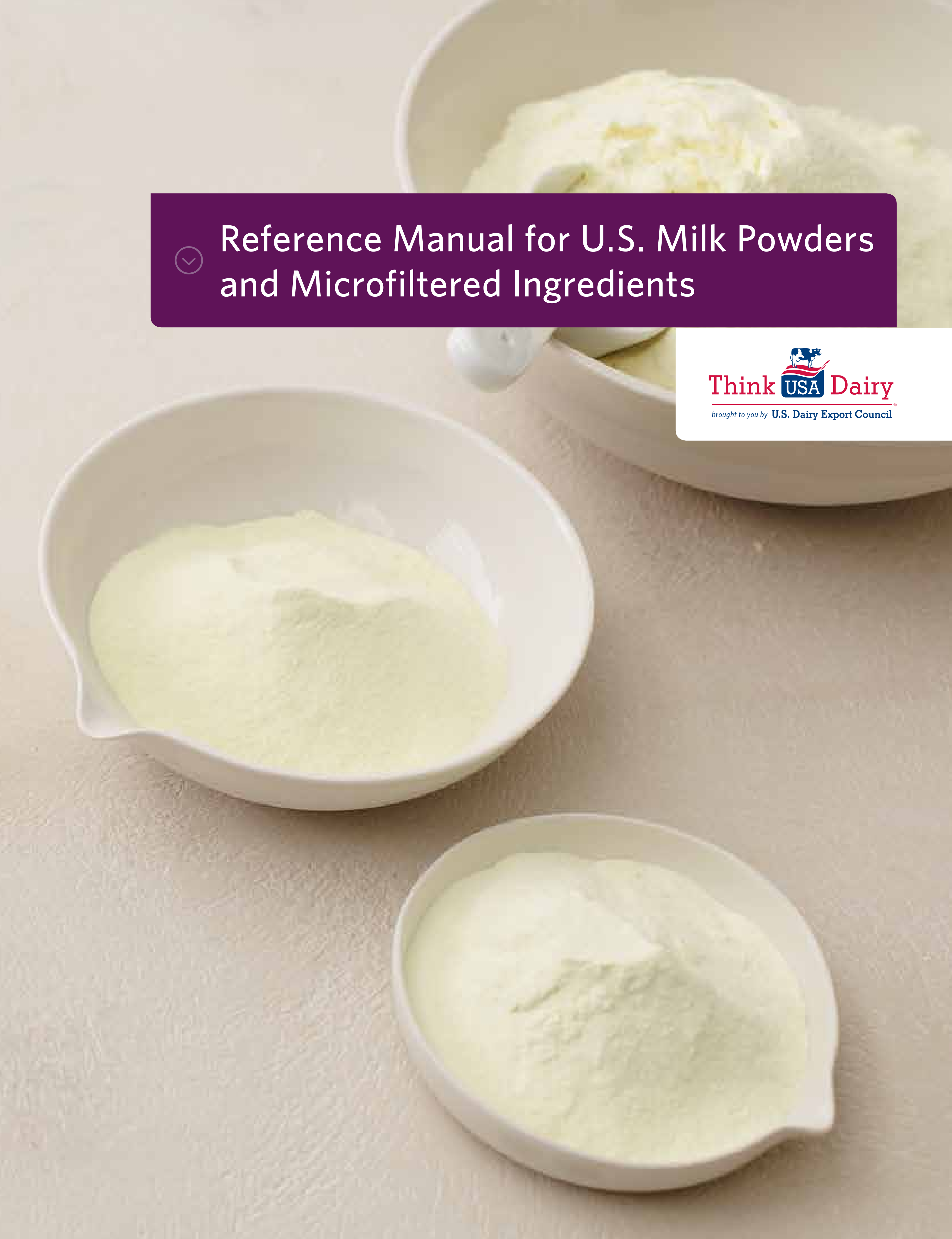
Reference Manual for U.S. Milk Powders and Microfiltered Ingredients



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ACKNOWLEDGEMENTS

The U.S. Dairy Export Council (USDEC) wishes to extend its appreciation to all the individuals, companies and associations who contributed to the development, review and production of this manual.

U.S. DAIRY EXPORT COUNCIL (USDEC)

USDEC is a non-profit, independent membership organization that represents the global trade interests of U.S. dairy producers, proprietary processors and cooperatives, ingredient suppliers and export traders.

Founded in 1995 by Dairy Management Inc., USDEC's mission is to enhance demand for U.S. dairy products and ingredients by securing access and assisting suppliers to meet market needs that facilitate sales. Activation occurs through research and collaboration with members, government, academia and numerous related organizations, whose common goal is to ensure the health and vitality of the U.S. dairy industry. USDEC, together with its network of overseas offices, also works directly with global buyers and end users to accelerate customer purchasing and innovation success with quality U.S. dairy products and ingredients.

Dairy Management Inc., the farmer-funded marketing, promotion and research organization, is USDEC's primary funder through the dairy checkoff program. The U.S. Department of Agriculture's (USDA) Foreign Agricultural Service provides export market development support, and membership dues fund the Council's trade policy initiatives.

This reference manual is designed to guide and educate international buyers and end users on purchasing and using U.S. milk powders and milk proteins. It is an information resource that includes:

- A description of the U.S. milk powder, milk protein concentrate (MPC) and milk protein isolate (MPI) industry
- Definitions of milk powder, MPCs and MPI products
- Descriptions of the processes used to produce milk powder and to enhance certain functional properties of skimmed milk powder
- Discussions of the functional and nutritional properties of milk powder and milk proteins
- Applications for these functional, nutritional dairy ingredients

USA U.S. Dairy Export Council®
Ingredients | Products | Global Markets

The Council's headquarters is in Arlington, Virginia (adjacent to Washington, DC) and can be contacted at:

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Global Presence

USDEC has an extensive network of staff and representatives around the world, from Asia to the Middle East and North Africa, Latin America and the United States. Representing the needs of its members as well as global buyers, end users and food and beverage industry stakeholders, USDEC proudly serves as a comprehensive resource for actionable U.S. dairy information.

USDEC representative offices are key to sharing timely insights about the U.S. dairy industry, its wide product offerings and the multifaceted nutritional and functional benefits of U.S. dairy products and ingredients. This is accomplished through one-on-one meetings, marketing events such as seminars, workshops and trade missions, participation in trade shows and conferences, as well as public relations and health professional engagement efforts.

Services Designed to Boost Global Sales of U.S. Dairy Products and Ingredients

- **Market Access and Regulatory Affairs:** A team of experts monitors the regulatory climate around the world to identify changes to tariffs, product standards, import requirements and other market access matters to facilitate trouble-free transactions.
- **Trade Policy:** Trade policy professionals work to achieve the best possible outcome for U.S. dairy products in trade negotiations and resolve ongoing trade disputes and threats to U.S. dairy export growth.
- **Market Development:** Cross-functional teams of marketing, research and other professionals identify best prospect, yet-untapped opportunities for U.S. dairy exports, and seize these opportunities through demand-driving programs and initiatives that accelerate customer success with U.S. Dairy in the global marketplace.

USDEC Members

USDEC builds on collaborative industry partnerships with processors, trading companies and others to increase global demand for U.S. dairy products. Since USDEC was founded in 1995, membership has grown to more than 120 companies and now represents 80% of U.S. dairy processors. USDEC's wide range of member companies and their dedicated staff are committed to fulfilling the dairy product needs of customers around the world, whether in Shanghai, Sao Paulo, Mexico City, Berlin, Riyadh, Manila, Dubai or any corner of the world. Visit ThinkUSAdairy.org for a complete list of our

members and to search for U.S. milk powder and other dairy ingredient suppliers.

ThinkUSAdairy.org: U.S. Dairy Resources at Your Fingertips

ThinkUSAdairy.org is an online and on-the-go resource tailored to the unique needs of global buyers, foodservice professionals and food manufacturers.

The website provides an inside look for buyers into the U.S. dairy industry and its extensive portfolio of products. It includes a robust tool to search for U.S. suppliers based on specific needs and product attributes (see "Discover U.S. Dairy" and "Supplier Search"). But that's not all! End users can learn more about the current culinary trends and nutrition facts related to dairy and find inspiration on how to use U.S. milk powder and milk proteins (see "Using Dairy" and "Nutrition & Trends"). This smartphone- and tablet-friendly site enables on-the-go access to a wealth of information.

From the ThinkUSAdairy.org homepage, microsites in additional languages including Arabic, Chinese (simplified), Korean, Spanish and Portuguese can also be accessed.

Please visit ThinkUSAdairy.org today to learn more about U.S. Dairy!

1 The U.S. Dairy Industry and Export Initiatives

1.1 OVERVIEW OF THE U.S. DAIRY INDUSTRY

With an ample and rising milk production capacity and competitive product portfolio, the U.S. dairy industry is well positioned and eager to fulfill the world's expanding appetite for dairy. Throughout the supply chain, from farm families and milk processors to product and ingredient manufacturers, the U.S. dairy industry is fully invested in being a long-term global supply and innovation partner that drives customers' business forward.

U.S. Dairy Farming Today

Advantageous land and resources, along with the adoption of modern and efficient farming practices, secure the United States' position as the world's largest producer of cow's milk. In 2017, the United States had 9.4 million cows and produced 97.7 million metric tons of milk across 40,000 farms. That's three times the milk production volume of New Zealand and Australia combined. The majority of U.S. dairy farms are family-owned and operated. With generations of experience, U.S. dairy farmers know that healthy, well-tended cows fed a nutritious diet consistently produce wholesome, high-quality milk. U.S. dairy farmers work closely with animal nutritionists and veterinarians to identify the right mix of feed ingredients to meet cows' nutritional requirements. In turn, the cow's powerful digestive system utilizes these dietary nutrients to produce wholesome, high-quality milk. Minimal season-to-season variance in feed quantity and nutrient composition ensures a steady milk supply throughout the year, in contrast to the cyclical volume typical of dairy cows that graze, as is common in some parts of the world.

Ample Growth Capacity

The United States has the land, infrastructure and technological resources in place to continue its expansion of milk production and dairy product offerings. As of 2017, 45% of the cumulative growth in incremental U.S. milk production between 2004 and 2017 on a total milk solids basis has gone to products destined for export markets. With U.S. milk production forecast to reach 100 million metric tons by 2019, this upward trajectory assures global customers a reliable, long-term source of wholesome dairy products. This steady future milk and dairy production growth capacity sets the United States apart from constraints that other milk-producing regions experience.

World-Class Product Portfolio

The United States' nearly 1,300 registered manufacturing facilities—from the largest food production operations in the world to small, boutique facilities for hand-crafted specialty items—follow strict food safety procedures to create an incredible variety of wholesome, quality dairy products and ingredients.

The United States leads the world as a single-country producer and exporter of nonfat dry milk/skimmed milk powder, MPCs and MPI and has heavily invested in new export-ready plant capacity to meet customers' growing and differentiated needs. The United States is also the largest single-country producer and exporter of whey ingredients, supplying a wide array of options from permeate to sweet whey to whey protein concentrates, whey protein isolates and milk whey protein (native whey) that meet varying needs for protein levels, functional properties and other specifications. A strong track record as the world's largest producer and exporter also makes the United States a trusted, go-to lactose source for quality nutrition, product functionality and consistent supply availability. U.S. production of milk proteins and micellar casein concentrate is also climbing, offering broader choice, to customers around the world.

Food and beverage companies, chefs and foodservice menu developers, nutritional products manufacturers, importers and humanitarian organizations count on U.S. dairy products to delight and nourish consumers around the world. For more information on specific U.S. products, including production and export volumes, functional and nutritional attributes and key usage applications, visit ThinkUSAdairy.org.

Figure 1.1
Rising Global Presence

Rising Global Presence

The dedication of American dairy farmer and processor communities reaches far beyond U.S. borders. Domestically focused a decade ago, the U.S. dairy industry today has embraced global markets and emerged as a leading dairy supplier worldwide. Today, one in seven tankers of milk leaving American farms is turned into products sold overseas. That is equivalent to 13.7 million metric tons of milk or the milk from 1.3 million U.S. cows. As global demand for dairy continues to rise, the U.S. dairy industry is meeting the challenge. U.S. dairy suppliers today are attuned to global customers' needs, with sales efforts increasingly supported by offices and representatives around the world. The industry is also fully invested in delivering a product portfolio that meets the selection, specifications and packaging global customers seek. The result has been a sharp upward trajectory in exports, achieving new records in seven of the 10 years between 2007 and 2016. This steady export growth affirms the United States' long-term commitment to collaborative partnerships with global customers.

1.2 QUALITY ASSURANCE

Everyone involved in U.S. Dairy—farm families, milk processors, product and ingredient manufacturers, scientists, government safety specialists and representatives of consumer and dairy institutions—works to ensure U.S. products meet strict U.S. regulatory standards and surpass customer and consumer expectations and requirements for quality and safety. Well-established laws, standards, traditions and values make U.S. Dairy a trusted partner for food and beverage companies and foodservice institutions around the world. The U.S. dairy industry wants to be the go-to choice for nutritious, fresh and wholesome dairy products and ingredients. So steps are taken from farm to table to consistently ensure delivery of nutritious, fresh and wholesome dairy products.

On the Farm

As the United States is a vast country with a diverse climate, U.S. Dairy farmers house and feed their cows in harmony with the weather conditions and the resources of the communities where they live and farm. Some cows graze year-round; others live in barns for protection from extreme cold and heat. All dairy farmers strive for healthy, well-tended cows, regardless of location or herd size. They know that cows fed a nutritious diet consistently produce wholesome, high-quality milk. Nearly all U.S. Dairy farms are family owned and have been for generations. Dairy farmers work diligently to protect their land and water, while milking the number of cows required to meet the market's demand and their family's needs. Their efforts are often aided by:

- Inspectors who counsel farmers regarding proper safety procedures and enforce national regulations
- On-farm tests for contaminants and pathogens
- Veterinarians who visit frequently to check animal health
- Animal nutritionists who ensure the cows eat a rich and nutritious diet
- Auditors who work with farmers to ensure cows are healthy and treated well, in alignment with The National Dairy FARM Program: Farmers Assuring Responsible Management

In the Plant

U.S. milk processors and manufacturers of dairy products and ingredients are fully invested in protecting the quality and safety of the milk they receive from U.S. dairy farmers. To deliver the finest products and ingredients to U.S. dairy customers worldwide, they often take steps above, beyond and in advance of regulatory requirements:

- Analysis of vulnerable points in company processes and application of innovative and proven measures to ensure quality and prevent and detect contamination
- Alignment with recognized international standards such as the Global Food Safety Initiative (GFSI) and Safe Quality Food (SQF) Institute
- ISO certification, both for processes and products
- Adoption of dairy product traceability from farm to customer

U.S. processors and manufacturers also invest in continuous improvement and sustainability. The Innovation Center for U.S. Dairy is a consortium of U.S. dairy farmers, U.S. dairy companies and food and beverage manufacturers collaborating with representatives of the U.S. government, academic institutions and non-governmental organizations. Together, they are working to further improve pathogen control, strengthen audit protocols and reduce risk in the supply chain.

Government Oversight

The U.S. Food and Drug Administration (FDA) enforces national laws that enhance the safety of dairy products and other foods and beverages made in the United States. State and local authorities regularly visit dairy farms and plants to verify compliance with all the rules. In addition, the USDA protects animal health and milk quality specification standards. In the United States, government standards and protocols are in place to ensure that pasteurized milk is produced safely. The FDA oversees a set of standards known as the Pasteurized Milk Ordinance (PMO) that specifies time and temperature requirements for pasteurization. It meticulously details how dairy facilities and plants must be constructed, equipped, cleaned and sanitized and how milk must be handled, stored and shipped. It also ensures consistent and rigorous inspections of dairy farms, processing facilities and products across the United States. As a final check, U.S. dairy products and ingredients are tested at multiple critical junctures from farm to plant to port. Only products that meet the U.S. government's rigorous standards are delivered to domestic and international food customers and consumers.

1.3 SUSTAINABILITY AND STEWARDSHIP

The U.S. dairy industry takes pride in the way its rich heritage of land stewardship and long-term commitment to sustainable dairy farming strengthens the industry's economic, environmental and social contributions. The dairy cow plays a key role in an environmentally-responsible, sustainable U.S. food system that serves the needs of current and future generations. A wide range of wholesome U.S. dairy products and ingredients start with the nutritious milk dairy cows produce.

Few foods deliver dairy's powerhouse of nutrients and health benefits in such an affordable, delicious and readily-available way. One cow, on average, produces 34 liters or nine gallons of milk per day. Each serving delivers calcium, vitamin D, potassium, protein and additional key nutrients essential for human health.

Dairy farm sustainability efforts get help from a cow's powerful four-stomach digestive system: 75% of a cow's diet is not digestible by humans. Cow nutrition plans not only boost milk production, but also create value from manufacturing by-products that would otherwise become landfill waste. U.S. dairy cow feed plans incorporate items such as citrus pulp from food and beverage processors and cottonseed from the fiber industry; the cows use the nutrition to produce milk.

Another sustainable by-product of U.S. dairy farms is cow manure, a natural fertilizer that also converts into a renewable energy source. Nutrient-rich cow manure fertilizes croplands to improve growth yields of crops for people and animals alike. One cow produces 64 liters (17 gallons) of manure per day. That's enough fertilizer to grow 25 kilograms (56 pounds) of corn or 38 kilograms (84 pounds) of tomatoes.

The U.S. dairy industry takes sustainability one step further to create additional value from manure. Anaerobic digester systems convert manure and commercial food waste into electricity, fuel for cars and trucks, fiber and, of course, fertilizer. The result translates into combined revenues and cost savings of (U.S.) $200 per cow per year.

The ultimate goal of the U.S. dairy industry's sustainability efforts is simple: Healthy People. Healthy Planet. Healthy Communities.

2 The U.S. Milk Powder Industry

2.1 OVERVIEW

Whether they are used to extend local milk supply, provide nutritional benefits, give convenience of use or provide functional or shelf life benefits, global food manufacturers have made milk ingredients an integral part of their success. They have come to trust the quality of U.S. milk ingredients with good reason. The United States is among the most efficient producers of milk powder with ample growth capacity, backed by the strictest set of food sanitary standards in the world. Together with its expanding product portfolio, significant investments in new plants and upgrades to existing facilities, as well as rising international focus, the U.S. dairy industry is well-positioned to supply a widening range of milk powder products that meet customers' specifications.

Large and Rising Production

With over one million metric tons produced as of 2017, the United States is the world's largest single-country producer of skimmed milk powder/nonfat dry milk (SMP/NDM). SMP is manufactured across the United States in small and large facilities with a range of capabilities.

U.S. manufacturers continue to boost year-on-year production of SMP, with production projected to reach 1.2 million metric tons by 2021. This upward trajectory attests to rising customer interest in the United States as a quality, large-volume supplier and partner that can fulfill their rising milk powder needs across a wide range of product applications. Moreover, the volume and share of exported U.S. SMP continues to grow in tandem with rising production. Over 50% of U.S. SMP is exported, with the United States accounting for approximately a quarter of the world's production.

Expanding Portfolio

The U.S. dairy industry recognizes that customers have different specification needs, depending on the end-use application. U.S. milk powder manufacturers utilize world-class technology and have invested in process improvements, as well as new and upgraded plant facilities to consistently meet and exceed customers' rigorous and specialized quality and sensory specifications for milk powder. This includes high-spec, low-spore powders for recombining and nutritional applications.

U.S. manufacturers are also ramping up production and exports of a broadening range of milk powder beyond NDM and SMP. Once an importer of milk protein concentrates, the U.S. has now shifted to becoming a rising exporter, with production exceeding 63,000 metric tons as of 2017.

Several U.S. dairy manufacturers in recent years have added capacity for production and exports of whole milk powder (WMP), as market dynamics warrant. This includes state-of-the-art flex plants that can shift between skimmed milk powder and whole milk powder productions in response to prevailing market demand circumstances. This capacity expansion is in response to export customers' requests, reflecting the U.S. dairy industry's ever-strengthening dedication and responsiveness to global customer needs.

Consistent Availability

Year-round cow's milk production ensures product availability at any time of the year, including the winter season. Customers can count on the United States to deliver a consistent and quality supply that retains its flavor and freshness during normal storage and handling conditions.

For updated statistics on U.S. milk powder production and exports, visit the milk powder section of USDEC's website: ThinkUSAdairy.org/products/milk-powders

2.2 GENERAL BENEFITS OF MILK POWDERS, MPCs AND MPI

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 skimmed 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 powder products are milk 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 powder 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

Milk protein concentrates and milk protein isolate are made by separating milk proteins from water as well as from other components of milk using physical separation processes.

The general benefits of MPCs and MPI include:

- Protein quality—Compact sources of protein, branched chain amino acids (BCAAs) and a digestible indispensable amino acid score (DIAAS) greater than 1 and a protein digestibility-corrected amino acid score (PDCAAS) score of 1
- Cost effective—The low cost and price volatility of MPCs and MPI allows for innovative uses in various means of application
- Storage—Retains high quality for at least 12 months under regular storage conditions
- Health—A good sources of minerals (calcium, phosphorus, etc.) which help to promote muscle recovery, lean body mass growth, gastrointestinal and cardiometabolic health

3 Production and Manufacturing Technologies

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Dry milk ingredients produced in the United States are manufactured under very strict conditions of hygiene and Good Manufacturing Practice (GMP). Regulatory control starts at the dairy farm, where milk producers must adhere to strict sanitary standards, the effectiveness of which are monitored regularly through visits by government inspectors. Regulations prescribe standards that address factors such as herd health, veterinary practices, construction and cleanliness of facilities at the farm, water supply, utensils and equipment, the milking process and worker hygiene. Of critical importance is the requirement that all milk is rapidly cooled to 10 ˚C (50 ˚F) within four hours of the first milking and to 7 ˚C (45 ˚F) within two hours of completion of milking.

Milk is transported in trucks that must carry the appropriate permit gained following rigorous inspection. Frequent cleaning and sanitizing is a specified requirement and must be formally recorded.

Processing facilities are similarly subject to strict regulations concerning construction, layout, suitability of equipment, etc. U.S. milk processing facilities were in the vanguard of the implementation of Hazard Analysis and Critical Control Points (HACCP) and quality management programs such as International Organization for Standardization (ISO), Safe Quality Food (SQF), etc. Such programs help to ensure the suitability and quality of employees and the process from raw material sourcing and reception to packaged end product. As a result, compliance with the Food Safety Modernization Act (FSMA) has not been as challenging to dairy processors as it has been to other sectors in the U.S. food industry that were less practiced in quality management than the U.S. dairy industry.

3.1 MILK RECEIVING AND PROCESSING

Acceptance of incoming milk trucks for unloading at the processing plant is contingent upon the arriving milk passing several tests including those for absence of antibiotic residue, pH and temperature. Accepted milk is off-loaded into large reception tanks and cooled to 7 ˚C (45 ˚F). Special attention is given to tracking and tracing each load of milk at this stage, as generally multiple tank loads are co-mingled in large, refrigerated milk storage silos.

Irrespective of end product—milk protein isolate (MPI), milk protein concentrate (MPC), whole milk powder (WMP), nonfat dried milk (NDM), skimmed milk powder (SMP) or buttermilk powder—the first step involves removal of cream using centrifugal separators. The variable fat content of milk and subsequent requirement for standardization means that this step is also necessary when producing WMP. In the latter case, a portion of cream is added back to the de-creamed milk to produce a process intermediate with standardized fat content between 26–40% fat. No other standardization is allowed under U.S. product definitions for WMP, NDM or buttermilk powder. The exception is SMP, for which no standard of identity exists in U.S. regulation, restricting its sale for use in the United States. Rather, SMP is defined in the Codex Alimentarius, and SMP manufactured in the United States is for export only. The Codex specification for milk powder differs from that of the United States, as standardization of protein content to equal or greater than 34% (on a milk solids nonfat basis) is allowed by addition of milk retentate, milk permeate or lactose. One consequence of these regulations is that U.S. produced NDM generally contains higher protein content than SMP produced outside the United States to the Codex standard.

Pasteurization is generally the next step in the process with all milk powders. In the United States, pasteurization of dairy products is defined in the Code of Federal Regulations and must comply with specific time-temperature combinations defined within the regulation, ranging from 63 ˚C (145 ˚F) for 30 minutes for batch treatments to 135 ˚C (275 ˚F) for 1–2 seconds for ultra-high temperature (UHT) processing. In practice, U.S. producers of milk powder generally use a continuous flow through heat exchanger arrangement for pasteurization set at 72 ˚C (161 ˚F) for 15 seconds, known as high-temperature-short-time (HTST) pasteurization. Individual states are allowed to define pasteurization conditions, but must, at a minimum, meet those defined in the CFR. For example, Idaho has mandated a temperature-time combination that is at least 72.2 ˚C (162 ˚F) for 16 seconds. Following pasteurization, an additional pre-heat or heat holding time is frequently included to adjust the functional properties and shelf life of the powder to match intended end use. This additional heat step is used to control the extent of denaturation of whey protein and deactivation of milk enzymes. In the case of WMP, such a pre-heat treatment improves keeping quality but can negatively affect solubility. It is this step that defines the product type as low, medium or high heat milk powder.

High pressure homogenization is only a necessary subsequent step in the case of whole milk powder manufacture and is included to ensure that large fat globules are dispersed into fine, protein-stabilized fat droplets of less than 1.0 μm diameter.

3.2 CONCENTRATION, FRACTIONATION AND ISOLATION

In the manufacture of NDM, SMP, WMP or buttermilk powder, the next step in production involves concentration. Water can be removed from the liquid milk stream much more efficiently by vacuum evaporation at this stage of the process rather than during drying. Indeed, the objective is to concentrate the milk as much as possible before feeding to the dryer. Generally, this is achieved through multiple cycles through a multi-stage (also called multiple-effect) vacuum evaporator. In a modern falling film vacuum evaporator, the product feed is introduced at the top of the stage, where it is distributed such that it flows as a thin film down the inside walls of multiple tubes that are suspended in a heated chamber. Under reduced pressure and elevated temperature, the liquid film of milk quickly starts to boil. Water vapor is drawn off at the bottom of the evaporator tubes thereby assisting gravity in drawing the flowing film to the base of the stage. At this point, vapor and concentrate are separated, and the concentrate advances to the next stage/cycle of the evaporator. The vapor is condensed, and the water recovered frequently is recycled. In addition, heat recovery systems are commonplace in modern evaporators, further improving efficiency.

In the case of milk, it is critical that heat load on the product is minimized during this concentration phase of the process to preserve functional and nutritional properties. The partial vacuum in the evaporator allows vapor to boil off when the evaporator is running at moderate temperatures of about 50 °C (122 °F). The target solids content depends on the type of dryer that is to be used. Most milk powders are produced by spray drying, in which case, evaporation continues to a solids content in the range 45–52%. Higher concentration elevates viscosity to levels too high for most spray driers, although with modified nozzles, feeds that reach 60% solids have been successfully dried. If a roller dryer is to be used, it is necessary to evaporate up to a solids content of 60–65%.

In the manufacture of some milk ingredients (i.e., MPCs and MPI) the next step would be a membrane fractionation or isolation process. First widely utilized commercially approximately 50 years ago for whey processing, membrane processing is now widely used for the safe and efficient concentration, fractionation and isolation of milk and milk components for the commercial production of a host of high-quality dairy ingredients. In membrane processing, milk is circulated under an applied pressure over a semi-permeable membrane with various pore sizes to selectively concentrate, fractionate or isolate milk and milk components based on their molecular size. The components of milk that are smaller than the membrane pores pass through and are known as the permeate, and the components that are larger than the membrane pores are known as the retentate.

Membrane filtration processes used in production of dairy ingredients (from smallest to largest membrane pore size) are: reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF). Because of their very small pore size, RO membranes only allow the water from milk to go through the membrane into the permeate. Hence, reverse osmosis is often used as a pre-concentration step prior to vacuum evaporation of milk in the manufacture of NDM, SMP or WMP. Nanofiltration (NF) has slightly larger pores and when milk is passed through nanofiltration membranes, water and some low molecular weight components like minerals and non-protein nitrogen (e.g. urea) will go into the permeate. Ultrafiltration (UF) has pores that will allow the next largest component lactose to pass through along with the water, minerals and non-protein nitrogen. As a result, UF provides a means to concentrate the macromolecules of milk (protein and fat from whole milk) or in the case of UF of skimmed milk, concentration of milk proteins. Hence, UF has been used to produce a family of MPCs and MPIs with protein concentrations of 40–90% and where the protein-to-lactose ratio and the protein-to-ash ratio has been increased relative to these ratios in milk. However, since conventional UF processes concentrate all the proteins from milk, the ratio of casein-to-whey protein remains the same as the original milk. Finally, microfiltration (MF) utilizes the largest pore size membranes. Because casein micelles are much larger on a molecular scale than the whey proteins, microfiltration of skimmed milk results in the permeation of whey proteins, lactose, minerals, non-protein nitrogen milk components and water, while selectively retaining milk caseins. As a result, the retentate results in a high protein product with a selectively higher casein-to-whey protein ratio than milk. MF milk retentate upon concentration and drying is described as micellar casein concentrate (MCC), microfiltered milk protein or native phosphocaseinate. Sometimes, in membrane processing, potable water is added back to the milk retentates and reprocessed to further remove lactose, soluble minerals and other low molecular weight constituents to further purify the milk proteins in a process known as diafiltration (DF).

