trade; and educate and support both U.S. dairy exporters and end-users of U.S. dairy ingredients.

The U.S. Dairy Export Council provides support to international buyers and end-users of dairy products by:

- Working closely with trade partners and end-users around the world to develop and nurture business relationships.
- Providing information about U.S. suppliers, their products and capabilities.
- Supporting end-users and the trade with conferences and technical seminars aimed at providing training and guidance on the use of U.S. dairy products.
- Furnishing applications and usage ideas for U.S. dairy ingredients.
- Helping drive the sale of U.S. dairy products by creating and supporting in-store and foodservice promotions.
- Creating point-of-sale materials highlighting the benefits of purchasing U.S. dairy products.

The U.S. Dairy Export Council facilitates communication between international buyers of dairy products and U.S. suppliers by:

- Acting as a central contact point for international buyers and U.S. exporters, matching prospective buyers with potential sellers.
- Compiling and maintaining comprehensive lists of buyers and sellers, which are available to overseas customers and members.
- Circulating product inquires from international buyers to a concentrated list of U.S. suppliers to generate price quotations.
- Hosting international buying delegations to familiarize end-users with the size and scope of the U.S. industry.
- Coordinating trade missions and participating in trade shows in overseas markets to help U.S. suppliers better understand the needs of these markets.

The Council's headquarters is in Arlington, Virginia (adjacent to Washington, D.C.).

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In addition, USDEC has set up a number of international offices with representatives in China, Europe, Hong Kong, Japan, Mexico, the Middle East, South America, South Korea, Southeast Asia and Taiwan. Please contact USDEC for further information and contacts.

The U.S. Dairy Export Council provides access to suppliers of the largest, safest milk supply in the world. USDEC has a global staff in place to provide potential buyers with a direct communication link to U.S. dairy products suppliers.

GLOSSARY

Some of the terms used in this manual have synonyms that are used in related industries or other countries. The intent of the following list is to reconcile the terms used in this manual with other frequently used terms and closely related words.

Term used in this manual or abbreviations.	Synonym, closely related word or brief definition.
ADPI	American Dairy Products Institute. www.adpi.org
Agglomerated	Instantized
Anhydrous milk fat (AMF)	Similar to butteroil. AMF: 0.15% moisture and 99.8% fat. Butteroil: 0.3% moisture and 99.6% fat.
DMI	Dairy Management Inc.
FDA	Food and Drug Administration, United States. www.fda.gov
Filled	Recombined milk products where all or some of the milkfat is replaced with vegetable oil/fat.
Mt	Metric tonne (or ton)
NFDM	Nonfat dry milk. Defined in the United States Code of Federal Regulations, Title 21, volume 2, part 131.125. (www.fda.gov)
Recombined	The milk product resulting from the combining of milkfat and milk-solids-nonfat in one or more of the various forms with or without water. This combination must be made so as to re-establish the product's specified fat-to-solids-nonfat ratio and solids-to-water ratio. FAO/WHO 1973, Codex Alimentarius.
Reconstituted	The milk product resulting from the addition of water to the dried or condensed form of the product in the amount necessary to re-establish the specified solids-to-water ratio. FAO/WHO 1973, Codex Alimentarius.
SMP	Skimmed milk powder. Defined in Codex Alimentarius Standard 207-1999
USDA	United States Department of Agriculture. www.usda.gov
WMP	Whole milk powder. Defined in Codex Alimentarius Standard 207-1999
DWM	Dry whole milk. Defined in the United States Code of Federal Regulations, Title 21, volume 2, part 131.147. (www.fda.gov)
USDEC	The U.S. Dairy Export Council, producer of this manual.
WPNI	Whey Protein Nitrogen Index

Use of Terms

Whereas the terms nonfat dry milk and skim milk powder are used interchangeably in this manual and oftentimes by the trade, the terms are actually defined by two different sets of regulations and authorities (FDA/USDA and Codex Alimentarius). In addition, regulations of individual governments may differ. Please consult local regulations for all pertinent information when purchasing milk powders, and for labeling purposes.

Whereas the terms dry whole milk and whole milk powder are used interchangeably in this manual and oftentimes by the trade, the terms are actually defined by two different sets of regulations and authorities (FDA/USDA and Codex Alimentarius). In addition, regulations of individual governments may differ. Please consult local regulations for all pertinent information when purchasing milk powders, and for labeling purposes.

Photo courtesy: Wisconsin Milk Marketing Board

1.1 OVERVIEW OF THE U.S. DAIRY INDUSTRY

The United States is the world's largest cow's milk producer, producing about 76 million mt of milk per year, or close to 20% of the world's milk supply. U.S. dairy farmers produce two-and-a-half times more milk than any European country and six times as much as Australia or New Zealand.

Each year, U.S. manufacturers process about 20 million mt of fluid milk products, 3.8 million mt of cheese, 900,000 mt of whey and lactose, 730,000 mt of milk powders, 780,000 mt of yogurt, 615,000 mt of butter and 680,000 mt of ice cream and frozen dairy products in over 1,100 processing plants, making the United States the largest dairy processing country in the world.[1]

Many of these dairy products are used as ingredients in the formulation of other foods. U.S. food processors with international recognition use U.S. dairy ingredients, including U.S. milk powders, to successfully develop bakery products, confections, meats, sauces, soups and other dairy foods for both domestic and export sales.

Photo courtesy: Wisconsin Milk Marketing Board

The United States has been able to achieve its current milk output through a combination of scientific and management advancements at all levels of production, processing, regulation and marketing. In the past 10 years, the country has increased milk production at an average of one million mt per year.

On the farm, management techniques, including expanded use of balanced feed rations have been instrumental in increasing milk output per cow. Between 1990 and 2004, average annual yield per cow increased from 6,600 kg to about 8,600 kg, while cow numbers decreased from about 10.8 million in 1980 to about 9 million in 2004. This type of production efficiency demonstrates the industry's ability to maximize its resources to meet the growing demand for dairy products worldwide. These same practices have led to improvements in the composition of milk, which have resulted in an increase of solids-nonfat (SNF) to meet food manufacturers' demands for more milk protein.

Advanced U.S. technologies ensure efficient collection and delivery of the highest quality milk and milk products. State-of-the-art milking and milk handling equipment, including automated milking systems, have improved the speed of cleaning, sanitizing, and cooling raw milk. Efficient delivery systems ensure timely transfer of raw milk to the processing plants.

Dairy farmers and dairy processors alike abide by strict U.S. sanitary standards. In addition to self-imposed sanitary guidelines, dairy farmers are visited regularly by government regulatory agencies, which conduct quality assurance and safety inspections at the farms. These inspectors confirm herd health, oversee veterinary practices, monitor sanitation of the facilities and milking equipment, and verify that the milk is being rapidly cooled and properly stored until delivered to processing facilities.

[1]Fluid milk data: commercial disappearence. Production data for other products. Sources: National Milk Producers Federation, Dairy Producers Highlights 2004, and United States Department of Agriculture.

At the processing facilities, milk is sampled for quality prior to acceptance, moves through sanitized pipes, vats and tanks as it is transformed into fluid milk and more than 400 varieties and styles of cheese, 100 flavors of ice cream and frozen yogurt, 75 flavors and set-types of yogurt, various milk powders and whey products, and numerous blends of butter and cultured products. Virtually all U.S. dairy processing plants employ quality management programs, such as HACCP or ISO, to ensure that the finished products meet the highest attainable standards. Halal/kosher certification of product is available.

The U.S. industry has made continued, large investments in new, state-of-the-art dairy manufacturing facilities. During the past decade, such developments have enabled a 45% reduction in the number of manufacturing facilities while average output per plant has more than doubled during the 1985-2001 period. Continued investment will mean still lower processing costs, higher milk volumes, and the highest product quality and consistency.

Employees at these facilities do more than manufacture dairy products. Through research and development laboratories, they generate new products and devise new uses for milk and its components. Dairy technologists and food scientists work together to discover how the functional properties of milk components can be preserved or modified by fractionation and other processing procedures. State-of-the-art equipment for drying milk, manufacturing cheese and processing whey has enabled the industry to create a wide variety of new products such as differentiated milk powders, low-carb milk, aseptic milk or a wide variety of high-value whey fractions. These new products have been developed to meet the expanding global demand for highly functional and nutritional dairy products and ingredients.

Photo courtesy: WestFarm Foods

As trade agreements continue to open global markets, other countries are able to benefit from using U.S. dairy products. These provide excellent value by combining product quality, functionality, price and service. International food manufacturers are able to import large quantities of U.S. dairy ingredients, including butter, anhydrous milkfat, skim milk powder, whole milk powder, cheese, lactose and whey, for use in the formulation of pizza, bread, beverages, infant formula, nutrition bars and hundreds of other food products. U.S. manufacturers are aware of the special needs of export customers and are able to customize dairy products to meet these individual requirements.

Additional information on specific milk powders is available from the suppliers of the products. The U.S. Dairy Export Council can provide the names, addresses and phone/fax information for U.S. companies processing and/or marketing each of the types of milk powders.

Currently, the United States offers the greatest number and largest variety of dairy product suppliers. With more than 800 U.S. dairy manufacturers of cheese, fluid milk, whey, milk powders, yogurt, butter, ice cream and other dairy products, buyers can choose from myriad suppliers – big or small – to meet their precise needs.

This handbook is designed to guide and educate international product developers on using U.S. milk powders. It is an information resource that includes:

- A description of the U.S. milk powder industry.
- Definitions of milk powder products.
- Descriptions of the processes used to produce milk powders and to enhance certain functional properties of skim milk powder.
- Discussions of the functional and nutritional properties of milk powders.
- Applications for these functional, nutritional dairy ingredients.

1.2 DAIRY EXPORT INCENTIVE PROGRAM (DEIP)

The Dairy Export Incentive Program (DEIP), was created to stimulate exports of products by offering Commodity Credit Corporation (CCC) bonuses. Announced by USDA in May 1985, the program was reauthorized by the Food, Agriculture, Conservation and Trade Act of 1990, the Uruguay Round Agreements Act of 1995, the Federal Agriculture Improvement and Reform Act of 1996, and the Farm Security and Rural Investment Act of 2002. The major objective of the U.S. DEIP program is to develop export markets for U.S. dairy products where U.S. products are not competitive due to price subsidies from other global sources.

As part of its World Trade Organization commitments resulting from the Uruguay Round Agreement on Agriculture, the United States has established annual export subsidy ceilings by commodity, with respect to maximum permitted quantities and maximum budgetary expenditures.

The program enables U.S. entities to make competitive sales in eligible countries of not less than 150 thousand metric tones of dairy products annually, including 68,201 mt of nonfat dry milk. DEIP enables exporters of U.S. dairy products to meet prevailing world prices for targeted dairy products and destinations.

DEIP helps U.S. dairy farmers, processors, manufacturers, and exporters gain access to foreign markets. As a result, the program allows the U.S. dairy industry to demonstrate the high quality of its products to interested international buyers. Any exporter interested in participating in DEIP must undergo a qualification process. The information that the exporter must submit as part of this process includes:

- Documented experience of selling dairy products for export within the preceding three calendar years.
- An office and agent for services of legal process in the United States (names and addresses).
- A description of business structure (how and where incorporated).
- A statement describing participation, if any, during the past three years in U.S. government programs, contracts, or agreements.
- In addition to being qualified for DEIP participation, exporters are required to post a performance security before submitting a request for a bonus.

The kind, type, grade and/or class of U.S. agriculture commodity specified as eligible for export under the applicable invitation includes:

Nonfat Dry Milk meeting the U.S. Standards for Grades of Nonfat Dry Milk.

Dry Whole Milk meeting the U.S. Standards for Grades of Dry Whole Milk.

Countries may be recommended for participation in DEIP by USDA program experts, members of the U.S. agriculture community, foreign government officials, and others.

All sales facilitated using DEIP are made by private sector companies, not the government. A prospective buyer must select a company from which to purchase dairy products. Prospective buyers should note that a company selling under DEIP must register, or qualify, to participate in DEIP and that registration is not an endorsement by the U.S. government.

For further information about the Dairy Export Incentive Program, contact:
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Tel: + 1-202-720-6122
Fax: + 1-202-720-0938

OVERVIEW

The United States has the largest supply of milk in the world, along with an abundance of land and considerable investment in research and development. In 2004, about 640 thousand mt of nonfat dry milk were produced.

On average, about 17-19 % of the world's skim milk powder production is manufactured at more than 80 plants in the United States, making the United States one of the largest milk powder producers in the world. These factors, together with strict sanitary and quality standards, year-round production, and a growing international focus have helped the U.S. dairy industry position itself as a premium dairy ingredient supplier to the world. Detailed information on the milk powder industry, including extensive statistics, is available from the American Dairy Products Institute (www.adpi.org).

The United States is one of the world's most efficient producers of milk, and production is year-round. This guarantees product availability at any time of the year, including the winter season. Production facilities are state-of-the-art, offering milk powders that retain their flavor and freshness during normal storage. U.S. plants have the ability to modify their products to meet specialized needs, thereby allowing the customer to respond to new opportunities in a fast time frame.

Working in cooperation with the U.S. Department of Agriculture (USDA), U.S. suppliers can offer a quality product at a competitive price. Through the assistance of the U.S. Dairy Export Incentive Program (DEIP) at USDA, U.S. suppliers can offer buyers a competitively priced milk powder product at prevailing world prices. Blends based on milk powders, which offer functional or nutritional benefits, are also available.

On the average, approximately 80% of U.S. skim milk powder is used within the United States. U.S. food manufacturers, big and small, depend on U.S. milk powder when formulating their products. The other 20% is exported, enabling manufacturers worldwide the opportunity to formulate with high-quality and consistent U.S. milk powders. Suppliers also offer blended products with differentiated composition and customized functionality that are competitively priced.

Whether they are used to extend local milk supply, provide nutritional benefits, give convenience of use, or provide functional or shelf-life benefits, food manufacturers have made U.S. milk powders an integral part of their success. They have come to trust the quality of U.S. milk powders with good reason. The United States has one of the strictest set of food sanitary standards of any country in the world.

General Benefits of Milk Powders

Milk is a complex biological fluid consisting of fats, proteins, minerals, vitamins, enzymes, lactose and water. Not only is milk a highly nutritious food, it is also a functional ingredient. However, sometimes it is difficult to transport, store or even formulate with milk in its fluid form. Therefore, processors employ technologies to remove the majority of water from fluid milk, which results in milk powder. The most common milk powders are skim milk powder, whole milk powder and buttermilk powder.

Milk powder contributes nutritionally, functionally and economically to a variety of foods including baked goods, confections, dairy products, recombined milk, meat, nutritional beverages, and prepared foods.

Milk powders are milk products with an extended shelf-life. By removing the majority of moisture from milk, fluid milk is converted into a shelf-stable, dry powder with a shelf life of 12 to 18 months, as compared to fresh pasteurized fluid milk's short shelf-life (less than 21 days).

The general benefits of milk powders include:

- Storage– Requires small spaces under regular storage conditions and retains high quality.
- Economy– Because mass and volume are reduced, transportation costs are less.
- Balance– Surplus milk powder can be reconstituted when fresh milk supplies are low.
- Use in Emergencies– Can be used under adverse conditions when fresh milk is unavailable.
- Formulations– Suitable for use as an ingredient in a wide variety of foods and beverages.
- Fortification– Can add additional milk protein, dairy calcium and other vitamins and minerals to a variety of foods.

The U.S. milk powder industry is one of the world's most efficient producers, with efficiencies continually being developed in the plant.

Through advances in production, the industry has been able to increase production output from 472,000 mt in 1992 to about 640,000 mt in 2004 (nonfat dry milk).

Photo courtesy: Dairy Management Inc.

Whether it is used to provide mouthfeel, upgrade visual appearance, enhance nutrition or perform one of a variety of other functional benefits, food manufactures worldwide have made U.S. milk powders an integral part of successful food formulations. They have come to trust the quality of U.S. milk powders with good reason: The United States has some of the strictest food sanitary requirements.

All U.S. milk powders are made from high quality milk in federally approved manufacturing facilities. Dairy farmers and dairy processors alike abide by strict U.S. sanitary standards. In addition to self-imposed sanitary guidelines, dairy farmers are visited regularly by government regulatory agencies, which conduct quality assurance and safety inspections at the farms. These inspectors confirm herd health, oversee veterinary practices, monitor sanitation of the facilities and milking equipment, and verify that the milk is being rapidly cooled and properly stored until delivered to the processing facilities. At processing facilities, each tanker of milk is tested to ensure it is negative for residual antibiotics prior to its unloading; milk then moves through sanitized pipes, vats and tanks as it is converted into a variety of dairy foods including milk powders. Virtually all U.S. dairy processing plants employ quality management programs, such as HACCP or ISO, to ensure that the finished products meet the highest attainable standards.

Photo courtesy: WestFarm Foods

All milk powder processes begin with liquid milk (skim milk, whole milk or buttermilk), which is stored at the processing plant at temperatures below 7°C. Raw whole milk has a variable fat content and cream is separated from the milk to facilitate standardization of the fat content prior to further processing. Centrifugal separators are used to further clarify the milk.

The milk is pasteurized (high-temperature, short-time) by heating to at least 72°C, and holding at or above this temperature for at least 15 seconds. (An equivalent temperature/time combination can be used). Heat treatment affects the functional properties of skim milk powder and the keeping quality of whole milk powder, so the temperature and time combinations can vary widely depending on the required properties. With skim milk powder, the extent of heat treatment can be related to the whey protein nitrogen index, which is related to the amount of soluble whey protein. Additional information on the classification of skim milk powder according to heat treatment applied can be found in the "Definitions" section of this manual.

For all milk powders, heat treatments are generally carried out at temperatures higher than those required for pasteurization. The aim is to destroy all pathogenic and most of the other microorganisms, to inactivate enzymes, especially lipase which could cause lipolysis during storage, and to activate the SH groups of β-lactoglobulin, thus increasing resistance of the powder to oxidative changes during storage.

Homogenization is not a mandatory step in whole milk or buttermilk processing, but is usually applied in order to decrease the free fat content. Fat globules depleted of protective membranes reduce milk powder solubility and increase its susceptibility to oxidative rancidity. Homogenization transforms free fat into fat globules. During homogenization, proteins adhere on globule surfaces to surround and stabilize the fat globules.

After pasteurization, other optional ingredients such as vitamins and minerals can be added to the milk. The milk then undergoes a two-part moisture-removal process: concentration and drying.

The first part of concentration involves pumping milk to a multiple effect vacuum evaporator system where water is boiled off at relatively low temperatures in a series of steps until the milk is concentrated to around 40-50% total solids. Omitting evaporation of the milk prior to drying is not economically feasible because the demand for energy would be severely increased. For example, the energy used to remove water in multiple effect evaporators with vapor recompression is about 10 times lower than in spray drying. Omission of evaporation would also result in inferior quality milk powder particles that contain occluded air (which impacts extended shelf-life.)

The second part involves drying in either a spray dryer or on a roller dryer. Additional, optional processing steps include instantizing. After processing, cooled milk powders are sifted and sent to blending and storage silos. Milk powders are then sampled, packed, check weighed and palletized as required for shipping.

Spray Drying

Spray drying involves atomizing concentrated milk into a hot air stream (180°-200°C). The atomizer may be either a pressure nozzle or a centrifugal disc. By controlling the size of the droplets, the air temperature, and the airflow, it is possible to evaporate almost all the moisture while exposing the drying particles to relatively low temperatures. Spray drying yields milk powders with excellent solubility, flavor and color. This is the most common procedure for manufacturing milk powders.

The spray drying process can be a single stage or a two stage process. The two stage process involves the spray dryer at the first stage with a static fluid bed integrated in the base of the drying chamber. The second stage is an external vibrating fluid bed.

Product is moved through the two stage process quickly to prevent overheating of the powder. Powder leaves the dryer and enters a system of cyclones that simultaneously cools it and removes powder dust from exhaust air.

Photo courtesy: WestFarm Foods

Roller Drying

Roller drying involves direct contact of a layer of concentrated milk with the hot surface of rotating rollers. This method is not often used because of the adverse affects the heat has on milk components. Heat often causes irreversible changes such as lactose carmelization, Maillard reaction and protein denaturation. Roller drying typically results in more scorched powder and lower solubility than spray drying.

Instantizing

The process of instantizing results in a milk powder with improved reconstitution properties. Instantizing is attained by agglomeration, a process of increasing the amount of void spaces between powder particles. During reconstitution, the voids are replaced by water. This enables a large amount of water to come into contact immediately with the powder particles during reconstitution.

With whole milk powder and buttermilk powder, a small amount of lecithin is typically applied during agglomeration. Lecithin is a natural phospholipid that improves the ability of high-fat products to dissolve in water.

There are two basic types of agglomeration processes: The "rewet" process, where agglomeration is carried out after the powder is obtained in dry form, and the "straight-through" process, where agglomeration is accomplished during drying.

Photo courtesy: Dairy Management Inc.

Figure 3.1
Basic Milk Powder Production

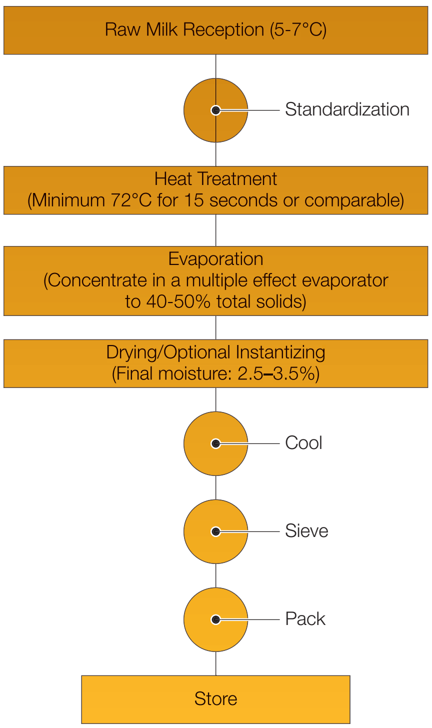

Figure 3.2
Instantizing-Rewet Process

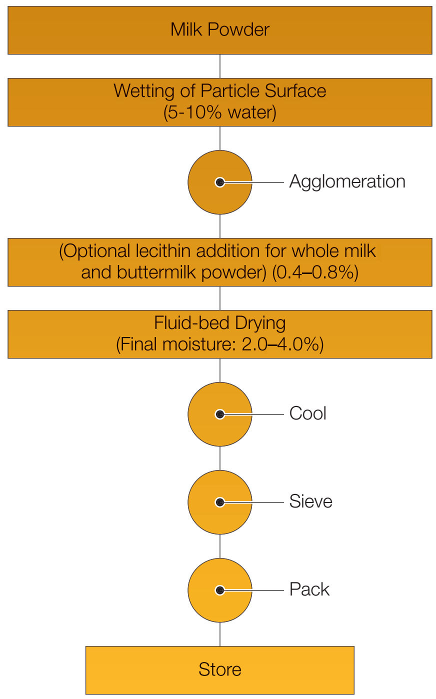

Figure 3.3
Instantizing-Straight-Through Process

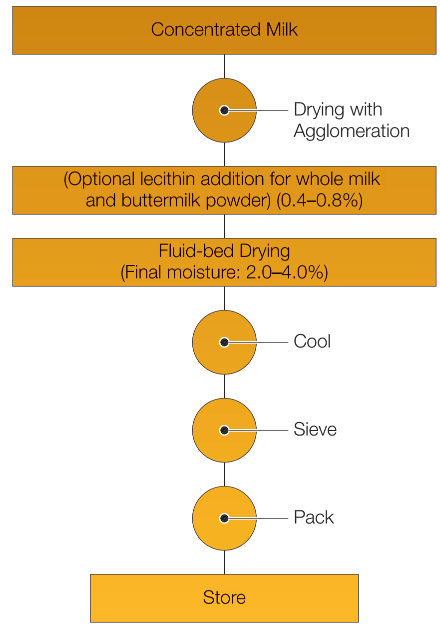

Photo courtesy: Dairy Management Inc.

4.1 GENERAL QUALITY CONTROL AND PLANT SURVEYS

U.S. suppliers offer a range of product approvals and certifications that guarantee their customers some of the highest quality powders in the world.

U.S. standards for grades of milk powders come from the Dairy Division of the United States Department of Agriculture. The standards are based on inspection and grading services and ensure a nationally and internationally understood language for efficient orderly trade. The United States leads the world in the creation and development of industry standards for testing milk powders. These were first adopted in 1929 and are updated on an as needed basis. The American Dairy Products Institute (ADPI) is an industry organization that compiles the USDA standards and publishes the standards in bulletin #916 for members. Standards can be ordered from the Institute (www.adpi.org).

Industry standards for milk powder, whole milk powder and buttermilk powder promote the utilization of milk powders by making available a uniform grading system. Because the U.S. fluid milk supply, its manufacturing facilities and its subsequent storage facilities, are all in accordance with some of the strictest procedures and practices in place in the world, milk powders made in the United States meet strict grade requirements.

These requirements are not designed to meet all end-uses. To determine the acceptability of a milk powder in a specific formulation, supplemental tests not included in the standards are often necessary. Buyers who use such standards in their purchasing decisions provide themselves with an added safeguard regardless of the particular purpose for which the milk powder is intended.

Milk powder standards are the basis for an effective quality control program. Major benefits are:

Assure Uniformity
Uniform quality of product is assured by grade specifications, accepted and understood throughout the milk powder industry. Milk powder standards enable both manufacturers and purchasers to specify the grade of product offered for sale or required for use.

Facilitate Purchase
Buyers and sellers are afforded a common language whereby a milk powder meeting specific product requirements is recognized by its grade name. Tests and grades are based on industry-approved analytical procedures. This eliminates unnecessary and detailed tests that vary between manufacturing and purchasing organizations.

Reduce Risk
The manufacturer of the milk assumes responsibility for delivering the grade of product offered. Many elements of risk are eliminated from the purchase since the buyer may have each purchase checked by grade analysis. Similarly, the manufacturer is protected against unreasonable complaints because the grade standards are succinct and based upon specific methods of analysis.

Plant Surveys

Each plant survey is conducted by experienced, highly trained USDA dairy inspectors who make detailed checks on more than 100 items. Only plants that meet these requirements are granted "approval status" and are eligible for grading and quality control services. Some of the items on a dairy inspector's list include:

1. The plant surroundings must be clean to prevent bacterial contamination and maximize product safety.
2. Areas such as the raw milk grading room, receiving line, manufacturing area and warehouse supply room must have adequate lighting.
3. Facilities must be of sound construction.
4. Incoming milk must be regularly analyzed to ensure high quality and product safety.
5. Personnel practices must be appropriate to maximize product safety.
6. All processing equipment must be kept sanitary and in excellent working condition to assure the buyer that the milk powder is protected from contamination.

Inspection and Grading

The final product is sampled by USDA inspectors. A computer program is used to select samples randomly and these samples are pulled from storage in the presence of the USDA inspector. The inspector examines each sample to determine compliance to the grade standard or contract specification and stamps packages with the official acceptance stamp or grade mark. They also issue certificates for product that complies with the standard or specifications. After inspection, dairy products are packaged under stringent, U.S. government regulated standards.

Laboratory Service

Laboratory service consists of analytical and quality control tests, including all chemical and bacteriological determinations essential for grading.

Personnel

The men and women who perform these services are experienced and well trained. Many inspectors and graders have college degrees in dairy manufacturing or food science, and have held responsible jobs in the dairy industry.

4.2 FOOD AND DRUG ADMINISTRATION STANDARDS OF IDENTITY

The Food and Drug Administration, part of the United States Department of Health and Human Services, has issued standards of identify for three types of dried milk products. These standards are part of the United States Code of Federal Regulations, Title 21, Volume 2. They can be downloaded by the FDA's website (www.fda.gov).

Section 131.125: Nonfat dry milk

Source: FDA. CFR, Title 21, Volume 2, Section 131.125. Revised April 1, 2003.

(a) Description. Nonfat dry milk is the product obtained by removal of water only from pasteurized skim milk. It contains not more than 5 percent by weight of moisture, and not more than 1.5 percent by weight of milkfat unless otherwise indicated.

(b) Optional ingredients. Safe and suitable characterizing flavoring ingredients (with or without coloring and nutritive carbohydrate sweetener) as follows: Fruit and fruit juice, including concentrated fruit and fruit juice, natural and artificial food flavorings.

(c) Methods of analysis. The following referenced methods of analysis are from "Official Methods of Analysis," 13th edition (1980). Copies may be obtained from the Association of Official Analytical Chemists International, 481 North Frederick Ave., Suite 500. Gaithersburg, MD 20877-2504.

- Milk fat content: "Fat in dried milk – Official Final Action," sections 16.199.200
- Moisture content: "Moisture – Official final action," section 16.192.

(d) Nomenclature. The name of the food is "Nonfat dry milk." If the fat content is over 1.5 percent by weight, the name of the food in the principal display panel or panels shall be accompanied by the Statement "Contains –% milkfat," the blank to be filled with the percentage to the nearest one tenth of 1 percent fat contained, within limits of good manufacturing practice. The name of the food shall include a declaration in the presence of any characterizing flavoring, as specified in Section 101.22 of this chapter.

Note: Section 131.127: Nonfat dry milk fortified with Vitamins A and D presents the standard for such a product that is to contain 200 IU of vitamin A and 400 IU of Vitamin D.

Section 131.147: Dry whole milk

Source: FDA. CFR, Title 21, Volume 2, Section 131.147. Revised April 1, 2003.

(a) Description. Dry whole milk is the product obtained by removal of water only from pasteurized milk, as defined in § 131.110 (a), which may have been homogenized. Alternatively, dry whole milk may be obtained by blending fluid, condensed, or dried nonfat milk with liquid or dried cream or with fluid, condensed, or dried milk, as appropriate, provided the resulting dry whole milk is equivalent in composition to that obtained by the method described in the first sentence of this paragraph. It contains the lactose, milk proteins, milkfat, and milk minerals in the same relative proportions as the milk from which it was made. It contains not less than 26 percent but less than 40 percent by weight of milkfat on an as is basis. It contains not more than 5 percent by weight of moisture on a milk solids non fat basis.

(b) Vitamin addition. Addition of vitamin A is optional. If added, vitamin A shall be present in such quantity that, when prepared according to label directions, each quart of the reconstituted product shall contain not less than 2,000 International Units thereof. Addition of vitamin D is optional. If added, vitamin D shall be present in such quantity that, when prepared according to label directions, each quart of the reconstituted product shall contain 400 International Units thereof. The requirements of this paragraph will be met if reasonable overages, within limits of good manufacturing practice, are present to ensure that the required levels of vitamins are maintained throughout the expected shelf life of the food under customary conditions of distribution.

