U.S. Dairy Export Council®

REFERENCE MANUAL FOR U.S. WHEY AND LACTOSE PRODUCTS








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

Véronique Lagrange
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U.S. Dairy Export Council

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ACKNOWLEDGEMENTS

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

GLOSSARY

Some of the terms in this manual have synonyms which are used in related industries or other nations. 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 abbreviation	Synonym or closely related term
Acid-type whey powder, acid whey powder	Dry acid whey
Dairy products solids	Permeate, deproteinized whey
Demineralized whey	De-mineralized whey, reduced-minerals whey, dry-reduced minerals whey
Permeate	Dairy products solids, deproteinized whey
Processed cheese	Process cheese
Reduced-lactose whey, reduced-lactose whey powder	Dry reduced-lactose whey
Skim milk powder, SMP	Nonfat dry milk, NFDM, NDM
Sweet-type whey powder, sweet whey powder	Dry sweet whey
Whey	Dairy whey
Whey cream	Milkfat from whey
Whey products	Includes various types of whey, whey protein concentrates, isolates and lactose
Whey powder(s)	Dry whey, dried whey—sweet of acid
Whole milk powder, WMP	Dry whole milk
WPC	Whey protein concentrate
WPI	Whey protein isolate

OVERVIEW

The United States is the world's largest dairy producer, marketing over 75 million metric tons of milk per year, or approximately 19.5% of the world's milk supply. U.S. dairy farmers produce two-and-a-half times more milk than any European country and seven times as much as Australia or New Zealand. More than one quarter of the world's whey and lactose—935,000 metric tons—is manufactured at over 200 whey plants in the United States. With one of the world's largest cheese industries, an abundance of land and investments in research and development, the U.S. whey industry is capable of unrestrained growth.

Each year, U.S. manufacturers process over 25 million mt of fluid milk, 3.7 million mt of cheese, 935,000 mt of whey and lactose, 700,000 mt of milk powders, 583,000 mt of yogurt, 540,000 mt of butter and 565,000 mt of ice cream, making the United States the largest dairy processing country in the world.

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

The United States has been able to achieve its current milk output through a combination of scientific and management advancements at all levels of production, processing, regulation and marketing. On the farm, management techniques, including expanded use of balanced feed rations and the use of superior genetics, have been instrumental in increasing milk output per cow. Between 1990 and 2000, average annual yield per cow increased from 6,720 kg to about 8,061 kg, while cow numbers decreased from nearly 10 million to slightly fewer than 9.1 million. This type of production efficiency demonstrates the industry's ability to maximize its resources to meet the growing demand for dairy products worldwide. These same practices have led to modifications in the composition of milk, which have resulted in an increase of solids-nonfat (SNF) to meet food manufacturers' demands for more milk protein.

Advanced U.S. technologies ensure efficient delivery of the highest quality milk products. State-of-the-art milking and milk handling equipment, including automated milking systems, have improved the speed of cleaning, sanitizing, and cooling product, as well as delivering it to processing plants.

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

At the processing facilities, milk moves through sanitized pipes, vats and tanks as it is transformed into more than 300 varieties and styles of cheese, 100 flavors of ice cream and frozen yogurt, 75 flavors and set-types of yogurt, various milk powder and whey protein products, and numerous blends of butter and cultured products. Virtually all U.S. dairy processing plants employ quality management programs, such as HACCP (Hazard Analysis Critical Control Point) or ISO (International Organization for Standardization), to ensure that the finished products meet the highest attainable standards.

The U.S. industry has made continued, large investments in new, state-of-the-art dairy manufacturing facilities. During the past decade, such developments have enabled a 45% reduction in the number of manufacturing facilities while total output has increased by 4% to 5% annually. Continued investment will mean still lower processing costs and higher milk volumes.

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

As trade agreements continue to open global markets, other countries are able to benefit from using U.S. dairy products. Additional information on specific whey and lactose ingredients is available from the suppliers of the products. The U.S. Dairy Export Council has available the names, addresses and phone/fax information for U.S. companies processing and/or marketing each of the types of milk powders.

Photo courtesy: Hilmar Cheese Company

This handbook is designed to guide and educate international product developers on using U.S. whey and lactose ingredients. It is designed as a resource that includes:

- A description of the U.S. whey industry.
- Definitions of most whey and lactose products.
- Descriptions of the processes used to produce whey and lactose ingredients, and to enhance their nutritional or functional properties.
- Discussions of the functional and nutritional properties of whey and lactose ingredients.
- Applications for these functional, nutritional dairy ingredients.

The U.S. Dairy Export Council recommends you always check with your U.S. supplier to obtain detailed product specifications, and that you consult local regulations regarding ingredient usage and labeling. The formulations in this manual are only provided for demonstration purposes and as a starting point for product development efforts.

THE U.S. DAIRY EXPORT COUNCIL

U.S. Dairy Export Council

USDEC is an independent, non-profit, trade association. The mission of USDEC is to unify the U.S. dairy industry's international market development efforts so the United States can be a more responsive supplier to international customers. USDEC works with U.S. suppliers to help them maximize all the benefits the industry has to offer: size, efficiency, consistency, high quality and state-of-the-art technology.

USDEC's activities fall into three broad categories: providing on-going service to trade partners; bringing potential buyers and sellers together to facilitate trade; and educating and supporting U.S. dairy exporters.

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

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

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

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

The U.S. Dairy Export Council provides support to the U.S. dairy industry by:

- Educating and informing U.S. dairy suppliers of the opportunities available internationally and advising them of the requirements of the international marketplace so they can offer products that meet end-user specifications.
- Representing the U.S. dairy industry in international trade policy forums to reduce trade barriers for U.S. products.
- Taking a proactive role with the International Dairy Federation to develop worldwide technical standards and helping exporters meet regulatory requirements.
- Researching, analyzing and communicating information on trends in dairy production, consumption and trade.

The Council's headquarters are located in Arlington, Virginia (near Washington, D.C.), and can be contacted at:

U.S. Dairy Export Council
2101 Wilson Boulevard, Suite 400
Arlington, Virginia 22201 USA
Phone: 1-703-528-3049
Fax: 1-703-528-3705
www.usdec.org

In addition, USDEC has set up a number of international offices with representatives in Mexico, Brazil, Korea, Japan, China, Taiwan, Southeast Asia, Europe and the Middle East. For a full list of international offices and contact information, please contact the U.S. Dairy Export Council or check www.usdec.org.

DAIRY MANAGEMENT, INC.

DAIRY MANAGEMENT INC.™

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

Since 1997, DMI, on behalf of America's dairy farmers, has been inviting food formulators and dairy processors and cooperatives in the United States to "D*o it with dairy*.™" Our "D*o it with dairy*" program was designed with the primary goal of changing the U.S. domestic market's perception of dairy ingredients. The program's original mission was to promote dry ingredients, and demonstrate the functional and nutritional benefits these ingredients offer in developing new and/or improved food and beverage products. In 2002 the program was expanded to include cheese and milkfat ingredients.

The "D*o it with dairy*" program offers premier services that help food companies excel in the marketplace. DMI has brought together some of the best food technologists, researchers and dairy ingredient specialists in the U.S. to develop and offer solutions to some of the industry's toughest food development challenges. Our technical support system helps U.S. food and beverage manufacturers make formulation decisions more quickly and easily. Members of the DMI technical support team made contributions to this manual.

I am pleased to have participated in making this manual available to you. I hope you will find it a valuable resource of comprehensive technical information to meet your product development needs along with specific applications solutions. Providing this type of technical assistance is part of the mission of DMI.

I am grateful to the many subject-matter experts who authored the various sections of this manual, and hope you will find it useful in your professional activities.

William C. Haines, Ph.D.
Vice President, Business to Business Marketing
Dairy Management, Inc.

DMI's headquarters are located in Rosemont, Illinois (near Chicago, IL), and can be contacted at:

Dairy Management Inc.™
10255 West Higgins Road, Suite 900
Rosemont, Illinois 60018-5616 USA
Phone: 1-800-853-2479
Fax: 1-847-803-2077
www.dairyinfo.com
www.doitwithdairy.com

AMERICAN DAIRY PRODUCTS INSTITUTE

American Dairy Products Institute (ADPI), the national trade association of the processed dairy products industry, was formed in April, 1986, through a merger of the 61-year old American Dry Milk Institute and the 15-year old Whey Products Institute. In April 1987, the Institute expanded the scope of its activities when the Evaporated Milk Association merged into the American Dairy Products Institute. Actions were initiated to establish a cheese division within the American Dairy Products Institute, and successful culmination of this effort occurred February 6, 1997. Current Institute membership includes manufacturers of evaporated and dry milks, cheese and whey products, firms that provide supplies and services to processors, and many companies that utilize these processed dairy products. While the majority of our members are located in the U.S., we have many international members as well—currently from 16 countries.

ADPI's business purpose is to become the most effective communicator of the positive attributes and benefits for the dairy products we represent. Our business purpose must be executed to the benefit of our members, their customers and consumers.

ADPI provides a variety of services to members, representing its members in governmental affairs, consumer affairs and product standards of identity. Our goal is to provide our members complete information about the industry from processing to utilization. ADPI provides standards for dry milks which can be found in the ADPI Bulletin 916, "Standards for Grades of Dry Milks Including Methods of Analysis," and for whey products which can be found in the ADPI Bulletin W-16, "Whey & Whey Products—Definitions, Composition, Standard Methods of Analysis." These publications and other materials can be ordered from:

American Dairy Products Institute
116 North York Street
Elmhurst, IL, 60126 USA
Phone: 1-630-530-8700
Fax: 1-630-530-8707
www.adpi.org

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WHEY AND LACTOSE: NATURAL MILK PRODUCTS 1

1.1 U.S. WHEY AND LACTOSE PRODUCTION: GENERAL OVERVIEW

World's Largest Whey Producer

More than one quarter of the world's whey and lactose — 935,000 metric tons — is manufactured at over 200 whey plants in the United States. With one of the world's largest cheese industries, an abundance of land and investments in research and development, the U.S. whey industry is capable of unrestrained growth.

Cutting-edge Technology and Innovations

The U.S. whey industry is a leader in the technological development and usage of whey proteins. Advances in technology and investments in research and development have enabled the U.S. whey industry to expand its product line from basic commodity products, sweet whey powder and demineralized whey to a variety of higher valued products, including whey protein concentrates (protein ranges from 34 percent to 80 percent) whey protein isolates (above 90 percent protein), and whey protein fractions or derivatives.

With investments in research and development, the U.S. whey industry is continuing its drive toward newer and more applicable forms of whey products.

Functional Properties

U.S. whey products possess many different functional properties that lend themselves naturally to multiple applications as food ingredients. Examples of whey products and some of their functional properties are listed in the adjacent table.

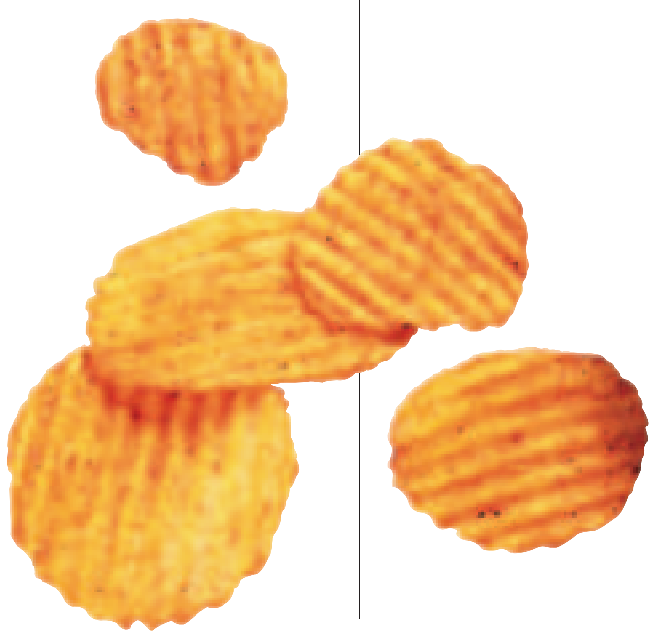
Product	**Functional Properties (please refer to text for further details)**
Whey powders*, permeate	Color and flavor development Solids Dispersible
Sweet whey	Dairy flavor and solids Solubility Dispersible
WPC34	Protein source Emulsification Solubility Mild dairy flavor Color and flavor development
WPC80	High protein level Emulsification Whipping Fat binding Solubility Heat setting/gelling Water binding
Whey protein isolates	High protein level Solubility
Demineralized whey products	Good source of nutritionally balanced whey and lactose Low mineral content Versatile functionality
Bioactive proteins/whey fractions	Stimulate growth of bifidus bacteria Reduce cholesterol Enhance iron transport Antibacterial properties Non-allergenic
Lactose	Moisture retention Texture agent Carie flow agent Color and flavor retention Browning agent and flavor developer Non-hygroscopic Pancoating Dispersible Excipient
Reduced lactose whey	Dairy flavor and solids Dispersible
Milk calcium	Highly bioavailable calcium Mild dairy flavor All-natural

*Non-hygroscopic demineralized, deproteinized and other modified products available.

Multiple Applications

The creation of a wide variety of whey products has led to new opportunities for usage in different food sectors. Some of the food sectors currently using whey include:

Food Sector	Product Examples	Functional Demands
Dairy	Ice cream, yogurt, dairy spreads, cheese products, beverages	Dairy solids, emulsification, viscosity, whippability
Meats	Processed meat, sausages, fish	Fat/water binding, gelling
Dry seasoning mixes	Mixes for potato chips, Mexican dishes, gravy	Dispersibility, flavor, low sweetness bulking
Bakery	Muffins, crusts for pies, breads, buns	Color, flavor development, heatsetting, shelf-life
Confections	Candy bars	Whippability, low sweetness bulking, egg replacement stability
Snack foods	Cookies, bars	Thermal expansion, nutrition
Beverages	Cocoa mix, coffee creamer, sports drinks, health drinks	Solubility, viscosity, nutrition, dairy flavor, protein quality
Nutraceuticals and sports foods	Energy bars and drinks, nutrient supplements for special needs	Bioactivity, protein quality, non-allergenicity



Different Protein, Mineral and Fat Levels to Fit the Buyer's Needs

U.S. suppliers specialize in meeting customer needs and tailoring their products to buyer's specifications. The latest in plant technology allows suppliers to vary the protein, mineral and fat levels in their products. U.S. whey suppliers can modify whey products through such technologies as demineralizing, crystallizing or ultrafiltration. Therefore, they offer products that can range in protein levels from less than 12% to over 90% and mineral levels between 1% and 28%. Modified whey products with enhanced functional and nutritional characteristics are also widely available and typically customized for optimal performance.

World's Strictest Sanitary and Quality Standards

The U.S. whey industry adheres to strict production practices, which ensure that all users of U.S. whey products obtain a safe, high-quality and nutritious product. U.S. whey products must abide by rigorous quality control standards that have been developed in cooperation with the United States Department of Agriculture (USDA) and the Food and Drug Administration (FDA). All products are tested and evaluated to ensure that they not only meet U.S. government standards, but also the requirements of the end-user. By adhering to the strictest sanitary and quality standards, the U.S. whey industry can guarantee that all end-users receive the highest quality product.

Nutritional Benefits

Incorporating U.S. whey products as a food ingredient provides exceptional nutritional benefits. High-quality U.S. whey products contain essential amino acids, are easily digested and provide a Protein Efficiency Ratio (PER) greater than 3.0. U.S. whey products are also rich in vitamins such as thiamin, riboflavin, pantothenic acid, Vitamin B_6 and B_{12}.

A Growing Export-oriented Industry

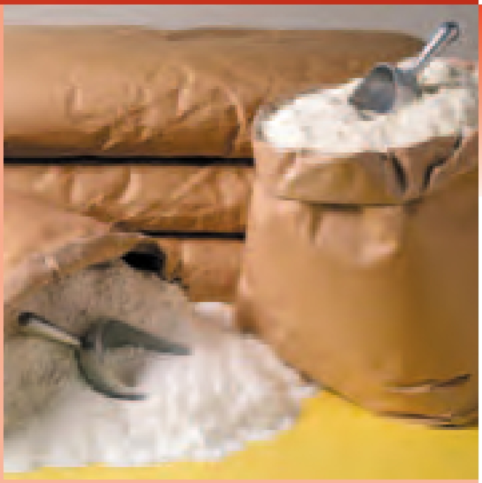
The continuing long-term trend of U.S. whey exports attests to the high quality and increasing use of U.S. whey products. From 1998-2001, total U.S. all dry whey exports grew 46%. The U.S. is already the top whey supplier in a large number of countries where the food and beverage manufacturing sector is dynamic and innovative. With unrestrained capacity for growth, continued investments in research and development and an increasingly international focus on exporting, USDEC and the U.S. whey industry are ready to help you use U.S. whey products to respond quickly to new opportunities and to gain market share.

U.S. Whey Exports 1996-2001 (1,000 metric tons)

	1996	1997	1998	1999	2000	2001
Whey	109.3	104.1	99.1	120.0	166.0	143.1
Whey protein concentrates	5.6	12.0	19.5	15.7	17.6	24.5
Lactose	74.5	82.2	75.5	80.1	99.5	127.2
Total	189.4	198.3	194.1	215.8	283.1	294.8

Source: U.S. Dairy Export Council and USDA

QUALITY STANDARDS, QUALITY ASSURANCE AND CERTIFICATIONS 2



By MR. F. TRACY SCHONROCK
Schonrock Consulting,
Fairfax Station, VA

2.1 UNITED STATES DEPARTMENT OF AGRICULTURE STANDARDS, GRADING SERVICES

United States Department of Agriculture (USDA)

The USDA, Agricultural Marketing Service (AMS), Dairy Standardization Branch has developed United States standards and United States specifications for many dairy products. These standards and specifications provide measures of quality based on attributes essential to buyers and consumers, such as flavor and keeping quality. The standards and specifications ensure a nationally and internationally understood language for efficient, orderly trade. The requirements for dry whey can be found in "United States Standards for Grades of Dry Whey." The nomenclature for the U.S. grade is "U.S. Extra." The U.S. grade of dry whey is determined on the basis of flavor, physical appearance, bacterial estimate, coliform count, milkfat content, moisture, and scorched particle content.

To be assigned a grade by the USDA, dry whey must meet the requirements of U.S. Extra Grade. This standard became effective December 14, 2000. It is available from the:

United States Department of Agriculture
Agricultural Marketing Service
Dairy Programs,
Dairy Standardization Branch
Room 2746-S
1400 Independence Avenue, SW
Washington, DC 20250-0230 USA
Phone: 1-202-720-7473
Fax: 1-202-720-2643
www.ams.usda.gov/dairy

Inspection and Grading Services

When you buy U.S. Extra Grade dry whey you are assured it is a wholesome, high quality product. The USDA, Agricultural Marketing Service (AMS), Dairy Grading Branch, provides this assurance. The grade standards and grading services, together, provided by the USDA aid in the orderly marketing of dairy products. For both buyers and sellers, this service guarantees the product meets specific grade or contract requirements, has uniform quality, and has good keeping quality. In order to have dry whey graded, the manufacturer must have their production facilities surveyed by the USDA.

United States Standards For Dry Whey U.S. Extra Grade

Flavor*	Normal, free from undesirable flavors
Physical appearance	Uniform color, free flowing, free from lumps, practically free from visible dark particles
Bacterial estimate SPC**	≤ 30,000/g
Coliform	≤ 10/g
Milkfat	≤ 1.50%
Moisture	≤ 5.0%
Scorched particle content	≤ 15.0 mg
Acidity	Not a requirement for grade. Helps to differentiate sweet from acid whey. This information is provided on the certificate.
Optional tests* **	
Protein (Nx6.38)	≥ 11%
Alkalinity of ash****	≤ 225 ml 0.1 N HCl/100 g

* Applies to the reliquified form.
** SPC = Standard plate count
*** These are optional requirements which are in addition to those listed above. Tests for these requirements may be run occasionally at the option of the U. S. Department of Agriculture and will be run whenever an interested party requests them.
**** Applies to sweet-type whey only.

2.2 PLANT SURVEYS

An experienced, highly trained dairy inspector conducts the plant survey. The survey involves detailed checks of more than 100 items. Only plants that meet these requirements are granted an "Approved Status" and are eligible for grading, quality control, and certification services. Manufacturing plants that have been granted an "Approved Status" are listed in the quarterly published booklet "Dairy Plants Surveyed and Approved for USDA Grading Service." It is available from the:

United States Department of Agriculture
Agricultural Marketing Service
Dairy Programs,
Dairy Grading Branch
Room 2746-S
1400 Independence Avenue, SW
Washington, DC 20250-0230 USA
Phone: 1-202-720-3171
Fax: 1-202-720-2643
www.ams.usda.gov/dairy/grade.htm

Inspection and Grading

The USDA offers many inspection and grading services to provide assurance of wholesome and high-quality products. These services include but are not limited to confirmation of grade, compositional analysis, condition of container examination, test weighing, and dispute resolution. The grader assures the integrity of all samples and examines each sample to determine compliance to the grade standard or contract specification. The results of the evaluations for products that comply with the standard or specification are documented on an official USDA certificate.

Some of the items on the dairy inspector's list include:

1. The plant surroundings must be clean to prevent bacterial or environmental contamination and maximize product safety.
2. Facilities must be of sound construction.
3. Areas such as the raw milk receiving, ingredient receiving, manufacturing, pasteurizing, packaging, supply storage and warehousing must have adequate lighting to facilitate inspection of products and the proper cleaning of equipment and facilities.
4. Incoming raw product is graded on a regular basis.
5. Incoming milk must be regularly analyzed to ensure high quality and product safety.
6. All processing equipment must be of a sanitary design, be properly maintained, and be properly cleaned to assure the buyer that the whey is protected from contamination.
7. Product handling practices, employee practices, and process controls must be maintained to assure product quality and safety.
8. Packaging and storage practices must be maintained to assure that product quality and safety are maintained for the buyer.

2.3 EXPORT CERTIFICATION AND LABORATORY SERVICES

Export Certification Services

Export certifications or attestations are routinely required by importing countries to document that products are fit for human consumption, are produced under sanitary wholesome conditions, are free from animal diseases, and are federally inspected. The USDA can provide export certifications meeting the requirements of most importing countries. The USDA, Dairy Grading Branch, is the authorized certification authority for dairy products destined for the European Union.

Laboratory Service

Laboratory service consists of analytical and quality control tests, including all chemical and bacteriological determinations essential in evaluation of class, quality, condition, and keeping properties. Exacting laboratory tests guarantee the quality and wholesomeness of the product. For example, dry whey requires five laboratory tests and a flavor test.

Personnel

The men and women who perform these services are experienced, well trained, and under the supervision of the USDA. Many product graders and plant inspectors are college graduates with majors in dairy manufacturing or food technology, and have held responsible jobs in the dairy industry.

Photo courtesy: Hilmar Cheese Company

The American Dairy Products Institute (ADPI)

ADPI has developed a variety of specifications for whey and related products, which can be beneficial for export marketing. Examples of such specifications are presented below. For additional information on ADPI's product specifications please contact the organization at:

American Dairy Products Institute
166 North York Street
Elmhurst, Illinois 60126 USA
Phone: 1-630-530-8700
Fax: 1-630-530-8707
www.adpi.org

2.4 KOSHER AND HALAL CERTIFICATION

Suppliers can obtain voluntary kosher or Halal certification from internationally recognized certification organizations. Due to the religious significance and sensitivity of the requirements for kosher or Halal certification, buyers are encouraged to contact suppliers well in advance so that appropriate sources of whey can be obtained. For additional information, please contact your supplier.

2.5 STATE DEPARTMENTS OF AGRICULTURE

Entities at the state level also certify processing plants. For additional information, please contact your supplier.

2.6 OTHER CERTIFICATION AND TESTS

In some cases, plants are also approved to meet industry standards to supply other industries. Some examples include American Institute of Baking, ISO 9000 Certification, PMO (Pasteurized Milk Ordinance), USPHS (United States Public Health Service), EPA (Environmental Protection Agency), etc. In addition, individual suppliers may have additional production, and finished product record keeping testing.

ADPI Typical Compositional Ranges

Criteria	Dry Whey (Sweet Type)	Permeate/ Dairy Products Solid	Reduced Minerals Whey	Whey Protein Concentrate	Whey Protein Isolate
Protein	11.0–14.5%	3.0–5.0%	11.0–15.0%	34.0–79.9%	92.0%
Lactose	63.0–75.0%	65.0–85.0%	70.0–80.0%	10.0–55.0%	0.5%
Milkfat	1.0–1.5%	0.0–1.5%	0.5–1.8%	1.0–10.0%	1.0%
Ash	8.2–8.8%	8.0–20.0%	1.0–7.0%	4.0–8.0%	2.0%
Moisture	3.5–5.0%	3.0–5.0%	3.0–4.0%	3.0–4.0%	4.5%
SPC*	≤ 30,000/g	≤ 30,000/g	≤ 30,000/g	≤ 30,000/g	≤ 30,000/g
Coliform	≤ 10/g	≤ 10/g	≤ 10/g	≤ 10/g	≤ 10/g
Salmonella	Neg. by test	Neg. by test	Neg. by test	Neg. by test	Neg. by test
Listeria	Neg. by test	Neg. by test	Neg. by test	Neg. by test	Neg. by test
Coagulase-positive Staphylococci	Neg. by test	Neg. by test	Neg. by test	Neg. by test	Neg. by test
Scorched particles	7.5–15.0 mg	7.5–15.0 mg	7.5–15.0 mg	7.5–15.0 mg	7.5–15.0 mg
Titratable acidity	0.10–0.15%	0.10–0.15%	–	–	–
pH	5.8–6.5		6.2–7.0	6.0–6.7	6.7–7.5
Color	Off white to cream	Off white to cream	Cream to dark cream	White to light cream	White to light cream
Flavor**	Normal whey flavor	Normal whey flavor	Normal whey flavor	Bland, clean	Bland, clean
Alkalinity of ash	≤ 225 ml 0.1 N HCL/100 g				

* SPC = Standard plate count
** Applies to the reliquified form
Note: The ingredient statement shall state the percent of the characterizing component (lactose, minerals, or protein.) The percent is declared in 5% increments for lactose and protein, 2% increments for minerals and whey protein isolate, or as actual percentage, provided an analysis of the product is supplied.
Source: ADPI Ingredient Description Brochure, Revised 1998.

Photo courtesy: Hilmar Cheese Company

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Sweet whey, as produced in the United States, is a product of cheese manufacture whereby coagulate is primarily achieved using enzymatic coagulation. Many types of cheeses are produced in the United States; however, Cheddar and Mozzarella types account for the majority of cheese manufactured.

3.1 TECHNOLOGIES FOR WHEY PROCESSING: AN OVERVIEW

Whey drawn from the cheese vat contains cheese particles or fines, lipids, acid, minerals, microorganisms and other milk components that were not trapped in the cheese curd. The cheesemaker typically uses centrifugation to remove cheese fines and most lipids from the whey. A clarifying centrifuge often is used to remove cheese fines while another type of centrifuge, known as a separator, removes the fat. The removed fat is known as whey cream. Removing the fat and cheese fines improves the quality of the final whey product.

Cheese culture microorganisms are added to milk to convert lactose into lactic acid during the manufacture of cheese. Some of these same cheese culture microorganisms are present in the whey where their ability to convert the lactose into lactic acid is undesired. Processors therefore either immediately pasteurize the whey to inactivate the cheese culture microorganisms or they quickly cool the whey to less than 7°C to stop acid production, and then pasteurize the whey.

Whey is pasteurized (high temperature, short time) by heating the whey to at least 72°C and holding at or above this temperature for a minimum of 15 seconds. Other time/temperature combinations can by used but 72°C/15 seconds is most common. Pasteurization ensures the elimination of any potential pathogens found in whey, inactivates the cheese culture microorganisms, and many other bacteria which may be in whey.

After pasteurization and removal of fines and whey cream, the whey is ready to be converted into the desired whey products. U.S. manufacturers use one or more of the following technologies to meet the functional and nutritional specifications of the end-users.

The processes used to produce whey products include:

- Evaporation and drying
- Centrifugation
- Crystallization
- Chromatography
- Ion exchange
- Electrodialysis
- Membrane processes
- Absorption (e.g. activated carbon for color removal)

3.2 EVAPORATION AND DRYING

- Processes common to almost all whey products
- Type of evaporation/drying affects the final product quality
- Proteins generally remain undenatured

Evaporation is the process of removing water from whey. Whey as taken from the cheese vat contains approximately 6 to 7% total solids. Evaporation increases the total solids of the whey by removing the water. Removing the water reduces transportation and storage costs for handling whey and therefore evaporation is a common process in the production of whey products. Evaporation is also a prerequisite for other processing steps such as crystallization and drying.

Vacuum concentration is a common type of evaporation. An evaporator under vacuum vaporizes and removes the water in whey at temperatures significantly below 100°C. The structure of whey proteins can be irreversibly altered (denatured) by heat; however lower temperatures are used during vacuum evaporation and whey protein denaturation is minimized.

The amount of vacuum used, type of evaporator and preheater time/temperature are important factors that can be varied to alter the final properties of whey. An example of a controlled alteration is the use of higher temperatures or holding times to produce high gelling whey powders. Typically, evaporator conditions are selected that minimize damage to whey proteins.

Drying is simply a further removal of water from the whey. There are many types of dryers, but whey produced for human consumption is dried almost exclusively on spray dryers, while drum dryers sometimes are used for drying whey for animal feed products.

Spray drying involves atomizing concentrated whey into a stream of hot air in a chamber. The water rapidly evaporates into the air thereby protecting the whey proteins from heat damage. The atomizer is either a pressure nozzle or a centrifugal disc. By controlling the size of the droplets, the air temperature and the airflow, it is possible to evaporate almost all of the moisture while exposing the solids to relatively low temperatures. Spray drying yields whey powders with excellent solubility, flavor and color.

Roller drying involves direct contact between a layer of concentrated whey and the hot surface of rotating rollers. Intense heat often causes irreversible changes in whey products such as non-enzymatic browning and protein denaturation. Roller dried whey products tend to be darker in color because of increased Maillard reactions, contain more scorched powder particles and have poorer solubility as compared to spray dried whey powders.

Spray dried whey products may be instantized to improve reconstitution properties. This is achieved by agglomeration of the fine spray dried whey particles into grape like clusters. The voids in the agglomerated powder facilitate dispersion and particle hydration.

Photo courtesy: Land O' Lakes Food Ingredients Division

3.3 VALUE-ADDED PROCESSES

Valuable whey components can be concentrated or isolated by a number of processes. Such processes include membrane technology, electrodialysis, ion exchange and crystallization.

Membrane Technologies

- Pressure-driven separation using semi-permeable membranes
- Typically use relatively low temperatures
- Designed for low to high product volumes
- Do not denature proteins
- Allow the production of WPC's 34 to 90%
- Include: reverse osmosis, nanofiltration, ultrafiltration, microfiltration

Membrane technology involves passing fluid whey across a semi-permeable membrane. A combination of pumps and valves creates a pressure gradient across the membrane, which drives the smaller molecules in the whey across the membrane, thereby concentrating the larger molecules and particles that cannot cross the membrane. The portion of the whey that cannot cross the membrane or is retained is referred to as retentate while the portion crossing or permeating the membrane is known as permeate.

It is possible to selectively separate or concentrate whey components by using membranes with different pore sizes or molecular weight cut-off. There are four classes of membranes used for processing whey: (1) reverse osmosis (RO), (2) nanofiltration (NF), (3) ultrafiltration (UF) and (4) microfiltration (MF). Membrane systems do not expose the whey to temperatures < 55°C, therefore thermally induced changes in protein quality are minimized.

Reverse osmosis membranes have the smallest pores. Only water crosses the membrane while all other components of the whey are retained. A common use of RO membranes is water desalination. These membranes are generally rated according to their ability to reject salt. Like vacuum concentration, RO systems do not change the ratios of the solid components of the whey but rather concentrate the solid components by removing only water. The extent of whey concentration by RO is limited by the increase in viscosity and osmotic pressure of the whey as water is removed.

Nanofiltration membranes are sometimes referred to as "loose" RO membranes. NF membranes allow some monovalent ions to cross the membrane along with the water resulting in a partial "desalting" of the whey. Because only minerals with a single charge are removed, NF membranes only slightly reduce the mineral content of whey. NF membranes may be used to reduce the sodium chloride content of some types of whey.

Ultrafiltration membranes have larger pores than RO or NF membranes. UF membranes permeate lactose and ash while retaining the proteins in whey thereby making UF membranes the standard tool for production of whey protein concentrates (WPCs). The greater the amount of lactose and ash removed, the higher the protein content of the WPC. Because the viscosity of the whey increases as protein concentrate increases, addition of water to the retentate to wash out additional amounts of lactose and minerals, in a process known as diafiltration, is necessary when producing WPCs with more than 50% protein.

Microfiltration membranes have the largest pores of the membrane separation processes. Smaller soluble proteins, peptides, lactose, minerals, non-protein nitrogen components, and water readily permeate MF membranes. Fat globules are retained by MF membranes therefore these membranes can be used to remove the small amounts of fat that are not recovered by centrifugation. Trace amounts of fat must be removed to produce WPIs.

Electrodialysis

- Does not denature proteins
- Makes continuous operations possible
- Suitable for 70-75% mineral removal

Electrodialysis also uses semi-permeable membranes, however, an electrical current replaces pressure as the driving force for separating whey components. Electrodialysis membranes allow only minerals to permeate while retaining lactose and proteins. An electrical current draws the charged mineral ions through the membranes and into a brine stream. Lactose is not affected by the current and proteins cannot cross the membranes, therefore only minerals are removed. Electrodialysis does not denature whey proteins while removing up to 75% of the minerals in whey.

Ion Exchange

- Does not denature proteins
- Allows for a high degree of purity
- Suitable for up to 98% mineral removal

Ion exchange is a type of chromatography. For example, when producing demineralized whey, whey passes through a column containing absorbent beads that bind the ions (charged minerals) in the whey. The remainder of the whey components such as protein and lactose pass through the column unhindered. The resulting whey therefore will have reduced amounts of minerals as compared to untreated whey. Ion exchange does not denature proteins and can remove up to 98% of the minerals in whey.

Chromatography

- Does not denature proteins
- Allows for a high degree of purity
- Suitable for value-added, high purity products

Chromatography processes use charged resins to separate proteins in whey from other components. The proteins bind to oppositely charged resin while components like lactose do not bind and therefore pass directly through the system. After the whey has passed through the column or tank containing the resin, a buffer is sent through the system to release the bound proteins. The proteins can be purified further by UF and then spray dried.

Chromatography can also be used to separate specific proteins from other proteins in whey. Lactoferrin and lactoperoxidase are positively charged at a pH typical for sweet whey. The major proteins of whey, Alpha-lactalbumin, Beta-lactoglobulin and bovine serum albumin are negatively charged at the same pH. When whey passes through a tank containing negatively charged resin, the positively charged lactoferrin and lactoperoxidase bind to the resin while the other proteins and whey constituents pass through the column. An alkaline solution is then sent through the column to release the bound proteins from the resin. The recovered proteins can then be washed and spray dried.

Crystallization

- A slow, batch process
- Often combined with other processes
- Does not denature proteins
- Used for the manufacture of non-hygroscopic whey, lactose production/removal
- When combined with refining/decanting to yield high purity lactose

Crystallization is used to produce either lactose or non-hygroscopic whey/permeate powder. Whey or permeate is concentrated to at least 50% total solids by evaporation where lactose is supersaturated such that the lactose will readily crystallize as the concentrated whey/permeate is cooled. After the whey/permeate has cooled sufficiently, the lactose crystals can be removed for further processing into high quality lactose, or the whey/permeate solution with crystallized lactose can be dried to produce non-hygroscopic whey/permeate powder.

3.4 OTHER PROCESSES

Several other processes can add value to whey. Included in value added types of processes are lactose hydrolysis, protein hydrolysis and custom denaturation.

Lactose Hydrolysis

Beta-galactosidase, an enzyme, can be added to whey to hydrolyze the disaccharide lactose into its component monosaccharides, glucose and galactose. Time and temperature are used to control the degree of lactose hydrolysis.

Protein Hydrolysis

Proteases are enzymes added to whey to hydrolyze the proteins. The type of protease added, time and temperature are used to control the type and degree of protein hydrolysis.

Custom Denaturation

Whey proteins can be denatured by heat to alter their functional properties. A combination of time and temperature is used to control the amount of whey protein denaturation. Controlled denaturation often is done during the preheating treatment. The amount of undenatured whey protein can be measured by the whey protein nitrogen index.