3.3 DRYING

To further minimize heat load, the concentrate is cooled after evaporation or membrane processing until sufficient volume is collected to start drying. The pooled concentrate is rapidly preheated and fed under high pressure to the spray dryer. The feed stream is atomized upon exit from the dryer nozzles or a rotary wheel creating a spray of tiny droplets. The size of the droplets can be controlled to fall within the range of about 10–500 μm, although generally a range of 100–200 μm is targeted. The concentrate temperature at atomization is high, often in the region of 205 °C (400 °F). Even though the air temperature in the drying chamber is high, the spray droplets cool very rapidly to about 93 °C (200 °F) within approximately three meters of ejection from the nozzle in tower form dryers, in part due to the cooling effect of water evaporating from the droplet. It is important that the droplets are not dried too quickly. Removal of water from the droplet surface too rapidly will result in the development of a hard shell with reduced moisture permeability. This effect is called case hardening. The outer shell traps residual moisture in the particle core and reduces solubility of the powder. In part to avoid this, in modern spray dryers, evaporation from the moist powder particle is completed in a second stage, comprising a fluid bed. Following this step, the dried powder, with a moisture content of 3–4%, is sifted to remove any lumps and usually passes by a rare earth magnet prior to packaging to ensure no foreign objects are present.

Before spray drying became so well developed, roller drying was a popular means of drying NDM, WMP or caseinates. This method involves applying a film of superheated concentrate (60–65%) of milk solids from the evaporator in a uniform manner onto the surface of large (~0.61 to 2.7 meter diameter, ~0.91 to 6.1 meters long) rotating, steam-heated drums. Significant moisture flashes off as the superheated

concentrate is applied and the remaining moisture is driven off as the hot drum rotates. The now solid film is separated from the roller surface by a blade and has the appearance of an enormous sheet of tissue paper. This continuous sheet is fed into a macerator which chops it into fine flakes, whereupon it is transported to the packaging line. One disadvantage of roller drying is that it exposes the milk powder to significantly higher heat load than spray drying. While modern roller dryers produce a readily wettable product, the higher levels of heat load can negatively affect milk powder solubility. In addition, the heat can induce Maillard browning reactions between lactose and protein present in the milk powder. This can be a problem at the edges of the milk powder film at the ends of the roller where film thickness is thinnest and most likely to overheat. Generally this part of the film is discarded to control the scorched particle scores of the end product. As a result, roller drying of milk powder is now less common. It does remain popular among producers of caseinate, as this ingredient is essentially lactose free and thus less susceptible to Maillard reactions.

3.4 INSTANTIZING

Milk ingredient powders designated for applications where dispersibility and solubility are key functional attributes can undergo post-drying processing such as agglomeration and instantizing. Ideally, instantized powder is produced in-line in the latter stages of the drying process. This can be achieved by manipulation of particle moisture using lower air temperatures to induce controlled powder particle agglomeration in the fluid bed. At this stage, a wetting agent such as lecithin may be sprayed onto the powder particles to further improve dispersbility. However, some dryers are not sufficiently equipped to allow this process and in such cases when powders need to be instantized,a rewet process is required. This process involves exposure of the powder to humidified air which induces particle clustering. The clusters are then dried in a stream of heated, filtered air and the product is packaged.

3.5 PACKAGING

The packaging area of milk ingredient powder plants presents the highest risk of contamination of the end product. This is because the product is momentarily exposed to the environment for the first time after passing the final microbiological kill step critical control point—pasteurization. It is essential to take strict measures to control the risk of contamination at the packaging stage. To this end, the packaging area is always designated a red zone, and employee traffic entering this area is limited and strictly controlled. Employees enter the red zone usually by crossing a physical hygiene barrier immediately after donning red zone clothing and taking additional sanitization steps. The packaging area is generally fed with filtered air and is continuously maintained under positive air pressure to prevent entry of airborne bacteria. Employees working in the packaging area are specially trained and measures such as dedicated red zone tools further limit the risk of contamination being carried in from outside the area. The majority of milk powder is packaged in Kraft bags with polythene inner liners or large totes.

Figure 3.1
Basic Milk Power Production

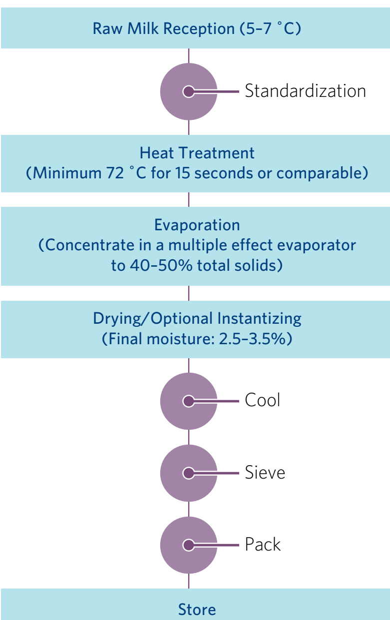


Figure 3.2
Instantizing-Rewet Process

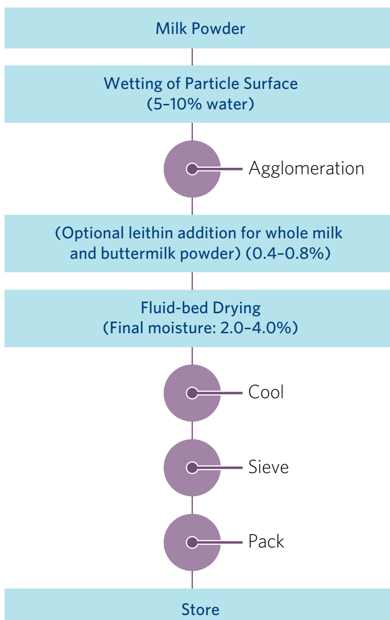
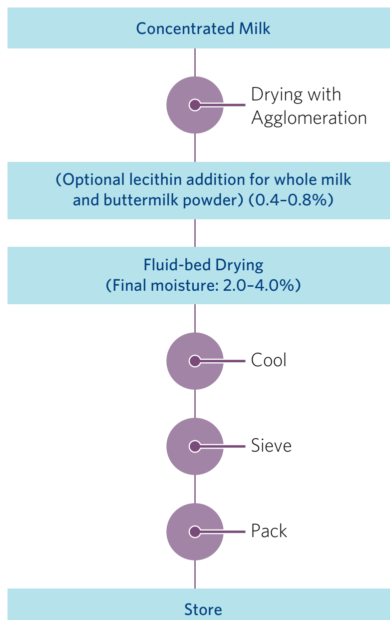


Figure 3.3
Instantizing-Straight-Through Process



4 Definitions, Composition and Uses

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4.1 NONFAT DRY MILK, SKIMMED MILK POWDER

While both the terms nonfat dry milk (NDM) and skimmed (or skim) milk powder (SMP) are used 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 (NDM), as defined by the Code of Federal Regulations (CFR), is obtained by removing water from pasteurized skimmed milk. It contains 5% or less moisture (by weight) and 1.5% or less milkfat (by weight) unless otherwise indicated. By removing moisture to the greatest extent possible, microbial growth is prevented. NDM 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 can be made by roller drying or spray drying, the latter being the most common. Spray dried nonfat dry milk powders are available in two forms:

1. Ordinary or non-agglomerated (non-instant)
2. Agglomerated (instant)

The Codex Alimentarius 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 must have been done 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 (SMP) which are:

- Maximum milkfat: 1.5% m/m
- Maximum water[(a)]: 5% m/m
- Minimum protein in milk solids nonfat[(a)]: 34% m/m

[(a)] The water content does not include water of crystallization of the lactose; the milk solids-not-fat content includes water of crystallization of the lactose.

The SMP standard also makes provisions 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 (5 g/kg), emulsifiers (lecithins, limited by GMP; mono- and diglycerides of fatty acids, 2.5 g/kg), 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.

Table 1: Typical Composition of Nonfat Dry Milk and Skimmed Milk Powder

Protein	34.0–36.0%
Lactose	51%
Fat	0.7–1.5%
Ash	8.2–8.5%
Moisture	
• Non-instant	3.0–4.0%
• Instant	3.5–4.5%
TYPICAL MICROBIOLOGICAL ANALYSIS	
Standard plate count	<10,000 cfu/g*
Coliform	10/g max
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*

Table 2: Typical Nutritional Composition of Nonfat Dry Milk (without added Vitamins A and D)

NUTRIENT	NONFAT DRY MILK, REGULAR, PER 100 g	NONFAT DRY MILK, INSTANT, PER 100 g
Water	3.16 g	3.96 g
Energy	1516 kJ (362 kcal)	1498 kJ (358 kcal)
Protein	36.16 g	35.10 g
Lipid (total, fat)	0.77 g	0.72 g
Ash	7.93 g	8.03 g
Carbohydrate (by difference)	51.98 g	52.19 g
Fiber, total dietary	-	-
Sugars, total	51.98 g	52.19 g
MINERALS		
Calcium	1257 mg	1231 mg
Iron	0.32 mg	0.31 mg
Magnesium	110 mg	117 mg
Phosphorus	968 mg	985 mg
Potassium	1794 mg	1705 mg
Sodium	535 mg	549 mg
Zinc	4.08 mg	4.41 mg
Copper	0.041 mg	0.041 mg
Manganese	0.020 mg	0.020 mg
Selenium	27.3 µg	27.3 µg

NUTRIENT	NONFAT DRY MILK, REGULAR, PER 100 g	NONFAT DRY MILK, INSTANT, PER 100 g
VITAMINS		
Vitamin C, total ascorbic acid	6.8 mg	5.6 mg
Thiamin	0.415 mg	0.413 mg
Riboflavin	1.550 mg	1.74 mg
Niacin	0.951 mg	0.891 mg
Pantothenic acid	3.568 mg	3.230 mg
Vitamin B6	0.361 mg	0.345 mg
Folate, total	50 µg	50 µg
Vitamin B12	4.03 µg	3.99 µg
Vitamin A, RAE	6 µg	4 µg
Vitamin D	-	-
Vitamin E	-	0.01 mg
Vitamin K	0.1 µg	-
LIPIDS		
Saturated, total	0.499 g	0.470 g
Monounsaturated, total	0.201 g	0.190 g
Polyunsaturated, total	0.030 g	0.030 g
Cholesterol	20 mg	18 mg
AMINO ACIDS		
Tryptophan	0.510 g	0.495 g
Threonine	1.632 g	1.584 g
Isoleucine	2.188 g	2.124 g
Leucine	3.542 g	3.438 g
Lysine	2.868 g	2.784 g
Methionine	0.907 g	0.880 g
Cystine	0.334 g	0.325 g
Phenylalanine	1.746 g	1.694 g
Tyrosine	1.746 g	1.694 g
Valine	2.420 g	2.349 g
Arginine	1.309 g	1.271 g
Histidine	0.981 g	0.952 g
Alanine	1.247 g	1.210 g
Aspartic acid	2.743 g	2.663 g
Glutamic acid	7.572 g	7.350 g
Glycine	0.765 g	0.743 g
Proline	3.503 g	3.400 g
Serine	1.967 g	1.909 g

Table 3: Typical Nutritional Composition of Nonfat Dry Milk (with added Vitamins A and D)

NUTRIENT	NONFAT DRY MILK, REGULAR, PER 100 g	NONFAT DRY MILK, INSTANT, PER 100 g
Water	3.16 g	3.96 g
Energy	1516 kJ (362 kcal)	1499 kJ (358 kcal)
Protein	36.16 g	35.1 g
Lipid (total, fat)	0.77 g	0.72 g
Ash	7.93 g	8.03 g
Carbohydrate (by difference)	51.98 g	52.19 g
Fiber, total dietary	-	-
Sugars, total	51.98 g	52.19 g
MINERALS		
Calcium	1257 mg	1231 mg
Iron	0.32 mg	0.31 mg
Magnesium	110 mg	117 mg
Phosphorus	968 mg	985 mg
Potassium	1794 mg	1705 mg
Sodium	535 mg	549 mg
Zinc	4.08 mg	4.41 mg
Copper	0.041 mg	0.041 mg
Manganese	0.02 mg	0.02 mg
Selenium	27.3 µg	27.3 µg
VITAMINS		
Vitamin C, total ascorbic acid	6.8 mg	5.6 mg
Thiamin	0.415 mg	0.413 mg
Riboflavin	1.55 mg	1.744 mg
Niacin	0.951 mg	0.891 mg
Pantothenic acid	3.568 mg	3.235 mg
Vitamin B6	0.361 µg	0.345 mg
Folate, total	50 µg	50 µg
Vitamin B12	4.03 µg	3.99 µg
Vitamin A, RAE	653 µg	709 µg
Vitamin A, IU	2179 IU	2365 IU
Vitamin E	-	0.01 µg
Vitamin D3 IU	11 µg	11 µg
Vitamin D	440 IU	440 IU
Vitamin K	0.1 µg	-

NUTRIENT	NONFAT DRY MILK, REGULAR, PER 100 g	NONFAT DRY MILK, INSTANT, PER 100 g
LIPIDS		
Saturated, total	0.499 g	0.467 g
Monounsaturated, total	0.2 g	0.187 g
Polyunsaturated, total	0.03 g	0.028 g
Cholesterol	20 mg	18 mg
AMINO ACIDS		
Tryptophan	0.51 g	0.495 g
Threonine	1.632 g	1.584 g
Isoleucine	2.188 g	2.124 g
Leucine	3.542 g	3.438 g
Lysine	2.868 g	2.784 g
Methionine	0.907 g	0.88 g
Cystine	0.334 g	0.325 g
Phenylalanine	1.746 g	1.694 g
Tyrosine	1.746 g	1.694 g
Valine	2.42 g	2.349 g
Arginine	1.309 g	1.271 g
Histidine	0.981 g	0.952 g
Alanine	1.247 g	1.21 g
Aspartic acid	2.743 g	2.663 g
Glutamic acid	7.572 g	7.35 g
Glycine	0.765 g	0.743 g
Proline	3.503 g	3.4 g
Serine	1.967 g	1.909 g

Packaging

Stitched or glued, multi-wall 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 (81 °F) and relative humidity less than 65%. The shelf life of non-instant skimmed 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 skimmed 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

Nonfat dry milk and skimmed milk powders are used in bakery, confectionery, dairy, meat products and prepared mixes 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

Table 4: Major U.S. Uses of NDM & SMP (2016)

Dairy industry	57.8%
Confectionery industry	22.5%
Baking industry	5.1%
Prepared dry mixes and dry blends	2.9%
Infant formula	1.6%
All other uses	10.1%

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 skimmed 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 1.51–5.99 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.

Table 5: Heat Classification of Milk Powders

CLASS	WHEY PROTEIN NITROGEN INDEX
Low-heat	> 6.0 mg/g
Medium-heat	1.51–5.99 mg/g
High-heat	< 1.5 mg/g

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-to-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-to-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.

Table 6: 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 cream • Confections • Meat products • Dry mixes
		High-heat	• Baked goods • Meat products • Dry mixes • Ice creams

Table 7: Benefits by Application and Heat Treatment

APPLICATION	TYPE OF MILK POWDER	BENEFIT
Pasteurized recombined milk	• Low-heat or medium-heat	• Will yield the freshest flavor
	• High-heat	• When a "cooked" flavor is desired
Extended shelf life milk (ESL)	• Low-heat or medium-heat	• Will yield the freshest flavor
	• High-heat	• When a "cooked" flavor is desired
UHT milk	• Low-heat or medium-heat	• To preserve flavor and prevent fouling in the plant
Retort sterilized milk	• Low-heat or medium-heat	• Simplicity and flexibility of processing
Recombined evaporated milk	• Low-heat or medium-heat	• Recommended for continuous flow process
Recombined sweetened condensed milk	• Low-heat or medium-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 or 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 standardization and cheese milk extension is the most common manufacture practice

4.2 DRY WHOLE MILK, WHOLE MILK POWDER

While both the terms dry whole milk (DWM) and whole milk powder (WMP) are used 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 (DWM) is usually obtained by removing water from pasteurized, homogenized whole milk. It may also be obtained by blending fluid, condensed or skimmed 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 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 must be done 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.

Packaging

Stitched or glued, multi-wall 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 (81 °F) 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. In particular, flavor quality is impaired if temperatures are too high and storage is extended.

Typical Applications

Dry whole milk and whole milk powders are used in bakery, confectionery, dairy, prepared mixes, sauces and soups as:

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

Table 8: Typical Composition of Dry Whole Milk, Whole Milk Powder

Protein	26.0–26.8%
Lactose	37.0–38.0%
Fat	27%
Ash	6.0%
Moisture	2.0–3.0%
TYPICAL MICROBIOLOGICAL ANALYSIS	
Standard plate count	<10,000 cfu/g*
Coliform	10 cfu/g max
E. coli	Negative
Salmonella	Negative
Listeria	Negative
Coagulase-positive *Staphylococci*	<10 cfu/g

OTHER CHARACTERISTICS	
Scorched particle content	
• spray dried	22.5 mg
• roller dried	32.5 mg
Titratable acidity	0.17% max
• spray dried	
• roller dried	
Solubility index	
• spray dried	1.5 mL
• roller dried	15.0 mL
Color	White to light cream color
Flavor	Clean, pleasing dairy flavor

*Extra grade

Table 9: Major U.S. Uses of Dry Whole Milk (2016)

Confectionery industry	76.5%
Dessert toppings	9.5 %
Infant formula	4.1%
Baking industry	3.9%
Dairy industry	2.9%
Hot cocoa	1.4%
All other uses	1.7%

4.3 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, skimmed milk powder, dry whey or products other than buttermilk, and may contain no added preservatives, neutralizing agents 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 (81 °F) 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.

Table 10: Typical Composition of Dry Buttermilk

Protein	32.0–34.4%
Lactose	48.0–48.5%
Fat	5.0–6.5%
Ash	8.4–8.5%
Moisture	3.0–4.0%
TYPICAL MICROBIOLOGICAL ANALYSIS	
Standard plate count	20,000 cfu/g*
Coliform	10 cfu/g max
E. coli	Negative
Salmonella	Negative
Listeria	Negative
Coagulase-positive *Staphylococci*	Negative
OTHER CHARACTERISTICS	
Scorched particle content	
• spray dried	less than 15 mg
• roller dried	less than 22.5 mg
Titratable acidity	0.10–0.18%
Solubility index	
• spray dried	1.25 mL
• roller dried	15.0 mL
Color	Uniform cream to dark color
Flavor	Clean, pleasing sweet dairy flavor

**Extra grade*

Typical Applications

Dry buttermilk is used in bakery, confectionery, dairy, sauces and soups as:

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

Table 11: Typical Composition of Milk and Buttermilk Powders (%)

	SKIMMED 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 <4.5% Buttermilk product
Ash	8.2–8.6	5.5–6.5	-
Moisture		5.5–6.5	
(Non-instant)	3.0–4.0	2.0–4.5	3.0–4.0
(Instant)	3.5–4.5		

Table 12: Major U.S. Uses of Buttermilk Solids (2016)

Dairy industry	53.1%
Prepared dry mixes and dry blends	22.0%
Bakery industry	12.1%
Confectionery industry	5.0 %
All other uses	7.8%

4.4 MILK PROTEIN CONCENTRATE AND MILK PROTEIN ISOLATE

Product Definition

Milk protein concentrate (MPC) and milk protein isolate (MPI) are obtained by the partial removal of non-protein constituents (lactose and minerals) from skimmed milk. MPCs are available in a range of protein levels—from 42% to 85%—with typical offerings at 42%, 56%, 70%, 75%, 80% and 85%. Each is identified by a number that represents the protein content of the product (for example, MPC 42 contains 42% protein by weight). The protein and lactose content of MPCs are inversely related; the higher the protein content, the lower the lactose content.

MPC 42 contains 42% protein and 46% lactose, while MPC 85 contains 85% protein and 3.2% lactose. MPI generally contains over 85% protein and typically lower lactose levels than MPCs.

MPC and MPI may be produced by filtration (microfiltration, ultrafiltration or diafiltration), dialysis or any other safe and suitable process in which all or part of the lactose may be removed.

Both MPC and MPI are available in spray dried form.

Packaging

Stitched or glued, multi-wall Kraft bag with polyethylene inner liner. No staples or metal fasteners.

- Net weight: 20.0–25.0 kg

Also available in plastic-lined tote bins.

Storage

Ship and store in a cool, dry environment at temperatures less than 27 °C (81 °F) and relative humidity less than 65%. Use within 18 months. Note that storage life is very dependent on storage conditions and this figure is only a guide.

Table 13: Typical Composition of MPC, MPI

	MPC 42	MPC 56	MPC 70	MPC 85	MPI	TEST METHOD
Protein %	42.0	56.0	70.0	85.0	>89.5	AOAC 991.20 or Standard Methods 15.131
Fat %	1.0	1.1	1.2	1.4	<1	AOAC 989.05 or Standard Methods 15.086
Lactose %	47.0	32.0	18.0	3.2	<10	Standard Methods 15.091 or by difference
Ash %	6.5	6.8	6.8	6.6	6.0	AOAC 945.46 or Standard Methods 15.041
Moisture %	3.5	4.1	4.0	3.8	5	AOAC 927.05 or Standard Methods 15.111

Table 14: Typical Composition of Commercially Available MPC and MPI

PRODUCT	PROTEIN %	FAT %	LACTOSE %	ASH %	MOISTURE %
MPC 40	39.5 min	1.25 max	52.0 max	10.0 max	5.0 max
MPC 42	41.5 min	1.25 max	51.0 max	10.0 max	5.0 max
MPC 56	55.5 min	1.50 max	36.0 max	10.0 max	5.0 max
MPC 70	69.5 min	2.50 max	20.0 max	10.0 max	6.0 max
MPC 80	79.5 min	2.50 max	9.0 max	8.0 max	6.0 max
MPC 85	85.0 min*	2.50 max	8.0 max	8.0 max	6.0 max
MPI	89.5 min*	2.50 max	5.0 max	8.0 max	6.0 max

**Protein content ≥85.0% is reported on a dry basis, all other parameters are reported "as is."*

Table 15: Typical Microbiological Analysis of MPC, MPI

Standard plate count	<30,000 cfu/g*
Coliform	10/g max
E. coli	<10 cfu/g
Salmonella	Negative/375 g
Listeria	Negative/25 g
Staphylococcus aureus	<10 cfu/g
Lead	<1 ppm

**Extra grade*

Typical Applications

Milk protein concentrate is used in meal replacement products, powdered nutritional beverages, nutrition bars, dairy beverages, yogurt and fermented milk products, frozen desserts, chocolate confectionery and coatings, salad dressings, soups and sauces as:

- A source of high-quality protein
- A thickening agent
- A fat stabilizer and replacer

Table 16: Major U.S. Uses of Milk Protein Concentrates (2016)

Mainstream nutrition	29.5%
Dairy industry	18.5%
Baking industry	14.5%
Sports powders	13.2%
Prepared dry mixes and dry blends	12.3%
Confectionery industry	7.7%
All other uses	4.3%

Table 17: Typical Levels of Incorporation for MPC and MPI

FOOD CATEGORY	APPLICATION	FUNCTION	MPC 42	MPC 56	MPC 70	MPC 80	MPC 85	MPI 90
Nutritional Products	Meal replacements and meal supplements (without meat or poultry)	Emulsification, heat stability, source of high quality protein, flavor	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%
	Powdered nutritional beverages	Source of high quality protein, organoleptic appeal	Up to 50%	Up to 50%	50-80%	50-80%	50-80%	50-90%
	Nutrition bars	Source of high quality protein, cohesiveness, flexibility, chewiness control	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%
	Children's foods and beverages	Source of high quality protein, heat stability	5-10%	5-10%	5-10%	5-10%	5-10%	5-10%
Dairy and Dairy-Based Products	Dairy beverages	Sedimentation stability, protein enrichment, mouthfeel	5-15%	5-15%	5-15%	5-15%	5-15%	5-15%
	Yogurt and fermented milk products	Texturizer, thickener	< 5%	< 5%	< 5%	< 5%	< 5%	< 5%
	Non-standardized cheese products	Texturizer, thickener, fat stabilization	1-10%	1-10%	1-10%	1-10%	1-10%	1-10%
	Spreads, dips and cream substitutes	Mouthfeel, fat replacement	1-10%	1-10%	1-10%	1-10%	1-10%	1-10%
	Frozen desserts	Stabilization, emulsification	1-10%	1-10%	1-10%	1-10%	1-10%	1-10%
Sugar-Based Products	Desserts and mousses	Foaming, reduction of lactose content	<5%	<5%	<5%	<5%	<5%	<5%
	Chocolate confectionery	Source of lactose, mouthfeel, dairy flavor	1-10%	1-10%	1-10%	N/A	N/A	N/A
	Snacks, coatings and fillings	Flavor carrier, dairy flavor, texture	1-10%	1-10%	1-10%	N/A	N/A	N/A
Dressings	Salad dressings	Emulsification, flavor	<5%	<5%	<5%	<5%	<5%	<5%
Others	Soups and sauces	Reduction of stabilizer, dairy flavor, creaminess	2-10%	2-10%	2-10%	2-10%	2-10%	2-10%

4.5 MICELLAR CASEIN CONCENTRATE (MICROFILTERED MILK PROTEIN)

Product Definition

Micellar Casein Concentrate (MCC), a type of microfiltered milk protein or native phosphocaseinate, is produced by microfiltration of skimmed milk. It differs from other concentrates of milk protein because the ratio of casein-to-whey proteins is altered (increased) compared to milk's ratio of casein-to-whey protein due to the microfiltration process. Additionally, the casein remains in its native (micellar) form.

Storage

Ship and store in a cool, dry environment at temperatures less than 27 °C (81 °F)and relative humidity less than 65%. Use within 18 months. Note that storage life is very dependent on storage conditions and this figure is only a guide.

Packaging

Stitched or glued, multi-wall Kraft bag with polyethylene inner liner. No staples or metal fasteners.

- Net weight: 20.0–25.0 kg

Product Composition

Like MPCs, MCCs can range in protein content from 41.5% to 89.5%.

The casein-to-whey protein ratio in MCC is typically is in the range of 82.18-95%:5%; whereas the typical ratio of casein-to-whey protein in milk is 80%:20%.

Table 18: Typical Composition of MMP and MCC

PRODUCT MMP/MC	PROTEIN %	FAT %	LACTOSE %	ASH %	MOISTURE %
42	41.5 min	1.25 max	51.0 max	6.0 max	5.0 max
70	69.5 min	2.50 max	16.0 max	8.0 max	6.0 max
80	79.5 min	3.00 max	10.0 max	8.0 max	6.0 max
85	85.0 min*	3.00 max	3.0 max	8.0 max	6.0 max
90	89.5 min*	3.00 max	1.0 max	8.0 max	6.0 max

** Protein content over ≥85.0% is reported on a dry basis, all other parameters are reported "as is."*

References

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American Dairy Products Institute. ADPI Dairy Ingredients Standards. Illinois (IL): ADPI; 2016.

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United States Department of Agriculture. 2016. National Nutrient Database for Standard Reference, Full Report (All Nutrients) 01154, Milk, dry, nonfat, regular, with added vitamin A and vitamin D.

United States Department of Agriculture. 2016. National Nutrient Database for Standard Reference, Full Report (All Nutrients) 01155, Milk, dry, nonfat, instant, without added vitamin A and vitamin D.

5 Quality Control and Grading Standards

5.1 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 milk powders in the world.

The U.S. standards for grades of milk powders come from the Dairy Division of the USDA. The standards are based on input and analysis of processor and user needs for product quality and functionality to 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.

Industry standards, specifications or commercial item descriptions (CIDs) for skimmed milk powder, whole milk powder, buttermilk powder and MPC promote the utilization of milk powders by making available a uniform grading system. The U.S. fluid milk supply, its manufacturing facilities and its subsequent storage facilities are all in accordance with some of the strictest regulations and practices in place throughout the world. Milk powders made in the United States meet strict safety and quality grade requirements.

Buyers who use such standards, specifications or CIDs in their purchasing decisions provide themselves with an added safeguard regardless of the particular purpose for which the milk powder is intended; however, these requirements cannot meet all possible end uses. To determine the acceptability of a milk powder in a specific formulation, supplemental tests not included in the standards, specifications or CIDs may be necessary.

Benefits

- **Ensure Uniformity:** Uniform quality of the product is ensured by conforming to grade standards which are accepted and understood throughout the milk powder industry. Milk powder standards, specifications or CIDs 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 designation. Tests and grades are based on internationally recognized analytical procedures. This eliminates unnecessary and detailed tests that may produce varying results between manufacturing and purchasing organizations.
- **Reduce Risk:** The manufacturer of the milk powder 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 and, if desired, certified by the USDA. Similarly, the manufacturer is protected against unreasonable complaints because the grade standards are succinct and based upon specific methods of analysis.

Conforming to milk powder standards, specifications or CIDs is the basis for an effective quality control program.

Plant Surveys

The USDA's Agricultural Marketing Service's (AMS) Dairy Grading Program conducts plant surveys (inspections) to ensure that milk powders are produced under sanitary conditions. 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 USDA requirements are granted an "Approved 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 rodent or pest infestation to maximize product safety.
2. Areas such as the raw milk receiving, milk storage, pasteurization, processing, product packaging and warehouse or supply rooms must have adequate lighting to facilitate cleaning and inspection of equipment and products.
3. Facilities must be of sound construction.

4. Incoming milk must be regularly analyzed to ensure high quality and product safety, including freedom from antibiotic contamination.
5. Personnel practices and attire must be appropriate to maximize product safety.
6. All processing equipment must be kept sanitary and in excellent working condition to ensure that the milk powder is protected from contamination.