(c) Optional ingredients. The following safe and suitable optional ingredients may be used: carriers for vitamins A and D, emulsifiers, stabilizers, anticaking agents, antioxidants, characterizing flavoring ingredients (with or without coloring and nutritive carbohydrate sweetener) as follows: fruit and fruit juice, including concentrated fruit and fruit juice and natural and artificial food flavoring.

(d) Methods of analysis. The following referenced methods of analysis are from "Official Methods of Analysis of the Association of Official Analytical Chemists," 13th Ed. (1980), which is incorporated by reference. Copies may be obtained from the Association of Official Analytical Chemists International, 481 North Frederick Ave., Suite 500, Gaithersburg, MD 20877-2504, or may be examined at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202-741-6030, or go to: http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html. Milkfat content – "Fat in Dried Milk-Official Final Action," sections 16.199-16.200. Moisture content – "Moisture-Official Final Action," section 16.192. Vitamin D content – "Vitamin D-Official Final Action," sections 43.195-43.208.

(e) Nomenclature. The name of the food is "Dry whole milk." The name of the food shall appear on the principal display panel of the label in type of uniform size, style, and color. The name of the food shall be accompanied by a declaration indicating the presence of any characterizing flavoring as specified in § 101.22 of this chapter. The following phrases in type size not less than one-half the height of the type size used in such name shall accompany the name of the food wherever it appears on the principal display panel or panels. The phrase "Contains _% milkfat," the blank to be filled in with the whole number closest to the actual fat content of the food. If vitamins are "added," the phrase "vitamin A," or "vitamin A added," or "vitamin D," or "vitamin D added," or "vitamins A and D," or "vitamins A and D added," as appropriate. The word "vitamin" may be abbreviated "vit."

(f) Label declaration. Each of the ingredients used in the food shall be declared on the label as required by the applicable sections of parts 101 and 130 of this chapter.

4.3 UNITED STATES DEPARTMENT OF AGRICULTURE GRADING

U.S. suppliers voluntarily participate in the U.S. standards for milk powders grading system. The standards are issued by the United States Department of Agriculture. The standards for grades themselves are summarized in this manual, and the documents can be downloaded from the USDA website (www.usda.gov).

General Grading Requirements

1. All nonfat dry milk, dry whole milk and dry buttermilk for human consumption must conform in all respects to Federal and State government regulations in force at the present time or that may subsequently be issued from time to time.
2. The milk powder must be made from fresh, sweet milk to which no preservatives, alkali, neutralizing agent or other chemical has been added and which has been pasteurized in the liquid state, before concentration, at a temperature of 72°C for 15 seconds, or its equivalent in bacterial destruction.
3. The milk powder must be reasonably uniform in composition. The color shall be white or cream and free from a brown or yellow color typical of overheated product and free from unnatural color. It must be substantially free from brown specks.
4. The flavor and odor of the milk powder in dry form or after reconstitution must be sweet, clean and free from rancid, tallowy, fishy, cheesy, soapy or other objectionable flavors or odors.
5. The milk powder must be packed in substantial containers, suitable to protect and preserve the contents without significant impairment of quality with respect to sanitation, contamination and moisture content under various customary conditions of handling, transportation and storage.
6. The presumptive coliform estimate of the milk powder must not exceed 10 per gram of milk powder.
7. The milk powder must be free from extraneous matter as described in Section 402(a) of the Federal Food, Drug and Cosmetic Act.

Source: American Dairy Products Institute, Bulletin #916. www.adpi.org

There are differences in composition, appearance, flavor and bacteriological standards between products that are "Extra Grade" vs. "Standard Grade." The following table on page 21 summarizes the grading criteria.

Heat Treatment Classification

The heat treatment classification is not a U.S. grade requirement, except for high-heat milk powder for which a higher solubility index is permitted. Product submitted for grading may be analyzed for heat treatment classification upon request and the results shown on the grading certificate. Heat treatment classification will be made available only upon a product graded by USDA. See section on definitions for additional information.

Specific Grading Requirements for Nonfat Dry Milk

Nonfat dry milk is the product obtained by the removal of only water from pasteurized skim milk. It conforms to the application provisions of the Code of Federal Regulations (see previous section) issued by the Food and Drug Administration. Basic compositional criteria are presented in the following table:

	Spray Dried	Roller Dried
Milkfat	<1.5%	<1.5%
Moisture	<5.0%	<5.0%

Extra Grade

"Extra Grade" indicates the highest quality U.S. nonfat dry milk. It shall be free from lumps, except those that break up readily under slight pressure.

Standard Grade

"Standard Grade" includes all nonfat dry milk that fails in one or more of the particulars to meet the requirements of "Extra Grade." It may contain small to moderate lumps, slight color and reasonably free of visible dark particles.

Grade Not Assignable

Milk powders are not assigned a grade for one or more of the following reasons:

1. Fails to meet the requirements for U.S. "Standard Grade." For instance, when it fails to meet the requirements for "Extra Grade."
2. Has a direct microscopic clump count exceeding 100 million per gram.
3. Has a coliform count exceeding 10 cfu per gram.
4. The skim milk powder is produced in a plant that is rated ineligible for USDA grading service or is not USDA approved.

There is no standard grade for instant nonfat dry milk.

Optional Tests

Copper content	1.5 ppm
Iron content	10 ppm
Vitamin A (when fortified)	2,000 IU per reconstituted quart
Vitamin D (when fortified)	400 IU per reconstituted quart

Specifications for U.S. Grades of Nonfat Dry Milk, Spray Process*

Characteristic	U.S. Extra Grade	U.S. Standard Grade
Flavor	Sweet, pleasing desirable flavor	Fairly pleasing flavor
Physical appearance	Uniform white to light cream	White or light cream May possess slight unnatural color
Bacterial estimate	<10,000 cfu/g	<75,000 cfu/g
Milk fat	<1.25%	<1.50%
Moisture	<4.0%	<5%
Scorched particles	<15 mg	<22.5 mg
Solubility index	<1.2 ml <2 ml (high heat)	<2.0 ml <2.5 ml (high heat)
Titratable acidity	<0.15% (lactic acid)	<0.17% (lactic acid)
Flavor Characteristics		
• Bitter	Not permitted	Slight
• Chalky	Slight	Definite
• Cooked	Slight	Definite
• Feed	Slight	Definite
• Flat	Slight	Definite
• Oxidized	Not permitted	Slight
• Scorched	Not permitted	Slight
• Storage	Not permitted	Slight
• Utensil	Not permitted	Slight
Physical Appearance		
Dry product:		
• Lumpy	Slight	Moderate
• Unnatural color	Not permitted	Slight
• Visible dark particles	Practically free	Reasonably free
Reconstituted product:		
• Grainy	Not permitted	Reasonably free

	Spray Dried	Roller Dried	Instant**
Milkfat	<1.25%	<1.25%	<1.25%
Moisture	<4.0%	<4.0%	<4.0%
Titratable acidity	<0.15%	<0.15%	<0.15%
Solubility index	<1.2 ml <2.0 ml (high heat)	<1.5.0 ml	<1.0 ml
Bacterial estimate	<10,000 cfu/g	<50,000 cfu/g	<10,000 cfu/g
Coliform count	–	–	<10 /g
Scorched particles	Disc B (15.0 mg)	Disc C (22.5 mg)	Disc B (15.0 mg)

*Summary, please refer to USDA Standard for Grade document for additional information.

**If lactose is used as a processing aid, the amount must only be that necessary to produce the desired effect, and it must not exceed 2.0% of the weight of skim milk powder.

Specific Grading Requirements for Dry Whole Milk

Dry whole milk, made by the spray or roller process is the product obtained by removal of water only from pasteurized milk which may have been homogenized. It contains not more than 5% by weight of moisture on a milk solids not fat basis, and not less than 26% but less than 40% by weight of milk fat. It conforms to the applicable provisions of the Code of Federal Regulations (see previous section). Alternatively, dry whole milk may be obtained by blending fluid, condensed or dried nonfat milk with liquid or dried cream or with fluid, condensed or dry milk.

It contains the lactose, milk proteins, milkfat, and milk minerals in the same relative proportions as the milk from which it was made.

When either or both vitamin A or D is added, they shall be present in such quantity that, when prepared according to label directions, each quart (0.9 l) of the reconstituted products shall contain not less than 2,000 IU of vitamin A and 400 IU of vitamin D.

Specifications for U.S. Grades of Dry Whole Milk*

Characteristic	U.S. Extra Grade	U.S. Standard Grade
Flavor	Sweet, pleasing desirable flavor	Sweet and pleasing
Physical appearance	Uniform white to light cream	White or light cream May possess slight unnatural color
Bacterial estimate	<10,000 cfu/g	<50,000 cfu/g
Coliform count	<10 /g	<10 /g
Milk fat	>26%, <40%	>26%, <40%
Moisture	<4.5% (weight on MSNF basis)	<5% (weight on a MSNF basis)
Scorched particles	<15 mg (spray process) <22.5 mg (roller dried)	<22.5 mg (spray process) <32.5 mg (roller dried)
Solubility index	<1.0 ml (spray process) <15 ml (roller dried)	<1.5 ml (spray process) <15 ml (roller dried)
Titratable acidity	<0.15% (lactic acid)	<0.17% (lactic acid)
Flavor Characteristics		
• Cooked	Definite	Definite
• Feed	Slight	Definite
• Bitter	None	Slight
• Oxidized	None	Slight
• Scorched	None	Slight
• Stale	None	Slight
• Storage	None	Slight
Physical Appearance		
Dry product:		
•Lumps	Slight pressure	Moderate pressure
•Unnatural color	None	Slight
•Visible dark particles	Practically free	Reasonably free
Reconstituted product:		
•Grainy	Free	Reasonably free

*Summary, please refer to USDA Standard for Grade document for additional information.

Extra Grade

"Extra Grade" indicates the highest quality U.S. dry whole milk. It shall be free from lumps, except those that break up readily under slight pressure.

Standard Grade

"Standard Grade" includes all milk powder that fails in one or more of the particulars to meet the requirements of "Extra Grade."

Grade Not Assignable

Dry whole milks are not assigned a grade for one or more of the following reasons:

1. Fails to meet the requirements for U.S. "Standard Grade."
2. Has a direct microscopic clump count exceeding 100 million per gram.
3. Fails to meet requirements for any optional test when such tests have been performed.
4. Produced in a plant found on inspection to be using unsatisfactory manufacturing practices, equipment or facilities, or to be operating under sanitary plant conditions.

Optional Tests

Copper content	1.5 ppm
Iron content	10 ppm
Vitamin A (when fortified)	2,000 IU (min) per reconstituted quart (0.9 liter)
Vitamin D (when fortified)	400 IU (min) per reconstituted quart (0.9 liter)

Specifications for U.S. Dry Whole Milk Extra Grade

	Spray Dried	Roller Dried
Milkfat	26.0–40.0%	26.0–40.0%
Moisture	4.5%	4.5%
Titratable acidity	0.15%	0.15%
Solubility index (max)	1.0 ml max	15.0 ml max
Bacterial estimate	10,000 cfu/g	50,000 cfu/g
Scorched particles	Disc B (15.0 mg)	Disc C (22.5 mg)

Specifications for U.S. Dry Whole Milk Standard Grade

	Spray Dried	Roller Dried
Milkfat	26.0–40.0%	26.0–40.0%
Moisture	5.0%	5.0%
Titratable acidity	0.17% max	0.17% max
Solubility index (max)	1.5 ml max	1.5 ml max
Bacterial estimate	50,000 cfu/g	50,000 cfu/g
Scorched particles	Disc C (22.5 mg)	Disc D (32.5 mg)

Photo courtesy: Dairy Management Inc.

Specific Grading Requirements for Dry Buttermilk

The United States Department of Agriculture defines dry buttermilk, and grades for it in its Standard for Grades of Dry Buttermilk and Dry Buttermilk Product. It defines dry buttermilk, made by the spray process or the atmospheric roller process, as the product resulting from drying liquid buttermilk that was derived from the churning of butter and pasteurized prior to condensing at a temperature of 71.6˚C (161˚F) for 15 seconds, or its equivalent in bacterial destruction. Dry buttermilk should have a protein content of not less than 30%. Dry buttermilk cannot be derived from nonfat dry milk, dry whey, or products other than buttermilk, and it cannot contain any added preservatives, neutralizing agents or other chemicals.

Dry buttermilk product is the product resulting from drying liquid buttermilk that was derived from the churning of butter and was pasteurized prior to condensing at a temperature of 71.6˚C (161˚F) for 15 seconds or its equivalent in bacterial destruction. Dry buttermilk product should have a protein content of less than 30%. Dry buttermilk product cannot be derived from nonfat dry milk, dry whey, or products other than buttermilk, and it cannot contain any added preservatives, neutralizing agents or other chemicals.

Specifications for U.S. Grades of Dry Buttermilk and Buttermilk Product*

Characteristic	U.S. Extra Grade	U.S. Standard Grade
Flavor	Sweet and pleasing	Fairly pleasing
Physical appearance	Cream to light brown	Cream to light brown
Bacterial estimate	<20,000 cfu/g	<75,000 cfu/g
Milk fat	>4.5%	<4.5%
Moisture	<4.0%	<5%
Scorched particles	<15 mg (spray process) <22.5 mg (roller dried)	<22.5 mg (spray process) <32.5 mg (roller dried)
Solubility index	<1.25 ml (spray process) <15 ml (roller dried)	<2 ml (spray process) <15 ml (roller dried)
Titratable acidity	>0.10%, <0.18%	>0.10%, <0.20%
Protein Content		
• Dry Buttermilk	>30%	>30%
• Dry Buttermilk Product	<30%	<30%
Flavor Characteristics		
• Unnatural	None	Slight
• Offensive	None	None
Physical Appearance		
• Lumps		
• Visible dark particles	Slight	Moderate

*Summary, please refer to USDA Standard for Grade document for additional information.

Comparison chart: Typical Composition of Milk and Buttermilk Powders (%)

	Skim Milk Powder	Whole Milk Powder	Buttermilk Powder
Protein	34.0–37.0	24.5–27.0	32.0–34.5
Lactose	49.5–52.0	36.0–38.5	46.5–49.0
Fat	0.6–1.25	26.0–28.5	>4.5% Buttermilk powder
			<4.5% Buttermilk product
Ash	8.2–8.6	5.5–6.5	
Moisture (non-instant) (instant)	 3.0–4.0 3.5–4.5	 2.0–4.5	 3.0–4.0

5 MAJOR CHARACTERISTICS OF MILK POWDERS AND TEST METHODS

OVERVIEW

The publication "Standards for Grades of Dry Milks, including Methods of Analysis" (ADPI, Bulletin 916-Revised) is available and covers the following topics in detail:

- Definitions of Dry Milk Products
- Approximate Composition and Food Value of Dry Milks
- General Grading Requirements
- Specific Grading Requirements
- Heat-treatment Classification for Nonfat Dry Milk
- Methods Reference
- Methods of Analysis
- Sampling – General
- Composition Sampling
- Specific Determinations
- Bacterial Estimate
  - Coliform Bacteria
  - Moisture
  - Milkfat
  - Solubility Index
  - Scorched Particles
  - Titratable Acidity
  - Dispersibility (instant nonfat dry milk)
  - Flavor and Odor
  - Total Ash and Alkalinity of Ash
  - Copper
  - Iron
  - Oxygen
  - Whey Protein Nitrogen in Nonfat Dry Milk

End users and manufacturers should refer to the ADPI Bulletin # 916 for detailed and updated information when needed. The following chapter provides an overview of characteristics, test methods and functionality of milk powder as a general reference.

U.S. industry standards for nonfat dry milk, dry whole milk, dry buttermilk and dry buttermilk product have been developed to promote the utilization of dry milks by making available a uniform grading system. These industry standards are published by the American Dairy Products Institute (ADPI), Elmhurst, IL, USA, and can be obtained directly from the Institute: www.adpi.org. According to ADPI, both manufacturers and purchasers express approval of the grading standards, because they deliver three major benefits: assure product uniformity, facilitate purchase and reduce risk for the buyer as the manufacturer of milk powders assumes the responsibility for delivering the grade of product offered.

5.1 GENERAL CHARACTERISTICS AND METHODS OF ANALYSIS

Chemical Properties

The chemical analysis of milk powder is mainly concerned with moisture, fat, total protein and non-protein nitrogen, lactose, ash and other nutrients such as calcium. For information on major nutrients, please refer to the nutrition chapter of this manual and typical composition sheets.

Milkfat Content

Various methods are available for measuring milkfat, including the Gerber test, which is typically used for routine quality control, and the Roese-Gottlieb test, which is the standard in most countries. Oftentimes, test results vary because not all tests measure free fatty acids or phospholipids. The presence of free fat is measured as it often results from the loss of emulsion stability in whole milk and fat-filled milks. Free fat at the surface of a powder particle may be subject to oxidation and may affect flowability and the wetting capacity of a powder.

Photo courtesy: Dairy Management Inc.

Moisture Content

Testing methods for moisture content include either a vacuum or mechanical convection oven, or the toluene distillation method. The objective of the test is to determine the volume of available or "free" moisture. Too high of a moisture content can contribute to unwanted microbiological growth or Maillard reaction browning. The toluene distillation method is very reproducible but also measures the water of crystallization. This "bound" water is not available for microbiological growth or Maillard reaction so it is not a factor in determining the quality of the powder.

Titratable Acidity

Titratable acidity is used as a measure of milk quality. It is composed of "apparent" and "developed" acidities. The test involves titrating a known quantity of reconstituted milk powder with a 0.1N NaOH solution and indicates the consumption of NaOH necessary to shift the pH value from that of fresh milk (about pH 6.6) to pH 8.2-8.4 (phenolphthalein end point). Fresh milk should have no significant amount of lactic acid present, since lactose should not have been decomposed by bacterial growth or severe heat treatment. However, various components of milk are acidic and contribute to the apparent acidity. Developed acidity is the portion of titratable acidity that develops as a result of undesirable bacterial production of lactic acid.

Physical and Functional Properties

Hygroscopicity

It is a measure of water absorption by a powder. It is often measured by passing air of a known humidity level (usually 80% at 20°C) over a powder until equilibrium is reached, then measuring the weight gain. Powders which absorb a lot of moisture may cake during storage, although there is no direct relationship between hygroscopicity and tendency to cake as other factors are involved as well.

Solubility Index

Solubility is an important feature of milk powders. Poorly soluble powders can cause processing difficulties and can result in economic losses as milk solids may be lost as insoluble material. Some of the factors which directly influence the insolubility of milk powders are: the presence of lactic acid in milk, the heat treatment of milk and the type of spray drying. The sediment produced when milk powders are reconstituted is measured in terms of an insolubility index. The traditional solubility test used worldwide actually measures insolubility. The test involves adding 10 g of skim milk powder or 13 g of whole milk powder to 100 ml of water at 25°C with high speed mixing for 90 seconds. The reconstituted milk is left for 15 min., then the amount of sediment at the bottom of the tube is measured in ml. and is termed solubility index.

Dispersibility

The ability of a powder to separate into individual particles when dispersed in water with gentle mixing is an important consideration in industrial settings where the formation of a sludge may demand greater energy input. Very dispersible powders typically exhibit good wettability and are agglomerated, with the absence of fine particles. Standard methods for determining dispersibility and wettability have been published by the International Dairy Federation. Techniques for measuring dispersibility are many and varied. All are subject to operator errors and are difficult to make reproducible between laboratories. They are, however, needed to determine how easily a powder goes into solution under normal home-mixing conditions.

Wettability

This defines the potential for a powder to wet and absorb water at a given temperature. In wetting, the voids within a powder are replaced by water. Composition, particle size and shape or the presence of surface free-fat, an inhibitory factor, affect the wettability of a powder. Wettability is also determined by the temperature of the water used so water temperature should always be specified in wettability tests. Milk powders which wet easily and quickly are often termed "instant" milk powders. Skim milk powder that is wetted in less than 15 seconds is termed "instant." There is no requirement for whole milk powder but it is advantageous that whole milk powder be wetted in about 30-60 seconds.

Flowability

This characteristic is a measure of the free-flow characteristic of a powder. Proper flow of milk powders is important for the manufacturer and end-users for proper packaging, handling and measuring. In general, powders with good flow properties are those with large agglomerates and few fines. However, due to the mechanics of powder flow properties, powders may exhibit different flowability when mixed.

Heat Stability

Milk powder used for recombined evaporated milk and other products have to have good heat stability, otherwise the protein precipitates during or shortly after sterilization. A high preheat treatment of the milk is needed to ensure, but is not a sufficient guarantee for, heat stability. The test for heat stability involves preparing the concentrated milk solution (8% fat, 18% milk solids nonfat), homogenizing, and determining if it can withstand over 3.5 minutes at desired temperature. Some countries allow the use of stabilizing salts such as mono- and disodium phosphate to the evaporated milk prior to canning and sterilization.

"Coffee Stability"

Coffee stability is a measure of a milk powder's resistance to protein instability and resistance to "feathering." Milk protein stability is affected by high temperature, low pH (as in coffee), water hardness (high levels of calcium, magnesium) and other factors. The denaturation of whey proteins affects the coffee stability of skim milk powder and there is some indication that powders with a Whey Protein Nitrogen Index (WPNI) equal or less than 3 mg/g undenatured whey protein exhibit the best coffee stability. Other factors such as milk protein composition, amino acid profile and overall protein level are also factors that influence stability. Coffee creamers are blends, typically stabilized with emulsifiers or sodium caseinates.

Whey Protein Nitrogen Index (WPNI)

WPNI is a method used for the determination of undenatured whey proteins in nonfat dry milk and was developed by the American Dairy Products Institute. It is also important in terms of functional properties and particularly in relation to the use of milk powders for the manufacture of some recombined milk products. The test measures the amount of soluble whey protein in skim milk powder. It gives an indication of the heat treatment that had been used on the milk prior to drying. The WPNI of a powder does affect the powder's functional properties and it is therefore commonly specified.

It is important to note that WPNI does not measure or necessarily indicate the heat stability of a powder, and therefore should not be used as an indicator of its suitability for recombined evaporated milk production. WPNI also does not measure or indicate the viscosity of a powder when used in recombined sweetened condensed milk. Separate tests are needed for these properties.

The WPNI range for medium heat powder is wide, and pre-heat treatment processes can be varied selectively to produce powders with different levels of undenatured whey protein within the range. The degree of denaturation required is a function of end-use. Medium heat milk powder is a multi-functional product, providing emulsification, water-binding, viscosity and flavor. Apart from its use in ice cream, confectionery and other manufactured food products, medium heat skim milk powder is a key ingredient in the manufacture of recombined sweetened condensed milk (RSCM).

Medium heat skim milk powder is typically chosen because the level of protein denaturation helps to control viscosity development in the final product. A pre-determined level of protein denaturation can be chosen which influences the initial viscosity and viscosity development throughout the shelf-life of the product. Recent studies have shown that the viscosity of RSCM is strongly affected by a powder's protein/lactose ratio. Hence, some low heat milk powder may be acceptable for RSCM manufacture. Manufacturers are encouraged to perform pilot tests with various powders to identify the most suitable product for their application.

The amounts of undenatured whey protein contained in one gram of powder is expressed in terms of a WPNI and three classes of powders are defined. The table shows the WPNI classification for skim milk powder and typical associated milk treatments.

Organoleptic Quality: Flavor

The organoleptic properties of milk powders are related to the qualities of the raw material, the chemical composition of the milk, the processing treatment received as well as other factors such as storage conditions. Generally, milk powders are expected to demonstrate a slightly sweet, clean flavor with no indication of rancidity or other off-flavor or odor. Some ends-users may prefer specific organoleptic profiles for particular applications. The use of a flavor lexicon, trained sensory panels and/or chemical tests may be useful to help define organoleptic properties of powders.

Heat Treatment Classification of Nonfat Dry Milk

This general classification is used for nonfat dry milk and the values and terms are defined in the USDA Standards for Grades of Nonfat Dry Milk.

Heat Treatment Classification of Nonfat Dry Milk

Classification	Typical Processing Treatment	Undenatured Whey Protein Nitrogen* (mg/g)	Recommended Applications
Low heat	Cumulative heat treatment of milk not more than 70°C for 2 minutes	Over 6.00	Fluid milk fortification, cheese milk standardization, cultured skim milk, starter culture, dairy drinks and recombined products, ice cream, yogurts
Medium heat	Cumulative heat treatment of 70–78°C for 20 minutes	1.51–5.99	Prepared mixes, ice cream, yogurts, confectionery, meat products, recombined milk products
High heat	Cumulative heat treatment of 88°C for 30 minutes	Under 1.50	Bakery, meat products, ice cream, prepared mixes

*Higher temperatures and/or extended holding times contribute directly to whey protein denaturation. This index is used as a measure of the cumulative heat effects during processing of skim powder.

The organoleptic assessment of milk powders remains very subjective as every powder may have a unique flavor profile. The assessment is directed more at identifying off-flavors. These can range from feed flavors present in the milk prior to drying, to flavor defects resulting from fat oxidation or lipolysis. Unfavorable heat treatment, moisture content and storage conditions can contribute to flavor problems. Organoleptic assessment is the easiest test to conduct and is one of the most critical tests for most users. Some volatile off-flavors from the milk powders can be detected without instruments. If the off-flavor is at a low concentration, the powder is reconstituted and tested at room temperature. It is important to let the reconstituted powder rehydrate properly, about 45-60 minutes, before tasting by a trained panel.

Scorched Particles

These occur as unsightly, discolored specks in milk powders. They are often the result of powder deposits in the spray drying system. With a low water activity and exposure to hot air, the milk powder deposits darken through the Maillard reaction and they can be perceived as sediment or dirt particles. On reconstitution, however, they typically dissolve and the powder defect most often disappears. Four procedures are in use for determination of scorched particles. Tests for spray dried and instant milk powders typically use the Water Disc method, while roller dried milk powders require the Sodium Citrate or Calgon (sodium hexametaphosphate), or the EDTA (ethylenediamine tetra-acetic acid) method. All four tests use a process that involves filtering a hydrated milk powder solution through a disc, and comparing the color of the mass on the dried disc with standard discs.

Microbiological Properties

Bacterial Estimate/ Standard Plate Count

The bacterial estimate is the estimated number of colonies that would have developed per gram of sample under specified conditions if the entire amount of sample had been examined. The most common method of analysis is bacterial growth on an agar plate, combined with colony counting.

Pyruvate

Pyruvate is found in milk as a metabolic product of bacteria. Presence of more than normal amounts of pyruvate in milk or milk products is an indication that high numbers of bacteria have grown in milk. While the bacteria themselves are largely destroyed by pasteurization, the heat-stable enzymes they produce are unaffected by heat treatment. Direct detection of low levels of enzymes is not easy, so the pyruvate test is useful, especially if vegetable oils are being used (lipolysis is strongly accelerated by the presence of lipolytic enzymes and coconut oil has a high amount of potential lauric acid). If test results yield low levels of pyruvate then neither bacteria nor heat-stable enzymes are usually present and active.

References for Methods of Analysis

American Dairy Products Institute. Standards for Grades of Dry Milks, including Method of Analysis. Bulletin 916 (Revised).
*The bulletin can be ordered from the American Dairy Products Institute. www.adpi.org

American Public Health Association (1985). Standard methods for the examination of dairy products. 15th edition. American Public Health Association.

Association of Official Analytical Chemists (1990). Official methods of analysis.

Association of Official Analytical Chemists. 15th edition.

6.1 NONFAT DRY MILK, SKIM MILK POWDER

Whereas the terms nonfat dry milk and skimmed milk powder are used interchangeably in this manual and oftentimes by the trade, the terms are actually defined by two different sets of regulations and authorities (FDA/USDA and Codex Alimentarius). In addition, regulations of individual governments may differ. Please consult local regulations for all pertinent information when purchasing milk powders and for labeling purposes.

Production Definition

Nonfat dry milk (as defined by FDA/CFR) is obtained by removing water from pasteurized skim milk. It contains 5% or less moisture (by weight) and 1.5% or less milkfat (by weight). By removing moisture to the greatest extent possible, microbial growth is prevented. Nonfat dry milk is classified for use as an ingredient according to the heat treatment used in its manufacture. There are three main classifications: high heat (least soluble), medium heat, and low heat (most soluble).

Extra grade nonfat dry milk powders are available in roller dried and spray dried form, the latter being the most common. Nonfat dry milk powders are available in two forms: ordinary or non-agglomerated (non-instant) and agglomerated (instant).

The Codex Alimentarius, in its standard 207-1999, describes milk powders and cream powder as milk products which can be obtained by the partial removal of water from milk or cream. The fat and/or protein content of the milk or cream may have been adjusted to comply with the compositional requirements of the standard, but the addition and/or withdrawal of milk constituents in such a way as not to alter the whey protein to casein ratio of the milk being adjusted. Milk retentate, milk permeate and lactose are allowed for protein adjustment purposes. The Codex Alimentarius standard sets compositional criteria for skimmed milk powder which are: maximum milk fat: 1.5% m/m, maximum water: 5% m/m, and minimum protein in milk solids non fat: 34% m/m. The standard also makes provision for the use of additives: stabilizers (sodium and potassium citrates, no more than 5 g/kg), firming agents (potassium chloride and calcium chloride, limited by GMP), acidity regulators (5g/kg), emulsifiers, anti-caking agents and antioxidants. Milk powders should also comply with the maximum limits established by the Codex Alimentarius Commission. In its Annex, the standard references additional quality factors and methods of analysis recommended by the International Dairy Federation.