QUESTIONS AND ANSWERS

Q. *What are the differences between* WPI *produced by microfiltration versus ion exchange/ chromatography?*

A. WPIs produced by either ion exchange/ chromatography or microfiltration have similar gross compositions. The most significant difference between WPIs produced by these two methods is the levels of glycomacropeptide (GMP) in WPIs manufactured by microfiltration. End-users that want to make claims based on the presence of GMP in their product must be sure to select WPIs made by MF. The functional properties of the two types of WPIs will otherwise be similar.

Q. *What is the whey protein nitrogen index* (WPNI)?

A. The whey protein nitrogen index is an indirect measure of the amount of whey proteins that are undenatured. The WPNI can reflect the degree of heat treatment received by the proteins during processing. The solubility of whey proteins often correlates with the WPNI value therefore the WPNI can be an important end-user specification.

Q. *What are scorched particles and are they important?*

A. Scorched particles are small, tan to brown color particles that may be readily visible to the naked eye. During drying, some whey may contact and stick to the sides of the dryer. These particles are exposed to higher temperatures in the dryer and eventually the adhering particles will dry sufficiently to fall from the walls of the dryer and into the dry whey powder. The exposure to higher temperatures causes particles to brown and become less soluble than typical whey powder particles. Depending on the final end-use for the whey powder, scorched particles may or may not be important. Because scorched particles are somewhat darker in color and insoluble, they can limit some applications for whey powder.

Q. *Why are demineralized whey products more expensive than sweet whey?*

A. Whey can be demineralized by either ion exchange or electrodialysis. Ion exchange involves processing with large amounts of water that must be treated before appropriate disposal. Electrodialysis uses large amounts of electricity that is very costly in most parts of the United States. The demineralized whey manufacturer must include the costs of these processes in the price of the final product to remain profitable.

3.5 ADVANCED WHEY INGREDIENT TECHNOLOGIES

The methods used to manufacture whey proteins provide some of the most interesting intersections of innovation and practicality. Researchers are studying unique variations on chromatography via ion exchange, affinity membranes, and bioselective adsorption, or a process called reverse micellar extraction to separate and purify specific whey proteins. For example, researchers at the University of Wisconsin, Madison, are accomplishing protein separations using membrane chromatography. Updated chromatographic methods, evolved from procedures originally developed for the biopharmaceutical industry 25 years ago, offer new opportunities to purify important proteins like lactoferrin and Beta-lactoglobulin when applied to whey.

At Utah State University, Logan, research demonstrates the feasibility of technical separation of lactoferrin and transferrin from whey. At the University of California, Davis, another promising whey protein separation technique under investigation uses reverse micellar solvents to achieve protein-specific isolations. Reverse micellar methods offer the potential for continuous extraction of specific proteins from an aqueous mixture, achieving simultaneous concentration and purification of specific proteins in an efficient manner.

The next step in advancing whey protein applications is to evolve the functionality of the proteins, increasing their suitability for new uses. Researchers are expanding the performance of whey proteins with a host of physical and chemical manipulations.

Extrusion of whey proteins yields texturized whey proteins that can compete with existing textured vegetable protein ingredients. Researchers have also developed a whey protein polymer that provides thickening, gelling and freeze-thaw stability normally achieved with hydrocolloids.

Another aspect of the reverse micellar purification process is the focus on microemulsion capabilities. New research in this domain supports the theory that Alpha-lactalbumin could play an important role in the formation of new types of biocompatible microemulsions for pharmaceutical, food and cosmetic applications.

Researchers from the University of California, Davis, have succeeded in developing and patenting a technology that utilizes whey proteins as microencapsulating agents. This new application for whey proteins allows the formation of thin films (walls) to surround liquid droplets or solid materials consisting of food ingredients, pharmaceuticals or other active compounds. Given whey proteins' unique functional capabilities and nutritive value, applications with nutraceuticals and pharmaceuticals may just be the beginning.

Adapted from: Innovations in Dairy. May 2000. Dairy Industry Technology Review. Dairy Management Inc. Reprinted with permission.

3.6 PROTEIN POLYMERIZATION AND MODIFICATION

By DR. ANAND RAO
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Introduction

Whey proteins provide excellent nutritional benefits as well as functional properties in processed foods. The functional properties of whey proteins can be enhanced or modified by many different methods—chemical, physical, or enzymatic methods. Some examples of chemical modification of proteins include acetylation, succinylation, esterification, amidation, phosphorylation, and thiolation. Functional changes may also be effected by using physical techniques such as thermal treatment or mechanical forces such as whipping and extrusion. The functional properties of proteins can be modified by using enzymes for either cross-linking to form larger polymers or for hydrolyzing to form small peptides and polypeptides.

This section will exclusively focus on the use of enzymes in production of protein polymers and hydrolysates and the resulting functional changes.

Polymerization

Enzymes are utilized to form intra-molecular and inter-molecular cross-links in whey proteins, resulting in complex polymers. Transglutaminase (TGase) is an enzyme that has been studied extensively for its effects in whey protein modification through crosslinking. TGase induces polymerization by catalyzing covalent interaction between lysine and glutamine residues of the polypeptide chains. The resultant polymers exhibit functional and rheological characteristics that are different from the original whey proteins.

The most significant effect of polymerization of whey proteins is the increase in gel strength, up to about 10 times the gel strength of non-polymerized whey proteins. Additional changes that result from polymerization include:

- Increased viscosity of polymer solutions, providing improved mouth feel in beverages.
- Higher viscosity solutions, providing the functionality of gums and/or stabilizers.
- Ability to form gels without heat in textured meats or other foods.
- Ability to form gels without the aid of gelling agents such as calcium salts.
- Stronger interaction of polymers improves the performance of whey protein based edible films. The moisture barrier property of the films is improved.

Protein cross-linking between whey proteins and other food proteins such as wheat gluten proteins can be induced by the use of TGase. Such cross-protein polymerization results in improved performance of dough in baked foods.

Hydrolysis

In principle, protein modification by hydrolysis is the opposite of polymerization. Proteases are the most common group of enzymes used to cleave the peptide bonds of a protein molecule, resulting in smaller peptides and polypeptides. The degree of hydrolysis, i.e., the degree to which the whey proteins are hydrolyzed, will affect the functional properties of the hydrolysates as food ingredients.

The changes in hydrolyzed product:

- Lower viscosity of solutions allows for incorporating higher protein levels in food formulations (beverages) without thickening.
- Increased solubility facilitates use in acidic beverages where intact proteins may cause precipitation and cloudiness.
- Increased emulsification properties. Not all hydrolyzed proteins will have emulsification properties. This property is dependent on the degree of hydrolysis and the type of peptides available in the hydrolysate. Suitable for use in oil-based formulations such as mayonnaise.
- Increased foaming capacity. Hydrolyzed proteins can provide 5 to10 times the foam volume compared to unhydrolyzed proteins. Appropriate for use in foam-based foods such as ice creams, frothy beverages, and whipped toppings.
- Reduced propensity for gelation, allowing for use as protein source in heat-processed beverages.
- Improved structural properties. Unhydrolyzed proteins bind water and form a strong network with other proteins in high protein formulations such as bars and cookies. This property can lead to hardening of texture and significant decrease in shelf life of such products. The peptides in hydrolyzed whey proteins disrupt this protein network and provide a soft chewy texture to the product.

In addition to the functional characteristics, hydrolysis of whey proteins produces peptides that may have biological activities. Some biological functions that have been attributed to whey peptides are:

- Anti-bacterial activity
- Anti-hypertensive activity
- Anti-cancer activity
- Opioid-like activity (reduction in heart rate and respiration)
- Increased metabolic assimilation

It is important to note that not all hydrolyzed whey proteins behave alike in a food formulation. Therefore, a formulation scientist may not be able to easily replace one hydrolyzed whey protein with another more economical source of hydrolyzed whey protein. Because the functional and biological properties of these ingredients vary greatly, it is essential to thoroughly evaluate them in a given formula and under specific processing conditions.

OVERVIEW

The following technical data sheets provide basic guidelines for composition, physical and chemical aspects, and applications of different whey products.

Whey is a natural dairy product. Just as variations exist in fluid and other dairy products from supplier to supplier, variations also exist in non-standardized whey products. Differences in raw material as well as differences in the processing systems can result in variations in the functional and nutritional properties of whey products. The manufacturing process used and the brand become more important as the protein content is increased and as processing variables are modified to enhance certain properties.

For high-end products, direct communication with the supplier is necessary to ensure exact product specifications, thereby reducing unwanted product variations for high-protein WPCs and WPIs. However, for sweet- and acid-type whey powders, reduced-lactose whey, demineralized whey and WPC34, variations in products are less of a concern to most end-users. The processing techniques most commonly used to manufacture each of the products are summarized in the Figures 4.1, 4.3, 4.4, 4.5, 4.11 and 4.12 in this section.

Most U.S. suppliers will provide technical specifications for their products.

4.1 SWEET WHEY POWDER

Product Definition

Sweet whey powder is obtained by drying fresh whey (derived from the manufacture of cheeses such as Cheddar, Mozzarella and Swiss) that has been pasteurized and to which no preservatives have been added. Sweet whey powder contains all the constituents of fresh whey, except water, in the same relative proportion.

Storage

Store and ship in a cool, dry environment at temperatures of less than 27°C and relative humidity less than 65%. Use within 6-12 months.

Typical Composition*

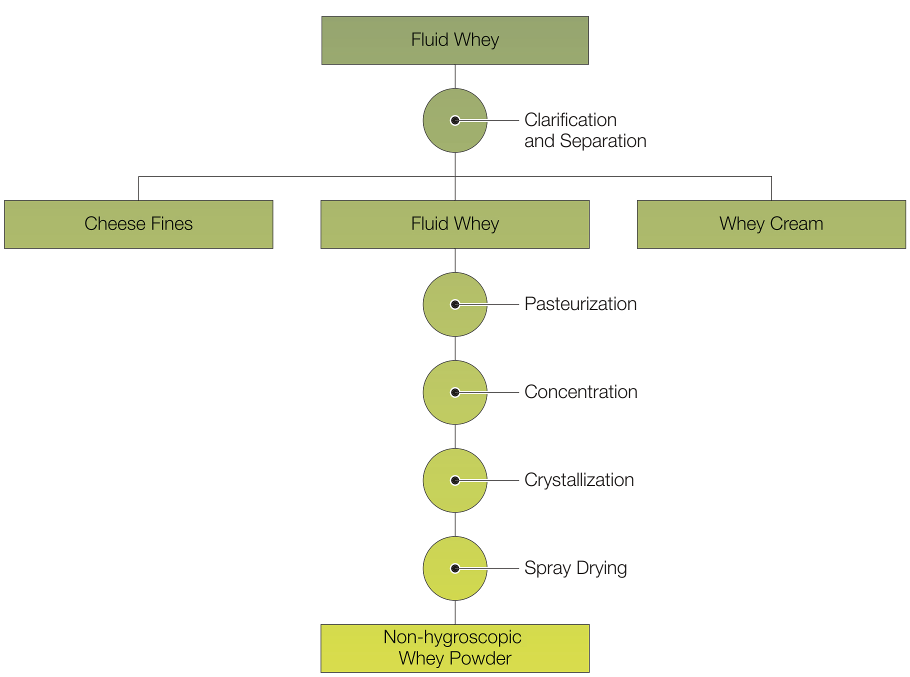
Protein	11.0%–14.5%
Lactose	63.0%–75.0%
Fat	1.0%–1.5%
Ash	8.2%–8.8%
Moisture	3.5%–5.0%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	≤30,000/g
Coliform	≤10/g
E. coli	Negative/g
Salmonella	Negative/100g
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0mg
Titratable acidity	0.10%–0.15%
Color	Off-white to cream
Flavor	Normal whey flavor

*Please consult your U.S. supplier for detailed product specifications.

Figure 4.1
Processing of Whey Powder



4.2 ACID WHEY POWDER

Product Definition

Acid whey powder is obtained by drying fresh whey (derived from the manufacture of cheeses such as cottage, cream cheese, and ricotta) that has been pasteurized and to which no preservatives have been added. Acid whey powder contains all the constituents of the original acid whey, except water, in the same relative proportion.

Storage

Store and ship in a cool, dry environment at temperatures of less than 27°C and relative humidity less than 65%. Use within 6-12 months.

Typical Composition*

Protein	11.0%–13.5%
Lactose	61.0%–70.0%
Fat	0.5%–1.5%
Ash	9.8%–12.3%
Moisture	3.5%–5.0%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	≤30,000/g
Coliform	≤10/g
E. coli	Negative/g
Salmonella	Negative/100 g
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0 mg
Titratable acidity	0.35%–0.44%
Color	Off-white to cream
Flavor	Normal whey flavor, slight acid

*Please consult your U.S. supplier for detailed product specifications.

4.3 REDUCED LACTOSE WHEY

Product Definition

Reduced lactose whey is obtained by the selective removal or hydrolysis of lactose from whey. The lactose content of the dry product may not exceed 60%. Reduction of lactose is accomplished by physical separation techniques such as precipitation or filtration or by enzymatic hydrolysis of lactose to glucose and galactose. The acidity of reduced lactose whey may be adjusted by the addition of safe and suitable ingredients.

Storage

Store and ship in a cool, dry environment at temperatures of less than 27°C and relative humidity less than 65%. Use within 6-9 months.

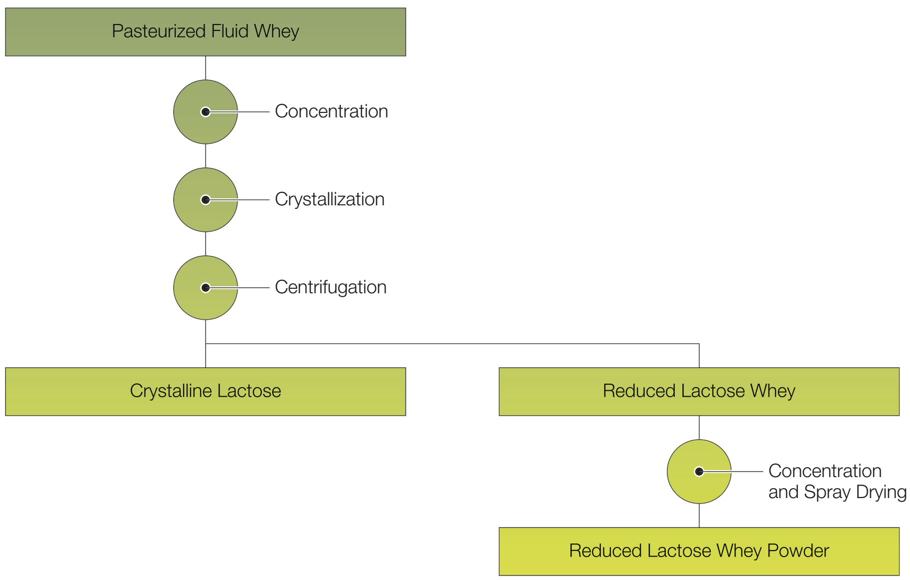
Typical Composition*

Protein	18.0%–24.0%
Lactose	52.0%–58.0%
Fat	1.0%–4.0%
Ash	11.0%–22.0%
Moisture	3.0%–4.0%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	≤30,000/g
Coliform	≤10/g
E. coli	Negative/g
Salmonella	Negative/100 g
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0 mg
Color	Cream to dark cream
Flavor	Normal whey flavor

Figure 4.3
Processing of Reduced Lactose Whey



4.4 DEMINERALIZED WHEY

Product Definition

Demineralized whey (also called reduced-minerals whey) is obtained by removing a portion of the minerals from pasteurized whey. Typical levels of demineralization are 25%, 50%, and 90%. The dry product may not exceed 7% ash. Demineralized whey is produced by separation techniques such as ion exchange, diafiltration or electrodialysis. The acidity of demineralized whey may be adjusted by the addition of safe and suitable ingredients.

Storage

Store and ship in a cool, dry environment at temperatures of less than 27°C and relative humidity less than 65%. Use within 9-12 months.

Typical Composition*

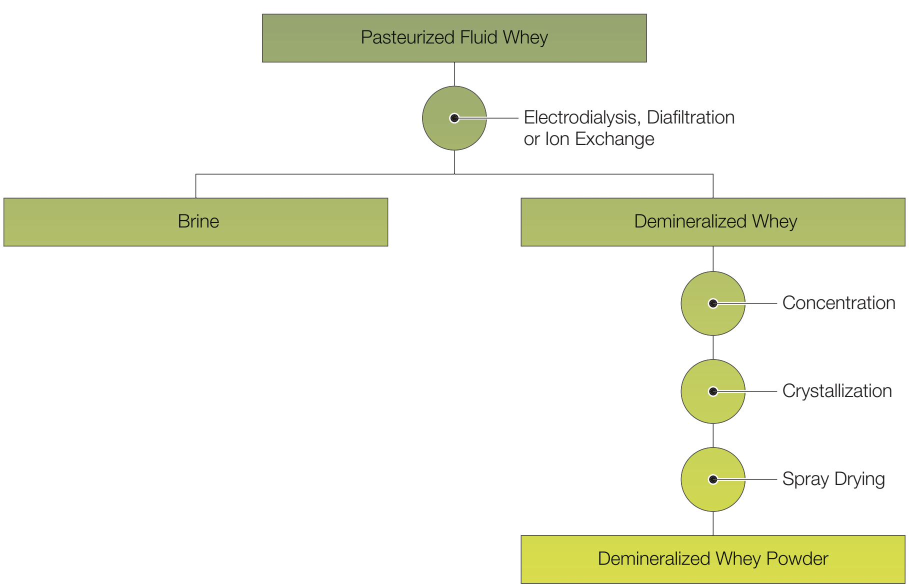
Protein	11.0%–15.0%
Lactose	70.0%–80.0%
Fat	0.5%–1.8%
Ash	1.0%–7.0%
Moisture	3.0%–4.0%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	≤30,000/g
Coliform	≤10/g
E. coli	Negative/g
Salmonella	Negative/100 g
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0 mg
pH	6.2–7.0
Color	Cream to dark cream
Flavor	Less salty whey flavor

*Please consult your U.S. supplier for detailed product specifications.

Figure 4.4
Processing of Demineralized Whey



4.5 WHEY PROTEIN CONCENTRATE 34% PROTEIN (WPC34)

Product Definition

Whey protein concentrate is obtained by removing sufficient non-protein constituents from pasteurized whey so that the finished dry product contains not less than 34% protein. WPC34 is produced by membrane separation processes. Acidity may be adjusted by the addition of safe and suitable ingredients.

Storage

Store and ship in a cool, dry environment at temperatures of less than 27°C and relative humidity less than 65%. Use within 9-12 months.

Typical Composition*

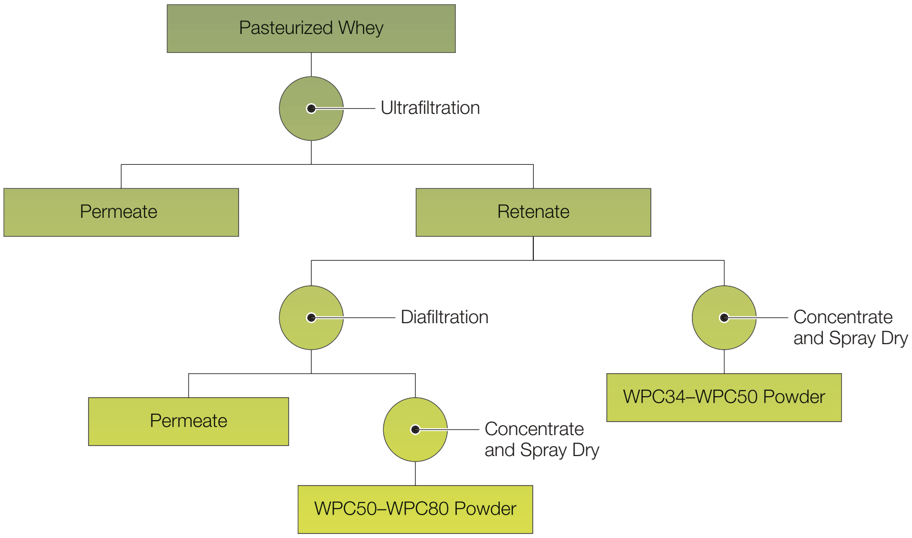
Protein	34.0%–36.0%
Lactose	48.0%–52.0%
Fat	3.0%–4.5%
Ash	6.5%–8.0%
Moisture	3.0%–4.5%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	≤30,000/g
Coliform	≤10/g
E. coli	Negative/g
Salmonella	Negative/100 g
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0 mg
pH	6.0–6.7
Color	White to light cream
Flavor	Bland, clean

*Please consult your U.S. supplier for detailed product specifications.

Figure 4.5
Processing of Whey Protein Concentrates



Heat Stability of Whey Protein Concentrates

By DR. A. HUGUNIN
Consultant,
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The heat stability of whey protein concentrates in food systems is influenced by a variety of factors such as pH, duration and intensity of the heat treatment, amount of calcium and presence of other ingredients.

Specifically, the following factors influence heat stability:

- Temperature >75°C
- Acidity, pH 3.5-6.0
- Protein concentration >5%
- Calcium and magnesium
- Lactose, sugar and fat concentration

In UHT-treated beverages, whey proteins can be denatured and flocculate if the process is not controlled and the formula adapted as needed. Manufacturers can also modify the production process to increase the heat-stability of whey proteins.

A typical heat stability test for heat-resistant whey protein concentrates included preparing a 100 ml solution of an 8% solution of WPC, heating to 70°C, cooling down to room temperature, autoclaving at 125°C for 10 minutes, cooling to room temperature, filtering the solution and measuring solids in the filtrate. The ingredient is considered heat-stable if over 95% of the solids pass through the filter (measured as % solids in filtrate/original solids).

Test method courtesy of Glanbia Nutritionals USA.

4.6 WHEY PROTEIN CONCENTRATE 50% PROTEIN (WPC50)

Product Definition

Whey protein concentrate is obtained by removing sufficient non-protein constituents from pasteurized whey so that the finished dry product contains not less than 50% protein. WPC50 is produced by membrane separation processes. Acidity may be adjusted by the addition of safe and suitable ingredients.

Storage

Store and ship in a cool, dry environment at temperatures of less than 27°C and relative humidity less than 65%. Use within 9-12 months.

Typical Composition*

Protein	50.0%–52.0%
Lactose	33.0%–37.0%
Fat	5.0%–6.0%
Ash	4.5%–5.5%
Moisture	3.5%–4.5%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	≤30,000/g
Coliform	≤10/g
E. coli	Negative/g
Salmonella	Negative/100 g
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0 mg
pH	6.0–6.7
Color	White to light cream
Flavor	Bland, clean

4.7 WHEY PROTEIN CONCENTRATE 60% PROTEIN (WPC60)

Product Definition

Whey protein concentrate is obtained by removing sufficient non-protein constituents from pasteurized whey so that the finished dry product contains not less than 60% protein. WPC60 is produced by membrane separation processes. Acidity may be adjusted by the addition of safe and suitable ingredients.

Storage

Store and ship in a cool, dry environment at temperatures of less than 27°C and relative humidity less than 65%. Use within 9-12 months.

Typical Composition*

Protein	60.0%–62.0%
Lactose	25.0%–30.0%
Fat	1.0%–7.0%
Ash	4.0%–6.0%
Moisture	3.0%–5.0%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	≤30,000/g
Coliform	≤10/g
E. coli	Negative/g
Salmonella	Negative/100 g
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0 mg
pH	6.0–6.7
Color	White to light cream
Flavor	Bland, clean

4.8 WHEY PROTEIN CONCENTRATE 75% PROTEIN (WPC75)

Product Definition

Whey protein concentrate is obtained by removing sufficient non-protein constituents from pasteurized whey so that the finished dry product contains not less than 75% protein. WPC75 is produced by membrane separation processes. Acidity may be adjusted by the addition of safe and suitable ingredients.

Storage

Store and ship in a cool, dry environment at temperatures of less than 27°C and relative humidity less than 65%. Use within 9-12 months.

Typical Composition*

Protein	75.0%–78.0%
Lactose	10.0%–15.0%
Fat	4.0%–9.0%
Ash	4.0%–6.0%
Moisture	3.0%–5.0%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	≤30,000/g
Coliform	≤10/g
E. coli	Negative/g
Salmonella	Negative/100 g
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0 mg
pH	6.0–6.7
Color	White to light cream
Flavor	Bland, clean

*Please consult your U.S. supplier for detailed product specifications.

4.9 WHEY PROTEIN CONCENTRATE 80% PROTEIN (WPC80)

Product Definition

Whey protein concentrate is obtained by removing sufficient non-protein constituents from pasteurized whey so that the finished dry product contains not less than 80% protein. WPC80 is produced by membrane separation processes.

Storage

Store and ship in a cool, dry environment at temperatures of less than 27°C and relative humidity less than 65%. Use within 9-12 months.

Typical Composition*

Protein	80.0%–82.0%
Lactose	4.0%–8.0%
Fat	4.0%–8.0 %
Ash	3.0%–4.0%
Moisture	3.5%–4.5%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	≤30,000/g
Coliform	≤10/g
E. coli	Negative/g
Salmonella	Negative/100 g
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0 mg
pH	6.0–6.7
Color	White to light cream
Flavor	Bland, clean

*Please consult your U.S. supplier for detailed product specifications.

4.10 WHEY PROTEIN ISOLATE (WPI)

Product Definition

Whey protein isolate is obtained by removing sufficient non-protein constituents from whey so that the finished dry product contains not less than 90% protein.
WPI is produced by membrane separation processes or ion exchange.

Storage

Store and ship in a cool, dry environment at temperatures of less than 27°C and relative humidity less than 65%. Use within 9-12 months.

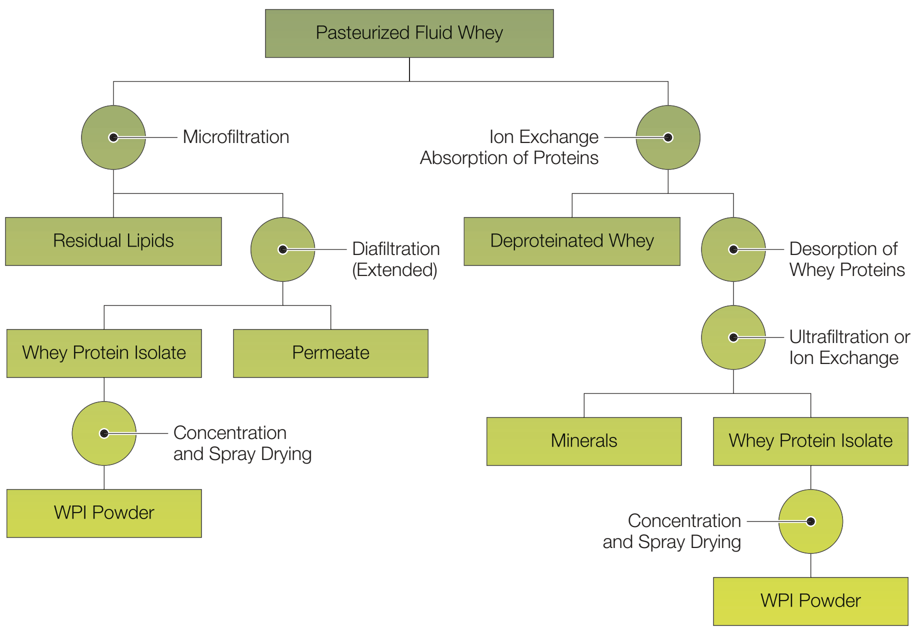
Typical Composition*

Protein	90.0%–92.0%
Lactose	0.5%–1.0%
Fat	0.5%–1.0%
Ash	2.0%–3.0%
Moisture	4.5%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	≤10–30,000/g
Coliform	≤10/g
E. coli	Negative/g
Salmonella	Negative/100 g
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0 mg
Color	Cream
Flavor	Bland, clean

Figure 4.10
Processing of Whey Protein Isolate



4.11 LACTOFERRIN

Product Definition

Lactoferrin is a 78 kilodalton glycoprotein consisting of single polypeptide chain linked to two glycans by N-glycosidic linkages. Its average concentration in cow's milk is 10 mg/l but lactoferrin is found in higher concentration in whey protein products: 30-100 mg/l of sweet whey. Lactoferrin is now produced commercially using cation exchange cross-flow membranes. It can also be isolated by chromatography and other methods. Lactoferrin is not only a source of amino acids but also a regulatory factor with broad biological roles that have been well documented.

Typical Composition*

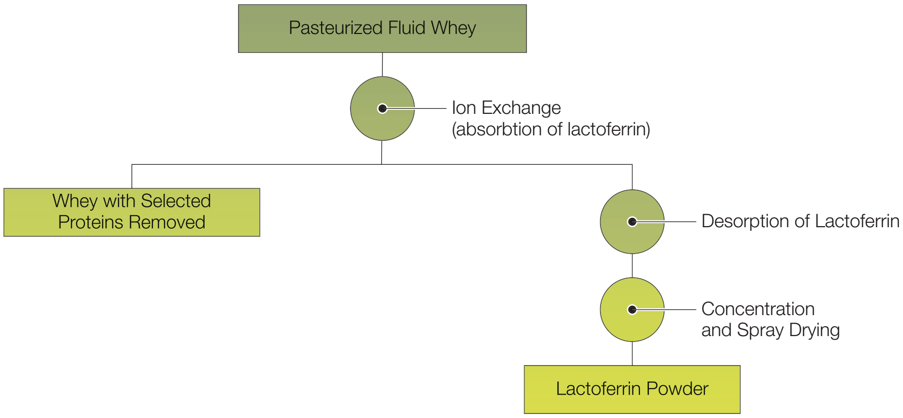
Protein content	>90%
Lactoferrin purity	>90%
Moisture	<5%
Ash	<1.5%
Iron saturation	
Low	<10 mg/100 g of protein
Medium	35 mg/100 g of protein
High	>100 mg/100 g of protein

Physical and Other Characteristics*

Form	Powder
pH	6–7
Solubility	>99%
Iron binding capacity	>85%
Standard Plate Count	<1000 cfu/g
Coliform	<10 cfu/g
Salmonella	0 cfu/g

*Please consult your U.S. supplier for detailed product specifications.

Figure 4.11
Processing of Lactoferrin



Functions and Benefits of Lactoferrin

Antibacterial Properties of Lactoferrin

Bactericidal and bacteriostatic activities have been attributed to the iron-scavenging properties of lactoferrin. Lactoferrin binds iron very strongly and makes this essential component unavailable to bacteria. Evidence from a number of studies, however, indicates that the antimicrobial mechanism of lactoferrin is more complex than simple nutritional deprivation. Other bacterial inhibitory effects have been ascribed to the binding of lactoferrin to enterocyte lactoferrin receptors. It was also found that bovine milk-derived lactoferrin was more potent than human lactoferrin against various Gram-negative and Gram-positive bacteria at concentrations between 0.3 µM and 3.0 µM. In another study on animals, lactoferrin appeared to protect against septic shock, an often fatal complication of bloodstream infections. Those who are particularly vulnerable to septic shock include the elderly, surgical patients and people with AIDS or other conditions that disable the immune system. Antiviral effects of lactoferrin against several types of human viruses have also been reported.

Inhibition of Free Radicals

Another biological function ascribed to lactoferrin is the protection against oxidative damage, by scavenging excess iron that catalyzes the undesired formation of free radicals. The excess formation of free radicals such as superoxides or hydroxyl radicals are among the main causes of the skin damage characterized by the appearance of wrinkles and other aging symptoms.

Iron Transport

Although considerable attention has been paid to many functions of lactoferrin, its primary nutritional contribution is presumed to be related to its iron-binding characteristics. Several studies have demonstrated that iron-saturated lactoferrin is an effective form of transport for iron in the diet. Lactoferrin is used in infant formulas to improve iron balance. Iron-saturated lactoferrin is a good source of readily bioavailable supplemental iron that can be used in dietary supplements, sports drinks and bars, and foods formulated specially for women. An additional advantage is that lactoferrin does not induce constipation as some inorganic iron supplements may. In Japan, new patents have focused on using iron-saturated lactoferrin to enrich foods such as fats and oils.

Milk and Dairy Products in Cancer Prevention: Focus on Lactoferrin

Milk and dairy products constitute an important part of the Western style diet. A large number of epidemiological studies have been conducted to determine effects of consumption on cancer development. It has been proposed that, whereas fats in general could promote tumor development, individual milk fats like conjugated linoleic acid could exert inhibitory effects. There is also considerable evidence that calcium in milk products protects against colon cancer. According to recent research reports, whey proteins may also be beneficial, as shown in human and animal studies. Experimental data have demonstrated that bovine lactoferrin inhibits colon carcinogenesis in the post initiation stage in animal studies. Results of other animal models have provided further indication that lactoferrin might find applications as a natural ingredient of milk with potential for chemoprevention of colon and other cancers.

Tsuda, U. et al. Milk and dairy products in cancer prevention: focus on bovine lactoferrin. Mutat. Res. 2000. (4)462:227-33.

Promotion of Cell Growth, Stimulation of Immunity

Lactoferrin has been shown to have beneficial effects on cell growth at the intestinal level. Lactoferrin ingestion may lead to more rapid restoration of normal digestive functions.

Recently, a few studies indicated that lactoferrin can stimulate a variety of cells of the immune defense system. Lactoferrin may present benefits as a supplement for the elderly or individuals with compromised immunity.

Antioxidant

Lactoferrin has the ability to bind and transport free iron and other divalent metal ions that catalyze the formation of superoxide radicals. This ability makes lactoferrin a potential inhibitor of oxidative processes that are metal-ion catalyzed. In that respect, lactoferrin has antioxidant properties. A Japanese patent describes a functional food product containing oils and fats fortified with iron in the form of iron-lactoferrin. The iron-lactoferrin acts both as a source of iron and as an antioxidant for the oil and fat in the food.

Stimulation of Bifidobacteria

Lactoferrin has been reported to stimulate the growth of Bifidobacteria. The importance of lactoferrin as a potent growth promoter of some strains of Bifidobacteria has been confirmed in recent studies. For this reason and the ones listed above, lactoferrin appears to be a health enhancing ingredient that offers benefits in dairy foods and other nutraceuticals formulated with probiotic cultures. Studies on infants have shown that supplementation with lactoferrin (100 mg/100 ml of formula) resulted in increased concentrations of Bifidobacterium species after three months of feeding.

Current Applications for Lactoferrin

Increased demand for natural antibiotics and for components to supplement infant formula and other specialty foods has stimulated interest in the isolation and effective utilization of lactoferrin. Lactoferrin is available commercially with different levels of iron saturation, ranging from <10 mg/10 g to over 100 mg/100 g of protein (see specification table). Products with a high level of iron can provide iron supplementation, while lactoferrin with low saturation is used for its bactericidal and bacteriostatic properties.

The major use for lactoferrin to date is infant formula. The addition of lactoferrin enriches the formulas, making them more similar to human milk, which naturally contains 20 more times lactoferrin. Iron-saturated lactoferrin is also utilized to enhance the absorption of iron.

Non-food uses of lactoferrin have developed in recent years. For example, the antibacterial activity of lactoferrin is utilized in toothpaste and mouthwash. An antibacterial mouthwash, for example, contains a combination of lactoferrin, lactoperoxidase and lysozyme.

4.12 LACTOPEROXIDASE

Product Definition

Lactoperoxidase is a glycoprotein with a molecular weight of 77.5 kilodaltons. It is an enzyme and natural anti-microbial agent present in sweet whey at a concentration of about 1-30 mg/l. Lactoperoxidase is part of a group of enzymes, which has antibacterial effects. Whey-based lactoperoxidase is relatively heat resistant.

Stability and Storage

Lactoperoxidase should be stored at 2-8°C. It is stable for over 6 months.

Typical Composition*

Protein	92%
Moisture	5%
Ash	3%

Physical and Other Characteristics*

Form	Green/brown powder
pH	6–7
Solubility (at <2% in water)	>99.9%
Standard Plate Count	<1000 cfu/g
Coliforms	<1/g
Staph. Aureus	Neg. in 1 g
Salmonella	Neg. in 5 g
Yeasts and mold	<10/g

*Please consult your U.S. supplier for detailed product specifications.

Function and Benefits of Lactoperoxidase

Antibacterial, Preservative Effects
Lactoperoxidase inactivates or kills a broad spectrum of microorganisms through an enzymatic reaction. The reaction involves two co-factors, hydrogen peroxide and thiocyanate ions, which, together with lactoperoxidase, constitute the lactoperoxidase system. Lactoperoxidase can inhibit certain Gram-negative bacteria (including E. coli and some strains of Salmonella) and is bacteriostatic against Gram-positive bacteria. The effectiveness of the lactoperoxidase system is dependent upon environmental conditions such as pH, temperature and cell density. In the presence of hydrogen peroxide and thiocyanate, the enzyme has an antibacterial effect against Gram-negative bacteria.

The lactoperoxidase system is a major part of the antibacterial activity in milk. The natural occurrence of lactoperoxidase can be used in the preservation of milk. Recently, lactoperoxidase has been added to yogurts to prevent additional acid production during storage.