Inspection and Grading

Only products produced in a facility that has successfully passed a USDA Plant Survey are eligible for 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, prepares official samples for analysis when required by the standard and stamps packages with the official acceptance stamp or grade mark. Inspectors also issue certificates for product that complies with the standard or specifications.

Laboratory Service

Laboratory service consists of analytical and quality control tests including all chemical and bacteriological determinations essential for establishing the final grade. Laboratory services also perform the necessary testing for the Salmonella Surveillance Program conducted by USDA under a memorandum of understanding with the U.S. Food & Drug Administration (FDA).

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, or have held responsible jobs in the dairy industry.

5.2 FDA STANDARDS OF IDENTITY

The Food and Drug Administration

The FDA, an entity of the U.S. Department of Health and Human Services, has issued standards of identity for three types of dried milk products. These standards of identity are published in the United States Code of Federal Regulations (CFR), Title 21, Part 131, Subpart B and can be downloaded directly from the FDA's website (www.fda.gov). Many other countries have their own standards of identity. U.S. dairy ingredient processors must also meet local standards for export into these countries.

§131.125 Nonfat dry milk

(a) *Description*. Nonfat dry milk is the product obtained by removal of water only from pasteurized skim milk. It contains not more than 5% by weight of moisture and not more than 1½% 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:

(1) Fruit and fruit juice, including concentrated fruit and fruit juice.

(2) Natural and artificial food flavorings.

(c) *Methods of analysis*. The following referenced methods of analysis are from "Official Methods of Analysis of the Association of Official Analytical Chemists," 19th Ed. (2012), which is incorporated by reference. Copies may be obtained from the AOAC INTERNATIONAL, 481 North Frederick Ave., Suite 500, Gaithersburg, MD 20877-2450 or may be examined at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call +1 202-741-6030.

(1) Milkfat content—"Fat in Dried Milk—Official Final Action," sections 16.199-16.200.

(2) 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 1½% by weight, the name of the food on the principal display panel or panels shall be accompanied by the statement “Contains _% milkfat,” the blank to be filled in with the percentage to the nearest one-tenth of 1% of fat contained, within limits of good manufacturing practice. The name of the food shall include a declaration of the presence of any characterizing flavoring, as specified in §101.22 of this chapter.

(e) *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.

§131.127 Nonfat dry milk fortified with vitamins A and D

(a) *Description*. Nonfat dry milk fortified with vitamins A and D conforms to the standard of identity for nonfat dry milk, except that vitamins A and D are added as prescribed by paragraph (b) of this section.

(b) *Vitamin addition*. (1) Vitamin A is added in such quantity that, when prepared according to label directions, each quart of the reconstituted product contains 2000 International Units thereof.

(2) Vitamin D is added in such quantity that, when prepared according to label directions, each quart of the reconstituted product contains 400 International Units thereof.

(3) The requirements of this paragraph will be deemed to have been 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:

(1) Carriers for vitamins A and D.

(2) Characterizing flavoring ingredients, with or without coloring, and nutritive carbohydrate sweetener, as follows:

(i) Fruit and fruit juice, including concentrated fruit and fruit juice.

(ii) Natural and artificial food flavorings.

(d) *Methods of analysis*. The following referenced methods of analysis are from “Official Methods of Analysis of the Association of Official Analytical Chemists,” 19th Ed. (2012), which is incorporated by reference. Copies may be obtained from the AOAC INTERNATIONAL, 481 North Frederick Ave., Suite 500, Gaithersburg, MD 20877-2450 or may be examined at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call +1 202-741-6030.

(1) Milkfat content—“Fat in Dried Milk—Official Final Action,” sections 16.199-16.200.

(2) Moisture content—“Moisture—Official Final Action,” section 16.192.

(3) Vitamin D content—“Vitamin D—Official Final Action,” sections 43.195-43.208.

(e) *Nomenclature*. The name of the food is “Nonfat dry milk fortified with vitamins A and D.” If the fat content is over 1½% by weight, the name of the food on the principal display panel or panels shall be accompanied by the statement “Contains _% milkfat,” the blank to be filled in to the nearest one-tenth of 1% with the percentage of fat contained within limits of good manufacturing practice. The name of the food shall include a declaration of the presence of any characterizing flavoring, as specified in §101.22 of this chapter.

(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.

§131.147 Dry whole milk

(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% but less than 40% by weight of milkfat on an as-is basis. It contains not more than 5% by weight of moisture on a milk solids not fat basis.

(b) *Vitamin addition*. (1) 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.

(2) 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.

(3) 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:

(1) Carriers for vitamins A and D.

(2) Emulsifiers.

(3) Stabilizers.

(4) Anticaking agents.

(5) Antioxidants.

(6) Characterizing flavoring ingredients (with or without coloring and nutritive carbohydrate sweetener) as follows:

(i) Fruit and fruit juice, including concentrated fruit and fruit juice.

(ii) 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," 19th Ed. (2012), which is incorporated by reference. Copies may be obtained from the AOAC INTERNATIONAL, 481 North Frederick Ave., Suite 500, Gaithersburg, MD 20877, or may be examined at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call +1 202-741-6030.

(1) Milkfat content—"Fat in Dried Milk—Official Final Action," sections 16.199-16.200.

(2) Moisture content—"Moisture—Official Final Action," section 16.192.

(3) 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.

(1) The phrase "Contains _% milkfat," the blank to be filled in with the whole number closest to the actual fat content of the food.

(2) If vitamins are added, the phrases "vitamin A," or "vitamin A added," or "vitamin D," or "vitamin D added," or "vitamins A and D," or "vitamins A and D added," can be used 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 of the CFR.

5.3 USDA GRADING

U.S. suppliers voluntarily participate in the USDA Inspection and Grading Programs. The standards, specifications or CIDs used are issued by the United States Department of Agriculture. The standards for grades themselves are summarized in this manual, and all of the documents can be downloaded from the USDA website (www.usda.gov).

General Grading Requirements

1. All nonfat dry milk, dry whole milk, dry buttermilk, MPC and MPI for human consumption must conform in all respects to federal and state government regulations in force at the time of grading or evaluation.
2. The milk powders 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 (162 °F) for 15 seconds, or its equivalent in bacterial destruction.
3. The milk powders 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 powders 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 powders 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 powders must not exceed 10 cfu per gram of milk powder.
7. The milk powders must be free from extraneous matter as described in Section 402(a) of the Federal Food, Drug and Cosmetic Act.

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.

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 Section 5.2) issued by the Food and Drug Administration. Basic compositional criteria are presented in the following table:

Table 1: Basic Compositional Criteria for Spray Dried and Roller Dried Nonfat Dry Milk

	SPRAY DRIED		ROLLER DRIED	
	EXTRA GRADE	STANDARD GRADE	EXTRA GRADE	STANDARD GRADE
Milkfat	<1.25%	<1.50%	<1.25%	<1.50%
Moisture	<4.0%	<5.0%	<4.0%	<5.0%

There are differences in composition, appearance, flavor and bacteriological standards between products that are Extra Grade versus Standard Grade.

Table 1 (continued)

- Extra Grade indicates the highest quality U.S. nonfat dry milk. It is determined on the basis of high parameters for flavor, physical appearance, bacterial estimate on the basis of standard plate count, milkfat content, moisture content, scorched particle content, solubility index and titratable acidity.
- Standard Grade is determined on the same basis as Extra Grade with slightly less stringent compositional parameters. It may contain small to moderate lumps, slight unnatural color and be reasonably free of visible dark particles. *There is no standard grade for instant nonfat dry milk.*
- Grade Not Assignable is assigned to milk powders for one or more of the following reasons:
  - Fails to meet the requirements for U.S. Standard Grade. Has a direct microscopic clump count exceeding 100 million per gram.
  - Has a coliform count exceeding 10 colony forming units (cfu) per gram.
  - The nonfat dry milk powder is produced in a plant that is rated ineligible for USDA grading service or is not USDA approved.

Table 2: Specifications for U.S. Grades of Nonfat Dry Milk, Spray Process

CHARACTERISTIC	EXTRA GRADE	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
Milkfat	<1.25%	<1.50%
Moisture	<4.0%	<5.0%
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

Table 2 (continued)

CHARACTERISTIC	EXTRA GRADE	STANDARD GRADE
Reconstituted product:		
Grainy	Not permitted	Reasonably free

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

	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)	<15.0 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)

**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 skimmed 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 milkfat. It conforms to the applicable provisions of the Code of Federal Regulations (see Section 5.2). 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 liter (1.06 quart) of the reconstituted products shall contain not less than 2,000 IU of vitamin A and 400 IU of vitamin D.

Table 3: 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
Milkfat	>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)

Table 3 (continued)

CHARACTERISTIC	U.S. EXTRA GRADE	U.S. STANDARD GRADE
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 is determined on the basis of flavor, physical appearance, bacterial estimate, coliform count, milkfat content, moisture content, scorched particle content, solubility index and titratable acidity.

	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)

Table 3 (continued)

Standard Grade

Standard Grade is determined on the same basis as Extra Grade with slightly less stringent compositional parameters.

	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)

Grade Not Assignable

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

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

Specific Grading Requirements for Dry Buttermilk

Dry buttermilk, made by the spray or roller process, is the product resulting from drying pasteurized liquid buttermilk that was derived from the churning of cream into 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 has a protein content of not less than 30%.

Dry buttermilk or dry buttermilk products 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.

Table 4: 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
Milkfat	>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)

Table 4 (continued)

CHARACTERISTIC	U.S. EXTRA GRADE	U.S. STANDARD GRADE
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	Slight	Moderate
Visible dark particles	Practically free	Reasonably free

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

Table 5: Typical Composition of Milk and Buttermilk Powders (%)

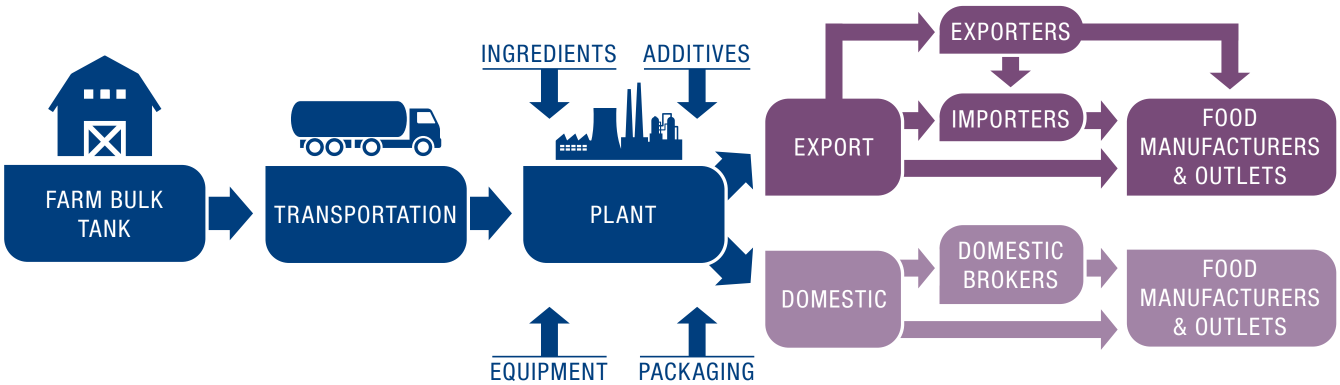
	SKIM MILK POWDER	WHOLE MILK POWDER	BUTTERMILK POWDER
Protein	34.0–37.0	24.5–27.0	32.0–34.5
Lactose	49.5–52.0	36.0–38.5	46.5–49.0
Fat	0.6–1.25	26.0–28.5	>4.5% Buttermilk <4.5% Buttermilk product
Ash	8.2–8.6	5.5–6.5	-
Moisture			
(Non-instant)	3.0–4.0	2.0–4.5	3.0–4.0
(Instant)	3.5–4.5		

Concentrated Milk Proteins

Concentrated milk proteins are marketed under the following names: milk protein concentrate (MPC) and milk protein isolate (MPI) and are obtained by concentrating bovine skimmed milk through filtration processes so that the finished dry product contains 40% or more protein by weight. These products are considered by the FDA as Generally Recognized as Safe (GRAS) under the GRAS Notification for Concentrated Milk Proteins: Milk Protein Concentrate (MPC) and Milk Protein Isolate (MPI), GRN 504.

- **Milk Protein Concentrate:** MPC is the product obtained by the partial removal of sufficient non-protein constituents (lactose and minerals) from skimmed milk so that the finished dry product contains 42% or more protein by weight. It contains the casein and whey proteins in their original proportions found in milk. It should not contain additions of separately produced casein (caseinate) and whey proteins. MPC is labeled to reflect the protein content of the finished product.

Figure 5.1
Traceability of Dairy Ingredients from Farm to Food Manufacturers and Outlets



Source: Innovation Center for U.S. Dairy

- **Milk Protein Isolate:** MPI is the substance obtained by the partial removal of sufficient non-protein constituents (lactose and minerals) from skimmed milk so that the finished dry product contains 90% or more protein by weight. It contains the casein and whey proteins in their original proportions found in milk, without combining separately produced casein (caseinate) and whey proteins. Product labeled as MPI must contain a minimum of 89.5% protein.

MPC and MPI may be produced by filtration (microfiltration, ultrafiltration and diafiltration), dialysis or any other process by which all or part of the lactose is removed by a safe and suitable procedure. Where microfiltration is used, the resulting product is microfiltered milk protein (MMP) or micellar casein concentrate (MCC). Both MMP and MCC are labeled to reflect their protein content. They can be used as a daily supplement for those who do not consume the recommended amount of protein in their diet or, in the case of MPI, those who are lactose intolerant. MPI has very high amino acid composition that makes it ideal for use in protein bars, meal replacement powders and health and wellness beverages.

Table 6: Typical Composition of Commercially Available MPC and MPI

PRODUCT	PROTEIN %	FAT %	LACTOSE %	ASH %	MOISTURE %
MPC 40	39.5 min	1.25 max	52.0 max	10.0 max	5.0 max
MPC 42	41.5 min	1.25 max	51.0 max	10.0 max	5.0 max
MPC 56	55.5 min	1.50 max	36.0 max	10.0 max	5.0 max
MPC 70	69.5 min	2.50 max	20.0 max	10.0 max	6.0 max
MPC 80	79.5 min	2.50 max	9.0 max	8.0 max	6.0 max
MPC 85	85.0 min*	2.50 max	8.0 max	8.0 max	6.0 max
MPI	89.5*	2.50 max	5.0 max	8.0 max	6.0 max

**Protein content ≥85.0% is reported on a dry basis, all other parameters are reported "as is."*

Table 7: Typical Composition of MMP and MCC

PRODUCT	PROTEIN %	FAT %	LACTOSE %	ASH %	MOISTURE %
MMP/MCC 42	41.5 min	1.25 max	51.0 max	6.0 max	5.0 max
MMP/MCC 70	69.5 min	2.50 max	16.0 max	8.0 max	6.0 max
MMP/MCC 80	79.5 min	3.00 max	10.0 max	8.0 max	6.0 max
MMP/MCC 85	85.0 min*	3.00 max	3.0 max	8.0 max	6.0 max
MMP/MCC 90	89.5 min*	3.00 max	1.0 max	8.0 max	6.0 max

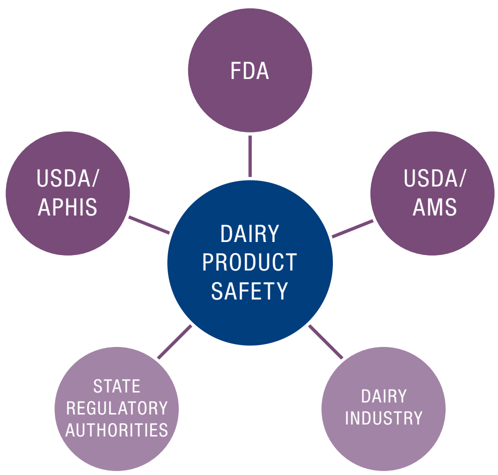
**Protein content ≥85.0% is reported on a dry basis, all other parameters are reported "as is."*

5.4 PRODUCT TRACEABILITY

The Food Safety Modernization Act (FSMA) requires U.S. processors to have in place a program that ensures their ability for rapid and effective tracking and tracing of foods and withdrawal from the marketplace, when necessary, any products that they produce. The goal is to shift the focus from responding to contamination to preventing it.

The Innovation Center for U.S. Dairy published a document entitled, "Guidance for Dairy Product Enhanced Traceability," a comprehensive evaluation of the process to develop a traceability method that will be acceptable under FSMA.

Figure 5.2
Product Safety



High quality products and traceability are equally important for participation in domestic or international markets and will bring increased rewards to those that have an effective system that minimizes or eliminates the market's loss in trust that follows a public safety crisis.

A successful traceability program must be able to accomplish the following three tasks. At a minimum, the traceability of all ingredients, materials and final products should be one level back and one level forward.

1. **Find the source of an issue.** The records of the bulks/ ingredients/materials should be able to identify when and where a suspect lot entered the process. It also should be able to quickly identify which Lot IDs contributed to a final product Lot ID.
2. **Find the commonality of products within an issue.** As soon as more than one final product is identified as contaminated, the manufacturer needs to identify the common origin or source of the problem quickly. The contaminated products could be multiple packages in one facility or different products across several facilities. The origin could be a bulk material, ingredient and equipment or packaging materials. Once the origin of the issue is identified, the manufacturer should:
3. **Find all the products that contain that commonality.** This will accomplish the final recall.

To accomplish these tasks, emphasis should be placed on the following two basic tenets.

1. Establish a lot numbering sequence(s) that is unique to your ingredients, packaging materials and final products. The lot numbering scheme should be able to uniquely identify individual lots in a manner that is easy for employees and buyers to understand.
2. Establish a record keeping system that collects sufficient data so that the ingredients, including all milk coming from the farms or purchased loads, used in a multi-component product can be quickly identified. Train employees to understand the identification system and focus on accuracy of the recorded data.

5.5 PRODUCT SAFETY

All producers and exporters of dry dairy products should have a working knowledge of the regulatory system in the United States as well as all requirements in countries to which they are exporting so they can assure customers that products are safe and wholesome. The formulation of regulations is a multi-party coordination of regulatory agencies and the industry.

The FDA is the primary regulatory agency responsible for all domestic dairy products, including those destined for export, and dairy products imported into the United States. All the regulations used by the FDA are published in the CFR and are available for any interested party to review. All parties wishing to produce, sell or buy dairy products can easily find the appropriate regulations governing U.S. dairy products. In addition to the CFR, the FDA is the agency that publishes and oversees the application of the Pasteurized Milk Ordinance (PMO). The PMO is a comprehensive document intended to establish uniformity of regulatory inspections of dairy farms and processing plants which are conducted by our state regulatory agencies. The PMO can be downloaded from the FDA website at www.fda.gov.

The USDA contains two agencies directly related to dairy products, the Animal and Plant Health Inspection Service (APHIS) and the AMS. APHIS is the regulatory authority for all animal health issues.

AMS administers programs that create domestic and international marketing opportunities for U.S. producers of food, fiber and specialty crops. AMS also provides the agriculture industry with valuable services to ensure the quality and availability of wholesome food for consumers across the country.

The Dairy Grading Program, an important agency within AMS, ensures both product safety through their inspection programs and also product quality through the development and publication of quality standards, specifications and CIDs. In cooperation with FDA through a memorandum of understanding, the Dairy Grading Program conducts the plant inspections for maintaining approval for milk product drying facilities.

State and local regulatory authorities, in all 50 states, issue and control the permits to the farms and the processing plants and conduct the routine inspections of the farms and processing plants within their jurisdictions. These inspections are done in accordance to the regulations established through the PMO or they may accept the inspections conducted by USDA. State and local participation is critical to ensuring product safety as they are the inspectors that begin the process by monitoring/regulating the conditions under which milk is produced and further processed in their geographic jurisdiction. These inspectors know their local farms and plants best.

Trade associations, such as the National Milk Producers Federation (NMPF), the American Dairy Products Institute (ADPI) and the International Dairy Foods Association (IDFA), represent the farmers and the processing plants to ensure that the needs of the industry are heard in the regulation rulemaking process.

5.6 AGRICULTURAL CHEMICALS AND DRUG RESIDUES CONTROL

The control and monitoring of agricultural chemicals and veterinary drugs in the United States is a multifaceted amalgamation of interlocking programs. These programs are all designed to ensure that the consuming public, both domestic and our international trading partners, receive the same safe, wholesome, high quality products.

Pesticide chemicals are monitored by the Environmental Protection Agency (EPA). Animal drug residues are monitored separately by the FDA and the USDA. The EPA, FDA and USDA all work together within their specific areas of expertise. In addition, each of the individual states cooperates with the federal agencies to ensure compliance.

Agricultural Chemicals and Pesticides

Both the FDA and the EPA are the federal level approval and control agencies for agricultural chemicals and pesticides.

The EPA, jointly with the states, has the legal authority and responsibility to register and license pesticides for use. This legal authority is granted through the provisions of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA); the Federal Food, Drug and Cosmetic Act (FFDCA); the Food Quality Protection Act (FQPA); and the Pesticide Registration Improvement Act of 2003.

Additionally, USDA independently conducts a monitoring program for agricultural chemicals in the food supply. This provides the United States with two independent monitoring programs for pesticides.

The state regulatory agencies conduct verification of proper labeling as an important control method. This activity is done by the states as they can control what is sold within their borders. Labels must be correct and within the requirements of the law so that improper chemicals, not suitable for lactating dairy animals, are clearly stated. This label review may also include testing of the pesticide to confirm that what is in the container and on the label are the same.

Animal Drug Residues

Within the FDA, there are two major areas of control for the use of animal drugs and animal feeds.

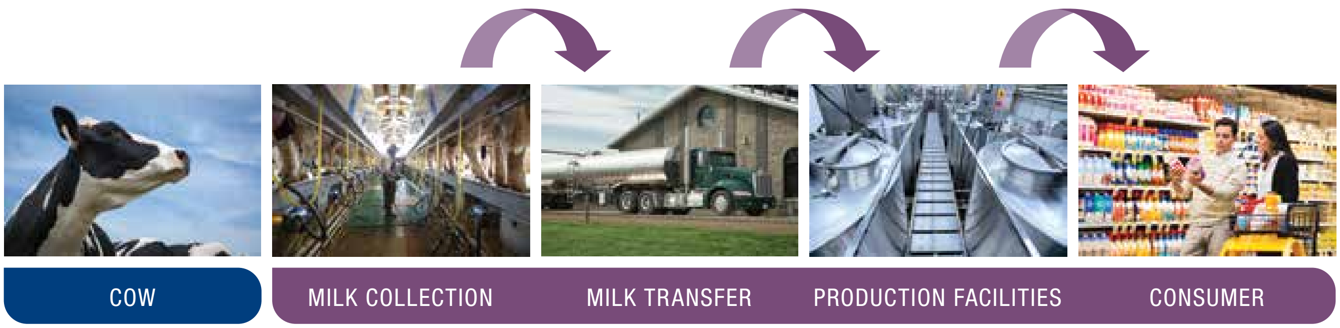
- The Center for Veterinary Medicine (CVM) is responsible for ensuring that animal drugs and medicated feeds are safe and that the food from treated animals is safe to consume.
- The Center for Food Safety and Applied Nutrition (CFSAN) has responsibility for food safety issues. The CFSAN's Milk Safety Branch exercises specific responsibility for the safety of dairy products via the PMO.

The CVM, Office of Surveillance and Compliance (OS&C), in cooperation with USDA, EPA and state agencies, has the responsibility to ensure that acceptable manufacturing procedures for medicated feed and the use of feed additives is maintained. One aspect of the CVM surveillance includes auditing of feed manufacturers and review of their medicated feed records to ensure compliance as well as to protect against cross contamination of feeds.

CFSAN's Milk Safety Branch is responsible for administering the National Drug Residue Milk Monitoring Program (NDRMMP) to ensure the safety of raw milk. This program is designed to screen all bulk milk pickup tankers for the presence of antibiotic residues before they can enter the processing facilities.

APHIS, Veterinary Services (VS), has the primary responsibility of controlling the detection, monitoring and spread of animal diseases. APHIS assists other federal agencies with the collection of monitoring samples for chemical and drug residues. Furthermore, APHIS protects and improves the health, quality and marketability of our nation's animals, animal products and veterinary biologics by: preventing, controlling and/or eliminating animal diseases; and by monitoring and promoting animal health and productivity. APHIS coordinates its surveillance and monitoring with the World Organization for Animal Health (OIE).

Figure 5.3
Summary



5.7 SUMMARY

The goal of the system of regulations, controls, monitoring inspections, standards and specifications is to ensure that dairy products produced and sold domestically and internationally are of the highest quality and safety, from the farm to the consumer's table.

The United States relies on a multiparty assembly of interrelated laws, regulations and inspection guidelines to ensure dairy product safety for all consumers, both domestically and internationally. Exported products meet all U.S. standards as well as the standards of the importing country.

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6 Major Characteristics and Test Methods for Dry Milk Ingredients

Dairy ingredients produced in the United States are renowned world-wide for their high quality and safety. The high quality is the result of adherence to federal and industry standards and striving by the industry for the highest quality possible. For example, the Food and Drug Administration (FDA) has standards that define the composition of products such as nonfat dry milk, nonfat dry milk fortified with vitamins A and D, dry whole milk and dry cream. The United States Department of Agriculture (USDA) has voluntary quality-grade standards used to clearly define the attributes of ingredients, making business transactions easier. Highly-skilled graders evaluate ingredients such as dry whole milk, instant dry whole milk, nonfat dry milk, instant nonfat dry milk, dry buttermilk and dry buttermilk products following the official grade standards and processes established by the USDA's Agricultural Marketing Service. The American Dairy Products Institute (ADPI) is a trade association that makes available industry standards for nonfat dry milk, instant nonfat dry milk, dry whole milk, dry buttermilk, dry buttermilk product and instant dry whole milk. ADPI also publishes industry standards for skimmed milk powder, whole milk powder, concentrated milk proteins and reduced-fat milk powder.

Detailed analytical methods for dry milk ingredients are published by several organizations. These include AOAC International which publishes the Official Methods of Analysis (OMA), the International Organization for Standardization (ISO) and the International Dairy Federation (IDF). Methods from all three of the previously named international organizations are referred to in the Codex Alimentarius Standards "Recommended Methods of Analysis and Sampling," CXS 234-1999 (last amended in 2017). In addition, the American Public Health Association (APHA) publishes two books that are widely used by the U.S. industry: *Standard Methods for the Examination of Dairy Products* (SMEDP) and the *Compendium of Methods for the Microbiological Examination of Foods*. ADPI and the GEA Company also offer protocols that are commonly used in industry. Since the methods' protocols are available via their websites or in hard copy, it is not the intent of this chapter to repeat this content.

The main purpose of this chapter is to provide a brief overview and general description about the importance of the major characteristics of milk powders and principles of important analytical methods covering key points. In addition, a brief section on the general description and importance of selected functional properties (such as gelling, emulsification, foaming and heat stability) of milk powders and high protein milk powders, such as milk protein concentrates, is also included as a general reference.

6.1 GENERAL CHARACTERISTICS AND METHODS OF ANALYSIS

The major characteristics of milk powders can be divided into five main groups:

- Organoleptic
- Chemical
- Physical
- Functional
- Microbiological

6.2 ORGANOLEPTIC CHARACTERISTICS

The organoleptic characteristics of milk powders and dried milk products mainly concern flavor, aroma and color, including the presence of darker particles called scorched particles. These are very important characteristics which govern consumer acceptability. The organoleptic properties of milk powders are generally affected by many parameters including the cow's diet, time lapse between milking and processing including the ability to refrigerate the milk promptly to preserve its freshness, the microbiological quality of the milk, chemical composition of the milk, the processing treatment received during the manufacturing of milk powders, as well as other factors such as storage conditions post processing.

Flavor, Aroma and Color

Skimmed milk powders (SMP), whole milk powders (WMP), high milk protein powders such as MPC80 and other dried dairy ingredients must have good flavor and aroma characteristics for direct consumption and food product applications. They should have clean, sweet and pleasant tastes and should be free of any flavor defects or other off flavors or odors. Off flavors present in dried dairy ingredients can carry through to the final end product and result in poor end product quality; therefore, flavor and sensory properties are considered very important criteria in grading milk powders and other dried dairy ingredients.

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.

Some end users may prefer very 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 the organoleptic properties of powders.

Abuse during processing and storage conditions can contribute to flavor issues. Organoleptic assessment is the easiest test to conduct and is one of the most critical tests for most users. Some volatile off flavors from milk powders can be detected without instruments. For taste testing, the powder is reconstituted and tested at room temperature. It is important to let the reconstituted powder rehydrate properly (about 60 minutes) before tasting by a trained panel. For SMP, the flavor may vary according to heat treatment (low, medium, high) given to the milk prior to evaporation and spray drying, and slight cooked flavors may be preferred by some end users.

Scorched Particles

Scorched particles are small particles of darkened milk powder that are a result of heat exposure in the spray dryer and in the systems that convey the milk powder to storage bins prior to packaging. The low water activity of the drying milk and exposure to the hot air allows the Maillard browning reaction to darken some particles of milk if they reside in the system too long. Scorched particles are considered undesirable by some end users, while, depending on the end use of the powder, their presence may be inconsequential.