Typical Composition

Protein	34.0–37.0%
Lactose	49.5–52.0%
Fat	0.6–1.25%
Ash	8.2–8.6%
Moisture	
(non-instant)	3.0–4.0%
(instant)	3.5–4.5%

Physical and Chemical Aspects

Typical Microbiological Analysis	
Standard Plate Count	<10,000 cfu/g*
Coliform	10/g (maximum)
E. coli	Negative
Salmonella	Negative
Listeria	Negative
Coagulase-positive *Staphylococci*	Negative
Other Characteristics	
Scorched particle content	
(spray dried)	7.5–15.0 mg
(roller dried)	22.5 mg
Titratable acidity	0.14–0.15%
Solubility index	
(instant)	1.0 ml
(spray dried, low heat)	1.2 ml
(high heat)	2.0 ml
(roller dried)	15.0 ml
Color	White to light cream color
Flavor	Clean, pleasing dairy flavor

*Extra grade

Nonfat Dry Milk—Typical Nutritional Composition (continued on page 34)

Nutrient	Per 100g Nonfat Dry Milk, with Added Vitamin A	Per 100g Nonfat Dry Milk, Instant
Water	3.16	3.96
Energy	362 Kcal, 1516 KJ	358 Kcal, 1498 KJ
Protein	36.16g	35.10g
Lipid	0.77g	0.72g
Carbohydrate (by difference)	51.98g	52.19g
Fiber, total dietary	0.0g	0.0g
Ash	7.93g	8.03g
Minerals		
Calcium	1257mg	1231mg
Iron	0.32mg	0.31mg
Magnesium	110mg	117mg
Phosphorus	968mg	985mg
Potassium	1794mg	1705mg
Sodium	535mg	549mg
Zinc	4.08mg	4.41mg
Copper	0.041mg	0.041mg
Manganese	0.020mg	0.020mg
Selenium	27.3µg	27.3µg
Vitamins		
Ascorbic acid	6.8mg	5.6mg
Thiamin	0.415mg	0.41mg
Riboflavin	1.550mg	1.74mg
Niacin	0.951mg	0.89mg
Pantothenic acid	3.568mg	3.23mg
Vitamin B_6	0.361mg	0.34mg
Folate	50µg	50µg
Vitamin B_{12}	4.03µg	3.99µg
Vitamin A, IU	2179	4
Vitamin A, RE	653µg	4µg
Vitamin E, apha-tocopherol	0.00mg	0.019mg
Lipids		
Saturated, total	0.49g	0.47g
Monounsaturated, total	0.20g	0.19g
Polyunsaturated, total	0.03g	0.03g
Cholesterol	20mg	18mg

Source: United States Department of Agriculture, Nutrient Composition Database

Nonfat Dry Milk—Typical Nutritional Composition (continued)

Nutrient	Per 100g Nonfat Dry Milk, with Added Vitamin A	Per 100g Nonfat Dry Milk, Instant
Amino acids		
Tryptophan	0.51g	0.49g
Threonine	1.63g	1.58g
Isoleucine	2.18g	2.21g
Leucine	3.54g	3.43g
Lysine	2.86g	2.78g
Methionine	0.99g	0.88g
Cystine	0.33g	0.32g
Phenylalanine	1.74g	1.69g
Tyrosine	1.74g	1.69g
Valine	2.42g	2.34g
Arginine	1.30g	1.27g
Histidine	0.98g	0.95g
Alanine	1.24g	1.21g
Aspartic acid	2.74g	2.66g
Glutamic acid	7.57g	7.35g
Glycine	0.76g	0.74g
Proline	3.50g	3.40g
Serine	1.96g	1.90g

Source: United States Department of Agriculture, Nutrient Composition Database

Packaging

Stitched or glued, multiwall kraft bag with polyethylene inner liner. No staples or metal fasteners.

- Net weight: 25.0kg
- Gross weight: 25.2–25.45kg

Also available in plastic-lined corrugated paperboard or aluminum tote bins.

Storage

Ship and store in a cool, dry environment at temperatures less than 27°C and relative humidity less than 65%. The shelf life of non-instant skim milk powder is 12–18 months, instant is 6–12 months. Note that storage life is very dependent on storage conditions and this figure is only a guide. Under ideal conditions, non-instant skim milk powder can retain its physical and functional properties for at least two years; however, quality will be impaired if temperatures and humidity are too high and storage is extended.

Typical Applications

Typical applications for bakery, confectionery, dairy, meat products and prepared mixes are used as:

- An economical source of nonfat dairy solids.
- A source of high heat dairy solids, important for good loaf volume in breads.
- A source of low heat dairy solids, important for optimizing sensory properties in dairy foods and beverages.
- An easily and readily transported and stored dairy ingredient.

Recommended Uses as a Function of Heat Treatment

Low heat	Fluid milk fortification Cottage cheese Yogurt and cultured milk Ice cream and frozen desserts Chocolate and flavored milk beverages Dairy products
Medium heat	Ice creams Confections Meat products Dry mixes
High heat	Baked goods Meat products Dry mixes Ice creams

Selecting Heat Treatment for Recombined Milk Products

The whey protein nitrogen index (WPNI) indicates the degree of heat denaturation of the whey proteins and is an indication of the heat treatment applied to the milk prior to drying. It is defined as the amount, in mg, of undenatured whey protein nitrogen remaining in 1 g of the skim milk powder. To be classified as low heat, a powder should have a WPNI of not less than 6 mg/g. A high heat powder will have a WPNI of less than 1.5 mg/g. The WPNI of a medium heat powder will be in the 1.5–6 mg/g range.

The heat classification is not applied to whole milk powder, for which the preheat treatment is applied to develop antioxidants that will preserve the flavor of the milk.

The typical heat treatment classification is a useful tool for processors. For bakery applications, the use of high heat powder is important, while for the manufacture of semi-hard and hard cheeses, a low heat treatment is critical. Yet, other important factors can influence the viscosity and characteristics of other recombined products such as sweetened condensed milks. One of these factors is the actual protein content, or protein/lactose ratio of the powder used. Higher protein content in the powder can significantly increase the viscosity of sweetened condensed milks, for example. In addition, the total amount of undenatured protein (a function of both total protein content and heat treatment) needs to be considered. Processors may be able to adjust their formulation (modifying the protein/lactose ratio) to obtain the desired final viscosity, rather than relying only on the heat treatment classification. For condensed milk products, consumers prefer specific viscosity ranges, which vary by country depending upon the final use of the products. Industrial users can also specify viscosity ranges when the condensed product is an ingredient for further processing. Process variables and product formulations can be adapted to allow the end-users to utilize a variety of milk powders. Suppliers can provide guidance, and pilot tests are generally recommended.

Application	Type of Milk Powder	Benefit
Pasteurized recombined milk	Low heat or medium heat High heat powder	Will yield the freshest flavor. When a “cooked” flavor is desirable.
Extended shelf life milk (ESL)	Low heat or medium heat High heat powder	Will yield the freshest flavor. When a “cooked” flavor is desirable.
UHT milk	Low heat or medium heat	To preserve flavor and prevent fouling in the plant.
Retort sterilized milk	Any heat classification Low heat or medium heat preferred	
Recombined evaporated milk	Low heat or medium heat	Recommended for continuous flow processes.
Recombined sweetened condensed milk	Medium heat or low heat	Viscosity of the final product is related to the heat treatment (increases with heat treatment applied) but other factors can strongly influence this general rule (protein content, minerals, etc.). Consult supplier for advice.
Blended products (containing whey, vegetable fat)	Low heat to medium heat	Viscosity is controlled with hydrocolloids, mineral control, and other means.
Cultured milks	Low heat, medium heat or high heat	Heat treatment of the yogurt milk before fermentation may be reduced when using high heat milk powder.
Fresh cheeses	Low heat, medium heat or high heat	Adjust process as a function of milk powder selected.
Other cheeses	Low heat milk powder	Milk standardization and cheese milk extension is the most common manufacture practice.

6.2 DRY WHOLE MILK, WHOLE MILK POWDER

Whereas the terms dry whole milk and whole milk powder are used interchangeably in this manual and oftentimes by the trade, the terms are actually defined by two different sets of regulations and authorities (FDA/USDA and Codex Alimentarius). In addition, regulations of individual governments may differ. Please consult local regulations for all pertinent information when purchasing milk powders and for labeling purposes.

Product Definition

Dry whole milk is usually obtained by removing water from pasteurized, homogenized whole milk. It may also be obtained by blending fluid, condensed or skim milk powder with liquid or dry cream or with fluid, condensed or dry milk, provided the composition of the whole milk powder conforms to U.S. Federal Standards. Dry whole milk conforms to U.S. Federal Standards. Dry whole milk must contain between 26% and 40% milkfat (by weight) on an "as is" basis and not more than 5.0% moisture (by weight or a milk-solids-not-fat (MSNF) basis. By removing moisture to the greatest extent possible, microbial growth is prevented.

Extra grade dry whole milk powders are available in roller dried and spray dried form, the latter being the most common. Vitamin and mineral fortification is also an option.

The Codex Alimentarius, in its standard 207-1999, describes milk powders and cream powder, as milk products which can be obtained by the partial removal of water from milk or cream. The fat and/or protein content of the milk or cream may have been adjusted to comply with the compositional requirements of the standard, but the addition and/or withdrawal of milk constituents in such as way as not to alter the whey protein to casein ratio of the milk being adjusted. Milk retentate, milk permeate and lactose are allowed for protein adjustment purposes.

Packaging

Stitched or glued, multiwall kraft bag with polyethylene inner liner. No staples or metal fasteners.

- Net weight: 25.0 kg
- Gross weight: 25.2–25.45 kg

Also available in plastic-lined corrugated paperboard or aluminum tote bins.

Storage

Ship and store in a cool, dry environment at temperatures less than 27°C and relative humidity less than 65%. Use within 6–9 months. Note that storage life is very dependent on storage conditions and this figure is only a guide. Milkfat is susceptible to oxidative reactions that are accelerated by increased temperature. Flavor quality, in particular, is impaired if temperatures are too high and storage is extended.

Typical Applications

Typical applications for bakery, confectionery, dairy, prepared mixes, sauces and soups are used as:

- An economical source of dairy solids, including milkfat.
- A convenient form of nutritious milk that doesn't require refrigeration, easily reconstituted.
- An easily and readily transported and stored dairy ingredient.

Typical Composition

Protein	24.5–27.0%
Lactose	36.0–38.5%
Fat	26.6–40.0%
Ash	5.5–6.5%
Moisture	2.0–4.5%

Physical and Chemical Aspects

Typical Microbiological Analysis	
Standard Plate Count	<10,000 cfu/g*
Coliform	10/g (maximum)
E. coli	Negative
Salmonella	Negative
Listeria	Negative
Coagulase-positive *Staphylococci*	Negative
Other Characteristics	
Scorched particle content (spray dried)	7.5–15.0 mg
(roller dried)	22.5 mg
Titratable acidity	0.15% (maximum)
Solubility index (spray dried)	1.0 ml
(roller dried)	15.0 ml
Color	White to light cream color
Flavor	Clean, pleasing dairy flavor

*Extra grade

U.S. Uses of Dry Whole Milk

Confectionery	78.1%
Dairy	8.0%
Dry mixes and blends	6.5%
Bakery	4.8%
Retail/home use	0.7%
Institutional	0.2%
Meat industry	0.2%
Soups	0.4%
Animal feed	1.1%

Source: Industry sources and ADPI, 2000

6.3 DRY BUTTERMILK

Product Definition

Dry buttermilk is obtained by removing water from liquid buttermilk that was obtained from the churning of cream into butter and pasteurized prior to condensing. It contains 5% or less moisture (by weight) and 4.5% or more milkfat (by weight). Dry buttermilk must have a protein content of not less than 30%. It may not contain, or be derived from, skim milk powder, dry whey or products other than buttermilk, and contains no added preservatives, neutralizing agent or other chemicals. By removing moisture to the greatest extent possible, microbial growth is prevented.

Extra grade dry buttermilks are available in roller dried and spray dried form.

Packaging

Stitched or glued, multiwall kraft bag with polyethylene inner liner. No staples or metal fasteners.

- Net weight: 25.0 kg
- Gross weight: 25.2–25.45 kg

Also available in plastic-lined corrugated paperboard or aluminum tote bins.

Storage

Ship and store in a cool, dry environment at temperatures less than 27°C and relative humidity less than 65%. Use within 6–9 months. Note that storage life is very dependent on storage conditions and this figure is only a guide. Buttermilk contains milkfat—and a high proportion of phospholipids. Flavor quality will be impaired if the product is stored at too high a temperature for too long.

Typical Composition

Protein	≥30.0–33.0%
Lactose	36.5–49.0%
Fat	4.5–7.0%
Ash	8.3–8.8%
Moisture	3.0–4.0%

Physical and Chemical Aspects

Typical Microbiological Analysis	
Standard Plate Count	<20,000 cfu/g*
Coliform	10/g (maximum)
E. coli	Negative
Salmonella	Negative
Listeria	Negative
Coagulase-positive *Staphylococci*	Negative
Other Characteristics	
Scorched particle content (spray dried)	7.5–15.0 mg
Scorched particle content (roller dried)	22.5 mg
Titratable acidity	0.10–0.18%
Solubility index (spray dried)	1.25 ml
Solubility index (roller dried)	15.0 ml
Color	Uniform cream to dark color
Flavor	Clean, pleasing sweet dairy flavor

*Extra grade

Typical Applications

Typical applications for bakery, confectionery, dairy, sauces and soups are used as:

- An economical source of dairy solids, including milkfat.
- A convenient form of buttermilk that doesn't require refrigeration, easily reconstituted.
- An easily and readily transported and stored dairy ingredient.

Major U.S. Uses of Buttermilk Solids

Frozen desserts, ice cream mixes	71%
Wet blends for dairy	28%
Confectionery industry	1%

Source: Industry sources and "Dry Milk Products, Utilization and Production Trends," ADPI, 2003.

Milk is a highly nutritious food composed of essential amino acids, calcium, and a variety of vitamins and minerals. Nutrient loss during heat processing and spray drying are typically minimal; however, nutrient levels do vary by milk source and season. The adjacent chart shows average nutrient values for skim milk powder, whole milk powder and buttermilk powder. See previous specification pages for composition ranges.

Comparative Typical Composition of Dry Milks*

	Nonfat Dry Milk	Dry Whole Milk	Dry Buttermilk
Protein (%)	36.00	26.50	34.00
Lactose (%)	51.00	38.00	48.00
Fat (%)	0.70	26.75	5.00
Moisture (%)	3.00	2.25	3.00
Total Minerals (%*)	8.20	6.00	7.90
Calcium (%)	1.31	0.97	1.30
Phosphorus (%)	1.02	0.75	1.00
Vitamin A (I.U./100 g)	36.40	1,091.30	507.10
Thiamin/Vitamin B_1 (mg/100 g)	0.35	0.26	0.26
Ribofalvin/Vitamin B_2 (mg/100 g)	2.03	1.48	3.09
Niacin/Vitamin B_3 (mg/100 g)	0.93	0.68	0.99
Niacin Equivalents (mg/100 g)	9.30	6.75	8.95
Pantothenic Acid (mg/100 g)	3.31	2.87	3.09
Pyridoxine/Vitamin B_6 (mg/100 g)	0.44	0.33	0.44
Biotin (mg/100 g)	0.04	0.04	0.04
Ascorbic Acid/Vitamin C (mg/100 g)	2.00	2.20	5.00
Choline (mg/100 g)	111.20	88.18	110.20
Energy (calories/100 g)	359.40	498.20	379.80

Source: American Dairy Products Institute.

*Please consult your supplier for detailed information to be used for nutritional labeling purposes. Compositional ranges should be used for specification purposes as the product composition may vary.

Typical Composition of Skim and Whole Milk Powders, Physical and Chemical Aspects

Nutrients/Typical Composition	Skim Milk Powder (Nonfat Dry Milk)	Whole Milk Powder (Dry Whole Milk)
Protein,[1] including essential amino acids:[2]	34.00–37.00%	24.50–27.00%
• Isoleucine	2.19%	1.59%
• Leucine	3.54%	2.58%
• Valine	2.42%	1.76%
• Methionine	0.91%	0.66%
• Phenylalanine	1.75%	1.27%
• Threonine	1.63%	1.19%
• Tryptophan	0.51%	0.37%
• Lysine	2.87%	2.09%
• Histidine	0.98%	0.71%
Lactose[1]	49.50–52.00%	36.00–38.50%
Lipids[1]	0.60–1.25%	26.00–40.00%
Ash,[1] Including minerals[2] (in mg/100 g of milk powder):	8.20–8.60%	5.50–6.50%
• Calcium	1,257.00	912.00
• Iron	0.32	0.47
• Magnesium	110.00	85.00
• Phosphorus	968.00	776.00
• Potassium	1,794.00	1,330.00
• Sodium	535.00	371.00
• Zinc	4.08	3.34
Moisture[1] (regular) (instant)	3.00–4.00% 3.50-4.50%	2.00–4.50%
Typical Microbiological Analysis		
Standard Plate Count	<10,000 cfu/g[3]	<10,000 cfu/g[3]
Coliform (max)	10/g	10/g
E.coli, *salmonella*, *listeria*, coagulase-positive *staphylococci*	Negative	Negative

[1]Typical composition and range, commercial products. Source: USDEC Milk Powder Manual V.II.
[2]Typical content as reported by USDA.
[3]Extra grade

7.1 DAIRY PROTEINS

An Overview of Protein Composition

Cow's milk powder is recognized as an excellent source of high quality protein. Protein accounts for about 38% of the total solids-not-fat content of milk. As shown on the table, cow's milk protein is a heterogeneous mixture of proteins.

Milk powder also contains small amounts of various enzymes. Of the total milk protein, about 80% is casein and 20% is whey protein. Whey protein consists primarily of β-lactoglobulin and α-lactalbumin. α-lactalbumin has a high content of the amino acid tryptophan, a precursor of niacin. Because of milk's tryptophan content, this food is an excellent source of niacin equivalent. Other whey proteins present are serum albumin, immunoglobulin, lactoferrin and transferrin.

Protein Composition and Characteristics of Cow's Milk

Protein and Protein Fraction	Approximate % of Skim Milk Protein	Isoelectric Point	Molecular Weight
Casein	**79.5**	**~4.6**	
α-s_1 Casein	30.6	4.96	24,000–27,000
α-s_2 Casein	8.0	5.27	25,000
β-Casein	28.4	5.20	24,000
κ-Casein	10.1	5.54	19,000
Casein fraction	2.4		21,000
Whey Protein (non-casein)	**20.3**		
β-lactoglobulin	9.8	5.2	36,000
α-lactalbumin	3.7	4.2–4.5	14,000
Blood serum albumin	1.2	4.7–4.9	66,000
Immunoglobulins	2.1	5.5–6.8	150,000–1,000,000
Miscellaneous (including proteose peptone)	2.4	3.3–3.7	4,100–40,000

Nutritive Value of Key Proteins

Protein Source	BV	PER	NPU
Whey protein concentrate	104	3.2	92
Whole egg	100	3.8	94
Cow's milk	91	3.1	82
Beef	80	2.9	73
Casein	77	2.7	76
Soy protein	61	2.1–2.2	61

BV: Biological value, PER: Protein efficiency ratio, NPU: Net protein utilization.
Sources: FAO, USDA, National Dairy Council.

Note: The tables in this text are presented to help compare dairy proteins with other proteins. Detailed information on protein needs and quality evaluation methods is available from the Food and Agriculture Organization (www.fao.org) and the United Nations University (www.unu.edu/unupress/).

Biological Value

Biological Value (BV) is a measurement of protein quality expressing the rate of efficiency with which protein is used for growth. Egg protein is often the standard by which all other proteins are judged. Based on the essential amino acids it provides, egg protein is second only to mother's milk for human nutrition.

The Biological Value (BV) is a scale of measurement used to determine what percentage of a given nutrient source is utilized by the body. The scale is most frequently applied to protein sources, particularly whey protein. Biological Value is derived from providing a measure intake of protein, then determining the nitrogen uptake versus nitrogen excretion. The theoretical highest BV of any food source is 100%. In short—BV refers to how well and how quickly your body can actually use the protein you consume.

Protein Efficiency Ratio

A protein of high quality is one that supplies all essential amino acids in quantities adequate to meet the individuals need for growth.

Federal regulations have stipulated that the protein efficiency ratio (PER) using a rat growth assay, utilizing casein as a reference protein (AOAC 1975), be used as a means of evaluating protein quality (Food and Drug Administration, 1986). A number of other countries have similar regulations. The standard protein casein has a PER of 2.7 (FAO, USDA, National Dairy Council). Any protein with a PER greater than 2.7 is regarded as an excellent quality protein (see table on page 42 for a comparison of PER values).

The PER method has been criticized for its lack of precision, reproducibility and appropriateness for measuring protein quality (McLaughlan et al, 1980, Bender, 1982, Sarwar et al 1989). In 1993, the FDA replaced the PER with the Protein Digestibility-Corrected Amino Acid Scoring, or PDCAAS, method (Hopkins, 1982, Fomon, 1993). It combines a measure of protein digestibility with an amino acid score based on a comparison with a natural or hypothetic reference protein (Young and Pellett, 1991). If the PDCAAS score if greater than or equal to 1.00, the protein is a good source of essential amino acids.

Several amino acid scoring systems have been developed to compare the concentration of a limiting essential amino acid in a protein of interest, to the concentration of those amino acids in a reference protein (Fomon 1993). There are differences in protein digestibility based on the protein's configuration, amino acid bonding, presence of interfering components of the diet (e.g. fiber, tannins, phytate), presence of antiphysiologic factors or adverse effects of processing (Fomon 1993). It should be noted that protein quality may be changed without modifying a specific amino acid. This may occur as a result of processing for example. In processing soy protein, moist heat inactivates the trypsin inhibitors that otherwise interfere with digestion, thus protein quality is improved without changing the protein score. Conversely the processing may negatively affect the availability of lysine as a result of Maillard reactions (Fomon 1993).

Net Protein Utilization

Net Protein Utilization (NPU) is another biological measure of protein quality that is often used, which includes an evaluation of protein digestibility as well as the content of essential amino acids.

Protein Digestibility Corrected Amino Acid Score (PDCAAS)

Although PDCAAS scoring is considered an appropriate test of protein quality, it too has its limitations (Darragh, 1999). There is considerable debate regarding the adequacy of the reference proteins, the truncation of the PDCAAS, the accuracy of scoring amino acid availability and the impact of the anti-nutritional factors (e.g. heat treatment) on the PDCAAS score.

Calculating PDCAAS requires an approximate nitrogen composition, the essential amino acid profile and the true digestibility score. Whey proteins have a higher score than virtually all other protein sources.

PDCAAs of Key Protein Sources

Ingredient	PDCAAS
Milk*	1.23
Whey protein*	1.15
Egg white	1.00
Soybean protein	.94
Whole wheat-pea flour (**)	.82
Chick peas (garbanzos)	.69
Kidney beans	.68
Peas	.67
Sausage, pork	.63
Pinto beans	.61
Rolled oats	.57
Black beans	.53
Lentils	.52
Peanut meal	.52
Whole wheat	.40
Wheat protein (gluten)	.25

Source: FAO, except for * European Dairy Association/ U.S. National Dairy Council (from INRA, France. Unpublished data).
**An example of mutual supplementation. Combining whole wheat and pea flours yields a protein with a higher PDCAAS than that of either product alone.

Health Benefits of Milk Proteins—An Overview

Individual milk proteins have been shown to exhibit a wide range of beneficial functions including enhancing calcium absorption and immune function. The antimicrobial mechanisms of whey proteins such as immunoglobulins, lactoferrin, lactoperoxidase, lysozyme and glycomacropeptide are now well documented (see table on page 44). Immunoglobulins from milk and whey have a prophylactic and therapeutic effect (clinically established in human adults) against specific micro-organisms causing diarrhea, gastritis and dysenteria. In addition to containing minerals that enhance bone growth, whey protein was recently reported to contain an active fraction that stimulated the proliferation and differentiation of cultured osteoblasts (bone-forming cells) (reviewed by Miller 2000).

Mature cow's milk contains an average 32 g of protein per liter, mostly casein (26 g/l) and whey (6 g/l) (Whitney et al. 1976; Jenness, 1979; Davies, Law, 1980; Stewart et al., 1987; Leonil et al., 2001). The caseins have been divided into four subclasses, α-s_1 casein, α-s_2 casein, β-casein, κ-casein αs_1. Bovine whey protein is constituted by numerous soluble proteins including β-lactoglobulin (3 g/l), α-lactalbumin (1 g/l), Bovine serum albumin (0.4 g/l), lactoferrin (0.1 g/l) immunoglobulins (<2 g/l), lysozyme (0.1 g/l) and other quantitatively minor fractions (i.e. lactoperoxidase, lipase, other enzymes and proteose peptone fractions).

The nutritional quality of a protein can be expressed in various ways. Protein Efficiency Ratio (PER), Protein Digestibility (PD), Biological Value (BV), Net Protein Utilization (NPU) and Protein Digestibility Corrected Amino Acid Score (PDCAAS) are frequently used to indicate the potency of a food protein as a source of amino acids. By all measures, whey proteins offer excellent protein quality.

Physiological Effects of Various Protein Fractions Found in Whey Protein

Protein Fraction	Biological Role or Function
β-lactoglobulin	β-lactoglobulin comprises about 50% of whey protein content. Although the specific biological role of β-lactoglobulin is not known, β-lactoglobulin binds to minerals (e.g., zinc, calcium, etc), fat soluble vitamins (e.g., Vitamin A & E), and lipids and is therefore important for a number of physiological processes [Horton, 1995, Nakajima et al., 1997]. Contains a high concentration of BCAA.
α-lactalbumin	α-lactalbumin comprises about 25% of whey protein and has been reported to have anticancer [Svensson, 1999], antimicrobial effects [Horton, 1995, Pellegrini, 2003], and immuno-enhancing properties [Horton, 1995, Montagne et al. 1999]. Research has also suggested that α-lactalbumin increased serotonin production in the brain, improved mood, and decreased cortisol levels [Markus, 2000].
Peptides	Whey derived peptides are believed to reduce cholesterol [Poullain et al., 1989], blood pressure [Korhonen, 2003, Shah, 2000, Abubakur et al., 1998], and protect against some forms of cancer [Tsai, 2000, Bounous, 2000].
Albumin	About 5% of whey protein consists of bovine serum albumin (BSA). BSA is believed to have antioxidant [Tong et al., 2000] and antimutagenic properties [Bosselaers et al., 1994]. Binds free fatty acids avidly; chelates pro-oxidant transition metals.
Immunoglobulins	Immunoglobulins (e.g., IgA, IgM, IgE, and IgG) support passive immune function. Although most of this research has been conducted on infants, research is now examining whether older adults may also benefit from increasing dietary intake of bovine immunoglobulins.
Lactoferrin	Lactoferrin is a protein that binds to iron and therefore has a number of potential applications [Layman, 2003]. Additionally, lactoferrin is believed to have anticancer [Tsuda, 2000, Tsuda, 2002], antimicrobial [Clare et al., 2003, Valenti et al., 1999, Cavestro et. al., 2002, Caccavo et al., 2002], antiviral [Florisa et al., 2003], antibacterial [Clare et al., 2003, Cavestro et al., 2002, Caccavo et al., 2002], and antioxidant properties [Wong et. al., 1997]. Anti-inflammatory and immune modulation.
Lactoperoxidase	Lactoperoxidase is an enzyme that breaks down hydrogen peroxide and has antibacterial properties. Lactoperoxidase has been used as a preservative and in toothpaste to fight cavities. Lactoperoxidase has also been reported to have antioxidant and immuno-enhancing properties [Wong et al., 1997].

Cow's milk protein (CMP) constitutes an important part of the protein in diets for young and adult humans, and such proteins are considered to have a high nutritional quality. The nutritional value of dietary proteins is usually related to their ability to achieve nitrogen (N) and amino acid requirements for tissue growth and maintenance (Bos et al., 2000, Tomé, 2002, Tomé et al., 2002). This ability depends both on the protein content in essential amino acids and on the digestibility of the protein and subsequent metabolism of the absorbed amino acids. Caseins are well known for their good nutritive value and excellent functional properties for food formulation (Friedman, 1996). The interest in whey proteins is newer than for caseins, but whey proteins are used increasingly for nutritional purposes because they consistently score high in traditional tests of protein quality and are of particular interest as a high quality source of rapidly available essential amino acids (Bouthegourd et al., 2002, Ha, Lien, 2003).

Milk Proteins and Infant Nutrition

While breastfeeding and human milk is the preferred source of nutrition for infants, there exist instances when the use of infant formula is needed. Milk powders are not an adequate source of nutrition for infants, and simple milk powder-based formula is not to be fed to infants. Formula specifically designed to meet the nutritional needs of infants, with medical supervision and prepared in hygienic conditions are the only adequate source of nutrition when breastfeeding is not possible and human milk not available as an alternative.

Protein sources in the diets of normal children are human milk, cow milk and soy protein. Infant formula manufacturers are increasingly adding whey proteins to cow milk based formulas to match the high concentration of whey proteins as found in human milk (see table page 45), and to formulas for infants with special needs including fussiness, colic and protein hypersensitivity (Halken 1993; Odelram, 1996, Ragno, 1993). In a double blinded clinical study, it was shown that an extensively hydrolyzed whey protein formula is effective in reducing the duration of crying (Lucassen, 2000). Traditionally, formulas made with extensively hydrolyzed casein were used to manage infants and children with severe cow milk allergies. In the 1990s, hydrolyzed whey protein formulas were found to be highly effective in managing infants with cow milk allergies and there was a significant cost, taste and odor advantage of these formulations over their casein counterparts.

Protein Composition of Human Milk and Cow Milk

	Human Milk (g/dL)		Cow Milk (g/dL)	
Total proteins	0.89		3.30	
Caseins	0.25		2.60	
Whey proteins	0.70		0.67	
α-Lactalbumin	0.26	(37)	0.19	(18)
β-lactoglobulin	–		0.30	(45)
Serum albumin	0.05	(7)	0.03	(4)
Lactoferrin	0.17	(24)	trace	
Other	0.07	(10)	0.15	(23)
Immunoglobulins	0.105	(15)	0.066	(10)
Lysozyme	0.05	(7)	trace	
Total non-protein nitrogen	0.50		0.28	

Data from Hambaeus L: Human milk composition, Nutr Abstr Rev, rev Clin Nutr 54:219-236, 1984.
*Values in parentheses are percentages of whey proteins.

Human milk is widely considered the ideal feeding for newborn infants (AAPCN, 1980). Since cow milk based formulas are relied upon to provide optimal nutritional support to infants whose mothers have chosen not to breast-feed, infant formula manufacturers goal is to minimize the compositional differences between human milk and cow milk.

One of the primary compositional differences between human milk and cow milk based formula is the relative differences in concentration of whey proteins (see table above). An approach to reducing these differences in whey proteins has been for manufacturers to increase the concentration of α-lactalbumin and lactoferrin in cow's milk using fractionation technology (Heine, 1996). However, this approach is too costly and not feasible for most infant formula markets. Another approach is to match the plasma amino acid profile of breastfed infants as closely as possible. A mathematical model was developed to yield a value that summarizes the closeness of the feeding to the plasma essential amino acid profile of the breastfed infant (Paule, 1996). A formula with a whey to casein ratio of 48:52 yielded a plasma amino acid profile closer to that of human milk than either formula with 60:40 or a formula with 100% whey protein.