Current Applications for Lactoperoxidase

Nutritional Products
Protection of intestinal flora, milk replacer or electrolyte additive to substitute for the use of antibiotics in the prevention of some neonatal infections.

Personal Care Products
Mouth care and skin care products, for the prevention of cavities and gingival infections, to prevent skin infections.

Based on clinical evidence, brushing teeth with toothpaste supplemented with lactoperoxidase reduces dental caries. Lactoperoxidase is also used in cosmetics and personal care items such as mouthwash, shampoos, and acne preparations.

Dairy Products
Preservation systems.

4.13 GMP (GLYCOMACROPEPTIDE)

Product Definition

Glycomacropeptides are isolated from fresh cheese whey using unique ion exchange and membrane technology. The powder is light colored, homogeneous, and free flowing. The flavor of the product is clean, and bland.

The glycosylated portion of caseino-macropeptide (CMP) is formed by rennin cleaving k-casein from the casein micelle. Rennin is used only with cheeses that produce sweet whey, therefore GMP will not be present in acid whey. Rennin is a protease secreted in the neonate's stomach, suggesting that glycomacropeptide normally accompanies whey proteins rather than caseins through the intestinal tract. Glycomacopeptide can suppress appetite via stimulation of pancreatic hormone cholecystokinin (CCK) release, alter pigment production in melanocytes, act as a prebiotic and has immunomodulatory actions. Physiologic activity of GMP depends upon its glycosylation.

Storage

Store at temperatures below 25°C, relative humidity below 65% and in an odor free environment.

Typical Composition*

Purity	97% ± 1%
Lactose	<1.0%
Fat	0.6% ± 0.2%
Ash	6.3% ± 0.2%
Moisture	6.0% ± 0.2%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	<2,500/g
Coliform	<10/g
E. coli	Negative
Salmonella	Negative
Listeria	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Color	Light colored
Flavor	Clean, bland

4.14 DAIRY PRODUCTS SOLIDS (PERMEATE)

Product Definition

This term is used to designate a "family" of products which have common specifications: 59% minimum lactose; 10% maximum protein and; 27% maximum ash. Examples of products meeting these specifications are permeate and de-proteinized whey, as well as other products which are often marketed under a brand name.

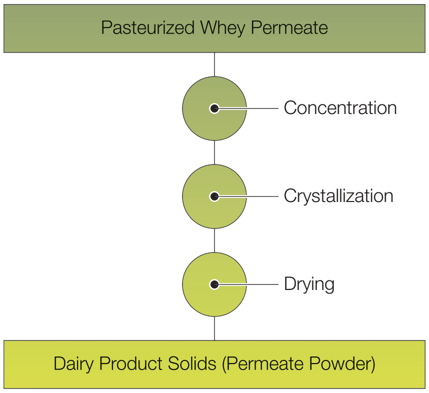
Manufacturers in the United States can use the term "dairy products solids," "de-proteinized whey," "modified whey" and "reduced protein whey" on the ingredient label.

Permeate

For the purpose of this manual, whey permeate is defined as a source of dairy solids obtained by the removal of protein and some minerals and lactose from whey. The separation is accomplished by ultrafiltration and diafiltration. The product is appropriately labeled to reflect protein, ash, and lactose content. The acidity of permeates may be adjusted by the addition of safe and suitable ingredients. Permeates represent an economical source of dairy solids for food and feed applications.

The major products are:
- Feed grade permeate
- Food grade permeate

Figure 4.14
Processing of Permeate



Feed Grade Permeate Typical Composition*

Protein	3.5–4%
Lactose	82.0%
Fat	0.2%
Ash	8.5%
Moisture	4–5%
Calcium	800 mg/100 g
Phosphorus	600 mg/100 g
Sodium	1000 mg/100 g
Magnesium	180 mg/100 g

Food Grade Permeate Typical Composition*

Protein	3.0 –8.0%
Lactose	65.0–85.0%
Fat	1.5% (maximum)
Ash	8.0–20.0%
Moisture	3.0–5.0%
Calcium	870 mg/100 g
Phosphorus	720 mg/100 g
Sodium	570 mg/100 g
Magnesium	130 mg/100 g

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	<30,000/g
Coliform count	<10/g
Listeria	Negative
Salmonella	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5–15.0 mg
pH	5.7–6.5
Color	White to cream
Flavor	Salty, slightly sweet
Appearance	Free-flowing powder

*Please consult your U.S. supplier for detailed product specifications.

Feed Applications

Whey products, including high-carbohydrate permeate, are consumed by a wide variety of animal species. The greatest utilization in the feed industry is by swine. Dairy and veal calves, dogs and cats, poultry and other animals nutritionally benefit from the uses of whey products in rations.

Food Applications

- Functions as a direct replacement of other dairy solids in many applications.
- Dissolves easily and blends uniformly.
- Functions as a source of lactose and proteins in bakery blends and products:
  - to give the brown crust in bakery blends and products.
  - to improve the appearance, color, flavor and texture of the finished product.
  - to reduce levels of sweeteners such as sucrose or corn syrups in bread applications.
  - to extend shortenings, giving more richness with minimum fat in piecrusts.

Other Uses and Benefits

Permeates as Media for Yeast

Permeates can be used as a medium to grow some types of yeast. In this process, a 65% protein permeate-yeast product can be produced to be fed to swine and other animals.

Permeates as Media for Other Fermentations

Permeates can be used as a medium to produce:
- Lactic acid, acetic acid, calcium magnesium acetate, citric acid and propionate
- Ethanol
- Methane
- Single cell proteins
- Glycerol
- Lipids and oils

Typical Applications

For feed, bakery, confectionery, fermentation, and other food and non-food products as:
- A cost-efficient source of lactose and other dairy solids in calf milk replacers, and swine feeding programs.
- A source of lactose and other dairy solids in bakery, confectionery products.
- An ingredient in yeast-leavened products.
- A raw material for fermentation medium in producing bacteriosin.
- A source of hydrolyzed permeates.

4.15 MINERAL-CONCENTRATED WHEY (REDUCED LACTOSE WHEY)

Product Definition

Mineral-concentrated whey is produced by the partial removal of lactose from whey. The mineral concentrated whey is spray-dried to provide a highly functional ingredient. Products defined as mineral-concentrated whey are:

- Reduced lactose whey
- Fractionated whey

Reduced lactose whey is defined in the U.S. Code of Federal Regulations (21 CFR 184.1979 (a)(2) 1991) as the substance obtained by the removal of lactose from whey. The lactose content of the finished dry product shall not exceed 60%. Removal of the lactose is accomplished by physical separation techniques such as crystallization, filtration, or dialysis. As with whey, reduced lactose whey can be used as a fluid, concentrate, or a dry product form. The acidity of reduced lactose whey may be adjusted by the addition of safe and suitable pH-adjusting ingredients.

Mineral-concentrated whey also functions to improve texture, flavor, solubility, and nutritional profile in food formulations. Foods containing mineral-concentrated whey will have a higher nutrient density than other comparable products.

The functions and benefits are:

- Good solubility, heat stability and economy.
- Lower lactose content helps minimize texture problems caused by lactose crystallization.
- High protein and mineral content helps provide the flavor and smooth texture desired in food products. Proteins contribute to the structure, texture, and integrity of the finished products by delivering the dispersibility and suspension characteristics of a colloidal system with the added benefit of an evenly distributed calcium content during processing.
- Conveys a milky flavor, helps emulsify added fats, provides good solubility and heat stability in sauces and gravies.
- A rich source of calcium, magnesium and phosphorus, which enhances nutritional value and flavor profile in comminuted meat products and sauces.

Typical Applications

For dairy, meat, confectionery, bakery, snacks, seasonings, soups, sauces and gravies, dry mixes, follow-up formula, frozen desserts, and nutritional soft drinks as:

- A cost-efficient source of dairy solids with a high mineral content.
- An alternative to other calcium sources or milk powders, when lower lactose concentrations are desired and higher mineral concentration is required.
- A nutritional ingredient in powdered beverages, nutritional drinks, dairy products, powdered soups and desserts and baked goods.

Reduced Lactose Whey

Typical Composition*

Protein	18.0–24.0%
Lactose	50.0–60.0%
Fat	2.5% (maximum)
Ash	14.0–22.0%
Moisture	3.0–5.0%
Calcium	940 mg/100 g
Magnesium	220 mg/100 g
Phosphorus	1,150 mg/100 g
Potassium	4,400 mg/100 g
Sodium	1,840 mg/100 g

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	10,000/g
Coliform count	10/g
E. coli	Negative
Listeria	Negative
Salmonella	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	15.0mg/25 g (maximum)
Appearance	Free-flowing powder
Color	Light cream
Flavor	Clean, slightly salty, whey flavor

*Please consult your U.S. supplier for detailed product specifications.

4.16 DAIRY MINERALS, CALCIUM

Whey Products as Source of Calcium

Calcium can be obtained in diet by various sources, but the most highly recommended source is dairy products. Dairy products are a significant source of calcium with high bioavailability. The ingredient milk calcium is derived from milk by a unique separation technique. Whey-based products are an excellent and cost-efficient source of dairy calcium.

Photo courtesy: Glanbia Nutritionals USA

Functions and Benefits of Dairy Calcium

- Dairy calcium is 100% natural (all natural "clean" label appeal) and contains a range of other minerals, such as phosphorus and magnesium.
- Dairy calcium contains very low levels of materials such as lead and aluminum, compared to some other sources of calcium.
- Calcium absorption from dairy sources is determined by the physiological need of the body for calcium, and when that need is high, essentially all of the dairy calcium is available for absorption. Sources of dairy calcium are more readily absorbed by the gastrointestinal tract than other sources, such as calcium carbonate, resulting in a relatively higher bioavailability.
- Calcium absorption from dairy sources is higher by Beta-galactosidase-deficient subjects than by subjects with a regular Beta-galactosidase.
- Lactose increases the dairy calcium absorption and bioavailability in infants compared to sucrose and starch hydrolyzates.
- Research studies link a higher calcium intake (1,575 mg/day) from dairy calcium during the first 20 weeks of pregnancy with a lower risk of gestational hypertension.
- Recommendations to consume dairy calcium as a way to meet calcium requirements also provides an opportunity to increase intake of potassium and magnesium, which have been linked with reduced risk of hypertension.
- The risk of consuming excessive amounts of calcium is also lower with dairy foods than with calcium supplements.

Range of Commercial Products Available

Whey products represent an ideal economical source for dairy calcium. The products are:

- Whey Powders
  – Sweet-type
  700-800 mg calcium/100 g
  – Acid-type
  2,054 mg calcium/100 g
- Reduced lactose whey
  800-900 mg calcium/100 g
- Whey protein concentrates
  500-700 mg calcium/100 g
- Whey protein isolates
  100-300 mg calcium/100 g
- Deproteinized whey
  600-700 mg calcium/100 g
- Whey permeate
  800-900 mg calcium/100 g
- Milk calcium minerals
  Approx. 23-28 g calcium/100 g

Milk Calcium Minerals and Concentrates

Product Description

Milk calcium minerals are a natural milk calcium that is predominantly in the form of calcium phosphate. There are various types of natural milk calcium products although most are fractionated from whey by one of several different isolation techniques, dried, and then ground into fine powders.

Production Processes

There are several different processes that can be used to manufacture milk minerals. The following is an example, please contact your supplier for specific and detailed information.

Typical Composition*

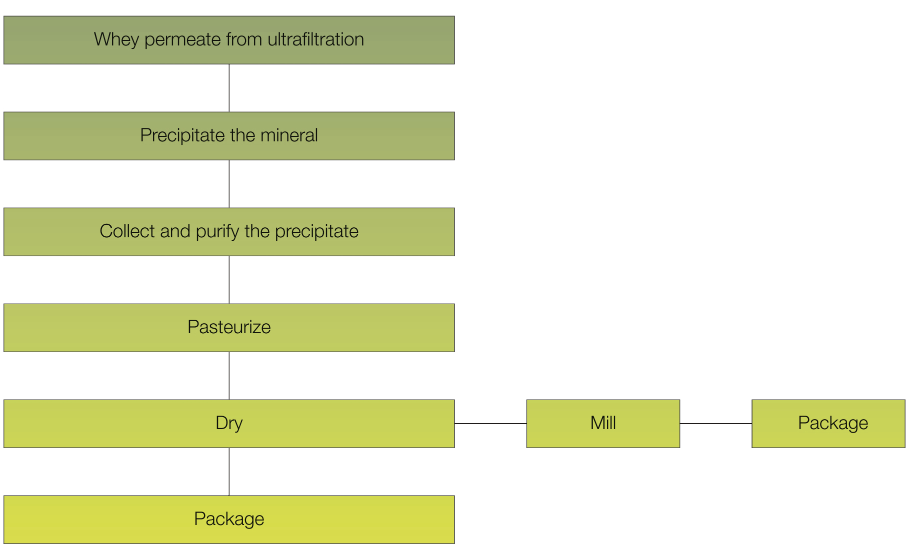
Calcium	23–28.0%
Phosphorus	13.0–14.00%
Ca: P ratio	1.7:1–2:1
Total Minerals	76.0–77.5%
Moisture	4.0%–7.0%
Protein	1.0–8.0%
Lactose	1.0–6.0%

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	<10,000/g
Coliform	<10/g
Coagulase-positive Staphylococci	Negative
Listeria	Negative/50 g
Salmonella	Negative/50 g
Other characteristics	
Appearance	Free-flowing powder
Color	White to cream color
pH (10%)	6.5–7.5 (may vary)
Particle size	Coarse: 95% <10 µm Fine: 95% <100 µm

*Please consult your U.S. supplier for detailed product specifications.

Figure 4.16
Processing of Milk Minerals



Information courtesy of Glanbia USA.

Typical Applications

- Nutritional supplements, such as tablets, capsules, nutritional bars, chews
- Calcium-fortified foods, such as baked goods, processed meats, dairy and confectionery products
- Calcium-fortified beverages, such as juices and dairy drinks

LACTOSE PRODUCTS DEFINITION, COMPOSITION, FUNCTIONS 5

OVERVIEW

Lactose is, by weight, the most abundant of the milk solids. Lactose is a disaccharide composed of the monosaccarides Alpha-D-glucose and Beta-D-galactose. It is a reducing sugar that can, in some circumstances, react freely with amino groups in proteins. Lactose is a useful source of dietary energy and it plays a role in calcium absorption. Several types and grades of lactose products exist, to meet the needs of various end-users. The U.S. dairy industry also can formulate custom and specialty products and blends. Please consult your supplier for additional information.

5.1 INDUSTRIAL GRADE LACTOSE PRODUCTS

Product Definition

Industrial grade lactose products describe a range of lactose products used in feed, fermentation and technical applications. Feed grade lactose is produced from deproteinized whey that is evaporated, crystallized and dried. The finished dry product contains more than 98% (w/w) lactose.

Typical Composition*

Lactose (minimum)**	98%***
Protein	0.5–1.0%
Fat	0.1%
Ash	0.1%–0.5%
Total Moisture**	4.5–5.5%

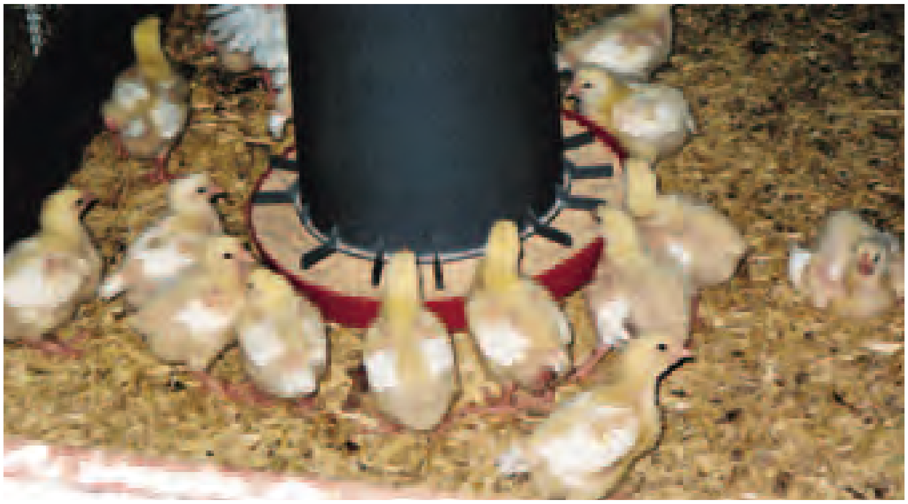
*Please consult your U.S. supplier for detailed product specifications.

**Includes bound water (includes all forms such as monohydrate).

***Includes all forms such as monohydrate.

Physical and Chemical Aspects*

Typical microbiological analysis	
Standard Plate Count	<50,000/g
Coliform count	100/g (maximum)
E. coli	Negative
Listeria	Negative
Salmonella	Negative/750g
Coagulase-positive Staphylococci	Negative
Other characteristics	
Appearance	Crystalline, free-flowing powder
Color	Light yellow
Flavor	Slightly sweet
Solution	Slightly turbid, slight yellow, slight whey aroma



5.2 FOOD GRADE LACTOSE PRODUCTS

Product Definition

Food grade lactose is produced by concentrating whey or permeate (a co-product of whey protein concentrate production) to supersaturate the lactose, then removing and drying the lactose crystals. Special processes of crystallization, as well as grinding and fractionated sifting, produce types of lactose which differ in particle size distribution. Today, the industry offers several types of lactose ranging from superfine to extra coarse crystals for all applications.

According to the U.S. Code of Federal Regulations (21CFR 168.122), lactose is the carbohydrate normally obtained from whey. It may be anhydrous or contain one molecule of water of crystallization or be a mixture of both forms.

The lactose content is not less than 98%, with the sulfated ash content not more than 0.3%, both on a dry basis. The pH of a 10% solution is not less than 4.5 or more than 7.5.

Typical Composition*

Lactose (minimum)**	99.0%***
Protein	0.1%
Fat	0%
Ash	0.1%–0.3%
Total Moisture**	4.5–5.5%

*Please consult your U.S. supplier for detailed product specifications.

**Includes bound water.

***Includes monohydrate or anhydrous.

Physical and Chemical Characteristics*

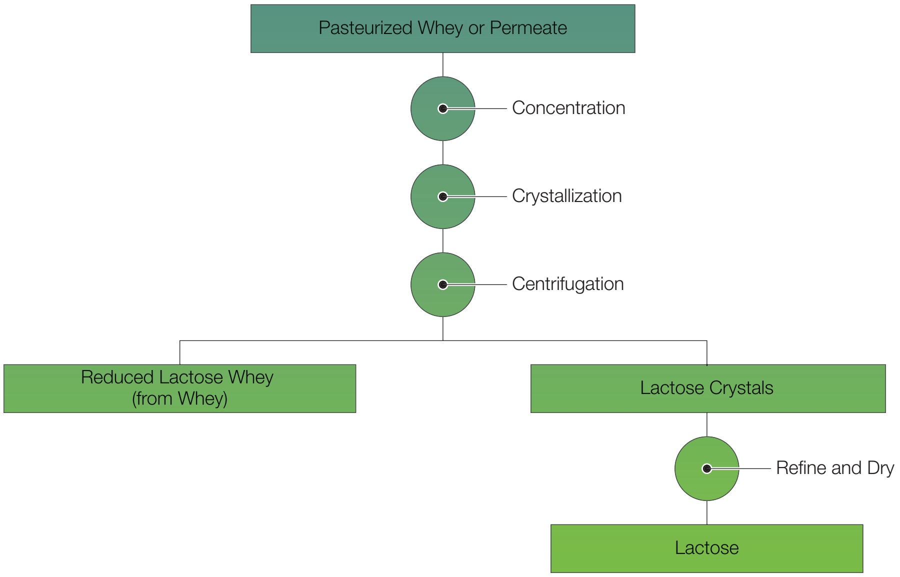
Typical microbiological analysis	
Standard Plate Count	5–15,000/g
Coliform count	<10/g
E. coli	Negative
Listeria	Negative
Salmonella	Negative
Coagulase-positive Staphylococci	Negative
Other characteristics	
Scorched particle content	7.5 mg/25 g (maximum)
Bulk density, tapped	0.7–0.9 g/ml (depends upon mesh size specification)
Appearance	Crystalline, free-flowing powder
Color	White to pale yellow
Flavor	Slightly sweet
Solution	Clear, colorless to slightly yellowish, odorless

Typical Composition of Lactose Products*

Component	Fermentation	Crude Grade	Edible Grade	National Formulary
Lactose	98.0	98.4	99.0	99.8
Non-hydrate moisture	0.35	0.30	0.50	0.10
Protein	1.00	0.80	0.10	0.01
Ash	0.45	0.40	0.20	0.03
Fat	0.20	0.10	0.10	0.00
Acidity as lactic acid	†	†	<2	<1

†Not typically determined.
Source: Morrissey, P.A. (1985).

Figure 5.2
Processing of Lactose



Functions and Benefits of Lactose in Food Grade Products

Natural
All natural "clean" label appeal.

Sweetness
Lactose is about 25% of the sweetness of sucrose. The benefits of lactose include:

- A clean sweet taste without after-taste.
- Increased solids content, viscosity and improved textural qualities without making the product too sweet.
- Providing an energy source in infant formulas, where too much sweetness is undesirable.

Synergistic effects of lactose with other food ingredients may include either sweetness enhancement or sweetness suppression. Examples of benefits include:

- Masking of the bitter after-taste of saccharine by lactose.
- Prolonging the duration of xylitol sweetness by lactose in chewing gum.

Solubility
Lactose is less soluble than sucrose, fructose and dextrose. The relative solubility of lactose (25°C) is about 30% that of sucrose. Although the relatively low solubility of lactose can limit its use in certain applications, the lower solubility can be an advantage in many applications, such as instantized products and microwaveable products. An example of such a benefit is because of its lower solubility lactose tends to crystallize to agglomerate thereby improving the dispersibility of certain products.

Crystallization
Lactose alters the crystallization behavior of other sugars, and is largely used to control crystallization in food formulations. With the addition of lactose, both lactose and sucrose crystals become smaller, and the tendency of sucrose crystals to combine together is reduced, thereby avoiding sandiness and yielding a softer and smoother crystalline mass.

Browning
Lactose can be used in food formulations to provide a desirable brown color. Heating lactose causes caramelization and/or Maillard reactions which produces brown colors. Lactose, as a reducing sugar, promotes controlled browning in foods by reacting with proteins, peptides and amino acids to form compounds which are highly flavored and golden brown in color.

- Caramelization occurs at high temperatures. When heated to 150°C-160°C, lactose turns yellow, then brown at 175°C. This property is beneficial in the production of caramel-type confections.
- Maillard reactions occur at lower temperatures. Lactose is very important in inducing controlled browning in baked goods, meat and sausage products, confectionery items and microwaveable foods. For example, in specialty breads, lactose produces a golden brown crust color that does not discolor or fade during storage.

Fermentation and Rheological Properties
Lactose has an exceptional position compared to sucrose and sugar replacers, because of its functionality. Because lactose is not fermented by baker's yeast (Saccharomyces cerevisiae) it remains available for Maillard and other reactions. Benefits include:

- Increased crust browning for enhanced color and flavor, and improved appearance in baking processes.
- Increased dough and pastry yields, and volume.
- Decreased fermentation tone and improved fermentation performance in baking.
- Leveling up inferior flour quality.

Lactose can enhance creaming of shortening and can be added at higher levels than sucrose or dextrose, without causing excessive sweetness. Benefits include:

- Fat reduction possible in cakes and pastries.
- Reduced sweetness in cakes possible.

Lactose is not fermented by brewer's yeast. Benefits can include:

- Increased viscosity, improved mouth-feel and flavor in beer production.

Moisture Absorption
Crystalline lactose absorbs very little moisture at high humidity compared to other sugars. The non-hygroscopic and free flow nature of Alpha-lactose monohydrate makes it an ideal dispersing agent for powdered foods.

Flavor, Aroma, and Color Absorption and Retention without Excessive Sweetness

Lactose is much more effective in binding and retaining flavor and aroma compounds than other sugars. This function enables a reduction in added flavors, resulting in possible cost savings. Lactose also absorbs and enhances the color compounds very effectively. The benefits of lactose:

- Provides a method of adequate dispersion and slow release of roasted coffee flavor.
- Masks off-tastes, and carries flavors and aromas in spices, seasonings and dry blends.
- Preserves red colors in sauces and ketchup.

Typical Applications

For bakery, confectionery, snack, frozen desserts, diabetic, dietetic, infant formula, baby foods, jams and preserves, sweeteners, instantized powders, meat products, savory mixes, soups and sauces, beer production, nutraceuticals and other foods as:

- A "modifier" in humanized infant formula to correct the balance between carbohydrate and protein in breast milk replacers based on cows' milk.
- A carbohydrate source for fermentation by selected starter cultures to produce lactic acid for preservation in dry sausage types, such as salami.
- An aid in masking off-flavors and after-tastes caused by emulsifying salts, phosphates, and other bitter compounds in the meat and sausage industry.
- A carrier of flavorings, aroma compounds, coloring agents and artificial sweeteners in confectioneries, baked goods, spices, and tabletop sweeteners.
- An additive to improve the free-flowing properties of powdered foods such as instantized spray dried milk powder.
- An encapsulating agent for volatile flavoring compounds or milkfat or other fats.
- A flavor and color-enhancer in salad dressings, mayonnaise, soups, sauces, baked goods and in fermentation processes.
- A crystallization behavior "modifier" of the other sugars to improve body, texture, chewiness and shelf-life of confectioneries such as chocolates, fondants, caramels, fudges, sweetened condensed milk and candy coating processes.

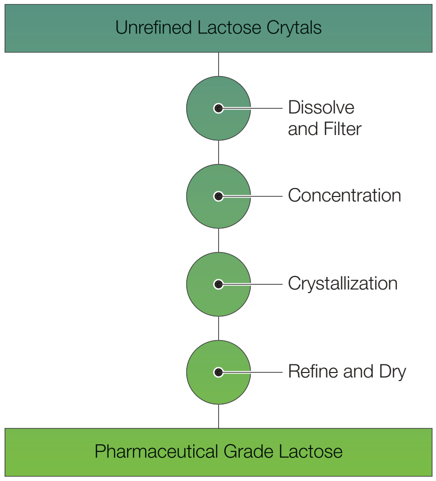
5.3 PHARMACEUTICAL GRADE LACTOSE

Product Definition

Pharmaceutical grade lactose is produced by concentrating whey or permeate (a co-product of whey protein concentrate production) to oversaturate the lactose, then removing, refining, drying and milling the lactose crystals.

Pharmaceutical grade lactose is produced to meet rigid specifications such as, specific form and size distribution—monohydrate, crystalline, 40 mesh to 325 mesh, and a spray-dried mixture of crystalline and amorphous lactose for all applications. All products meet the requirements of the U.S., European, and Japanese Pharmacopeia.

Figure 5.3.1
Processing of Pharmaceutical Lactose



Typical Composition*

Lactose (minimum)	99.8%
Protein	0.01%
Fat	0%
Ash	0.03%
Moisture	4.5-5.5%

Physical and Chemical Characteristics*

Typical microbiological analysis	
Standard Plate Count	<100/g
E. coli	Negative
Salmonella	Negative
Coagulase-positive Staphylococci	Negative
Penicillin residues	Negative
Pesticide residues	Negative
Other characteristics	
Acidity or alkalinity	0.1 ml of 0.1N NaOH
Clarity and color: 10% 1 cm at 400 nm	0.01
Heavy metals	<5.0 ppm
Loss on drying	0.3%
Protein and light absorbing impurities:	
At 210–220 nm	0.06
At 210–300 nm	0.02
Residue on ignition	0.1%
Specific rotation	+54.4° to +55.9°
Bulk density, tapped	0.70–0.90 g/ml (depends upon mesh size specification)
Appearance	Pure white, crystalline, free-flowing powder
Solution	Clear, colorless, odorless
Flavor	Slightly sweet

*Please consult your U.S. supplier for detailed product specifications.

Defining Pharmaceutical Grade Lactose

By HARRY G. BRITTAIN
Center for Pharmaceutical Physics,
Milford, NJ

Copy courtesy:
Foremost Farms USA
Baraboo, WI

Lactose has an empirical formula of $C_{12}H_{22}O_{11}$, and a molecular weight of 342.30 Daltons. A variety of experiments have established its structure as 4-O-(Beta-D-galactopyranosyl)-D-glucopyranose (Figure 5.3.2).

Lactose is obtained from milk in crystalline form by evaporation of the whey remaining after removal of the fat and precipitation of the casein. It is less sweet than sucrose, and is also less soluble in water than either sucrose or glucose.

Types of Lactose

Lactose can be obtained in either a hydrated (specifically as a monohydrate) or anhydrous form. The monohydrate form is obtained by crystallization out of water solution around ambient temperature, while the anhydrous form is produced by crystallization at temperatures exceeding 93°C, e.g., spray drying. The monohydrate form will not evolve its water when dried under ordinary conditions. The two forms exhibit different crystal shapes (Figures 5.3.3 and 5.3.4).

Lactose may also be spray dried, to yield a widely used and free flowing form that consists largely of the monohydrate form (depends of drying conditions). This substance also exhibits a characteristic particle shape (Figure 5.3.5).

Figure 5.3.2
Empirical Formula of Lactose

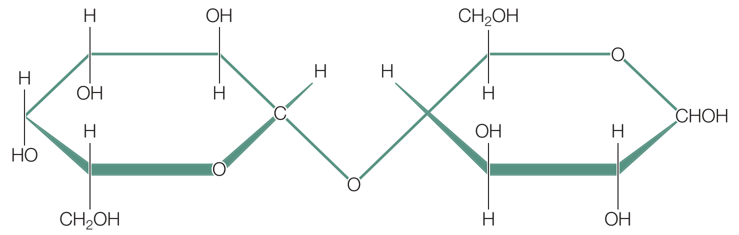


Figure 5.3.3
Lactose Monohydrate

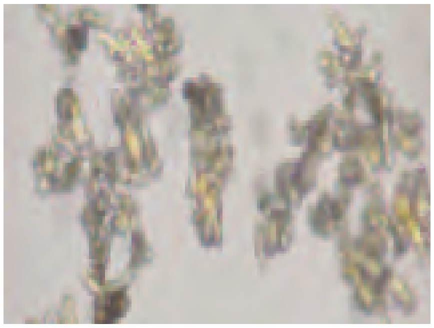


Figure 5.3.4
Lactose Anhydrate (Anhydrous Lactose)

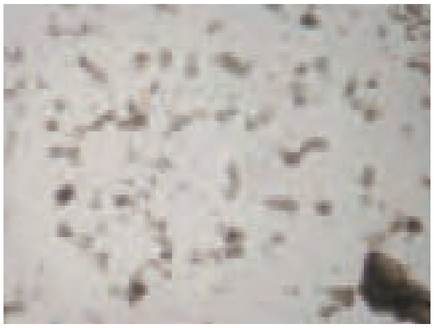
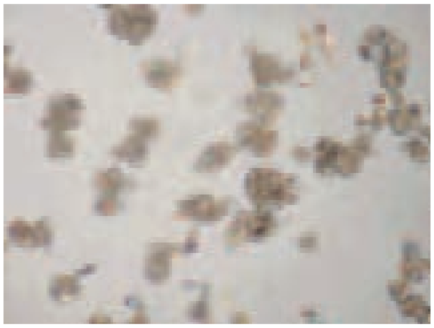


Figure 5.3.5
Lactose Spray Dried



Uses of Lactose in Pharmaceutical Products

Lactose displays little or no reactivity with most drugs, and generally displays an acceptable degree of stability. For lactose to be pharmaceutically acceptable (i.e., NF grade), lactose must be demonstrated to be free of protein. The substance is available in a wide variety of particle size distributions, the coarsest of which exhibit excellent degrees of flowability, as do the spray-dried modifications.

Most typically, regular lactose monohydrate is used as a diluent in tablets that have been manufactured by the wet granulation process. The spray-dried monohydrate form and the anhydrous form are usually employed in formulations that are to be dry granulated and directly compressed. The spray-dried modification is also widely used as a filling agent in capsule formulations.

The various types of lactose exhibit superior physical properties that have enabled its widespread use in the pharmaceutical industry. The most important of these include the following:

- Lactose is derived from natural sources, has only a moderately sweet taste.
- Lactose is readily obtained in a chemically pure form, which is cost-effective with other excipients.
- Lactose is, for the most part, both chemically and physically non-reactive with most drug substances.
- Lactose is available in a variety of natural and modified forms, each of which exhibits advantageous and characteristic physical properties (i.e., flowability, particle size, compactability, and stability).

In addition to its use as a filler and diluent in tablets and capsules, lactose has also found an important role as the carrier of choice for delivery of drug substances through inhalation. After being coated onto respirable grade lactose, drug substances may be delivered through dry powder inhalation to relatively deep locations in the lower airways of the lung. Here an optimization of particle size is most important, and it has been established that the use of either too large or too small particles is detrimental. The morphology of the carrier lactose particles also affects the efficiency of delivery. As a result, respirable lactose has been developed into a high-technology excipient, and its range of application is predicted to greatly increase in the future.

Test Procedures Defining Pharmaceutical Grade Lactose

Test Method	Lactose Monohydrate	Lactose Anhydrate
Clarity and color of solution	A solution of 1g in 10ml of boiling water is clear and nearly colorless.	A solution of 1g in 10ml of boiling water is clear and nearly colorless.
Specific rotation	Dissolve 10g by heating in 80ml of water at 50°C. Allow to cool, and add 0.2ml of 6N NH4OH. Allow to stand for 30 minutes, and dilute with water to 100ml. The specific rotation at 20°C is +54.4°–+55.9.°	Dissolve 10g by heating in 80ml of water at 50°C. Allow to cool, and add 0.2ml of 6N NH4OH. Allow to stand for 30 minutes, and dilute with water to 100ml. The specific rotation at 20°C is +54.4°–+55.9.°
Acidity or alkalinity	Dissolve 6g by heating in 25ml of carbon dioxide-free water, cool, and add 0.3ml of phenolphthalein test solution. The solution is colorless, and not more than 0.4ml of 0.1 N NaOH is required to produce a red color.	Dissolve 6g by heating in 25ml of carbon dioxide-free water, cool, and add 0.3ml of phenolphthalein test solution. The solution is colorless, and not more than 0.4ml of 0.1 N NaOH is required to produce a red color.
Loss on drying	Dry the sample at 80°C for 2 hours. The regular monohydrate form loses not more than 0.5% of its weight, and the modified monohydrate form loses not more than 1.0% of its weight.	Dry the sample at 80°C for 2 hours.It loses not more than 0.5% of its weight.
Residue on ignition	When a sample is ignited at a temperature of 600 ± 25°C, not more than 0.1% remains.	When a sample is ignited at a temperature of 600 ± 25°C, not more than 0.1% remains.
Water content	Between 4.5% and 5.5%, when determined using Karl Fischer titration on a sample dissolved in 2:1 methanol/formamide.	Not more than 1.0%, when determined using Karl Fischer titration on a sample dissolved in 2:1 methanol/formamide.
Heavy metals	Dissolve 4g of sample in 20ml of warm water, add 1ml of 0.1 N hydrochloric acid, and dilute with water to 25ml. The metals are precipitated with sulfide, and the sample compared to a suitable reference. The limit is 5µg/g.	Dissolve 4g of sample in 20ml of warm water, add 1ml of 0.1 N hydrochloric acid, and dilute with water to 25ml. The metals are precipitated with sulfide, and the sample compared to a suitable reference. The limit is 5µg/g.
Microbial limits	The total aerobic microbial count does not exceed 100/g, the total combined molds and yeasts count does not exceed 50/g, and it meets the requirements of the test for absence of *Escherichia coli*.	The total aerobic microbial count does not exceed 100/g, the total combined molds and yeasts count does not exceed 50/g, and it meets the requirements of the test for absence of *Escherichia coli*.
Content of alpha and beta anomers	Not applicable.	The relative anomeric amounts are determined using gas chromatography after the test sample has been derivatized using a silylation reagent.
Protein and light absorbing impurities	Measure the light absorption of a 1% (w/v) solution in the range of 210 to 300nm. The absorbency divided by the path length (in centimeters) is not more than 0.25 within 210 to 220nm, and not more than 0.07 within 270 to 300nm.	Measure the light absorption of a 1% (w/v) solution in the range of 210 to 300nm. The absorbency divided by the path length (in centimeters) is not more than 0.25 within 210 to 220nm, and not more than 0.07 within 270 to 300nm.
Labeling	Where the labeling states the particle size distribution, it also indicates the d10, d50, and d90 values and the range for each. Modified Lactose Monohydrate is also labeled to indicate the method of modification.	Where the labeling states the particle size distribution, it also indicates the d10, d50, and d90 values and the range for each.