Depending on the type of powder to be analyzed, different sets of procedures are used for the determination of scorched particles. For example, sample preparation will differ, but all the methods involve filtration of reconstituted milk using a filter disc or pad, followed by a visual comparison of the material remaining on the dried disc with the ADPI "Scorched Particle Standards for Dry Milks" photoprint or standard disc for classification. Based on this comparison and depending on the weight, intensity and color of the scorched particles observed on the filter disc, the scorched particles are expressed as Disc A (7.5 mg), Disc B (15.0 mg), Disc C (22.5 mg) or Disc D (32.5 mg). Most manufacturers and end users prefer the ADPI method for the analysis of scorched particles. The procedure and description on how to interpret the results is provided with a picture and is available from ADPI as well as in *Standard Methods for the Examination of Dairy Products* and the analytical methods published by GEA Niro.

6.3 CHEMICAL CHARACTERISTICS

The chemical analysis of milk powder mainly involves moisture, fat, total protein, non-protein nitrogen, lactose, ash and other nutrients such as calcium. Important routine tests are described below.

Moisture Content

Moisture content is an important parameter as it has a huge impact on the microbial quality, shelf life and storage-related changes in milk powders. The objective of analyzing moisture content is to determine the percentage of un-bound or "free" moisture in milk powder. The aim is to be below 5%, following the regulations of the CFR or the Codex standard. Other levels, for example, 4% may be targeted to meet voluntary quality standard or buyer's specifications. The moisture content, and more specifically the water activity, can influence the keeping quality of the powder. Too high moisture content and temperature may promote browning of milk powders during storage due to the Maillard reaction, thus compromising their shelf life. Higher moisture content can also promote lactose crystallization and clumping of the powder. It can also lead to some of the flavor and color defects as described earlier in section 6.2 of this chapter.

Different methods are used by the industry for the determination of moisture content in dried products, depending on the type of dried product to be analyzed or the purpose of the moisture determination. The most common method for the determination of moisture is a gravimetric method, which involves the determination of loss in weight in percentage after drying powder. The drying conditions will have an impact on the results obtained. The AOAC 927.05 method recommends drying under vacuum at 100 °C (212 °F) for approximately five hours. Whereas the ISO 5537 (IDF 26) employs forced ventilation and a much lower temperature of 87 °C (288.6 °F). Drying at a temperature of 100 °C (212 °F) or higher may allow for the release of part of the water of crystallization along with the free moisture, thus increase the mass loss, resulting in an overestimation of the free-moisture content of the sample.

Producers and end users may choose to determine total moisture (free and bound). Total moisture in dried products can be determined using the Karl Fischer (KF) titration method. When using this method, the determination of moisture is based on calculating the concentration of iodine in the KF reagent and the total amount of KF reagent used for the titration. This method may be used for any kind of dried milk product, particularly for those containing crystallized lactose powders. Furthermore, many producers may be interested to determine the water of crystallization. The water of crystallization (%) of a powder can be simply determined by calculating the difference between the total moisture and free moisture determined as per methods described earlier. Details on the gravimetric methods for moisture determination can be found in the Official Methods of Analysis (OMA) as published by AOAC, IDF, ISO and SMEDP. Details about the Karl Fischer method can be found in SMEDP and Rückold et al., 2000.

pH

The pH is the negative log of the hydrogen ion concentration. It is a measurement of hydrogen ion activity indicating acidity. The electric potential between sensing electrode and reference electrode is determined by the use of a pH probe and meter calibrated using buffers with defined pH values. The normal pH of milk is between 6.6 and 6.8. The normal pH of SMP and WMP should be in the range of 6.5 to 6.8. Lower pH would negatively impact the functionality of SMP and WMP. The procedure for the determination of pH can be found in SMEDP 15.022. In this procedure, the pH measurement is done on a 10% reconstituted solution of nonfat dry milk powder or a 13% reconstituted solution of dry whole milk powder.

Titratable Acidity

Many naturally present components in milk are acidic in nature and may contribute to the acidity of milk, which is generally known as apparent acidity, whereas the developed acidity is the portion of titratable acidity that develops as a result of the conversion of lactose to lactic acid by action of bacterial growth. The titratable acidity (TA) test is used as a measure of milk quality. Higher titratable acidity generally indicates that the lactose in milk has been metabolized to produce lactic acid by bacterial growth. Fresh milk or good quality milk should not contain any developed lactic acid since lactose should not have been decomposed by bacterial growth.

The measurement of titratable acidity includes measuring both apparent acidity and developed acidity. There are several methods used to measure TA. In the United States, titratable acidity is typically expressed as (%) lactic acid and is determined by the titration of a known amount of reconstituted milk with 0.1 N NaOH using phenolphthalein or pH as an indicator. The amount of NaOH used to shift the pH value from that of fresh milk (about 6.7) to a pH of 8.2–8.4 (phenolphthalein end point) is measured and the percent TA is calculated. The higher the amount of 0.1 N NaOH used, the higher the titratable acidity and vice versa. Procedure and details of the calculation can be found in SMEDP 15.021 and ADPI. ISO 6091 (IDF 86) is another proposed method but it differs slightly from the typical U.S. methods.

Milkfat Content

The Gerber, Mojonnier and Rose-Gottlieb methods are common methods available for measuring fat content in milk and dairy products. In the Gerber method, fat is separated by the addition of sulphuric acid and amyl alcohol in fat-containing milk products directly in specially calibrated butyrometers followed by centrifugation. This simple method is generally used for routine quality control, whereas the Rose-Gottlieb method and Mojonnier method (slightly modified version of Rose-Gottlieb method) is more specialized and, in most countries, is considered as the standard method for the analysis of milkfat in powders. In this method, the fat of the powder is extracted using solvents, followed by a removal of the solvents using evaporation and drying. Often, test results may vary depending upon the methods used for analysis because some methods used for the determination of milkfat can measure the free fatty acids or phospholipids and some methods cannot measure these components. SMEDP, AOAC, IDF and ISO covers the Rose-Gottlieb and Mojonnier methods. The modified Mojonnier ether extraction method is recognized by IDF/ISO and AOAC. The method numbers are ISO 1736:2008 (IDF 9:2008) and AOAC Official Method 989.05 and 932.06 for the sample preparation and modified protocol when starting with a dried milk sample.

Free Fat Content

This test is mainly used for WMP and other fat-containing powders. Ideally, for most product applications, with the exception of milk chocolate manufacture, all the fat present in WMP should be present as fine globules covered with a membrane and distributed evenly in the particles; however, there is a portion of fat that is not covered by the membrane. This portion of the fat is termed as surface free fat or free fat. Often, the presence of free fat may result from the loss of emulsion stability in whole milk and fat-filled milks. The surface free fat of a powder may lead to the deterioration of flavor due to rapid oxidation and thus may affect consumer acceptability. The amount of surface free fat in powders will have a direct influence on their shelf life and is also directly responsible for non-wettable surface when the powder is mixed with cold water, thus affecting its wettability and flowability. Therefore, it is important to determine the surface free fat content of milk powder.

The determination of free fat on the surface of milk powder particles is based on extraction of the fat on the surface of the particles using a solvent such as petroleum ether or toluene.

Protein

Protein is a very economically valuable component of milk and milk based dry ingredients. It is highly nutritious and has a significant impact on various functional characteristics such as gelling, water binding, emulsification, foaming, whipping, viscosity, etc. A number of standards have protein content requirements. For example, CODEX STAN 207-1999 requires that SMP contain a minimum protein level of 34% on a solids-not-fat (SNF) basis. The Kjeldahl principle is the standard method used to determine the nitrogen content of the sample which is then multiplied by 6.38, the factor to convert the result to milk protein. Methods for the determination of protein are detailed by SMEDP, AOAC, ISO and IDF. The total nitrogen determination in milk by the Kjeldahl method is recognized by IDF/ISO and AOAC. The method numbers are ISO 8968-1:2014 (IDF 20-1:2014) and AOAC Official Method 991.20 and 930.29 for the sample preparation and modified protocol when starting with a dried milk sample.

6.4 PHYSICAL CHARACTERISTICS

Hygroscopicity

Hygroscopicity is the ability of a powder to absorb moisture from the surrounding air. Milk powders and many other dry dairy ingredients are hygroscopic in nature. This means they can readily absorb moisture from the humid atmosphere. When the moisture level in the air is high, and if unprotected by packaging, milk powders absorb moisture from the atmosphere and become sticky, caked or lumpy, and consequently exhibit reduced flowability and solubility. Such changes affect the ease of handling and use of the product.

The hygroscopicity of milk powders is a measure of the amount of moisture that can be absorbed by a given amount of milk powder from the air. It is often measured by passing air of a known humidity level (usually 80% humidity at 20 °C [68 °F]) over a powder until equilibrium is reached, then measuring the weight gained by the powder. Milk powders with higher hygroscopicities are undesirable, as powders which absorb higher amounts of moisture may cake during storage. Lactose content and state impacts water absorption of dairy powders (e.g., powders with low lactose content such as MPC80 absorb low moisture and may not lead to stickiness and caking, while powders with high lactose content, such as whey powders, absorb moisture and lead to stickiness and caking). Detailed methods for determining hygroscopicity are available from GEA Niro and Schuck et al.

Bulk Density

Bulk density is a measure of the mass of milk powder that occupies a fixed volume. It depends on a number of factors such as particle density, particle internal porosity and arrangement of particles in the container. Categories of bulk density include compact density, tap density, loose bulk density and aerated bulk density. The bulk density of milk powder is important for deciding on the appropriate machinery for processing. For method details, please refer to the IDF Standard 134:2005 (ISO 8967) method and GEA Niro Analytical Method No. A2a.

Water Activity (a_w)

Water activity, a_w, is an expression of the water availability as a solvent or reagent. It is characterized by the ratio between the water vapor pressure of the product and the vapor pressure of pure water at the same temperature. In the case of water, the water activity is 1. In the case of foods, the water activity is < 1, due to the capacity of the chemical components of the food to bind water. It is expressed on a dimensionless scale of 0 to 1. The a_w of dried milk product is largely a function of moisture content and temperature. The a_w increases with an increase in the storage temperature. The composition and state of the individual components in the dairy powder also play an important role.

It has been reported that water activity controls the microbial growth or microbial stability of a particular food. In fact, a critical a_w also exists below which no microorganisms can grow, indicating that the microbial growth in food is governed not only by the moisture content of the food, but by the water activity. In addition to microbial growth, water activity also controls storage-related changes such as lipid oxidation, the Maillard reaction and caking in milk powders. With an increase in water activity of more than 0.3, or the moisture content of higher than approximately 7%, milk powders may become hygroscopic, resulting in the crystallization of the lactose. For method details, refer to the ISO 21807:2004 method.

Degree of Caking

The degree of caking is the amount of powder appearing as lumps which cannot pass through a 500 micrometer (μm) mesh sieve after allowing the powder first to absorb moisture from the air with known humidity until equilibrium is reached and then releasing moisture by drying. What is left on the sieve is expressed as the degree of caking. This method may be used for all dried products. For more details see GEA Niro Method A15a.

Flowability

The proper flow of milk powders is important for both manufacturers and end users for ease in packaging, handling and measuring. Flowability is the ability of a powder to flow and is measured as the time in seconds necessary for a given volume of powder to leave a rotary drum through a slit of a specific size. This is a measure of the free-flowing characteristic of milk powder. Powders with large agglomerates and few fine particles generally have good free flowing properties. GEA Niro has a test procedure for the determination of flowability.

Wettability

As the term suggests, the wettability of powder is the potential for a powder to wet and absorb water at a given temperature. In fact, the International Dairy Federation (IDF) has defined wettability as “the time in seconds required for all the particles of an instant dry milk sample to become wetted (to sink below the water surface or assume a 'typical' wet appearance) when placed on the surface of water.”

During the process of wetting, water enters the voids between powder particles through capillary action and replaces the air in the voids. Agglomerated powder has better wettability compared to non-agglomerated and fine particles. Factors such as composition, particle size and shape or the amount of surface free fat may affect the wettability of a powder. Wettability is affected by the temperature of the water used;

therefore, water temperature should always be specified in wettability tests. Milk powders that wet easily and quickly are often termed instant milk powders. For example, skimmed milk powder that is wetted in less than 15 seconds is termed instant. There is no requirement for whole milk powder, but whole milk powder with wettability of less than 60 seconds is generally preferred by end users. Various after-drying processes and best practices (such as agglomeration or lecithin treatment of powder particles, producing powder particles with high density and gentle transport of agglomerates) can help to improve the wettability of dried milk ingredients. GEA Niro has a test procedure for the determination of wettability.

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. Milk powders with good dispersibility typically exhibit good wettability. If the milk powder is not readily dispersed in water, it tends to form lumps or sludge. The formation of sludge may lead to longer time and higher energy input to completely solubilize the powder.

Various techniques are available for measuring the dispersibility of milk powders. These techniques determine how easily a powder goes into a solution under normal home-mixing conditions; however, many of them are not standardized. They are subject to operator errors, making it difficult to obtain reproducible results between laboratories. Standard methods for determining dispersibility and wettability have been published by IDF and Schuck et al., 2012. A powder sample of known water content is evenly spread on the surface of 25 °C (77 °F) water. The mixture is stirred manually for a short time and part of the mixture is filtered through a sieve. The total solids content of the collected liquid is determined. Finally, dispersibility is calculated from the mass of the test portion and the values for water content and total solids.

Solubility Index

Solubility, which corresponds to the disappearance of the granular structure after complete solubilization and rehydration of the powder, is an important characteristic of milk powders. Poorly soluble powders can cause processing difficulties, will not have the desired functionality and can result in economic losses as milk solids may be lost as insoluble material. Various factors may contribute to the poor solubility of milk powders such as the presence of very fine particles in non-agglomerated skimmed milk powder or a high milk protein content powder, such as MPC with more than 70% protein content, which may take a long time to solubilize completely. Other factors which directly influence the insolubility of milk powders are linked to the severity of the cumulative heat treatments received during the manufacturing and drying process.

The traditional solubility test actually measures insolubility. The sediment produced when milk powders are reconstituted is measured in terms of an insolubility index. This test involves dissolving the powder in water at specific temperature using a mixer for 90 seconds. The reconstituted milk is then left for 15 minutes and the amount of sediment at the bottom of the tube is measured in milliliters after centrifugation, which is termed as the solubility index. Several sources such as GEA, ADPI, IDF and ISO offer protocols to measure insolubility index of dried milk and milk products.

Whey Protein Nitrogen Index

The whey protein nitrogen index (WPNI) expresses the amount of undenatured whey proteins in nonfat dry milk and other milk powders. The value obtained is the basis of the heat classification for skimmed milk powder: low-, medium- or high-heat. The WPNI value provides an indication of the severity of the cumulative heat treatment that has been received during the entire manufacturing of the milk powder. The severity of the overall heat treatment affects the extent of the whey protein denaturation, their aggregation and interactions with the casein micelles—ultimately it affects the functional properties of the milk powders. Since the WPNI gives an indirect indication of functional properties, the WPNI of nonfat dry milk and skimmed milk powder is commonly specified. WPNI is expressed as milligrams (mg) of undenatured whey protein nitrogen per gram of powder.

The principle of the WPNI test involves the rehydration of the milk powder, the removal of casein and the heat denatured whey proteins by filtration. The undenatured whey proteins present in the filtrate are then denatured by adding HCl and turbidity develops (depending on the concentration of the whey proteins present in the filtrate). The turbidity is measured as percent transmittance in a spectrophotometer at a wavelength of 420 nm.

By using a standard curve, this reading can be converted directly into milligrams of undenatured whey protein nitrogen/g powder.

Many end users decide the end use of milk powders based on its WPNI. For example, high-heat powder (WPNI <1.5 mg/g of powder) is most suitable for bakery applications, whereas low-heat powder (WPNI >6.0 mg/g of powder) is ideal for fluid milk fortification and cheese milk. Medium-heat milk powder is a multifunctional product, providing emulsification, water binding, viscosity and flavor; thus, it is used in a wide variety of food applications. Apart from its use in ice cream, confectionery and other manufactured food products, medium-heat SMP is a key ingredient in the manufacture of recombined sweetened condensed milk. The WPNI range for medium-heat powder is wide (1.51–5.99 mg/g powder), so the preheat treatment can be varied to produce powders with tailor-made functional properties. The two types of medium-heat powders are: 1) medium-heat (4.50–5.99mg/g of powder) and 2) medium high-heat powders (1.51–4.49mg/g of powder). It is important to note that WPNI does not necessarily measure or provide an indication about the heat stability of a powder and should not be used as an indicator of its suitability for recombined evaporated milk production. WPNI also does not either measure or indicate the viscosity of a powder when used in recombined sweetened condensed milk; thus, separate tests are needed for these properties. Manufacturers are encouraged to perform pilot tests with various powders to identify the powder type with the most suitable WPNI range for their application.

This general classification is used for NDM and the values and terms are defined in the Supplement to U.S. Standards for Grades of Nonfat Dry Milk (Spray Process).

Table 1: Heat Treatment Classification of Nonfat Dry Milk

CLASSIFICATION	WHEY PROTEIN NITROGEN INDEX* (mg/g)	RECOMMENDED APPLICATIONS
Low-heat	≥ 6.00	Fluid milk fortification, cheese milk standardization, cultured skimmed milk, starter culture, dairy drinks and recombined products, ice cream, yogurts
Medium-heat	1.51-5.99	Prepared mixes, ice cream, yogurts, confectionery, meat products, recombined milk products
High-heat	≤1.50	Bakery, confectionery, meat products, ice cream, prepared mixes, water binding, gelation

**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 the entire process of SMP manufacture, including preheat treatment and heating received during evaporation and spray drying.*

6.5 FUNCTIONAL CHARACTERISTICS

Milk powders and high protein, dry dairy ingredients such as MPCs are used as multifunctional ingredients in the formulations of many food products. In addition to providing excellent nutritional value, these ingredients contribute to unique flavor, desirable texture and many other functional properties (such as gelling, water binding, emulsification, stabilization, foaming, whipping and viscosity) in the final products. Moreover, they are widely accepted by consumers as natural ingredients and can provide consumer-friendly “clean labels” on packaged foods. Because of their unique functionalities, these ingredients are considered very important by the food and beverage industry.

Water Binding and Gelling

Dairy proteins are used as a gelling agent. The gel network is supported by electrostatic, hydrogen, hydrophobic and covalent bonds. Furthermore, the gel network is influenced by environment conditions like pH, temperature, pressure and salts. There are two commonly used major types of gels: rennet induced gels (e.g., cheese) and acid induced gels (e.g., yogurt).

These gels hold water and fat, providing structural support and water binding properties. The gelling and water binding properties of milk proteins may contribute to several aspects of food including overall visual appearance, microstructure and rheological properties, which ultimately contribute to the mouthfeel, overall sensory perception and various functionalities of food products. The water binding capacity of ingredients can have significant effects on the machinability of final products by modifying the viscosity of the food. Water retention also affects the rheology and texture of food. Dried dairy ingredients such as milk powders and MPCs are used in cheese, yogurt, soup, sauces and many other food products because of their excellent gelling or water binding properties. Increased moisture content in many foods, through the gelling and water binding properties of dairy ingredients, helps to enhance the sensory profile by increasing flavor release, which is especially important in formulating reduced fat products such as reduced fat sauces and soups.

Emulsification

Emulsification is an important property of milk powders and dairy protein ingredients. Emulsification is related to a milk powder protein's ability to adsorb and unfold rapidly at the oil-water interface and stabilize an emulsion droplet. At times, this property is referred as its surface activity. Dried protein ingredients possess excellent emulsification properties and are widely used in effectively forming and stabilizing the emulsion in many products such as sauces, soups and ice cream as well as in bakery products and cheese.

The excellent emulsification properties of dairy ingredients aid in the efficient dispersion of fat in many products, which can reduce the fat level in some product formulations and prevent defects such as creaming, coalescence and oiling off, allowing all ingredients to remain evenly dispersed.

Foamability

For certain product applications such as espresso coffee, ice cream and bakery products, mousse, whipped toppings and meringues, the foam formation or foamability is an essential characteristic for the development of texture and mouthfeel desired by the consumer. Milk protein has an excellent ability to generate stable foam, including stabilization of steam-frothed milks, which makes milk powders and MPCs desired ingredients for such applications. The milk powders containing citrate salt have enhanced foaming properties at both low and high temperature applications. The addition of citrate at 0.1 mol/kg milk solids-not-fat to milk concentrate during powder manufacture has been shown to enhance steam-frothing properties of milk. GEA Niro has a method for measurement of foamability.

Heat Stability

Dried dairy ingredients are used in the formulations of various foods and beverages. In many instances, these foods and beverages are subjected to severe heat treatments such as UHT treatment or retort sterilization in order to extend their shelf life and to ensure safety for human consumption. It is therefore important to ensure that milk powders and dried dairy ingredients intended for use in food and beverage applications, which will require severe heat treatment, be heat stable.

Milk undergoes heat treatment first at the manufacturing stage and then through further heating of food products containing the reconstituted milk powder as an ingredient. Thus, the heat stability of milk powder is highly desirable for further heat treatments. For example, milk powder intended for use in recombined evaporated milk, UHT or retort sterilization should possess excellent heat stability, otherwise the protein will coagulate during or shortly after heat processing.

To evaluate whether milk powder and dried ingredients are suitable for severe heat treatments, it is normal practice to determine their heat stability. The heat stability of milk is a function of its protein stability and the ability of proteins to survive severe heat processing without detrimental changes such as excessive turbidity, increased viscosity, phase separation, precipitation or gelation. The heat stability of milk is sensitive to pH, milk salts and milk protein concentration. There are several methods that can be used to determine the relative resistance to heat-induced coagulation and precipitation of milk solids. While a standard method of determination of heat stability does not exist, the heat coagulation time (HCT) is widely used. The test involves preparing a milk solution which is then sealed into a glass tube and placed in a temperature-controlled oil bath until coagulation occurs. The time to visible coagulation is measured. Commonly used temperatures are 140 °C (285 °F) for normal milk or 120 °C (248 °F) for concentrated milk.

Coffee Test

Milk proteins' stability is affected by high temperature and low pH (as in coffee). The thermostability in an acidic environment is expressed by the number of white particles on the surface after reconstituting the powder in hot coffee. The IDF 203 ISO 15322:2005 method (also known as the coffee stability test) measures the stability of protein and its resistance to feathering. The protein stability of powders used for hot beverages is analyzed by adding the powder to hot coffee and determining whether there are flocculated (clumped) particles on the surface. If the protein in the milk powder were not stable, it will lead to feathering, or coagulation, of proteins when mixed with hot coffee beverage. It is important to ensure that milk powders and dried dairy ingredients withstand the coffee test.

The thermostability of dried ingredients is affected by various factors such as water hardness (high levels of calcium, magnesium) and is important to consider in interpreting the results of the coffee test. Furthermore, factors such as milk protein composition, the amino acid profile, overall protein level and whey protein denaturation also influence the coffee stability of SMP.

6.6 MICROBIOLOGICAL CHARACTERISTICS

Standard Plate Count/Aerobic Plate Count/ Total Plate Count

Standard plate count (SPC) is the most commonly used method by the dairy industry to estimate mesophilic microbial populations in dairy products. It is expressed as colony forming units (CFU) per gram and is an indicator of product quality that is built into many product specifications. For example, the USDA voluntary specification for "U.S. Extra Grade" classification of non-instant nonfat dry milk requires that the product not contain more than 10,000 CFU per gram by standard plate count. The most common method of analysis is bacterial growth on standard methods agar plate incubated at 32 °C (89.6 °F) for 48 hours. Procedures for determining SPC in dairy products are contained in SMEDP, the FDA's Bacteriological Analytical Manual (BAM) and AOAC.

Milk powders often carry specifications for thermophilic bacteria. The method also uses standard methods agar but will incubate at 55 °C (131 °F) for 48 hours.

Coliform

The coliform test measures levels of a group of bacteria that are aerobic and facultatively anaerobic, gram-negative, non-spore forming rods that are able to ferment lactose with the production of acid and gas at 32–35 °C (89.6–95 °F) within 48 hours, when grown on violet red bile agar plates.

A qualitative test for coliform bacteria using lactose broth consists of three phases—presumptive, confirmed and completed. The presumptive test is positive when a culture tube containing lactose and inoculated with test sample, incubated at 35 °C (95 °F) for 24 hours, produces gas. In the confirmation test, a selective medium containing lactose is inoculated with suspected bacteria and further incubated at 35 °C (95 °F) for 24 hours. If gas is produced, then the completed test is performed to confirm the presence of coliform bacteria for gas production.

The coliform bacteria count is an indication of the quality of the practices used to ensure proper processing, cleaning and sanitation, including post-processing contamination. It is a part of many product specifications. Procedures for determining coliforms in dairy products are contained in SMEDP.

Mesophilic & Thermophilic Aerobic Spore Count

Only certain types of bacteria can form bacterial endospores (spores) as a survival mechanism when the environmental conditions are no longer suitable for growth. Spores are extremely resistant to heat and other techniques normally used to kill vegetative organisms during food processing. The dormant cell type can survive for years under dry conditions. It is important to recognize that not all spores are the same, their characteristics will depend on the organism from which they are formed and the conditions under which they were produced. For example, there are differences in their ability to resist heat treatments and in their capacity to germinate and outgrow to a vegetative organism.

Spore requirements in milk and dairy powders are typically linked to the final product's specifications—its processing, storage conditions, shelf life and buyer's preference. While specifications are commonly provided, the lack of uniformity in testing protocols continues to be a global challenge and source of confusion. There are a multitude of methods used to measure spore levels. The results obtained can vary and are highly dependent on the test method chosen. In addition, the nature of spores makes it difficult to precisely determine spore count levels in powder samples.

Typically, mesophilic and thermophilic spores or spore-forming organisms will be the focus of milk powder testing. As with other microbiological tests on powder samples, spore testing is performed on reconstituted milk powder, where a 1:10 dilution is often used. Unique to spore testing, an aliquot of the reconstituted sample is first given a heat treatment (heat-shock) which has two functions: 1) it is expected to kill the vegetative cells—allowing the colony forming unit (CFU) count to reflect only the spore count, and 2) it helps trigger spore germination. The temperature and duration of the heat treatment varies between methods and will impact the spore count results. Temperatures from 80 °C (176 °F) to 106 °C (229 °F), for 10 minutes to 30 minutes, are used; higher heat loads (e.g. greater than 100 °C [212 °F] or 106 °C [223 °F] for 30 minutes) will also have the effect of killing heat-sensitive spores, thus allowing selection of the portion of the spore population with the highest heat resistance.

Next, depending on the expected spore level in the sample, serial dilutions may be performed to ensure readability of the plates. The sample is plated using either a pour plate or a spread plate technique. The type of agar media used to allow the outgrowth of the spores into vegetative organisms that form colonies on the agar also varies depending on the method chosen. Recent studies have demonstrated that the choice of media will impact the number of CFU counted, though won't have as much of an impact as the heat treatment and incubation temperature chosen. Commonly used agars include: Tryptic Soy Agar (TSA), Plate Count Milk Agar (PCMA), Standard Method Agar (SMA) or Plate Count Agar (PCA), Dextrose Tryptone Agar (DTA) and Brain Heart Infusion Agar (BHI). Once solidified, the plates will be inverted and placed in an incubator at a selected temperature between 30–35 °C (86–95 °F), approximately 48–72 hours, for mesophilic counts, or; 55 °C (131 °F), for approximately 48 hours, if thermophilic organisms are the focus. Procedures for determining aerobic bacterial spores and other spore formers in dairy products are available in Standard Methods for Examination of Dairy Products (SMEDP), the Compendium of Methods for the Microbiological Examination of Foods and by ISO and IDF.

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7 Nutritional Properties of Milk Powders, Milk Protein Concentrates and Milk Protein Isolates

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Nonfat and whole milk powders, MPCs and MPI are nutritious foods and ingredients rich in high quality protein, minerals and vitamins. The package of nutrients delivered by these ingredients makes them ideal for use in a variety of products ranging from dairy products to food aid supplementation to products designed for athletes and the elderly. This chapter provides nutritional information on these ingredients and highlights the latest science related to the benefits of their consumption.

7.1 AN OVERVIEW OF DAIRY PROTEIN COMPOSITION

Cow's milk powder is recognized as an excellent source of high quality protein. Protein accounts for about 36% and 26% of the total solids in nonfat dry milk and dry whole milk powder, respectively.

As shown in Table 1, cow's milk protein is a heterogeneous mixture of proteins. Of the total milk protein, about 80% is casein and 20% is whey protein. Casein consists of **α**-s1 casein, **α**-s2 casein, **β**-casein, **κ**-casein and casein fractions. Whey proteins, which remain soluble after precipitation of casein, consist primarily of **β**-lactoglobulin and **α**-lactalbumin. Other whey proteins present are serum albumin, immunoglobulin and lactoferrin.

Table 1: Proteins of Cow's Milk

PROTEIN AND PROTEIN FRACTION	COMPOSITION IN SKIMMED MILK (g/L)
CASEIN	
α-s1-Casein	12–15
α-s2-Casein	3–4
β-Casein	9–11
κ-Casein	2–4
WHEY PROTEIN (NON-CASEIN)	
β-Lactoglobulin	2–4
α-Lactalbumin	0.6–1.7
Serum albumin (SA)	0.4
Immunoglobulins	0.45–0.75
Lactoferrin	0.02–0.1

Depending on the product, commercial MPCs and MPI can range in protein content from 40% to greater than 90%. The filtration process concentrates casein and whey proteins resulting in a ratio similar to milk (80% casein and 20% whey). Micellar casein products contain a higher ratio of casein.