Manufacturers have focused on the amino acid requirements of infants primarily because their requirements are higher during infancy than any other stage in life as reflected in their rapid rate of growth and development. Amino acids have functions beyond serving as a substrate for protein synthesis or as an energy source. They are also involved in the synthesis of hormones, host defenses, bile acids and neurotransmitters. Plasma amino acids even affect behavior. Increasing the plasma tryptophan concentration by supplementing infants with increased tryptophan in their feeding will elevate the conversion of tryptophan to serotonin and melatonin in the brain, leading to changes in sleep behavior (Steinberg 1992). Plasma tryptophan is just one example of the importance of amino acid balance in infants.

Cow's Milk Protein Allergy (CMPA)

A food allergy is an adverse reaction to a food mediated by a dietary antigen. The prevalence of food allergies changes with age (Madsen, 1997, Crespo, Rogdriguez, 2003, Tome, 2003) and is highly variable depending on geography. Allergy to cow's milk, eggs and fish begin primarily before age 2 while allergy to fruit, legumes or vegetables occurs mainly after the 2nd year of life (Crespo et al., 1995). The incidence of cow milk protein allergy is approximately 2–3 % in infants and by age 3 many have outgrown their allergy to cow milk protein (reviewed by Tome, 2003, Host and Halken, 1990, Hattevig et al., 1993). The incidence of CMPA in infants who are breast-fed ranges from 0.5– 1.5% (Host et al., 1988, Saarinen et al 1999). However, the incidence of CMPA rises to 20% in infants with elevated risk for allergy (Host 1995, 1990). Even children with atopic dermatitis outgrow their food allergies (Sampson, 1985, Isolauri et al., 1992, Isolauri & Turjanmaa, 1996). Infants with CMPA exhibit various symptoms ranging from loose stools, chronic diarrhea or dermatitis seen in 50-60% of cases to respiratory symptoms (wheezing, sneezing) noted in about 30% of cases (reviewed by Tome, 2003). Cow milk allergy in adults is rare but persists longer. Only 28% of cow milk allergic adults were symptom-free when milk was reintroduced to their diet after 4 years.

Any number of the 20 to 30 protein fractions in cow milk may elicit an allergic reaction in humans (Docena et al., 1996, Wal, 1998). The main allergens in cow milk protein (CMP) are believed to be found in the casein fraction and in the whey proteins: alpha lactalbumin and beta lactoglobulin. Investigators examining the IgE responses to allergens in humans have reported that patients are more reactive to caseins than whey proteins. Furthermore, patients diagnosed with persistent CMPA (few years) were reacting against caseins (Sicherer and Sampson, 1999). A plausible explanation for this is that patients with persistent versus transient CMPA have differential IgE binding (B cell) epitopes (Chatchatee et al., 2001). Characterization of allergenic epitopes in patients with CMPA currently underway in several laboratories (Nakajima-Adachi et al., 1998; Elsayed et al., 2001, Piastra et al., 1994, Inoue et al., 2001) may result in highly specific therapies to treat food allergies.

Milk and cow milk products are of particular importance to infants. Infants allergic to CMP temporarily use substitute formulations such as soy protein formulas or extensively hydrolyzed CMP formulations (containing almost no residual antigens). Later, oral tolerance to CMP is affected by the infant's early exposure to some residual cow milk antigen. In fact, introducing a partially hydrolyzed protein, with relatively high residual antigenicities, to the infant's diet has been shown to not induce an allergic reaction (sensitization) but to result in oral tolerance (Pahud et al., 1988, Fritsche et al., 1997, Fritsche, 1998). Also, the low allergen load in human milk has been demonstrated to be a prerequisite to inducing oral tolerance to proteins in children at risk for allergies (Host, 1994, Kilburn et al., 1998). Factors inducing oral tolerance are yet unclear. Further investigation into the mechanism of cow milk protein tolerance is important to the management of diets of humans with CMP allergy, especially infants at risk for allergy. These infants are dependent on human milk.

Milk Protein and Body Composition

Dietary whey proteins, which represent 20% of the protein in milk powders, have been shown to be highly effective in preserving muscle mass (Renner, 1983, Poullain et al., 1989, Boza, 2000, Bouthegourd et al., 2002, Belobrajdic et al., 2003), decreasing body fat and increasing glutathione concentrations (Lands et al 1999). Increases in muscle mass with whey protein supplementation requires resistance training (Cribb, 2002). However, whey supplementation (20 g/day for 12 weeks) without vigorous exercise enhanced glutathione status, improved anaerobic athletic performance and reduced body fat mass (Lands et al., 1999). Compared to a casein or carbohydrate supplemented animal, rodents on a whey protein diet had lower body fat and more muscle mass during a six week study (Bouthegourd, 2002). The percentage of body fat is affected more by muscle mass than by physical fitness level (Calles-Escandon et al., 1995, Nagy et al., 1996, Levadoux et al., 2001, Inelmen et al., 2003). Furthermore, preventing a decline in muscle mass thus improves the percentage of body fat. The consumption of whey protein also leads to a greater level of satiety and lower food intake than a diet consisting of other proteins (Anderson and Moore, 2004). Milk proteins high in BCAAs act via casomorphins which act on gastric receptors to slow down gastric motility (Daniel, 1990). The physiological responses to a dairy protein diet are highly desirable in weight loss management. Whey proteins incorporated into the diet are a significant health benefit to the elderly, patients with HIV, cancer, and athletes.

Key Components of Milk Proteins: Branched Chain Amino Acids

Whey proteins ability to stimulate muscle protein synthesis is due to its amino acid profile being in ratios similar to skeletal muscle (Wolfe, 2000, Volpi et al., 2003). Whey proteins have a greater concentration of branched chain amino acids than any other protein (Walzem et al., 2002, Layman and Baum, 2004). The high concentration of the branched chain amino acid leucine in whey protein has a key role in muscle DNA transcription pathways of protein synthesis (Anthony et al., 2001). The BCAAs leucine, isoleucine and valine, are needed for the production of muscle glutamine, which in turn controls muscle protein synthesis (Kimbal and Jefferson, 2002). Glutamine is also used as a source of energy for the muscle during periods of metabolic stress and in immune function (Walsh et al., 1998). Whey's amino acid composition is 26% branched chain amino acids and 6% glutamate (Bucci and Unlu, 2000, Layman and Baum, 2004, see table below) which are exclusively used by muscle to synthesize glutamine. A diet rich in whey protein results in a greater intake of leucine which due to its unique regulatory action on muscle protein synthesis, insulin signal and glucose-alanine pathway results in a desirable glycemic control and increased synthesis of muscle protein.

Leucine and BCAA Content of Foods*

	Leucine	BCAA
Whey protein isolate	14%	26%
Milk protein	10%	21%
Egg protein	8.5%	20%
Muscle protein	8%	18%
Soy protein isolate	8%	18%
Wheat protein	7%	15%

*Values reflect grams of amino acids/100 g of protein. Source: USDA Food Composition Tables.

Cysteine is the rate-limiting amino acid in glutathione formation (Droege and Holm, 1997). Cysteine is also needed to preserve muscle mass by regulating protein metabolism (Hack et al., 1997). During periods of metabolic stress, the essential metabolism of cysteine by the liver is disrupted (Hack et al., 1997). The pathway of cysteine metabolism by the liver maintains muscle glutamine stores and glutathione synthesis. Compared to other proteins, whey also has a rich source of cysteine which is easily assimilated by the body (Walzem, 2002).

Milk Proteins and Glutathione Production

Whey protein has a unique capacity to increase glutathione production (Bounous, 2000, Bouthegourd et al., 2002). Many researchers have reported on whey's capacity to increase glutathione concentrations within a number of different cells in the body (Lands et al., 1999, Bounous, 2000, Watanabe et al., 2000, Zemel et al., 2000, Agin et al., 2001, Micke et al., 2002, Walzem et al., 2002). Glutathione (GSH) is a tripeptide of glycine, cysteine and glutamic acid. Since cysteine represents the limiting amino acid for GSH synthesis and contains the suphhydryl group for GSH actions, a sufficient supply is essential. GSH maintains many substances in their reduced state and takes part in the cell's defense against oxygen radicals (Cotgreave et al., 1998, Townsend et al., 2003). Glutathione can directly scavenge free radicals and also acts as a cosubstrate in the GSH peroxidase catalyzed reduction of peroxides, which makes it central to defense mechanisms against intra- and extracellular stress. Glutathione and GSH transferases are major components in the metabolism of a variety of drugs (Lomeastro and Malone, 1995). GSH is also involved in the transport of amino acids and in the synthesis of leukotrienes which are important in the inflammatory response. Low plasma GSH levels are indicative of muscle loss whereas adequate plasma GSH is found in patients with increased muscle mass.

Dairy Proteins and HIV/AIDS

Patients diagnosed with HIV are at nutritional risk at any stage of their illness. Optimal nutritional management is a critical part of their medical treatments (Baum et al., 1994, Bartlett, 2003). Side effects of the disease and/or antiviral treatments include: hyperglycemia, elevated serum lipids, atherosclerosis, central obesity, gastrointestinal symptoms and increased insulin resistance (Nerad et al., 2003). Also, loss of muscle mass or lean body mass has been shown to be a strong prognostic indicator for the survival of patients with HIV (Wheeler et al., 1999, Kotler et al., 1989, Guenter et al., 1993). A whey protein diet is an ideal complement to the medical treatment of HIV patients with its excellent composition of amino acids and role in catabolic conditions. A diet rich in whey protein, which has been shown to preserve muscle mass by stimulating muscle protein synthesis, has been recommended in HIV therapy (Task force on nutrition in AIDS, 1989, AIDS Nutrition Services Alliance, 2002). The current recommendations state to consume 1.0–1.4 g of protein/kg/day to maintain body weight. Using a highly purified whey protein in the diet would enable an HIV patient to achieve such a high protein intake (e.g. 84 g per day for a 70 kg male).

Because of their potential role in the stimulation of the immune system, whey proteins have also been used in the nutrition of HIV patients. Studies have documented the benefits of whey protein isolates consumption by HIV patients, resulting in substantial reduction in virus activity and increased survival expectancy. HIV infection is characterized by an enhanced oxidant burden and a systemic deficiency of glutathione (GSH), a major antioxidant, and cysteine (Herzenberg et al., 1997, Droge et al., 1993, deQuay et al., 1992). Numerous studies have shown that whey proteins help enhance the body's immune system by raising glutathione levels. Glutathione is a powerful anti-oxidant with the ability to help the body reduce the risk of infections by improving the responsive ability of the immune system (Cotgreave et al., 1998). Individuals with HIV often have reduced levels of glutathione, which negatively affects their immune system (Droge et al., 1994, Buhl et al., 1989). A study of HIV-infected patients consuming 45 g of whey proteins for 6 months concluded that supplementation with whey proteins persistently increased plasma glutathione levels in patients with advanced HIV infections and that the treatment was well tolerated (Micke, 2002). Larger, long-term trials are still needed to evaluate how this positive influence translates into a more favorable course of the disease.

Dairy Proteins and Elderly Nutrition

Both men and women by age 70-80 have experienced a 20-40% decline in muscle strength (Doherty, 2003). To date 30% of those older than 60 years have a condition called sarcopenia or loss of muscle (Doherty, 2003). Exercise alone does not seem to halt the age related loss in muscle mass and increase of body fat accumulation (Feigenbaum, 1999). Significant loss of muscle mass and increased fat mass are believed to be an underlying cause for ailments typically associated with the elderly such as osteoporosis, diabetes and decreased resistance to infection (Evans, 1997, Dutta, 2001, Levadoux et al., 2001, Doherty, 2003, Inelman et al., 2003).

In elderly, the post-prandial protein synthesis is reduced compared to healthy young individuals (Doherty, 2003, Dorrens and Rennie, 2003). Thus, whey protein's ability to stimulate post-prandial protein synthesis as demonstrated in elderly patients (Dangin et al., 2002) is critical. Further evidence that whey protein should be an important element in the diet of the elderly is the fact that elderly women who increased their dietary intake of protein reduced bone mineral loss and the risk of fracture (Bell and Whiting, 2002, Hannan et al., 2000). Since calcium retention is an important issue particularly for the elderly, the concern for urinary excretion of calcium noted in patients with increased protein intakes is justifiable. Not only are animal proteins less likely to cause an increase in urinary excretion of calcium than vegetable proteins but they also increase intestinal absorption of calcium at intake levels ranging from 0.7 to 2.1 g/kg (Kerstetter et al., 2003).

Dairy Proteins and Sports Nutrition

The beneficial effect of combining dairy protein supplementation with resistance training has been a topic of intense discussion in the scientific community (Fry et al., 2003, Demling and De Santi, 2000, Cribb et al., 2002, Cribb et al., 2003). A whey protein supplement (60 g/d) provided to a cohort of overweight men was effective in decreasing fat mass and increasing fat-free mass (Demling, 2000). Supplementations including whey protein with other minerals, vitamins and carbohydrates provided even better results than whey protein supplements alone. Many resistance training studies are flawed due to the lack of consistency in training techniques, training intensity and frequency among and between study cohorts. The two best well-controlled studies, however, do substantiate that positive body composition changes occur with resistance training while on a whey protein isolate containing diet (Cribb et al., 2002, Cribb et al., 2003). In a ten-week resistance training program, athletes provided a whey protein isolate (1.5 g/kg/day) experienced a weight gain five times greater than the control group. The DEXA (dual energy x-ray absorptiometry) body composition assessment revealed that the whey-supplemented group had a significant decrease in body fat (1 kg) and increased muscle mass as opposed to the casein-supplemented group (Cribb et al., 2002). In a second study the whey-supplemented group gained twice as much fat-free mass as the carbohydrate, whey protein isolate and creatine supplemented counterparts in this eleven week resistance training program (Cribb et al., 2003). There are conflicting reports on whether whey protein alone, or in conjunction with a carbohydrate or casein supplemental mixture with whey protein, provides the optimum dietary support for improving body composition. Better controlled studies are needed to better understand the composition of whey protein diets on strength and body composition in resistance training athletes.

7.2 CARBOHYDRATES

Lactose, the principal carbohydrate in milk powder, accounts for about 54% of the total solids-non-fat content of milk. Minor quantities of oligosaccharides, glucose and galactose are also present in milk powder. Researchers speculate that galactose may have a unique role in the rapidly developing infant brain. Lactose is the first and only carbohydrate every newborn mammal consumes in significant amounts. In infants, some lactose enters the colon where it promotes the growth of beneficial lactic acid bacteria which may help combat gastrointestinal disturbances.

Lactose is a natural disaccharide consisting of one galactose and one glucose unit. It can be hydrolyzed by the enzyme beta-galactosidase into its individual sugars. The slow hydrolysis of lactose by the body during digestion generates a prolonged energy supply. Being a carbohydrate, it provides about 4 calories per gram. Because digestion of lactose is much slower than of glucose and fructose, lactose is considered relatively safe for diabetics. It does not cause a sharp increase in blood glucose levels like sweeteners, and therefore has a nutritional advantage in the diabetic diet.

Because of the delayed transit time through the digestive system, a part of the sugar reaches the colon intact and is used as a substrate for the growth of beneficial intestinal flora such as bifidobacteria. Growth of bifidobacteria results in an acid environment, which inhibits the growth of *E. coli* and other putrefying and pathogenic organisms. For infants, this is especially important for resistance against intestinal infections. In both infants and adults, lactose in the diet contributes to the maintenance of stable, healthy intestinal flora.

Lactose is recognized for stimulating the intestinal absorption of calcium. The effect is independent of the presence of vitamin D and is exerted on the diffusional component of the intestinal calcium transport system. Since lactose acts on passive calcium absorption, its effect is dependent on calcium intake levels. At low levels, vitamin D-dependent active calcium transport dominates and little effect of lactose is observed. Various mechanisms are responsible for this, one being that the metabolism of lactose by intestinal flora increases the concentration of lactic acid in the intestinal tract. Consequently, pH decreases, improving the solubility and availability of calcium. Lactose is also capable of forming complexes with calcium, influencing the transport of calcium through the intestinal epithelium membranes in a positive way.

Some individuals have difficulty metabolizing lactose because of reduced lactase levels, a condition called lactase nonpersistence. Recent research indicates that most persons with lactase nonpersistence are able to consume the amount of lactose in 250–500 ml of milk a day if taken with a meal. A number of low-lactose and lactose-reduced milks are also available. Lactose-free milk has about 99% of its lactose hydrolyzed.

7.3 LIPIDS

Milk fat contributes unique characteristics to the appearance, texture, flavor and satiability of dairy foods and foods containing dairy ingredients. It is also a source of energy, essential fatty acids, fat-soluble vitamins and several other health-promoting components. Milk fat is not only characterized by a number of different fatty acids, but also by their chain length. More than 400 different fatty acids and fatty acid derivatives have been identified in milk fat.

Emerging scientific findings indicate that milk fat contains several components such as conjugated linoleic acid (CLA), sphingomyelin, butyric acid and myristic acid which may potentially protect against major chronic disease. Milk fat may also have a beneficial effect on bone health, according to experimental animal studies.

Typical Fatty Acid Profile of Milk Fat

Fatty Acid	Carbon	%	Class
Butyric	4:0	3.3	Saturated, short chain
Caproic	6:0	1.6	
Caprylic	8:0	1.3	Saturated, medium chain
Capric	10:0	3.0	
Lauric	12:0	3.1	
Myristic	14:0	9.5	Saturated, long chain
Palmitic	16:0	26.3	
Stearic	18:0	14.6	
Palmitoleic	16.1	2.3	Mono-unsaturated
Oleic	18:1	29.8	
Linoleic	18:2	2.4	Poly-unsaturated
Linolenic	18:3	0.8	

Vitamins in Milk—Typical Content in 100 g of Whole Fluid Milk

Vitamin A–activity	126 IU (31 RE)
Vitamin D	1.13–2.80 IU
Vitamin E	80 µg
Ascorbic acid	0.94 mg
Thiamin	0.038 mg
Riboflavin	0.162 mg
Niacin	0.084 mg
Niacin equivalents	0.856 mg
Pantothenic acid	314 mg
Vitamin B_6	0.042 mg
Folate	5 µg
Vitamin B_{12}	0.357µg

Adapted from National Dairy Council. New Knowledge of Milk and other Fluid Dairy Products, 1993.

7.4 VITAMINS

All of the vitamins known to be essential to humans have been detected in milk. Vitamins A, D, E, and K are associated with the fat component of milk and are therefore contained in greater amounts in whole milk powder than reduced-fat milk powders. Vitamin A plays important roles in vision, cellular differentiation, growth, reproduction and immuno-competence. Both vitamin A and its precursors, carotenoids, are present in milk. Milk and milk products are an important source of vitamin A in the diet. Vitamin D, a fat-soluble vitamin which enhances the intestinal absorption of calcium and phosphorus, is essential for the maintenance of a healthy skeleton throughout life. Vitamin E (mainly tocopherol) is an antioxidant, protecting cell membranes and lipoproteins from oxidative damage by free radicals. This vitamin also helps maintain cell membrane integrity and stimulate the immune response. Vitamin K is necessary for blood clotting and may also have a protective role in bone health.

In addition to the essential fat-soluble vitamins, milk and other dairy foods also contain all of the water-soluble vitamins in varying amounts required by humans. Significant amounts of thiamin (vitamin B_1) which acts as a coenzyme for many reactions in carbohydrate metabolism, are found in milk. Milk is also a good source of riboflavin or vitamin B_2. Other vitamins include panthotenic acid, vitamin B_6 and vitamin B_{12}.

Note: Content in various types of milk powders may vary. Non-fortified nonfat dry milk contains significantly lower amounts of fat-soluble vitamins.

Typical Concentration of Vitamins in Milk Powders (/100 g)

	Skim Milk Powder	Whole Milk Powder	Buttermilk Powder
Ascorbic acid (mg)	6.8	8.6	5.7
Thiamin (mg)	0.415	0.283	0.392
Riboflavin (mg)	1.550	1.205	1.579
Niacin (mg)	0.951	0.646	0.876
Pantothenic acid (mg)	3.5	2.2	3.1
Vitamin B_6 (mg)	0.361	0.302	0.338
Folate (µg)	50	37	47
Vitamin B_{12}	4.03	3.25	3.82
Vitamin A (IU)	36	922	18
Vitamin A (RE)	8	280	54
Vitamin D (IU)		3.34	
Vitamin E (mg)	0.221	16.3	0.4

Source: U.S. Department of Agriculture. ARS. Ag. Handbook No. 8-1. Composition of Foods.

7.5 MINERALS

Milk powders and milk products are important sources of major minerals, particularly calcium, phosphorous, magnesium, potassium and trace elements such as zinc. About 99% of the body's calcium is in bone and teeth. Throughout life, calcium is continually being removed from bones and replaced with dietary calcium. Consequently, the need for an adequate supply of dietary calcium is important throughout life, not only during the years of skeletal development. Prolonged calcium deficiency is one of several factors contributing to osteoporosis. Calcium also fulfills several important physiological functions in human metabolism, as evidenced by its role in blood coagulation, myocardial function, muscle contractility, and integrity of intracellular cement substances and various membranes. An adequate amount of calcium protects against hypertension and possibly some cancers. Calcium in milk reduces the risk of kidney stones.

Typical Minerals Content of Milk Powders (mg/100 g)

Mineral	Whole Milk Powder	Nonfat Dry Milk
Calcium	912	1,257
Iron	0.47	0.32
Magnesium	85	110
Phosphorus	776	968
Potassium	1,330	1,794
Sodium	371	535
Zinc	3.34	4.08

Source: U.S. Department of Agriculture. A.R.S. Ag. Handbook No. 8-1. Composition of Foods.

One of the minerals showing the greatest deficiency in the world population is calcium. Milk products such as milk powders are rich sources of calcium. Milk powders can be used as ingredients to fortify other manufactured food products that are poor in calcium. An important aspect is that a number of studies have demonstrated the superior bioavailability of calcium found in milk vs. calcium from other sources. Recent studies have confirmed the role of dairy foods such as milk powders in increasing peak bone mass and slowing age-related bone loss. It is important to appreciate that nutrition, in particular calcium and vitamin D, are among several factors influencing both optimal bone health and the development of osteoporosis. Not only are milk powders and other dairy foods calcium-dense foods, but these foods also contain other nutrients important to bone health such as vitamin D, protein, phosphorus, magnesium, vitamin A, vitamin B_6 and trace elements such as zinc. Few foods other than milk products provide such a concentrated source of calcium that is readily available for absorption. Recommended calcium intakes vary according to age group, stage of life and country's health authorities. For official recommendations, guidance is also available from the World Health Organization.

Milk powders are also important sources of phosphorus, magnesium and potassium. Milk powders contain many trace elements and their content is highly variable, depending on raw milk content—a function of the state of lactation, storage condition and other factors. Examples of such trace elements are zinc, selenium and iodine. Iron is found in low concentrations in milk powders.

Dairy Products and Adiposity

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In the early 1980s, we undertook an intervention study of obese black Americans who suffered from hypertension and who were asked to consume, for a one year period, two daily servings of yogurt, in addition to their diet. The yogurt consumption resulted in an extra intake of 400–1,000 mg of calcium daily. In addition to the anticipated effect on blood pressure, the yogurt supplementation resulted in a loss of body fat of 4.9 kg over one year. At the time, the possible mechanism explaining the weight loss was not understood.

Since then, a number of recent studies have documented that calcium intake is inversely related with the risk of obesity, and we have developed a plausible mechanism to explain this relationship. That mechanism is based on the observation that a high calcium intake reduces the serum 1,25-dihydroxycholecalciferol (1-25-dihydroxyvitamin D_3, 1,25-$(OH)_2$-D, also referred to here as calcitriol) level. This active form of vitamin D stimulates the influx of calcium ions into fat cells, which promotes obesity, as follows. Ca^{2+} ions are needed by the adipocytes for the transcription of fatty acid synthetase, a key enzyme in de novo lipogenesis; high levels of Ca^{2+} in the fat cell also inhibit lipolysis. Accordingly, the increase in intracellular Ca^{2+} elicited by calcitriol cause an increase in lipogenesis, a decrease in lipolysis and a consequent expansion of fat storage. In addition, we have also shown that calcitriol acts via a Ca^{2+}-independent mechanism to inhibit the transcription of uncoupling protein 2 (UCP2). It is a multifunctional protein which may increase energy dissipation by the fat cell (although this is controversial) and which stimulates the clearing away of larger, older fat cells via apoptosis (programmed cell death). Indeed, we have shown that calcitriol inhibits the destruction of fat cells by apoptosis and that reduction of calcitriol levels by high calcium diets increases fat cell apoptosis. Accordingly, since dietary calcium inhibits calcitriol levels, it should reduce lipogenesis, increase lipolysis and fat oxidation and increase apoptosis. As a result, increasing dietary calcium to suppress calcitriol levels is an attractive approach for weight management. Indeed, in studies conducted in mice, low calcium diets prevented fat loss, whereas high calcium diets accelerate it. What makes this research particularly relevant is that when the calcium is provided by dairy products, the fat loss and attenuation of weight and fat gain is accelerated. It is probable that the increased effect of dairy vs. supplemental calcium is due to bioactive compounds found in milk that act in synergy with the calcium.

This hypothesis has been tested in animal experiments, analyses of population data sets and in human intervention studies. The studies on animals were conducted with transgenic mice which exhibit a human-like pattern of obesity-related gene expression and which are susceptible to diet-induced obesity. In the studies, mice received feed containing 1.2% calcium (the control's diet contained only 0.4% calcium). The calcium diet led to a decrease in lipogenesis of 51%, an increase in lipolysis by a factor of 3–5, and substantial reductions in body weight and fat content. Studies on mice were also conducted comparing a high calcium diet (1.2% of the calcium derived from calcium carbonate), medium dairy diet (1.2% calcium derived from nonfat dry milk, which also replaced 25% of protein) and a high dairy diet (2.4% calcium derived from nonfat dry milk, which replaced 50% of the protein). Greater weight reduction, 19, 25 and 29%, respectively, were observed in the high calcium, medium dairy and high dairy diets. The differences were significant over the control group which was only exposed to energy restriction and where an 11% weight loss was observed.

The datasets analyzed came from the U.S. National Health and Nutrition Examination Study (NHANES III) database. These indicated an inverse association between calcium intake and percentage of body fat and have now been confirmed in a number of other population studies.

In human intervention studies, the effect of a 24-week dietary calcium supplementation were studied in subjects with a body mass index in the 30–39 kg/m^2 range, and who therefore were classified as obese. The subjects were randomized into a group receiving a calcium-supplemented diet, a diet supplemented with dairy, and a control group. Although all three groups received equal levels of caloric restriction, the dairy-based diet augmented the loss of weight and fat by 70% and 64%, respectively; although the calcium supplements also augmented weight and fat loss, they were only about half as effective as the dairy-rich diet. Additional studies have also shown that dietary calcium not only accelerates weight and fat loss, but also results in increased loss of fat in the trunk (abdominal region), which is a more desirable health pattern.

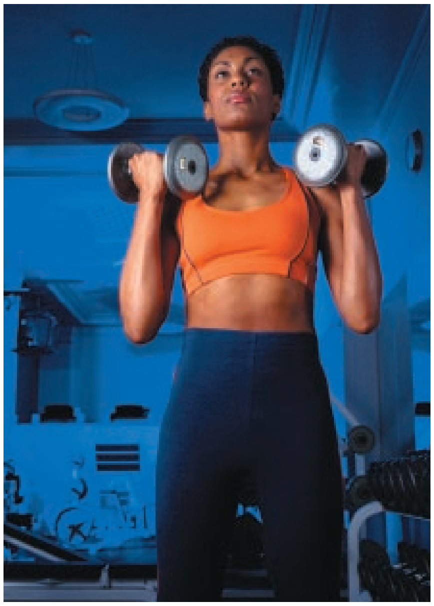
All the studies conducted to date clearly indicate the benefits of a high calcium diet for the management of obesity, with markedly greater effect for dairy vs. nondairy sources of calcium. The additional components of dairy responsible for the effect are under investigation, but preliminary data indicated that bioactive components found the whey fraction of milk protein may play an important role. It is possible that angiotensin converting enzyme inhibitors found in the whey proteins (which constitutes 20% of the protein in nonfat dry milk), as well as the rich concentration of branched chain amino acids found in whey, may contribute to the antiobesity effect of dairy. This research has important implications for the prevention of obesity among children and adults alike, in developed as well as developing countries where the prevalence of obesity is rising to alarming levels.

Dairy Products Protect Against Colon Cancer

Animal experiments and human epidemiological intervention studies have demonstrated that the consumption of dairy products, such as milk powders, is associated with a lowered risk of developing colon cancer. In the Western world, colon cancer is among the most prevalent cancer types, and diet explains 30–60% of the risk that the disease becomes manifest. Multiple dairy components account for protection against the development of colon cancer. Calcium is one of them. The mechanism that may play a role in calcium's protective action is the formation of calcium-phosphate complexes with mutagenic or toxic compounds in the intestinal lumen. These complexes precipitate and leave the intestine with the faecal bulk without any harm to colon epithelial cells. Protection can also be attributed to dairy proteins. Some animal studies have demonstrated that whey protein components confer protection against the development of colon cancer. This effect is explained, in part, because these proteins are sources of both antioxidants and sulphur amino acids. Whey proteins represent 20% of milk's proteins and are found in milk powder in the same proportion.

Milk After Exercise Promotes Recovery of Muscle

The recommended daily protein intake for people who exercise ranges from 1g per kilo of body weight to 2g, for those following more intense training. A usual dairy serving, such as 300ml of low-fat milk (or approximately 30g of milk powder) provides about 10g of protein. Studies have shown that the combination of essential amino-acids and carbohydrates stimulate protein synthesis in muscles, and results in greater insulin response after physical exercise than carbohydrates alone. Supplementation of the diet of endurance athletes with low fat milk (or skim milk powder) prevents the decline in serum levels of branched-chain amino acids and increases levels of other essential amino acids, as compared to supplementation with a placebo or carbohydrates. These conditions point to reduction of muscular damage and improved conditions for muscular protein synthesis after the ingestion of milk.



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The functional properties may be defined in relation to their performance as powders and to their performance as foods or in use as ingredients in formulated foods. The functional properties of milk powders are typically dependent upon: powder composition, the influence of processing conditions prior to drying and drying conditions themselves.

The major components in milk powder (proteins, lactose, milkfat) affect the way in which milk powders perform and their suitability for each type of application.