NUTRITIONAL PROPERTIES OF WHEY, LACTOSE AND MILK MINERALS PRODUCTS 6

6 NUTRITIONAL PROPERTIES OF WHEY, LACTOSE AND MILK MINERALS PRODUCTS

Edited by CARLA SORENSEN
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Whey protein concentrates have been produced commercially for a number of years and have long been valued for their functional characteristics. At the same time, the excellent nutritional properties of whey proteins became more widely recognized, and factors such as their high quality, rich amino acid profile, and ease of digestibility expanded their market opportunities.

OVERVIEW

Today whey protein is a common ingredient in products including infant formula, specialized enteral and clinical protein supplements, and sports nutrition products. More recently the product mix has been expanded to include unique products specific to weight management and mood control.

Advancements made in the development of processing technologies, including ultrafiltration, microfiltration and diafiltration membrane, and ion-exchange, have made it possible to separate individual protein fractions into relatively pure forms. This commercial separation has expanded the use of whey protein fractions as nutritional supplements and as ingredients in cosmetic and pharmaceutical products. Examples of recent advances include the following: 1) whey proteins as physiologically functional food ingredients, 2) Alpha-lactalbumin and Beta-lactoglobulin, major whey protein components, as nutritional and specialized physically functional food ingredients and 3) minor whey protein components, such as lactoferrin and glycomacropeptides, as specialized food ingredients and important biotechnological reagents.

Scientific evidence continues to accumulate that whey contains a variety of nutrient factors capable of improving health and preventing disease. In particular, newer information in the areas of nutrient bioavailability, regulation of cellular growth and maturation, probiotics, prebiotics, toxin elimination and pathogenic virulence indicates that there is potential to produce healthful functional foods and pharmaceuticals to reduce both infectious and chronic diseases using whey products. The full health-enhancing potential of whey and whey components in such products is currently underdeveloped, although an increasing number of manufacturers are starting to take advantage of the nutritional and functional benefits of whey when designing new products. As consumer demand for health-promoting foods increases, whey products are an obvious choice to fill this role in the market.

Whey products contain proteins, vitamins, a wide variety of minerals and other constituents such as lactose and lipids. The amounts vary by product and Table 6 provides detailed information on the composition of common whey protein products. The composition of whey may vary, depending on milk source and the manufacturing process involved. Please consult your U.S. supplier for more information.

Table 6
Nutritional Composition of Selected Commercial Whey Products

		Value per 100 grams of Edible Portion					
Nutrient Ingredient	**Units**	**Dry Sweet Whey[1]**	**Whey Protein Concentrate 34% WPC34[2]**	**Whey Protein Concentrate 80% WPC80[2]**	**Whey Protein Concentrate 80% Hydrolyzed**	**Whey Protein Isolate WPI[2]**	**Whey Protein Isolate Hydrolyzed**
Proximates							
Water	g	3.19	3.93	4.11	4.00	4.50	4.50
Energy	kcal	353.00	369.00	412.00	400.00	371.00	360.00
Energy	kj	1476.00	1542.00	1722.00	1672.00	1550.00	1504.00
Protein	g	12.93	34.36	80.00	80.00	90.75	90.00
Total lipid (fat)	g	1.07	3.93	6.60	6.25	0.50	0.50
Carbohydrate, by difference*	g	74.46	50.80	5.31	6.00	0.87	0.50
Ash	g	8.35	6.99	3.98	3.75	3.38	4.50
Minerals							
Calcium, Ca	mg	796.00	569.00	423.00	400.00	600mg	200.00
Iron, Fe	mg	0.88	0.89	1.20		5.00	5.00
Magnesium, Mg	mg	176.00	104.00	50.00	50.00	15.00	10.00
Phosphorus, P	mg	932.00	547.00	0.00	325.00	25.00	30.00
Potassium, K	mg	2080.00	1680.00	517.00			800.00
Sodium, Na	mg	1079.00	630.00	255.00	225.00	450.00	1000.00
Zinc, Zn	mg	1.97	0.21				
Copper, Cu	mg	0.07					
Manganese, Mn	mg	0.009	0.06				
Selenium, Se	mcg	27.20					
Vitamins							
Vitamin C, total ascorbic acid	mg	1.50	2.00				
Thiamin	mg	0.519	0.36				
Riboflavin	mg	2.208	1.80				
Niacin	mg	1.258	0.37				
Pantothenic acid	mg	5.62					
Vitamin B_6	mg	0.58					
Folate, total	mcg	12.00					
Folic acid	mcg	0.00					
Folate, food	mcg	12.00					
Folate, DFE	mcg_DFE	12.00					
Vitamin B_{12}	mcg	2.37					
Vitamin A, IU	IU	44.00	100.00				
Vitamin A, RE	mcg_RE	10.00					
Vitamin E	mg_ATE	0.029					
Lipids							
Fatty acids, total saturated	g	0.684					
Fatty acids, total monounsaturated	g	0.297					
Fatty acids, total polyunsaturated	g	0.034					
Cholesterol	mg	6.00	97.00				

Note: Blank fields indicate that no data was available.
[1] Source: USDA Nutrient Database for Standard Reference, SR14. http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl
Other data including fluid whey and dry acid whey available at this site.
[2] Data obtained from product specification sheets and nutrition analysis provided by U.S. whey manufacturers.
Please consult your supplier for exact information.

Table 6 (continued)
Nutritional Composition of Selected Commercial Whey Products

		Value per 100 grams of Edible Portion				
Nutrient Ingredient	**Units**	**Dry Sweet Whey[1]**	**Whey Protein Concentrate 34% WPC34[2]**	**Whey Protein Concentrate 80% WPC80[2]**	**Whey Protein Isolate WPI[2]**	**Whey Protein Isolate Hydrolyzed**
Amino acids						
Tryptophan	g	0.205	0.630	1.200	1.500	1.300
Threonine	g	0.817	2.380	5.360	6.250	6.100
Isoleucine	g	0.719	1.920	4.800	5.900	4.500
Leucine	g	1.186	3.520	8.080	13.000	9.400
Lysine	g	1.030	2.920	7.840	9.150	9.800
Methionine	g	0.241	0.600	1.600	2.050	2.000
Cystine	g	0.253	0.750	2.720	3.100	1.700
Phenylalanine	g	0.407	1.050	2.480	2.300	
Tyrosine	g	0.363	0.630	2.240	3.150	3.200
Valine	g	0.697	1.760	4.456	5.350	4.100
Arginine	g	0.375	0.700	2.000	2.650	1.700
Histidine	g	0.237	0.710	1.200	1.350	2.400
Alanine	g	0.598	1.580	4.080	6.000	3.300
Aspartic acid	g	1.269	3.630	8.000	9.000	8.900
Glutamic acid	g	2.248	4.840	13.280	13.000	11.400
Glycine	g	0.280	0.660	1.360	2.350	1.300
Proline	g	0.786	1.900	5.120	4.800	8.600
Serine	g	0.622	1.800	4.080	5.000	4.100
Other						
*Lactose	g	74.46	50.80	5.31	0.87	0.50

Note: Blank fields indicate that no data was available.
[1] Source: USDA Nutrient Database for Standard Reference, SR14. http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl
Other data including fluid whey and dry acid whey available at this site.
[2] Data obtained from product specification sheets and nutrition analysis provided by U.S. whey manufacturers.
Please consult your supplier for exact information.

6.1 NUTRITIONAL PROPERTIES OF WHEY PRODUCTS

By DR. ROSEMARY L. WALZEM
Kelberg Animal & Food Science Center, Texas A&M University, College Station, TX

Copy contributed by:
U.S. *Dairy Export Council, Arlington*, VA

Proteins

Whey proteins have been used for many years as highly nutritious food supplements. Nevertheless, research is still uncovering aspects of their simple ability to provide amino acids. The physical properties of whey proteins in the gut are quite distinct from the properties of caseins. Micellar casein forms clots within the stomach, which slows their exit from the stomach and increases their hydrolysis prior to entering the small intestine. Alternatively, whey proteins are "fast" proteins, and they reach the jejunum almost immediately. Their hydrolysis within the intestine, however, is slower than that of the caseins, thus their digestion and absorption occurs over a greater length of the intestine. It has been argued that this provides a unique delivery of both the amino acids and peptides.

The biological value of whey protein is high in comparison to that of other dietary proteins, as is their content of essential amino acids. Protein quality refers to the ability of a particular protein to provide nitrogen in a balanced pattern of essential and non-essential amino acids. In humans, growth and nitrogen retention have been used to assess protein quality for infants and nitrogen balance for adults. The protein efficiency ratio (PER) of a protein source measures the weight gain of young animals per gram of protein eaten over a given time period. Protein needs differ throughout the life cycle, and proteins differ in their ability to provide readily used amino acids for these differing needs. As a result, different amounts and types of proteins can best meet the needs of specific groups, e.g., infants, athletes or the elderly, and at different physiological conditions, e.g., after stress. The relatively high proportion of sulfur amino acids, especially cysteine, is predicted to be of especial value in conditions of immune activation. The high cysteine content of whey would be predicted to spare tissue proteins because acute phase proteins that are produced in response to immune challenge are themselves inordinately enriched in cysteine.

Milk proteins are often divided into two broad classes: caseins and whey proteins. Approximately 80% of the proteins in milk are caseins, and these are coagulated and separated as cheese curd (see Table 6.1.1).

The whey proteins (also called milk serum proteins) are the proteins that remain soluble when caseins are coagulated by either enzyme or acid. The whey proteins include Beta-lactoglobulin, Alpha-lactalbumin, bovine serum albumins, immunoglobulins and protease-peptones fractions. Part of the protease-peptones have been identified as proteolytic degradation products of Beta-casein.

The heat-sensitive whey proteins (Beta-lactoglobulin, Alpha-lactalbumin, bovine serum albumins and immunoglobulins) differ in molecular weights and properties such as isoelectric points (see Table 6.1.2).

Table 6.1.1
Concentration of Major Milk Proteins

Protein	Concentration (g/l)	Approximate % of Total Protein
Caseins	**24–28**	**80**
Alpha-casein	15–19	42
Beta-casein	9–11	25
Kappa-casein	3–4	9
Gamma-casein	1–2	4
Whey proteins	**5–7**	**20**
Beta-lactoglobulin	2–4	9
Alpha-lactalbumin	1–1.5	4
Protease-peptones	0.6–1.8	4
Blood proteins	1.4–1.6	2
serum albumin	0.1–0.4	1
Immunoglobulins	0.6–1.0	2
Total		**100**

Source: Fennema, 1965.

Table 6.1.2
Characteristics of Heat-Sensitive Proteins in Cheese Whey

Protein	Approximate % of Whey Proteins	Molecular Weight	Isoelectric Point
Beta lactoglobulin	48	18,400–36,800	5.2
Alpha-lactalbumin	19	14,200	5.1
Protease-peptones*	20	4,000–80,000	5.1–6.0
Blood proteins:	13	69,000	4.8
serum albumin	5	69,000	4.8
immunoglobulins	8	160,000	5.5–6.8
Total	**100**		

*Degradation products of various milk proteins including Beta-caseins.
Source: de Wit, 1981; Harper, 1984.

The functional properties of whey proteins are influenced by a number of compositional and processing variables including:

- pH: The pH values increase logarithmically. A pH 4.0 solution is 10 times as acidic as a pH 5.0 solution, and 100 times as acidic as a pH 6.0 solution. As the concentration of hydrogen ions in a solution increases, the negative charge on the proteins is neutralized. At the pH identified as the isoelectric point for a protein, the charge on the protein becomes neutral, and the proteins will not migrate in an electric field. At this pH, the physical properties of proteins (solubility, conductivity, stability and degree of hydration) are at a minimum.
- Calcium ion concentration
- Salt concentration
- Previous heat treatments
- Residual lipid content
- Protein concentration

Digestion of Whey Proteins

As stated above, unlike caseins, whey proteins empty rapidly from the stomach and transit to the upper intestine. This difference in digestion rate is not insignificant and has been shown to influence whole body protein synthesis. The whey proteins Beta-lactoglobulin, Alpha-lactalbumin, lactoferrin and immunoglobulins have been detected intact in the intestinal lumen. Lactoferricin generation from lactoferrin within the human stomach, as well as survival of this protein within the intestine of a rat model, was recently demonstrated by sensitive and specific SELDI affinity mass spectrometry. Some dietary proteins and polypeptides reach the intestinal mucosa in significant amounts and then may be absorbed intact. Transcytosis of intact protein was detected for Beta-lactoglobulin, Alpha-lactalbumin, prolactin and lactoferrin, but not for casein. The absorption of large molecules in antigenic and biologically-active quantities is believed to play a role in the different physiological and immunological responses that contribute to oral tolerance and its regulation. The nature of whey protein digestion seems to contribute to retention of whey protein and peptide bioactivity within the gut.

Although the major role of whey proteins is to provide dietary nitrogen and amino acids, there are several physiological roles that have been either defined or suggested for minor whey proteins or peptides. These components can provide passive protection against infection; modulate digestive and metabolic processes; and act as growth factors for different cell types, tissues and organs.

Properties of Individual Whey Proteins

Alpha-lactalbumin

Alpha-lactalbumin comprises 2%–5% of skim milk total protein. This protein is a calcium-binding protein and has a high affinity for other metal ions, including Zn^{+2}, Mn^{+2}, Cd^{+2}, Cu^{+2} and Al^{+3}. Alpha-lactalbumin is the "B" protein of the lactose synthase enzyme complex, which catalyzes the last step in the biosynthesis of lactose. For this reason, it is of major interest in terms of the control of milk secretion. Purified Alpha-lactalbumin is used commercially in infant formula because it is structurally and compositionally similar to the major protein in human breast milk. Purified Alpha-lactalbumin is also used as a sports food protein, as it is a good source of branched-chain amino acids. Branched chain amino acids are utilized by muscle and several reports have associated improved performance with the consumption of diets enriched in them.

Lactoferrin

In recent years it has become clear that certain dietary proteins and peptides have specific biological activities. Protein fractions such as lactoferrin have been identified that have bioactive properties at low concentration. Lactoferrin is a protein with a number of exciting functional properties, and is already used in many commercial products such as chewing gum, infant formulas, sports and functional foods, veterinary and feed specialties, and personal care items such as mouthwash and toothpaste.

Lactoferrin comprises only a small portion, 0.2%–0.8%, of skim milk protein but is a higher proportion of whey, and is relatively easily enriched by taking advantage of its unusual cationic binding properties. Lactoferrin has antibacterial and antioxidant properties and is the major nonspecific disease resistance factor found in the mammary gland, and it probably mediates protection against microbial infection of the mammary gland. Lactoferrin sequesters and solubilizes iron, thus controlling the amount of iron in metabolism. Although isolated about 30 years ago, the precise biological roles of lactoferrin are still emerging. Bovine lactoferrin is highly homologous to other lactoferrins and transferrins.

Lactoferrin has long been considered an important component of the host defense against microbial infection. Although the antimicrobial activity of lactoferrin has been well described, its mechanism of action has not been completely characterized. The antimicrobial effect of lactoferrin is linked to its iron-binding activity because lactoferrin binds iron and renders it unavailable for bacterial growth, and more recent investigations have found that the protein is directly bacteriostatic via its actions on bacterial membranes.

Lactoferrin also has the ability to modulate immune functions and is a growth factor for various cell types. Lactoferrin also exhibits antioxidant activity.

Enzymes

Enzymes are quantitatively minor proteins in milk, and most are not synthesized by the mammary gland but arrive adventitiously following passage from blood or from the breakdown of mammary cells. The enzymes are mainly destroyed in the process of digestion and are of little nutritional significance. Lactoperoxidase is an oxidoreductase that breaks down hydrogen peroxide. This component of milk and whey products is an enzyme with antibacterial properties. The lactoperoxidase system is recovered during the lactoferrin purification process and is used commercially in various cosmetics and as a food preservative. The lactoperoxidase system is a major part of the antibacterial activity of milk, is thermostable and is not inactivated by pasteurization. Lactoperoxidase has been studied as a means of controlling acidity development and pH shift during refrigerated storage of yogurt. Lactoperoxidase has been suggested for use as a natural preservative and it plays a role in the keeping quality of pasteurized milk. In combination with other preservatives, lactoperoxidase is being used as a cavity-inhibiting ingredient in dental products.

Specific Amino Acids in Whey

Sulfur-containing Amino Acids

Whey proteins have proportionately more sulfur-containing amino acids (cysteine, methionine) than casein, which contributes to their having a higher PER than casein, 3.2 versus 2.5. Any protein with a PER of 2.5 is considered good quality. The high sulfur-containing amino acid content of whey proteins is important to their ability to enhance immune-function and antioxidant status via modulation of the sulfur-containing tripeptide glutathione. Also, as whey proteins have a relative surplus of some essential amino acids (lysine, threonine, methionine, isoleucine), they are effective supplements to vegetable proteins, which often are limiting in those amino acids. Thus, whey proteins have favorable effects on many common proteins that have a PER of less than 2.5, including soya, peanuts, corn and wheat gluten.

Branched-chain Amino Acids

Among all protein sources, whey proteins contain the highest concentration of the branched-chain amino acids-L-isoleucine, L-leucine and L-valine. Virtually every amino acid present in sweet-type whey exceeds Food and Agriculture Organization/World Health Organization (FAO/WHO) nutritional intake recommendations, both for children aged 2–5 and for adults. For adults, whey proteins often offer more than double the minimum FAO/WHO standards.

Branched-chain amino acids must be present in the muscle cells to promote protein synthesis. However, these amino acids are unique as they are also metabolized for energy by muscle rather than by the liver. Through this action, they are thought to help increase carbohydrate bioavailability while helping to counteract muscle protein breakdown during exercise.

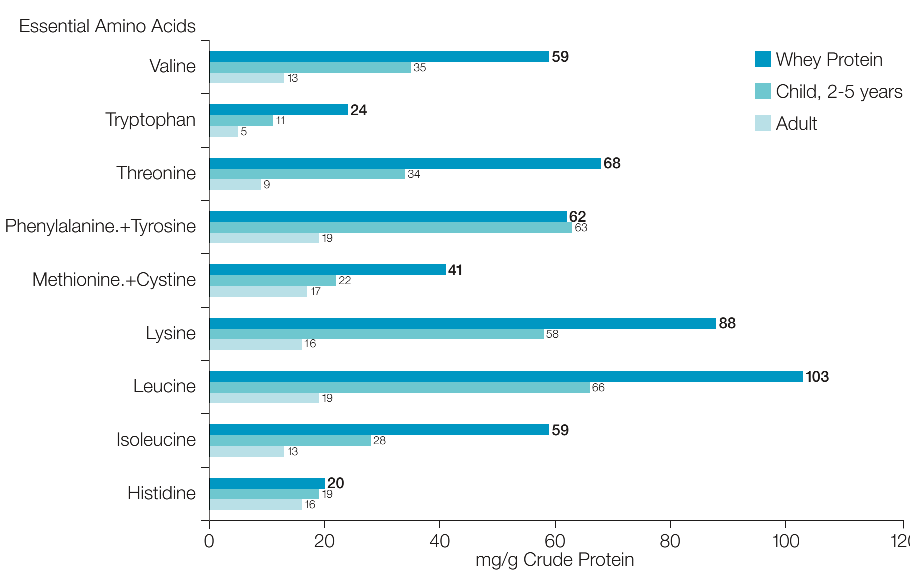
Branched-chain amino acids provide safe nutritional support for athletes and individuals seeking optimal lean muscle mass. A study with competitive wrestlers showed that a combination of moderate energy restriction and branched-chain amino acid supplementation induced significant and preferential losses of visceral adipose tissue, and allowed maintenance of a high level of performance. In another study, a mixture of the three branched-chain amino acids was supplied to subjects during two types of sustained intense exercise, a 30 km cross-country race and a full marathon. This study showed that intake of branched-chain amino acids during exercise can prevent or decrease the net rate of protein degradation caused by heavy exercise. Branched-chain amino acid supplements appeared to prevent chronic hypoxia-related loss of body mass and muscle loss in 16 subjects who participated in a 21-day trek at a mean altitude of 3,255 m. Although subjects in these cited studies consumed mixtures of pure branched-chain amino acids, researchers reported that whey protein is an excellent source of these amino acids: crude whey protein containing per gram 103 mg leucine, 59 mg isoleucine and 59 mg valine. Thus properly formulated low-lactose whey protein-containing products are prime sources of nutrients for sports nutrition foods and beverages.

The proteins of whey are easily digested and contain all the essential amino acids in the proper proportions, and they rate as an excellent nutritional source.

Using the Protein Digestibility-Corrected Amino Acid Scoring (PDCAAS) method, whey protein rates a value of 1.0 because it is highly digestible and it meets or exceeds the recommended amount of each essential amino acid. Using another method to measure protein quality—The Protein Efficiency Ratio (PER) value—whey also ranks high on the scale. The higher the PER value, the better the protein. Casein, the reference protein, has a PER value of 2.5. Proteins with a PER greater than 2.5 are considered to be quality proteins. Whey protein, with the PER greater than 3.0, is considered to be a nutritionally excellent protein.

Virtually every amino acid present in sweet-type whey exceeds Food and Agriculture Organization/World Health Organization (FAO/WHO) nutritional intake recommendations, both for children aged 2 to 5 and for adults (see Figure 6.1.3). In many cases, for adults, whey proteins offer more than double the minimum FAO/WHO standards.

Figure 6.1.3
Essential Amino Acid Profile of Whey Protein and Nutritional Requirements of Selected Groups (FAO/WHO)



Source: Glass, L. and T.I. Hedrick. FAO/WHO. 1976.

Whey Proteins compare favorably to many common proteins that have a PER of less than 2.5, including soy, peanuts, corn, and wheat gluten (see Figure 6.1.4.). These proteins have limited concentrations of certain essential amino acids. Because of whey protein's balanced amino acid profile, whey products are excellent ingredients for protein fortification. By fortifying certain vegetable proteins with whey proteins, scientists have achieved PER values significantly greater than 2.5 and greater than the average of the PER values for the two proteins. In each blend, whey protein contributed no more than 50% of the total protein.

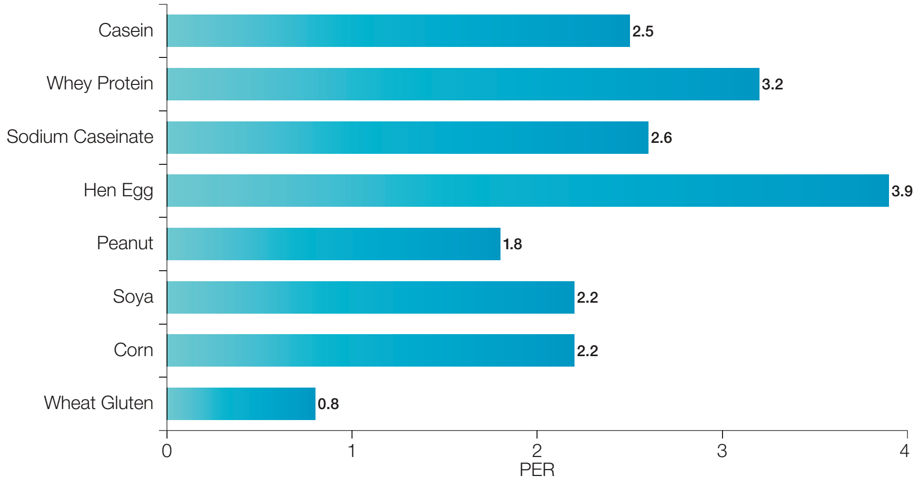
Vitamins

The water soluble vitamins in milk remain in the serum and are collected with the whey. The concentration of vitamin C is reduced during the processing, and whey is not considered a significant source of vitamin C. The concentration of other water soluble vitamins in sweet whey powder is presented in Table 6.1.5.

Vitamins are large molecules and they are concentrated by ultrafiltration. Whey products will naturally fortify the thiamin, riboflavin, pantothenic acid, vitamin B_6 and vitamin B_{12} content of foods. Suppliers can provide specific information on the vitamin contents of their whey products.

Vitamin A is the most abundant fat soluble vitamin in milk. Vitamins A, D, E, and K are separated with the milk fat that is entrapped in the curd and separated with the whey cream.

Figure 6.1.4
Protein Efficiency Ratios (PER) of Various Animal and Vegetable Proteins



Source: Anon. 1972.

Table 6.1.5
Water Soluble Vitamin Content of Sweet Whey Powder

	WHO Recommended Daily Intake*		
Vitamin	**Child 1-3 years**	**Adult Male**	**Sweet Whey Powder Content/100g****
Thiamin (B_1)	0.5 mg	1.2 mg	0.5 mg
Riboflavin (B_2)	0.8 mg	1.8 mg	2.2 mg
Niacin (PP)	9.0 mg	19.8 mg	1.3 mg
Pantothenic Acid	NA	NA	5.6mg
Vitamin B_6	NA	NA	2.4µg
Folic Acid	100.0 µg	200.0 µg	12.0 µg
Vitamin B_{12}	0.9 µg	2.0 µg	2.4 µg

Sources:
* World Health Organization. 1974.
** Potosi and Orr. 1976.

Minerals

Data in Table 6.1.6 indicates that whey powder is a good source of certain essential minerals. For mineral content of specific whey products, please refer to Section 6.7.

As the pH of milk decreases during acid cheese production, more of the salts dissociate. This results in higher concentrations of soluble calcium, magnesium, zinc and phosphorus in acid whey. The concentrations of calcium and other minerals may be altered during whey processing. Mineral concentrations are reduced by electrodialysis and ultrafiltration, and adjusted to achieve unique functional properties. Information for mineral content of specific products should be obtained from the supplier of the product.

Lactose

Lactose is a disaccharide that is hydrolyzed by the enzyme Beta-galactosidase into glucose and galactose molecules. The slow hydrolysis of lactose by the body during digestion generates a prolonged energy supply. Lactose stimulates the growth of acid forming lactobacilli in the intestinal tract.

Recent nutritional studies suggest that lactobacilli help fight intestinal disorders and that lactose could be used in dietary therapy for ailing infants.

Numerous studies have demonstrated that lactose increases calcium absorption and retention. It may also improve the absorption of magnesium and zinc. In animal studies, lactose extended life expectancy and reduced the accumulation of body fat.

Table 6.1.6
Essential Minerals Content of Acid and Sweet Whey Powders

Mineral	WHO Recommended Daily Intake* Adult Male	Acid Whey Powder Content/100g**	Sweet Whey Powder Content/100g**
Calcium	500 mg	2,054 mg	796 mg
Zinc	22 mg	6.31 mg	1.97 mg
Magnesium	300 mg	199 mg	176 mg
Phosphorus		1,348 mg	932 mg

Sources:
* World Trade Organization. 1974.
** Potosi and Orr. 1976.

The lactose content of whey products vary from about 74-75% in sweet whey, to less than 1% in whey protein isolate. Please refer to Table 6.1 or manufacturers' specifications for more data. Detailed information on the nutritional and physiological properties of lactose is presented in Section 6.9.

The information contained in this section is drawn from a review article which appeared in *Critical Reviews in Food Science, Vol. 42, pg.* 353-375. RL Walzem, CJ Dillard, JB German. "Whey Components: Millenia of Evolution Creates Functionalities From Mamalian Nutrition: What We Know and What We May Be Overlooking."

6.2 BIOLOGICAL PROPERTIES OF WHEY COMPONENTS

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Copy contributed by: American Dairy Products Institute Elmhurst, IL

Almost all of the individual whey proteins have been reported to have one or more biological activities, although the degree of evidence supporting the claims is variable. Some claims are strongly substantiated, whereas others are based on limited information. The status of the various activities is dynamic, with new information becoming available almost daily. The following table (Table 6.2.1) gives the biological activity and the different whey proteins reported to have that activity. An effort has been made to list the activities in decreasing order to the degree to which the claims are substantiated, although the demarcation is somewhat fuzzy. In the majority of cases, the biological activity in humans is not substantiated with clinical trials. Our base of knowledge is dynamic and rapidly expanding, with new information continually appearing. A much more solid information base can be expected over the next several years.

Table 6.2.1
Biological Activity of Whey Proteins

Biological Activity	Whey Proteins with Reported Activity*	Comments
Antimicrobial Action/wound healing	a) Lactoferrin, lactoperoxidase, lysozyme b) Lactoferricin (pepsin derived peptide from lactoferrin)	a) Supported by both in vitro and some in vivo studies. The proteins are being used/applied commercially; combinations are synergistic. b) More antimicrobial than lactoferrin.
Passive immunity—disease protection	a) Whey protein concentrates, colostrum derived b) Immunoglobulin concentrates; immunoglobulins	a) Have been proven effective in calves and pigs. b) Hyper-immunization increases specific Ig activity for some, not all bacterial antigens.
Bifidobacteria growth factor/control of intestinal microflora	Casein glycomacropeptide	a) Has been used commercially. Confirmed in trials with infants and one trial on human adults. b) Oligosaccharide portion considered most active.
Anti-viral activity	a) Lactoferrin b) Lactoferricin c) Whey protein concentrates	a) Supported by three in-vitro studies, one showing the antiviral property being independent of iron binding. b) Supported by single study. c) Only limited studies support this claim.
Anti-cancer activity	a) Whey protein concentrates b) Alpha-lactalbumin c) Lactoferrin	a) Fairly strong support based on cell culture. Studies and in vivo in mice and rats. b) Support based primarily on cell culture studies. c) Based on limited studies from one laboratory.
Gut microflora control	Whey protein concentrates	Support primarily on in vitro studies.
Immunomodulating activity	a) Whey protein concentrates b) Lactoferrin c) Casein glycomacropeptide d) Alpha-lactalbumin	a) Based on in vitro studies and several in vivo studies in mice—enhanced humoral antibody responses. b) Supported by cell culture studies and in vivo studies with experimental animals. c) Five reports supporting this activity—with different specific functions. d) Based on a single report.

*Where whey protein concentrates have been reported to have biological activity, the specific factor involved can not be determined in most cases. A specific component may be involved, or more probably the effect is caused by products formed by the action of digestive enzymes. These could include peptides, glycopeptides or oligosaccharide components.

Whey proteins have one or more of the following three biological functions in food:

- A source of essential amino acids
- A source of proteins for defense against microbial infections
- A source of growth factors and modulators

The biological properties of whey and its components have both current and future potential significance in the nutrition and health of people. Among the components that can be important are: Beta-lactoglobulin, Alpha-lactalbumin, BSA, immunoglobulins, lactoferrin, lactoperoxidase, proteose-peptone, milk fat globule membrane protein, glycomacropeptide, glycophosphopetides, other native and derived peptides, including whey protein hydrolysates, whey lipids [conjugated linoleic acid (CLA), sphingolipids and butyric acid].

The health and nutritional value of the components can be divided into several categories:

(a) high quality nutritional source of amino acids;
(b) anti-microbial action, especially in the gut;
(c) growth enhancement of desired gut microflora, such as bifidobacteria;
(d) immuno-enhancing properties;
(e) control of specific diseases, including cancer;
(f) antitoxin activity;
(g) provide the basis for development of infant foods similar to human milk through combinations of the different factors.

In some cases, whey protein concentrates and isolates will contain sufficient concentration of components to provide physiological functionality, and in other cases the components need to be concentrated or isolated. However, this review will focus primarily on the role of the individual whey proteins in nutrition and health.

Table 6.2.1 (continued)
Biological Activity of Whey Proteins

Biological Activity	Whey Proteins with Reported Activity*	Comments
Bacterial antitoxin activity	a) Lactoferrin b) Casein glycomacropeptide c) GMP derived peptides d) Glycated-Beta-lactoglobulin and glycated Alpha-lactalbumin	a) Multiple reports confirming activity. b) Supported by single report. c) Supported by several studies. d) Support only by a single in vitro study—not confirmed.
Promotion of growth of some animal cells	Lactoferrin	One in vivo study and 2 patents claiming application.
Platelet binding (anti-thrombic activity)	a) Lactoferrin b) GMP derived peptide	a) Limited evidence to support this claim. b) Three studies in support.
Anti-inflammatory	Lactoferrin	Based on single 1996 report.
Anti-hypertensive	Hydrolyzed whey protein isolate, GMP derived peptide (108-110)	Supported by two reports.
Control of cellular glutathione levels	Whey protein concentrate	Based on limited studies. Considered to possibly serve as an antioxidant and in the repair of DNA. Requires further confirmation.
Diet suppressant—reduction in gastric secretion	Casein glycomacropeptide	Based primarily on studies with dogs, primarily studied by a single research group.
Control of PKU	Casein glycomacropeptide	Is aromatic amino acid free, but not known to have been used for control of PKU.
Opioid effect (reduction in heart rate and respiration)	Peptides derived from GMP, Beta-lactoglobulin, Alpha-lactalbumin	Limited evidence to support this effect, primarily in experimental animals.

*Where whey protein concentrates have been reported to have biological activity, the specific factor involved can not be determined in most cases. A specific component may be involved, or more probably the effect is caused by products formed by the action of digestive enzymes. These could include peptides, glycopeptides or oligosaccharide components.

General Nutritional Aspects

As noted previously, whey proteins are considered to have among the highest nutritional values of all food proteins. As individual fractions become available, knowledge of their individual amino acid profiles will become increasingly important.

Hambreaus (1982) gave a comparison of the essential amino acid composition of several proteins of interest in comparison with the FAO provisional amino acid scoring pattern presented in Table 6.2.2.

The amino acid composition of individual whey proteins is presented in Table 6.2.3.

Table 6.2.2
Essential Amino Acid Content of Selected Proteins (mg/g protein)

Amino Acid	Human Milk	Total Whey Protein	Casein	FAO Provisional Amino Acid Scoring Pattern
Isoleucine	45	76	54	40
Leucine	89	118	95	70
Lysine	66	113	81	55
Methionine + cysteine	33	52	32	35
Phenylalanine + tyrosine	71	70	111	60
Threonine	44	84	47	40
Tryptophan	NA	24	16	10
Valine	49	72	75	50
Total	–	**609**	**511**	**360**

Table 6.2.3
Amino Acid Composition of Selected Whey Proteins (mg/g protein)[1]

Amino acid	Beta-lactoglobulin	Alpha-lactalbumin	BSA	Immuno-globulins	Glycomacro-peptide	Lactoferrin
Essential						
Isoleucine	63	62	24	30	110	26
Leucine	136	104	104	96	170	106
Lysine	105	108	101	68	58	78
Methionine + cysteine	56	67	67	41	20	70
Phenylalanine + tyrosine	68	87	125	106	0	77
Threonine	44	50	58	105	174	52
Tryptophan	20	52	3	27		17
Valine	54	42	61	96	89	66
Other						
Alanine	54	15	79	48	59	98
Arginine	25	11	40	41	0	58
Aspartic[2]	100	169	92	41	77	99
Glutamic	174	117	136	123	190	98
Glycine	9	24	26	52	9	74
Histidine	15	29	29	32	0	14
Proline	49	16	48	100	116	44
Serine	33	43	48	115	78	50

[1]Calculated from data of Kinsella and Whitehead (1989)
[2]Includes both amine and acidic forms

Biological Properties of Whey Proteins

The general biological properties of milk proteins have been reviewed (Fox and Flynn 1992). Some of the properties are influenced by more than one whey component, including:

- Binding proteins
- Bifidis factors
- Growth factors
- Biologically active peptides

Binding Proteins

A number of different proteins are capable of binding adjuncts, which can have significance to their biological functionality. In a number of instances, the exact biological function, if any, remains ill defined or unknown.

Table 6.2.4 summarizes the binding characteristics and possible biological function of various whey proteins.

There are several minor proteins that bind vitamins including B_{12} binding protein, folate binding protein and riboflavin binding protein. There is some evidence that the binding of the vitamins assist in the absorption of the appropriate vitamin and may have a very specific function in this regard (Fox and Flynn 1992). The mechanisms for such transfer are not clear at this time.

Bifidus Factors

Factors, which stimulate the growth of Bifidobacteria, are known to be important in the health of infants, and this topic has been reviewed by Fox and Flynn (1992).

Bifidobacteria represent more than 95% of the faecal microflora of breast fed infants, and this predominance has been related to the presence of stimulatory factors in human milk. Bifidobacteria are also found as the major faecal microflora of formula fed babies, but the predominating strains are different. B. *bifidum* is the major strain in breast fed infants, with some B. *longum*. Dominant strains in formula fed infants are B. *longum*, with lesser amounts of B. *bifidum*, B. *infantis*, B. *adolescentis* and B. *breve*.

Factors that stimulate Bifidobacteria include:

- Pantethine—required by some strains, including B. *bifidum*
- N-acetyl glucosamine containing saccharides (Bifidus factor 1)
- Some glycoproteins and peptides (Bifidus factor 2)
- Oligosaccharides from a wide range of materials
- Lactulose

Gyorgy (1953), Gyorgy and Rose (1955) and Gyorgy et al. (1954 a,b,c,) reported that N-acetylglucosamine-containing saccharides are essential for the cell wall synthesis of B. *bifidum*. This factor is present in large quantities in human milk, but not in bovine (cow's) milk. Most of the bifidus growth factors in human milk are non-dialyzable and are considered to be mixtures of glycoproteins or higher oligosaccharides.