Dairy products, such as milk powders and milk protein concentrates, are sources of high quality proteins since they are rich sources of essential amino acids needed for building muscle and other proteins in the body. Essential (indispensable) amino acids are required for growth and must be obtained from the diet since the body cannot synthesize them at all or in sufficient quantities. The nine amino acids considered to be essential in the diet include: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. Three of these amino acids (isoleucine, leucine and valine) are branched chained amino acids. Branched chain amino acids, in particular leucine, play important roles in the body including stimulation of muscle protein synthesis, which will be discussed in more detail later in this chapter. The amino acid composition of dry milk products, MPCs and MPI are provided in Table 2.

Table 2: Amino Acid Composition of Milk Powders, Select MPCs and MPI

AMINO ACID (g/100 g OF PRODUCT)	SKIMMED MILK POWDER[1]	WHOLE MILK POWDER[2]	MPC40[3]	MPC70[3]	MPC85[3]	MPI[3]
Isoleucine	2.19	1.59	1.69	3.17	3.75	3.83
Leucine	3.54	2.58	3.15	5.83	6.86	6.98
Valine	2.42	1.76	2.04	3.75	4.46	4.51
Histidine	0.98	0.71	0.92	1.70	2.01	2.06
Lysine	2.87	2.09	2.65	4.96	5.90	5.98
Methionine	0.91	0.66	0.66	1.52	1.88	2.01
Phenylalanine	1.75	1.27	1.63	3.00	3.54	3.57
Threonine	1.63	1.19	1.37	2.56	2.98	3.00
Tryptophan	0.51	0.37	0.47	0.87	0.96	1.02
Alanine	1.25	0.91	0.96	1.77	2.11	2.16
Arginine	1.31	0.95	1.19	2.18	2.62	2.66
Aspartic acid	2.74	2.00	2.49	4.60	5.37	5.45
Cystine	0.33	0.24	-	-	-	-
Cysteine	-	-	0.24	0.43	0.51	0.52
Glycine	0.77	0.56	0.55	0.97	1.13	1.15
Glutamic acid	7.57	5.51	6.98	12.95	15.20	15.45
Proline	3.50	2.55	3.03	5.71	6.67	6.95
Serine	1.97	1.43	1.60	3.07	3.57	3.53
Tyrosine	1.75	1.27	1.67	3.23	3.89	3.93

Values reported are for [1]Milk, dry, nonfat, regular without added vitamin A and vitamin D; and [2]Milk, dry, whole, without added vitamin D, respectively.[3]USDEC: Medallion Labs average analysis of industry samples (MPC40: n=1, MPC70: n=3, MPC85: n=2, MPI: n=4).

Protein Quality

Numerous methods have been used to measure protein quality. These include: biological value (BV), net protein utilization (NPU), protein efficiency ratio (PER) and protein digestibility-corrected amino acid scoring (PDCAAS). Dairy products and ingredients receive high scores using all four methods. These scores are based on protein retention or growth resulting from a test protein given to animals and have been largely replaced by the PDCAAS method discussed on the next page. In addition, a new quality scoring method, Digestible Indispensable Amino Acid Score (DIAAS), recently has been recommended for use by FAO. The BV, NPU and PER scores for various proteins are shown in Table 3.

Table 3: Quality Score of Key Proteins

PROTEIN SOURCE	BIOLOGICAL VALUE (BV)	PROTEIN EFFICIENCY RATIO (PER)	NET PROTEIN UTILIZATION (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

Table 3 (continued)

PROTEIN SOURCE	BIOLOGICAL VALUE (BV)	PROTEIN EFFICIENCY RATIO (PER)	NET PROTEIN UTILIZATION (NPU)
Casein	77	2.7	76
Soy protein	61	2.1–2.2	61

Unlike BV, NPU and PER measures, PDCAAS evaluates protein quality based on the amino acid requirements of humans, and in 1990, was adopted by the Food and Agricultural Organization of the United Nations/World Health Organization as the preferred method to determine protein quality. In 1993, the FDA also replaced the PER method with PDCAAS (58 Fed Reg 2079) with exception to infant foods which still utilize PER as the protein quality measurement.

The formula to calculate PDCAAS as follows:

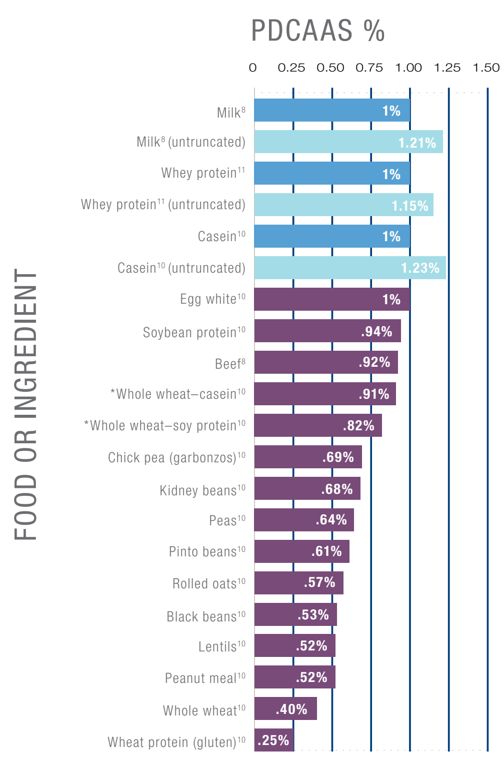
$$\text{PDCAAS(\%)} = \frac{\text{mg of limiting amino acid in 1 g of test protein}}{\text{mg of same amino acid in 1 g of reference protein}} \times \text{true fecal digestibility (\%)} \times 100$$

Milk and dairy ingredients receive high PDCAAS scores, which reflect their ability to provide essential amino acids to the diet. Because MPCs and MPI proteins are obtained through a filtration process, their PDCAAS scores are expected to be similar to dried skimmed milk.

Although PDCAAS scoring is considered an appropriate test of protein quality and is routinely used, it too has its limitations. One limitation of PDCAAS is that the protein digestibility value is based on fecal crude protein digestibility as determined in a rat assay. Such values are imprecise because they do not take into account the contribution of microbial metabolism in the colon to fecal protein. Furthermore, when using the PDCAAS scoring system, values for high quality proteins such as milk and whey are "truncated," i.e., rounded down to 1.0 when in fact their values are well over 1.0, based on the view that the PDCAAS does not need to be higher than 1.0 for any protein.

However, truncated PDCAAS scores of high quality proteins remove information regarding the ability of these proteins to compensate for lower levels of essential amino acids provided by low quality proteins in mixed diets. Also, the impact of anti-nutritional factors (such as trypsin inhibitors) often found in plant protein sources on the PDCAAS is not addressed. Finally, the amino acid scoring patterns used reflect the minimum amount of protein requirements, not necessarily optimum intakes. The PDCAAS of key protein sources are listed in Figure 7.1.

Figure 7.1 PDCAAS of Key Protein Sources



*Examples of the impact of blending proteins with high and low PDCAAS

In recent years researchers have proposed a new method—the Digestible Indispensable Amino Acid Score (DIAAS)—to determine protein quality. The DIAAS is similar to PDCAAS in that DIAAS is based on the ratio of an indispensable amino acid in a gram of a food protein to that in a reference protein. It differs in that it uses an improved value (amino acid digestibility measured from samples collected at the terminal ileum of the small intestine) as opposed to the less precise fecal crude protein digestibility used in PDCAAS. Amino acid digestibility measured at the terminal ileum provides a better indication of the amount of amino acids absorbed. Ideally amino acid digestibility should be determined in humans, but since this is not practical, growing pigs are the next best, followed by growing rats.

The DIAAS should be determined for each indispensable amino acid in the food protein, and the lowest value is set as the DIAAS of the protein. Unlike PDCAAS, when a food protein has a DIAAS greater than 1.0, it should not be truncated. DIAAS values have recently been published for 14 proteins in growing male rats. MPC and whey proteins had the highest values of the proteins studied. Of interest, the researchers noted that untruncated PDCAAS values were generally higher than DIAAS values, especially for proteins of poorer quality which may have practical importance in populations consuming marginal or poor quality proteins in their diet. As more data are developed on ileal amino acid digestibility of foods in humans, DIAAS may take the place of PDCAAS as the best method for determining food protein quality.

7.2 HEALTH BENEFITS OF MILK PROTEINS

Milk proteins are high quality proteins due to their excellent digestibility and ability to provide essential amino acids. In addition to providing essential amino acids for growth and development, milk proteins contain high amounts of the branched chain amino acids (BCAA)—leucine, isoleucine and valine. The BCAA, most importantly leucine, have been shown to best stimulate muscle protein anabolism and decrease protein breakdown.

Table 4: Essential Amino Acid and Leucine Content of Foods

SOURCE	ESSENTIAL AMINO ACIDS, % TOTAL PROTEIN	LEUCINE, % TOTAL PROTEIN
PLANT SOURCES		
Lentil	40	7.9
Black bean	39	8.4
Maize	38	12.2
Soy	38	8.0
Pea	37	7.8
Rice	37	8.2
Oat	36	7.7
Hemp	34	6.9
Potato	33	5.2
Wheat	30	6.8
ANIMAL SOURCES		
Whey	52	13.6
Milk	49	10.9
Casein	48	10.2

Table 4 (continued)

SOURCE	ESSENTIAL AMINO ACIDS, % TOTAL PROTEIN	LEUCINE, % TOTAL PROTEIN
Beef	44	8.8
Egg	44	8.5
Cod	40	8.1
Human muscle	45	9.4

As shown in Table 5, milk proteins can also exert physiological effects in the body. Individual milk proteins have been shown to exhibit a wide range of beneficial functions, such as enhancing calcium absorption and immune function. The antimicrobial mechanisms of whey proteins, such as immunoglobulins, lactoferrin, lactoperoxidase, lysozyme and glycomacropeptide have been documented. Immunoglobulins from milk and whey have a prophylactic and therapeutic effect against specific micro-organisms causing diarrhea, gastritis and dysentery. Korhonen provides an extensive current review of the protein sub-fractions in bovine colostrum and milk and their physiological effects and health benefits.

Table 5: Reported Physiological Effects of Milk Proteins

PROTEIN FRACTION	BIOLOGICAL ROLE OR FUNCTION
Caseins • α-s1-Casein • α-s2-Casein • β-Casein • κ-Casein	Serve as mineral carriers. Bioactive peptides from casein may have anti-hypertension, antithrombotic, antimicrobial, immune-modulating and opioid agonist effects.
β-Lactoglobulin	Serves as a transporter, binds to minerals, fat soluble vitamins and lipids. Contains a high concentration of BCAA. Peptides obtained from this protein fraction have been shown to have anti-hypertensive and anti-microbial activity, lower blood cholesterol and induce oral tolerance.
α-Lactalbumin	This protein or its peptides have been reported to have immune-modulating effects: anti-microbial, anti-viral, anti-hypertensive and antioxidant activities. May improve mood, sleep and stress level, likely due to enhanced serotonin levels. New research has indicated a potential role for bovine α-lactalbumin and oleic acid (BAMLET) complexes which may kill tumor cells and play a role in cancer prevention.
Albumin	May have antioxidant and anti-cancer properties. Binds free fatty acids.
Immunoglobulins	Immunoglobulins (e.g., IgA, IgM, IgE and IgG) support passive immune function. Bovine immunoglobulin preparations may have benefits in both infants and older adults.
Lactoferrin	Binds to iron and is believed to have antimicrobial, antiviral, anti-inflammatory, anti-cancer and immuno-regulatory properties. May help improve eradication of *H. pylori* and iron status. May be beneficial for oral, intestinal and bone health. Its use may also be helpful in reduction of sepsis and infections, particularly in low birth weight infants.
Lactoperoxidase	Has antibacterial properties. It has been used as a preservative and in toothpaste to fight cavities and also reported to have antioxidant and immuno-enhancing properties.

In addition to amino acid composition, digestibility rates can impact both the rate and duration of amino acids delivered to the bloodstream. The digestibility rates of the two main fractions of milk proteins, casein and whey, are different. Casein forms curds in the stomach, which slows digestion and entrance into the small intestine. In contrast, whey protein is quickly digested and produces a rapid rise in circulating amino acid levels in the blood and thus has been designated a "fast" protein. Differences in the rate and duration of amino acids entering the bloodstream can impact physiological signaling processes, such as stimulation of muscle protein synthesis, and can also impact the optimal timing to consume the protein. When digested, dairy proteins are also a source of a number of bioactive proteins and peptides which may exert health benefits beyond the nutrition they provide. The impact of many of these peptides has been shown *in vitro* or in animal studies; for example, Chatterton and coworkers have reported on the anti-inflammatory effects of milk peptides, which may benefit the infant gastrointestinal system. More clinical research is needed to confirm the benefits of milk peptides to human health; however, some peptides, such as those that lower blood pressure, have been shown to be effective in humans. Products specifically designed to increase availability of peptides that lower blood pressure have been commercially produced and sold in the marketplace.

7.3 THE IMPACT OF MILK PROTEINS ON NUTRITION, PHYSIOLOGY AND HEALTH

Body Composition

Body composition is the relative proportion of body fat and fat free mass (organs, bone and muscle tissue) that make up the human body. Increased body fat and reduced muscle and bone mass generally occur with aging and can lead to chronic diseases such as cardiovascular disease, stroke, type 2 diabetes and osteoporosis as well as lower productivity and quality of life. A person's ability to burn energy is dependent, in part, on his or her body composition. The loss of muscle that occurs with aging and reduced physical activity reduces one's energy needs and often results in increased body fat. An active lifestyle and resistance exercise can help maintain muscle. Also, increased dietary protein intake can help blunt the loss of muscle that occurs with aging. The consumption of dairy foods has been shown to have a beneficial impact on reducing body fat and increasing fat free mass in some but not all studies; this effect is more consistent when combined with caloric restriction. A meta-analysis of interventional studies showed that most indicated that calcium ingestion improved body composition, but the benefits were only detected when a regular calcium intake of about 700 mg/day or lower was increased to about 1,200–1,300 mg/day.

Some research has indicated that calcium provided in dairy foods may exert a greater effect than other sources of calcium. Thus, other components of dairy are likely involved, and dairy proteins have been suggested to be major contributors. Mechanisms by which casein and whey proteins may beneficially affect body composition can include increasing satiety, thermogenesis and lipid oxidation. A study by Baer and coworkers found that whey supplementation increased the loss of body weight and body fat when compared to carbohydrates without caloric restriction. The effects of soy protein on body weight and body fat were not different from either the whey or carbohydrate groups. Whey supplementation resulted in lower waist circumference than either soy or carbohydrate supplementation. Tahavorgar and coworkers compared the effects on appetite, weight loss and anthropometric measures of 65 g/day whey protein versus 60 g/day soy protein as meal preloads in obese men for 12 weeks. They found that the whey protein preload was significantly more effective than the soy preload in terms of appetite suppression, reducing caloric intake and reducing body weight, BMI and waist circumference.

Chocolate milk is a convenient, yet affordable post-workout beverage. Chocolate milk is an optimal source of dairy proteins, fluid and sodium, which all aid in muscle recovery, reduced muscle damage and muscle glycogen re-synthesis.

Milk consumption is encouraged for children and adolescents, but recently its consumption in the United States has declined while childhood obesity has increased. Dror conducted a systematic review and meta-analysis of 22 studies examining the relationship between dairy product consumption and obesity in children and adolescents. The results showed no association between dairy intake and adiposity in early and mid-childhood but a modestly protective effect of dairy intake against adiposity in adolescence (12–19 years). The mechanisms by which dairy consumption was mildly protective against obesity in adolescents are not understood, but could be the same as those protective against cardiometabolic health, described later in this chapter.

Researchers in Europe also conducted a cross-sectional study to determine the dietary risk factors for cardiovascular disease (CVD) risk among adolescents (12.5–17.5 years) in eight countries. They measured dietary intakes, anthropometrics and several indices of CVD risk, including blood lipids, blood pressure and insulin resistance in 511 boys and girls. The results showed that consumption of dairy products was the best predictor of low versus high CVD risk. The results for girls versus boys were different. For example, the anthropometric measurements—waist circumference and sum of skinfolds—were inversely associated with consumption of total dairy products in both boys and girls; however, among the girls only, a highly significant inverse association was found between CVD risk score and overall dairy consumption. These observations lend additional support to the recommendations to encourage milk consumption through childhood and adolescence.

Consumption of milk and/or dairy proteins has also been shown to improve body composition when combined with resistance exercise or as part of a weight management program.

Dairy Proteins and Nutrition for the Elderly

A loss of both skeletal muscle and function and bone mass occurs with aging, and the elderly are at increased risk for sarcopenia and osteoporosis when compared to younger individuals. Sarcopenia refers to the loss of muscle mass and function and affects 5–13% of 60–70 year olds and 11–50% of the elderly over the age of 80. The loss of muscle is often accompanied by an increase in body fat. Sarcopenia is associated with many age-related chronic diseases including osteoporosis, cardiovascular disease, metabolic syndrome, diabetes and premature death. Older individuals have an impaired ability to use dietary protein to build muscle mass and strength, and their muscle synthesis following consumption of protein is reduced when compared to healthy young individuals. New evidence indicates that older adults need more protein to support good health and recovery from illness. Recently the Geriatric Medicine Society, in cooperation with other scientific organizations, formed an international expert panel to review dietary protein needs with aging. Recommendations for protein intake for maintaining muscle mass were 1.0–1.2 g protein/kg body weight/day; for those exercising, 1.2 g/kg body weight/day, and 1.2–1.5 g/kg body weight/day for individuals with acute or chronic illnesses.

A Cochrane review concluded that protein supplementation can enhance both muscle mass and function in the elderly; this effect is further enhanced when combined with exercise. Similarly, a meta-analysis of six studies found that protein supplementation at levels between 10 and 63 grams per day, primarily from dairy proteins, resulted in 38% more fat free mass and a 33% increase in strength compared to placebo. In another systematic review and meta-analysis of nine randomized controlled trials, 462 older adults either consumed protein supplements and performed resistance training or were in the control group which performed resistance training but received no supplement. In three studies the protein was supplemented on a body weight basis between 0.3 and 0.8 g/kg while in the other six trials it was supplemented on a daily basis at levels between 6–40 g/day. The only significant difference noted was an increase in fat free mass in the group receiving the supplement; there were no increases in muscle mass or strength associated with consumption of the protein supplement.

The type of protein consumed may have an impact on maintaining muscle mass. Some, but not all studies, have shown fast proteins (such as whey) may have an advantage over slower absorbed proteins, such as casein, and animal proteins (specifically dairy) may have benefits over plant-based proteins such as soy. Recently, studies supplementing milk protein concentrate in frail elderly combined with exercise resulted in increased muscle mass or physical function.

Both consumption of protein after exercise rather than before, and also throughout the day, are suggested strategies to help maintain muscle mass in the elderly. Additional research is warranted to further optimize protein supplementation strategies to help maintain muscle with aging. A recent consensus statement pertaining to the role of dietary protein in maintaining muscle and bone health in postmenopausal women recommends optimal dietary protein intakes between 1.0–1.2 g/kg body weight/day with at least 20–25 g of high quality protein such as dairy at each meal, adequate vitamin D (800 IU/day) and calcium (1,000 mg/day) intakes alongside physical activity 3–5 times a week combined with protein intake in close proximity may help promote age-related muscle and bone health.

Concern has been raised that higher protein diets could enhance bone loss, due to an increase in calcium excretion which would increase the risk for osteoporosis; however, evidence on the benefits of dietary protein intake on bone health has some researchers recommending increased protein intake to promote bone health. A systematic review and meta-analysis found a small but beneficial effect of dietary protein on lumbar spine bone mineral density. Numerous studies have also shown that low protein intake is associated with a loss of bone mineral density while higher protein intakes are associated with bone health, particularly with adequate dietary calcium intake. Higher protein consumption may positively affect bone health through maintaining muscle mass, increased calcium absorption and effects on growth factors such as insulin growth factor-1 (IGF-1).

Sports Nutrition

The International Society of Sports Nutrition's position on protein and exercise recognizes that a vast amount of research supports the increased need for dietary protein in individuals engaged in regular exercise. Protein intake of 1.4–2.0 g/kg body weight/day for physically active individuals is safe and may improve the adaptation to exercise training. Moreover, the society states that use of supplemental protein in various forms is a practical way of ensuring adequate and quality protein. Protein intakes above the current RDA for protein (0.8 g/kg body weight) have been suggested by others as well. In a joint position statement, the American College of Sports Medicine, Academy of Nutrition and Dietetics and Dietitians of Canada recommend protein intakes of 1.2–1.7 g/kg body weight per day. A recent meta-analysis was conducted to investigate the efficacy of protein supplementation on the response of muscles in younger and older adults to prolonged resistance exercise. Data from 22 clinical trials which included 680 subjects showed a positive effect of protein supplementation on fat free mass and strength gains in both younger and older subjects.

Proteins from milk are excellent high quality proteins for athletes that can be easily obtained through the diet and via supplementation. Milk proteins have been shown to stimulate post-exercise muscle protein synthesis to a greater effect than soy proteins in many, but not all, studies. Numerous studies have been conducted to investigate the impact of consuming milk proteins, especially whey, on post-exercise muscle protein synthesis. The amount of protein required to stimulate protein synthesis is believed to be age-dependent; 20 g and 40 g of whey protein are required to achieve maximal protein synthesis in younger and older subjects, respectively. Whey protein is considered a "fast protein," which is quickly digested and delivers increased levels of amino acids to the blood, making it an excellent post-exercise supplement. The high levels of essential amino acids, including the branched chain amino acids and especially leucine, stimulate muscle protein synthesis. Advantages of whey protein over more slowly digested proteins such as casein on muscle protein synthesis are particularly apparent during the early phases of recovery, while slower digested proteins such as casein deliver a prolonged increase in blood amino acids later in the recovery period.
Thus, milk powders and milk protein concentrates, which contain both whey and casein, are also ideal proteins for development of post recovery supplements. In addition to protein, minerals provided by dairy products, such as sodium, potassium and calcium, may serve as a post-exercise source of electrolytes for rehydration. Studies have demonstrated the consumption of fluid milk can help build and repair muscle following exercise—powdered milk should exert similar effects. Furthermore, for exercisers wishing to lose weight, the consumption of skim milk after exercising has been shown to lower food intake at the subsequent meal by 25% compared to an isoenergetic orange drink.

Whey also has been shown to be effective in attenuating the loss of lean body mass that occurs during weight loss diets. Hector et al. placed obese subjects on a low calorie diet and supplemented them with either whey protein, soy protein or an isoenergetic carbohydrate supplement for two weeks. They found that all groups showed a reduction in post-prandial muscle protein synthesis rates, but the rate after whey protein intake was higher than that after soy protein. This study supports the position that use of whey protein during weight loss diets can help preserve lean body mass.

Cardiometabolic Health

Metabolic syndrome is clinically identified as having at least three metabolic risk factors including abdominal obesity; elevated triglycerides, blood pressure and fasting glucose levels; and lowered HDL-cholesterol. Metabolic syndrome increases the risk of developing heart disease and other health problems, including type 2 diabetes mellitus and stroke. A systematic review found that the consumption of dairy foods was inversely associated with metabolic syndrome. Additional studies have confirmed this inverse association or found an inverse association with dairy product intake and type 2 diabetes. As indicated earlier, the consumption of higher protein diets can help prevent the loss of muscle mass and increase in body fat that accompanies aging and also in individuals on weight loss diets. Increased dairy protein consumption also has been shown to reduce abdominal fat, which is particularly associated with metabolic disorders. In addition to dairy proteins' impact on body composition, physiological effects on other biomarkers of metabolic disease include improved glucose levels, insulin sensitivity, lower arterial stiffness and blood pressure, and a more healthy blood lipid profile. In a recent study by Arciero et al., it was shown that the addition of three 20 gram servings of whey per day was effective in improving body composition and markers of cardiometabolic health. When exercise was added, the improvements in body composition and cardiometabolic markers were enhanced.

Other nutrients, including calcium, magnesium and potassium—in addition to protein provided by dairy products such as milk powders and milk protein concentrate—may contribute to improved cardiometabolic health. Reviews on the impact of protein on the management of type 2 diabetes and, specifically, on the impact of dairy components on cardiometabolic syndromes have been recently published.

7.4 SPECIAL POPULATIONS: INFANTS AND CHILDREN WITH MALNUTRITION

STATEMENT OF PRINCIPLES

USDEC and Dairy for Global Nutrition fully support the 1981 International Code of Marketing of Breastmilk Substitutes and the guidance by the World Health Organization on Community-Based Management of Severe Acute Malnutrition.

In emergency settings, the hierarchy of actions taken to adhere to the principle of "do not harm" related to the Infant and Young Child Feeding Guideline practices includes, first, support of breastfeeding and re-lactation whenever possible followed by wet nursing for the infant. If neither of these actions are possible, the use of breast milk substitutes for children less than six months (where the need has been established using skilled individual level of assessment) should use Codex-compliant infant formula. Modified animal milks should be utilized as a temporary stop-gap option. For infants older than six months who are not breast fed, the focus should be on complementary feeding support. Use of breast milk substitutes are only considered in exceptional cases (e.g. where an infant over six months has been established on replacement feeding in the context of HIV or other medical conditions).

ADDITIONAL RESOURCES

- Publications by the World Health Organization, available at www.who.org
  - International Code of Marketing of Breastmilk Substitutes published by the World Health Organization, 1981
  - Acceptable medical reasons for the use of breastmilk substitutes, 2009
  - Guidelines on HIV and infant feeding, 2010
- Publications by the World Food Programme, available at www.wfp.org
  - Technical Specifications for Ready-to-Use Supplementary Food, 2016
- Publication by the USDA, available at www.usda.gov
  - Commercial Item Description, Ready-to-Use Therapeutic Food (RUTF), 2012
- Publications by the United States Agency for International Development (USAID), available at www.usaid.gov
  - USAID Commodity Specification Super Cereal Plus for Use in International Food Assistance Programs, 2016
  - Delivering Improved Nutrition, April 2011
  - Nonfat Dry Milk Supplementary Feeding Policy, November 2001
  - Nonfat Dry Milk Therapeutic Feeding Policy, November 2001

Dairy Ingredients in Food Assistance Programs

Globally it is estimated 155 million (22.9%) children under five years of age are stunted (child is too short for his/her age) and 52 million were wasted (child is too thin for his/her height), of which over 16 million were severely wasted in 2016. Undernutrition and stunting in the first two years of life can reduce a child's chance of survival and have long-term implications, including lower cognitive ability and school performance, shorter adult height, lower adult wages and decreased offspring birth rate. If accompanied by rapid weight gain later in childhood, there is also increased risk for chronic disease as adults. When protein intake and protein quality are low, children suffer from malnutrition, stunted growth and are less able to fight infections.

For cases of severe acute malnutrition (SAM) requiring hospitalization, supplement products F-75 and F-100 are used, formulated with 100% of the protein from milk powder. Community-based treatment of SAM relies on ready-to-use therapeutic foods (RUTF) that typically contain 25–30% skimmed milk powder or whey protein concentrate in addition to sugar, oil, peanut butter and a vitamin/mineral mix. In 2007, the World Health Organization and others recommended that uncomplicated forms of SAM should be treated in the community rather than in a hospital setting. In addition, the recommendation specifically stated that "at least half of the proteins contained in the foods should come from milk products." This level of dairy ingredients is nutritionally important. As shown in a randomized, double-blind clinical study comparing the efficacy of a RUTF containing 10% milk supplemented with soy versus a RUTF with 25% milk, the higher milk formulation resulted in a significantly better rate of recovery. Rates of gain in weight, height and mid upper arm circumference (MUAC) were also higher in the group receiving the 25% milk RUTF. In a large randomized, controlled trial of children with SAM in Zambia, Irena and coworkers tested the hypothesis that a milk-free RUTF made with soy, maize and sorghum would have equivalent effects as RUTF containing 25% milk on recovery rates. They found that the milk-containing RUTF produced significantly better rates of weight gain and shorter treatment time versus the non-milk RUTF; recovery was particularly improved among children less than two years old. The study did not prove equivalence between the milk-free and milk-containing RUTFs, as had been hypothesized. Bahwere and coworkers (2014) have shown that the more economical whey protein concentrate performs as well as dried skimmed milk in RUTF when treating SAM. These results indicate it is difficult to attain the growth and recovery benefits of milk ingredients by combinations of grain-based ingredients; however, substitution of dry skimmed milk with another dairy protein source, like whey, can be made without impacting the efficacy of the RUTF for the treatment of SAM.

In contrast to SAM, programs for the management of moderate acute malnutrition (MAM) had remained virtually unchanged for 30 years and prompted renewed efforts to improve their efficacy and effectiveness. Numerous reviews and consultations have recommended the inclusion of animal-based foods, like dairy, to improve specially formulated products for the treatment and prevention of MAM. In 2008, the World Health Organization and others held a consultation on the dietary management of malnutrition in children. Among the recommendations it is stated that, "the addition of animal source foods to a plant-based diet promotes recovery of moderately malnourished children."