Functional Properties of Major Milk Powder Components

Whey Proteins	Caseins
• Whipping/foaming	• Fat emulsification
• Gelation	• Foaming
• Solubility at low pH	• Solubility at pH >6
• Heat denaturation	• Water binding
• Lactose	• Milk fat
• Low sweetening power	• Creaming
• Humectant	• Unique flavor
• Color development, browning	• Gloss
• Free-flow agent	• Flavor carrier
• Flavor development	• Low melting temperature range

Solubility

Dairy protein functionality is dependent upon ingredients' solubility in a solution. In their native state, casein and whey proteins are highly soluble in food and beverage systems and, as a result, are frequently used for their emulsifying and whipping/foaming properties. However, excessive heating results in protein denaturation, decreasing solubility.

Poor solubility (high-solubility index) in milk powders is caused by subjecting the milk to high temperatures, particularly at high total solids level during processing.

Roller-dried powders, because of the higher temperatures attained, have significantly greater solubility indices (less soluble) than spray-dried powders.

Since milk proteins are sensitive to heat, the extent of their denaturation reflects the heat treatment applied and is used for classifying skim milk powder (high-heat, medium-heat and low-heat). Heat classification provides an indication of the suitability of skim milk powder for specific applications. By controlling thermal denaturation, the degree of solubility can be manipulated.

Milk powders, depending upon their composition, generally consist of small, single particles of high bulk density. Non-instant skim milk powder tends to be rather dusty. As a result, reconstitution is difficult because the skim milk particles tend to clump together on the surface of the reconstituting liquid and have poor wettability.

In the case of whole milk powder and buttermilk powder, the wettability problem is compounded because of free fat forming a hydrophobic film on the surface of the dry particles. For this reason, lecithin is often added during the drying process to help improve the powder's ability to dissolve.

The process of instantizing, which involves a drying process that causes agglomeration, enhances reconstitution properties in cold liquids by improving one or more of the following properties: wettability, sinkability, dispersibility, rate of hydration and solubility.

Emulsification

The manufacture of food emulsions, typically oil-in-water systems, is a highly energetic and dynamic process in which oil/water interfaces are protected by adsorption of surfactants and partially lost again by recoalescence of those emulsion droplets that are not protected quickly enough by surfactants. Recoalescence is an important phenomenon in emulsions stabilized by proteins because of the relatively slow development of a stabilizing surface film of proteins around new emulsion droplets.

The proteins in milk powders can quite successfully act at oil/water interfaces to form and stabilize emulsions. Emulsification properties can be enhanced by controlled denaturation of the protein. In particular, the rate of diffusion to the newly formed oil/water interface and the rate of adsorption and unfolding increase with increasing temperature, enhancing the formation and stabilization of emulsion droplets. The unfolding of the dairy protein exposes hydrophobic amino acid residues that facilitate the ability of the protein to orient at the oil/water interface.

The ability of dairy proteins to stabilize oil/water emulsions is affected by pH and ionic strength of the aqueous phase. The presence of lecithin in milkfat also contributes to the emulsification properties of milk powders.

Gelation

Dairy proteins, in their undenatured form, have the ability to form rigid, heat-induced irreversible gels that hold water and fat, and provide structural support. Gelation is a two-step mechanism that involves an initiation step, the unfolding or dissociation of protein molecules, followed by an aggregation reaction, resulting in gel formation. For the formation of a highly ordered gel, it is essential that the aggregation step proceed at a slower rate than the unfolding step.

Two types of aggregates can form, depending on how much charge the native protein carries. Linear aggregates occur when the charge repulsion is large, and globular, random aggregates when the repulsion is small. The type of aggregation affects the gel's opacity.

Water Binding

The amount of water held in gel under a given set of conditions is referred to as its water-holding or water-binding capacity. This water, enclosed in the gel's three-dimensional structure, can reduce the cost of food (water is inexpensive) and improve sensory perception.

Water binding is especially important when milk powders are used in viscous food products such as beverages, soups, sausages and custards. Moreover, the water binding and associated properties (i.e., swelling gelation and viscosity) of proteins are the major determinants of texture in a number of processed food products such as cheese, yogurt and reduced-fat dairy foods.

Also, milk powder increases the water binding capacity of bread dough in direct proportion to the amount added. This has a positive effect on texture, flavor and product shelf life.

Whipping/Foaming

An important property of milk proteins is their surface-active behavior. They easily adsorb to fat globule interfaces during homogenization and to the air bubble interface during whipping. It is well established that both caseins and whey proteins have the same ability to do so.

Foaming is defined as the creation and stabilization of gas bubbles in a liquid. Essential for the formation of protein-based foams is a rapid diffusion of protein to the air-water interface to reduce surface tension, followed by partial unfolding of the protein. This results in the encapsulation of air bubbles and in the association of protein molecules leading to an intermolecular cohesive film with a certain degree of elasticity.

These criteria are best fulfilled with milk powders containing proteins that are undenatured (molecularly soluble), not in competition with other surfactants at the air/water interface (i.e. fatty compounds), and stabilized by an increased viscosity when the foam has been formed (addition of water binders).

The whipping properties of dairy protein ingredients are affected by several factors including concentration and state of the dairy proteins, pH, ionic environment, (pre-) heat treatment and the effect of lipids. As dairy protein concentration increases, foams become denser with more uniform air bubbles and a finer texture. Generally, overrun increases with protein concentration to a maximum value, after which it decreases again.

Milk powders are beneficial in the development of foams, characteristic of frozen desserts, whipped toppings, meringues and mousses. Specifically, skim milk powder improves foam structure and texture in cakes.

Viscosity

The dairy proteins in milk powders play an important role in controlling the texture of many food products. They are used to modify the rheological properties of foods.

Dependent upon the state of the protein, dairy proteins can contribute a desired viscosity to a wide range of foods such as soups, sauces, salad dressings, batters and yogurts. Viscosity development is closely related to gelation properties and protein-protein interactions.

Browning/Color

Although not normally thought of as a functional property, browning is important in many foods. Milk powders contribute to browning when the protein and reducing sugar lactose undergo Maillard browning. For example, during baking or cooking, the protein's amine groups react with lactose and other reducing sugars present in formulations, delivering an appealing color to baked goods and sauces. Lactose does not get fermented by baker's yeast in yeast-leavened bakery products. It remains available for crust color development.

Milkfat's pleasant cream color rounds out the color of viscous products such as sauces, soups, salad dressing and beverages. It also contributes to opacity.

Flavor/Aroma

Overall, dairy proteins are quite bland, and contribute no foreign or off-flavors to foods when used as an ingredient. During heat processing, the lactose present in milk powders reacts with dairy proteins leading to the production of different flavors including sour organic acids balanced by sweet and bitter substances.

The milkfat present in milk powders provides creamy, dairy notes and richness. Milkfat also acts as a flavor carrier for fat-soluble ingredients, spices, herbs and sweet flavors. Milkfat's low melting point ensures complete flavor release.

Functionality of Milk Powders in Recombining Applications

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The production of recombined milk products is a major application for milk powders in international markets and most countries where milk production is not sufficient to meet local demand for dairy products. While the production of recombined evaporated (condensed) milk (REM) and recombined sweetened condensed milk (RSCM) continues to be an important industry, there has been a large increase in the production of UHT recombined milk products in the past decade. Milk powders are also ingredients in the production of extended shelf-life (ESL) milks.

Recombined milk products can be made from a combination of skim milk powder and anhydrous milk fat; skim milk powder, buttermilk powder and anhydrous milk fat; whole milk powder and skim milk powder; or by simply using whole milk powder. Cream powder or emulsifiers are typically added to those formulations.

The source of fat can be vegetal in the case of "filled" products. Fortified products, designed to meet the needs of specific population targets, can be manufactured with the addition of whey proteins, calcium, iron, bioactive components and other dairy or non-dairy ingredients. In these cases, the nutritional content, flavor and functionality of the recombined products is significantly different from that of fresh milk.

Water is one of the critical, and most important (by volume), ingredients of recombined milk products. It should be potable and needs to be checked regularly from a bacteriological standpoint. Spore contamination of recombined milk products often finds its source in the water used in manufacture. Preferred methods of water purification include sodium ion exchange and reverse osmosis. While effective against some bacteria, chlorination is not effective against spores.

Data available from the scientific literature suggests that the total hardness of the water, in carbonate equivalent, should not exceed 100 ppm, with the total dissolved solids less than 350 ppm, and not in excess of 500 ppm.

Additives such as gums, carrageenans or emulsifiers can be added at different steps of the process and processors should contact the suppliers of these ingredients for their recommendations.

It is preferable to heat the water to be used for reconstitution to 40–55°C, and when adding fats, ensure they are added at a temperature that is higher than their melting point. This may require, when utilizing AMF in drums, for example, holding the fat for a day or two at a temperature of 45–50°F. The use of water colder than 30°C may result in the formation of powder lumps, unless advanced mixing systems are employed.

The powder should be allowed to rehydrate for about 20 min. to allow for the milk protein system and minerals to re-equilibrate. In most operations, the time needed to disperse the powder in the tank and filter it, allows sufficient time for this rehydration process to take place. Recombined liquid milk is not a shelf-stable product and processors need to ensure pasteurization or further heat processing follows rehydration promptly to improve its original microbiological quality. If intermediate storage is required during the process, the temperature of the milk should be kept below 7°C, preferably 4°C.

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From Functionality to Applications

Function	Characteristics	Functional Benefits	Marketing Benefits	Applications	Page
Emulsification	Presence of hydrophilic and hydrophobic groups on milk proteins.	■ Creates stable emulsions. ■ Prevents fat globules from forming one large mass. ■ Versatile and all-natural emulsifying ingredient.	■ Improves product appearance, thus making it more appealing to the consumer. ■ Contributes to an appealing ingredient label.	■ Bakery ■ Confectionery ■ Dairy/recombined milk ■ Meat ■ Nutritional beverages ■ Prepared foods	**71** **77** **83** **95** **99** **103**
Gelling	Milk components form irreversible gels under specific conditions.	■ Bind large quantities of water and non-protein compounds. ■ Improves mouthfeel. Helps lubricate and provide the creamy, smooth texture of fat.	■ Appeals to the health-conscious by creating lower fat products with the taste of full-fat.	■ Confectionery ■ Dairy/recombined milk ■ Meat ■ Prepared foods	**77** **83** **95** **103**
Water binding and viscosity building	Under specific conditions, protein molecules unfold and form a gel. The three-dimensional structure of the gel binds water.	■ Provides fat-like attributes in products, allowing a reduction in fat content. ■ Retains water, which reduces product costs. ■ Increases viscosity, which has a significant effect on machinability. ■ Improves product texture, creating moister products. Increases viscosity in rehydrated and fluid products.	■ Reduced-fat products appeal to health-conscious consumers, especially if they can duplicate the full-fat mouthfeel. ■ Reduced ingredient costs can translate into lower consumer prices or increased marketing expenditures. ■ A moister product equates to a fresh product. ■ Improves product texture, increasing consumer appeal.	■ Bakery ■ Confectionery ■ Dairy/recombined milk ■ Meat ■ Nutritional beverages ■ Prepared foods	**71** **77** **83** **95** **99** **103**
Whipping/ foaming	Surface active properties of milk proteins create and stabilize gas bubbles in a liquid.	■ Helps maintain foam stability. ■ Helps improve whip volume.	■ Maintains foam properties, which enhances visual appeal and the finished product. ■ Provides structure and texture.	■ Bakery ■ Confectionery ■ Dairy/recombined milk ■ Nutritional beverages	**71** **77** **83** **99**

From Functionality to Applications (continued)

Function	Characteristics	Functional Benefits	Marketing Benefits	Applications	Page
Flavor enhancement	Lactose reacts with milk proteins leading to the production of flavorful compounds. Milk powders have a bland, sweet dairy flavor. Milkfat carries fat-soluble ingredients throughout a formulation. Milkfat's low melting point ensures complete flavor release.	■ Can provide baked, brown flavor during baking and heating. ■ Can provide creamy dairy notes. ■ Milkfat ensures even flavor distribution.	■ Clean flavor and aroma with no evidence of off-flavors enhances customer appeal. ■ Homogeneous and consistent flavor.	■ Bakery ■ Confectionery ■ Dairy/recombined milk ■ Meat ■ Nutritional beverages ■ Prepared foods	**71** **77** **83** **95** **99** **103**
Browning/ color	Lactose, a reducing sugar, serves as a substrate for the Maillard reaction. Milk powders contribute a creamy, dairy color as well as opacity.	■ Accentuates color development during cooking and baking. ■ Improves opacity in lower fat foods.	■ Enhanced visual appeal, thus increasing consumer appeal. ■ Lower fat foods appeal to health concious consumers.	■ Bakery ■ Confectionery ■ Dairy/recombined milk ■ Nutritional beverages ■ Prepared foods	**71** **77** **83** **99** **103**
Nutritional enrichment	Possess high-quality proteins — all of the amino acids required for a healthy diet — in a readily digestible form. Is high in lactose, a disaccharide that is slowly digested. Milk powders are high in calcium and rich in thiamin, riboflavin and other nutrients.	■ Can improve the nutritional profile of a food product. ■ Lactose increases calcium absorption and stimulates the growth of acid-forming lactobacilli in the intestinal track. ■ Provides vitamin enrichment. ■ Provides mineral fortification.	■ Contributes to a food's healthy image and clean label. ■ Represents a natural and good source of soluble vitamins. ■ Offers advantages in dietary therapy.	■ Bakery ■ Dairy/recombined milk ■ Nutritional beverages ■ Prepared foods	**71** **83** **99** **103**

STATEMENTS OF PRINCIPLES

The information on infant nutrition and the formulations presented in this, and other, USDEC publications are provided for demonstration purposes and as a starting point for product development efforts. USDEC supports the internationally recognized principles and protocols regarding the use of dairy ingredients in food assistance programs.

Statement on Infant Feeding, Codex Standards for Foods for Infant and Children (Codex Alimentarius, 1989).

The value of breast milk as an ideal food for the infant during the first six months of its life cannot be too strongly stressed. However, poor health of the mother and certain social conditions can reduce lactation, separate the infant from the mother or otherwise make breastfeeding impossible. In these circumstances, it is necessary to use alternative foods such as infant formula to overcome the lack of breast milk.

Prioritization of Alternatives for Infant Feeding in Emergencies (World Health Organization. Department of Emergency and Humanitarian Action, 2002).

Breastfeeding is the first and best feeding option for infants. No other food or liquid is required during the first 6 months of life—especially in emergency situations. Other, less preferable, feeding options may be appropriate in certain circumstances. These are, in decreasing order of preference—wet nursing (where HIV risk is not high*), and breast milk from a milk bank. If neither of these options are possible or acceptable, the next least dangerous option is generically labeled infant formula with clear instructions on safe preparation. Agencies working in the area of infant feeding should have supplies of such formula for the small number of infants requiring it. Contact details of companies producing generically labeled infant formula can be obtained from Baby Milk Action (www.babymilkaction.org). Should interruptions in the generic supply occur it may be necessary to buy commercially labeled formula on the local market.
As a very last resort and only when it is not possible to undertake any of the above options, home-made recipes may be considered (please obtain information from the World Health Organization (WHO) or a physician). Home-made formula lacks key micro-nutrients that are necessary for adequate development and should therefore only be given for a few days until one of the other feeding options can be established.

*The practice of wet nursing may be unacceptable or inappropriate in situations of high HIV prevalence where testing, support and counseling are not available (see WHO/UNICEF/UNAIDS, 1998 for more details).

- Please refer to the International Code of Marketing of Breast-Milk Substitutes published by the World Health Organization, available at: www.who.org.
- Please also refer to the following documents published by USAID and available at: www.usaid.gov.:

  Policy on the Use of Non-fat Dry Milk for Supplementary Feeding,
  Policy on the Use of Non-fat Dry Milk for Therapeutic Feeding,
  Policy on the Use of Non-fat Dry Milk for Title II Monetization.

ALLERGIES AND INTOLERANCE: A FEW KEY FACTS

Milk allergy and lactose intolerance are totally different conditions that require different nutritional approaches. The following information only highlights a few key points. Please consult a physician and nutrition professional for further information.

Babies are not born allergic but may become allergic if exposed, during the first few months of life, to milk, egg or other proteins. Cow's milk allergy develops in less than 3% of infants. For most of these infants, the reactivity to cow's milk protein is usually outgrown by their third birthday. The American Academy of Pediatrics recommends delaying the introduction of cow's milk until one year of age. More information on other allergens is available from www.aap.org.

Lactose intolerance is very different from milk allergy. It has been estimated that up to 75% of the world's population has a genetically controlled limited ability to digest lactose, the principal carbohydrate in milk and other dairy foods. Limited digestion of lactose can lead to unpleasant gastrointestinal symptoms, termed lactose intolerance.

Milk and dairy ingredients provide a cost-efficient source of carbohydrate, protein and calcium to children and adults where protein-calorie malnutrition is prevalent.

Yet, lactose maldigestion in a majority of non-Caucasian children in developing countries has implications for public health and nutrition policy. How much and in which form milk (lactose) is delivered needs to be considered.

Successful management strategies for those with lactose intolerance include, among others (1) drinking milk in servings of one cup (230 ml) or less (less than 25 g of skim milk powder or less than 20 g of sweet whey per serving), (2) drinking milk with a meal or other foods (or consume dairy ingredients in conjunction with other, non-dairy ingredients), (3) consume other dairy products such as fermented milks, yogurts or cheese, or use lactose-reduced or lactose-free milk or ingredients (such as whey protein concentrates or isolates).

According to the World Health Organization, clinically significant lactose intolerance is unusual in severely malnourished children. In confirmed intolerance cases among these children, WHO recommends replacing milk partially or completely by yogurt or a commercial lactose-free formula.

U.S. dairy ingredients offer a range of solutions for food assistance programs. New processing technologies to concentrate and modify the composition of milk have made it possible to produce an array of ingredients, including many that are tailor-made for specific food aid applications. U.S. dairy ingredients represent a versatile solution for food assistance programs. They lend themselves to utilization in nutritional preparations, as well as in monetization programs.

The most commonly used ingredient is nonfat dry milk. It is made by removing water from pasteurized fat-free milk. It contains 5% or less moisture and 1.5% or less milkfat (by weight). NFDM is white to light cream in color, with a mild dairy flavor. Major types of NFDM include instantized, high heat, medium heat or low heat. NFDM is often recombined for the manufacture of a variety of dairy products and nutritional beverages. It is also a common ingredient in child/infant formula, baked goods, confections and fortified prepared foods such as soups.

Dry whole milk is made by removing water from pasteurized whole milk. U.S. Extra grade DWM contains between 26% and 40% milkfat with a moisture level of 4.5% (by weight). It has applications in confections, baked goods, soups and some child/infant formula and nutritional preparations.

Milk ingredients have applications in virtually every food category, including fortified mixes, fermented milks (yogurts, kefir), lactic cultured products, baked goods such as flatbreads, beverages, confections, infant formula, dairy foods, meat products, sauces and soups, nutritional products and nutraceuticals. In many applications, dairy ingredients are considered critical to the nutritional value of the product as well as its taste, aroma, mouthfeel, keeping qualities (shelf-life) and texture. These diverse applications in the food processing sector make SMP and other milk ingredients particularly suitable for income-generating activities and monetization programs.

As with many dry ingredients, it is critical that only clean water and other ingredients with the appropriate microbiological, sensory and functional attributes be utilized in recombined and reconstituted milk products. It is also essential that sanitary/hygenic manufacturing conditions be established and controlled to insure the safety of the finished product, up to the time of consumption.

Packaging: U.S. dairy ingredients such as milk powders and whey are typically shipped in 50 lbs. or 25 kg multiwall poly-lined bags. Plastic-lined corrugated paperboard or other types of tote bins are also used. Specialty, high value ingredients are available in smaller quantities. Please consult your U.S. supplier for more information.

9.1 BENEFITS OF FOOD ASSISTANCE PROGRAMS

Dry dairy ingredients deliver nutrition and functionality that have many benefits and make them an important addition for food assisted programs.

Diverse nutritional benefits:

- rich in high quality proteins,
- an excellent source of calcium with high bioavailability,
- a source of other minerals and vitamins,
- presence of bioactive and health-enhancing compounds that have applications in therapeutic feeding,
- complement proteins, of vegetal origin.

Versatile:

- can be used for recombination* or fortification purposes,
- are ready to use, do not require further cooking or preparation,
- can also be used as binders, emulsifiers, or texture and shelf-life extension agents in a variety of food/dairy products,
- mixes well and can serve as carriers for vitamins, minerals, other nutrients.

Universal:

- a mild flavor is well accepted in many cultures,
- as an ingredient, promotes color and flavor development to increase consumer appeal,
- application uses in a wide range of recipes and industrial formulations in most countries.

Long shelf-life:

- When stored in a dry, cool place, dry dairy ingredients have a shelf-life of up to three years. Additional shelf-life studies and recommendations for storage under different conditions are available upon request.

U.S. dairy ingredients can be used in direct feeding programs (school lunch, soup kitchens), in emergency distribution situations,* and in monetization programs.

*Whenever dry dairy ingredients are reconstituted, a clean source of water should always be used. Reconstitution should be done in hygienic conditions and the recombined product should be stored in conditions that will ensure its safety up to the time of consumption.

9.2 OVERVIEW: NUTRITIONAL BENEFITS OF DAIRY INGREDIENTS

Please refer to the nutrition section of this manual for more information (see Section 7).

The consumption of cow's milk and dairy ingredients contributes to health throughout life. According to the American Academy of Pediatrics, the nutritional adequacy of diets for children should be achieved by consuming a wide variety of foods, and children should be provided with sufficient energy to support their growth and development and to reach or maintain desirable body weight. Dairy ingredients are nutrient-dense and provide abundant amounts of high-quality proteins, vitamins and minerals necessary for growth and development.

Straight cow's milk (fresh or dried) is not recommended for infants during the first 12 months of life. Human milk is recommended to support infants' rapid growth and development during this period. In circumstances that make breastfeeding impossible or unadvisable, commercially prepared iron-fortified cow's milk-based formulas are used. These formulas contain dairy ingredients such as whey protein concentrates, lactose and milk powders as well as other nutrients, and they are formulated to provide adequate nutrition.

Studies indicate that intake of calcium-rich foods, such as skim milk powder and other whey protein concentrates, during childhood and adolescence is an important determinant of achieving peak bone mass and minimizing future risk of osteoporosis.

During adulthood, intake of dairy foods and ingredients provides essential nutrients needed for body maintenance and protection against major chronic diseases such as osteoporosis, for example. Milk powder and whey protein concentrates furnish a generous supply of critical nutrients (easily digestible proteins, calcium) in relation to calories: an important factor when designing nutritional rations for pregnant and lactating women as well as seniors and HIV infected individuals.

Experimental studies indicate that cow's milk may help to increase bone strength and enhance immune function. Furthermore, several physiological roles have been either defined or suggested for minor whey proteins or peptides. These components can provide passive protection against infection, modulate digestive and metabolic processes, and act as growth factors for different cell types, tissues and organs.

Dairy Proteins: How They Compare

Nutritionally, cow's milk protein is considered to be high quality because it contains, in optimal amounts, all of the essential amino acids that our bodies cannot synthesize, in proportions similar to human essential amino acid requirements.

For many years the standard to determine protein quality was the Protein Efficiency Ratio, or PER. The standard protein, casein, had a PER of 2.7. Any protein with a PER greater than 2.7 is regarded as an excellent quality protein. In 1993, the FDA replaced the PER with the Protein Digestibility-Corrected Amino Acid Scoring, or PDCAAS, method. If the PDCAAS is greater than or equal to 1.00, the protein is a good source of essential amino-acids.

The tables in this text are presented to help compare dairy proteins with other proteins. Detailed information on protein requirements and quality evaluation methods is available from the Food and Agriculture Organization (www.fao.org) and the United Nations University (www.unu.edu/unupress/).

Protein Source	BV	PER	NPU
Whey protein concentrate	104	3.2	92
Whole egg	100	3.8	94
Cow's milk	91	3.1	82
Beef	80	2.9	73
Casein	77	2.7	76
Soy protein	61	2.1–2.2	61

BV: Biological value, PER: Protein efficiency ratio, NPU: Net protein utilization.
Sources: FAO, USDA, National Dairy Council.

The Protein Digestibility Corrected Amino Acid Score (PDCAAS) measures the protein quality, based on the amino-acid requirements of humans. Criteria needed for PDCAAS are approximate nitrogen composition, essential amino acid profile and true digestibility. Whey proteins have a higher score than virtually all other protein sources.

PDCAAS of Key Protein Sources

Ingredient	PDCAAS
Milk*	1.23
Whey protein*	1.15
Egg white	1.00
Soybean protein	.94
Whole wheat-pea flour (**)	.82
Chick peas (garbanzos)	.69
Kidney beans	.68
Peas	.67
Sausage, pork	.63
Pinto beans	.61
Rolled oats	.57
Black beans	.53
Lentils	.52
Peanut meal	.52
Whole wheat	.40
Wheat protein (gluten)	.25

Source: FAO, except for * European Dairy Association/ U.S. National Dairy Council (from UNRA, France. Unpublished data).
**An example of mutual supplementation. Combining whole wheat and pea flours yields a protein with a higher PDCAAS than that of either product alone.

Typical Calcium Concentration of Major U.S. Dairy Ingredients

Dairy Ingredients	Typical Calcium Content in mg/100 g
Whey protein concentrate	500–700 mg/100 g
Whey protein isolate	600 mg/100 g
Sweet whey	700–800 mg/100 g
Whey permeate	800–900 mg
Mineral-concentrated whey	>5,000 mg/100 g
Whole milk powder	950–1,000 mg/100 g
Skim milk powder	1,300 mg/100 g
Milk minerals	23,000–28,000 mg/100 g

Calcium in Dairy Ingredients and Milk Minerals

Milk powders are an excellent source of calcium and can be used for fortification purposes. Milk minerals can be extracted from the whey stream, yielding a product that contains about 80% minerals, 10% lactose and 5% protein. "Milk calcium" is a product that contains minerals (up to 28% calcium, 13.5% phosphorus, 1.4% magnesium and 0.8% potassium) that are balanced for optimal bone health and with good bioavailability. Several recent studies have shown that milk minerals are an optimal form of calcium supplementation because they not only provide calcium, but also key minerals (magnesium, potassium, zinc) that are critical to bone-building.

Milk calcium has a protective role against osteoporosis. Studies have demonstrated that the calcium absorption efficiency from non-dairy fortified sources was 25% less than that from a dairy source. Nutritionists can not only use milk calcium as an ingredient for fortification purposes, but can also take into consideration other mineral-rich dairy ingredients when formulating products and rations.

Health Enhancing Benefits of Dairy Ingredients

Individual milk proteins have been shown to exhibit a wide range of beneficial functions including enhancing calcium absorption and immune function. The antimicrobial mechanisms of whey proteins such as immunoglobulins, lactoferrin, lactoperoxidase, lysozyme and glycomacropeptide are now well documented. Immunogloblulins from milk and whey have a prophylactic and therapeutic effect (clinically established in human adults) against specific micro-organisms causing diarrhea, gastritis and dysentery.

Studies have also documented the benefits of whey protein isolates for HIV patients. HIV patients who consumed whey protein isolates exhibited substantial reduction in virus activity and increased survival expectancy. Numerous studies have shown that whey proteins help enhance the body's immune system by raising glutathione levels. Glutathione is a powerful anti-oxidant with the ability to help the body reduce the risk of infections by improving the responsive ability of the immune system. Individuals with HIV often have reduced levels of glutathione, which negatively affects their immune system. These individuals need a "boost" to their immune system, which they can obtain from a diet rich in whey proteins. The newest research included feeding HIV-infected patients with 45 g of whey proteins for 6 months in a double blind clinical trial. The study concluded that supplementation with whey proteins persistently increased plasma glutathione levels in patients with advanced HIV infections and that the treatment was well tolerated.

9.3 U.S. GRADES: WHAT DO THEY MEAN?

Please refer to the Standards section of this manual for more information (see Section 4).

U.S. suppliers of milk powders voluntarily participate in the U.S. standards for milk powders grading system.

"Extra Grade" indicates the highest quality milk powder. It should be free from lumps, except those that break up readily under mild pressure. "Standard Grade" includes all milk powder that fails in one or more of the particulars to meet the requirements of "Extra Grade." It may contain small to moderate lumps.

The Commodity Credit Corporation only purchases extra grade nonfat dry milk powder. Most of the supply is low heat milk powder, the rest consists of medium and high heat product.

Copies of the United States Standards for Milk Powders are available from www.usda.gov or the U.S. Dairy Export Council. A commodity fact sheet for nonfat dry milk under USDA's food aid programs is available at www.fas.usda.gov.

Typical Applications, Benefits of Milk Powders and Usage Recommendations

Category	Functional Benefits	Nutritional Benefits	Typical Usage Level (by weight)	Type of Milk Powder to be Used
Bakery	Color and flavor development, Increased appeal, Improved texture, Shelf-life increased.	High lysine content complements plant protein, improves biological value.	Flat breads: 0.5% Naans: up to 2% Baking mixes: 2–3% Bread: 0.5% Biscuits, crackers: 2–4% Cakes: 2–3% Pastries:2–3% Tortilla: 1–2%	High heat SMP, WMP
Confectionery	Flavor and color development, emulsification where applicable.	Increases protein and calcium density.	Chocolate coatings 15% Caramel: 4–5% Icing, fillings: 2–5%	Medium heat SMP
Dairy	Source of dairy solids: Stabilizes, gels, binds water, enhances flavor/aroma.	Increases protein and calcium density.	Dairy drinks*, fluid milk cultured milks yogurt, kefir, quark, koumiss, soft fresh cheeses	Low to medium heat SMP
Processed foods	Improves texture in processed or imitation meats, enhances texture, flavor and visual appeal in dry, mixes (soups, sauces). Can mask off-flavors.	High lysine content complements plant protein, improves biological value. Can significantly increase calcium content.	Soups and sauces (dry mixes): 7–10% Processed meats: 5–10%	Medium heat SMP, high heat SMP, WMP Medium heat SMP
Nutritional products	Stabilizes beverages, emulsions, increases opacity, binds ingredients.	Source of high-quality proteins, calcium, magnesium, phosphorous and bioactive components.	Nutrition bars and cereal mixes: 5–25% Infant formula:** 15–35% Follow-up, senior drink mixes: >50% Flavored, enriched mixes: >70–80%	Low heat SMP, instantized SMP

*Milk powders can be used as sole solids source (100%) or for fortification purposes (10% of total weight). Guidelines for reconstitution are available from the U.S. Dairy Export Council.
**Please refer to policies and statements listed on pages 64-65.