A large number of different compounds have been associated as bifidus growth factors. Predominant among these have been oligosaccharides (Hartemink et al. 1994). Gibson and Wang (1994 a,b) showed that Bifidobacteria utilized fructo-oligosaccharides as a carbon source, including inulin and oliofructose. Different oligosaccharides appear to favor different strains of Bifidobacteria.

Several components of cow's cheese whey and cheese whey protein concentrates are known to stimulate Bifidobacteria. Generally, the major growth factor in cheese whey is considered to be the casein glycomacropeptide, with the activity being primarily associated with the oligosaccharide portion of the molecule. Pahwa et al. (1989), using gel permeation chromatography found the bifidus factor in 10 different fractions in milk acid hydrolysates of rennet whey. Gyorgy et al. (1974) found a growth factor that was not dialyzable and considered to be a conjugate form of the casein macropeptide.

Whether the oligosaccharides from other whey proteins have any growth factor activity for Bifidobacteria remains to be determined. It is known that oligosaccharides from a number of plant sources have been mentioned as promoting Bifidobacteria growth—these include soybeans, Jerusalem artichokes and onions. Evidence is increasing that specific Bifidobacteria have positive health effects in humans (Araki et al. 1999, Fukashima et al. 1998, Gracheva et al. 1999). Fukashima et al. (1998) found that feeding viable Bifidobacteria to healthy Japanese children increased faecal levels of both total IgA and anti-polio virus IgA.

Table 6.2.4
Binding Characteristics of Selected Whey Proteins

Protein	Material Bound	Biological Effect	Reference
Beta-lactoglobulin	Vitamin—Retinol Vitamin D and cholesterol	Not established Not established	Fox and Flynn (1992) Wang et al. (1997)
Alpha-lactalbumin	Mineral—calcium and zinc	Modifies protein and significant to its function in lactose synthesis May enhance calcium transport	Kinsella and Whitehead (1989) Pantako et al. (1994)
Bovine serum albumin	Mineral Lipid	Unknown Modifies structure, biological function unknown	Peters (1985)
Lactoferrin	Metal—iron	Potential for iron transport, iron absorption and antimicrobial activity	Lonnerdal and Lyer (1995)

Note: All references can be found in the reference section at the end of this manual.

6.3 HEALTH ENHANCING PROPERTIES OF WHEY PROTEINS AND WHEY FRACTIONS

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Bioactivities of Whey Proteins

The major individual proteins derived from whey, Beta-lactoglobulin, Alpha-lactalbumin, lactoferrin and lactoperoxidase all have commercial applications. Research describing a number of their properties and biological functions is presented below as well as those of whey proteins in general. The aspects by which whey proteins act on the health of the gastrointestinal tract are summarized in Table 6.3.1. The multiple examples of whey proteins and other whey constituents that illustrate these properties are cited to provide an indication of principle. However, a substantial body of literature that increases monthly, adds to this knowledge and further identifies the specific molecules and mechanisms behind these effects. Beyond the interaction with the gut and intestinal immune functions, more and more benefits are being tested that are logical predictions from the molecular actions at the level of the intestine, immune system and cellular biology. Of these, beneficial effects of whey proteins have been reported in relation to inhibition of cancer cell growth adjuvant, as antihypercholesterolemia agents and as anti-aging agents.

Growth

The growth-promoting properties of milk are well established, but discouragingly little knowledge actually extends to understanding at the molecular level how these properties are achieved. For example, successful, controlled and balanced growth of key organs and tissues do prove superior in milk-based diets per se, but exactly which proteins, factors, etc. are responsible for achieving this benefit are not completely known. Most particularly, from the gastrointestinal tract and beyond, to bones, skin and muscle, growth is superior when animals are fed milk proteins relative to the same basic nutrients in a non-milk form.

Growth-supporting effects have been suggested to be due to 1) enhanced absorption of essential nutrients such as calcium, 2) controlled delivery of amino acids to particular tissues, 3) direct stimulation of cellular growth via receptor activation and 4) inhibition of inflammatory cytokines that promote tissue disassembly and indirectly decrease growth. It is entirely likely that given the importance of milk as a growth supporting food, that multiple mechanisms have evolved to achieve this net effect and that many of these mechanisms have yet to be determined. Whey components contain several known growth-supporting factors, including lactoferrin, EGF and IGF1. There is an interesting question that emerges from this body of knowledge. What value is stimulating growth in adults? The answer to this question ironically is surfacing with the emergence of the deteriorative diseases of aging such as osteoporosis. It has become clear in the course of studying osteoporosis that bone is not a static structure but is a tissue that is constantly turning, and in which tissue destruction and tissue growth are constantly opposing each other. During aging, the disassembly of bone begins to take quantitative superiority over bone growth. As more research has been done on other tissues like muscle and nervous tissues, this theme of constant tissue replacement has become central. Thus, growth support may become even more important to maintaining health through aging. In fact, therapeutic growth hormone has become a significantly beneficial clinical intervention for the elderly that even supports the immune system.

Development

The mammalian infant is conspicuous for its immature development at birth. Humans especially, are born with organs and tissues in a formative state, and the provision of specific factors that support development is clearly an activity of milk. Whey proteins are again conspicuous for their ability to support development in both in vitro models and in vivo studies. Applications of such activities and concentrated factors would be a logical strategy for food products in which supporting development is a desired outcome. Recovery of tissues post-trauma and injury are the most obvious examples. It has been speculated, although the results are not yet clear, that whey proteins provide a significant benefit to recovery of tissues when the stress is not serious damage or trauma, such as the stress associated with exercise. Nevertheless, the mechanisms of action known for the various factors in whey are consistent with such benefits.

Maturation

The various tissues and cellular systems of mammals, including humans, undergo processes of maturation both early in life and throughout the life cycle. Examples include the development of self-non-self recognition by the immune system in infancy and tolerance to various antigens throughout life. The well-recognized interaction between whey components and the immune system is one of the most promising nutritional properties of whey. Particularly, in aging adults in whom immune senescence becomes a serious threat to an appropriate response to pathogens, the inclusion of maturation supporting factors in the diet would be beneficial. It is also attractive to speculate that many of the benefits of yogurt-like products on the immune system are the result of the positive interaction between beneficial probiotic bacteria and whey components consumed simultaneously with them.

Protection

The substantial body of knowledge emerging on the antimicrobial properties of whey proteins such as lactoferrin has brought this benefit of milk components even beyond the scientific community to general acceptance by a large lay audience. Although it is not the subject of this review, an apparent evolved benefit of milk has been to promote through a variety of effective means, a microfloral population with many protective properties. The value of whey components as prebiotics in stimulating a beneficial microflora is not as well established to date; yet this awareness is continuing to develop. The value of whey components in protection is a nutritional benefit that is directly transferable to adults in all life stages.

Elimination

The aggressive and rapid elimination of toxic substances and microorganisms is a largely overlooked benefit of protective nutrients, especially those in milk. The most obvious mechanism of action of toxin-binding glycoproteins and glycolipids in milk is to supply the same molecules to the digestive tract that are present on the surfaces of intestinal cells. By binding toxins in the gut contents, their elimination becomes a vivid example of simplicity in action. Gastrointestinal contents are propelled by the combination of fluid viscosity and peristalsis. The fact that whey components stimulate and regulate smooth muscle cell functions has become an area of intense interest as it has become clear that the decrease in gut motility is an important factor in the deterioration of optimal gastrointestinal functions during aging (Table 6.3.1).

These various actions of milk components, largely retained in whey, have long been recognized to be of value to infants but only recently have the mechanisms of action become of clear and attractive value to adults. Perhaps it is not an overstatement to suggest that although we are still within the realm of research in which single component actions are being discovered, the next generation in which the positive interaction between different components is discovered will be even more exciting. The example of the positive interaction as antibacterial agents between lysozyme, which attacks bacterial cell walls, and lactoferricin, which attacks cell membranes, is logically the first of many such complementary molecular systems that evolved together within milk to protect infants. Other benefits discussed below, which have been discovered and are of most obvious benefits to adults, are even more intriguing to research scientists in discovering what value they provide to infants.

Table 6.3.1
Biaction of Whey Components

Target	Mechanism	Example	Implications
Growth	Cell cycle stimulation of intestinal cells	IGF–1	Promote tissue repair
Maturation	Bind to and activate natural receptors in intestinal cells	TGFb	Intestinal integrity
Protection	Disrupt pathogenic bacterial membrane	Lactoferricin	Pathogen inhibition
Prevention	Stimulate beneficial bacteria	Lactoferrin	Prebiotic effects
Elimination	Endotoxin binding	Immunoglobulins	Toxin excretion

Bioactive Non-protein Whey Components

There is considerable interest in several of the non-protein components of whey. These components include the major constituent lactose and the minor bioactive components, especially those in the globule membrane fraction, including sphingolipids and gangliosides. Although the concentration of lipids in whey is low, the amount present in a commercial preparation of whey is dependent on the fractionation technique.

The myriad functions and actions of whey proteins discovered to date illustrate not only interesting biological activities in their own right, but provide ample evidence of a coordinated system of biological actions designed through evolution. These actions are not simply to carry essential nutrients but rather to protect, nourish and support the maximal physiological status of the growing mammal. The mechanisms of these actions discovered to date are so complex and disparate, that the major proportion of beneficial properties have likely not yet been discovered. Whey from bovine milk contains a significant number of the already described beneficial activities of human milk including components that provide protection from pathogens, intestinal growth regulation, immune maturation, probiotic support and of course, a balanced composition of proteins with excellent overall nutritional quality. The science and applications of nutrition are moving ahead from the study of essential nutrients to begin to understand the role of non-essential nutrients, structures and bioactive factors in foods. In this context, milk and whey are emerging as excellent models, not only for research but also for direct application to value-added foods.

The information contained in this section is drawn from a review article which appeared in *Critical Reviews in Food Science, Vol.* 42, *pg.* 353-375. RL Walzem, CJ Dillard, JB German. "Whey Components: Millenia of Evolution Creates Functionalities From Mamalian Nutrition: What We Know and What We May Be Overlooking."

6.4 WHEY PROTEIN AND SPORTS NUTRITION

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Recently U.S. whey products have become very popular ingredients in sports nutrition. The past decade has seen increasing popular interest in healthy lifestyles based on regular exercise, such as cycling, running, aerobics, swimming, bodybuilding, weight training and cross country skiing. This increase in the number of muscle and fitness enthusiasts has prompted a growing consumer demand for protein sports beverages, specialized nutritional drinks, nutritional snack bars and other products designed to optimize athletic performance. A growing body of scientific evidence indicates whey proteins deliver important physiological benefits for consumers seeking superior physical performance and recovery.

Whey proteins are both easily digested and have excellent metabolic efficiency, giving the protein a high biological value. They also contain the highest concentration of branched chain amino acids (BCAAs) available from any natural food protein source. During exercise, whole body protein synthesis is decreased, and proteins are mobilized into free amino acids. Skeletal muscles take up BCAAs from the blood and break them down into glucose for energy. Therefore BCAAs are unique among amino acids in their ability to provide an energy source during endurance exercise. Whey proteins are specially suited to sports drink and bar formulations. They provide a high concentration of BCAAs (20-26 g per 100 g protein), a high quality, pure protein with little or no fat, cholesterol or lactose, and they have excellent bioavailable calcium.

Whey, Energy and Sport

The body's energy requirements are met by carbohydrates, fats and proteins. The main source of energy in short and medium term exercise is carbohydrate as glycogen. This is gradually replaced by lipid, as the exercise period becomes longer. Proteins can also be used as a source of energy particularly during prolonged exercise. The oxidation of amino acids, mainly BCAAs, can provide 10%-15% of the total energy required during exercise.

Performance Nutrition and Proteins

Proteins play a central and significant role in performance nutrition for athletes and there is a growing interest in protein metabolism associated with sports activities. Muscle protein contains about one third of their amino acids as BCAAs. They have an important functional role and are constantly renewed at a rate of 250-300 g per day. Proteins are important in sports nutrition in three areas: endurance, strength/power training and muscle fiber repair. Endurance is the ability to continue exercising muscles for an extended period of time. Muscle endurance depends on the adequacy of muscle glycogen stores and blood glucose. Proteins can provide an additional source of energy to spare muscle glycogen and help maintain blood glucose levels. An athlete can improve endurance through dietary manipulations that increase muscle glycogen storage. Protein supplements are known to increase muscle glycogen storage needed for prolonged exercise.

Why Athletes Require Additional Dietary Protein/Amino Acids

- To cover increased loss of amino acids oxidized during exercise
- To cover increased mitochondrial protein content, that requires increased protein content
- To provide additional raw materials to replace exercise-induced muscle damage
- To provide supplemental raw materials to enhance muscle protein synthesis

Protein Power and Sports Connection

Amino acids provide the building blocks of cellular structures, which are necessary for human metabolism and supply the body with energy. As much as 15% of the energy spent during exercise can come from proteins, with a large percentage coming from one amino acid, leucine. Before amino acids can be used for energy, deamination or transamination must occur to remove nitrogen. Athletic training can double the levels of important transaminases, and this significantly increases the body's ability to utilize leucine and other amino acids for energy. Several studies using leucine turnover measurements show an increase of up to 20% in protein turnover during aerobic exercise. The case for increased protein needs during exercise is also supported by studies showing increased excretion of 3-methyl histidine, increased urea nitrogen losses, and depression of protein synthesis.

Studies show an increased utilization of primarily the BCAAs, leucine, isoleucine, and valine during exercise. The BCAAs are degraded by active skeletal muscles to release nitrogen, which is combined with pyruvate in muscles to form alanine. The liver removes nitrogen from alanine to form glucose as a source of energy. However, turnover rates for other amino acids, such as lysine, are unaffected by exercise. Nitrogen losses have been shown to increase or not change during and after exercise though no detectable amount of muscle mass is lost during exercise.

Special Protein Requirements and Sports

To maintain fitness and overall health, the U.S. Recommended Daily Allowance (RDA) for protein is 0.8 gram per kg body weight. At 70 kg, for example, this equals 56 g of protein per day. However, an individual's protein requirements also depend on lifestyle, physical condition, overall health, age, sex, carbohydrate status, previous level of protein intake, training level, and type, duration and intensity of exercise.

In general, the RDA is sufficient for a sedentary lifestyle, but exercise increases the need for protein. The American Diet Association (ADA) and other nutritionists associations have reported that 1.5 g protein per kg body weight, which is considered an adequate amount for athletes, is required for maximal protein deposition (97 to 105 g of protein per day for a 70 kg individual). These protein intakes are recommended for keeping the body in nitrogen balance, or to give a positive balance with increased muscle mass for certain athletes or other individuals requiring more muscle mass.

Nutritional considerations of strength/power athletes participating in bodybuilding, weightlifting, wrestling, and self-defense are different than other sport groups. Nitrogen balance studies indicate levels of protein up to 2.0 g per kg body weight per day may be required for endurance and strength/power athletes to remain in positive balance. Body builders are known to take in large quantities of whey proteins. Some consume higher than 2.0 g protein per kg of body weight. They recognize that increasing lean muscle mass requires additional protein intake and demanding bouts of exercise.

It does not take much extra protein to supply amino acids for enlarging muscles. However, no protein is 100% utilized. The loss of efficiency in high-quality protein utilization is about 30%, and in poorer-quality protein, it is about 60%. Theoretically, to build 100 g of extra protein, the athlete must consume 130 g of high–quality protein or 160 g of lower-quality protein in a week. Ingestion of very high amounts of protein, and particularly lower quality proteins, increases metabolic stress to organs such as the kidney, which must process the overload of materials. It is clearly much more desirable to eat proteins with the best biological value, such as whey proteins.

Table 6.4.1
Examples of Activity and Protein Requirements

Activity	Protein g/kg body weight/day
Sedentary workers	0.8
Individuals regularly active in endurance exercise: aerobics, jogging, etc.	1.2–1.4
Power/Speed athletes: sprinters, track cyclists, bodybuilders, etc.	1.3–1.6
Power/Strength athletes: judo, boxing, weightlifting, etc.	1.5–2.0
Endurance athletes: marathon runners, road cyclists, triathletes, etc.	1.5–2.0

U.S. whey proteins deliver superior value. All proteins are good, but some are better. The ideal sports protein should meet these criteria:

- A good balance of essential and nonessential amino acids
- An abundant supply of BCAAs
- Low in fat, and cholesterol

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

Table 6.4.2
Nutritive Value of Key Proteins

Protein Source	BV	PER	NPU
WPC	104	3.2	92
Soy protein	74	2.1	61
Whole egg	100	3.8	94
Cow's milk	91	3.1	82
Casein	77	2.5	76
Beef	80	2.9	73

PDCAAS measures protein quality based on the amino acid requirements of humans. Criteria needed for PDCAAS are approximate nitrogen composition, essential amino acid profile, and true digestibility. According to this method, the PDCAAS of an ideal protein that meets all the essential amino acid requirements of the human body has a value of 1.00. Whey proteins have a PDCCAS of 1.14, a score that exceeds 1.00 for soy protein. The U.S. dairy industry is a leader in proprietary whey protein processes used by the sports nutrition industry.

Table 6.4.3
Typical PDCAAS of Key Proteins

Protein Source	PDCAAS
Whey protein isolate*	1.14
Casein	1.00
Milk protein isolate	1.00
Soy protein isolate	1.00
Egg white powder	1.00
Ground beef	1.00
Canned lentils	0.52
Peanut meal	0.52
Wheat gluten	0.25

*Check with your supplier for exact composition.

Benefits of Whey Proteins in Sports Nutrition

- Easily digestible high quality protein—provides additional energy, spares endogenous protein.
- Contains high levels of BCAAs: leucine, isoleucine, and valine—may increase time to exhaustion.
- Good source of sulfur containing amino acids such as cysteine and methionine—maintains antioxidant levels in the body, and are thought to stabilize DNA during cell division.
- Contains high levels of arginine and lysine—may stimulate growth hormone release, and thus stimulates an increase in muscle mass and a decline in body fat.
- Contains glutamine—helps muscle glycogen replenishment and prevents decline in immune function from overtraining.
- Excellent source of bioavailable calcium—reduces stress fractures during exercise and prevents bone loss in hypoestrogenic female athletes.

Whey proteins contain a high level of BCAAs (~26%). These amino acids provide an additional benefit for sports beverages designed to provide energy for those who undergo intense or prolonged exercise. The BCAAs (leucine, isoleucine and valine) are taken up directly by skeletal muscles during extensive exercise, rather than first being metabolized through the liver like other amino acids. Since the body's demand for these amino acids increases during exercise, athletes who want to preserve muscle mass may benefit by increasing their consumption.

Whey has 10.3 g leucine, 5.9 g isoleucine and 5.9 g valine per 100 g of protein. There are some variations in amino acid composition depending on the origin and the processing of the protein. Different processes produce whey proteins with different BCAA contents. In the US, dairy companies produce whey proteins with enhanced levels of BCAAs specifically tailored for sports beverages and sports bar applications.

Table 6.4.4
BCAA Content of Key Proteins

Protein Source	BCAAs g/ 100 g Protein
WPI	26
Egg white powder	22
Milk protein isolate	20
Soy protein isolate	17

BCCAs Aid Recovery

BCAAs are thought to decrease muscle protein degradation during exercise and allow athletes to train more intensively for longer periods of time. There is evidence they can help revive athletes after intense exercise and aid recovery, and these topics have become active subjects for sports medicine research. The current theory is that during prolonged exercise, BCAAs are oxidized by skeletal muscle, the carbon part is used as fuel and the nitrogen part is used to make the amino acid alanine, which then goes to the liver where it is turned into glucose for energy. For athletes who want to protect their existing mass, the idea is to take whey protein fortified products naturally rich in BCAAs before and after the exercise. Exercise can be considered to be a "metabolic stress" like injury or trauma. Under these conditions, muscle tissue is progressively catabolized to provide the liver with precursors for glucose. Therefore BCAAs can be extremely beneficial in the diet of athletes as aid to recovery.

BCAAs Delay Fatigue

Marathoners talk of "hitting the wall" and cyclists speak of 'bonking'. Both groups experience fatigue in intense events lasting longer than an hour. It has been proposed that ingestion of BCAA might delay fatigue during prolonged aerobic exercise by delaying central fatigue. Several field studies using BCAA supplementation with runners, soccer players, and cross-country skiers have shown beneficial effects on performance.

U.S. Whey Proteins, Muscle Growth and Fatigue Prevention

Whey proteins are rich in arginine and lysine. Arginine and lysine are among the amino acids thought to possibly stimulate growth hormone, a potentially beneficial response for bodybuilders. Proteins may stimulate release of growth hormone, which is an anabolic hormone or stimulator of muscle growth. Since the use of anabolic drugs was banned from competition, strength/power athletes have sought legal, natural substances to help build bigger muscles. Whey proteins offer natural alternatives to anabolic-androgenic steroids for bodybuilders.

Whey contains glutamine, a conditionally essential amino acid. Glutamine has been studied for its role in preventing fatigue and over-training in athletes. It is conditionally essential because in certain situations, it may be needed in the diet. It acts as a fuel for dividing cells. It makes up 60% of the amino acid pool in skeletal muscle, so athletes are cautious not to allow any shortage in the belief its absence would reduce muscle growth and increase muscle breakdown. Glutamine plays an important role in binding ammonia, which is a molecule produced by muscles in exhaustive conditions. Supplementing with whey proteins may increase the need to have more glutamine in the formula since nitrogen from BCAA's may be incorporated into ammonia. While under stress, the body's glutamine requirements can increase considerably. Adding glutamine provides opportunities for whey product line extensions. Glutamine can also be used in sports drinks, bars and instant drink mixes. Formulators may enhance their formulas by adding glutamine into products.

Glycomacropeptides and Sport

Glycomacropeptides are formed during the cheese making process from the reaction of chymosin with k-casein. These proteins are strictly Kappa casein-derived peptides that are collected and concentrated during ultrafiltration of whey. Whey proteins contain about 15%-20% glycomacropeptides (GMPs). Glycomacropeptides are biologically active proteins with a positive effect on the digestive system. "Digestion regulators" are considered important in sports nutrition. Glycomacropeptides have been shown to stimulate the synthesis and release of cholesystokinin in the body. Cholesystokinin plays a role in the regulation of digestive functions as an appetite suppressant. Other functions linked with GMPs include growth factors for bifidus bacteria in the intestine, antiviral activity, modulating digestion, improved calcium absorption, antibacterial properties and improvement of the immune system.

6.5 WHEY PROTEINS AND CARDIOVASCULAR HEALTH

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A growing body of scientific evidence reveals that U.S. whey contains various bioactive components that may have a positive effect on cardiovascular health. Certain bioactive peptides may protect against hypertension through angiotensin converting enzyme (ACE) inhibition and opioid-like activity. Bioactive whey peptides may also be involved in inhibiting platelet aggregation and lowering cholesterol levels. Other whey components such as calcium, magnesium, zinc, B-vitamins, and certain lipid fractions may also help reduce the overall risk of cardiovascular disease.

Food scientists generally favor whey proteins because of their high biological value, excellent functional properties and clean flavor profile. U.S. whey ingredients are used throughout the world in beverages, bars and other food systems. Newer whey ingredients include hydrolyzed whey proteins that contain high levels of bioactive peptides, and milk mineral complex, which is rich in calcium, phosphorus and other minerals. These two ingredients show particular promise as components of functional foods designed to improve cardiovascular health. Whey ingredients might also be used as components of other foods such as fermented or hyperimmune milk drinks, or products with increased levels of conjugated linoleic acid (CLA), to produce a new generation of dairy products designed to promote cardiovascular health. For many years, low fat dairy foods have been recommended as part of a total diet to reduce the risk of cardiovascular disease. Recent research reveals that specific components of whey may also positively impact coronary health.

Whey-derived Peptides and Blood Pressure

The two major risk factors contributing to the worldwide incidence of cardiovascular disease are hypertension and dyslipidemia. Whey based peptides have demonstrated activity that may reduce both risk factors. Recent research has shown that bioactive whey peptides may be involved in these functions:

- ACE inhibitory activity
- Opioid-like activity
- Antithrombotic activity
- Cholesterol-reducing activity

Whey peptides may also have other functions, including antioxidant activity, which improves overall cardiovascular health.

Whey proteins can be broken down into various bioactive peptides through enzymatic proteolysis. This process can occur during gastrointestinal digestion, by fermentation of milk, or through controlled reactions in the laboratory or whey processing facility. Regardless of the method of hydrolysis, in order to exert antihypertensive activity, the peptides must be absorbed from the intestine in an active form.

Relatively high levels of bioactive peptides could potentially be produced using low amounts of whey. These whey peptides could enter peripheral blood intact and potentially exert systemic effects. The table below shows potential yield of bioactive peptides from ingestion of 1g of whey.

Yield of Alpha-lactophorin	35.2mg
Yield of Beta-lactophorin	30.2mg
Yield of serophorin	0.5mg

Various lactic acid bacteria, including *Lactobacillus* GG and *Lactococcus lactis*, have been shown to hydrolyze milk proteins into bioactive peptides. Studies with the antihypertensive peptides from sour milk have shown that these peptides can be absorbed in the digestive system. Research with infants confirms that di- and tripeptides can be easily absorbed in the intestine. Newer studies indicate that fairly long peptides can cross the intestinal barrier in adults and reach the target organ.

When developed as food ingredients, the processing of these peptides is vital to their activity. Severe heat treatment will have a negative affect on the bioavailability of whey peptides, so processors must carefully monitor production parameters. Careful selection of enzymes for proteolysis will result in maximum biological activity and limit development of bitter flavor notes. U.S. whey manufacturers have shown world leadership in manufacturing and testing whey peptides.

ACE Inhibitory Activity

Whey peptides have shown angiotensin converting enzyme (ACE) inhibitory activity, both in vitro and in animal experiments. The overall effect of an ACE inhibitor is the control of high blood pressure through dilation of blood vessels and its effect on blood volume.

While angiotensin I is an inactive hormone; angiotensin II is a molecule that directly constricts vascular smooth muscle, thereby increasing blood pressure. It also has numerous other effects on the cardiovascular system, such as decreasing the renal output and increasing water retention. Angiotensin converting enzyme, ACE, converts the inactive angiotensin I into angiotensin II. An ACE inhibitor blocks this reaction by competitive inhibition, and prevents the effects of angiotensin II. ACE also contributes to the inactivation of bradykinin, a potent vasodilator that is also involved in the control of blood pressure.

Several milk-derived peptides have been shown to have ACE inhibitory activity. ACE inhibiting peptides that are derived from casein are called casokinins, while those that are derived from whey are called lactokinins.

ACE is present in a large number of tissues including plasma, kidney, lung and brain. In order to exert an antihypertensive effect in vivo, the Ace-inhibitory peptides must be absorbed from the intestine and delivered to the target organ. While earlier research with sour milk isolated a number of casein fractions with ACE inhibiting and antihypertensive properties, newer studies have shown that numerous whey fractions also possess ACE-inhibiting activity.

In recent research, ACE inhibiting fragments from both Alpha-lactalbumin and Beta-lactoglobulin were formed by using various enzymes. It has been shown that ACE prefers substrates containing hydrophobic (aromatic or branched side-chains) amino residues at the C-terminal position. Whey fractions hydrolyzed with trypsin alone or a combination of trypsin, pepsin, and chymotrypsin, showed ACE inhibitory activity as outlined in Table 6.5.1. ACE inhibition is measured by the concentration of substance needed to inhibit 50% of original ACE activity, (IC50). A lower IC50 value indicates higher efficacy.

Whey Ingredients with Antithrombotic Activity

Thrombosis, defined as the formation or presence of a blood clot within a blood vessel, is another major risk factor in cardiovascular disease. Fibrinogen is a plasma protein that is produced in the liver and is converted into fibrin during blood clot formation. The fixation of fibrinogen to the platelets is necessary for platelet aggregation. Milk peptides are believed to inhibit this platelet fixation.

Some whey peptides have been investigated for their antithrombotic activity. Studies demonstrate that a glycomacropeptide (GMP) derived peptide may be involved in platelet binding. Another study also gives limited evidence that lactoferrin-derived peptides may be involved in platelet binding. Further knowledge of roles of whey-derived peptides may show promise in the treatment of thrombosis.

Glycomacropeptide

Glycomacropeptide is formed during the cheese making process. Rennet or chymosin hydrolyzes the peptide bond between residues 105 and 106 of k-casein to produce the resulting molecule, GMP, which is eluted in the whey fraction. The C-terminal portion of the molecule contains residues 106-169 from k-casein. GMP comprises 10 to 15% of the protein of whey processed by microfiltration/ultrafiltration. The large GMP molecule can not be absorbed, and must be broken down into smaller peptides to have an effect on blood components.

Casoplatelins are made up of fragments 106-116 of the GMP molecule. These compounds have been shown to inhibit both aggregation and I-fibrinogen binding to ADP-treated platelets. Several other fragments have been shown to have antithrombotic activity: these include fragments 108-110, 106-112, and 113-116. A GMP derived peptide shown to have antihypertensive activity was fragment 108-110.

Whey Proteins and Cholesterol Levels

Whey proteins have also been shown to reduce blood cholesterol levels in animal studies. Elevated LDL-cholesterol and triacylglycerol levels are associated with an increased risk of atherosclerosis. However, there is an inverse relationship between HDL-cholesterol and atherosclerosis. Numerous clinical trials have shown that for each 1% reduction in total plasma cholesterol levels, there is a 2% reduction in coronary events in subsequent years.

In an animal study on albino rats, the use of condensed whey or lactose-hydrolyzed condensed whey in yogurt was shown to have a beneficial effect on cholesterol levels. In this study, whole milk and standard yogurt had no hypocholesterolemic effect, but standard yogurt containing lactose-hydrolyzed condensed whey and bifidus yogurts lowered serum cholesterol. In general, yogurts changed HDL-cholesterol little, but tended to raise triacylglycerols. There was marked lowering of LDL-cholesterol in rats given either type of yogurt fortified with whey protein.

A second study found that whey protein lowered liver cholesterol levels when fed at low amounts (10 g/kg feed), and significantly reduced both plasma and liver cholesterol levels when fed at high rates (150 g/kg feed). In another rat study, whey protein versus casein significantly reduced plasma cholesterol concentration by about 35%. The plasma cholesterol lowering as induced by extra whey protein in the diet was due to decreases in the VLDL fractions.

Overall, whey peptides exhibit a wide range of bioactive properties, and thus show much promise as components of functional foods. The following table (Table 6.5.1) highlights specific bioactive peptides and their function.

Table 6.5.1
Other Bioactive Peptides Derived from Whey Protein

Precursor Protein	Fragment	Peptide Sequence	Name	Function
Alpha-lactalbumin	50–53	YGLF	Alpha-lactophorin ACE inhibition	Opioid agonist
Beta-lactoglobulin	102–105	YLLF	Beta-lactophorin stimulatory effect on ileum	Non-opioid
Beta-lactoglobulin	146–149	HIRL	Beta-lactotensin	Ileum contraction
GMP	106–116 108–110 106–112 113–116	MAIPPKKNQDK	Casoplatelins	Antithrombotic activity
GMP	108–110	IPP		Antihypertensive activity
Bovine serum albumin	399–404	YGFQDA	Serophorin	Opioid activity
Bovine serum albumin	208–216	ALKAWSVAR	Albutensin	Ileum contraction ACE inhibition

Adapted from Shah, 2000, and Korhonen et al., 1998.
References are available from the U.S. Dairy Export Council

6.6 WHEY PROTEIN ISOLATE VERSUS SOY PROTEIN ISOLATE: EFFECTS IN HUMANS

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A double blind comparative pilot trial evaluating the effect of whey protein isolate and soy protein isolate in healthy adults.

OVERVIEW

This paper covers the results from "A comparative pilot trial evaluating the effect of whey protein isolate and isolated soy protein in healthy adults." This study was funded by Davisco Foods International, and was conducted at Peak Wellness, Inc. in Greenwich, CT.

With all the accumulating evidence regarding the beneficial properties of whey protein isolate (WPI) and soy protein isolate, commonly referred to as isolated soy protein (ISP), it is desirable to compare some of the benefits these protein sources may offer to a person seeking and living a healthy lifestyle. Research has revealed positive health benefits from both whey protein isolate and isolated soy protein. For example, soy protein is believed to reduce cholesterol (Gardner, Newell et al. 2001), reduce the incidence of certain cancers (Hakkak, Korourian et al. 2000; Ronis, Rowland et al. 2001), maintain bone mineral density important for the prevention of osteoporosis, and reduce menopausal symptoms. Whey protein isolate has been extensively researched in clinical trials for its effect on the immune system (Bounous, Batist et al. 1989; Bounous, Gervais et al. 1989; Bounous, Batist et al. 1991; Bounous and Gold 1991; Bounous, Barauchel et al. 1992; Bounous and Molson 1999), for enhancing protein synthesis and athletic recovery (Schena, Guerrini et al. 1992; Esmarck, Anderson et al. 2001), and for its content of bioactive peptides (Meisel, Frister et al. 1989; Guimont, Marchall et al. 1997; Mullally, Meisel et al. 1997).

However, despite both these proteins being promoted in the consumer market, limited comparative data exists with respect to their effects on blood and other parameters as indices of general health.

Objective

The objective of this pilot trial was to define the effect of WPI and ISP, in healthy exercising adults, in terms of body composition, exercise performance, immune system parameters, serum amino acids, sex hormones, thyroid function and blood lipid profile.

Study Design

The design of the study was a double blind, prospective and randomized pilot trial that was 12 weeks long. To participate in the study, subjects were required to be greater than 18 years of age, and have a minimum of 6 months of weight training experience. In total 30 adults were recruited for the study and randomized into 1 of 2 groups. Fifteen (15) subjects received WPI, specifically BiPRO® manufactured by Davisco Foods International, Inc. and 15 subjects received ISP, specifically SUPRO® manufactured by Protein Technologies, Inc.

As a brief comparison, the composition and protein quality of WPI and ISP is shown in Table 6.6.1. WPI has a higher protein content of 97.5% on a dry weight basis, compared to 92.5% protein on a dry weight basis for ISP. There are only minor differences in the other components. For protein quality, both proteins have the maximum value of 1.0 for PDCAAS, protein digestibility corrected amino acid score, indicating that both proteins have the ability to supply essential amino acids in the minimum amounts needed to meet human requirements.

Table 6.6.1
Composition and Protein Quality

Composition	WPI[1]	ISP[2]
Protein (% db)	97.5	92.5
Fat (%)	<1.0	3.0
Ash (%)	<3.0	4.1
Moisture (%)	5.0	5.0
Carbohydrate (%)	<1.0	<1.0
Protein Quality		
PDCAAS	1.0	1.0

[1]Davisco Foods International, Inc.
[2]Protein Technologies, Inc.

For this study, protein supplements in the form of chocolate flavored powdered beverage mixes were developed. The beverages were formulated to contain 30 g protein per serving and were flavored to mask any difference in taste between WPI and ISP. Researchers and subjects were blinded to the identity of the protein supplement. Participants were instructed to consume 2 servings daily for a total of 60 g protein per day.

Subjects performed resistance training 3 times per week. This training was a full body type program that was supervised at the facility by the exercise physiology department. Participants also completed 24-hour diet recalls and met biweekly with the registered dietician to ensure dietary and supplement compliance.

A brief summary of the data collected throughout the study included body composition measurements and blood analysis. Body composition tests included monitoring of body weight and percentage of body fat, with body fat percentage tested using bioelectric impedance analysis and Lange calipers. Specific blood tests were taken at week 0 (baseline), week 6 and week 12. These blood tests included the amino acids glutamate, cystine, methionine, lysine and the antioxidant glutathione. There was also blood withdrawn for thyroid function (T3, T4 and TSH), cholesterol, including total cholesterol, HDL, LDL, triglycerides, and the hormones, testosterone and estradiol.

Data Analysis

In total, 12 weeks of data were analyzed. Data were analyzed for differences between the groups, meaning the WPI supplemented group and the ISP supplemented group. Data were also analyzed for differences between the sexes in each group to determine a gender effect. P values <0.05 were considered statistically significant. Of the 30 participants that started the study, 3 people dropped out during the study and therefore 27 participants were included in the analysis, with 14 subjects in the whey group and 13 subjects in the soy group. By gender, there were 16 females and 11 males in the study.

Results

The following graphs (Figures 6.6.2–6.6.12) will illustrate the significant results from the study.

Glutathione Results for All Subjects

Figure 6.6.2 shows the glutathione (GSH) results from analyzing the data for all subjects. There was a significant increase in GSH within the whey group at both week 6 and week 12. There was no significant change in GSH within the soy group over the 12 weeks of the study.