The use of whey or skimmed milk powder in fortified blended foods for malnourished infants and young children or people living with HIV was reviewed by Hoppe and coworkers. The authors suggested benefits of adding dairy ingredients to fortified blended foods included: improvement of protein quality that allows for a reduction of total protein which could have metabolic benefits; a reduction in anti-nutrients as a result of utilizing less soy and cereal; and improved flavor. The USAID's Office of Food for Peace published a report in 2011 on ways to improve the nutrition quality of food aid products. It concluded that fortified blended foods based on cereals/vegetable protein/oil that are used as emergency food aid should include dairy-based ingredients to improve the protein quantity and quality. Michaelsen and coworkers have also concluded that supplementary foods that provide one quarter to one third of the daily protein requirement such as milk powder or whey protein concentrate (34%) are adequate to improve growth in children with moderately acute malnutrition (MAM). In 2012, WHO reviewed the evidence regarding the adequacy of supplementary foods for the management of MAM, and concluded that, "the inclusion of milk powder as an ingredient improves the amino acid profile (has a high PDCAAS) and is a good contributor of bioavailable calcium and potassium. In addition, it has a specific stimulating effect on linear growth and insulin growth and IGF-1 levels in the child and does not contain anti-nutrients."

Studies have been conducted utilizing ready-to-use supplemental foods (RUSFs) or lipid-based nutrient supplements (LNS) containing dairy and improved fortified blended foods, such as Super Cereal Plus (sometimes referred to as CSB++) where dairy ingredients have been added to improve protein quality for the treatment of MAM. When compared to corn soy blends with added sugar and oil, LNS supplements, all containing dairy ingredients, have shown better results in the treatment of children with MAM. LaGrone and coworkers have shown that CSB++ was equally effective in recovery rates when compared to two RUSFs. In 2013, a Cochrane analysis was conducted to examine the impact of providing specially formulated foods for treating children with MAM. The use of LNS increased the number of children recovered and improved weight gain, weight-for-height and MUAC compared to use of any blended foods at full doses. However, when specific types of blended foods and LNS were compared, use of the enriched blended food (CSB++) resulted in similar outcomes to LNS. Ackatia-Armah and coworkers found that CSB++ was intermediate between RUSF and locally processed blended foods without dairy for treatment of MAM. Sayyad-Neerkorn and coworkers compared the effectiveness of long-term supplementation of LNS to Super Cereal Plus on the incidence of acute malnutrition and stunting in young children. No differences were found between treatment on the incidence of MAM or SAM. In addition, no differences were found in the incidence of stunting or severe stunting over the follow up period. Authors concluded that both products should be considered when planning preventative distributions.

Recently, Batra and coworkers conducted a pilot study in young children ages three to five in Guinea-Bassau in preschool settings which compared RUSFs containing 15% and 33% of protein from dairy sources versus weight-listed controls. Results of the study showed that for children who consumed supplements for more than 50 days, consumption of either dairy-containing RUSFs increased weight-for-age Z-scores compared to the control group. In addition, the RUSF containing 33% protein from dairy, but not 15% from dairy, eliminated a decrease in MUAC observed from controls.

The nutritional contribution milk-based ingredients make to supplementary foods goes beyond their high quality protein. As reviewed by Michaelsen, dairy products provide peptides, bioactives and minerals (potassium, magnesium and phosphorus) that could have growth stimulating effects. In addition, the lactose content of milk-based ingredients may stimulate growth via a prebiotic effect and/or an improvement of mineral absorption. More research is needed to delineate the effects these various components have, as well as the optimal doses needed.

BENEFITS FOR 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 such as phosphorus and potassium
- Low-lactose alternatives (MPCs and MPI)
- Presence of bioactive and health enhancing compounds that have applications in therapeutic feeding
- Complement proteins of vegetal origin
- Superior DIAAS of 1 and greater (when compared to plant-based 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 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, 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

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.*

Milk Consumption and Pregnancy

Babies born with low birth weights are more likely to have health complications. Studies have shown that when pregnant women consume milk, they are less likely to experience intrauterine growth retardation and are more likely to deliver healthy weight babies. Intrauterine growth retardation is a condition in which an unborn baby is below the 10th weight percentile for his or her age. There are many causes, but poor maternal nutrition is among them.

Ludvigsson and Ludvigsson surveyed new mothers for their milk consumption during pregnancy and correlated it with the birth weights and other birth statistics of their babies. They found that low milk intake (less than 233 mL per day) correlated with intrauterine growth retardation, but not with low birth weights or risk of pre-term births. Women who consumed more than 100 mL of milk per day gave birth to babies who weighed on average 134 g more than the babies of mothers who drank no milk. Similarly, Mannion and coworkers followed pregnant women who chose to consume less than 233 mL of milk per day and compared their pregnancy outcomes against those of women who chose to consume at least 233 mL of milk per day. They found that the women who consumed less milk gave birth to babies who weighed significantly less than those whose mothers drank more milk during pregnancy. Each cup of milk was associated with a 41 g increase in birth weight. Olsen and coworkers found that, compared to women who consumed no milk during pregnancy, those who consumed between one and six glasses of milk per day had babies with birth weights up to 100 g heavier. Further analysis indicated that the higher weight gain was associated with the protein content of the milk while the fat content of the milk did not impact birth weights. Heppe and coworkers extended and confirmed these findings; they showed that when pregnant women consumed two to three glasses of milk during their first trimester, they gave birth to babies with larger head circumferences and higher birth weights. They also concluded that the higher intake of protein from milk, but not the carbohydrate and fat, was responsible for the higher birth weights.

These observational studies illustrate the value of milk in the diets of pregnant women and their developing babies. Avoiding intrauterine growth retardation and its complications is a great concern for pregnant women. Babies born with higher birth weights start their lives with a greater chance for good health.

7.5 NON-PROTEIN COMPONENTS OF MILK

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. Lactose is a natural disaccharide consisting of one galactose and one glucose unit. It is a unique sugar in that it is found naturally only in milk and is the first and only carbohydrate every newborn mammal consumes in significant amounts.

Lactose is hydrolyzed by the enzyme **β**-galactosidase (also known as lactase) into its individual sugars. The slow hydrolysis of lactose by the body during digestion generates a prolonged energy supply. As a carbohydrate, it provides about four calories per gram. Because digestion of lactose is much slower than that of glucose and fructose, lactose has a low glycemic index. It does not cause a sharp increase in blood glucose levels like caloric sweeteners, and therefore may have a nutritional advantage in the diabetic diet. Lactose also reaches the colon of infants where it promotes the growth of beneficial lactic acid bacteria which may help combat gastrointestinal disturbances and enhance 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 minerals (such as calcium and magnesium) in infants, although its effect in adults remains controversial.

Some individuals have difficulty metabolizing lactose because of reduced lactase, the enzyme involved in lactose digestion. Most individuals produce sufficient levels of lactase at birth but for some, after the age of two, intestinal lactase activities may decline. This decline can result in a reduced ability to digest lactose, termed malabsorption. Lactose intolerance is the gastrointestinal problem that occurs when the amount of lactose consumed exceeds the body's ability to digest and absorb it. Strategies to avoid lactose intolerance symptoms include consuming smaller amounts of milk more frequently, consuming milk with meals, consuming cheese or cultured dairy foods and choosing lactose-free dairy products. The National Medical Association issued a consensus statement in 2013 recognizing that while lactose intolerance may exist at higher rates in African American and Hispanic American populations, the benefits of consuming dairy products for health are equally important for these groups, and efforts should be made to include low lactose dairy products in their diets.

Because lactose is removed in the production of milk protein concentrates, higher protein-containing MPCs can contain minimal amounts of lactose. The high-protein, low-lactose ratio makes MPC an excellent ingredient for protein-fortified beverages and foods and low-carbohydrate foods, where low lactose levels are desired.

Milk oligosaccharides are minor carbohydrates found in cow and human milk. It is believed that oligosaccharides found in human milk exert benefits beyond providing nutrition, such as development and modulation of gut flora, however commercial use is limited due to its source. Bovine milk oligosaccharides are being investigated as a viable alternative. Of interest is the finding that bovine milk oligosaccharides may not only be structurally related to human milk oligosaccharides but in some cases have the same composition. Results of this research may lead to a better understanding of how dairy foods, such as milk powders, may help modulate gastrointestinal micro flora and also provide a value-added bioactive food ingredient for the infant formula and food industry.

Lipids

Milkfat is a source of energy, essential fatty acids, fat soluble vitamins and several other health promoting components. Milkfat is characterized by a number of different fatty acids of varying chain length.

Table 6: Fatty Acid Content in Dry Whole Milk and Skimmed Milk Powder

SOURCE	CARBON	DRY WHOLE MILK (G/100 G)	SKIMMED MILK POWDER (G/100 G)	CLASS
Butyric	4:0	0.866	0.028	Saturated, short chain
Caproic	6:0	0.240	0.006	Saturated, short chain
Caprylic	8:0	0.269	0.007	Saturated, medium chain
Capric	10:0	0.596	0.018	Saturated, medium chain
Lauric	12:0	0.614	0.014	Saturated, medium chain
Myristic	14:0	2.820	0.083	Saturated, long chain
Palmitic	16:0	7.522	0.235	Saturated, long chain
Stearic	18:0	2.853	0.085	Saturated, long chain
Palmitoleic	16:1	1.196	0.022	Monounsaturated
Oleic	18:1	6.192	0.167	Monounsaturated
Linoleic	18:2	0.460	0.019	Polyunsaturated
Linolenic	18:3	0.204	0.011	Polyunsaturated

Values reported are for [1]Milk, dry, whole, without added vitamin D and [2]Milk, dry, nonfat, regular without added vitamin A and D, respectively.

The composition of milkfat has been reviewed in detail and more than 400 different fatty acids and fatty acid derivatives have been identified in milkfat. Milkfat contains several components such as conjugated linoleic acid, phospholipids (such as sphingomyelin) and butyric acid, which may protect against major chronic disease. Recently, plasma levels of the trans-fatty acid, trans-palmitoleic acid, have been associated with lower insulin resistance, more healthy blood lipid profiles and reduced incidence of diabetes. Emerging science indicates that the relationship between the consumption of dairy fat or higher-fat dairy products and risk of chronic disease is of less concern today. For a more detailed review on this topic, see the National Dairy Council's science brief entitled, "Whole and Reduced Fat Dairy Foods."

Minerals

Milk powders, milk protein concentrates and milk protein isolate are excellent sources of major minerals, particularly calcium, phosphorus and potassium. They also provide other minerals such as magnesium and trace elements such as zinc.

Table 7: Comparative Composition of Dry Milks, Select MPCs and MPI

NUTRIENT	NONFAT DRY MILK[1]	DRY WHOLE MILK[1]	MPC40[2]	MPC70[2]	MPC85[2,3]	MPI[2,3]
Water (%)	3.16	2.47	4.47	5.55	5.57	5.76
Energy (kcal/100 g)	362.00	496.00	353.00	353.00	355.00	355.00
Protein (%)	36.16	26.32	39.70	70.70	87.73	90.14
Fat (%)	0.77	26.71	0.45	0.62	1.01	0.81
Lactose (%)	51.98	38.42	42.10	14.40	9.19	1.80
Total minerals (%)	7.93	6.08	7.91	7.26	7.11	6.64
Calcium (mg/100 g)	1257.00	912.00	1350.00	1943.00	2105.00	2053.00
Magnesium (mg/100 g)	110.00	85.00	116.00	110.00	103.00	97.80
Phosphorus (mg/100 g)	968.00	776.00	992.00	1273.00	1340.00	1278.00
Potassium (mg/100 g)	1794.00	1330.00	1680.00	745.00	360.50	272.00
Selenium (µg/100 g)	27.30	16.30	34.10	73.10	90.40	95.20
Sodium (mg/100 g)	535.00	371.00	387.00	184.00	90.40	68.00
Zinc (mg/100 g)	4.08	3.34	4.74	8.61	10.23	10.70
Vitamin A (IU/100 g)	22.00	934.00	<50.00	<50.00	<50.00	<50.00
Vitamin B12 (µg/100 g)	4.03	3.25	4.57	8.88	10.51	9.57

Values reported are for [1]Milk, dry, nonfat, regular without added vitamin A and vitamin D; and [2]Milk, dry, whole, without added vitamin D, respectively. [3]USDEC: Medallion Labs average analysis of industry samples (MPC40: n=1, MPC70: n=3, MPC85: n=2, MPI: n=4). Protein content greater or equal to 85 is reported on a dry basis, all others are reported "as is."

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 plays several important physiological functions in human metabolism, as evidenced by its role in vascular and muscle function, nerve transmission and hormone secretion. An adequate amount of calcium helps protect against hypertension, some cancers and possibly body fat, diabetes and elevated total and LDL cholesterol. Calcium in milk also reduces the risk of kidney stones. Next to calcium, phosphorus is the most abundant mineral in the body. The main function of phosphorus is the development of bones and teeth which contain 85% of an adult's body phosphorus. Among other important roles, phosphorus helps maintain normal blood pH and is involved with energy transfer, enzyme activation, protein synthesis and tissue growth. Adequate potassium intake may help reduce the risk of hypertension and stroke, age related bone loss and kidney stone formation. Magnesium serves several roles in the body, including energy production and transport, protein production, muscle and nerve function and normal blood glucose and pressure.

Milk powders and milk protein concentrates can be used as ingredients to fortify other manufactured food products that are poor in calcium. Few foods other than milk products provide such a concentrated source of calcium that is readily available for absorption. Not only are milk powders and MPCs calcium-dense, but they also contain other nutrients important to bone health such as protein, potassium, phosphorus, magnesium, vitamin A, vitamin B6 and trace elements such as zinc. 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.

Vitamins

Milk powders contain many vitamins that are essential for human health. Vitamins are organic substances found in food that are required in minute amounts by the body for regulation of metabolism and normal growth and function. They can be classified as either fat soluble or water soluble vitamins.

Table 8: Concentration of Vitamins in Milk Powders (per 100 g)

VITAMIN	SKIMMED MILK POWDER[1]		WHOLE MILK POWDER[2]	
	g	% DV[3]	g	% DV
Ascorbic acid (mg)	6.80	8	8.60	10
Thiamin (mg)	0.42	35	0.28	23
Riboflavin (mg)	1.60	123	1.21	93
Niacin (mg)	0.95	5	0.65	3
Pantothenic acid (mg)	3.57	71	2.27	45
Vitamin B6 (mg)	0.36	21	0.30	18
Folate total (µg)	50.00	13	37.00	9
Choline (mg)	169.20	31	117.40	21
Vitamin B12 (µg)	4.03	168	3.25	135
Vitamin A (IU)	22.00	-	934.00	-
Vitamin A (RAE)	6.00	1	258.00	29
Vitamin D (IU)	0.00	-	20.00	5
Vitamin E (mg)	0.00	-	0.58	3
Vitamin K (µg)	0.10	-	2.20	2

Values reported are for [1]Milk, dry, nonfat, regular without added vitamin A and vitamin D1 and [2]Milk, dry, whole, without added vitamin D2, respectively.
[3]Percent DV = Percent Daily Value; source of DV values used in calculating percentage DV: 81 FR 33982.

Vitamins A, D, E and K are fat soluble and are stored by the body in fat. Because they are stored in fat, higher concentrations of vitamins A, D, E and K are found in greater amounts in whole milk powder than reduced-fat milk powders. Vitamin A is important for normal vision, epithelial cell integrity, gene expression, embryonic development, growth and immune function. Both vitamin A and its precursors, carotenoids, are present in milk. Vitamin A deficiency can be found across the globe but is particularly predominant in Africa and Southeast Asia. In developing countries, increased vitamin A intakes have been shown to reduce night blindness. Vitamin A supplementation has also been shown to reduce the risk of mortality in young children, infants and in pregnant/postpartum women. The main function of vitamin D is to maintain normal calcium and phosphorus levels in the blood by enhancing their absorption by the intestine. Thus, it plays an essential role in growth and maintenance of healthy bones across the lifespan. Vitamin D also may play a role in nerve, muscle and immune systems. 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 water-soluble vitamins in varying amounts required by humans. Water soluble vitamins, (vitamins B and C), are not stored and, when consumed in excess, are excreted by the body. Thus, they need to be replenished regularly. Significant amounts of thiamin (vitamin B1), which acts as a co-enzyme for many reactions in carbohydrate metabolism, are found in milk. Milk is also a good source of riboflavin (vitamin B2). Other vitamins include niacin (vitamin B3), pantothenic acid (vitamin B5), vitamin B6, vitamin B12 and folate. In addition, milk products supply the amino acid, tryptophan, which can be used by the body to make niacin; 60 mg of tryptophan equals 1 mg of niacin. Some specific functions provided by the water soluble vitamins are listed in Table 9.

Table 9: Vitamins in Milk and Their Functions in the Body

VITAMIN	FUNCTION
FAT SOLUBLE	
Vitamin A	Plays a role in vision, bone growth, reproduction, cell functions and immune system; is an antioxidant that may protect your cells against the effects of free radicals.
Vitamin D	Helps the body absorb calcium which bones need to grow; plays a role in nerve, muscle and immune systems.
Vitamin E	Is an antioxidant that may protect cells against the effects of free radicals; plays a role in immune system and metabolic processes.
Vitamin K	Helps make proteins for healthy bones and tissues and for blood clotting.
WATER SOLUBLE	
Vitamin C (Ascorbic acid)	Important for skin, bones and connective tissue; promotes healing and iron absorption; is also an antioxidant that may protect cells against the effects of free radicals.
Vitamin B_1(Thiamin)	Helps the body's cells convert carbohydrates into energy; essential for the functioning of the heart, muscles and nervous system.
Vitamin B_2 (Riboflavin)	Important for body growth and red blood cell production; helps in releasing energy from carbohydrates; works with the other B vitamins.
Vitamin B_3 (Niacin)	Helps the digestive system, skin and nerves to function; also important for converting food to energy.
Vitamin B_5 (Pantothenic acid)	Essential for growth, helps the body break down and use food; plays a role in the production of hormones and cholesterol.
Vitamin B_6 (Pyridoxine)	Helps the body make antibodies to fight disease; maintain normal nerve function; make hemoglobin; break down proteins; keep blood sugar (glucose) within normal ranges.
Vitamin B_9 (Folate)	Helps the body make healthy new cells; helps prevent neural tube defects in children. (Especially important for all women who may become or are pregnant).
Vitamin B_{12}	Important for metabolism; helps in the formation of red blood cells and in the maintenance of the central nervous system.

Adopted from U.S. Library of Medicine, Bethesda, MD

Dairy Products May Protect Against Colon Cancer

Colon cancer is the third most common cancer in men and the second in women worldwide, accounting for 8% of all cancer deaths, making it the fourth most common cause of death from cancer. Studies have demonstrated that the consumption of dairy products is associated with a lower risk of developing colon cancer. The role of dairy foods and milk on colon cancer was reviewed as part of the Continuous Update Project Report: Food, Nutrition, Physical Activity and the Prevention of Colon Cancer. According to the report's conclusions, both milk and calcium "probably protect against colon cancer."

A recent systematic review and meta-analysis on milk and total dairy products also concluded they were associated with a reduction in colon cancer risk in both men and women. More recently, another systematic review and meta-analysis of over 900,000 subjects and over 5,000 cases of colorectal cancer showed an inverse association between consumption of milk and risk of colon cancer in men. However, this study found no association between consumption of milk and rectal cancer in men, or milk and colon or rectal cancer in women. No protective association was found between consumption of solid cheese or fermented milk and colorectal cancer. The observations of a benefit related to milk consumption but not to cheese or fermented milk in men, but of no benefits to women by any form of dairy product, may relate to the amount of product consumed.

Multiple dairy components, such as calcium, vitamin D, sphingolipids, conjugated linoleic acid and butyrate may account for the protection against the development of colon cancer. 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 via the feces without harm to colon epithelial cells. Protection can also be attributed to dairy proteins. New research has indicated a potential role for α-lactalbumin and oleic acid complexes in cancer prevention and lactoferrin has been shown in multiple *in vitro* studies to increase the apoptosis (cell death) of cultured cancer cells.

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8 Functional Properties and Performance of Milk Powders

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Aside from their contribution to nutrition, milk powders deliver significant functional properties that contribute to the structure, stability, appearance and taste of the food products into which they are incorporated. How milk powders influence these properties is largely a reflection of their composition, the drying method and the heat treatment they were subjected to during their manufacture. The major components in milk powder (proteins, lactose, milkfat, minerals) affect their performance and suitability for each type of application.

8.1 FUNCTIONAL PROPERTIES OF MILK POWDERS

Table 1: 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
Low sweetening power	Creaming
Color development, browning	Gloss/appearance
Free-flow agent	Flavor carrier
Flavor development	Low melting temperature range

Solubility

Dairy protein functionality is dependent upon the 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) of 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 drying 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 nonfat dry milk and skimmed milk powder as high-heat, medium-heat or low-heat. Heat classification provides an indication of the suitability of these milk powders for specific applications. By controlling thermal denaturation, the degree of solubility can be intentionally targeted.

Milk powders, depending upon their composition, generally consist of small, single particles of high bulk density. Non-instant (non-agglomerated) skimmed milk powder tends to be rather dusty. As a result, reconstitution is difficult because the skimmed 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 use of a drying process that causes agglomeration, enhances reconstitution properties in cold liquids by improving wettability, dispersibility, rate of hydration and/or solubility.

Emulsification

The manufacture of food emulsions, typically oil-in-water systems, is a highly energetic and dynamic process. 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. Casein is an amorphous protein meaning that it lacks the organized folded structure of globular whey proteins. This attribute means that it can rapidly adsorb at the oil/water interface and partition its hydrophilic and hydrophobic groups into the appropriate water or oil phase without undergoing the slow process of denaturation. However, this benefit is significantly reduced in high-heat milk powders where casein molecules remained trapped in whey-coated milk micelles during homogenization.

In contrast, compact globular, native whey proteins can diffuse and adsorb quite rapidly to newly created oil/water interfaces but their partitioning process is slow due to the slow unfolding (surface denaturation) process. This process along with the preceding diffusion and adsorption steps can be accelerated by use of elevated temperature during homogenization which serves to denature whey proteins in a controlled manner during the emulsification process. 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, are able to form rigid, heat-induced irreversible gels that hold water and fat and that 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 occur when the repulsion is small. The type of aggregation affects the gel's opacity and is dependent on gelation conditions (i.e., pH, temperature, ionic strength).

Water Binding

The amount of water held in a gel under a given set of conditions is referred to as its water-holding or water-binding capacity. This water, enclosed in a 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 food products such as beverages, soups, sausages and custards. Moreover, water binding and associated properties of proteins (i.e., swelling, gelation and viscosity) are the major determinants of texture in 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. Both casein and whey proteins have the same ability to do so.

Foaming is defined as the creation and stabilization of gas bubbles in a liquid. A rapid diffusion of protein to the air-water interface to reduce surface tension, followed by partial unfolding of the protein is essential for the formation of protein-based foams. 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 undenatured proteins (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).

While both casein and whey proteins can stabilize foams, contrary to the case with emulsions, whey proteins tend to produce the most stable foams. This is partly explained by the higher level of elasticity that whey proteins contribute to the protein film at the air-water interface.

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 that are characteristic of frozen desserts, whipped toppings, meringues and mousses. Specifically, skimmed 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.

Depending on the state of the protein, dairy proteins can contribute a desired viscosity to a wide range of foods such as soups, sauces, salad dressings, baking batters and yogurts. Viscosity development is closely related to gelation properties, water binding properties and protein-to-protein interactions previously discussed.

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 free amino group reacts with lactose and other reducing sugars present in formulations to deliver an appealing caramel color to baked goods and sauces. Lactose is not fermented by baker's yeast in yeast-leavened bakery products so it remains available for crust color development.

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

Flavor/Aroma

Overall, the flavor of dairy proteins is quite mild and they contribute no foreign or off-flavors to foods when used as ingredients. 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.

Table 2: From Functionality to Applications

FUNCTION	CHARACTERISTICS	FUNCTIONAL BENEFITS	MARKETING BENEFITS	APPLICATIONS
Emulsification	Presence of hydrophilic and hydrophobic groups on milk proteins	Creates stable emulsions Prevents fat globules from forming one large mass Versatile and naturally occurring emulsifying agent	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
Gelling	Milk components form irreversible gels under specific conditions	Binds large quantities of water and non-protein compounds Improves mouthfeel. Helps lubricate and provide the creamy, smooth texture of fat	Appeals to health-conscious consumers by creating lower fat products with the taste of full-fat	Confectionery Dairy/recombined milk Meat Prepared foods
Water binding and viscosity building	Under specific conditions, protein molecules unfold and form a gel. The three-dimensional structure of the gel binds to 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
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
Flavor enhancement	Lactose reacts with milk proteins leading to the production of flavorful compounds. Milk powders have a mild, 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 Nutritional beverages Prepared foods

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	Enhances visual appeal, thus increasing consumer appeal Lower fat foods appeal to health-conscious consumers	Bakery Confectionery Dairy/recombined milk Nutritional beverages Prepared foods
Nutritional enrichment	Possess high-quality proteins—all essential 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 tract 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 for dietary therapy	Bakery Dairy/recombined milk Nutritional beverages Prepared foods Medical and special dietary foods

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9 Milk Powders in Bakery and Confectionery Applications

9.1 BENEFITS OF MILK POWDERS IN BAKERY AND CONFECTIONERY APPLICATIONS

Bakery and confectionery manufacturers worldwide benefit from the nutritional, functional and supply advantages of high quality U.S. milk powders which are consistently available on a year-round basis. Milk powders are valued for their wide range of functional benefits that enhance the flavor, texture, visual appeal and shelf life of baked goods and confections, while also enhancing nutrition as a source of vitamins and minerals—like calcium—and protein. Milk powders further contribute to a clean ingredient label.

When selecting a milk powder ingredient, it is not just the type of ingredient that matters (e.g., WMP vs. SMP/NDM vs. MPC) but also the product specifications. While low spore and other tight-specification powders typically used in recombined and nutritional applications can also be used in bakery/confectionery products, they are often unnecessary from a performance and/or product quality perspective and will typically add substantially to the cost. Rather, working with suppliers to ascertain the appropriate product specifications for end-use application can offer a range of more economical supply options for bakery and confectionery ingredients, improving bottom lines.

Baked Goods

Milk powders are a common ingredient in a wide array of baked goods such as cakes, cookies, pastries and crackers, as well as in dry blends used in baked product formulations. The major components in milk powders (proteins, lactose and, in the case of WMP, milkfat) affect the way in which milk powders perform and their suitability for different types of bakery applications. For example, NDM and MPCs help build body and texture in bread whereas WMP improves structure in bread by creating finer, more uniform air bubbles. Buttermilk powder has been used in specialty bakery products to provide a short texture without excessive dryness.

Chocolate Confections

Milk powders are similarly an attractive fit for chocolate confections. Selection of the appropriate milk powder ingredients can aid confectionery manufacturers in producing economically viable products with high consumer acceptance.

WMP, as well as NDM/SMP, can be utilized in both milk chocolates and milk/white chocolate-flavored compound coatings. NDM/SMP offers the advantage of a longer shelf life and is less sensitive to the development of off-flavors, thanks to the lower fat content (<1.5%). The SMP heat treatment influences the final flavor profile of the chocolate. While low-heat SMP is widely available and commonly used, SMP produced using higher heat treatments can possess some of the cooked and caramelized flavors which are desirable in milk chocolates.

Compound coating formulations do not have standards of identity (in the United States); therefore, product developers may have more flexibility in the use of dairy-based ingredients than in chocolate formulas. If milk powder is used to prepare a coating, it is typically SMP. Since the melting point of the coating fats can be tailored, there is no need to use a source of milkfat such as AMF to adjust the hardness of the finished product.

MPCs can also provide a concentrated source of protein for textural, sensory and functional properties in confectionery manufacturing, although the U.S. Food and Drug Administration does not allow MPC use in standard-of-identity chocolate. MPCs can be used as the milk solids source in the formulation of milk chocolate flavored coatings for ice cream, candy bars and other enrobing applications. Typically, lower-protein MPCs are selected for use in chocolate coatings.

Sugar Confections

Milk powders can also play a critical role in the texture, flavor and manufacturing of many sugar confectionery products, such as caramels, toffee, nougat and malted milk balls. The composition of dairy components in a caramel formulation influences the browning reaction due to varying amounts of lactose, whereas the composition of protein also plays a role in the caramelization process. The fat-containing ingredients used in the formulation of caramels also influence the texture, mouthfeel and shelf life of the finished product. While high-quality caramels can be produced using skimmed milk powder and milk protein concentrates as partial or total replacements of the milk component, care must be taken to not exceed the saturation point of the lactose.

When using MPCs, lower-protein options are typically used in caramels and toffees, while high-protein (80%–90% protein) MPCs are more suited for aerated confectionery like nougats. SMP is a good fit and often used for vacuum aerated confectionery products such as malted milk balls.

Additional benefits of milk powders are discussed in Table 1.