Classification of Milk Powders and Pre-heat Treatment Used for Manufacture

Type of Powder	Undenatured Whey Protein (mg/g of powder)	Typical Heat Treatment Conditions	Major Applications for Food Assistance Programs
Low heat	≥6	72–75°C, 15–20 sec	Fluid milk fortification, recombined milks and beverages, cultured products, drinks, nutritional mixtures and blends
Medium heat	1.51–6.0	85–105°C, 1–2 min	Prepared mixes, confectionery, ice cream, recombined milk products, nutritional blends
High heat	≤1.5	125–135°C, 2–6 min	Bakery products, processed foods, meat products

9.4 STORAGE RECOMMENDATIONS

Nonfat dry milk or skim milk powder (SMP) has low moisture and fat contents and, when stored in dry, cool conditions, has a shelf life in excess of two years. Specifically, when stored at 15°C and a relative humidity of 75%, skim milk powder has a minimum shelf life of two years, an average shelf life of three years and a maximum shelf life of four years.

Milk powders are hygroscopic: they tend to attract water readily from humid atmospheres. When moisture levels are excessive, milk powders may become sticky, caked or lumpy, and exhibit reduced flowability and solubility. These changes affect the ease of use of the product, requiring grinding for example, and may affect the flavor, but do not represent a health or safety problem. If the powder's moisture content exceeds 15%, the powder then becomes susceptible to microbiological growth and should not be used.

Skim milk powder should have a mild flavor and aroma. After extended storage, some milk powder may develop slight off-flavors. These may be noticed in rehydrated or "recombined" milk products. However, milk powders for use as ingredients in manufactured foods and dry blends generally do not need to meet high of standards, such as palatability and redispersibility.

Dried skim milk products stored in optimal conditions in proper packaging show essentially no change in color, even during two years of storage at 35°C. In commercial situations, most dried milk products are susceptible to reactions that can result in small changes in the physical properties of the product, its palatability and nutritive value. These changes, however, do not significantly impact the nutritional benefits of milk powders. Vitamin and protein quality losses during storage of milk powders, when stored in good conditions, are negligible.

Skim milk powder should be stored in sanitary, cool, dry conditions, away from strong odors. Milk powders from bags that have been opened or damaged during transit or storage, or that appear spoiled, contaminated or tampered with in any fashion should never be used.

9.5 RESOURCES FOR PRIVATE VOLUNTARY ORGANIZATIONS

Suppliers: Information on U.S. dairy exporters is available on USDEC's website (www.usdec.org), which features direct links to the organization's members.

The U.S. Dairy Export Council (www.usdec.org) provides in-depth information on U.S. dairy ingredients, formulations, specifications and a link to U.S. suppliers of these products. Free technical manuals, in English, Spanish, Russian, Chinese and several foreign languages, and CD-ROMS are available from USDEC upon request. Information can also be downloaded from USDEC's website.

The American Dairy Products Institute (www.adpi.org) provides access to ordering information for the Institute's publications such as standards for grades and methods of analysis.

The food composition database of the **U.S. Department of Agriculture** (www.nal.usda.gov/fnic/foodcomp/) provides detailed nutritional information on all dairy products (including detailed mineral, vitamin, fatty acid contents).

Dairy Management Inc. (www.dairyinfo.com) provides direct links to:

www.doitwithdairy.com: specification information for, and formulations using milk powder and whey ingredients. Information for food processors and technologists.

www.nationaldairycouncil.org: a resource for current scientific research that supports the health benefits of dairy foods, or to locate basic dairy nutrition facts. Information for health professionals and consumers.

www.nutritionexplorations.org: nutrition information for educators and parents. Includes materials in Spanish.

For information on specific food aid programs administered by the **United States Department of Agriculture** or the **U.S. Agency for International Development**, and specifications for dairy ingredients under these programs, please consult, respectively, www.fas.usda.gov and www.usaid.gov.

The U.S Agency for International Development has a breastfeeding promotion policy, related policies, and a number of important policies on skim milk powder (nonfat dry milk).

USAID's breastfeeding promotion policy states that "the sub-committee on nutrition has concluded that breastfeeding remains the best source of nutrition for the great majority of infants and should continue to be promoted and supported among mothers who are not known to be HIV-infected. They have also recommended that, when considering infant feeding options for mothers who test positive for HIV, replacement feeding (RF) (nutritionally complete breastmilk substitutes) should be considered only if acceptable, feasible, affordable, sustainable and safe. Other international health documents stress that, in areas of high infectious disease burden, the accessibility, affordability, and services of the health care systems must be of sufficient quality to adequately address the increase associated with less-than-optimal breastfeeding."

USAID has reintroduced the blended commodity corn-soy milk, containing 15% skim milk powder (nonfat dry milk). Additional information and updates are available at: www.usaid.gov.

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10.1 BAKERY APPLICATIONS FOR MILK POWDERS*

U.S. *product developers and manufacturers benefit from the nutritional, functional and economical attributes of high-quality* U.S. *milk powders on a year-round basis.*

Bakery products are an ideal application for milk powders. In the United States, 7.6% of all skim milk powder, 6.4% of all whole milk powder and 30.6% of all buttermilk powder is used directly in bakery products. A significant percentage of milk powders used in dry blends are also used for bakery products.

Benefits of Milk Powders in Bakery Products

Milk powders assist product developers in the formulation of a variety of bakery products. Milk powders provide flavor and functionality in bakery items like biscuits, breads, cakes, cookies and muffins. U.S. bakers include high-quality U.S. milk powders in formulation because of the nutritional, functional and economical benefits milk powders add to bakery products. In addition, manufacturers are assured of a consistent, year-round supply of U.S. milk powders.

Increased Nutritional Value

Milk powders deliver exceptional nutritional value to bakery products. They are a source of high-quality protein, with the amino acids readily digestible and completely bio-available. Milk powders are high in soluble vitamins and minerals including calcium, phosphorus, and magnesium, and can be used to fortify bakery products. (Only 100 g of skim milk powder contains 1,300 mg calcium.) Milk powders contribute to a healthy image and a clean ingredient label.

Emulsification

The proteins in milk powders can successfully act at oil/water interfaces to form and stabilize emulsions. The lecithin present in milkfat also assists in stabilizing emulsions.

Water Binding

Undenatured dairy proteins are able to form rigid, heat-induced, irreversible gels. Water-binding capacity refers to the water held in a gel under a given set of conditions. This water, enclosed in the gel's three-dimensional structure, can reduce the cost of food (water is inexpensive) and improve sensory perception.

The water-binding capacity of a dough can have a significant effect on machinability. Water retention also affects the texture and perceived freshness of bakery products, with moistness implying freshness.

Foaming

Formation of foams is very important in bakery products and is similar to the formation of an emulsion. Foaming is defined as the creation and stabilization of gas bubbles in a liquid. As dairy protein concentration increases, foams become denser with more uniform air bubbles of a finer texture.

Foams improve the structure and texture of bakery products such as cakes and muffins. The most challenging test of foaming properties is the ability of the protein foam to hold up and set during the baking process, as is necessary in angel food cake.

When bakers use skim milk powder to provide structure, high-heat skim milk powder is the ingredient of choice. Structure development in bakery products is inversely correlated to the undenatured whey protein nitrogen (WPN) value in skim milk powder (the lower the WPN value, the greater the foaming functionality). High-heat skim milk powder prevents loaf volume depression in breads. On the other hand, low-heat skim milk powder reduces dough extensibility and gives poor loaf volume.

Browning/Color

The lactose and protein present in milk powders contribute, through the Maillard browning reaction, to the golden brown color in bakery products. During baking, the protein's amine groups react with lactose and other reducing sugars present in the formulation, delivering an appealing color while also contributing to flavor.

Flavor/Aroma

Milk powders contribute a subtle, pleasant dairy flavor and aroma to bakery products. Very little flavor comes from the dairy proteins, which are quite bland and contribute no foreign or off-flavors. Most of the flavor comes from the milkfat in whole milk powder, which adds richness to certain bakery products. Milkfat also acts as a flavor carrier for fat-soluble ingredients, spices, herbs and sweet flavors. Milkfat's low melting point ensures complete flavor release.

Also, during the baking process, the lactose present in milk powders reacts with dairy proteins leading to the production of different flavors including sour organic acids balanced by sweet and bitter substances.

*All the formulas provided in this section are for demonstration purposes and as a starting point for product development efforts. Adjustments may be required. Please check local regulations for the use of product names and specific ingredients. For further assistance, please contact U.S. suppliers or the U.S. Dairy Export Council.

10.2 BAKERY FORMULATIONS

The following formulas do not represent all the applications or the only potential formula for the application. Product developers are encouraged to modify formulas and evaluate other applications perceived appropriate to their product line and market.

Biscuits

Ingredients	Usage Level (%)
Flour	45.60
NFDM	4.10
Whey protein concentrate	4.00
Baking powder	2.90
Salt	0.90
Water	27.50
Vegetable oil	15.00
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Combine flour, whey protein concentrate, NFDM, baking powder and salt.
2. Add water and oil.
3. Stir quickly with fork, just until dough is mixed.
4. Drop dough by spoonfuls on ungreased baking sheet.
5. Bake in preheated 232°C (450°F) oven for 10 to 12 minutes, until brown.

Bread, White

Ingredients	Usage Level (%)
Flour, bread	54.20
Water	37.20
Sugar, granulated	3.30
Shortening	2.00
Dry whey	1.10
Salt	1.00
Yeast	0.70
Whole milk powder	0.50
Total	**100.00**

Procedure:

1. Combine and mix all dry ingredients on low speed for 3 minutes.
2. Add shortening and water, mixing on low speed for 2 minutes.
3. Mix on medium speed for 11-22 minutes or until dough passes gluten test (when pulled dough stretches with no rough tearing).
4. Proof dough, about 32°C (90°F), until double in size, about 1 hour.
5. Shape into loaves and place in greased loaf pans. Allow to full proof until double, about 30-45 minutes.
6. Bake at 204°C (400°F) for 20-30 minutes.

Cake, Yellow Layer

Ingredients	Usage Level (%)
Flour, cake	27.13
Sugar, granulated	27.13
Water	17.85
Eggs, liquid	13.32
Shortening	11.10
Skim milk powder	2.22
Vanilla (2x)	0.55
Salt	0.55
Baking powder	0.15
Total	**100.00**

Procedure:

1. Lightly cream sugar, salt, skim milk powder and shortening.
2. Add cake flour and water. Blend on low speed until smooth.
3. Add egg in three stages. Blend well.
4. Add flavor and baking powder with final egg. Mix well.
5. Bake at 190°C (375°F) for 25 minutes.

Cookies, Sugar

Ingredients	Usage Level (%)
Flour, all purpose	41.79
Sugar	22.82
Butter	14.71
Water	8.35
Eggs	5.59
Whole milk powder	3.05
Skim milk powder	2.50
Vanilla	0.70
Salt	0.35
Baking powder	0.14
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Cream butter with sugar.
2. Add vanilla, eggs and water.
3. Add dry ingredients, mix until well blended.
4. Chill dough for 1 hour.
5. Roll out, 1.25 cm (1/2 inch) thickness, cut into rounds.
7. Bake at 190°C (375°F) for 8 to 10 minutes.

Crackers

Ingredients	Usage Level (%)
Flour, bread	55.78
Water	17.33
Butter	12.89
Egg	10.01
Whole milk powder	2.52
Salt	1.11
Baking powder	0.36
Total	**100.00**

Procedure:

1. Sift flour, salt and baking powder together.
2. Add butter, milk, and egg. Mix to make stiff dough.
3. Knead and roll the dough very thin (about 3.2 mm thick).
4. Cut into squares or rounds and place on parchment-lined baking sheets. Prick crackers with fork.
5. Bake at 204°C (400°F) for 10 minutes.

Croissants

Ingredients	Usage Level (%)
Water	27.4
Flour, bread	26.50
Butter (roll-in)	19.83
Flour, high-gluten	17.68
Skim milk powder	3.41
Sugar, granulated	2.55
Yeast, compressed	1.77
Salt	0.86
Total	**100.00**

Procedure:

1. Pre-blend dry ingredients in an industrial mixer with bowl and dough hook at #1 speed for 1 minute.
2. Add water and yeast: mix at #1 speed for 1 minute and #2 speed for 3 minutes. Final dough temperature should be 16°C (60°F).
3. Remove dough from mixing bowl and pre-shape into a rectangular form.
4. Cover dough and allow it to rest 20 minutes before sheeting (to 12.5 mm thickness).
5. Apply roll-in butter to the surface of 2/3 of the dough.
6. Three fold, rest 20 minutes; four fold, rest 30 minutes; three fold and retard overnight.
7. Bake at 176°C (350°F) for 14 minutes.

Doughnuts, Cake-type

Ingredients	Usage Level (%)
Flour, all purpose	39.32
Water	31.40
Sugar	15.85
Vegetable oil	3.88
Soy flour, defatted	3.88
Skim milk powder	2.00
Baking powder	1.73
Salt	0.62
Egg yolk, dried	0.52
Vanilla	0.36
Whey protein concentrate-80%	0.35
Lecithin	0.09
Total	**100.00**

Procedure:

1. Cream oil, sugar and salt.
2. Sift all the dry ingredients together.
3. Mix the above mixtures at low speed until well blended.
4. Add water to the combined mixes and blend for 2 minutes on medium speed.
5. Fry in an oil bath held at 176°C (350°F), turning as needed to secure completed and even browning.

Muffins

Ingredients	Usage Level (%)
Flour, cake	30.15
Water	23.70
Sugar	19.65
Butter, melted	12.45
Eggs	9.35
Skim milk powder	2.35
Baking powder	1.55
Salt	0.40
Vanilla (2x)	0.40
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Mix dry ingredients, set aside.
2. Blend melted butter, eggs and vanilla.
3. Add dry ingredients to wet ingredients, mixing just until incorporated.
4. Spoon 75 g of batter into muffin cups.
5. Bake at 196°C (385°F) for 15 minutes.

Pancakes, Buttermilk

Ingredients	Usage Level (%)
Water	50.50
Flour, all-purpose	24.50
Eggs	10.55
Vegetable oil	5.90
Buttermilk powder	4.85
Sugar, granulated	2.50
Baking powder	0.90
Salt	0.30
Total	**100.00**

Procedure:

1. Combine all dry ingredients.
2. Add beaten egg, water and oil. Mix until homogenous.
3. Pour onto griddle in 43 g portions. Flip once to brown on both sides. Pancakes are ready to turn when they bubble and edges look slightly dry.

High Protein Chocolate Chip Cookie

Ingredients	Usage Level (%)
Brown sugar	20.85
Whey protein concentrate-80%	17.85
Pastry flour	17.85
Chocolate chips	17.35
Butter	12.65
Water	9.00
Eggs	2.50
Skim milk powder	1.25
Vanilla extract	0.30
Salt	0.20
Sodium bicarbonate	0.20
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Cream butter with sugar.
2. Add vanilla and eggs.
3. Add dry ingredients, mix until blended.
4. Add chocolate chips.
5. Bake at 190°C (375°F) for 8 to 10 minutes.

Savory Cheese Scone

Ingredients	Usage Level (%)
Flour, all purpose	37.55
Water	22.85
Cheddar cheese	15.45
Butter	13.10
Whole egg powder	4.60
Skim milk powder	2.05
Baking powder`	1.90
Hard grating cheese	1.85
Salt	0.60
Spice	0.05
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Combine the flour, egg powder, skim milk powder, baking powder, and salt in a mixing bowl.
2. Stir well with a fork to mix and aerate.
3. Add the butter and cut into the flour mixture, using a pastry blender or two knives, or work in, using your fingertips, until the mixture looks like bread crumbs.
4. Add the cheeses and spice, mix lightly.
5. Add the water, mix only until the dry ingredients are moistened.
6. Gather the dough into a ball and press so it holds together. Turn the dough out onto a lightly floured surface. Knead lightly 12 times. Pat the dough into a circle 1.25 cm (1/2 inch) thick.
7. Cut the dough onto pie-shaped pieces, place 2.5 cm (1 inch) apart on baking sheet.
8. Bake at 225°C (450°F) for about 12 minutes or until the tops are browned. Serve hot.

11.1 CONFECTIONERY APPLICATIONS FOR MILK POWDERS*

U.S. *product developers and manufacturers benefit from the nutritional, functional and economical attributes of high-quality* U.S. *milk powders on a year-round basis.*

In the United States, 78.6% of all whole milk powder and 14.3% of all buttermilk powder are used directly in confections. Milk powders are a critical ingredient in the formulation of milk chocolate candy, nougats, frosting, and creams.

Benefits of Milk Powders in Confectionery Products

Milk powders assist product developers in the formulation of a variety of confectionery products. Milk powders provide flavor and functionality in confectionery items like caramels and icings.

U.S. confectioners include high-quality U.S. milk powders in formulations because of the functional and economical benefits milk powders add to confectionery products. In addition, manufacturers are assured of a consistent, year-round supply of U.S. milk powders.

*All the formulas provided in this section are for demonstration purposes and as a starting point for product development efforts. Adjustments may be required. Please check local regulations for the use of product names and specific ingredients. For further assistance, please contact U.S. suppliers or the U.S. Dairy Export Council.

Emulsification
The proteins in milk powders can successfully act at oil/water interfaces to form and stabilize emulsions. The lecithin present in milkfat also assists in stabilizing emulsions.

Gelation
Undenatured dairy proteins are able to form rigid, heat-induced, irreversible gels that hold water and fat, and provide structural support to confections. Two types of aggregates can form: linear or globular. The type of aggregation affects the gel's opacity, an important property in confections.

Water Binding
Water-binding capacity refers to the water held in a gel under a given set of conditions. This water, enclosed in the gel's three-dimensional structure, can reduce the cost of food (water is inexpensive) and improve sensory perception. The firm, chewy texture of several confections is related to the binding of water by casein.

Foaming
Formation of foams is very important in confections and is similar to the formation of an emulsion. Foaming is defined as the creation and stabilization of gas bubbles in a liquid. As dairy protein concentration increases, foams become denser with more uniform air bubbles of a finer texture. The incorporation of air is important in confections such as nougat, frosting and various creams.

Browning/Color
The lactose and protein present in milk powders contribute, through the Maillard browning reaction, to the caramelized color associated with many confections. During heating, the protein's amine groups react with lactose and other reducing sugars present in the formulation, delivering an appealing color while also contributing to flavor.

Flavor/Aroma
Milk powders contribute a subtle, pleasant dairy note and aroma to confections. Very little flavor comes from the dairy proteins, which are quite bland and contribute no foreign or off-flavors. Most of the flavor comes from the milkfat, which adds richness to certain confections. Milkfat also acts as a flavor carrier for fat-soluble ingredients and various flavors. Milkfat's low melting point ensures complete flavor release.

Also, during the cooking process, the lactose present in milk powders reacts with dairy proteins leading to the production of different flavors.

11.2 CONFECTIONERY FORMULATIONS

The following formulas do not represent all the applications or the only potential formula for the application. Product developers are encouraged to modify formulas and evaluate other applications perceived appropriate to their product line and market.

Caramel Candy

Ingredients	Usage Level (%)
Sugar, granulated	35.40
Sweetening syrup	34.00
Partially hydrogenated coconut oil	12.00
Water	7.00
Skim milk powder	4.20
Dry sweet whey	4.20
Butter	3.00
Lecithin	0.10
Salt	0.10
Total	**100.00**

Procedure:

1. Combine all ingredients and mix on high speed for 5 minutes.
2. Cook to 120°C (248°F). Pour onto silicone paper. Cover with plastic wrap and cool.

Chocolate Candy/Coating

Ingredients	Usage Level (%)
Sugar, granulated	46.00
Cocoa butter	19.75
Skim milk powder	15.00
Chocolate liquor	13.00
Anhydrous milkfat	6.00
Lecithin	0.25
Total	**100.00**

Procedure:

1. Blend skim milk powder, chocolate liquor, sugar and half of the cocoa butter in a heavy-duty mixer.
2. Refine the paste on a three-roll or five-roll refiner to 20-30 micron particle size.
3. Add the lecithin, remaining cocoa butter and anhydrous milkfat.
4. Conch in a hot-jacketed mixer until desired taste and viscosity are obtained.
5. Temper and cast into molds or use to enrobe or dip centers.

Icing, Fudge

Ingredients	Usage Level (%)
Sugar, powdered (10x)	57.36
Water	29.40
Cocoa powder	5.86
Butter	5.05
Skim milk powder	2.20
Salt	0.13
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Mix sugar, cocoa, milk and butter with a paddle blender.
2. Combine water, butter and salt over heat. Bring to a boil.
3. Beat liquid mixture into solid mixture. Beat until smooth.

Icing, Reduced-fat Vanilla

Ingredients	Usage Level (%)
Sugar, powdered (10x)	68.60
Water	14.30
Shortening	9.50
Skim milk powder	4.00
Whey protein concentrate-80%	1.70
Starch	1.30
Butter flavor	0.30
Vanilla (2x)	0.30
Total	**100.00**

Procedure:

1. Blend dry ingredients on #1 speed in a mixer fitted with paddle attachment.
2. Add shortening and blend uniformly.
3. Add hot tap water (60°C) and vanilla. Mix on #2 speed to achieve a smooth, uniform consistency.

Frosting, Chocolate

Ingredients	Usage Level (%)
Powdered sugar	70.30
Butter	13.00
Boiling water	10.30
Cocoa powder	5.50
Vanilla extract	0.60
Skim milk powder	0.20
Salt	0.10
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Mix powdered sugar, skim milk powder, salt and cocoa powder.
2. Add boiling water, butter and vanilla.
3. Beat with mixer on low until mixed.
4. Beat on medium for 1 minute.

Frosting, Vanilla

Ingredients	Usage Level (%)
Powdered sugar	77.00
Butter	10.60
Boiling water	10.25
Skim milk powder	1.15
Vanilla extract	1.00
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Mix powdered sugar and skim milk powder.
2. Add boiling water, butter and vanilla.
3. Beat with mixer on low until mixed.
4. Beat on medium for 1 minute.

12.1 DAIRY AND RECOMBINED MILK APPLICATIONS FOR MILK POWDERS*

U.S. *product developers and manufacturers benefit from the nutritional, functional and economical attributes of high-quality* U.S. *milk powders on a year-round basis.*

The largest use of milk powders world-wide is in dairy foods and recombined milk products. In the United States, 65.4% of all skim milk powder, 1.1% of all whole milk powder and 31.5% of all buttermilk powder is used directly in dairy foods and recombined milk products.

USE OF TERMS

The terms nonfat dry milk (NFDM) and skim milk powder (SMP) are used as synonyms in many sections of this manual. Refer to Section 4 for compositional standards for each product. Please note that NFDM and SMP may have different protein contents, hence different functionality. Please contact your supplier for more information.

*All the formulas provided in this section are for demonstration purposes and as a starting point for product development efforts. Adjustments may be required. Please check local regulations for the use of product names and specific ingredients. For further assistance, please contact U.S. suppliers or the U.S. Dairy Export Council.

Benefits of Milk Powders in Recombined Milk Products

Recombined milk products can be made from a combination of skim milk powder and anhydrous milk fat; skim milk powder, buttermilk powder and anhydrous milk fat; whole milk powder and skim milk powder; or by simply using whole milk powder. Cream powder or emulsifiers are typically added to those formulations.

Water Binding

Research indicates that water binding increases as the concentration of denatured whey proteins increases. Therefore, when selecting skim milk powder strictly for its water-binding capacity, choose varieties that are highly denatured, i.e. high heat skim milk powder.

Whipping/Foaming

Formation of foams is very important in dairy products like ice cream. Foaming is defined as the creation and stabilization of gas bubbles in a liquid. As dairy protein concentration increases, foams become denser with more uniform air bubbles of a finer texture.

Color

Milk powder enhances the appearance of dairy foods, particularly reduced-fat products. Removing fat from dairy foods results in changes in the product's appearance, specifically whiteness and opacity, because milkfat globules reflect light and provide whiteness. Milk powders restore an appealing look to reduced-fat dairy foods by providing opacity.

Flavor/Aroma

Milk powders enhance the dairy flavor of dairy foods. Very little flavor comes from dairy proteins, which are quite bland and contribute no foreign or off-flavors. Most of the flavor comes from the milkfat, which adds richness to certain dairy products. Milkfat also acts as a flavor carrier for fat-soluble ingredients, spices, herbs and sweet flavors.

By far, the largest use for milk powders is recombined dairy products, with more than one third of total world production being exported for this use.

Recombined milk products are defined as the milk products resulting from the combining of milkfat and milk-solids-nonfat, with or without water. This combination must be made so as to re-establish the product's specified fat-to-solids-nonfat ratio and solids-to-water ratio. The term "filled" is used when all or some of the milkfat is replaced with vegetable oil.

Recombination is used in countries with an insufficient milk supply for its population, or its milk supply is seasonal and needs supplementations. Furthermore, because refrigeration capabilities in such countries are less available, products that do not require refrigeration, such as recombined evaporated milk and recombined sweetened condensed milk, are very appealing. Recently, production of other recombined dairy products such as recombined ultra-high temperature pasteurized (UHT) milk, recombined soft cheese and recombined yogurt, have increased in volume. All such applications require a specific functionality and quality of milk powder.

Ingredient Selection

The traditional approach to the manufacture of recombined milk products is to use skim milk powder and anhydrous milkfat. However, the fat source could also be frozen, unsalted butter, but this is somewhat inconvenient to handle. With recent improvements in the keeping quality of whole milk powder, it too can be used in recombined milk products. Whichever powder is chosen, the higher the heat treatment used in its manufacture (i.e. the lower the whey protein nitrogen index), the better the oxidative stability will be of the recombined product. This results from the formation of sulphydral groups during the heat treatment, which act as natural antioxidants.

In some recombined milk products, 5-12% of the skim milk powder is replaced by buttermilk powder to provide a more balanced flavor. Buttermilk powder also contains phospholipids, which are not present in either skim milk powder or anhydrous milkfat. By using buttermilk in the manufacture of a recombined milk product, it will contain all the major components of the real milk product the recombined product represents. Because phospholipids contain unsaturated fatty acids that can auto-oxidize and produce off-flavors, many product developers prefer to formulate recombined dairy products without buttermilk powder.

Recombined Milk Product

Other ingredients used in the formulation of recombined milk products include a country's local milk or cream supply, and, where permitted, vegetable oils such as coconut or palm. However, vegetable oils, because of their high degree of unsaturated fatty acids, easily oxidize, creating different types of formulation and storage problems.

Recombination Process

The recombination process begins with dispersion of skim milk powder in water at 40-50°C (104-122°F). Water quality is important and should be checked routinely, especially if it is ground water. Chemical, physical, biological and radiological minimum and maximum levels for water must be established.

Powder is fed into the water via a hopper with care taken to avoid air incorporation, which causes foaming. Various techniques are used to add the powder to the water. The most common method is to empty the milk powder bags in a dry room with a dust removal system, because a great deal of dust is generated in this step.

It is important to use milk powders that possess the specific properties that the recombined milk product requires. For example, fluid milk requires a medium to low-heat skim milk powder (WPN >3.5) because high-heat products may yield an undesirable cooked flavor.

Reconstituted milk powders need a minimum of 15 to 20 minutes hydration time in order to minimize any chalky or powdery mouthfeel. Sometimes prior to further processing, manufactures hold the reconstituted milk overnight at 4°C (39°F) to ensure full hydration.

Reconstituted powders are pumped through a duplex filter to separate out any undissolved milk powder particles and any other extraneous matter. From here the process varies according to the product being made. (See following pages.)

12.2 RECOMBINED FLUID MILK

Traditional whole cow's milk typically has a slightly higher level of fat than recombined fluid full-fat milk products. Sometimes the level of solids-nonfat is increased to 10% to improve nutrition and flavor.

Typical Composition of Recombined Fluid Full-fat Milk

	Traditional Whole Milk	Recombined Full-fat Milk
Fat	3.5%	3.0%
Solids-nonfat	8.5%	10.0%
Total solids	**12.0%**	**13.0%**

Powder Requirements

Whey protein nitrogen	>3.5 low heat to low medium heat
Solubility index	<0.25 ml clean dairy flavor
Microbial	Good quality
Pyruvate test	<90 mg/kg powder*

*The pyruvate test is important in the manufacture of UHT milk because proteolytic and lipolytic enzymes are not destroyed by ultra-high temperature pasteurization. If pyruvate is present in large amounts, it will cause bitter flavors to develop.

Low heat skim milk powder yields a better initial flavor in recombined fluid milk than powder with a whey protein nitrogen value less than 6.0. However, the keeping quality of long life milk is not as good when low heat skim milk powder is used.

Process

The skim milk powder (and buttermilk powder, if used) is dissolved in water at 40-50°C (104-122°F). Hydration time must be at least 20 minutes; however, overnight hydration at temperatures less than 6°C (43°F) is recommended. Some form of de-aeration may be needed before homogenization. After hydration, the milk is heated to 60-65°C (140-149°F) and the butteroil (or frozen unsalted butter) is added. The product is homogenized at 17 MPa in a one stage homogenizer or in a two stage homogenizer at pressure of between 14-24 MPa first stage and 2-7 MPa second state. After homogenization, the milk is pasteurized (72°C (161°F)/15 sec) and cooled to 4-6°C (39-43°F) before blending and packing.

A typical heat treatment for sterilized milk is 120°C (248°F) for 10 minutes. This kills microorganisms and bacterial spores, while also deactivating enzymes. Unfortunately, the severe heat treatment does reduce the nutritive value of the milk. It's particularly detrimental to the water-soluble vitamins and the amino acid lysine. The most noticeable defect for those consumers accustomed to fresh milk is the strong cooked flavor.

Ultra-high temperature (UHT) pasteurization of milk is typically done at 140°C (284°F) for 4 seconds. This kills microorganisms and bacterial spores, while also deactivating enzymes. This heat process maintains desirable nutritive and flavor milk qualities so that it more closely resembles fresh milk. The UHT processing equipment and the aseptic filling unit do not normally run at the same speed so it is necessary to either have an aseptic buffet tank or to recycle surplus milk back into the process.

12.3 RECOMBINED CHEESE AND CULTURED MILK PRODUCTS

The nature and composition of recombined cheese and cultured milk products varies considerably according to local tastes. Soft cheeses with high moisture content, bland or acid flavor, tender bodies and open texture are more successfully produced using recombined milk than are structured cheese.

Cheeses that have been successfully manufactured using recombined milk include Feta, Domiati, Kashkaval and Haloumi. Cultured products such as yogurt and cottage cheese can also be made with recombined milk. Flavors and sweeteners are selected on the basis of masking the undesirable cooked flavor that comes from the high heat skim milk powder typically used in recombined yogurt precuts.