Figure 6.6.3 shows the same data as Figure 6.6.2 but represents the time trend analysis. The time trend represents the mean change in GSH at 6-week intervals. Group analysis revealed significantly different time trends between the two groups. Within the whey group, the average GSH value increased 3.46 units per 6 weeks, while in the soy group, the average GSH value decreased 0.79 units per 6 weeks. These results indicate that WPI bolsters glutathione, a key antioxidant in the red blood cell, which may prolong the life of the cell, enhance immunity and promote health in general, while ISP may not have the same effect on cellular health.

Figure 6.6.2
Glutathione Results for All Subjects

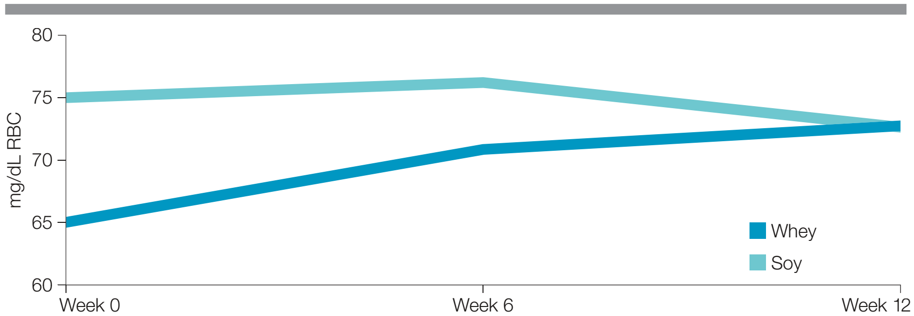
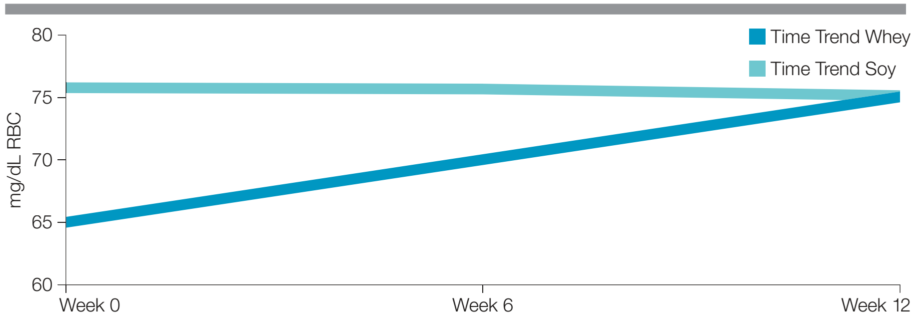


Figure 6.6.3
Glutathione Results for All Subjects (time trend data)



Methionine Results for All Subjects

Shown in Figure 6.6.4 are the methionine results, from analyzing the data for all subjects. Within the whey protein group, over six weeks, there was a significant increase in methionine levels of 12.29 units from baseline values. Over the 12 weeks, the whey group also showed a significant increase in methionine, an increase of 7.5 units from baseline. The soy group did not have any significant changes in serum methionine over 6 or 12 weeks. These results indicate that although whey and soy protein have the same PDCAAS values, indicating high protein quality, only WPI had an impact on serum methionine levels which may be attributable to the higher methionine levels in whey protein compared to soy protein.

Figure 6.6.4
Methionine Results for All Subjects (time trend data)

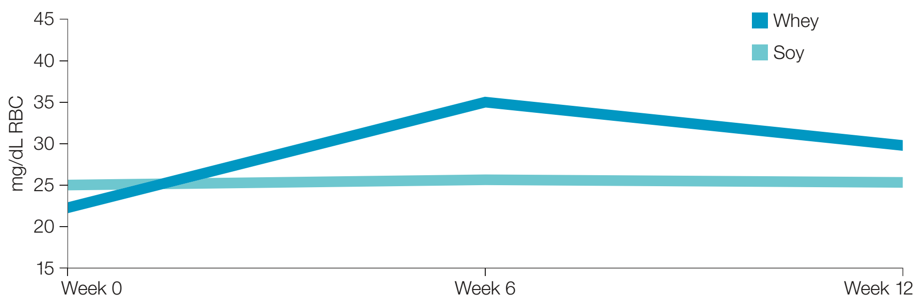


Figure 6.6.5
Total Cholesterol Results for All Subjects (time trend data)

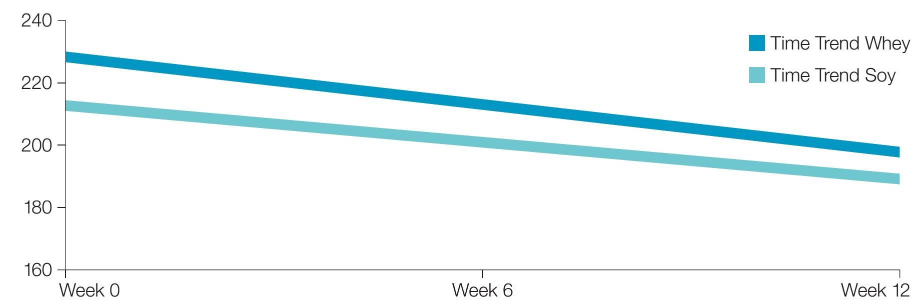
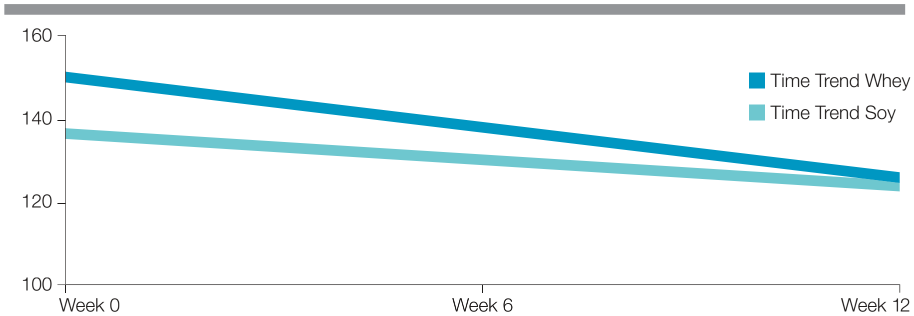


Figure 6.6.6
LDL Cholesterol Results for All Subjects (time trend data)



Blood Lipids

Total Cholesterol Results for All Subjects

Shown in Figure 6.6.5 are the time trend results for total cholesterol. There was a significant decrease in total cholesterol within both the WPI group and the ISP group after 12 weeks, a decrease of 6% for ISP and 15% for WPI. However, there was no significant difference between groups. These results are promising for whey, given the numerous publications showing the cholesterol lowering effect of soy protein and the recently approved health claim in the United States for soy protein and cardiovascular health.

LDL Cholesterol Results for All Subjects (time trend data)

Shown in Figure 6.6.6 are the time trend data for LDL cholesterol. There was a significant decrease in LDL cholesterol within each group, a drop of 10% for the soy protein group, and a drop of 20% for the whey group. However, there was no significant difference between groups.

HDL Cholesterol Results for All Subjects

Shown in Figure 6.6.7 are the time trend data for HDL cholesterol. No significant changes in HDL cholesterol were seen in either group.

Triglyceride Results for All Subjects (time trend data)

Figure 6.6.8 shows the time trend data for triglycerides. There was only a significant drop in triglycerides within the soy protein group.

Thyroid Results for Male Subjects

Looking at gender differences, shown in Figure 6.6.9 are the results for T4 thyroid hormone for male subjects in the study. Although there were no significant differences within groups due to the small samples sizes, at week 12, the males in the soy group had a significantly greater decrease in T4 value from baseline than that of the whey group. There was a mean change from baseline of 1 unit for the males in the soy group, from 7.7 to 6.6 ug/dL compared to a mean drop from baseline of 0.1 unit for the men in the whey group, or a drop from 7.6 to 7.5 ug/dL. These results indicate that 60 g of ISP ingested daily by men may alter thyroid function. The fact that ISP was found to effect thyroid is consistent with animal and human data.

Cystine Results for Male Subjects

Figure 6.6.10 shows the cystine results for male subjects in the study. At week 6, the men in the whey group had a significantly higher change from baseline value for cystine than men in the soy group, a mean increase from baseline of 5.2 units for the men in the whey group and a mean decrease from baseline of 9 units for men in the soy group. These results are significant since cystine is a sulfer containing amino acid important for many processes in the body and is the direct precursor to glutathione within the cell.

Figure 6.6.7
HDL Cholesterol Results for All Subjects (time trend data)

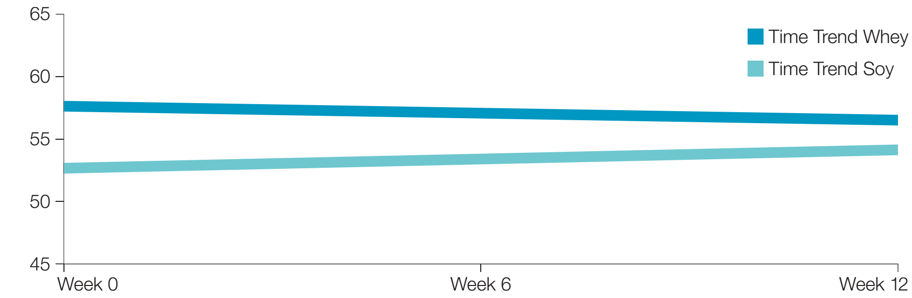


Figure 6.6.8
Triglyceride Results for All Subjects (time trend data)

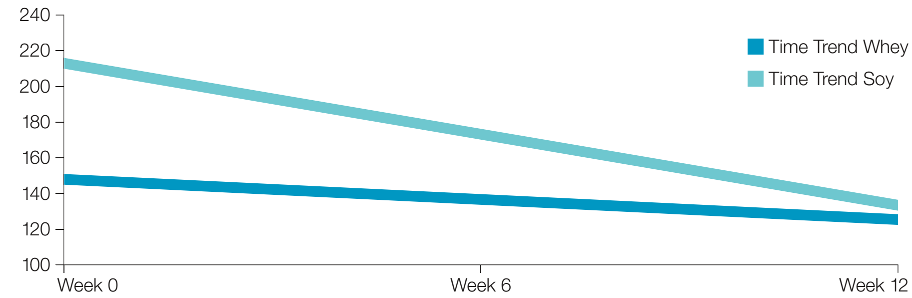


Figure 6.6.9
Thyroid Results for Male Subjects

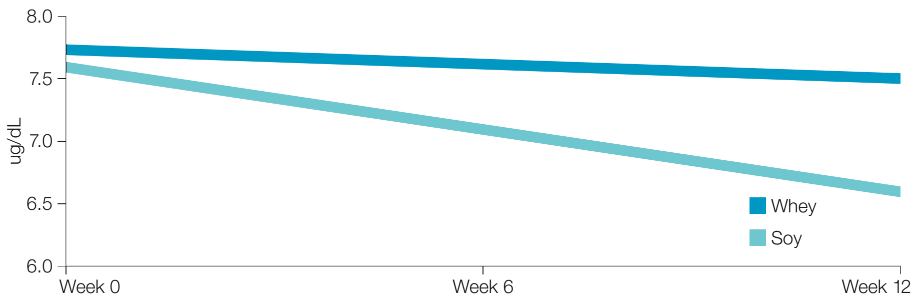
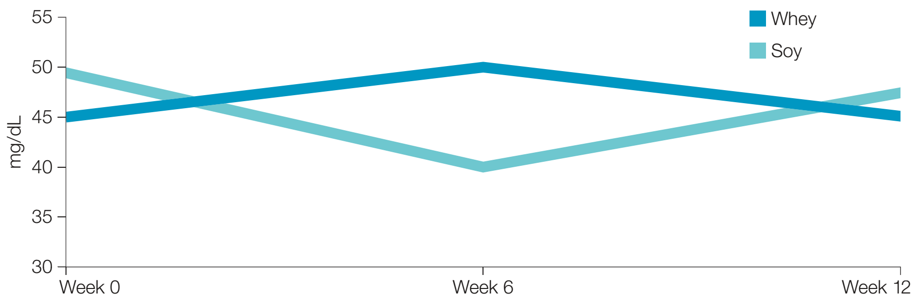


Figure 6.6.10
Cystine Results for Male Subjects



Estradiol Results for Female Subjects

Shown in Figure 6.6.11 are the estradiol results for women. At week 12, the whey group had a significantly greater decrease from baseline estradiol value than that of the soy group, a decrease from baseline of 21.4 units for the women in the whey group and a mean decrease from baseline of 0.2 units for women in the soy group. This indicates that whey protein isolate may have antiestrogenic effects. This finding, coupled with recent work by Dr. Badger (Hakkak, Korourian et al. 2000), showing that whey protein may reduce the size of breast tumors in animal studies is worthy of more research.

Glutathione Results for Female Subjects

Figure 6.6.12 shows the glutathione time trend results for women. There were significantly different time trends between the whey group and the soy group. In the whey group, the average GSH value increased 2.99 units per 6 weeks, while in the soy group, the average GSH value decreased 2.89 units per 6 weeks. The results indicate that whey protein isolate contains the naturally occurring precursors that can enhance glutathione.

Summary

In general, our findings demonstrate that the daily ingestion of 60 g of WPI or ISP had a positive effect on lipid profiles over the 12 weeks of the study, as indicated by the drop in total cholesterol and LDL cholesterol in both groups.

In addition our data demonstrates that ISP significantly lowered T4 levels in men, confirming earlier reports of a possible adverse effect of soy on thyroid function, with unkown long-term side effects. WPI exhibited no such adverse influence.

WPI decreased estradiol in women indicating that whey may have anti-estrogenic effects whereas ISP may not offer any protection against estrogen driven adverse health conditions.

WPI did significantly increase intracellular GSH which confirms whey proteins' immunoenhancing properties.

In summary, our findings from this pilot study demonstrate that WPI had a more positive impact than ISP on biomarkers of good health in exercising adults. Further studies need to be conducted to explore these results more fully.

Figure 6.6.11
Estradiol Results for Female Subjects

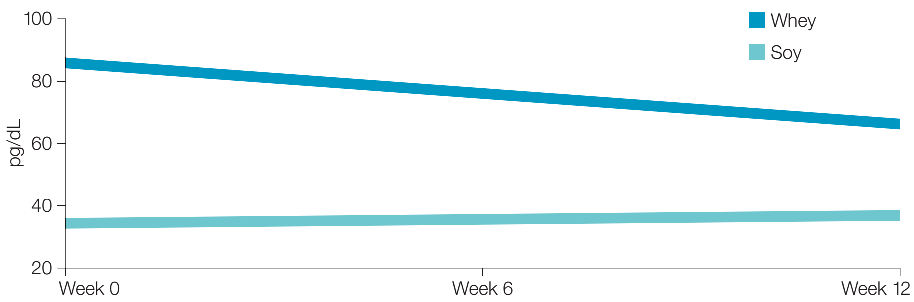
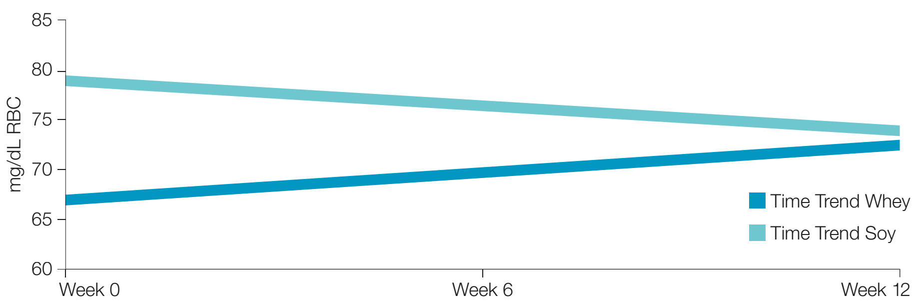


Figure 6.6.12
Glutathione Results for Female Subjects (time trend data)



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6.7 WHEY PRODUCTS, MILK MINERALS AND DAIRY CALCIUM: NEW FINDINGS AND BENEFITS

Edited by DR. DOUG DiRIENZO
National Dairy Council,
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Whey Products as a Source of Calcium

Calcium can be obtained in the diet by various sources, but the most highly recommended source is dairy products. Dairy products are a source of calcium with high bioavailability. The ingredient milk calcium is derived from milk by a unique separation technique. Whey-based products are an excellent and cost efficient source of calcium (500-2,000 mg/100 g, see table for more details). In addition, natural milk calcium (and other calcium-rich whey ingredients) presents advantages in terms of their neutral taste and bland odor. All natural and obtained from milk, these ingredients are preferred by consumers and help manufacturers design products with a "clean label" and natural image.

More Calcium is Needed

The Food and Nutrition Board of the Institute of Medicine (IOM) of the National Academy of Sciences (NAS) released new recommendations for calcium and related nutrients. These new recommendations—now called Dietary Reference Intakes (DRIs)—update and expand the Recommended Dietary Allowances (RDAs) set in 1989 by the National Academy of Sciences. The gap between calcium intakes and calcium recommendations is much wider than previously thought. Most people are not meeting the new recommendations for calcium. In addition, new scientific findings have added further support to the beneficial role of calcium in health. The World Health Organization sets recommendations for calcium intake, as well as individual countries health authorities, therefore recommended intakes might be different from those referred to in this manual. Please consult local recommendations for intake, claims and product labeling.

Calcium Recommendations

Children 4-8	800 mg
Preteens and teens 9-18	1,300 mg
Adults 19-50	1,000 mg
Adults 51 and older	1,200 mg

Source: National Academy of Science

Bioavailability of Calcium From Dairy Sources

There are many factors that influence calcium bioavailability. Both exogenous and endogenous factors influence calcium bioavailability. Level of calcium intake, vitamin D status, phytates, oxalates, lipids, phosphopeptides and other proteins, lactose, phosphorus and caffeine are among the exogenous factors influencing the intestinal calcium absorption.

Dairy foods and ingredients are not only rich in calcium, but the calcium from these sources is readily available. Normal healthy individuals absorb about 20 to 35% of the calcium in dairy foods and ingredients. Studies have shown that the calcium absorption efficiency from non-dairy calcium fortified sources (such as fortified soy milk) was 25% less than that from a dairy source. For this reason, manufacturers can rely on dairy ingredients rich in calcium (from milk powders, whey minerals to various types of whey ingredients) to provide adequate fortification with a highly bioavailable calcium content. Furthermore, dairy calcium is 100% natural (all natural "clean" label appeal) and contains a range of other minerals such as phosphorus and magnesium.

Table 6.7.1 presents the typical calcium content of major dairy ingredients.

Table 6.7.1
Typical Calcium Content of Major Dairy Ingredients

Dairy Ingredient	Typical Calcium Content, in mg/100 g
Demineralized whey	<100 mg/100 g
Whey protein concentrate	500–700 mg/100 g
Whey protein isolate	600 mg/100 g
Reduced-protein (deproteinized) whey	600–700 mg/100 g
Sweet whey	700–800 mg/100 g
Whey permeate	800–900 mg/100 g
Reduced lactose whey	800–900 mg/100 g
Mineral concentrated whey	>5,000 mg/100 g
Whole milk powder	950–1,000 mg/100 g
Skim milk powder	1,300 mg/100 g
Acid whey	2,000 mg/100 g
Milk minerals	23,000-28,000 mg/100 g

Note: Typical values only. Please consult your U.S. dairy ingredient supplier for more information.

Major Functions of Calcium in the Body

Calcium's Role in Bone Development

Bones serve as a basic support system protecting vital organs and as a reservoir for calcium—the most abundant mineral in the body. In fact, 99% of the body's calcium is found in bones and teeth (the other 1% is found in cells, blood, and other body fluids). Despite its static appearance, bone is constantly being formed and broken down. This process, called remodeling, is the resorption (breaking down) of existing bone and deposition of new bone to replace that which has been broken down. At any one time, about 10% to 15% of bone surfaces are undergoing remodeling. A number of interrelated hormonal, nutritional, mechanical, and genetic factors influence remodeling.

Resorption of old bones and formation of new bone is processes that continuously overlap. The importance of these processes varies at different times throughout the life cycle. In general, from birth until about age 20, the bones are in a phase of active growth. Beginning in the 40s or later, resorption of existing bone starts to exceed formation of new bone, resulting in a net loss. Age-related bone loss is influenced by both genetic and environmental factors.

The body's calcium status depends more on overall nutritional factors than just calcium intake. Some nutritive factors influence the body's absorption of calcium, while other factors affect calcium retention or urinary calcium excretion. Urinary losses of calcium are a big determinant of calcium loss.

Calcium nutriture depends not only on calcium intake, but also on numerous dietary and nondietary factors that influence calcium metabolism. Dietary factors aiding calcium absorption and retention include: vitamin D, lactose (which stimulates the intestinal absorption of calcium in laboratory animals and in human infants), fiber, phosphorus, protein, sodium and other elements.

Calcium and Chronic Disease Prevention

Increasing scientific evidence indicates that an adequate calcium intake reduces the risk of several major chronic diseases including osteoporosis, hypertension, colon cancer, and possibly cardiovascular disease and kidney stones. These diseases are responsible for considerable morbidity and mortality in many patients, as well as rising national health expenditures.

Osteoporosis

Osteoporosis (porous bones) is a skeletal disease in which bones become so fragile they spontaneously break as a result of a minor fall or even from everyday activities. Decreased bone mass and microarchitectural damage to bone tissue cause the bones to become fragile.

The rate of osteoporosis has reached epidemic proportions in many countries of the world and is responsible for considerable morbidity, mortality, and economic costs. Diet, specifically calcium intakes below the recommended levels throughout life, may increase the risk of osteoporosis. Also, an inadequate vitamin D status contributes to low bone mass. Ensuring an adequate calcium and vitamin D status throughout life is estimated to reduce osteoporotic fracture risk by 50% or more. Other dietary factors like sodium, protein, and fiber may influence the risk of osteoporosis by impacting calcium status. However, if calcium intake is adequate, these other dietary factors have relatively little effect on osteoporosis risk.

Osteoporosis experts agree that an optimal intake of calcium throughout life, from early childhood and adolescence through the postmenopausal and later adult years, reduces the risk of osteoporosis. Research indicates that it is never too early or too late to improve bone health and reduce the risk of osteoporosis. Intake of milk and milk products has been demonstrated to protect against osteoporosis by increasing bone retention and reducing fractures.

In a study involving over 5,500 women, 50 years of age and older from six countries, an adequate calcium intake from milk decreased the number of hip fractures by 35%.

Menopause and Bone Loss

During menopause, accelerated bone loss is due mostly to the sharp decline in estrogen levels. Estrogen replacement therapy is the most effective means to slow bone loss, especially in the first six to eight years after menopause. Adequate calcium intake, while less effective than estrogen in slowing bone loss, nevertheless is important at this time. In women who were between three and six years past menopause, increasing calcium intake to 1,700 mg/day for three years slowed bone loss, although the combination of calcium and estrogen therapy was more effective than calcium alone. A high calcium intake may reduce the dosage of estrogen necessary to prevent bone loss in postmenopausal women. A recent meta-analysis found that increasing calcium intake in conjunction with estrogen increased bone mass in the spine, hip, and arm about three times more than with estrogen alone.

In postmenopausal women, bone loss is minimized by calcium intakes of 1,000 to 1,500 mg/day. Particularly noteworthy is the finding of significantly fewer fractures by women who consumed about 1,700 mg calcium/day compared to women who consumed 700 mg calcium/day.

Calcium and Premenstrual Syndrome

Calcium supplementation, in recent research, is being linked to a decrease in premenstrual syndrome (PMS) symptoms. Dr. Susan Thys-Jacobs states that "clinical trials in women with PMS have found that calcium supplementation effectively alleviates the majority of mood and somatic symptoms." A recent double-blind, placebo-controlled study of 466 women with PMS concluded that "calcium was effective in reducing emotional, behavioral, and physical premenstrual symptoms (Pearlstein). This study showed a 48% reduction in the PMS symptoms score by the third treatment cycle, compared to the baseline (Thys-Jacobs, AJOG). The current research results have indicated a positive impact of calcium on premenstrual syndrome symptoms. Future research goals include determining the calcium's mechanism in reducing PMS symptoms, as well as looking into the potential ability of PMS to be an indicator for increased osteoporosis risk.

Hypertension

In the U.S. the Joint National Committee on Direction, Evaluation and Treatment of High Blood Pressure recommends consuming adequate amounts of calcium (as well as potassium and magnesium) to help reduce blood pressure. A review of 25 epidemiological studies investigating the relationship between the intake of calcium or calcium-rich foods and blood pressure found that the majority of these studies supported an inverse relationship. The beneficial effect of calcium on blood pressure provides yet another reason to ensure adequate intake of calcium-rich foods as part of a healthy diet. An advantage of milk minerals (as an ingredient for enrichment) over other calcium sources, is that this ingredient provides highly bioavailable calcium in balance with other minerals to optimize health benefits.

A diet containing an adequate amount of calcium is recommended as a nonpharmacological lifestyle modification for the prevention and treatment of high blood pressure. Many studies have demonstrated that calcium reduces the risk of hypertension or high blood pressure, especially in certain subgroups of the population.

Although increased calcium intake generally lowers blood pressure more in adults than in children, a blood-pressure-lowering effect of calcium has been demonstrated in some young children, especially those whose calcium intakes are initially low. In teens, differences in calcium intake have been observed between those with high-normal and low-normal blood pressure. Because as many as one half of children with high blood pressure may have hypertension as adults, children should consume an adequate intake of calcium.

High Blood Pressure, Pregnancy and Calcium

Pregnancy-induced high blood pressure occurs in 10% to 20% of pregnancies. Studies have shown that increasing pregnant women's calcium intake by 1,500 to 2,000 mg/day reduced the incidence of pregnancy-induced high blood pressure by 70% and preeclampsia by 62%. Further, consuming optimal amounts of calcium reduced the likelihood of developing preeclampsia.

Based on numerous clinical studies, researchers acknowledge that the beneficial effects of calcium on blood pressure might be even greater if calcium is derived from food, such as milk and milk products, instead of supplements. The findings that milk has a better antihypertensive effect than calcium alone support this speculation. In addition to calcium, milk and milk products contain potassium and magnesium, each of which has been demonstrated to reduce blood pressure.

Cardiovascular Disease

Coronary heart disease (CHD) is the most common and serious form of cardiovascular disease in the U.S. Cigarette smoking, high blood pressure (hypertension), and elevated blood cholesterol levels are the major risk factors for this disease. Calcium may protect against CHD by its effect on two of these risk factors: hypertension and blood lipid levels. In patients with mild to moderate hypercholesterolemia, an increased calcium intake lowers total and LDL (low-density lipoprotein) blood cholesterol levels. Calcium alone is not responsible for milk's protective effect against stroke. Total calcium intake or intake of calcium from nondairy sources did not have the same protective effect as milk.

Colon Cancer

Experimental animal and human evidence supports the hypothesis that calcium intake inversely correlates with colon cancer risk and cell proliferation in the colonic mucosa. Colon cancer is the third leading cause of cancer deaths in the U.S. and a leading cause in many countries. Both genetics and environmental factors contribute to this disease. While some dietary factors are suspected of contributing to colon cancer, others are thought to be protective. Several components in cow's milk fat such as conjugated linoleic acid, sphingolipids, and butyric acid have been found to protect against colon cancer in experimental animal and laboratory studies. Findings from a number of scientific studies indicate that calcium intakes in excess of current recommendations may reduce risk of colon cancer.

Studies to date indicate that calcium intake of 1,500 to 2,000 mg/day—amounts greater than current calcium recommendations of 1,000 to 1,200 mg/day for most adults—are necessary to protect against colon cancer, especially in individuals at risk of this disease. However, further studies are needed to firmly establish calcium's protective effect against colon cancer and to determine the mechanism(s) involved. Advice to increase calcium intake above current recommendations to protect against cancer is considered premature at this time.

6.7.1 PART II: BALANCE IN DIETARY MINERAL CONSUMPTION

By DR. ERIC BASTIAN
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Monroe, WI

Recently, the importance of dietary calcium has increased because research has established that calcium is not only essential for bone growth and development, it is also important for regulation of cell function, nerve conduction, muscle contraction, and blood coagulation. In addition, calcium provides a protective role against osteoporosis, essential hypertension, gestational hypertension, hypercholesterolemia, certain cancers (colon and mammary) and possibly gallstones.

Several population segments in both developed and developing countries have low calcium intake. Calcium supplementation and fortification has become increasingly important and calcium is being incorporated into many food products around the world. Calcium supplements are usually calcium salts such as calcium citrate, calcium lactate, calcium carbonate, and calcium phosphate.

In the hype that has surrounded calcium supplementation and fortification, one of the basic principles of nutrition balance has been neglected and overlooked. Obviously, to maintain proper composition of mineral in the bone, there must be adequate absorption and delivery of all bone minerals to bone sites in the human body.

Phosphorus is required for bone growth and maintenance, and most recommendations for phosphorus are to maintain a dietary calcium:phosphorus ratio of 2:1. Because most of the calcium supplements deliver only calcium and none of the other bone building minerals such as magnesium, potassium, zinc and other minerals required for good bone health.

Just as Ca/Mg/K ratios have received little attention among researchers in the osteoporosis area, ratios of the required micronutrients also have received little attention. The effects of calcium supplementation with and without zinc, copper and manganese showed that bone loss in postmenopausal women could be only partly arrested by Ca supplementation, but to fully maintain bone mass, trace minerals were required. It can be concluded that many minerals are required for optimal bone growth and health, but that the extreme focus on only calcium has, in a sense, inhibited the promotion of a balanced approach for mineral supplementation, particularly for segments of the population that are at risk for osteoporosis.

One mineral supplement that has been widely accepted in Asia and is recognized there as the "premier" bone building supplement is "milk calcium" (more accurately called milk mineral). It has been recently shown by several studies that milk mineral contains the appropriate balance of minerals for optimal bone health. Milk mineral is an ingredient that retains the mineral balance of milk while allowing for mineral supplementation into products that traditionally do not contain good ratios of bone building minerals.

Table 6.7.1
Typical Composition of Milk Minerals

Component		Percentage
Ash		**70.00%**
Calcium		25.00%
Phosphorus		14.00%
Ca/P		1.79
Ca/PO4		0.58
Magnesium		1.50%
Sodium		0.65%
Potassium		0.83%
Zn (mg/100 g)	27.40	
Cu (mg/100 g)	0.37	
Fe (mg/100 g)	1.88	
Organic Mineral (citrate)		**9.00%**
Total Mineral Content		**79.00%**

6.8 NUTRITIONAL AND PHYSIOLOGICAL PROPERTIES OF LACTOSE

By LOIS McBEAN
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Lactose or milk sugar is a disaccharide that is hydrolyzed by the enzyme beta-galactosidase into glucose and galactose molecules. The slow hydrolysis of lactose by the body during digestion generates a prolonged energy supply. Because lactose has a low glycemic index, or causes a slow rise in blood glucose relative to a standard, this sugar may be beneficial for diabetics. Diets that emphasize foods with a low glycemic index may have important health benefits. Lactose increases the absorption of minerals such as calcium, magnesium, and zinc in laboratory animals and human infants. Compared to other sugars such as sucrose, lactose has minimal ability to produce tooth decay. By stimulating the growth of beneficial intestinal bacteria such as Bifidobacteria and Lactobacilli and inhibiting pathogenic bacteria, lactose contributes to a healthy intestinal flora.

Lactose, Glycemic Index and Carbohydrate Metabolism

Lactose has a relatively low glycemic index, which may make this sugar beneficial for diabetics. The glycemic index of a carbohydrate or food refers to the increase in blood glucose relative to a standard such as glucose or white bread. Foods with a low glycemic index cause a slow, modest rise in blood glucose levels. In contrast, foods with a high glycemic index cause a faster, higher increase in blood glucose. An increase in blood glucose elicits secretion of insulin, which controls blood glucose levels. However, because of insulin deficiency in diabetics, blood glucose levels remain elevated and adverse health effects result if treatment with insulin and/or diet is not provided. Lactose has a lower glycemic index (65) than either glucose (138), honey (104), or sucrose (87). Diets that emphasize low glycemic index foods not only may help decrease the risk of developing diabetes and improve blood sugar control in diabetics, but such diets may also have other health benefits. By improving insulin sensitivity and lowering blood lipid levels, low glycemic index diets may help reduce the risk of heart disease.

Lactose and Mineral Absorption

Lactose in the diet stimulates the intestinal absorption and retention of calcium, as well as other minerals such as magnesium, zinc and manganese. This beneficial effect of lactose is shown in laboratory animals and in human infants. Less clear is whether lactose has a unique effect on the absorption of minerals such as calcium in adults. Lactose's ability to stimulate the intestinal absorption of calcium is independent of vitamin D and, because lactose acts on passive calcium absorption, its effect is not influenced by calcium intake. The mechanisms involved are unknown. However, increased mineral solubility, particularly for calcium absorption, has been proposed. The metabolism of lactose by intestinal flora increases lactic acid concentration in the intestinal tract, which reduces the pH in the intestinal lumen and increases calcium solubility. Lactose's effect on the absorption of calcium and other minerals may depend on its presence in the distal bowel. In Caucasians who generally maintain a relatively high level of the intestinal enzyme lactase, which hydrolyzes lactose, little lactose reaches the distal intestine. In contrast, in other populations with low lactase levels, the higher amount of lactose in the distal intestine may favor mineral absorption.

Lactose and Dental Caries

The low cariogenicity (caries-producing effect) of lactose compared to other sugars has been confirmed by many studies. Lactose is metabolized slowly by oral plaque microorganisms, which results in a minimal effect on plaque pH. In contrast, sucrose is metabolized quickly and pH values fall to levels conducive to caries promotion. Also, unlike sucrose, which supports the formation of dental plaque, lactose does not give rise to dental plaque. Lactose, in contrast to sucrose, is considered to be either noncariogenic or minimally caries-promoting.

Lactose: Its Prebiotic, Bifidogenic Effects

Lactose stimulates the growth of beneficial intestinal flora but inhibits the growth of pathogenic bacteria and endotoxins. Because of lactose's slow transit time through the digestive system, some undigested lactose reaches the colon where it is used as a substrate for the growth of beneficial lactic acid bacteria such as Bifidobacterium bifidum and Lactobacillus. Growth of these lactic acid bacteria results in an acid environment that inhibits the growth of pathogenic organisms. Lactose is a starting material for prebiotics such as lactulose, lacitol, lacto-sucrose, and lacto-oligosaccharides that selectively stimulate the growth of health-promoting bacteria (i.e., probiotics) such as bifidobacterium in the colon. Specific strains of bifidobacteria are reported to inhibit the growth of pathogens, stimulate the immune system, restore the gut flora after antibiotic therapy, and have positive effects on antibiotic-associated diarrhea. The potential health benefits of modifying the intestinal flora are being recognized. Intake of lactose by infants, children and adults may increase resistance to intestinal infections and contribute to the maintenance of a healthy intestinal flora.

Lactose Intolerance

Lactose is a disaccharide found naturally in the milk of mammals. It is found in cow's milk and many other dairy products. During digestion, the intestinal enzyme lactase breaks down lactose into the simple sugars, glucose and galactose, for absorption into the bloodstream. Most people produce sufficient amounts of lactase at birth and during childhood to digest usual amounts of dietary lactose. However, some individuals, as they age, may have a low level of intestinal lactase, which can result in lactose maldigestion. Many lactose maldigesters can consume the amount of lactose in at least one cup of milk when consumed with a meal. Moreover, tolerance to lactose can be improved by gradually increasing intake of lactose-containing foods such as milk and other dairy products.

6.9 WHEY PROTEINS IN MEDICAL AND FEEDING APPLICATIONS (INCLUDING HIV)

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Whey proteins resonate across a wide range of criteria for superior human food ingredients: natural, good flavor, functional human nutrition factors, cow's milk source, a variety of forms to choose from, good availability, cost effective, exceptional healthy image, continuing research, food processing performance, among others.

We know that whey proteins evolved as critical components of mammalian milk (mother's milk) on which the survival of all mammals depend with each new generation of young. This is truly the nutritional miracle of mammalian milk. Significantly, the cross species nutritional value—cows to humans—is also remarkable. For these two reasons alone, whey protein is deserving of our attention as a source of functional ingredients with powerful value that we must continue to explore, but most importantly, actively apply in the formulation of nutritious foods.

Whey protein use in human food, while advancing rapidly, remains an exciting and rapidly changing domain for understanding it's broad-spectrum performance in human nutrition. Whey proteins can be used in nutrition programs. An example is ABCI's recent inclusion of whey protein (80%) in an experimental maize flour-based fortified biscuit designed for malnourished Mayan children in Guatemala. This work was done in collaboration with MainStay Foods of Guatemala. Through the use of WPC80, a 85% daily value ("DV") of protein requirement was achieved, including the nine essential amino acids, for a child if they eat three of these 50g biscuits a day. In addition, the flavor, texture, and color of the biscuit were improved, and protein levels sustained through baking.