Table 1: Additional Benefits of Milk Powders

FUNCTION	BAKED GOODS	CONFECTIONS
Nutrition	Milk powders are a source of high-quality protein with the amino acids readily digestible and bioavailable. Whey protein—which represents 20% of the protein in milk powders—is valued for its many health-enhancing properties.	
	Milk powders are high in soluble vitamins and minerals such as calcium, phosphorus and magnesium, and can be used to fortify bakery products (100 g of SMP contains 1,300 mg of calcium).	
Emulsification	The proteins in milk powders can successfully act as oil/water interfaces to form and stabilize emulsions.	
	Good emulsification of lipids helps dough rise evenly, contributing to a good texture in breads and other baked goods.	The lecithin present in milkfat assists in stabilizing emulsions.
Gelation	Undenatured dairy proteins are able to form rigid, heat-induced, irreversible gels.	
		These gels 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 and important property in confections.
Water binding	Water-binding capacity refers to the water held in a gel under a given set of circumstances. 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.	The firm, chewy texture of several confections is related to the binding of water by casein.
Foaming	Foaming is defined as the creation and stabilization of gas bubbles in a liquid. Foaming is important in bakery and confections and is similar to the formation of an emulsion. As dairy protein concentration increases, foams become denser with more uniform air bubbles of a finer texture.	
	Foams improve the structure and texture and visual appeal of breads, cakes and muffins. The most challenging test of foaming properties in bakery applications is the ability of the protein foam to hold up and set during the baking process, as is necessary in angel food cake. To provide structure, high heat SMP is the ingredient of choice. Structure development is inversely correlated to the undenatured WPN value in SMP. The lower the WPN value, the greater the foaming functionality. High heat SMP prevents loaf volume depression in breads. Low heat SMP reduces dough extensibility and results in poor loaf volume.	The incorporation of air is important in confections such as nougat, frosting and various creams.
Browning/ color	Through the Maillard browning reaction, the lactose and protein present in milk powders accentuates color development. During heating and 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.	
	The Maillard browning reaction contributes to the golden-brown color in bakery products.	The Maillard browning reaction contributes to the caramelized color associated with many confections.
Flavor/aroma	Milk powders contribute a subtle, pleasant dairy note and aroma to baked goods and 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 bakery and confectionery products. Milkfat acts as a flavor carrier for fat-soluble ingredients and various flavors. Milkfat's low melting point ensures complete flavor release. During the baking/cooking process, the lactose present in milk powders reacts with dairy proteins leading to the production of different flavors. All in all, the understated flavor of milk powders allows other flavors to develop fully.	

9.2 BAKERY FORMULATIONS

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

Baking Powder Biscuits

INGREDIENTS	USAGE LEVEL (%)
Flour	45.60
Water	27.64
Shortening	15.00
Whey protein concentrate, 80%	**4.00**
Skimmed milk powder, low-heat	**3.94**
Baking powder	2.95
Salt	0.87
Total	**100.00**

**Formula courtesy of the Wisconsin Center for Dairy Research, University of Wisconsin-Madison*

Procedure:

1. Sift together flour, baking powder, salt and WPC 80 in a bowl.
2. Cut shortening into dry ingredients, using a pastry blender or a fork.
3. Mix SMP with cold water and add all at once to dry ingredients, mixing with a fork until evenly moist.
4. Turn onto lightly floured surface. Knead lightly about 6 times, or until ball of dough comes together.
5. Pat dough to a thickness of about 1.25 cm (0.5 inch) and cut into 6 cm (2.5 inch) diameter circles.
6. Bake on an ungreased pan in a 232 °C (450 °F) oven for 10 minutes, or until golden brown.

Muffins

INGREDIENTS	USAGE LEVEL (%)
Flour, cake	30.15
Water	23.70
Sugar	19.65
Butter, melted	**12.45**
Eggs	9.35
Skimmed 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 (2.6 oz) of batter into muffin cups.
5. Bake at 196 °C (385 °F) for 15 minutes.

Savory Cheese Scone

INGREDIENTS	USAGE LEVEL (%)
Flour, all-purpose	37.55
Water	22.85
Cheese, cheddar	**15.45**
Butter	**13.10**
Whole egg powder	4.60
Skimmed milk powder	**2.05**
Baking powder	1.90
Cheese, hard grating	**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, skimmed 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 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 (0.5 inch) thick.
7. Cut the dough into pie-shaped pieces, place 2.5 cm (1 inch) apart on baking sheet.
8. Bake at 232 °C (450 °F) for about 12 minutes or until the tops are browned. Serve hot.

Yellow Layer Cake

INGREDIENTS	USAGE LEVEL (%)
Flour, cake	27.13
Sugar, granulated	27.13
Water	17.85
Egg, liquid	13.32
Shortening	11.10
Skimmed milk powder	**2.22**
Vanilla (2x)	0.55
Salt	0.55
Baking Powder	0.15
Total	**100.00**

Procedure:

1. Lightly cream sugar, salt, skimmed milk powder and shortening.
2. Add 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.

9.3 CONFECTIONERY FORMULATIONS

The following formulas do not represent all the applications or the only potential formula for the applications. 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
Skimmed 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
Skimmed milk powder	**15.00**
Chocolate liquor	13.00
Anhydrous milkfat	**6.00**
Lecithin	0.25
Total	**100.00**

Procedure:

1. Blend skimmed milk powders, 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.

Frosting, Vanilla

INGREDIENTS	USAGE LEVEL (%)
Powdered sugar	77.00
Butter	**10.60**
Boiling water	10.25
Skimmed milk powder	**1.15**
Vanilla extract	1.00
Total	**100.00**

Procedure:

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

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

Icing, Reduced-Fat Vanilla

INGREDIENTS	USAGE LEVEL (%)
Powdered sugar	68.60
Water	14.30
Shortening	9.50
Skimmed 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 (140 °F) 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
Skimmed 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, skimmed 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.

Nougat

INGREDIENTS	USAGE LEVEL (%)
PART 1	
Malt	16.9
Water	6.9
Trehalose	5.9
Sugar, fine granulated	5.9
Lactose	**3.1**
Salt	1.0
PART 2	
Whole milk powder	**15.9**
Anhydrous milkfat (AMF)	**12.2**
Milk paste	**0.4**
PART 3	
Egg white	1.4
Sugar, fine granulated	0.8
PART 4	
Peanuts	16.9
Almonds	12.7
Total	**100.00**

Procedure:

1. Mix ingredients in Part 1 and bring to a boil of 124 °C (255 °F); add the pre-whipped egg white and fine sugar (Part 3).
2. Add ingredients from Part 2 and blend.
3. Blend into paste form and add the ingredients in Part 4.
4. Put into mold and press, cut it into blocks after coagulation. Remove from tray by rolling up dried material while still warm. Wrap the roll in plastic wrap. It will keep at room temperature for at least two months, or longer in the freezer.

10

Dairy and Recombined Milk Applications of Milk Powders

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Liquid milk has a limited shelf life due to high water activity facilitating breakdown of milk components, supporting activity of enzymes and allowing growth of microorganisms. Drying milk sufficiently reduces the water activity of the resulting powder, slowing these deterioration processes and protecting it against microbial spoilage under ambient conditions. Milk powders are essentially the preserved forms of the solid components in milk. Skimmed milk powder (SMP), as defined by the Codex Alimentarius Commission, or nonfat dry milk (NDM) as prescribed by the U.S. Food and Drug Administration, describe nonfat milk solids and whole milk powder (WMP), as defined by both jurisdictions, represent the total milk solids in a dry form. Similarly, buttermilk powder (BMP) is the total solids in sweet cream buttermilk converted into a powder. BMP is very close to SMP in composition except that it contains a higher concentration of phospholipids as compared to those in SMP. It is convenient to reconstitute these shelf-stable powders into liquid products as desired. That is, SMP into "reconstituted skimmed milk" and WMP into "reconstituted whole milk" simply by mixing the required quantity of potable water with the calculated quantity of the dry product.

Further, milkfat can be separately preserved in the form of anhydrous milkfat (AMF) (or butteroil), cream powder, frozen butter or frozen plastic cream; the first two being relatively stable at room temperature. It is a convenient industrial practice to produce a fluid milk (a "recombined milk") representing the original milk merely by blending SMP or NDM along with AMF (or any of the above mentioned, concentrated milkfat products). In this manner, SMP can be converted into reconstituted skimmed milk and combined with AMF to produce "recombined milk" as an alternative to reconstituted whole milk from WMP.

For the sake of simplicity, whether reconstituted or recombined, all products derived through blending of milk powder and water, with or without the fat component, are often termed "recombined" milk or milk products.

Liquid milk, milk products and several dairy-based formulations can be easily manufactured using SMP and AMF. Milk powders also make it possible to produce several recombined milk products from the preserved products, often without necessitating elaborate production protocols required to achieve concentration of one or more of the milk constituents, as compared to the conventional practices of manufacturing those products from fresh fluid milk. The calculated quantities of the preserved (or dried) ingredients and water can be readily blended together as required to meet the finished product composition, thus doing away with processes such as cream separation and evaporation.

Table 1: Ingredients of Recombined Milk and Products

	TYPICAL RANGE OF COMPOSITION			
INGREDIENT	**SOLIDS NONFAT**	**PROTEIN**	**FAT**	**MOISTURE**
MILK SOLIDS NONFAT				
Skimmed milk powder **Nonfat dry milk**	94%	35% 37%	1%	3-5%
Buttermilk powder	95%	35%	5%	3%
MILKFAT				
Anhydrous milkfat			99.8%	
Butteroil			99.5%	
Cream powder			40-75%	
BOTH MILK SOLIDS NONFAT & MILKFAT				
Whole milk powder			>26%	3%
Partially skimmed milk powder			2-25%	

10.1 INGREDIENT SELECTION

The flavor stability of WMP is relatively limited as compared to that of SMP under ambient storage conditions; therefore, SMP or NDM are the preferred forms of preserved nonfat milk solids, with the fat component of milk preserved as AMF or butteroil. SMP and BMP are similar in composition, but BMP is not suited alone for recombination into a fluid milk. But sometimes, use of a small quantity of BMP together with SMP helps improve the flavor perception of recombined milk.

Much of the functionality of milk powders is associated with their protein content. Since the protein content varies given the type of the powdered product, it is important to consider the protein content of the milk powder ingredient when calculating the quantity required in the formulation of the particular recombined milk product. More importantly, as discussed below, many reconstitution properties of milk powder are determined by the level of pre-heat treatment given to the milk prior to drying and the resulting degree of denaturation of whey proteins in the powder. Accordingly, the right choice of skimmed milk powder—whether low-heat, medium-heat or high-heat powder—is key to the successful application of milk powder.

Generally, wherever milk powder with relatively intact (native state) whey proteins is required, a low-heat SMP is used. Whereas, in certain other applications, a high-heat SMP will be a necessary choice when substantially denatured whey proteins are required to yield a desired attribute in a recombined product. When manufacturing recombined fluid milk and related products, use of low-heat SMP results in a better, more bland, fresh milk flavor; however, this may result in earlier off-flavor development as compared with use of a high-heat powder. This is primarily due to the presence of sulfhydryl compounds that impart an antioxidant property to the high-heat SMP.

SMP and AMF (or any other appropriate combination of SNF- and milkfat-sources) may be easily processed together into recombined milk; however, emulsifiers are sometimes useful in getting the desired emulsification of the fat in the recombined milk formulation. An example of where this is required is in fat-filled milk powder (FMP), a blend of nonfat milk solids and a vegetable fat (palm oil or coconut oil) in a powder form. It is a stable powdered product which has a long history of use in a variety of recombined milk formulations throughout many East Asian countries.

10.2 FUNCTIONALITY OF MILK POWDERS

Storage stability of the powdered milk under ambient conditions is its biggest virtue, making it possible to preserve milk solids in a relatively simple way. Additionally, as has been discussed elsewhere in this manual, milk powders have several physical properties that greatly enhance functionality in recombination and other dairy product applications. Many of these properties are attributed to the proteins present in dried milk products. Among important functional properties of milk protein are emulsification, water holding, water binding, whipping (air incorporation) and flavor binding. Depending upon the application, these properties play different roles. Other constituents of milk powder, namely lactose and minerals, add to the body of the recombined product and/or impart the desired sensory and nutritional status to the resulting product. Certain functional properties of milk powders can be manipulated during their manufacture to achieve the desired quality of the recombined milk product. The more relevant functional properties of milk powders are briefly discussed in the following paragraphs.

Reconstitution Properties

The ability of milk powders to go into solution when mixed with water is due to several characteristics of the powders such as dispersibility, wettability, sinkability and solubility. Unlike many edible-protein powders, the high solubility of milk powder without the aid of any additives is attributable to the solubility of its proteins; however, it is also appreciably influenced by conditions such as pH of the original fluid milk, the heat stability of the milk prior to drying and the intensity of heat treatment during preheating and/or drying. Reconstitution properties can be further improved in the manufacturing process by effecting “instantization” via agglomeration and/or lecithination (incorporation of lecithin, a surface-active agent), usually during drying. Although not directly associated with the reconstitution ability of milk powder, the flowability of powder is relevant to the reconstitution process. Large scale reconstitution of milk powder calls for a good free flowing characteristic for rapid, uniform and continuous in-line introduction of the powder into water. An agglomerated powder scores well on this count, although its bulk density is usually lower than a non-agglomerated powder. Similarly, the heat stability of milk powder (or the reconstituted milk) is crucial to the production of recombined sterilized milk and recombined evaporated milk which involves a high-heat treatment of the final product.

Water Binding

The ability of milk proteins and milk powder to absorb water and swell at the particle level, to a great extent, defines the reconstitution ability of milk powder and the resulting mouth-feel of the finished product. The water holding or water binding characteristics of the proteins, essentially the holding of water by the protein matrix and adsorption of water at the surface of protein particles, is also of considerable practical significance in several other dairy applications of milk powders. Casein is capable of holding a much larger amount of water (2–4 g water/g protein) as compared to whey protein (0.3–0.4 g water/g). Although whey proteins, when heat treated, generally have their water binding capacity increased due to denaturation, it may not necessarily be the case with whey proteins in skimmed milk subjected to heat treatment due to the presence of casein in that solution.

Emulsification

Casein, the major milk protein, has excellent emulsifying properties. Not only does it effectively participate in emulsification of milkfat when recombining skimmed milk powder and milkfat (in the form of AMF or butteroil, or any other fat-source product) with water, but also imparts the emulsifying capacity to powdered milk or the recombined product derived therefrom in further applications. Emulsification as well as the stability of the resulting emulsion depends on several factors such as size of the fat globules (droplets), presence of other emulsifying agents, pH and other compositional aspects of the product. In recombined milk and milk products, milk protein emulsifies milkfat in reconstituted skimmed milk, and at the same time, in conjunction with homogenization, helps stabilize the emulsion and prevent creaming.

Whipping or Foam Formation

Proteins present in milk, particularly whey proteins, have excellent foaming capacity; therefore, recombined milk and milk products are able to undergo foaming. While milk proteins help foam formation, stable foam is ensured by means of fat globule aggregates present in the air bubble lamellae. Such foam formation (or whipping) leading to an increased specific volume of the product is important in recombined whipped cream, ice cream and certain dairy desserts. Homogenized cream does not whip adequately because of difficulty in bringing about the required fat globule aggregation, but with use of suitable emulsifiers such as glycerolmonostearate, stable foam formation may be achieved.

Flavor and Flavor Binding

Properly manufactured, packaged and stored under satisfactory conditions, milk powders have a flavor very close to that of the original milk; therefore, recombined milk and dairy products have a good, though mild, flavor attributable to milk solids. However, the milkfat source, whether AMF or butteroil, must also be obtained from high-quality raw material and stored under proper conditions so as to avoid any possible off-flavor development which could otherwise be carried through into the recombined product. It is particularly important when recombined milk is consumed as liquid milk or converted into cheese where no flavoring is normally added. Nevertheless, a high-quality milkfat will only enhance the flavor status of the recombined milk and its derivatives. Milkfat not only imparts a pleasant mouthfeel and richness to the recombined product, but also acts as a vehicle for added flavoring, as many flavor compounds are fat soluble. Thus, the flavor of recombined milk allows added flavorings to blend well and be carried by the product, enhancing consumer appeal in products such as flavored milk, ice cream and desserts.

Furthermore, the tendency for proteins, particularly whey proteins such as β-lactoglobulin and bovine serum albumin (BSA), to bind flavor compounds can have implications in the amount of flavoring to be used. Also, the impact of processing, such as heat treatment, on such a protein-flavor interaction would have to be considered with respect to selection of the type of milk powder for use in recombination. For example, heat treatment of β-lactoglobulin may lead to an increased number of hydrophilic (water-attracted) binding sites on the protein molecules, but decrease the affinity for certain volatile flavor/aroma compounds. Since the nature of the protein-flavor interaction also determines the extent and sequence of release of the flavor in the mouth (during consumption), use of appropriate pre-treatment of milk before and during drying could enhance its application potential depending on the desired end result.

10.3 TYPES OF RECOMBINED MILK AND MILK PRODUCTS

As convenient preserved forms of milk solids, milk powders (and AMF) permit ready recombination into liquid milk of high quality. The liquid variants of recombined milk include pasteurized milk (usually blended with fresh pasteurized milk), sterilized flavored milk/chocolate milk and ultra high-heat (UHT) treated plain or flavored milk. Several conventional dairy products can easily be manufactured from recombined milk without any major modifications. Recombined cultured products and coagulated or curd products including cheese are among such products. Several cheese varieties have been produced using recombined milk. Depending on the type of skimmed milk powder, minor manipulations of the manufacturing protocol are sometimes desirable, such as the addition of certain salts aimed at modification of ionic equilibria in the milk. In most dairy recombination, blending of fresh milk (up to 50%) with recombined milk results in better end products.

A greater advantage can, however, be realized in producing products which conventionally require concentration of milk. Thus, manufacture of recombined sweetened condensed and evaporated milks can be accomplished by directly taking the calculated quantities of SMP, AMF and water, doing away with the evaporation step and directly formulating to the finished product concentration before proceeding with heat treatment and packaging. In a similar manner, recombined cream and cream products, as well as dairy desserts including many of the South Asian milk sweets, can successfully be obtained from milk powders. While milk powder has multiple dairy as well as other food applications, dry mixes that contain nonfat milk powder, anhydrous milkfat or butteroil and other minor ingredients are dairy product formulations which can be dry-blended, allowing the customer to conveniently reconstitute and then prepare/process the finished product. A few such formulations have been given in the last section of this chapter.

10.4 THE PROCESS OF RECOMBINING FLUID MILK

The unique feature of the recombination process is its flexibility regarding the desired composition of the finished product. The standardization step of conventional milk processing and product manufacture can be conveniently eliminated by just using the right quantities of the starting materials. Thus, it is relatively simple to have the targeted compositional characteristics in the recombined milk and its products. As stated above, the powder properties can greatly determine its suitability for use in the recombination process. For the purpose of producing recombined fluid milk, milk powder should meet certain requirements as shown in Table 2.

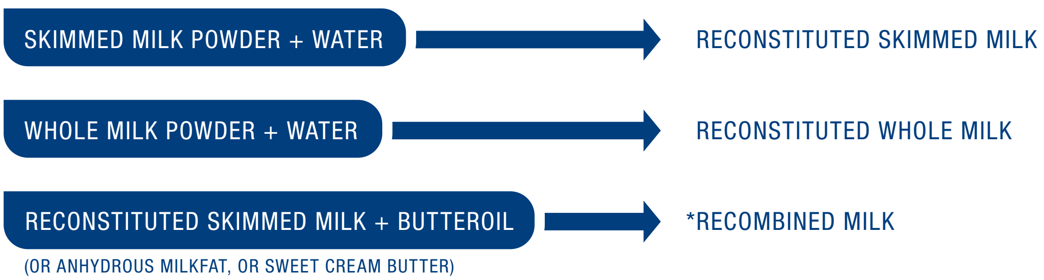
Table 2: Requirements for Milk Powder Meant for Recombined Fluid Milk

CHARACTERISTIC	REQUIREMENT
Whey Protein Nitrogen Index	> 3.5 mg/g undenatured whey protein nitrogen (that is, low-heat to low-medium-heat)
Solubility index	< 0.25 mL
Pyruvate test	< 90 mg/kg powder*
Microbial quality	Good
Sensory status	Mild, clean "milk solids" or "dairy" flavor; free from objectionable scorched particles and lumps

**The pyruvate value is indicative of the microbial count (psychrotrophic count) in the milk used for powder manufacture; a high test value suggests large quantities of thermal resistant proteases and lipases of microbial origin which can potentially cause bitterness and/or age gelation in UHT milk.*

The basic recombination process is depicted in Figure 1. The desired ingredients, namely, SMP, BMP (if desired) and butteroil (or AMF, cream powder) are weighed (for a batch process). The recombination process begins by dispersing the powder into the calculated amount of potable water. This entails dosing of the powder into a recirculation loop comprised of a tank of the required capacity, a recirculation pump, a heat exchanger of matching capacity and a powder mixing and in-line dispersing device attached to a powder-feeding hopper.

Figure 10.1
Basic Recombination Process



** Or, recombined reduced-fat milk, recombined cream or recombined concentrated milk depending on the relative quantities of SMP, water and anhydrous milkfat used.*

Since milk powder particles are porous, they introduce an appreciable amount of air into the reconstituted milk and, therefore, it is necessary to de-gas the milk preferably before mixing it with butterfat and processing further. Special devices are available to not only permit introduction of milk powder with minimum amount of air but also to de-gas the liquid through vacuumization during the reconstitution process. Examples of such equipment include the Tetra Almix Batch Vacuum mixer and Almix I200-200 In-line mixer. De-aeration is necessary not only for minimizing excessive foaming in the tank but also for a normal operation of the homogenizer.

Lactose and most of the milk salts in milk powder are quickly dissolved in water; however, milk protein particles, particularly casein micelles, are in a largely dehydrated state in powder. Even after their dispersion in water during reconstitution, a certain minimum contact time is necessary to permit complete rehydration of these particles. The recommended rehydration time is a minimum half an hour before homogenization, but a more complete rehydration is achieved when holding the milk overnight at refrigerated temperature. Thorough rehydration helps eliminate a possible chalky or powdery mouthfeel in the milk.

Passing the milk through an in-line strainer would remove powder particles that are not completely hydrated.

Introduction of milkfat in the form of cream powder can be simultaneous with the SMP reconstitution process. However, AMF, butteroil or frozen cream would need to be melted before being added to the reconstituted skimmed milk. Also, the melted fat product needs to be dispersed into a sufficiently fine form so as to form a pre-emulsion that would allow the mixture to flow uniformly into the downstream homogenizer where final emulsification takes place. Single-stage homogenization is adequate for recombined fluid milk. However, if the concentration of fat in the recombined product is higher than normal (particularly when the fat:SNF ratio exceeds 0.70) two-stage homogenization becomes necessary in order to prevent creaming; the second stage, low-pressure treatment breaks the aggregates of fine fat globules formed upon first-stage homogenization of the high-fat milk, which would otherwise lead to rapid fat separation. If an emulsifier is required, it will usually be added to the melted fat before mixing the latter with reconstituted skimmed milk. While converting a full cream milk powder (that is, WMP) into fluid milk entails dispersion of the powder in water, it would be necessary to employ homogenization in order to achieve the desired fat emulsification.

The final heat treatment of recombined milk may be conventional pasteurization giving a shelf life similar to that of fresh pasteurized milk, which is 10–21 days under refrigeration; however, UHT treatment brings about inactivation of all microorganisms as well as spoilage enzymes in the milk. When post-heating contaminants that may enter during the packaging process or through the packaging material are kept very low in number, this product will have an extended shelf life of up to 3–8 weeks when held below 5 °C (41 °F). The heat-treated milk is cooled to 5 °C (41 °F) or lower in either case.

UHT treatment coupled with aseptic packaging significantly reduces the possibility of the presence of microbes (vegetative or spores) in the milk and thereby renders the latter stable under ambient conditions. The major advantage of such a treatment as compared to the conventional (in-container) sterilization of milk is that nutritional losses in terms of destruction of certain water-soluble vitamins such as thiamine and essential amino acids such as lysine, and the development of off-flavors are all minimized. UHT milk also has a better appearance due to minimized browning caused by the heat treatment. Thus, the resulting milk is closer to fresh pasteurized milk in its nutritive value and sensory appeal.

UHT heating by means of direct steam injection could give a nutritionally and organoleptically better product because of a more immediate temperature increase and decrease, thereby reducing the total heat load while still applying a compliant sterilizing treatment as compared to indirectly applied heating. However, the latter process is relatively less complicated to run and requires less stringent process control. UHT processing and aseptic packaging often necessitates an aseptic buffer tank between the processing and packaging units as the working capacities of the two may not always match with each other; therefore, it typically incurs a higher cost of capital investment for equipment.

Conventional sterilization (retort sterilization) of recombined milk involves a heat treatment range of 110 °C (212 °F)/20 min to 120 °C (248 °F)/10 min in the container. Although it is more effective than UHT treatment in destroying heat resistant enzymes and preventing age gelation (thickening during storage), the sensory attributes of the product as well as nutritional quality are adversely affected; and it tends to undergo rapid browning and stale flavor development during ambient storage. However, special milks such as flavored or chocolate milk can successfully be produced using either of the two sterilization processes. A hybrid process combining partial continuous-flow UHT treatment and in-bottle final sterilization has been claimed to offer the advantages of both retort and UHT processes.

10.5 RECOMBINED MILK PRODUCTS

Recombined Cheese and Cultured Milk Products

Several cultured milk products conventionally involve use of a higher than normal milk solids level and a relatively intense heat treatment prior to incubation with the desired starter organisms. The higher solids content contributes to the desired body and texture characteristics of the product and the high-heat treatment produces certain protein degradation products that are known to favor culture growth. Denatured whey proteins increase the water binding in the fermented products and enhance their viscosity and consistency characteristics. Recombined milk, particularly the one made out of high-heat milk powder, would therefore be typically suitable for this purpose. Flavored yogurt, both set-style and stirred type, can be produced from recombined milk. In the case of cheese, the relatively weak curd obtained from recombined milk is especially suited for certain soft, high-moisture varieties having a tender body and mild acid or bland flavor whereas, for semi-hard and hard varieties, use of a slightly higher solids level in the recombined milk, with or without appropriate additives, would help enhance the curd strength and obtain a good quality product.

Requirements for SMP

Low-heat SMP has much of its whey protein in the native (not denatured) state and there is little interaction between whey protein and casein; hence, recombined milk from low-heat powder has a good rennetability and the resulting curd has normal strength. On the other hand, high-heat powder represents a considerable interaction between the two proteins, and the resulting κ-casein - β-lactoglobulin complex impairs the rennetability of the milk leading to a weak curd with retarded syneresis. Additives such as calcium chloride and acid calcium phosphate (or, mono-calcium phosphate) help restore the rennetability to a considerable extent and appreciably improve the curd forming characteristics. Several cheese varieties native to some Mediterranean, Middle Eastern and North African countries have been obtained from recombined milk. These include Feta, Domiati, Kashkaval and Haloumi. Cottage cheese, a fresh cheese variety popular in Europe and North America, can also be manufactured from recombined milk. Good quality Paneer, a high-moisture, fresh variety cheese of South Asia has been manufactured from recombined milk with the addition of a source of ionic calcium which contributes to a firm coagulum.

Table 3: Milk Powder Requirements for Cheese and Yogurt

POWDER PARTICULARS	REQUIREMENT
WPNI for cheese	> 4.5 mg, preferably > 6.0 mg, undenatured whey protein nitrogen/g powder (low-heat)
Heat No. for cheese*	< 80
Thiol No. for cheese**	< 7.5
WPNI for yogurt	3.0 or less undenatured whey protein nitrogen/g powder (medium- and high-heat)
Rennetability	Good
Culture growth	Normal; free from inhibitory substances

** Indicative of precipitability of whey protein along with casein*
*** Indicative of unfolding of whey protein as result of denaturation*

Cheese prepared from recombined milk (9% SNF and 3.5% fat) gives cheese with better moisture retention and overall quality; however, in recent times the modified process involving membrane separations and remixing has been extensively used because of greater yield. According to this approach, microfiltered recombined milk (15% total solids) is subjected to ultrafiltration (UF) and the resulting UF permeate (carrying whey protein) is concentrated by means of reverse osmosis (RO), and then the RO retentate is mixed, and then the RO retentate is mixed with the UF retentate to obtain what is known as cheese pre-mix, which is then converted into cheese.

Recombined Evaporated Milk

Evaporated milk is a shelf-stable concentrated milk product without any preservative added to it. While production of SMP and AMF are a means for preserving total milk solids for later use, recombined evaporated milk preserves those same milk solids while offering functionality for the consumer not easily gained using SMP and AMF directly. For example, evaporated milk is a liquid product which is more convenient to use in many domestic applications such as coffee whitening, baking and so on. Also, the state of the fat (finely dispersed globules) in evaporated milk makes the recombined product particularly preferable to SMP or WMP.

Evaporated milk (or, a blend of evaporated skimmed milk and vegetable fat), typically containing 7.6% fat and 17.7% nonfat solids, has a creamy consistency and smooth texture. It owes its storage stability to the in-can thermal sterilization involved in its production. Retort sterilization of concentrated milk is, therefore, a critical step in the manufacturing process for evaporated milk primarily due to the tendency toward heat destabilization of colloidal casein micelles leading to undesirable coagulation. Therefore, the process needs to be properly controlled. The challenge is even greater when producing the recombined product. Several factors such as feed of dairy animals, developed acidity of milk, pre-heat treatment of the milk, degree of concentration, homogenization of the concentrate and use of stabilizing salts affect the physical stability of the product during sterilization. Proper control of these variables can yield a high quality evaporated milk. However, there is a limited scope for process manipulation in production of recombined evaporated milk. The major determinant is the quality of the SMP used as the starting material. High-heat SMP (WPNI < 1.5 mg/g powder) giving a concentrate base with adequate heat stability (a 20 % dispersion with the addition of disodium phosphate withstanding heating at 120 °C [248 °F] for not less than 20 min) is considered suitable.