Powder Requirements

Whey protein nitrogen for cheese	>4.5 preferably >6.0, low heat
Whey protein nitrogen for yogurt	<3.05 medium and high heat
Rennetability	Good
Fermentation	Non-inhibitory substances

For cheese, low heat skim milk powders provide more ionic calcium than high heat powders and minimum interaction of κ-casein with β-lactoglobulin. These affect the rate of milk coagulation, curd strength and syneresis. A rennet coagulum made from recombined milk using low heat skim milk powder has a higher curd tension than a coagulum made from high heat skim milk powder. Some manufacturers use additives such as calcium chloride or mono-calcium phosphate to improve the use of medium heat skim milk powder for cheesmaking because low heat powder is often in short supply.

For cultured products such as yogurt, viscosity and stability are important finished product criteria; therefore, powder selection is based on water-binding capacity. Medium to high heat milk powders provide the water binding capabilities required for optimum body consistency in recombined yogurt.

Process

After the reconstitution and recombining steps explained on the previous pages, manufacturing follows traditional cheese or yogurt making processes. Adjustments need to be made to compensate for the heat treatment and homogenization the milk has already received during the recombination process. For example, in cheesemaking, rennet temperatures should be increased in order to obtain better curd syneresis during draining of the vat. Some manufacturers concentrate the recombined milk using ultrafiltration, thus increasing the dry matter content to more closely resemble the dry matter content of the cheese to be produced.

12.4 RECOMBINED EVAPORATED MILK

Just like traditional evaporated milk, recombined evaporated milk has about 15% less moisture than the fluid milk from which it is made. It is typically canned and heat sterilized in order to extend shelf life.

Typical Composition of Recombined Evaporated Milk

	Traditional Whole Milk	Recombined Full-fat Milk
Fat	7.5%	7.8%
Solids-nonfat	17.7%	17.8%
Total solids	**25.2%**	**25.6%**

Powder Requirements

Whey protein nitrogen	High heat
Stability*	Heat stable

*Refers to the earlier comments on the heat stability test. This is done with a 20% dispersion of skim milk powder with and without the addition of disodium phosphate. The minimum coagulation time is 21 minutes if phosphate has been added.

Process

The skim milk powder is added via a hopper and mixed with water at 40-45°C (104-113°F). Foaming needs to be kept to a minimum. The mix is hydrated for 20 minutes or overnight at 4°C (39°F). The milk is then heated, the fat is added and it is homogenized at 50-70°C (122-158°F) at pressures of 20 MPa first stage and 3.5 MPa second stage. Disodium orthophosphate or monosodium orthophosphate is normally added to assist protein stability. After canning, the product is sterilized. Normal sterilization is 120°C (248°F) for 12 minutes followed by cooling to 32-35°C (90-95°F).

Sometimes carrageenan is incorporated into the mix with the skim milk powder. This reduces fat separation during storage. Also the product is often fortified with vitamins A and D prior to homogenization.

12.5 RECOMBINED SWEETENED CONDENSED MILK

Recombined sweetened condensed milk is typically made with milkfat; however, in Asia, it is often made using vegetable oil (filled). Just like traditional sweetened condensed milk, recombined sweetened condensed milk has about 70% less moisture than the fluid milk from which it is made. It is typically canned and heat sterilized in order to extend shelf life.

Process

Skim milk powder is dissolved in water using agitation to the highest possible level of total solids in order to obtain the best value. During agitation, the mix is heated to 40-60°C (104-140°F). Fat and sugar are added. The mixture is homogenized at 2-3.5 MPa (for a low viscosity product) or up to 7MPa (for higher viscosity), then heated at 80-90°C (176-194°F) for 30 seconds to 2 minutes and flash-cooled in a vacuum pan to 32°C (90°F). Sterile lactose hydrate crystals are added to promote lactose crystallization, and the product is cooled further before canning aseptically.

Typical Composition of Recombined Sweetened Condensed Milk

	Traditional Sweetened Condensed Milk	Recombined Sweetened Condensed Milk: Using Milkfat	Recombined/Filled Sweetened Condensed Milk: Using Vegetable Oil
Fat	8.0%	9%	7%
Solids-nonfat	64.8%**	33%	20%
Total solids	**72.8%****	**42%**	**Varies**

Powder Requirements

Whey protein nitrogen	Medium and low heat
Reconstitutability	Good
Viscosity*	As specified by the user
Age thickening ratio	1.5–2.0

*The viscosity of recombined and filled sweetened condensed milks varies by the amount and type of fat used during recombination.

12.6 DAIRY AND RECOMBINED MILK FORMULATIONS

The following formulas do not represent all the applications or the only potential formula for the application. Product developers are encouraged to modify formulas and evaluate other applications perceived appropriate to their product line and market.

Cheese Food, Pasteurized Process American

Ingredients	Usage Level (%)
Cheddar cheese	65.85
Water	19.50
Skim milk powder	5.00
Dry sweet whey	4.00
Sodium citrate	2.40
Cream, fluid sweet	2.00
Disodium phosphate	0.50
Salt	0.50
Sorbic acid	0.19
Color	0.06
Total	**100.00**

Procedure:

1. Grade, clean and pass cheese through a grinder to an approximate diameter of 25 mm.
2. Blend the ground cheese with color, sorbic acid and cream in an industrial mixer until uniform.
3. Add 1/3 of the water to the blender and mix until uniform.
4. Prepare a slurry of dry sweet whey and skim milk powder with 1/3 water.
5. Transfer the uniform cheese blend to a heating vessel and while agitating add phosphate and citrate emulsifiers and salt as the blend is being heated.
6. When the blend is about 60°C (140°F), slowly add the remaining water and the whey/skim milk powder slurry. Continue agitation.
7. Heat sufficiently to about 82°C (180°F) to ensure pasteurization.
8. Pour molten cheese food into a form. Cover. Seal. Cool.
9. Keep refrigerated during transfer, storage and distribution.

High Protein, Enriched Beverage Mix (Meal Replacement Type, Mocha Flavor)

Ingredients	Usage Level (%)
Fructose and sucrose	24.60
Skim milk powder	23.20
Whey protein concentrate-80%	22.00
Creamer	12.00
Vegetable oil	6.00
Instant coffee	4.20
Cocoa powder	3.00
Gum blend (stabilizer)	1.50
Natural flavor	1.40
Milk minerals (calcium source)	1.30
Vitamins/mineral premix	0.80
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Mix sucrose, fructose and gum blend.
2. Add coffee, mix well.
3. Add the remaining ingredients, except oil, mix for 5 minutes.
4. Slowly add oil, mix for additional 5 minutes.
5. Rehydration: 40 g of dry beverage mix with 240 mls (8 ounces) of water.

Chocolate Drink

Ingredients	Usage Level (%)
Water	85.95
Sugar, granulated	7.50
Skim milk powder	5.80
Cocoa	0.50
Cellulose gel	0.25
Total	**100.00**

Procedure:

1. Disperse cellulose gel in water using high-speed agitation. Completely hydrate, approximately 15 minutes.
2. Gradually add skim milk powder, sugar and cocoa. Mix well. (Avoid air incorporation.)
3. Pasteurize, homogenize and fill packages.

Ice Cream, Hard-Pack

Ingredients	Usage Level (%)
Water	45.85
Cream, 40% fat	25.00
Sugar, granulated	16.00
Skim milk powder	10.32
Dry sweet whey	2.58
Stabilizers and emulsifiers	0.25
Total	**100.00**

Procedure:

1. Blend all ingredients into a uniform suspension in a batch tank.
2. Test the mix and restandardize if necessary.
3. Pasteurize milk at 82°C (180°F) for 23 seconds.
4. Homogenize—two stage homogenization recommended with 14.1 MPa in the first stage and 3.5 MPa in the second stage.
5. Cool rapidly to 0-4°C (32-39°F).
6. Age the mix for at least 4 hours.
7. Optionally, completely dispersible flavorings can be added to the mix prior to freezing.
8. Freeze in two stages. Freeze to 0 to -1°C (32-30°F) in the first stage in an ice cream freezer at a rapid rate to a discharge temperature of -6 to -7°C (21-19°F).
9. Optionally, add particulate materials or syrups through a fruit feeder.
10. In the second stage, harden the ice cream by reducing the temperature of the product to at least -18°C (0°F) in the center of the packages as quickly as possible.

Ice Cream, Hard-Pack Premium

Ingredients	Usage Level (%)
Cream, 40% fat	45.00
Water	31.10
Sugar, granulated	17.85
Skim milk powder	5.30
Egg yolk solids	0.50
Stabilizers and emulsifiers	0.25
Total	**100.00**

Procedure:

1. Blend all ingredients into a uniform suspension in a batch tank.
2. Test the mix and restandardize if necessary.
3. Pasteurize milk at 82°C (180°F) for 23 seconds.
4. Homogenize—two stage homogenization recommended with 14.1 MPa in the first stage and 3.5 MPa in the second stage.
5. Cool rapidly to 0-4°C (32-39°F).
6. Age the mix for at least 4 hours.
7. Optionally, completely dispersible flavorings can be added to the mix prior to freezing.
8. Freeze in two stages. Freeze to 0 to -1°C (32-30°F) in the first stage in an ice cream freezer at a rapid rate to a discharge temperature of -6 to -7°C (21-19°F).
9. Optionally, add particulate materials or syrups through a fruit feeder.
10. In the second stage, harden the ice cream by reducing the temperature of the product to at least -18°C (0°F) in the center of the package as quickly as possible.

Ice Cream, Low-Fat

Ingredients	Usage Level (%)
Whole milk	55.00
Water	18.30
Sugar, granulated	10.00
Skim milk powder	8.00
Whey protein concentrate-80%	4.00
Sweetener syrup solids	4.00
Stabilizer	0.70
Total	**100.00**

Procedure:

1. Mix dry ingredients into milk with a powder horn.
2. Pasteurize milk at 82°C (180°F) for 23 seconds.
3. Homogenize—two stage homogenization recommended with 14.1 MPa in the first stage and 3.5 MPa in the second stage. Final product temperature should be 5.5°C (42°F).
4. Hold at 0-4°C (32-39°F) overnight.
5. Freeze.

Ice Cream, Nonfat

Ingredients	Usage Level (%)
Skim milk	75.30
Sugar, granulated	10.00
Skim milk powder	6.00
Whey protein concentrate-80%	4.00
Sweetener syrup solids	4.00
Stabilizer	0.70
Total	**100.00**

Procedure:

1. Mix dry ingredients into milk with a powder horn.
2. Pasteurize milk at 82°C (180°F) for 23 seconds.
3. Homogenize—two stage homogenization recommended with 14.1 MPa in the first stage and 3.5 MPa in the second stage. Final product temperature should be 5.5°C (42°F).
4. Hold at 0-4°C (32-39°F) overnight.
5. Freeze.

Ice Cream, Soft-Serve Dry Mix

Ingredients	Usage Level (%)
Skim milk powder	44.82
Sugar, granulated	29.88
Sweetener syrup solids	13.44
Butter powder	10.46
Carboxymethyl cellulose	0.45
Guar gum	0.35
Emulsifier	0.30
Carrageenan	0.30
Total	**100.00**

Procedure:

For mix:
1. Combine all ingredients. Store.

For Soft-Serve:
2. Mix 3 kg of the dry blend into 5.7 liters of cold water using rapid agitation.
3. Allow to hydrate for 10-20 minutes. Stir.
4. Allow to hydrate for 10-20 minutes. Stir.
5. Pour into soft-serve machine.
6. Freeze mix and serve at or below -10°C (14°F).

Sour Cream, Nonfat

Ingredients	Usage Level (%)
Skim milk	73.60
Water	13.83
Skim milk powder	3.73
Cream, 40% fat	3.52
Starch	2.60
Whey protein concentrate-80%	1.52
Gum blend	0.80
Titanium dioxide	0.40
Culture	As needed
Total	**100.00**

Procedure:

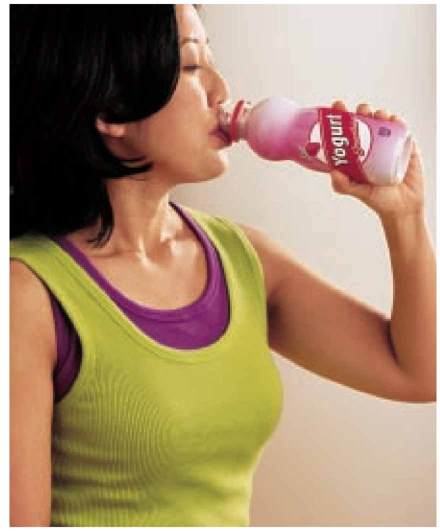
1. Mix all ingredients, except culture. Heat to 69°C (156°F). Homogenize at 2 MPa.
2. Heat to 85°C (185°F) and hold for 30 minutes without agitation.
3. Cool to 7°C (45°F) overnight.
4. Warm to 30°C (86°F), inoculate with culture, and incubate at 30°C overnight.
5. Cool to 7°C (45°F).
6. Store refrigerated.

Yogurt, Low-Fat, Stirred

Ingredients	Usage Level (%)
Milk, skim	75.46
Milk, 1% fat	18.87
Cream, 40% fat	2.98
Skim milk powder	1.99
Stabilizer	0.70
Culture	As needed
Total	**100.00**

Procedure:

1. Mix all ingredients, except culture.
2. Pasteurize at 85-90°C (185-194°F) for 15 seconds or 80-82°C (176-180°F) for 30 minutes. Homogenize at 10-14 MPa.
3. Cool to 34-41°C (93-106°F). Inoculate with yogurt cultures until pH is 4.20-4.65.
4. Cool to less than 15°C (59°F).
5. Stir.
6. Package.
7. Store refrigerated.



Yogurt Drink

Ingredients	Usage Level (%)
Water	89.60
Skim milk powder	6.24
Lactose	2.28
Whey protein concentrate-80%	1.88
Culture	As needed
Sweetener	As required
Total	**100.00**

Procedure:

1. Combine all ingredients.
2. Heat to 82°C (180°F) and hold for 15 minutes. Cool to 36°C (97°F).
3. Inoculate with culture. Incubate for 6 hours, or until final pH is 4.25-4.35
4. Cool to 7°C (45°F).
5. Sweeten with sweetener of choice to desired sweetness level.
6. Store refrigerated.

MEAT APPLICATIONS FOR MILK POWDERS 13

13.1 MEAT APPLICATIONS FOR MILK POWDERS*

U.S. *product developers and manufacturers benefit from the nutritional, functional and economical attributes of high-quality* U.S. *milk powders on a year-round basis.*

*All the formulas provided in this section are for demonstration purposes and as a starting point for product development efforts. Adjustments may be required. Please check local regulations for the use of product names and specific ingredients. For further assistance, please contact U.S. suppliers or the U.S. Dairy Export Council.

Benefits of Milk Powders in Meat Products

Milk powders are used by product developers in the formulation of a variety of meat products. U.S. manufacturers include high-quality U.S. milk powders in formulations because of the functional benefits milk powders add to combined meat products such as sausage and bologna. In addition, manufacturers are assured of a consistent, year-round supply of U.S. milk powders.

Emulisification
The proteins in milk powders can quite successfully act at oil/water interfaces to form and stabilize emulsions. The lecitithin present in milkfat also assists in stabilizing emulsions.

Gelation
Undenatured dairy proteins are able to form rigid, heat-induced, irreversible gels that hold water and fat, and provide structural support to meat products.

Water Binding
Water-binding capacity refers to the water held in gel under a given set of conditions. This water, enclosed in the gel's three-dimensional structure, can reduce the cost of food (water is inexpensive) and improve sensory perception.

Flavor/Aroma
Milk powders enhance the flavor of meat products. The milkfat present in some milk powders act as a flavor carrier for fat-soluble ingredients, spices and herbs. Milkfat's low melting point ensures complete flavor release.

13.2 MEAT FORMULATIONS

The following formulas do not represent all the applications or the only potential formula for the application. Product developers are encouraged to modify formulas and evaluate other applications perceived appropriate to their product line and market.

Bologna

Ingredients	Usage Level (%)
Cellulose Casings:	
Chicken trimmings*	35.18
Bull meat	26.39
Beef trimmings	26.39
Skim milk powder	4.18
Salt	2.65
Cure (see formula below)	2.42
Onions	2.20
Pepper, white	0.33
Coriander	0.11
Allspice	0.05
Sage	0.05
Garlic	0.05
Shaved ice	As needed
Total	**100.00**

*Pork may be substituted.

Cure:	
Dextrose	67.15
Sodium nitrate	23.08
Water	7.67
Nitrite of soda	2.10
Total	**100.00**

Procedure:

For Cure:

1. Combine all ingredients.
2. Mix until dissolved.

For Bologna:

1. Finely chop garlic and mix with cure.
2. Grind meats separately through 68 mm plate.
3. Place bull meat and beef trimmings with shaved ice in silent cutter. After a few resolutions, add salt and cure.
4. Add skim milk powder and shaved ice alternately until all skim milk powder has been used.
5. Add seasoning and chicken trimmings. Also add shaved ice until proper consistency is obtained. Chop fine.
6. Stuff into cellulose casings.
7. Place in smokehouse. Start at 49°C (120°F), gradually raise temperature to 74°C (165°F) until desired color appears, approximately 2-1/2 to 3 hours.
8. Cook at 71°C (160°F) until internal temperature reaches 69°C (156°F).
9. Cool with cold water shower.

Corned Beef Loaf

Ingredients	Usage Level (%)
Artificial Casings:	
Boned beef (briskets, plates, etc.)	80.79
Skim milk powder	12.12
Salt	4.04
Cure (see formula below)	2.22
Pepper, black	0.40
Bay leaves, crushed	0.15
Allspice	0.10
Cloves, ground	0.10
Onion powder	0.05
Garlic powder	0.03
Total	**100.00**

Cure:	
Dextrose	67.15
Sodium nitrate	23.08
Water	7.67
Nitrite of soda	2.10
Total	**100.00**

Procedure:

For Cure:

1. Combine all ingredients.
2. Mix until dissolved.

For Corned Beef:

1. Run beef through large lard cutting plate and mix well with salt and cure.
2. Cure for 5 days at 3-5°C (37-41°F). Place meat in nets for easier handling.
3. Put into steam-jacketed kettle with enough water to cover meat.
4. Cook for about 3-1/2 hours at 74-77°C (165-171°F).
5. Place spices in a muslin bag and add to meat while cooking.
6. Remove bag of spices after cooking.
7. Put meat mixture in blender. While mixing, sprinkle with skim milk powder. Add cooking water to give it proper consistency. Mix well.
8. Chill mixture.
9. When firmly set, stuff into artificial casings.

Cotto Salami

Ingredients	Usage Level (%)
Cellulose Casings:	
Boneless chucks	51.17
Beef cheek meat*	21.32
Beef trimmings*	12.79
Cold water	5.12
Skim milk powder	4.05
Salt	2.56
Cure (see formula below)	2.35
Pepper, black	0.37
Garlic	0.16
Cardamon	0.11
Total	**100.00**

*Pork may be substituted.

Cure:	
Dextrose	67.15
Sodium nitrate	23.08
Water	7.67
Nitrite of soda	2.10
Total	**100.00**

Procedure:

For Cure:

1. Combine all ingredients.
2. Mix until dissolved.

For Salami:

1. Finely chop garlic and mix with cure.
2. Grind chucks through 3.2 mm plate and beef through 9.5 mm plate.
3. Place all meats in mixer. Add salt, cure and water.
4. Sprinkle with skim milk powder and seasoning. Mix well.
5. Stuff into cellulose casings.
6. Hang in cooler at 3-5°C (37-41°F) for 48 hours.
7. Place in smokehouse. Start at 50°C (122°F), gradually raising temperature to 77°C (171°F) at the end of 7 hours.
8. Place under hot shower to wash grease off.
9. Cool with cold water shower. Keep in sausage room until dry.

Meat Loaf

Ingredients	Usage Level (%)
Ground beef	55.23
Water	11.05
Ketchup-1	8.98
Ketchup-2	8.98
Skim milk powder	5.03
Eggs, slightly beaten	4.93
Cornflakes, crushed	2.76
Onion, chopped	1.97
Salt	0.54
Worcestershire sauce	0.50
Thyme	0.03
Total	**100.00**

Procedure:

1. Combine ground beef, skim milk powder, cornflakes, ketchup-1 and chopped onion. Mix well.
2. Add water and seasonings to slightly beaten eggs. Blend into met mixture.
3. Form into loaf in loaf pan.
4. Spread ketchup-2 over top of loaf.
5. Bake at 176°C (349°F) for 1 hour.

Roast Beef Loaf

Ingredients	Usage Level (%)
Artificial Casings:	
Boneless chucks	58.36
Beef plate meat	19.48
Skim milk powder	9.35
Ketchup	7.79
Salt	2.73
Onions, grated	1.56
Pepper, white	0.39
Worcestershire sauce	0.15
Bay leaves, crushed	0.19
Total	**100.00**

Procedure:

1. Grind meat through large plate grinder.
2. Put into steam-jacketed kettle with enough water to cover meat. Bring to boil.
3. Add remaining ingredients, except skim milk powder. Cook slowly until tender.
4. Put meat mixture in blender. While mixing, sprinkle with skim milk powder. Add (30-35% by weight) cooking broth. Mix well.
5. Chill mixture.
6. When firmly set, stuff into artificial casings.

14.1 NUTRITIONAL BEVERAGE APPLICATIONS FOR MILK POWDERS*

U.S. *product developers and manufacturers benefit from the nutritional, functional and economical attributes of high-quality* U.S. *milk powders on a year-round basis.*

The category of nutritional beverages is one of the fastest growing beverage segments in the United States. All types of milk powders are used either directly or indirectly (via dry mixes) in the formulation of nutritional beverages.

*All the formulas provided in this section are for demonstration purposes and as a starting point for product development efforts. Adjustments may be required. Please check local regulations for the use of product names and specific ingredients. For further assistance, please contact U.S. suppliers or the U.S. Dairy Export Council.

Benefits of Milk Powders in Nutritional Beverages

Milk powders are used by product developers in the formulation of a variety of nutritional beverages. In the United States, all types of milk powders are used either directly or indirectly (via dry blends) in the formulation of nutritional beverages. U.S. manufacturers include high-quality U.S. milk powders in formulations because of the nutritional, functional and economical benefits milk powders add to beverages. In addition, manufacturers are assured of a consistent, year-round supply of U.S. milk powders.

Increased Nutritional Value
Milk powders deliver exceptional nutritional value to beverages. They are a source of high-quality protein, with the amino acids readily digestible and completely bio-available. Milk powders are high in calcium and soluble vitamins, and can be used to fortify beverages. (Only 100 g of skim milk powder contain 1,300 mg calcium.) Milk powders contribute to a healthy image and a clean ingredient label.

Emulsification
The proteins in milk powders can quite successfully act at oil/water interfaces to form and stabilize emulsions. The lecithin present in milkfat also assists in stabilizing emulsions.

Water Binding
Undenatured dairy proteins are able to form rigid, heat-induced irreversible gels. Water-binding capacity refers to the water held in a gel under a given set of conditions. This water, enclosed in the gel's three-dimensional structure, can reduce the cost of food (water is inexpensive) and improve a beverage's mouthfeel and texture.

Whipping/Foaming
Formation of foams is very important in beverages such as nutritional shakes. Foam formation is similar to the formation of an emulsion. Foaming is defined as the creation and stabilization of gas bubbles in a liquid. As dairy protein concentration increases, foams become denser with more uniform air bubbles of a finer texture.

Flavor/Aroma
Milk powders contribute a subtle, pleasant dairy note and aroma to beverages. Very little flavor comes from the dairy proteins, which are quite bland and contribute no foreign or off-flavors. Most of the flavor comes from the milkfat, which adds richness to certain beverages. Milkfat also acts as a flavor carrier for fat-soluble ingredients. Milkfat's low melting point ensures complete flavor release.

14.2 NUTRITIONAL BEVERAGE FORMULATIONS

The following formulas do not represent all the applications or the only potential formula for the application. Product developers are encouraged to modify formulas and evaluate other applications perceived appropriate to their product line and market.

High Protein, Enriched Beverage Mix (Meal Replacement Type, Mocha Flavor)

Ingredients	Usage Level (%)
Fructose and sucrose	24.60
Skim milk powder	23.20
Whey protein concentrate-80%	22.00
Creamer	12.00
Vegetable oil	6.00
Instant coffee	4.20
Cocoa powder	3.00
Gum blend (stabilizer)	1.50
Natural flavor	1.40
Milk minerals (calcium source)	1.30
Vitamins/mineral premix	0.80
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Mix sucrose, fructose and gum blend.
2. Add coffee, mix well.
3. Add the remaining ingredients, except oil, mix for 5 minutes.
4. Slowly add oil, mix for additional 5 minutes.
5. Rehydration: 40g of dry beverage mix with 240mls (8oz) of water.

Chocolate Drink

Ingredients	Usage Level (%)
Water	85.95
Sugar, granulated	7.50
Skim milk powder	5.80
Cocoa	0.50
Cellulose gel	0.25
Total	**100.00**

Procedure:

1. Disperse cellulose gel in water using high-speed agitation. Completely hydrate, approximately 15 minutes.
2. Gradually add skim milk powder, sugar and cocoa. Mix well. (Avoid air incorporation.)
3. Pasteurize, homogenize and fill packages.

Demineralized Whey-based Infant Formual Mix[1]

Ingredients	Usage Level (%)
Demineralized whey (approximately 1% minerals)	43.00
Fat blend*	28.00
Skim milk powder	16.00
Lactose	11.30
Vitamins and minerals*	1.20
Lecithin	0.50
Water	As needed
Total	**100.00**

*Vitamins, minerals and fat content must be adjusted to meet the minimum and maximum limits as recommended by national authorities.

[1]The value of breast milk as an ideal food for the infant during the first six months of its life cannot be too strongly stressed. However, poor health of the mother and certain social conditions can reduce lactation, separate the infant from the mother or otherwise make breastfeeding impossible. In these circumstances it is necessary to use alternative foods such as infant formula to overcome the lack of breast milk. (Statement on Infants Feeding, Codex Standards for Foods for Infants and Children, Codex Alimentarius 1989.) Please consult a physician or dietitian for use of formula for infant nutrition.

Procedure:

1. Calculate formula. Add demineralized whey, skim milk powder and lactose to water. The quantity of water should be that required to produce an easily processed, concentrated liquid.
2. Heat the solution to approximately 60°C (140°F) and mix in the lecithin, fat blend, vitamins and minerals.
3. Continue heating to pasteurize. Homogenize—two stage homogenization recommended with pressures of 14.1 MPa in the first stage and 3.5 MPa in the second.
4. Spray dry and agglomerate for easier reconstitution.
5. To rehydrate, blend 10% dry formula and 90% potable water by weight. Heat to pasteurize, and cool to feeding temperature.

Milk-Based Infant Formula Mix[1]

Ingredients	Usage Level (%)
Lactose	38.30
Skim milk powder	34.00
Fat blend*	27.00
Lecithin	0.50
Vitamins and minerals*	0.20
Water	As needed
Total	**100.00**

*Vitamins, minerals and fat content must be adjusted to meet the minimum and maximum limits as recommended by national authorities.

[1]The value of breast milk as an ideal food for the infant during the first six months of its life cannot be too strongly stressed. However, poor health of the mother and certain social conditions can reduce lactation, separate the infant from the mother or otherwise make breastfeeding impossible. In these circumstances it is necessary to use alternative foods such as infant formula to overcome the lack of breast milk. (Statement on Infants Feeding, Codex Standards for Foods for Infants and Children, Codex Alimentarius 1989.) Please consult a physician or dietitian for use of formula for infant nutrition.

Procedure:

1. Calculate formula. Add skim milk powder and lactose to water. The quantity of water should be that required to produce an easily processed, concentrated liquid.
2. Heat the solution to approximately 60°C (140°F) and mix in the lecithin, fat blend, vitamin and minerals.
3. Continue heating to pasteurize. Homogenize—two stage homogenization recommended with pressures of 14.1 MPa in the first stage and 3.5 MPa in the second.
4. Spray dry and agglomerate for easier reconstitution.
5. To rehydrate, blend 10% dry formula and 90% potable water by weight. Heat to pasteurize, and cool to feeding temperature.

Whey Protein Concentrate-Based Infant Formula Mix[1]

Ingredients	Usage Level (%)
Lactose	37.00
Fat blend*	27.00
Whey protein concentrate-34%	18.50
Skim milk powder	16.00
Vitamins and minerals*	1.00
Lecithin	0.50
Water	As needed
Total	**100.00**

*Vitamins, minerals and fat content must be adjusted to meet the minimum and maximum limits as recommended by national authorities.

[1]The value of breast milk as an ideal food for the infant during the first six months of its life cannot be too strongly stressed. However, poor health of the mother and certain social conditions can reduce lactation, separate the infant from the mother or otherwise make breastfeeding impossible. In these circumstances it is necessary to use alternative foods such as infant formula to overcome the lack of breast milk (statement on Infants Feeding, Codex Standards for Foods for Infants and Children, Codex Alimentarius 1989.) Please consult a physician or dietitian for use of formula for infant nutrition.

Procedure:

1. Calculate formula. Add whey protein concentrate, skim milk powder and lactose to water. The quantity of water should be that required to produce an easily processed, concentrated liquid.
2. Heat the solution to approximately 60°C (140°F) and mix the lecithin, fat blend, vitamins and minerals.
3. Continue heating to pasteurize. Homogenize/two stage homogenization recommended with pressures of 14.1 MPa in the first stage and 3.5 MPa in the second.
4. Spray dry and agglomerate for easier reconstitution.
5. To rehydrate, blend 10% dry formula and 90% potable water by weight. Heat to pasteurize, and cool to feeding temperature.

15.1 PREPARED FOOD APPLICATIONS FOR MILK POWDERS*

U.S. *product developers and manufacturers benefit from the nutritional, functional and economical attributes of high-quality* U.S. *milk powders on a year-round basis.*

The category of prepared foods, which includes dry mixes, salad dressings, sauces and soups, is an ideal application for milk powders. In the United Sates, 9.3% of all skim milk powder and 15.7% of all buttermilk powder is used directly in dry mixes. Being in powder form enables product developers to add dairy solids to formulations limited by moisture content.

*All the formulas provided in this section are for demonstration purposes and as a starting point for product development efforts. Adjustments may be required. Please check local regulations for the use of product names and specific ingredients. For further assistance, please contact U.S. suppliers or the U.S. Dairy Export Council.