While we strive to delve deeply into the exceptional performance factors of whey protein, at the same time we must aggressively employ this complex functional material as an ingredient of the foods we are formulating. For whey protein to confer its benefits, we must be using it in foods, and assuring that those foods get to the people who need them.

This can be built upon many ingredient criteria including:

- Performance goals: whey proteins meeting the nutritional needs of the health conscious and athletes.
- Preventative intervention: whey proteins fortifying the diets of the nutritionally deprived.
- Therapeutic care: whey proteins strengthening immune function through nutrition, for example, of those living with HIV/AIDS.

Moreover, functional claims made about performance of whey protein in human nutrition are substantiated by a bulwark of published and ongoing research that can be cited by food processors.

Whey proteins and HIV, *herpes infection*

The spread of sexually transmitted diseases, including human immunodefficiency virus type 1 (HIV-1) and herpes infections have continued despite educational efforts spearheaded as a response to the HIV-1 epidemic. This has suggested the need for prophylactic measures, including the application of topical antiviral agents. Researchers at the LFK Research Institute of the New York Blood Center worked on the chemical modification of Beta-lactoglobulin, the major protein of whey, that led to the generation of a potent HIV-1 inhibitor, shown to also have activity against herpes simplex virus 1 and 2. In agreement with results on inhibition of HIV-1 infection, this lactoglobulin derivative appears to be the acid anhydride-modified protein of choice as an antiviral agent against herpes viruses. The widely available source of lactoglobulin from whey for the production of these compounds also suggests, according to researchers at the Center, its potential application for diminishing the frequency of HIV transmission.

Neurath, A.R. et al. 3-Hydroxyphtaloyl beta-lactoglobulin. III. Antiviral activity against herpes viruses. Antivir. Chem. Chemother. 1998. 9(2): 177-84.

Other studies have focused on the role of whey proteins in the diet of HIV-seropositive individuals. HIV infection is characterized by an enhanced oxidant burden and a systemic deficiency of the tripeptide glutathione, a major antioxidant. Different strategies to increase glutathione levels have been suggested, including oral supplementation with whey proteins. Studies have demonstrated that in patients who maintain adequate total caloric intake, the addition of "bioactive" whey protein concentrate as a significant portion of total protein intake increases body weight and shows elevation of glutathione content of mononuclear cells toward normal levels. Long-term clinical trials remain needed to show how supplementation with whey proteins can translate into a more favorable course of the disease.

Micke, P. et al. Oral supplementation with whey proteins increases plasma glutathione levels of HIV-infected patients. Eur. J. clin. Invest. 2001. 32(2): 171-178.

Bounous. G. et al. Whey proteins as food supplement in HIV-seropositive individuals. Clin. Invest. Med. 1993. 16(3): 204.

7.1 FUNCTIONAL PROPERTIES OF WHEY PRODUCTS

Edited by
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While research into whey proteins, utilization and functionality continues, whey ingredients already offer numerous functional benefits to food formulators. The functional properties of whey ingredients are dictated by the functionality of the whey proteins. Whey proteins possess solubility over a wide pH range, create viscosity through water-binding, form gels, emulsify, bind fat, facilitate whipping, foaming and aeration, enhance color, flavor and texture, and bring with them numerous nutritional advantages.

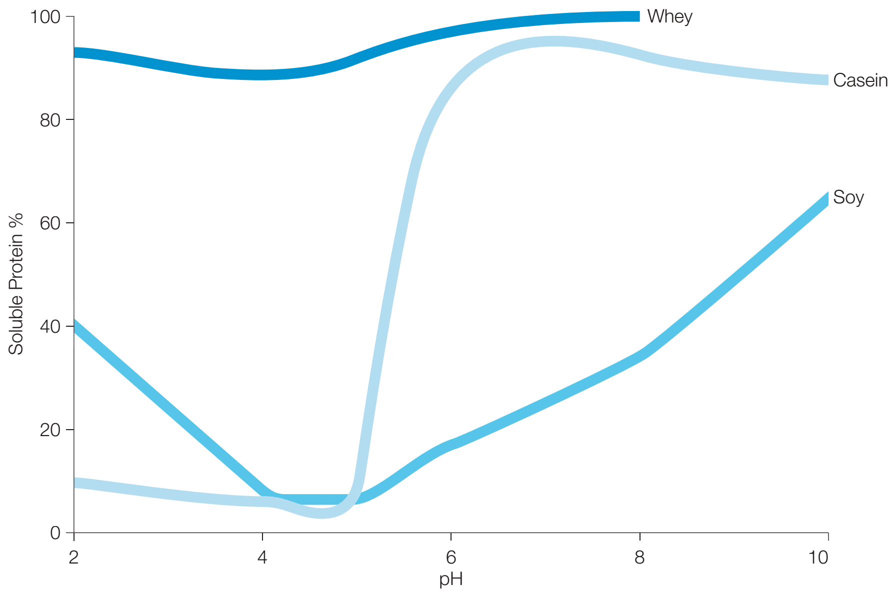
Solubility

Whey proteins are highly soluble, especially when compared to sodium caseinate and soy proteins (see Figure 7.1). The solubility of a protein depends on its water-binding capacity and its physical state. Whey protein concentrates are typically very soluble though their water binding capacities are relatively low.

In most processed foods, processing is simplified and product consistency is improved by using ingredients that are soluble and easily dispersed. In ready-to-drink beverages, a protein ingredient with good solubility would not result in a drink with protein flocculation or sedimentation. Soluble proteins are also important in processed soups and sauces where curdling, sedimentation and separation from insoluble proteins are highly undesirable. In chopped meats, salad dressings, dairy and bakery products proteins provide many other functional properties that are affected by their solubility.

In general, protein solubility is affected by heat and most foods are heat-processed, whether it involves baking bread, cooking caramel, or retorting soup for preservation purposes. Heating to temperatures above 70°C can cause denaturation or partial loss of solubility between pH 3-5 because some of the whey proteins aggregate and precipitate at their isoelectric points (pH 4.5-5.5). Other ions, such as calcium, will also increase the loss of solubility with heat. Whey proteins that have not been heat denatured exhibit excellent solubility over a wide pH range. An aqueous solution of whey protein concentrate, heated to 90°C for 5 minutes will still have 80% of the whey protein remain soluble. In dilute solutions above pH 6.5, whey proteins remain soluble when heated at a temperature of 80°C for 10 minutes or longer. The heat stability of whey proteins in heated food products can be improved by the addition of sugar, as in confections and ready to eat drinks. In high acid systems with pH less than 3.5, such as a fruit-flavored beverage or salad dressing, the acid solubility of whey proteins is especially important.

Figure 7.1
Solubility of Proteins as affected by pH



Water-Binding and Viscosity

Water binding and viscosity are related functional properties. Products that bind large quantities of water such as starches and gums create viscosity. When whey proteins are heated, the bonds that are responsible for their globular structure break down. As the protein molecule unfolds, additional water binding sites are created, which increases the viscosity of the solution.

In nutritional beverage products, low viscosity allows product developers to increase protein levels in a drink without damaging visual appeal, taste or texture. Whey can add turbidity or opacity contributing to a creamy or milky appearance in a beverage.

In products such as puddings and yogurts, water-binding properties help produce a more viscous texture and control separation. Yogurts fortified with WPC synerese (lose water) significantly less than yogurts fortified with skim milk powder.

In chopped meats and bakery products, water binding contributes to the texture of the meat emulsion and bakery dough. In these products, water binding reduces cooking and baking losses, improves yields and contributes to the moistness of the final product. Increased moisture content in dairy foods helps enhance the sensory profile by increasing flavor release.

Water binding properties contribute to the formulation of reduced-fat products by adding fat-like attributes such as lubricity and mouthfeel. In addition, certain whey products add opacity to reduced-fat dairy formulations.

Gelling

Under specific conditions whey proteins form non-reversible gels. Gel characteristics depend upon the protein concentration, the pH of the solution, calcium ion concentration and sodium ion concentration.

For example, gels formed in solution with 3%-5% protein concentrations and at a temperature of 55°C-70°C tend to be more translucent and softer. More opaque gels are formed when higher protein concentrations (10%) are heated to higher temperatures (90°-100°C). In acidic conditions, gels tend to be opaque, wet and weak. In neutral and higher pH solutions, gels tend to be more translucent and elastic.

The unique gelling properties of whey proteins maintain moistness in baked goods and meats, add opacity to beverages and dairy products, and improve texture and mouthfeel in reduced-fat products, bakery products, processed cheese, yogurt, puddings and custards, and chopped meats and seafood.

Emulsification

Whey proteins have both hydrophilic (water attracting) and hydrophobic (water repelling) groups.

Whey proteins are proposed to form interfacial membranes around oil or water globules by absorbing at the oil/water interface. At the interface, the proteins partially unfold to stabilize the globules and prevent coalescence and oiling off. Whey proteins function, as well as traditional emulsifiers (such as egg yolk powder), in mayonnaise-type dressings, and are lower in cholesterol.

The stability of whey protein emulsions can be further enhanced by adding gums or heating the system to create a protein gel. Heating the proteins will reduce the fat mobility and minimize coalescence while gelation can provide complete entrapment of the fat emulsion. The emulsification properties of whey proteins can be an advantage in most processed food products, including margarine, sauces, chopped meats and seafood, ice cream mixes, bread dough, cake batters and salad dressings.

Whipping, Foaming and Aeration

The formation of a foam is similar to the formation of an emulsion, only in this case, whey proteins function to stabilize the interface between two air cells.

The speed of air incorporation and the stability of the foam are dependent on a number of parameters, including total solids, protein and carbohydrate concentration, pH, the concentration of calcium and other ions, and whipping method.

Whey proteins can be used to partially replace or extend eggs in bakery products, offering economic advantages as well as a more consumer-friendly label. Good whipping and foaming properties are crucial to the production of whipped toppings, marshmallow and nougat, icings, ice cream and frozen yogurt.

Flavor

In their pure form, whey proteins are very bland in flavor. However, depending on the application, whey can either serve to bring out already present flavors, or add flavor of its own.

For example, when whey proteins are heated, volatile sulfides are produced. Free amino acids are also converted to flavorful compounds by the heat and chemical interaction with other compounds. Whey proteins provide a range of flavors as well as aroma to bakery products.

In other food categories, such as beverages and confections, whey's bland, slightly sweet flavor allows other fruit and chocolate flavors to come through. In soups and sauces, spices and herb flavors are accentuated.

Whey minerals also enhance dairy and meat flavors, and enhance savory foods. In applications where the mineral flavor might be a disadvantage, demineralized whey or WPC with lower mineral content are available from U.S. suppliers.

Dispersibility

Generally, whey ingredients have good dispersibility but in applications such as a dry beverage mix it is especially important. For applications that require the whey ingredient to dissolve in water quickly and without an excessive amount of agitation, there are instantized forms of WPC and WPI available. The process of instantizing or agglomeration involves the use of a unique spray drying process, which produces agglomerates with improved wettability, sinkability, and dispersibility.

Edible Film Formation

Edible films are defined as a thin layer of edible material formed on a food as a coating or placed on or between food components. Edible films are used to prevent quality changes in foods by functioning as barriers to moisture, oxygen, oil and aromas. Edible films have also carried food ingredients, increased the integrity of foods and reduced the packaging requirements for food products. Whey protein ingredients have the ability to form water-based edible films that are transparent, bland, and flexible with excellent oxygen, aroma, and oil barrier properties at relatively low humidity. Whey protein isolates at concentrations from 5% to 10% have typically been used for this application.

Antioxidant Activity

Some research has been done using whey and WPC for its antioxidant properties in foods. Whey has been evaluated for its ability to prevent lipid oxidation in pre-cooked meats such as pork and salmon. Commercial application of whey for this purpose has not been evaluated but could be an additional benefit when used in high fat applications such as meats.

Adhesion

The adhesion properties of whey products help to improve the homogeneous texture of food products. WPCs may be used to adhere breadcrumbs or batters to meat, fish, or vegetables or aid in adhering meat pieces together. The addition of WPC to a bakery glaze could improve its adherence to the product. For toppings such as sesame seeds or poppy seeds, WPC solutions may be used to adhere the seeds to the surface of bread products.

Browning

Due to their composition, the combination of lactose and protein in whey products provides the necessary components for the development of heat-induced browning. Similar to the functionality described in lactose ingredients, whey products also participate in Maillard browning and caramelization reactions. Most whey ingredients contain a significant amount of lactose, which can contribute to browning, especially important in baked products and caramel confections. Whey protein-lactose browning will also occur in products cooked by microwave where the lower surface temperatures are insufficient for the browning produced in a conventional oven.

8.1 FUNCTIONAL PROPERTIES OF LACTOSE PRODUCTS

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Flavor, Color Absorption and Retention

Lactose is several times more effective than most sugars in attracting and holding volatile aromas and flavors. It shows equal affinity for aldehydes, ketones, and esters—the volatile flavor compounds that are important in many foods.

In addition to absorbing flavors, lactose enhances and renders many flavors more distinguishable to the taste. Likewise, lactose has a strong tendency to absorb synthetic and natural colors. In tomato sauce, for example, lactose can reduce the acid taste, enhance the tomato flavor and preserve the red color.

Lactose is used as a food flavor diluent to provide adequate dispersion and slow flavor release in food products. Anhydrous lactose is especially good at retaining volatile flavors such as roasted coffee flavor. Lactose is also known for retarding flavor loss during processing and storage of foods.

Browning

Lactose is a reducing sugar, and it will react with amines to form typical Maillard reaction (non-enzymatic browning) compounds. It also caramelizes, although the temperature at which it caramelizes is higher than most sugars. Lactose will begin to caramelize at 150-160°C and turn brown at 175°C.

In both caramel-type confections and bakery products, the color and flavor development from the lactose and amine-lactose interactions is desired. The crust color of breads and rolls is enhanced by high-lactose whey products (sweet whey, deproteinized whey) and is more golden-brown than the crust color produced by dextrose. Many cookies and crackers have added caramel colors or other natural and artificial colors, otherwise they lose their golden brown color over time. The addition of lactose will help maintain the desired golden brown color throughout the baked product's shelf life.

Hygroscopicity

The Alpha-monohydrate form of lactose is very stable. It is non-hygroscopic and will remain free flowing in high temperatures and high relative humidity. This is one reason for using lactose as a carrier for other ingredients such as high-intensity sweeteners, flavors and seasonings.

By controlling the drying of high lactose whey products, the percentage of lactose in the Alpha-monohydrate form can be maximized. These whey products are also non-hygroscopic and are excellent bulking and flow agents in dry mixes, and dry soup and sauce mixes. The non-hygroscopic properties of lactose can aid in controlling hygroscopicity of confections, such as fondants, during storage. The crystals also facilitate dispersion in water.

Supersaturated solutions of lactose may exist in non-crystalline forms termed "lactose glass" or "amorphous lactose." Lactose in this form is very hygroscopic. This affinity for moisture is an asset in preserving the moistness and tenderness in baked goods and confections. Lactose has bulking and osmotic pressure affects associated with sucrose, important properties for the formulation of preserves and fruit products.

Sweetness

A 10% sucrose solution is equal to a 20-30% lactose solution in perceived sweetness. At common concentrations in foods, lactose is one-fifth to one-third as sweet as sucrose. This is an advantage because excessive sweetness does not limit the use of lactose. Sweetness is often controlled using lactose in confections like chocolate or pectin jellies.

Solubility/Crystallization

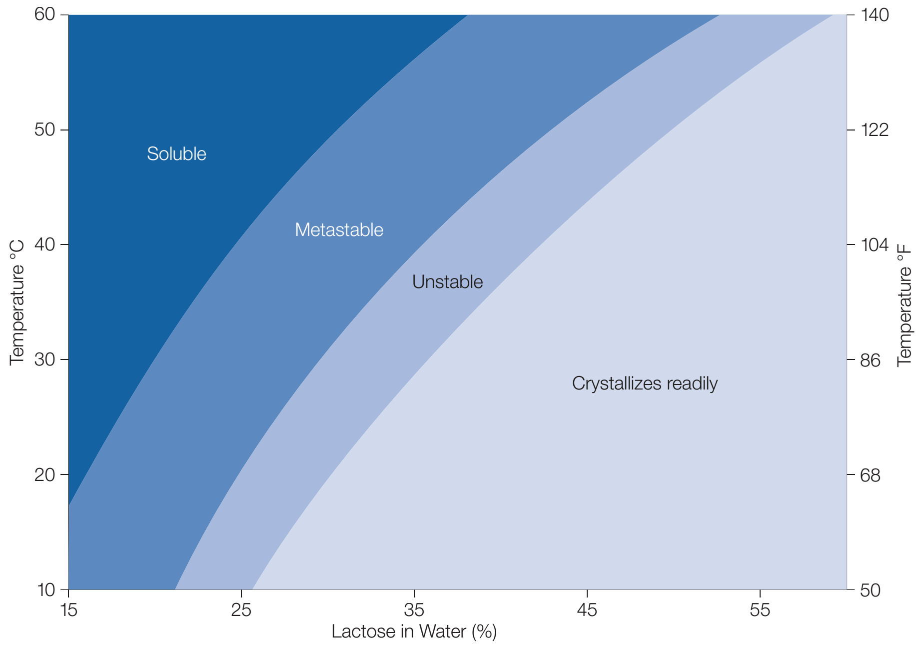
Lactose is soluble, but less so than the other common sugars such as sucrose, fructose and dextrose.

The solubility of lactose is limited when adding either lactose or dairy ingredients with high concentrations of lactose to foods. To avoid crystal formation and sandy texture, WPCs are added for the maximum concentration of whey in frozen desserts. Reduced-lactose whey is used to maximize total whey in processed cheese foods. In confections, addition of corn syrup and fat can aid in controlling crystallization. In other products such as sweetened condensed milk, crystallization is controlled by adding lactose seed crystals to the saturated solution. The crystals that form are very small and impalatable.

When the size of lactose crystals is controlled, crystallization can be an advantage in creating a desired texture in some confection products. In panning of confections, lactose retards crystallization of sucrose, which allows the coating to be formed at lower temperatures.

Figure 8.1 relates the solubility of lactose in water at specific temperatures.

Figure 8.1
The Solubility of Lactose In Water at Specific Temperatures



Fermentation Substrate

Lactose is converted to lactic acid by lactic cultures. This fermentation process is important to both flavor and texture. Some cultures can also convert lactose to proprionic acid. Dependent upon the concentration, the propionic acid produced can control mold growth. Lactose is not fermented by baker's yeast. Fermented whey and lactose products are used in the baking industry as natural preservatives for bread and other baked goods. In yeast-leavened bakery products, the lactose remains available for crust color development, emulsification of shortening and water retention.

Other products produced by the fermentation of lactose include ethanol, butanol, citric acid, single cell protein, ammonium lactate, extracellular microbial polysaccharides and fuel gas (anaerobic fermentation).

Tableting Excipient

Lactose has the properties important for a suitable excipient including particle size, flowability, binding properties, stability, wettability, blending and compatibility. When used in candy tablets, the other properties, such as color and flavor absorption and retention, and rapid solubility are an advantage. Lactose products have been developed with exceptional flow properties for high-speed tablet machines. Pharmaceutical lactose, which is more refined than edible lactose, is used for these applications.

Lactose Particle Size

U.S. edible grade lactose can be selected by particle size to fit the need of an application. Particle size is often listed by mesh size, with 30, 80, 100, and 200 mesh as common products. Please consult with your supplier for more information.

Typically, finer grinds are used for applications such as icings, compound coatings, dry mix beverages, and seeding of sweetened condensed milk. Dry blended products may also require specific particle size to match the other ingredients in the mix. The larger to medium particle sizes can be used in baked products, infant formula, coffee creamers, canned and frozen foods and frozen desserts.

Table 9.1 and Table 9.2 are listings of many of whey's functions, the particular whey characteristic responsible for each function, the benefits of each function and a listing of corresponding food applications.

Table 9.1
Whey Products

Function	Characteristics	Functional Benefits	Marketing Benefits	Applications
Emulsification	Presence of hydrophilic and hydrophobic groups on whey proteins.	■ Creates stable emulsions. Prevents fat globules from forming one large mass. ■ Functions as well as egg yolk, yet lower in cholesterol than egg yolk powder. ■ Versatile. Can be used in a wide variety of systems.	■ Improves product appearance, thus making it more appealing to consumers. ■ A lower cholesterol content means greater appeal to health-conscious consumers. ■ Using whey instead of eggs lessens microbiological risks.	■ Meat and seafood products ■ Ice cream mixes ■ Baked goods, including cake batters and bread dough ■ Beverages ■ Mayonnaise-type dressings
	Whey components aid in the dispersion of milkfat and shortening.	■ Helps facilitate fat reduction.	■ Reduced-fat products appeal to health-conscious consumers.	■ Dairy products ■ Baked goods
Gelling	Whey components form non-reversible gels under specific conditions.	■ Gels bind large quantities of water and non-protein compounds. ■ Improves mouthfeel. Helps lubricate and provides the creamy, smooth texture of fat.	■ Appeals to the health-conscious by creating a reduced-fat product with the taste of a full-fat product.	■ Meat and seafood products ■ Dairy products such as processed cheese food and yogurt ■ Desserts, such as flan
		■ Provides strength through protein-gluten interactions.	■ Better texture and, therefore, better taste.	■ Pasta products
Water binding and viscosity building	Under specific conditions, protein molecules in whey unfold.	■ 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.	■ Reduced ingredient costs can translate into lower consumer prices or increased marketing expenditures. ■ A moister product equates to a fresher product. ■ Reduced-fat products appeal to health-conscious consumers, especially if they can duplicate the full-fat mouthfeel.	■ Baked goods ■ Dairy products ■ Chopped meat and seafood products ■ Salad dressings ■ Sauces and soups
		■ Increases viscosity in dry mixes.	■ Improves product texture, increasing consumer appeal.	■ Dry sauces and other mixes ■ Coffee creamers
		■ Increases viscosity in beverages.	■ Low viscosity allows the use of high concentrations of protein in beverages, thus reducing the need to consume large quantities of the product to gain nutritional benefit.	■ Nutritional beverages

Table 9.1 (continued)
Whey Products

Function	Characteristics	Functional Benefits	Marketing Benefits	Applications
Whipping, foaming and aeration	Surface active properties of whey proteins.	■ Helps maintain foam stability. ■ Helps improve whip volume. ■ Can be used to replace egg whites.	■ Maintains foam properties, which enhances visual appeal of the finished product as well as taste and texture. ■ Using whey instead of eggs lessens microbiological risks.	■ Baked products, such as meringues and certain cakes ■ Confectionery products, such as icings ■ Ice cream and other frozen desserts
Nutritional enrichment	Possess high-quality proteins — all the amino acids required for a healthful diet — in a readily digestible form. Whey products are high in calcium content and rich in thiamin, riboflavin, panthotenic acid and other nutrients.	■ Can be used alone or in tandem with soy, wheat and other proteins to improve the nutritional content of products. ■ Lactose increases calcium absorption and stimulates the growth of acid-forming lactobacilli in the intestinal track. ■ Provides vitamin enrichment. ■ Provides mineral fortification.	■ Contributes to a food's healthful image and clean label. ■ Represents a natural and good source of soluble vitamins. ■ Offers advantages in dietary therapy.	■ Nutritional products, including infant formula ■ Baked goods ■ Dairy products ■ Beverages ■ Meat and seafood products ■ Sauces ■ Soups ■ Salad dressings
Flavor enhancement	In whey protein products, flavorful compounds are generated during heating through thermal degradation of amino acids.	■ Can provide toasted, bread-like or cracker-like flavors.	■ Clean flavor and aroma with no evidence of off-flavors enhance customer appeal.	■ Baked goods
		■ Can provide nutty flavors.	■ Clean flavor with no evidence of off-flavor enhances customer appeal.	■ Confectionery products
		■ Can provide buttery flavor.	■ Clean flavor with no evidence of off-flavor enhances customer appeal.	■ Snacks
	Dry sweet whey products feature a bland flavor profile.	■ Bland, slightly sweet flavor allows other flavors to develop to full potential.	■ Clean flavor with no evidence of off-flavor enhances customer appeal.	■ Confectionery products ■ Beverages ■ Dry mixes and sauces
	Whey minerals enhance meat and dairy flavors.	■ Enhances the natural flavors of meats, cheeses and other milk products.	■ Clean flavor with no evidence of off-flavor enhances customer appeal.	■ Processed meats ■ Dairy products
Neutrality	Low mineral content for demineralized whey and some WPC products.	■ Offers nutritional and functional advantages of whey where mineral flavor is not desired. ■ Eliminates salty flavor.	■ Clean flavor with no evidence of off-flavor enhances customer appeal.	■ Frozen desserts ■ Confections

Table 9.2
Lactose Products

Function	Characteristics	Functional Benefits	Marketing Benefits	Applications
Texture agent	Lactose crystal formation can be controlled.	■ Helps create desired texture.	■ Creates product appearance that consumers desire in confectionery products.	■ Confections
Carrier	Lactose in monohydrate form is non-hygroscopic.	■ Remains free-flowing in high temperature and high relative humidity.	■ Maintains visual appeal and ensures even dispersion, enhancing its usability as well as the taste of the food in which it is used. ■ All-natural "clean" label appeal	■ High-intensity sweeteners ■ Flavors and seasonings and yogurt ■ Dry mixes
Bulking agent	Lactose in monohydrate form is non-hygroscopic.	■ Provides volume and weight with low sweetness.	■ Promotes mixing, processing and handling efficiency with little impact on product taste, which can translate into lower consumer prices or increased marketing expenditures.	■ Coffee whiteners
Flow agent	Lactose in monohydrate form is non-hygroscopic.	■ Keeps products from caking, improves flow properties and dispersability.	■ Ensures quality in dry mixes.	■ Dry mixes
Shelf-life extension	Amorphous form of lactose is highly hygroscopic.	■ Helps preserve moistness and tenderness of products.	■ Reduces stales, thus improving cost efficiency.	■ Baked goods
Binds water	Amorphous form of lactose is highly hygroscopic.	■ Retards moisture loss, minimizes syneresis.	■ Helps maintain visual appearance.	■ Dairy products ■ Baked goods
Reduces sweetness	Lactose is one-fifth to one-third as sweet as sucrose at common concentrations in food.	■ Provides carbohydrates without excess sweetness, compatible in savory foods.	■ Product meets consumer taste profile without being too sweet.	■ Icings ■ Savory fillings
Flavor retention	Lactose is more effective than most sugars in attracting and holding volatile aromas and flavors.	■ Renders many flavors more distinguishable to taste, absorbs flavors.	■ Maintains flavor quality in food products aimed at the health-conscious consumer.	■ Baked goods ■ All-natural products

Table 9.2 (continued)
Lactose Products

Function	Characteristics	Functional Benefits	Marketing Benefits	Applications
Color retention	Lactose is more effective than most sugars in attracting and holding volatile aromas and flavors.	■ Strong tendency to absorb natural and synthetic colors results in savings in ingredient costs.	■ Lower ingredient costs translate into lower consumer prices or increased marketing expenditures.	■ Snacks ■ Microwaveable products
Browning agent	Lactose, a reducing sugar, serves as a substrate for the Maillard reaction.	■ Accentuates color development during cooking and baking.	■ Enhanced visual appeal, thus increasing consumer appeal.	■ Bakery products
Flavor development	Lactose, a reducing sugar, serves as a substrate for the Maillard reaction.	■ Contributes to the development of toasted flavors.	■ Improved flavor increases customer appeal.	■ Baked goods ■ Confectionery products
Fermentation substrate	Lactose is converted to lactic acid by lactic cultures.	■ Available for fermentation and development of flavor.	■ Improved flavor and texture increases consumer appeal.	■ Yogurt, yogurt beverages
Controls mold growth	Some cultured whey can convert lactose to propionic acid.	■ Helps extend shelf-life naturally, without chemical mold inhibitor.	■ Clean label.	■ Baked goods
Remains available in yeast-raised products	Lactose is not fermented by bakers yeast.	■ Remains available for crust color development, emulsification of shortening, water retention.	■ Enhances visual appeal, which promotes greater consumer appeal.	■ Yeast-leavened baked goods
Excipient	Lactose can be compressed by pressure into tablets.	■ Can be compressed directly without preliminary step (wet granulation), allows use of high-speed tablet machines.	■ Cost effective ingredient that improves processing efficiency,which can translate into lower consumer prices or increased marketing expenditures.	■ Drugs and nutritional supplements in tablets ■ Confectionery products

Table 9.3 identifies some of the desired properties in different types of foods. In addition, the table lists the particular whey products that will assist food formulators in achieving those functional properties.

Table 9.3
Whey Ingredients and Their Important Functional Properties

Product Category	Desired Function	Sweet Whey Powder	Acid Whey Powder	Deproteinized Whey	Demineralized Whey	WPC34	WPC50	WPC75	WPC80	WPI	Lactose
Bakery	Emulsification					●	●	●	●	●	
	Heat setting						●	●	●	●	
	Color and flavor development	●		●		●					●
	Whipping	●					●	●	●	●	
	Water binding			●		●	●	●	●	●	
	Dairy flavor	●		●		●	●				●
	Acid flavor		●								
	Gelling				●			●	●	●	
	Solubility					●	●	●	●	●	
	Nutrition					●	●	●	●	●	
Breads and breading	Adhesion					●	●	●	●	●	
	Color and flavor development	●		●		●					●
	Fat barrier						●	●	●	●	
Beverages	Solubility/colloidal stability			●	●	●	●	●	●	●	
	Acid stability				●	●	●	●	●	●	
	Thermal stability				●	●	●	●	●	●	
	Water binding/viscosity				●	●	●	●	●	●	
	Emulsification					●	●	●	●	●	
	Dairy flavor			●	●	●	●				
	Nutrition					●	●	●	●	●	
Cheese, processed	Emulsification			●		●	●	●	●	●	
	Water binding					●	●	●	●	●	
	Dairy flavor	●		●		●					
	Nutrition					●	●	●	●	●	
	Gelling							●	●	●	
Confectionery	Aeration				●		●	●	●	●	
	Solubility			●		●	●	●	●	●	●
	Emulsification					●	●	●	●	●	
	Gelling				●			●	●	●	
	Crystallization	●		●	●						●
	Color and flavor development	●		●	●						●
	Dairy flavor	●		●	●	●					
	Pan coating										●
	Tabletting										●
	Nutrition					●	●	●	●	●	
Dry mixes	Dispersibility	●		●		●	●	●	●	●	●
	Non-hygroscopicity	●		●		●	●	●	●	●	●
	Bulking agent	●		●	●	●					●

Table 9.3 (continued)
Whey Ingredients and Their Important Functional Properties

Product Category	Desired Function	Sweet Whey Powder	Acid Whey Powder	Deproteinizede Whey	Demineralized Whey	WPC34	WPC50	WPC75	WPC80	WPI	Lactose
Frozen desserts	Emulsification					●	●	●	●	●	
	Aeration					●	●	●	●	●	
	Solubility	●		●	●	●	●	●	●	●	
	Dairy flavor	●		●	●	●					
	Water binding					●	●	●	●	●	
	Fat replacement							●	●	●	
	Nutrition					●	●	●	●	●	
Substitution dairy products	Solubility	●			●	●	●	●	●	●	
	Dairy flavor	●		●	●	●					
	Emulsification					●	●	●	●	●	
	Aeration					●	●	●	●	●	
	Nutrition					●	●	●	●	●	
Infant formula	Nutrition				●	●	●	●	●	●	●
	Emulsification					●	●	●	●	●	
	Solubility				●	●	●	●	●	●	●
	Dairy flavor				●	●	●	●	●	●	●
Chopped meats, sausages and surimi	Emulsification					●	●	●	●	●	
	Water binding						●	●	●	●	
	Fat binding						●	●	●	●	
	Solubility					●	●	●	●	●	
	Initial low viscosity					●	●	●	●	●	
	Gelling							●	●	●	
	Nutrition						●	●	●	●	
Salad dressings	Acid stability				●	●	●	●	●	●	
	Emulsification					●	●	●	●	●	
	Nutrition					●	●	●	●	●	
	Dairy flavor			●	●	●	●				
Sauces, soups and gravies	Solubility				●	●	●	●	●	●	
	Emulsification					●	●	●	●	●	
	Dairy flavor			●	●	●					
	Water binding/viscosity					●	●	●	●	●	
	Nutrition					●	●	●	●	●	
Yogurt	Solubility				●	●	●	●	●	●	
	Dairy flavor				●	●					
	Water binding					●	●	●	●	●	
	Nutrition					●	●	●	●	●	

BAKERY APPLICATIONS FOR WHEY AND LACTOSE PRODUCTS 10

Formulary edited by
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10.1 AN OVERVIEW AND LATEST DEVELOPMENTS

By BRIAN STROUTS
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The baking industry is driven by consumer demands and economic benefit. The wants and needs of the consumer are basically two-fold, they desire a bakery product that is appetizing and appealing, and, at the same time, delivers on quality attributes such as convenience, freshness, or added benefit. How does the use of whey and/or lactose in bakery products help the baker meet these demands? The answer is by delivering both function and cost benefit to bakers as they strive to meet the customer demands.

Sweet whey is the most widely used whey product in baked goods, largely due to its low cost. Whey protein concentrate (WPC) and whey protein isolate (WPI) offer the most functionality in bakery formulations to improve characteristics.

Whey proteins are available as powders that contain 34%, to greater than 90% protein, have low to high solubilities and water binding capabilities, exhibit temperature-induced changes in functionality from room temperature to 85°C, and are selectively stable or unstable to influences of ionic strength and pH.

Certain generalizations can be made when using whey proteins in breads and cakes. Heat-treated proteins tend to improve moistness and texture. Denatured protein interacts differently with water and other components than protein in its native state. Whey protein powder with lower lipid content has also been shown to improve baked product texture.

WPC34 (34% protein) is commonly used in most types of baked goods to replace skim milk powder because of its milky flavor note and identical protein level. WPCs, with higher protein levels, have been used in glazes, as a replacement for milk or eggs, for biscuits, bread, and pastry to improve color and gloss. Whole egg or egg whites can be replaced with whey protein concentrate 80% (WPC80) or whey protein isolate (WPI). The simplest replacements of eggs with whey products are in bakery products requiring less aeration, such as cookies, scones, or fruitcakes.

Although foam cakes, such as Angel Food, are a difficult application for whey products, WPI can be used in batter cakes. Replacement of egg whites in white cake or whole egg in yellow cake with WPI results in improved volume, appearance, and nutrition. Ingredient cost of the formulation is also reduced. WPI is used successfully to replace whole egg in cookies, while providing improved color, thickness, and chewiness. Total egg replacement is not always the goal of a product reformulation. Partial replacement of the egg with whey protein can still provide some economic advantages while improving nutrition of the finished product.

Until they are denatured, WPCs are stable ingredients with high solubility in acidic to basic systems with low water binding abilities. The proteins begin to denature at around 60-65°C, and further denature when heating to 85°C. This temperature range is expected since WPCs are composed of many different types of proteins contributing to the overall behavior of the WPC. Rather than forming a precipitate upon denaturation, some WPCs yield a soluble protein in dilute solution and a gel at higher protein concentrations. Because high heat- treated skim milk powder has been the preferred dairy ingredient for bakery applications; it is the soluble, high water binding, heat-denatured whey proteins that are thought to have the best replacement applications. In addition to higher water binding at room temperature, some WPCs have a wide range of denaturation temperatures. This is of interest because the denaturation is further influenced by the stabilization effect of added sugars and the localization of proteins at film interfaces rather than in solution.

Batter systems can be reformulated to take advantage of whey protein properties. As an example, it may be possible to decrease the amount of chemical leavening because WPCs delay the heat-setting effect of increasing the gas expansion phase of the baking process. The thinning of these batters at higher temperatures can then be controlled by adjustments to the moisture content of the formula or the use of added gums.

Ensuring quality in the finished baked product requires the setting of the expanded structure formed during baking. When typical whey proteins are directly substituted for egg proteins there is a noted collapse of the structure in the later stages of baking. The reasons for this loss of structure could be the result of many variables. The failure may be related to the decreased batter thickening, insufficient leavening action, over-expansion of the structure, or disruption of the film at the surface of the air cells. To be effective, the whey protein must form films to stabilize one air cell, allow for cell expansion, and then set the structure through ingredient interaction. When product structure issues are addressed through reformulation, the final cake texture tends to be softer and more fragile. Although this may commonly be seen as a fault, it could be an advantage depending upon the application. For example, in low-fat or fat-free cake formulations where tough texture and reduced volumes are an issue, the use of whey proteins may be an effective tool to improve product quality.