The Recombined Evaporated Milk Process

Skimmed milk powder is added via a hopper into water at 40–45 °C (104–113 °F) and the mixture is vigorously agitated. Foaming should be kept to a minimum. The mix is hydrated for 20–30 minutes or overnight at 4 °C (39 °F). The milk is then heated to 60–65 °C (140–149 °F), subjected to de-aeration and melted fat at a similar temperature is added in the presence of brisk agitation. The resulting coarse emulsion is homogenized at 50–70 °C (122–158 °F) and pressures of 20 MPa first stage and 3.5 MPa second stage. Sodium citrate (potassium citrate), disodium (or dipotassium) orthophosphate or monosodium (or monopotassium) orthophosphate may be normally added to stabilize casein during subsequent heat sterilization. Running a pilot sterilization test is helpful in determining the type and quantity of the stabilizing salt to be used. After canning, the product is sterilized, normally in the range of 116 °C (241 °F) for 15 minutes to 120 °C (248 °F) for 12 minutes followed by cooling to 32–35 °C (90–95 °F). Continuous rotary retorts are effective in handling large-scale sterilization of evaporated milk in cans.

Sweet cream buttermilk powder at 4–5% appreciably improves the heat stability of the product. It can, therefore, be used for part replacement of the SMP in recombined evaporated milk. Sometimes added as a stabilizer, carrageenan is incorporated into the product during reconstitution of the skimmed milk powder. It reduces fat separation during storage. Also, the product is often fortified with vitamins A and D prior to homogenization.

Recombined Sweetened Condensed Milk

Sweetened condensed milk contains, on an average, 8.1% fat, 20.2% SNF and 45.2% sugar. A corresponding "sugar ratio" (that is, concentration of sugar in the solution of sugar plus water in the product) of 63 generates sufficiently high osmotic pressure to adequately protect it against microbial spoilage. Sweetened condensed milk is thus a form of milk solids preserved by means of sugar; therefore, transforming milk powder, also preserved milk solids, into sweetened condensed milk through recombination serves to provide milk solids in a form whereby they can easily be put to the desired application such as in baking, in confectionery and chocolates and as a tea and coffee whitener. Recombined sweetened condensed milk is typically made using milkfat together with SMP; however, in some Asian countries, it is often made using vegetable oil/fat such as palm or coconut oil instead of milkfat, and the product is called recombined sweetened condensed filled milk. Just like conventional 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 but not heat sterilized; instead, added sugar helps extend its shelf life.

The Recombined Sweetened Condensed Milk Process

Employing a mixing tank with a recirculation loop provided with static mixer and in-line heat exchanger, the calculated quantity of skimmed milk powder (medium- to-low-heat) is dissolved in water at about 40 °C (104 °F). The resulting reconstituted skimmed milk concentrate is heated to about 60 °C (140 °F), de-aerated and added with melted fat and sugar. The mixture is passed through a strainer and followed by homogenization at 2–3.5 MPa (for a low viscosity product) or up to 7 MPa (for higher viscosity), and then heated in the range of 80 °C (176 °F) for two minutes to 90 °C (194 °F) for 30 seconds before cooling in a tubular heat exchanger or flash-cooling in a vacuum pan to 32 °C (90 °F). Heat-sterilized, finely ground lactose monohydrate is added as "seed" material to promote lactose crystallization while the product is constantly stirred for at least one hour. It is finally cooled to 16 °C (60 °F) or below before canning aseptically.

Recombined Cream

Milkfat can be incorporated into reconstituted skimmed milk in such proportion that a dairy cream with the desired fat content is obtained. Use of buttermilk powder can help improve the product quality. A low-pressure homogenization together with additives, such as emulsifiers, is generally used to produce recombined cream meant for different purposes. Addition of proteose-peptone, a protein-based emulsifier of milk origin, can be resorted to for preparing cream entirely of dairy origin. Both whipping cream and whipped cream have been manufactured by recombining skimmed milk solids and milkfat, and using suitable additives including stabilizers and emulsifiers. A 30%-fat level in recombined cream can serve several purposes which include the production of UHT cream and cream cheese. In the case of whipping cream, the product must allow formation of stable aggregates or clusters of partially destabilized fat globules, however UHT processing necessitates that the milkfat emulsion is sufficiently stable to withstand the high-heat treatment. To meet both requirements, a UHT treated recombined whipping cream (35% fat) could be obtained by using butteroil, SMP (7.5%) and glycerol mono-stearate (0.1%) and employing low-temperature 48 °C (118 °F) homogenization in two stages, first at 1.4–2.1 MPa and the second at 0.7 MPa.

Recombined Butter

Unlike most other dairy products, butter, comprised of 80% or more milkfat, is a water-in-oil emulsion. Recombination involves dispersing 14–15% of a 6–7% nonfat milk solids solution into melted milkfat (nonfat milk solids in final butter of about 1%) followed by cooling and crystallization in a specialized multi-stage scraped-surface heat exchanger. Butteroil or AMF is the principal form of milkfat. Recently, Ghee, the Indian counterpart of butteroil, has also been used in production of recombined butter. Other ingredients may include table salt, color and emulsifiers.

10.6 RECOMBINED PRODUCT FORMULATIONS USING MILK POWDERS

Chocolate Drink

INGREDIENTS	USAGE LEVEL (%)
Fructose and sucrose	24.60
Skimmed 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/minerals mix	0.80
Total	**100.00**

Procedure:

1. Disperse cellulose gum in water using high-speed agitation. Allow to hydrate for approximately 15 minutes.
2. Gradually add a dry blend of skimmed milk powder, sugar and cocoa. Mix well. (Avoid air incorporation.)
3. Pasteurize, homogenize and package.
4. Keep refrigerated during transfer, storage and distribution.

Pasteurized Processed Cheese Food

INGREDIENTS	USAGE LEVEL (%)
Cheddar cheese	**65.85**
Water	19.50
Skimmed 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 grind natural cheese in an extrusion-type grinder with perforations of about 5-millimeter diameter.
2. Blend the ground cheese with color, sorbic acid and cream in an industrial mixer.
3. Add 1/3 of the water to the blender and mix thoroughly.
4. Prepare a slurry of dry sweet whey and skimmed milk powder with 1/3 water.
5. Transfer the homogeneous 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/skimmed milk powder slurry. Continue agitation.
7. Heat sufficiently to about 82 °C (180 °F) to ensure pasteurization.
8. When the all the visible free fat is absorbed back into the cheese mass being processed and the latter acquires a creamy consistency, transfer the molten cheese food to hopper of the packaging machine. Allow the hot packs to cool.
9. Keep refrigerated during transfer, storage and distribution.

Yogurt (Low-Fat, Stirred)

INGREDIENTS	USAGE LEVEL (%)
Milk, skimmed	**75.46**
Milk, 1% fat	**18.87**
Cream, 40% fat	**2.98**
Skimmed milk powder	**1.99**
Starch	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 and incubate until a pH of 4.20–4.65 is attained.
4. Cool the product to below 15 °C (59 °F) and package.
5. Keep refrigerated during transfer, storage and distribution.

Yogurt Drink

INGREDIENTS	USAGE LEVEL (%)
Water	89.60
Skimmed milk powder	**6.24**
Lactose	**2.28**
Whey protein concentrate, 80%	**1.88**
Culture	As needed
Sweetener	As needed
Total	**100.00**

Procedure:

1. Combine all dry ingredients and disperse the mixture into water.
2. Heat the mixture to 82 °C (180 °F) and hold for 15 minutes. Cool it to 36 °C (97 °F).
3. Inoculate with culture. Incubate for 6 hours, or until a pH of 4.25–4.35 is reached.
4. Cool to 7 °C (45 °F).
5. Sweeten with sweetener of choice to desired sweetness level.
6. Keep refrigerated during transfer, storage and distribution.

Ice Cream (Soft Serve, Dry Mix)

INGREDIENTS	USAGE LEVEL (%)
Skimmed milk powder	**44.82**
Sugar, granulated	29.88
Corn 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:

Dry mix:

1. Blend all ingredients. Package and store.

Soft serve:

1. Mix 30 g of the dry blend into 5.7 liters of cold water using rapid agitation.
2. Allow the mixture to hydrate for 10–20 minutes. Stir.
3. Pour it into soft-serve machine.
4. Freeze the mix and serve at or below -10 °C (14 °F).
5. Keep refrigerated during transfer, storage and distribution.

Ice Cream (Hard Pack)

INGREDIENTS	USAGE LEVEL (%)
Water	45.85
Cream, 40% fat	**25.00**
Sugar, granulated	16.00
Skimmed 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 re-standardize if necessary.
3. Pasteurize the mix at 82 °C (180 °F) for 23 seconds.
4. Homogenize in two stages: 14.1 MPa in the first 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 rapidly in an ice cream freezer to a discharge temperature of -6 to -7 °C (21–19 °F).
9. Optionally, add particulate materials or syrups through a fruit feeder.
10. Finally, 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.
11. Keep refrigerated during transfer, storage and distribution.

Ice Cream (Hard Pack, Premium)

INGREDIENTS	USAGE LEVEL (%)
Cream, 40% fat	**45.00**
Water	31.10
Sugar, granulated	17.85
Skimmed 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 re-standardize if necessary.
3. Pasteurize the mix 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 and then 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.
11. Keep refrigerated during transfer, storage and distribution.

Ice Cream (Low-Fat)

INGREDIENTS	USAGE LEVEL (%)
Whole milk	**55.00**
Water	18.30
Sugar, granulated	10.00
Skimmed 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 the mix 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 the mix at 0–4 °C (32–39 °F) overnight.
5. Freeze the aged mix into ice cream.
6. Package the product and transfer the same to hardening.
7. Keep refrigerated during transfer, storage and distribution.

Ice Cream (Nonfat)

INGREDIENTS	USAGE LEVEL (%)
Skimmed milk	**75.30**
Sugar, granulated	10.00
Skimmed milk powder	**6.00**
Whey protein concentrate, 80%	**4.00**
Sweetener syrup solids	4.00
Stabilizers	0.70
Total	**100.00**

Procedure:

1. Mix dry ingredients into milk with a powder horn.
2. Pasteurize the mix 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 the mix at 0–4 °C (32–39 °F) overnight.
5. Freeze the mix, package the product and transfer it to a hardening chamber.
6. Keep refrigerated during transfer, storage and distribution.

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11 Nutritional Food and Beverage Applications for Milk Powders and Dairy Ingredients

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Improving health and wellness by healthy eating habits has been a major global trend over the past couple of decades. Consumer awareness about the health and nutritional benefits of the food and beverages they consume is playing a key role in driving demand for better-for-you products. The global demand for the nutritional food and beverage category is continuously rising and, as a result, thousands of new products are being launched every year.

The global food and beverage category with the highest growth over the last decade is sports, meal replacement and nutritional beverages. Milk powders as well as dairy protein ingredients such as MPC, MPI, MCC and other tailor-made ingredients are commonly used either as ready-to-drink or powdered nutritional beverage mix formulations. These ingredients are authentic, trusted food ingredients and are ideal for a wide range of nutritional and functional applications. They are important sources of high quality milk proteins and valuable minerals such as calcium, phosphorus, potassium, zinc and magnesium. In addition, purchasers are assured of a consistent, year-round supply of U.S. milk powders.

The information included in this chapter is intended to support product developers and prepared food manufacturers in the selection and optimization of dairy ingredients by providing general characteristics, practical tips and selected examples of formulations.

11.1 FUNCTIONAL AND NUTRITIONAL BENEFITS OF MILK POWDERS AND DAIRY PROTEIN INGREDIENTS

Traditionally, many foods and beverages, especially nutritional and meal replacement beverages, have been formulated using sodium and calcium caseinates; however, in recent years, evolving consumer interests are driving the demand for tailor-made, value-added, functional and nutritional dairy ingredients that are suitable for specific food and beverage applications.

High protein ingredients such as MPC, MPI and MCC are gaining wide popularity for flavor and functionality. They are versatile ingredients that can provide protein enhancement and clean dairy flavor without adding a significant level of lactose to food and beverage formulations. During their manufacture, they can be tailored to optimize specific functional properties. For example, research has focused on improving heat stability and emulsification properties.

In addition to their use across many food applications, MPC, MPI and MCC with greater than 80% protein are used in nutritional beverages such as high protein nutritional/dietetic formulations, meal replacement, clinical and enteral beverage formulations, products for weight management and for healthy aging, powdered dietary supplements and sports nutrition products.

Depending on the finished product requirements and the needs of the consumer, either ingredients based on complete milk proteins (such as milk powders, MPC or MPI) or MCC can be used. The selection of these ingredients may also be influenced by requirements for color and flavor, nutritional content, formulation pH, type of heat treatment (e.g., pasteurization, retort or UHT) and desired length of shelf life.

The functional properties of milk powders and proteins are illustrated in greater detail in Chapter 8.

In addition to functional benefits, recent clinical studies have generated new knowledge about potential health benefits of consuming milk and milk products. Casein and whey proteins are classified as high quality proteins based on amino acid composition, digestibility and bioavailability. They contain a relatively high proportion of essential amino acids scoring higher than nearly all other protein sources across a wide range of assessment methods including the PDCAAS and DIAAS methods. Several published reports are available in the literature around specific health benefits and nutrition aspects of dairy proteins.

During their manufacture, dairy ingredients can also be tailored or improved by using different processing conditions such as pre-heat treatment of milk. For example, altering the heat treatment during manufacture of SMP or NDM will change the Whey Protein Nitrogen Index (WPNI), which represents the percent of whey protein denaturation. This impacts the functional properties of the powder. The severity of the pre-heat treatment used will determine the WPNI value and heat classifications (e.g., high-heat, medium-heat and low-heat) as shown in Table 1.

Table 1: Heat Classifications and Associated Functionality of SMP and NDM in Foods and Beverages

SMP AND NDM HEAT CLASSIFICATION	WHEY PROTEIN NITROGEN INDEX (MG/G OF POWDER)	EXAMPLES OF FUNCTIONALITY IN THE FINAL PRODUCT AND RECOMMENDED USES
High-heat	More than 6.0	• Prevents loaf volume depression in bakery products • Used when high moisture-absorbing quality is desirable (e.g., in meat, confectionery, bakery, soups, sauces, prepared foods)
Medium-heat	1.51–5.99	• Used in ice cream and frozen desserts, dry mixes, confections and other applications in which water absorption and flavor are important (e.g., prepared mixes, meat products)
Low-heat	Below 1.50	• Possesses optimum sensory qualities • Ideal for use in dairy products and beverages • Most common source of instant SMP and NDM Applications include fortification of fluid milk and manufacture of cottage cheese, cultured skimmed milk, starter cultures, chocolate milk and ice cream

11.2 NUTRITIONAL FOOD AND BEVERAGE FORMULATIONS

The following food and beverage formulation examples are intended to support product developers in the selection and optimization of dairy ingredients. These formulations serve only as examples and do not represent all possibilities; therefore, product developers are encouraged to modify formulas to meet the processing and finished product specification needs of their organization as well as to satisfy market demand.

All product formulations included in the following section are available at ThinkUSAdairy.org.

French Vanilla Meal Replacement Beverage

INGREDIENTS	USAGE LEVEL (%)
Skimmed milk	**91.37**
Granulated sugar	4.57
Cream	**2.28**
Milk protein concentrate, 85% (MPC 85)	**0.46**
Hamulsion BRCDR*	0.78
Vanilla	0.38
Hamulbac XMU**	0.16
Total	**100.00**

Developed at the Wisconsin Center for Dairy Research, University of Wisconsin-Madison

**G.C. Hahn-MPC, monoglyceride, diglyceride, tetrasodium pyrophosphate, carrageenan, glucose **G.C. Hahn-tetrasodium pyrophosphate, glucose*

Procedure:

1. Disperse all dried ingredients into 60 °C (140 °F) water under high shear.
2. Adjust the pH to pH 7.0–7.1 by adding Hamulbac XMU.
3. Hydrate for 1 hour and maintain the pH to 7.0–7.1.
4. Heat to 85 °C (185 °F).
5. Homogenize at 3,600/700 psi.
6. Cool to 25 °C (77 °F).
7. Bottle and retort with rotation at 10 rpm at 121 °C (250 °F) for 4 to 5 minutes.

Café Mocha

INGREDIENTS	USAGE LEVEL (%)
Water	92.26
Milk protein concentrate, 85% (MPC 85)	**4.52**
Sugar, white, granulated	1.54
Autocrat Columbian Freeze Dried Coffee	0.77
Vanilla powder	0.09
Salt, table	0.04
Barry Callebaut Cocoa processed with alkali	0.77
Stevia	0.01
Total	**100.00**

Developed at the Dairy Products Technology Center, California Polytechnic State University

Procedure:

1. Combine all dry ingredients (milk protein concentrate, sugar, coffee, salt, cocoa and Stevia).
2. Mix 20 g of dry milk with 8 fluid ounces of hot water.
3. Mix well.

Chai Tea Latte

INGREDIENTS	USAGE LEVEL (%)
Water	87.27
Sugar	6.14
Milk protein concentrate, 85% (MPC 85)	**4.34**
Natural Black Tea Powder #23863 Virginia Dare TE48	2.05
Cinnamon, ground	0.07
Cardamom, ground	0.06
Cloves, ground	0.03
Ginger, ground	0.03
Nutmeg, ground	0.01
Total	**100.00**

Developed at the Wisconsin Center for Dairy Research, University of Wisconsin-Madison

Procedure:

1. Combine all dry ingredients (sugar, milk protein concentrate, black tea powder and spices).
2. Mix 33 g of dry mix with 8 fluid ounces of hot or cold water.
3. Mix well.
4. Enjoy. Pour over ice if desired.

Chocolate Nutritional Beverage Dry Mix

INGREDIENTS	BAKER'S (%)	USAGE LEVEL (%)
Milk protein concentrate, 85% (MPC 85)	**83.00**	**40.36**
Fructose	40.00	19.44
Whey protein concentrate, 34% (WPC 34)	**38.44**	**18.68**
Dutch cocoa powder, 10–12% fat	16.00	7.78
Oat bran	11.36	5.52
Guar gum	6.08	2.95
Rice bran, fine grind	6.08	2.95
Vitamin/mineral premix	2.34	1.14
Vanilla cream flavor	2.00	0.97
Malt flavor	0.30	0.15
Aspartame	0.12	0.06
Total		**100.00**

Developed at the Dairy Products Technology Center, California Polytechnic State University

Preparation:

1. Weigh all ingredients into a bowl and dry blend to completely mix.
2. Store in air-tight container until use.

To Prepare:

1. Add 30 g (1 oz) of dry mix to 250 mL (8.5 oz) glass of skimmed milk.
2. Stir or shake to completely suspend.
3. For a thicker consistency, allow beverage to stand at 4 °C (39 °F) for 1 hour.
4. Serve cold.

Cucumber Lemon Yogurt Drink

INGREDIENTS	USAGE LEVEL (%)
Reduced fat milk	**90.21**
Milk permeate (dried)	**6.49**
Nonfat dry milk	**0.92**
Cucumber puree	2.20
Natural lemon flavor	0.15
Yogurt culture (CHR Hansen YCX11)	0.02
Probiotics (CHR Hansen F-DVSABC)	0.01
Total	**100%**

Developed at the Wisconsin Center for Dairy Research, University of Wisconsin-Madison

Procedure:

1. Blend permeate and nonfat dry milk into milk with high-speed mixer. Allow to hydrate for 30 minutes.
2. Warm mix to 60 °C (140 °F) and homogenize at 2,500/700 psi.
3. Pasteurize mix at 85 °C (185 °F) for 30 minutes.
4. Cool to 42°C (108°F).
5. Inoculate with culture and add probiotics.
6. Incubate at 42 °C (108 °F) for 4 to 5 hours until pH reaches 4.2.
7. Mix in cucumber puree and lemon flavor.
8. Cool to 4 °C (39 °F) and store at refrigeration temperatures.

Breakfast Bites

INGREDIENTS	USAGE LEVEL (%)
Dough formula (84 g)	***(62.64)***
Bread flour	19.60
Water	14.03
Whole wheat flour	4.60
Milk protein concentrate, 80% (MPC 80)	**3.80**
Unsalted butter	**3.39**
Clover honey	3.07
Egg substitute (Original Egg Beaters®, ConAgra Foods)	2.94
Nonfat dry milk powder	**2.51**
Soluble fiber (5 g) (ADM/Matsutani, Fibersol®-2)	2.51
Rolled oats	2.14
Whey permeate	**1.94**
Whey protein concentrate, 80% (WPC 80)	**1.66**
Yeast, dry active	0.45
Filling Formula (50.1 g)	***(37.36)***
IQF frozen scrambled eggs (Michael's Foods)	17.44
Medium cheddar cheese, shredded	**17.44**
Diced yellow onion	0.95
Diced green bell peppers	0.76
Romano cheese, shredded	0.71
Black pepper	0.06
Total	**100.00 %**

Developed at the Wisconsin Center for Dairy Research, University of Wisconsin-Madison

Procedure:

Filling

1. Blend IQF frozen scrambled eggs, diced yellow onion and green bell pepper, cheddar and Romano cheeses and black pepper uniformly.

2. Weigh 18 g of filling per piece.

Dough

1. Blend the MPC 80, nonfat dry milk powder, whey permeate, WPC 80 and water together. Allow to hydrate for 30 minutes.

2. Dry blend bread flour, whole wheat flour, oats, Fibersol-2 and yeast.

3. Melt butter.

4. Heat the hydrated dairy ingredients to 43 °C (110 °F).

5. Combine egg substitute, honey and melted butter. Add to dry ingredients and mix at low speed with a dough hook for 12 minutes.

6. Allow dough to proof so it doubles in size (about 1 hour at 41 °C/106 °F).

7. Form 30 g balls of dough.

Assembly

1. Roll out 30 g of dough to about 1/4 inch thickness.

2. Place approximately 18 g of filling on the dough layer.

3. Completely enclose filling to keep cheese in the dough during baking.

4. Bake at 204 °C (400 °F) on parchment-covered baking sheets for approximately 12 minutes. Adjust time as necessary based on product size.

Strawberry Sunrise Waffle

INGREDIENTS	USAGE LEVEL (%)
Yogurt Waffle Formula (100 g)	***(98.75)***
Nonfat plain Greek yogurt	**22.50**
Water	18.42
Egg liquid	12.00
Cake flour	11.45
Whole wheat flour	11.45
Granulated sugar	6.25
Whey protein concentrate, 80% (WPC 80)	**4.60**
Nonfat dry milk	**4.60**
Butter, unsalted	**4.60**
Milk calcium and minerals	1.65
Baking powder	0.75
Salt	0.29
Vanilla extract (Virginia Dare)	0.17
Cinnamon	0.02
Yogurt Sauce Formula (optional), 15 g	***(1.25)***
Strawberry syrup	0.75
Fresh strawberry, chopped	0.20
Nonfat plain Greek yogurt	**0.20**
Granulated sugar	0.10
Total	**100.00**

Developed at Dairy Product Technology Center, California Polytechnic State University

Procedure:

Waffle

1. Hydrate whey protein concentrate and nonfat dry milk with 100% of the water with constant agitation for 30 minutes. Add milk calcium and minerals after 30 minutes and hydrate another 20 minutes.

2. Mix dry ingredients.

3. Mix wet ingredients, including hydrated dairy powders, and mix in the yogurt.

4. Slowly mix the dry ingredients into the wet ingredients.

5. Mix batter for 5 minutes with a high-speed mixer.

6. Preheat waffle iron at a medium to low setting.

7. Spray waffle iron with nonstick spray and pour 200 g of batter on waffle iron.

8. Cook until golden brown and serve warm with 15 g of yogurt sauce with strawberries.

Yogurt Sauce with Strawberries

1. Mix sugar into syrup. Let sugar dissolve into syrup for 5 minutes.

2. Add yogurt to syrup and sugar. Mix with a high-speed mixer for 5 minutes.

3. Heat on low temperature while stirring, only long enough to slightly warm sauce.

4. Add fresh chopped strawberries and serve 15 g with the waffle.

Chocolate Pudding

INGREDIENTS	USAGE LEVEL (%)
Water	66.75
Sugar	15.00
Skimmed milk powder	**12.40**
Modified starch	3.00
Cocoa powder	2.75
Salt	0.10
Total	**100.00**

Procedure:

1. Blend all ingredients.

2. Heat the mixture to 82 °C (180 °F).

3. Cool.

Yogurt Drink

INGREDIENTS	USAGE LEVEL (%)
Water	89.60
Skimmed milk powder	**6.24**
Lactose	**2.28**
Whey protein concentrate, 80% (WPC 80)	**1.88**
Culture	As needed
Sweetener	As needed
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 to desired level with sweetener of choice.

6. Store refrigerated.

Bread Pudding for the Ages

INGREDIENTS	USAGE LEVEL (%)
Pudding Formula (100 g)	***(98.20)***
Water	36.20
Sweet potato	10.80
Sugar, light brown	10.80
Eggs, liquid	5.40
Figs	5.40
French bread	5.35
Bread, whole wheat	5.35
Butter, unsalted	**4.95**
Milk protein concentrate, 80% (MPC 80)	**4.05**
Maple syrup	3.15
Prunes	2.25
Milk calcium and minerals	1.40
Flaxseed, Golden Ultra Fine Milled (Glanbia Nutritionals)	1.36
Vanilla extract (Virginia Dare)	0.50
Baking powder	0.38
Whey permeate (dairy product solids)	**0.20**
Natural caramel flavor (Gold Coast Ingredients)	0.18
Salt	0.18
Nutmeg	0.15
Cinnamon	0.15
Oat Topping Formula (10 g)	***(0.90)***
Oats	0.71
Whey crisps, crushed	**0.12**
Sugar, light brown	0.06
Cinnamon	0.01
Yogurt Bourbon Sauce Formula (10 g)	***(0.899)***
Nonfat plain Greek yogurt	**0.580**
Powdered sugar	0.290
Nonfat dry milk	**0.020**
Natural bourbon flavor (Gold Coast Ingredients)	0.007
Cinnamon	0.001
Nutmeg	0.001

Developed at the Dairy Products Technology Center, California Polytechnic State University

Procedure:

Oat Topping

1. Crush whey crisps until fine pieces are formed.
2. Mix whey crisps with oats, cinnamon and brown sugar.
3. Serve 10 g portions on top of each bread pudding.

Yogurt Bourbon Sauce

1. Mix nonfat dry milk and powdered sugar into yogurt with a high-speed mixer for 5 minutes.
2. Add nutmeg, cinnamon and bourbon flavor. Warm on low heat.
3. Serve 10 g portions on top of each bread pudding.

Pudding

1. Preheat oven to 204 °C (400 °F).
2. Chop whole wheat and French bread into 1/4-inch squares, and toast in oven until golden brown (about 10 minutes, depending on batch size).
3. Hydrate MPC for 30 minutes with 100% of the water. Add milk calcium and minerals after 30 minutes and hydrate another 20 minutes.
4. Chop figs, sweet potatoes and prunes, and put to the side.
5. Mix dry ingredients, including permeate.
6. Mix flavors into wet ingredients, hydrated dairy powders and egg.
7. Slowly mix dry ingredients into wet ingredients. Mix in toasted, cubed bread and figs.
8. Cover and place in refrigerator for 5 minutes.
9. Take pudding mixture out of refrigerator and mix in prunes and sweet potatoes.
10. Spray mini pie pan with nonstick spray and pour in 100 g of pudding mixture.
11. Add 10 g of topping.
12. Bake in oven at 204 °C (400 °F) for 30 minutes, covered with foil.
13. Freeze at least 24 hours.
14. Reheat covered 15 minutes in toaster oven at 204 °C (400 °F). Uncover and cook an additional 5 to 7 minutes until the topping is golden brown.
15. Pour 10 g of warmed sauce on top of the bread pudding.

Lentil Power Soup

INGREDIENTS	USAGE LEVEL (%)
Water	38.70
Tomato, chopped	12.64
Lentils	10.00
Carrots, frozen, diced (NORPAC Foods)	6.94
Celery, frozen, diced (NORPAC Foods)	6.94
Bell pepper, green, frozen, diced (Gregg & Associates)	5.14
Bell pepper, red, frozen, diced (Gregg & Associates)	5.14
Onion, white, chopped	4.17
Micellar casein concentrate	**3.20**
Milk protein concentrate	**3.20**
Olive oil	2.08
Lemon pepper powder	0.50
Whey permeate (dairy product solids)	**0.69**
Ginger root, raw	0.07
Garlic, fresh, raw	0.07
Turmeric powder	0.28
Salt	0.14
Curry powder	0.10
Total	**100.00**

Developed at the Institute for Dairy Ingredient Processing, South Dakota State University

Procedure:

1. Soak the lentils in warm water for 30 minutes.
2. Hydrate the dairy protein ingredients (micellar casein concentrate and milk protein concentrate) in 2 tablespoons of warm water for 15 to 30 minutes.
3. Boil the lentils in a pan with 1/2 cup water until they become soft and all water is absorbed. Set aside.
4. Heat olive oil in a saucepan. Add garlic, ginger and turmeric powder, followed by the chopped onion.
5. Add the rest of the chopped vegetables and the lentils. Cook on medium heat until vegetables are soft.
6. Add the hydrated dairy protein ingredients and mix well.
7. Add the curry powder and lemon pepper powder, salt and whey permeate. Mix well and cook for 10 to 15 minutes.
8. If desired, garnish with coriander.

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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)
NDM	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. www.ThinkUSAdairy.org
WPNI	Whey Protein Nitrogen Index

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.

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