Benefits of Milk Powders in Prepared Foods

Milk powders are used by product developers in the formulation of a variety of prepared foods. Milk powders provide flavor and functionality in prepared foods like dressings, dry mixes, sauces and soups. U.S. manufacturers include high-quality U.S. milk powders in formulations because of the functional and economical benefits milk powders add to prepared foods.

Increased Nutritional Value
Milk powders deliver exceptional nutritional value to beverages. They are a source of high-quality protein, with the amino acids readily digestible and completely bio-available. Milk powders are high in calcium and soluble vitamins, and can be used to fortify food applications. (Only 100 g of skim milk powder contain 1,300 mg calcium.) Milk powders contribute to a healthy image and a clean ingredient label.

Emulsification
The proteins in milk powders can quite successfully act at oil/water interfaces to form and stabilize emulsions. The lecithin present in milkfat also assists in stabilizing emulsions.

Gelatin
Undenatured dairy proteins are able to form rigid, heat-induced, irreversible gels that hold water and fat, and provide structural support in salad dressings, soups and sauces, especially those that are highly viscous. Two types of aggregates can form: linear or globular. The type of aggregation affects the gel's opacity, an important property in many food products.

Water Binding
Water-binding capacity refers to the water held in a gel under a given set of conditions. This water, enclosed in the gel's three-dimensional structure, can reduce the cost of food (water is inexpensive) and improve sensory perception.

The water-binding properties of milk powders are very important in the formulation of reduced-fat dressings, sauces and soups because of the fat-like attributes, such as lubricity, and mouthfeel that they contribute. Research indicates that water binding increases as the concentration of denatured proteins increases. Therefore, when selecting skim milk powder strictly for its water-binding capacity, choose varieties that are highly denatured, i.e. high-heat skim milk powder.

Color
Milk powder enhances soups, sauces and dressings, particularly reduced-fat cream-style products. Removing fat from soup or dressing results in a change in the product's appearance, specifically whiteness and opacity, because milkfat globules reflect light and provide whiteness. Milk powders restore an appealing look to reduced-fat dairy foods by providing opacity.

Flavor/Aroma
Milk powders enhance the dairy flavor of dressings, salads and soups. Very little flavor comes from dairy proteins, which are quite bland and contribute no foreign or off-flavors. Most of the flavor comes from the milkfat, which adds richness to certain formulations. Milkfat also acts as a flavor carrier for fat-soluble ingredients, spices, herbs and sweet flavors. Milkfat's low melting point ensures complete flavor release.

15.2 PREPARED FOOD FORMULATIONS

The following formulas do not represent all the applications or the only potential formula for the application. Product developers are encouraged to modify formulas and evaluate other applications perceived appropriate to their product line and market.

Sauce, Cheddar Cheese

Ingredients	Usage Level (%)
Water	52.24
Cheddar cheese, sharp, grated	32.40
Whole milk powder	7.58
Starch, waxy maize	3.70
Worcestershire sauce	3.36
Mustard, dry	0.65
Cayenne pepper	0.06
Bay leaf	0.01
Total	**100.00**

Procedure:

1. Mix half of the water with the starch. Reserve.
2. Mix remaining ingredients. Using wire whisk, whip continuously over low heat.
3. When smooth and all cheese is melted, add starch mixture.
4. Bring to a boil. Strain through fine mesh.
5. Chill.

Sauce, Chicken

Ingredients	Usage Level (%)
Water	76.71
Whole milk powder	10.02
Sherry	4.13
Butter	2.63
Starch, waxy maize	2.44
Chicken base	2.07
Bay leaf	1.69
Onion, minced	0.20
Pepper, white	0.11
Total	**100.00**

Procedure:

1. Mix milk powder, water, chicken base, bay leaf and pepper. Simmer over low heat.
2. Mix starch with a little of the sherry to make a smooth paste. Add to simmering liquid and bring to boil. Immediately remove from heat and strain.
3. Sauté onions in butter until soft. Add remaining sherry and simmer for 1 minute. Add to the sauce.
4. Chill.

Sauce, Fish

Ingredients	Usage Level (%)
Water	52.46
Whole milk powder	8.70
Lobster base	8.15
Onion, minced	7.80
Thyme, chopped	7.58
Celery, minced	7.58
Arrowroot	4.24
Paprika	1.36
Lemon pepper	1.07
Parsley, chopped	1.05
Bay leaf	0.01
Total	**100.00**

Procedure:

1. Mix all ingredients expect arrowroot and half of the water. Simmer.
2. Separately, mix the arrowroot with remaining water to make a whitewash.
3. Add whitewash to simmering liquid and bring to a boil.
4. Simmer 5 minutes. Strain.
5. Chill.

Sauce, Vegetable

Ingredients	Usage Level (%)
Water	32.71
Red pepper, minced	11.10
Tomato sauce	10.49
Whole milk powder	8.70
Green pepper	8.35
Onion, minced	7.34
Celery, minced	5.58
Chicken base	4.50
Arrowroot	3.75
Vegetable oil	2.25
Garlic, minced	2.21
Sugar, granulated	1.91
Thyme, dry	0.61
Creole seasoning	0.48
Bay leaf	0.02
Total	**100.00**

Procedure:

1. Sauté vegetables in the oil until soft.
2. Add seasoning, whole milk powder and half of the water. Bring to a simmer.
3. Mix remaining water with the arrowroot to make a whitewash.
4. Add the whitewash to the simmering sauce. Bring to boil.
5. Add tomato sauce. Simmer for 10 minutes. Remove bay leaf.
6. Chill.

Soup, Cream of Broccoli

Ingredients	Usage Level (%)
Water	71.14
Broccoli, florets, frozen	16.12
Skim milk powder	8.00
Chicken base	3.00
Starch, corn	1.42
Onion powder	0.18
Garlic powder	0.12
Pepper, white	0.02
Total	**100.00**

Procedure:

1. Blend all dry ingredients. Set aside.
2. Mix water and broccoli together. Bring to boil. Simmer for 5 minutes.
3. Add dry ingredients. Mix well. Simmer for 5 more minutes.

Soup, Cream of Potato

Ingredients	Usage Level (%)
Emulsion:	
Cream, heavy (36% fat)	9.45
Water	8.50
Skim milk powder	5.50
Butter, melted	1.35
Whey/caseinate emulsifier blend	1.20
Soy protein isolate	0.15
Puree:	
Water	2.50
Onion, diced Individually Quick Frozen	2.40
Carrot, cooked	1.30
Soup:	
Potato, cooked, diced	31.30
Carrot, cooked, diced or sliced	4.30
Celery, cooked, sliced	3.20
Salt	2.00
Thickener:	
Water	11.60
Starch, waxy maize, freeze/that stable	5.00
Flour, wheat	2.00
Steam condensate	8.25
Total	**100.00**

Procedure:

Emulsion directions:

1. Hydrate soy protein in water at 43-46°C (109-115°F) for 10-15 minutes, with stirring.
2. Add skim milk powder and emulsifier blend; stir until uniform.
3. Add melted butter, cream and vegetable oil; heat with live steam to 57-60°C (135-140°F).
4. Homogenize in two stages: First stage at 14.1 MPa, second state at 3.4 MPa.
5. Add to mixing kettle.

Puree directions:

1. Simmer carrots and onions in puree water for 10 minutes; puree with blender.
2. Add to mixing kettle.

Thickener directions:

1. Mix all ingredients until uniform.

Soup directions:

2. To mixing kettle containing emulsion and puree, add soup ingredients along with any other garnishes or spices, mixing constantly.
3. Heat with live steam to 77°C (171°F).
4. Add thickener slurry and heat to 90-93°C (194-199°F), with stirring.
5. Cool and freeze.

16.1 INTERNATIONAL FOOD AID APPLICATIONS FOR MILK POWDERS*

U.S. *product developers and manufacturers benefit from the nutritional, functional and economical attributes of high-quality* U.S. *milk powders on a year-round basis.*

The applications highlighted in this category, featuring bakery, recombined milk products and prepared foods, were formulated for food aid programs. The applications are currently being used in a variety of programs including 416(b), Food for Progress, Global Food for Education, Title II and Maternal Health and Community Nutrition. The recipes show the versatility of nonfat dry milk and how it can be easily integrated into any cuisine throughout the world.

This section was developed to raise awareness of Private Voluntary Organizations (PVOs) about the possible applications for dried milk ingredients. U.S. dairy ingredients can be used in direct feeding programs (school lunch, soup kitchens), in emergency distribution situations,* and in monetization programs.

The U.S. Dairy Export Council would like to recognize the contribution of the U.S. Potato Board (USPB) and would also like to extend its appreciation to Global Food & Nutrition Inc., Chef Bonnie Moore, Save the Children, Adventist Development & Relief Agency, and CARE.

*All the formulas provided in this section are for demonstration purposes and as a starting point for product development efforts. Adjustments may be required. Please check local regulations for the use of product names and specific ingredients. For further assistance, please contact U.S. suppliers or the U.S. Dairy Export Council.

**Whenever dry dairy ingredients are reconstituted, a clean source of water should always be used. Reconstitution should be done in hygienic conditions and the recombined product should be stored in conditions that will ensure its safety up to the time of consumption.

Benefits of Nonfat Dry Milk in Food Aid Programs Include:

Diverse Nutritional Benefits:
- Rich in high quality proteins,
- An excellent source of calcium with high bioavailability,
- A source of other minerals and vitamins,
- Presence of bioactive and health-enhancing compounds that have applications in therapeutic feeding,
- Complement vegetal origin proteins.

Versatile:
- Can be used for recombination** or fortification purposes,
- Are ready to use, do not require further cooking or preparation,
- Can also be used as binders, emulsifiers and texture and shelf-life extension agents in a variety of food/dairy products,
- Mixes well and can serve as a carrier for vitamin, minerals, other nutrients.
- Can be used in combination with other food aid commodities.

Universal:
- Have a mild flavor, well accepted in many cultures,
- As an ingredient, promote color and flavor development to increase consumer appeal,
- Find applications in a wide range of recipes and industrial formulations in most countries.

Long Shelf-life:
- Stored in a dry, cool place, dry dairy ingredients have a shelf-life of up to three years. Additional shelf-life studies and recommendations for storage under different conditions are available upon request.

16.2 INTERNATIONAL FOOD AID FORMULATIONS

The following formulas do not represent all the applications or the only potential formula for the application. Product developers are encouraged to modify formulas and evaluate other applications perceived appropriate to their product line and market.

Iced Coffee Milk (serves 24)

Ingredients	
Reconstituted milk*	6 quarts
Instant coffee	1/2 cup
Sugar	1 cup

*To prepare the milk: Stir 8 cups (19.2 ounces by weight) of skim milk powder into 5 2/3 cups of cold water.

Procedure:

1. In a large mixing bowl (or in a blender), combine the milk, instant coffee and sugar; stir until the coffee and sugar are dissolved.
2. Chill thoroughly.

Single Serving

Ingredients	
Reconstituted milk*	1 cup
Instant coffee	1 teaspoon
Sugar	2 teaspoons

*To prepare the milk: Stir 8 cups (19.2 ounces by weight) of skim milk powder into 5-2/3 cups of cold water.

Procedure:

1. In a large mixing bowl (or in a blender), combine the milk, instant coffee and sugar and stir until the coffee and sugar are dissolved.
2. Chill Thoroughly.

Variation:
Blend fruit to the mix instead of coffee.

Enriched Crackers

Ingredients	Usage Level (%)
Flour	55.10
Skim milk powder	5.10
Salt	1.10
Water	24.90
Vegetable oil	13.80
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Combine flour, skim milk powder and salt.
2. Add water and oil.
3. Mix well to make a stiff dough. Knead until dough is smooth, about 5 minutes.
4. Roll the dough very thin (about 2-3 mm thick).
5. Cut into squares and place on parchment-lined baking sheets.
6. Bake in preheated 230°C (450°F) oven for 10 to 12 minutes.

Enriched Roti-Style Bread

Ingredients	Usage Level (%)
Flour	58.00
Skim milk powder	3.30
Salt	0.50
Vegetable oil	1.70
Water	36.50
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Combine flour, skim milk powder, and salt.
2. Add water and oil.
3. Mix well for 2 or 3 minutes.
4. Turn dough out onto a well-floured surface. Knead until smooth and pliable, about 10 minutes.
5. Preheat an unoiled skillet. Divide dough into 40 g (1.4 ounce) balls.
6. Flatten the balls with the palm of your hand. Roll out each piece into a 18 to 25 cm (7-10 inch) diameter round.
7. Cook the roti for 1 minute before turning. Cook an additional minute.

Milky Biscuits

Ingredients	Usage Level (%)
Flour	45.60
Skim milk powder	8.10
Baking powder	2.90
Salt	0.90
Water	27.50
Vegetable oil	15.00
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Combine flour, skim milk powder, baking powder and salt.
2. Add water and oil.
3. Stir quickly with fork, just until dough is mixed.
4. Drop dough by spoonfuls on ungreased baking sheet.
5. Bake in preheated 230°C (450 °F) oven for 10 to 12 minutes, until brown.

Milky Potato Biscuits (serves 12)

Ingredients	
Flour, all purpose	1 cup
Potato flakes	1 cup
Vegetable shortening or lard	1/2 cup
Reconstituted milk*	2/3 cup
Sugar	1 tablespoon
Baking powder	1 tablespoon
Iodized salt	1/2 teaspoon

*To prepare the milk: Stir 2/3 cup (1.6 ounces by weight) of nonfat dry milk into 1-7/8 cups of cold water.

Formula adapted from USDEC recipe for food aid in collaboration with USPB.

Procedure:

1. Preheat the oven to 177°C (350°F) degrees.
2. In a mixing bowl, combine the flour, potato flakes, sugar, iodized salt and baking powder.
3. Make a well in the center of the dry ingredients and cut in the shortening.
4. Add the milk and stir with a wooden spoon until just combined.
5. Turn the dough out onto a lightly floured board and gently knead until the dough forms a ball. Roll the dough 12 mm (1/2 inch) thick. Using a biscuit or cookie cutter, cut out 5 cm (2-inch) rounds and place the biscuits on baking sheets.
6. Bake for 15 minutes or until the biscuits are barely golden.

Potato Crackers (makes about 4 dozen crackers)

Ingredients	
Flour, all purpose	2 cups
Cream cheese	4 ounces
Reconstituted milk*	3/4 cup
Potato flakes	3/4 cup
Sugar	1/4 cup
Vegetable oil	1/4 cup
Salt, iodized	1/2 teaspoon
Baking soda	1/2 teaspoon

*To prepare the milk: Stir 2/3 cup (1.6 ounces by weight) of nonfat dry milk into 1-7/8 cups of cold water.

Formula adapted from USDEC recipe for food aid in collaboration with USPB.

Procedure:

1. In a large bowl, combine the flour, potato flakes, sugar, iodized salt and baking soda.
2. Stir in the oil, 1/2 cup milk and cream cheese.
3. Wrap the dough tightly in plastic wrap and refrigerate for at least 10 minutes.
4. When you are ready to make the crackers, preheat the oven to 177°C (350°F).
5. Roll out the dough on a lightly floured surface until it is paper thin and prick it several times with a fork. Brush the dough with the remaining milk and sprinkle with coarse iodized salt.
6. With a knife or pizza cutter, cut the dough into random cracker shapes.
7. Place the crackers on a cookie sheet in a single layer and bake for about 6 minutes or until golden and crisp.

Protein-Enriched Thin Bread (Lavosh-Style)

Ingredients	Usage Level (%)
Flour	57.80
Sugar	0.70
Skim milk powder	3.00
Salt	1.10
Water	32.90
Vegetable oil	4.50
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Combine flour, sugar, skim milk powder, and salt.
2. Add water and oil.
3. Mix well to make a stiff dough. Knead until dough is smooth, about 5 minutes.
4. Divide dough into 50 g (1.8 ounce) balls. Roll each ball on lightly floured surface until paper thin. Place on ungreased baking sheet.
5. Bake in preheated 230°C (450°F) oven for 10 to 12 minutes, until brown.

Protein-Enriched Unleavened Bread

Ingredients	Usage Level (%)
Flour	45.40
Skim milk powder	3.50
Whey protein concentrate-80%	2.40
Salt	0.60
Vegetable oil	3.50
Water	44.60
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Combine flour, milk powder, whey protein concentrate-80% and salt.
2. Add water and oil.
3. Mix well for 2 or 3 minutes.
4. Pour onto greased cookie sheets or three 20 cm (8-inch) square pans.
5. Bake at 230˚C (450°F) for 20 minutes.

Unleavened Bread

Ingredients	Usage Level (%)
Flour	45.40
Skim milk powder	5.90
Salt	0.60
Vegetable oil	3.50
Water	44.60
Total	**100.00**

Formula courtesy of the Dairy Products Technology Center, California Polytechnic State University.

Procedure:

1. Combine flour, skim milk powder and salt.
2. Add water and oil.
3. Mix well for 2 or 3 minutes.
4. Pour onto greased baking sheets or pans.
5. Bake at 230°C (450°F) for 20 minutes.

Pizza Dough
(makes 2 large pizzas or 36 mini pizzas)

Ingredients	
Pizza Dough	
Dry yeast	1-1/2 teaspoons
Warm reconstituted milk*	2 cups
Olive or vegetable oil	2 tablespoons
Flour, all purpose	2-1/2 cups
Potato flakes	1-3/4 cups
Salt, iodized	2-1/2 teaspoons
Pizza Topping	
Tomato sauce	1 cup
Chopped, cooked peppers, onions or mushrooms (optional)	1 cup
Grated cheese	2 cups

*To prepare the milk: Stir 2/3 cups (1.6 ounces by weight) of nonfat dry milk into 1-7/8 cups of cold water. To avoid spoilage, use immediately or cover, refrigerate and use within 3 to 5 days.

Formula adapted from USDEC recipe for food aid in collaboration with USPB.

Procedure:

For Dough:

1. In a large mixing bowl, dissolve the yeast in the warm milk.
2. Whisk in the oil and 2 cups of flour. Cover with a clean towel and let rise 1-1/2 hours at room temperature.
3. Stir in the remaining flour, potato flakes, and iodized salt.
4. Turn the dough onto a floured board and knead for 4 to 5 minutes or until the dough is smooth and elastic.
5. Let rest at room temperature, covered with a towel for 30 minutes before rolling.

For Pizza:

1. Preheat the oven to 230°C (450°F).
2. Dust a work surface with flour. Divide the pizza dough in half and roll each half out into a 23-25 cm (9-10 inch) circle.
3. Place each dough circle on a baking sheet. Spread 1/2 cup of tomato sauce on each pizza. If desired, sprinkle the peppers, onions or mushrooms on top of the sauce. Sprinkle with grated cheese.
4. Bake the pizzas in the hot oven for 15 minutes (8 minutes for mini pizzas) or until the crust is golden brown.

Potato & Cheese Croquettes
(makes 60, 6 cm (2-1/2 inch) croquettes)

Ingredients	
Potato flakes, standard	2-1/2 cups
Flour, all purpose	1-1/4 cups
Reconstituted milk*	1-2/3 cups
Egg yolks	5
Cottage cheese	2/3 cup
Swiss cheese, grated	1-1/4 cup
Nutmeg, ground	1/4 teaspoon
Breadcrumbs	1-1/2 cup
Vegetable oil	2 quarts
Salt, iodized	To taste
Pepper	To taste

Formula courtesy of USPB; recipe adapted to include NFDM.

Procedure:

1. In a large mixing bowl, combine the potato flakes and flour. Stir in the milk, egg yolks, cottage cheese, Swiss cheese and nutmeg. Season with iodized salt and pepper.
2. Form the mixture into 60, 6 cm (2-1/2 inch) cylinders and place them on a cookie sheet.
3. Place the breadcrumbs on a small plate. Roll each croquette in the breadcrumbs and return them to the cookie sheet. Refrigerate until ready to cook.
4. Heat the oil in a large pot over medium-high heat. Carefully drop the croquettes, a few at a time, into the hot oil and fry until they are golden brown, about 30 seconds. Using a slotted spoon, remove the croquettes from the oil and drain them on paper towels.

Potato Bundt Cake (yield one 25cm (10 inch) bundt cake)

Ingredients	
Bundt Cake	
Potato flakes, standard	1 cup
Flour, all purpose	2 cups
Baking powder	1 tablespoon
Salt, iodized	1/4 teaspoon
Butter or oil (at room temperature)	1/2 cup
Sugar	1 cup
Eggs	3
Vanilla	2 teaspoons
Reconstituted milk*	1 cup
Optional Icing	
Sugar, confectioner's	1 cup
Water	2 tablespoons

*To prepare the milk: Stir 2/3 cup (1.6 ounces by weight) of nonfat dry milk into 1-7/8 cups of cold water.

Formula courtesy of USPB; recipe adapted to include NFDM.

Procedure:

1. Preheat the oven to 177°C (350°F). Grease a 10-inch bundt or tube pan and set it aside.
2. In a large bowl, mix the potato flakes, flour, baking powder and iodized salt together.
3. In a separate bowl, beat the butter (or oil) and sugar together for a few minutes, until the mixture is fluffy.
4. Add the eggs, one at a time, to the sugar mixture. Add the vanilla.
5. Fold in half of the flour mixture, then the milk and finally the remaining flour mixture.
6. Pour the batter into the prepared pan. Bake the cake for 40 to 45 minutes or until the cake is golden brown and a toothpick inserted into the middle of the cake comes out clean.
7. Cool the cake for 10 minutes before removing it from the pan. Cool the cake completely and store it in an airtight container at room temperature.

Optional Icing:

1. In a small bowl, stir the sugar and water together.
2. Drizzle the icing over the top of the cake.

Mexican Spice Cake (yield one 25cm (10 inch) bundt cake)

Ingredients	
Potato flakes	1 cup
Flour, all purpose	2 cups
Reconstituted milk*	1 cup
Baking powder	1 tablespoon
Cocoa powder or grated cocoa	1 tablespoon
Cinnamon, ground	1/2 teaspoon
Salt, iodized	1/4 teaspoon
Butter or oil (at room temperature)	1/2 cup
Sugar	1 cup
Eggs	3
Vanilla	2 teaspoons
Sugar, confectioner's (optional for dusting)	

*To prepare the milk: Stir 2/3 cup (1.6 ounces by weight) of nonfat dry milk into 1-7/8 cups of cold water.

Formula courtesy of USPB; recipe adapted to include NFDM.%

Procedure:

1. Preheat the oven to 177°C (350°F). Grease a 10-inch bundt or tube pan and set it aside.
2. In a large bowl, mix the potato flakes, flour, baking powder, cocoa powder, cinnamon and iodized salt together.
3. In a separate bowl, beat the butter (or oil) and sugar together for a few minutes, until the mixture is fluffy.
4. Add the eggs, one at a time, to the sugar mixture. Add the vanilla.
5. Fold in half of the flour mixture, then the milk and finally the remaining flour mixture.
6. Pour the batter into the prepared pan. Bake the cake for 40 to 45 minutes or until the cake is golden brown and a toothpick inserted into the middle of the cake comes out clean.
7. Cool the cake for 10 minutes before removing it from the pan. Cool the cake completely and store it in an airtight container at room temperature.
8. If desired, serve the cake dusted with confectioner's sugar.

Black Bean and Cheese Empanadas/Spicy Chicken Empanadas (makes 48 Empanadas)

Ingredients	
Dough	
Potato flakes, standard	1-1/2 cups
Flour, all purpose	2-1/4 cups
Salt, iodized	3/4 teaspoon
Sugar	1 tablespoon
Vegetable shortening or lard	1 cup
Reconstituted milk*	1/2 cup plus 2 tablespoons
Filling (black bean and cheese)	
Black beans, drained	2 cups
Monterey jack cheese	1/4 cup
Poblano chili peppers, roasted, seeded & chopped	1/2 cup
Garlic, minced	1 clove
Cilantro, fresh & chopped	2 tablespoons
Lime juice, fresh	2 tablespoons
Salt, iodized	To taste
Pepper	To taste
Filling (chicken)	
Vegetable oil	1 tablespoon
Onion, chopped	1/4 cup
Garlic, minced	1 clove
Chicken, shredded & cooked	1/2 pound
Tomatoes, chopped	1/2 cup
Poblano chili peppers, roasted, seeded & chopped	1/2 cup
Jalapeño chili pepper, seeded & finely minced	1 teaspoon
Cilantro, fresh & chopped	2 tablespoons
Cumin, ground	1/4 teaspoon
Salt, iodized	To taste
Pepper	To taste

*To prepare the milk: Stir 2/3 cup (1.6 ounces by weight) of nonfat dry milk into 1-7/8 cups of cold water. To avoid spoilage, use immediately or cover, refrigerate and use within 3 to 5 days.

Formula courtesy of USPB; recipe adapted to include NFDM.

Procedure:

For Dough:

1. Place the potato flakes, flour, iodized salt and sugar in a large mixing bowl. Using two knives, cut in the butter or shortening until the mixture resembles course meal.
2. Stir in the ice water until a ball of dough forms.
3. Form the dough into a 10 cm (4-inch) disk, wrap it in plastic wrap and refrigerate until completely chilled, about 1 hour.
4. Roll the dough out on a lightly floured surface. Cut the dough into 48, 8 cm (3-inch) rounds and place them on a cookie sheet.

For Black Bean and Cheese Empanadas:

1. Place the beans in a large mixing bowl and mash them with a fork.
2. Stir in the cheese, poblano chili peppers, garlic, cilantro and lime juice. Season with iodized salt and pepper.
3. Preheat the oven to 190°C (375°F).
4. Brush the rounds of empanada dough lightly with the beaten egg, place about a teaspoon of bean filling on each round, fold the dough in half and crimp the edges with a fork.
5. Place the stuffed empanadas on a cookie sheet and bake until golden brown, about 15 to 20 minutes.

For Spicy Chicken Empanadas:

1. In a small skillet, heat the oil over medium heat. Add the onion and garlic and cook until they are soft and translucent, about 5 minutes.
2. Transfer the onion mixture to a large mixing bowl and cool.
3. Add the chicken, tomatoes, poblano and jalapeno chili peppers, cilantro and cumin. Season with iodized salt and pepper.
4. Preheat the oven to 190°C (375°F).
5. Brush the rounds of empanada dough lightly with the beaten egg, place about a teaspoon of chicken filling on each round, fold the dough in half and crimp the edges with a fork.
6. Place the stuffed empanadas on a cookie sheet and bake until golden brown, about 15 to 20 minutes.

Spinach Mashed Potatoes (serves 20)

Ingredients	
Onions, yellow, finely chopped	2 cups
Reconstituted milk*	6 cups
Spinach, finely chopped	9 cups
Potato flakes, standard	6 cups
Reconstituted milk, cold*	2-1/4 cups
Salt, iodized	2-1/4 teaspoon
Pepper	To taste

*To prepare the milk: Stir 3-1/3 cups (8 ounces by weight) of nonfat dry milk into 10-1/3 cups of cold water. To avoid spoilage, use immediately or cover, refrigerate and use within 3 to 5 days.

Formula courtesy of USPB; recipe adapted to include NFDM.

Procedure:

1. In a large skillet, heat the butter over medium heat. Add the onions and cook until they become soft and translucent, about 6 to 8 minutes. Add the spinach and cook until the spinach has just wilted, about 1 minute more. Remove from heat and set aside.
2. In a large pot, bring the 6 cups of milk and 2-1/4 teaspoons of iodized salt to a boil and remove from heat. Add the cold milk. Using a spoon, gradually and gently stir in the potato flakes. Do not overwork.
3. Gently fold the spinach mixture into the potato mixture. Season with iodized salt and pepper. Serve warm.

   It may be necessary to add water (1/8 cup at a time) to thin the potatoes to the desired consistency. Alternatively, add potato flakes (1 tablespoon at a time) to thicken them.

Carrot Mashed Potatoes (serves 20)

Ingredients	
Onions, yellow, finely chopped	1 cup
Carrots, peeled & chopped	4 cups
Butter (margarine or oil)	1/2 cup
Reconstituted milk*	5-1/3 cups
Potato flakes, standard	5-1/3 cups
Reconstituted milk, cold*	2 cups
Salt, iodized	2 teaspoon
Pepper	To taste

*To prepare the milk: Stir 2-2/3 cups (6.4 ounces by weight) of nonfat dry milk into 7-1/2 cups of cold water. To avoid spoilage, use immediately or cover, refrigerate and use within 3 to 5 days.

Formula courtesy of USPB; recipe adapted to include NFDM.

Procedure:

1. Cook the carrots in boiling water until they are completely tender, about 10 minutes. Drain the carrots and mash them with a fork or potato masher. Keep warm and set aside.
2. In a large saucepan or soup pot, heat the butter over medium heat. Add the onions and cook until they become soft and translucent, about 6 to 8 minutes. Add the 5-1/3 cups of milk and 2 teaspoons of iodized salt and bring the mixture to a boil.
3. Remove from heat and add the cold milk. Using a spoon, gradually and gently stir in the potato flakes. Do not overwork.
4. Gently fold the onions and pureed carrots into the potato mixture. Season to taste with iodized salt and pepper. Serve warm.

   It may be necessary to add water (1/8 cup at a time) to thin the potatoes to the desired consistency. Alternatively, add potato flakes (1 tablespoon at a time) to thicken them.

Potato Pancakes
(makes 40, 8 cm (3-inch) pancakes)

Ingredients	
Vegetable oil (for frying)	1/2 cup
Onions, finely chopped	2 medium
Green bell peppers, finely chopped	2 medium
Tomatoes, finely chopped	2 medium
Potato flakes, standard	5 cups
Flour, all purpose	5 cups
Baking powder	2-1/2 teaspoons
Eggs, well beaten	5
Reconstituted milk*	3-3/4 cups
Sour cream	1 cup
Salt, iodized	To taste
Pepper	To taste

*To prepare the milk: Stir 1-1/3 cups (3.2 ounces by weight) of nonfat dry milk into 3-3/4 cups of cold water.

Formula courtesy of USPB; recipe adapted to include NFDM.

Procedure:

1. In a small skillet, heat a tablespoon of oil over medium heat. Add the onions and bell peppers and cook until they become soft and translucent, about 5 minutes. Add the tomatoes and cook for an additional 5 minutes. Remove from heat and allow to cool.
2. In a mixing bowl, combine the potato flakes, flour and baking powder. Gently stir in the egg, milk, and cooked vegetables. Season with iodized salt and pepper. Form the potato mixture into 40 cakes.
3. In a large skillet, heat a few tablespoons of oil over medium high heat. Cook the cakes (a few at a time) until they are golden brown on each side, about 3 minutes per side.
4. Serve with sour cream.

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