Dairy products, such as skim milk powder, are added in developed doughs, such as bread, for faster dough development during mixing and for added strength in the baked bread. However, native whey proteins tend to have the opposite effect when added to the dough. Dough development time is increased and loaf volume is decreased. The same whey proteins that interfere with gluten structure formation may offer some protection to the protein network in frozen dough. Newer whey protein concentrates with heat-denatured, soluble proteins may be better suited for use in fresh dough.

Dairy ingredients influence mixing time and the water absorption properties of bread dough. Sodium caseinate increases water absorption and shortens mixing time, functioning in almost the opposite manner than whey ingredients. Whey ingredients contribute to browning and dairy flavor, enhance nutritional content by contributing calcium and complete the protein in wheat by adding the essential amino acid lysine that is deficient in wheat proteins. In whey ingredients, calcium appears to have the most effect on bread firmness. Whey protein ingredients with lower calcium content may also help retain bread softness better than those with higher calcium content, regardless of other variables.

Whey and whey products have been used in various bakery applications to improve nutrition, color, volume, and texture of baked goods and as a replacer for egg products and nonfat dry milk. Common usage can be found in icings, fillings, glazes, yeast breads, cookies, and cakes.

The top five uses of whey in bakery products are:

1. As an egg replacer in cakes,
2. As an aid in retaining softness in bread,
3. To enhance browning in all types of bakery products,
4. To improve quality of low-fat cakes,
5. To improve the nutritional aspects of bakery products through increased protein and calcium content.

10.2 WHEY PRODUCTS IN BAKED GOODS

By KIMBERLEE J. BURRINGTON
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Whey-based ingredients in bread:

- Enhance crust browning
- Improve toasting qualities
- Enhance crumb structure (provide a fine, even crumb without additional dough conditioners)
- Have the potential to slow staling of bread, thus increasing shelf-life
- Enhance bread flavor

Whey proteins are an important functional component in bread formulations. They enhance crust browning, crumb structure and flavor, improve toasting qualities and retard staling. Whey-based ingredients can be customized to meet specific protein, minerals and lactose compositions. This is important because composition and degree of denaturation affect whey ingredient functionality.

The following parameters provide a guideline for selecting a whey-based ingredient for application in a bread formulation:

- In order to optimize loaf volume, the whey-based ingredient should be low in lactose, high in protein and the protein should be significantly denatured.
- Optimum usage levels vary, but 2%-3% is a good starting point to obtain maximum benefits.
- Water absorption is lower for whey ingredients than for flour, with water absorption increasing as protein denaturation levels increase; therefore water requirements may need to be adjusted depending on the whey ingredient used.
- Time required to mix dough to maximum consistency (resistance) may increase (mixogram time to peak).
- If the whey-based ingredient is high in lactose, adjustments in the process or other ingredients may be needed to maintain yeast growth and carbon dioxide production.
- Baking time and temperatures may require adjusting because crust color might develop more rapidly with whey-based ingredients.

Functional Benefits

There are specific functional properties that are associated with whey proteins. They include: (1) solubility, (2) water binding/absorption, (3) viscosity, (4) gelation, (5) cohesion, adhesion and elasticity, (6) emulsification and (7) foaming. Most of these characteristics are important in the processing of baked goods. The reformulation of bakery products with added whey protein (supplementation) is done for functional reasons. Whey protein concentrates (WPCs) have found uses in biscuits, cookies, cakes, sponges, icings and glazes to improve texture and appearance. Dough volume can be increased in bread and cake, and moistness can be improved in a variety of products. Whey protein isolate (WPI), whey protein concentrate 34% (WPC34) and whey protein concentrate 80% (WPC80) have been found to improve the color, thickness and chewiness of full fat and low-fat cookie formulations. WPIs and WPCs with more than 75% protein can be added to cake formulations to improve volume and appearance.

Whey products are used by the baking industry because of their functional benefits. Some of the benefits recognized by consumers include good crust color developed through the Maillard browning reaction, good dairy flavor, softer crumb and extended shelf-life. Additional benefits that the baker may recognize are the ability to reduce ingredient costs by partially or completely replacing egg products, milk powder or other ingredients such as shortening. Less commonly recognized are the nutritional benefits of adding whey proteins to bakery products. Whey proteins have a high concentration of lysine, the deficient amino-acid in wheat protein. Increasing the ratio of whey proteins to wheat protein results in an improved amino-acid profile. Bread, soft rolls and buns are the major applications for whey products. A typical usage level of whey or lactose in bread, soft rolls and buns is 2%-4% of the flour weight.

Functionality

Whey protein concentrates (WPCs) have many functional properties, most of which are associated with the whey proteins. Some of the basic functionalities that a WPC can provide are whipping/foaming, emulsification, high solubility, gelation, water binding, and viscosity development. Generally, WPCs with higher protein content have improved functionality over those with lower protein content. Other factors that influence their functionality are the whey source, amount of heat treatment received during manufacture, and lipid and mineral content. Whey protein conformation and functionality are interrelated and dictated by changes in their globular folded structure. Their functional properties are affected by several factors within a food application, including concentration, state of the whey proteins, pH, ionic environment, (pre-) heat treatment, and the presence of lipids. In the native state, whey proteins are highly soluble and adeptly perform emulsification and whipping functions in a food application. Heating whey proteins can result in a loss of solubility due to the denaturation of the proteins, especially in the pH range of 4.0-6.5. While solubility is adversely affected by heat, emulsification can be improved through controlled heat denaturation. As the whey protein unfolds, hydrophobic amino acid residues are exposed, which enhance the ability of the protein to orient at the oil/water interface. The presence of salts during the emulsification process influences whey protein conformation and solubility. In their undenatured form, whey proteins can form rigid gels that hold water and fat and provide structural support. The formation of disulfide bonds and ionic bonding controlled by calcium ions appears to determine gel structure. The water-binding abilities of whey proteins can help reduce formula costs as the proteins hold additional water. Viscosity development is closely related to gelation and other protein-protein interactions. Foaming properties are best when the whey proteins are undenatured, not competing with other surfactants at the air/water interface, and stabilized by an increase in viscosity when foam formation occurs. Whey proteins also contribute to browning by reacting with lactose and other reducing sugars present in a formulation, providing color to heated products. WPCs are also bland tasting and contribute no foreign or off-flavors when used as an ingredient.

Nutrition

Whey protein concentrates contribute nutrition to a food application through their mineral content as well as their protein content (see Nutrition Section 16 of the Reference Manual). Whey proteins are also considered a complete protein because they contain all the essential amino acids in amounts adequate for human use. They are considered high quality because they contain the essential amino acids in amounts proportional to the body's need for them. WPCs also contain significant amounts of calcium and other minerals that can be added advantages when fortifying food products.

Whey Protein Concentrates in Baked Products: Functionality in Specific Products

Breads

Dairy ingredients have been used extensively in the development of breads. A softer, more tender crumb is often produced as a result of whey product addition. Breads made with WPC have also exhibited these benefits but with some necessary modifications made to the WPC, to optimize its performance in bread. In tests performed using WPC34, WPC50 and WPC80 in breads, WPC34 produced the softest bread because it contained the least amount of calcium. The amount of calcium plays a role in the rate of firming of bread. The mechanism behind this suggest that lower calcium WPCs aggregate at higher temperatures in the baking process, when there is more gelatinized starch, allowing the whey protein chains to extend between the starch chains and decrease retrogradation. Increasing the lactose content in the dough can also produce bread that retains its softness for a longer period of time. This softness has been attributed to better emulsification of the fat in the formula. Lactose crystals in baked goods also have unique water holding capacity. Optimal mixing times were increased with the use of all WPCs. When 2%, 4% and 6% addition of WPC were tested, the 4 % level of WPC34 yielded the highest loaf volumes. Controlled heat treatment of WPC34 to achieve partial denaturation of the whey proteins has also been shown to improve bread moistness and texture.

Decreasing fermentation time is detrimental to bread quality when using WPCs. Typically, the shorter the fermentation time, the more sensitive the bread is to whey proteins. WPCs (up to 2% protein addition) have been used in bread made by the sponge dough process. The bread quality was improved by using high protein WPC, denaturing the protein to the same degree as for high heat nonfat dry milk and adding sodium stearoyl-2-lactylate. Generally, the higher the protein content of the WPC, the greater the loss in loaf volume. Besides improving the softness of bread, WPCs are often used to perform many of the functions of eggs in baked products.

Cakes

In cakes, more protein is needed for crumb strength. The finished structure of a cake is dependent upon the gelatinization of starch and denaturation of protein. The addition of sugar in cakes increases the gelation temperature of gluten so the finished structure of the cake cannot be obtained without the addition of a protein with a lower gelation temperature. Whole eggs and egg whites are added to achieve this desired structure. Successful application of WPC as egg replacers in cakes is inversely related to the sugar and fat level in the cake system. Egg whites in cakes can be partially or totally replaced with WPCs with a high protein content (WPC80). The higher the sugar and the lower the fat, the harder it is to make an acceptable cake with a complete replacement of whole egg with WPC. The higher protein WPCs generally are required for cake applications because of the requirement for gelation.

The WPC34, WPC50, and WPC80 products are well suited to partially replace the functions of whole egg in a cake application. WPC80 is better suited for egg white replacement. WPCs can provide body and viscosity to cake batters to help entrap air and retain carbon dioxide produced by the leavening system. They can also help in retaining moisture in cakes. Another ingredient that can be replaced in a baked product is fat. The addition of WPC80 (at a 2% level) to a low fat pound cake formula can result in a higher volume, softer product that is preferred over both a full fat control and a low-fat control (no WPC80) in moistness, flavor and overall characteristics.

Cookies

Replacement of whole egg with WPC in a soft cookie is also possible. In less aerated products, such as cookies, replacement of skim milk powder or egg is easily accomplished. Whey added to cookies is an economical source of dairy solids. Both WPC34 and WPC80 have been found to improve the color, thickness, and chewiness of cookies. In reduced fat cookies, combinations of WPC80, modified starch, emulsifiers and water are able to replace whole eggs and shortening. This addition results in batters with similar spread and in baked cookies with similar texture, flavor and overall preference when compared to the control. Egg whites in formulas for scones and crepes can be replaced with WPC80. The substitution is made on an equal protein basis. The resulting products are similar to control products in overall acceptance, but they are generally more tender in texture.

Pie Crusts

Whey or lactose can be added to pie crusts. Whey at approximately 2%-3% or lactose at 6%-8% of flour weight aid in emulsifying the shortening. This allows for a reduction in shortening without sacrificing the tender, flaky texture. Bakers also report improvements in color and flavor of the baked crust.

Bakery Mixes

Bakery mixes are generally one of three different types: complete mix (only require the addition of water), dough base and dough concentrate. Dough bases or partial mixes require that the end-user adds water as well as oil or shortening and eggs. Dough concentrates are specifically designed for continuous, high throughput, automated production. Used for fat reduction, high solubility, water binding, and moisture retention, they blend well with other ingredients in a bakery dry mix. Mild flavor is another attribute of WPCs that typically blends well with baked products. The bland, dairy flavor of WPC enhances many of the browning type flavors that develop during baking. The added browning that results due to the lactose content also contributes to an appealing surface color.

Crackers

In contrast to cookies, crackers contain little or no sugar. They are formulated with higher protein flours, often a mixture of soft and hard wheat. The functional requirements for WPC in crackers are similar to that in breads. WPC has been used to replace flour in yeast leavened crackers. WPC34 gives superior results over WPC75 (when using WPC75, less than 5% of the flour can be replaced). The longer the fermentation time, the more satisfactory is the cracker.

Bakery Glazes

Bakery glazes based upon whey protein concentrates and caseinates have numerous advantages over traditional glazes made from whole eggs and water. The whey-based glaze is microbiologically stable and salmonella-free. It tends to be less prone to microbial growth in the holding tank, although good sanitation practices are always necessary. As a top spray on proofed bread or rolls, this type of glaze gives good adhesion of toppings such as seeds and crushed grains.

Nutritional Products

Another area where WPCs deliver a tangible benefit is that of baked products designed for the nutritionally conscious. Products such as energy bars or sports bars often are fortified with protein ingredients and minerals. WPC80 products are ideal for these applications because WPC80 brings not only high protein concentrations but also the highest level of calcium, which could reduce the need to add additional calcium in a vitamin, fortified product. Protein fortification is an excellent application for WPCs. More emphasis will likely be placed on the contributions of both protein and minerals in main stream food products. With protein levels ranging from 34%-80% in WPCs and calcium levels from 500-600 mg per 100 g of product, WPCs have a lot to contribute nutritionally to an application. Specialty breads may be an area of interest as well as the cereal bar or energy bar type products.

The typical levels used in baked products can add small benefits to the overall nutrition of the product. The best returns nutritionally are found in fat replacement. Replacing fat with protein has nutritional label appeal to most consumers.

Processing Considerations

There is a need to maintain consistent processing conditions for all WPCs so consistent functionality can be delivered to the customer at all times. It is also necessary for the applications technologist to understand the processes for preparation of each baked product and what changes would have to be made to easily incorporate a WPC. Whether it is proof time, mixing times, order of addition of ingredients or levels of ingredients, optimization is needed whenever ingredient changes are made to a formula.

Consistent quality is of great importance to a customer. Many U.S. manufacturers of WPCs have the capabilities of producing consistent, high quality products. It is important for their customers to work closely with them so they can understand their quality and functionality goals.

QUESTIONS AND ANSWERS

Q. *Is proof time affected by the addition of whey to bread or sweet rolls?*

A. Proof times should remain the same but could increase with the addition of whey to these products depending on the amount added. Generally, the more protein added, the more sensitive the dough is during fermentation.

Q. *I observed that the dough is becoming more sticky when whey is added. Is it normal? How do I remedy this problem?*

A. Yes, doughs can become stickier when whey is added. Usually stickiness increases with the level of whey added to the dough. You could decrease your level of addition or change the order of addition of the whey.

Q. *Is it preferable to use "denatured" whey?*

A. Generally, some denaturation is desirable for baked products. Heating the whey, which partially unfolds the proteins in the whey so they have enhanced water-binding capabilities and improved emulsification, causes denaturation. Most whole dried whey will have some level of denaturation due to typical processing conditions.

Q. *Will adding sweet whey result in a lower volume for cakes?*

A. No, research has shown that the addition of 15% whey solids (based on flour) to yellow cake formulations, containing 20%-40% shortening and 100% sugar, yielded improved volume.

Q. *Can sweet whey or WPC34 be used in frozen doughs? What level will work?*

A. Yes, sweet whey and WPC34 can be added to frozen doughs at typical levels of 1%-6%.

Q. *In which products can WPC80 replace egg whites? What percent replacement is possible?*

A. It has been very difficult for WPCs to completely replace egg whites in cakes without loss of cake volume. Levels of replacement less than 50% should be achievable without significant losses in cake quality.

Q. *Will whey powder result in excessive browning?*

A. Not necessarily. The addition of whey powder will increase browning in a baked product proportional to the amount of whey powder added.

Q. *Will the addition of whey powder or WPC34 impact yeast-raised products?*

A. Addition of either of these products should not significantly affect the quality of yeast-raised products. The higher protein products have been shown to increase proof times, decrease finished volumes, and affect crumb structure. Both whey products should provide improvements in crumb structure, texture, and crust color.

Q. *WPC80 is very expensive. Why should I use it and for which products?*

A. WPC80 should be used for products that require a strong gel structure. It can be used for a partial replacement of egg white, whole egg, or other functional ingredients that contribute to structure. Cakes and soft cookies are good applications. WPC80 can also provide protein to an energy bar type product without contributing the off flavors that other protein sources provide.

Q. *Is it true that WPCs can replace emulsifiers?*

A. WPCs do have emulsifying capabilities. It may be possible to reduce the level of emulsifiers used in a baked product for their contribution to increasing shelf life. WPCs have been shown to improve crumb texture in breads over their shelf-life.

Q. *When using WPC in a pound cake (WPC80 as replacement for egg white, 50% substitution), the volume of the product is lower than the control formulation. What should be done to improve the volume?*

A. First of all, make sure you are replacing the egg white on a protein-protein basis. Often it is not as simple as replacing one ingredient with another to achieve a comparable product. Some slight increases in leavening, changing the order of addition of the ingredient, or increasing the mixing time may help to improve the volume.

Q. *When using WPC34 in cookie dough, it makes the dough too sticky. Furthermore, the cookie spreads out too much. Any tips on preventing this from happening?*

A. Try adding the WPC34 in the creaming stage so the shortening can coat the lactose and protein. Decrease the amount of water you are adding, to also help with stickiness and increased spread. Typically, the addition of WPC34 to cookies will yield less spread in a cookie.

Q. *Adding WPC80 in cookie and cake dough makes the dough too sticky. How can this be prevented?*

A. Stickiness is related to the amount of fat or emulsifiers you still have in the dough, along with the amount of WPC80 you are adding. Try adding the WPC80 in the creaming stage, decreasing the amount of water you are using or perhaps adjusting the level of emulsifier/shortening.

Q. *I plan on using sweet whey as a calcium source. In what form is calcium in whey and is it well absorbed by the body?*

A. Calcium is in the form of calcium phosphate in whey. It has been shown to have greater bioavailability (in animal studies) than calcium carbonate, calcium lactate, and calcium citrate.

Table 10.2
Recommended Level of Addition as % of Flour

	Recommended Usage Level (%)						Expected benefit for all categories of whey ingredients to varying degrees depending on protein level.
	Sweet Whey	WPC34 to WPC50	WPC80	Demineralized Whey, Modified Whey	Lactose	Permeate, Low Protein Whey	
White bread	2–6	2–6	2–6	2–6	2–4	1–5	Extend shelf life, improve crumb structure and softness, provide crust browning.
Pastries and sweet rolls	2–8	2–8	2–8	2–6	4–6	1–5	Extend shelf-life, improve crumb softness, provide surface browning.
Cookies and biscuits	2–5	2–4	2–4	2–5	3–4	1–5	Provide surface browning, improve tender texture, provide partial egg replacement.
Crackers	1–5	1–4	1–3	2–6	1–5	1–5	Contribute to cracking stability and surface color.
Pizza dough	1–5	1–4	1–3	2–6	1–5	1–5	Provide structure, freeze-thaw stability, crust browning.
Cakes	2–4	4–8	4–8*	1–6	10–15	1–6	Provide soft crumb, partial egg replacement, add surface browning.
Icings and fillings	1–3	1–2	1–2	1–3	1–3	1–3	Partial replacement for sugar, adds water-binding capabilities for overall stability, reduces sweetness.
Low fat, low sugar baked goods	2–10†	3–9**	3–5**	2–10†	2–10†	2–10†	Partial replacement for fat and/or sugar, adds water-binding and some emulsifying capabilities, reduces sweetness.

*Replacement of up to 50% egg white.
**Replacement of up to 50% fat.
†Replacement of up to 25% sugar.

10.3 USING LACTOSE AND PERMEATE IN BAKED GOODS

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Whey permeate is a cost-efficient source of dairy solids for bakery applications.

Permeate:
- Enhances crust browning
- Improves flavor
- Retains moisture
- Serves as a source of calcium
- May be used as a salt replacer

Also known as dairy product solids or de-proteinized whey, whey permeate is a cost-efficient ingredient that finds many uses in bakery applications. Typical food grade permeate contains 65% to 85% lactose, 8% to 20% ash, and 3% to 8% protein. Maximum fat content is 1.5%. Usage levels for permeate range from 2% to 5% in breads, rolls and cookies to 5% to 10% in biscuits and muffins.

Lactose is a disaccharide obtained from whey or permeate. Edible or food grade lactose contains a minimum of 99% lactose, 0.1% to 0.3% ash, and 0.6% to 0.1% protein. The lower ash content allows for higher usage levels in a wide variety of baked goods.

Lactose can be used in baking to achieve specific functional benefits. Lactose works well in baked applications where ash and protein might cause undesired side effects, or where a more controlled application is desired.

Lactose:
- Lowers sweetness
- Increases browning
- Retains moisture
- Enhances flavors

Key Benefits for Bakers

Crust Color Development

Unlike sucrose, the lactose in whey permeate is a reducing sugar. Thus it is able to contribute to brown crust formation through both Maillard browning and caramelization. The Maillard reaction creates browning through a reaction between a reducing sugar and amino acids or proteins. Increasing temperature, increasing pH, and lowering water activity all increase the rate of Maillard browning. Caramelization occurs through a series of dehydration, condensation and polymerization reactions. Lactose turns yellow when heated to 150° to 160°C and browns at 175°C.

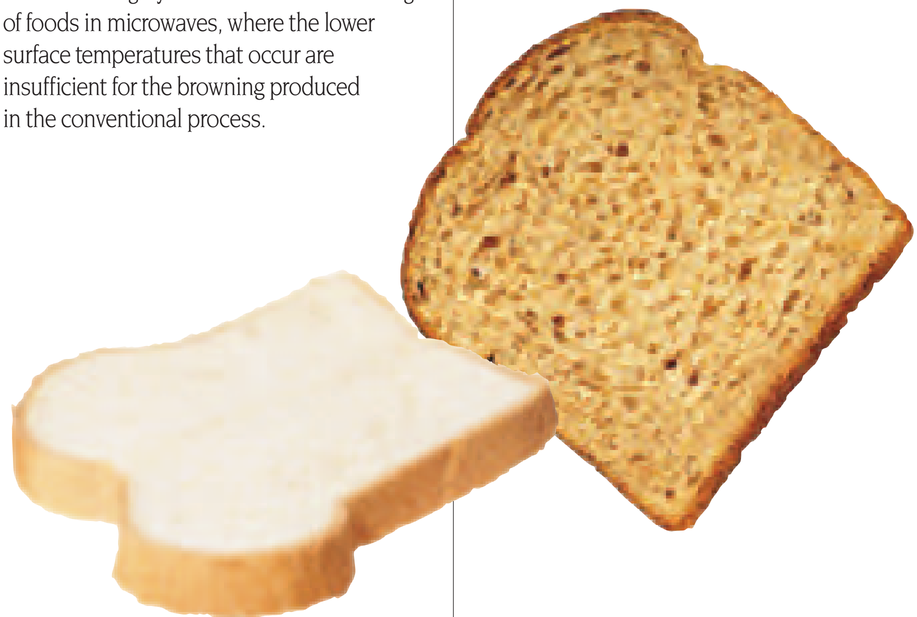
Lactose and permeate are very efficient as browning agents, and sometimes bake times and temperature may need to be adjusted. Individual applications may vary, but some formulas would benefit by a reduction in bake temperature of 25°C, with a corresponding increase in bake time to achieve a golden brown crust without excess browning. Permeate may produce some slight variations in crust color. In applications where a very uniform crust color is desired, choose lactose or a higher value dairy ingredient such as skim milk powder.

The controlled browning of lactose protein mixtures is highly desirable for the browning of foods in microwaves, where the lower surface temperatures that occur are insufficient for the browning produced in the conventional process.

Sweetness and Flavor

The relative sweetness of lactose is low compared to other sweeteners. Lactose has approximately 15% to 30% of the sweetness level of sucrose. The lower sweetness allows lactose or permeate to be used in applications where higher solids are desired without excess sweetness. Maillard browning and caramelization of lactose contribute to toasted brown and burnt sugar notes.

Lactose has a strong affinity for flavorings and flavors. Its unique volatile flavor-binding and enhancing properties are particularly useful in bakery products with delicate flavors. Because lactose binds volatile flavor components, there is less flavor loss during processing and storage. Permeate can enhance and complement certain bakery flavors such as spice, coconut, vanilla and chocolate.



Fermentation

In yeast-raised products such as bread and rolls, lactose is not fermented, and thus can be used at higher levels than sucrose without affecting yeast activity. In general, sugars are needed for fermentation to progress, and salts retard fermentation. On a dry basis, a typical lean white bread formula might contain 2% sugar, 2% salt, and up to 5% nonfat dry milk. Whey permeate could be used in this system, with subsequent reductions in the other three ingredients. The minerals in permeate will exert an inhibitory effect on yeast activity, and thus will limit usage levels.

Lactose is much less soluble than sucrose, and consequently it does not affect the level of free water necessary for yeast activity. The addition of lactose shortens proofing time, especially where the overall level of sugar is high. Lactose gives a more elastic dough and increases bread volume. Lactose also improves kneading characteristics and improves stability and gas retention. Lactose should be added to the dry ingredients, and should not be dissolved in the aqueous phase. The positive lactose function seems related to the fact that it is in a crystalline stage during fermentation but dissolves in the aqueous phase during baking.

Moisture Retention

Staling or firmness of bread results primarily from starch retrogradation, a complex process that involves recrystallization. Lactose does not recrystallize after cooling and thus helps retard staling over time. In addition, lactose functions as a humectant to extend the shelf life of baked goods. Lactose and permeate also impede gluten formation, resulting in a more tender crumb structure. Lactose extends shortening in bakery products, enabling a fat reduction in certain recipes.

Salt Substitution

Whey permeate may be used to replace part or all of the salt in baked goods. The salt level of permeate may be a limiting factor in some sweet applications. In pound cake, it was found that when used at a level of 5%, permeate could replace part of the dairy and sugar components and all of the salt. Levels above 5% resulted in an overly salty product. In general, reducing the salt will permit a higher level of permeate use. Permeate works well in cheese and savory applications such as pizza crust, cheese bagels, herb breads and biscuits.

Hydrolyzed Lactose Syrup

By treating liquid whey permeate with an immobilized enzyme, it is possible to produce a hydrolyzed lactose syrup. This ingredient has found use in bakery applications in some European countries. Research has shown positive results with a product with 50 to 75% hydrolysis and some level of demineralization. However, this product is not widely used or available at this time.

Table 10.3.1
Typical Applications, Recommended Usage Levels and Benefits

Bakery Product	Usage Levels % Flour Weight		Benefits
	Lactose	Permeate	
Breads and rolls	3–4	2–4	• Produces golden brown color (does not turn dull in storage) • Improves softness • Reduces shortening requirements by up to 50% by replacing up to 50% sucrose
Cakes and muffins	10–15 sugar replacement	5–6 sugar replacement	• Maximum tenderness without excessive sweetness • Golden brown, flavorful crust • Produces and improves cake volume • Accentuates flavor
Cookies	3–5	3–5	• Increases mixing tolerance • Eases release from rotary dies • Assures ideal fat distribution • Sharpens and enhances flavor • Controls sweetness level • Produces optimum tenderness and ideal crust color • Produces richer tasting cookies
Crackers		Up to 5	• Accentuates color and enhances flavor
Pizza crust	3–4	2–4	• Produces golden crust color • Enhances flavor
Pastries and sweet rolls	4–5	2–4	• Produces golden brown color • Enhances flavor • Improves softness and tenderness • Reduces shortening and sucrose requirements
Pie crusts and shells	8	4	• Shorter, flakier, more tender crusts • Impacts uniform, pleasing color to top and bottom crusts • Increases mixing tolerance • Provides greater latitude as to types of flour used • Extends shortening content (shortening can generally be reduced by about 5%) • Distributes fat ideally with minimum mixing • Retards sogginess

10.4 LACTOSE FUNCTIONALITY

By KIMBERLEE J. BURRINGTON
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In baking, lactose is often used to replace sucrose for a variety of functional benefits. Compared to other sugars, lactose results in low relative sweetness, increased browning, enhanced emulsification action, moisture retention, non-hygroscopicity and enhanced flavors. When replacing sucrose (up to 50%), lactose can contribute to improved crumb texture and freshness, increased volume, reduced fat levels, improved gas retention, and enhanced flavor. Lactose also shortens proofing times, especially where the overall sugar level is high. Doughs containing lactose show a tendency to rise faster during the initial stages of proofing and show improved stability and gas retention. Lactose readily reacts with proteins (Maillard reaction) giving baked goods a highly flavored, desirable golden-brown color. Caramelization by heat during baking also contributes flavor and color. Lactose influences and enhances the controlled browning of bakery goods, leading to shorter baking times and lower temperatures to achieve even, stable, golden brown colors. This is a particular benefit in products targeted for microwave finishing. Lactose has unique, volatile flavor binding and enhancing properties, which are particularly useful in products with delicate flavors. Lactose has a strong affinity for flavorings and flavors. It is able to absorb and accentuate flavors. This enables a reduction in added flavors.

Lactose also extends shortening in bakery products, enabling a fat reduction in certain recipes. Since lactose is not fermented by baker's yeast, it retains its functionality characteristics through baking and storage.

QUESTIONS AND ANSWERS

Q. *Can I use lactose and whey permeate interchangeably in a bakery formula?*

A. In some applications lactose can be used at slightly higher levels. This is because permeate contains salt which may limit usage levels. When using permeate, some adjustment for the salt levels is generally recommended.

Q. *Do bakery yeasts ferment lactose?*

A. No, bakery yeasts do not ferment lactose. They can however, ferment their component sugars, glucose and galactose.

Q. *Is lactose a reducing sugar?*

A. Yes, lactose is a reducing sugar and therefore will contribute to Maillard browning.

10.5 BAKERY FORMULATIONS

Wire-Cut Butter Cookie

Ingredients	Usage Level (%)
Bread flour	27.65
Butter	27.70
Pastry flour	18.50
Powdered sugar	18.50
Water	5.79
Sweet whey	1.16
Salt	0.30
Baking soda	0.40
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Place butter and sugar in the bowl of a 5-qt Kitchen Aid mixer, equipped with paddle.
2. Mix on the lowest speed for 30 seconds to incorporate butter and sugar. Increase to medium speed and cream for 2 minutes.
3. Add water and beat for 2 minutes at medium speed.
4. Slowly add combined dry ingredients (pastry flour, bread flour, salt, baking soda, and whey). Scrap sides of bowl and mix for another minute at low speed.
5. For small batches, place dough between 2 pieces of parchment and sheet to 4 mm thickness and cut into 60 mm circles with a cutter. For larger batches, dough can be wire-cut. Place on parchment-covered cookie sheet in 4 x 6 configuration.
6. Bake at 190°C (375°F) for 10 minutes, or until light golden brown.

Cake-Type Doughnuts

Ingredients	Usage Level (%)
Flour	39.32
Water	31.40
Sugar	15.85
Vegetable oil	3.88
Soy flour, defatted	3.88
Skim milk powder	2.00
Baking powder	1.73
Salt	0.62
Egg yolk, dried	0.52
Vanilla	0.36
WPC80	0.35
Lecithin	0.09
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Weigh dry ingredients (flour, soy flour, skim milk powder, baking powder, dried egg yolks, and WPC80) together.
2. Cream oil, sugar and salt together, until completely mixed.
3. Sift dry ingredients over oil mixture, and beat at low speed until well blended.
4. Slowly add water to the batter and blend for 2 minutes on medium speed.
5. Fry in an oil bath held at 176°C (350°F), turning as needed to obtain complete and even browning.

Baked Cherry Energy Bars

Ingredients	Usage Level (%)
Brown rice syrup	22.10
Brown rice krisp cereal	14.10
Rolled oats, old-fashioned	10.60
Rolled oats, quick	10.60
Water	10.60
Dried cherries	8.80
Dried cranberries, cherry-flavored	7.10
Plum paste	6.50
Whey protein isolate	4.80
Unsalted butter	3.40
Glycerine	0.80
Black cherry flavor	0.50
Sodium bicarbonate	0.10
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Combine the first 9 ingredients, except water, in the bowl of a large mixer. Mix on low speed for 2 minutes.
2. Add butter, black cherry flavor, and glycerine, and mix on low for 1 minute.
3. Add water and sodium bicarbonate and mix on low for 1-1/2 minutes.
4. Sheet bars to 11 mm thickness and cut into 3.75 cm x 3.75 cm (1-1/2" x 1-1/2") pieces. Place on parchment-lined pans so they are not touching each other.
5. Bake in commercial reel oven at 204°C (400°F) for 7 minutes.

Low-fat Bakery Custard (Flan Style)

Ingredients	Usage Level (%)
Skim milk	69.44
Water	18.99
Sugar	5.83
WPC80, high-gelling	3.80
Starch	1.02
Vanilla	0.64
Salt	0.28
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Mix a small amount of water with WPC80 to make a paste. Slowly add remaining water and set aside for 30-40 minutes.
2. Scald the skim milk and cool to about 60°C (140°F).
3. Add milk and other ingredients to whey protein solution.
4. Add mixture to custard cups and cover.
5. Place cups in trays with hot water and bake at 175°C (350°F) for 45 minutes.
6. Cool and store at 4°C (40°F) until consumed.

No-Bake Cheesecake

Ingredients	Usage Level (%)
Graham cracker crust	–
Cream cheese	51.69
Cream	19.14
Sugar	15.51
Water	6.67
WPC80, high-gelling	5.16
Vanilla	0.87
Gelatin	0.50
Lemon peel, grated	0.30
Salt	0.16
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Mix together the cream cheese, sugar and WPC80.
2. Add vanilla, lemon peel, salt and cream. Blend to incorporate.
3. Add half of the water to the gelatin in a small bowl. When the gelatin is softened, add remaining water (use boiling water) and heat over simmering water until gelatin is dissolved. Stir into the cheese mixture.
4. Pour into graham cracker piecrust. Refrigerate until set (about 3 hours).

Pizza Dough

Ingredients	Usage Level (%)
Bread flour	59.53
Water	33.44
Oil	2.38
Dry yeast	1.49
Sugar	1.19
Salt	1.07
Sweet whey	0.90
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Add yeast to warm water with a pinch of sugar and set aside undisturbed for about 5 minutes.
2. Add all remaining ingredients to the bowl of a Kitchen Aid mixer, equipped with a dough hook.
3. Mix on low speed until ingredients are well combined. Increase to medium speed and knead for 8-10 minutes.
4. Place in a greased bowl, covered with plastic wrap. Proof at 27-32°C (80-90°F) for 1-1/2 hours.
5. Punch down and let dough rest for 5 minutes. Shape on a pizza pan, adding sauce and pizza toppings.
6. Let dough rest 10 minutes and then bake at 288°C (550°F) until crust is golden brown and toppings are bubbly.

Plain Muffins

Ingredients	Usage Level (%)
Pastry flour	38.88
Water	31.95
Butter, melted	11.23
Sugar	11.23
WPC80	4.00
Baking powder	2.24
Salt	0.47
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Mix together all the dry ingredients and make a well in the center.
2. Pour melted butter and water into the well.
3. Mix dry ingredients with wet ones, just until incorporated.
4. Spoon 70 g batter/cup into lined muffin pan.
5. Bake at 188°C (375°F) for 10 minutes.

Pound Cake

Ingredients	Usage Level (%)
Butter, unsalted	26.67
Eggs, whole	21.25
Cake flour	20.21
Sugar	20.00
Milk, whole	5.46
Whey permeate	5.00
Vanilla	0.87
Baking powder	0.54
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Cream butter (room temperature) in mixing bowl for 1 minute at medium speed.
2. Add sugar gradually, creaming for 4 minutes at medium speed.
3. Slowly add beaten eggs in 4 portions, scraping down bowl after each addition. Beat at medium speed for at least 30 seconds after each addition.
4. Combine dry ingredients (cake flour, whey permeate, baking powder) and add alternately with milk and vanilla, beginning and ending with dry ingredients.
5. Weigh out 775 g for each prepared pan (greased, parchment-lined 22.5 cm x 12.5 cm (9" x 5") loaf pan).
6. Bake in conventional oven 180° C (350°F) for 55-65 minutes, or in a commercial reel oven at 148°C (300°F) for 45 minutes.

Reduced-fat Brownies

Ingredients	Usage Level (%)
Powdered sugar	46.48
Bleached flour	26.54
Vegetable oil	8.20
Dutched cocoa	6.76
Dried plum powder	5.75
All-purpose shortening	4.09
Egg white powder	1.45
Salt	0.29
Vanilla	0.25
Sodium bicarbonate	0.19
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Preheat oven to 176°C (350°F).
2. Place dry ingredients in medium bowl. Add shortening, oil and vanilla and stir with paddle on low for 1 minute, or until evenly distributed.
3. Add 2/3 cup water and blend approximately 50 strokes by hand, or until mixture is well blended.
4. Spread evenly in a 22.5cm x 32.5cm (9" x 13") baking pan, greased on the bottom only.
5. Bake for 22 minutes at 176°C (350°F), or 20 minutes if using a dark, non-stick metal pan. If using a convection oven, bake at 149°C (300°F) for 18 minutes.

White Layer Cake

Ingredients	Usage Level (%)
Water	34.34
Sugar	27.45
Cake flour	22.36
Shortening	10.10
WPC80	2.00
Baking powder	1.40
Emulsifier	1.00
Salt	0.60
Vanilla	0.50
Xanthan gum	0.25
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Place all dry ingredients in the bowl of a Kitchen Aid mixer and blend on low for 1 minute.
2. Add shortening and mix 1 minute on low and 1 minute on medium speed.
3. Add 1/2 of the water mixed with vanilla and mix for 1 minute on low and 1 minute on high speed.
4. Add 1/2 of the remaining water and mix for 1 minute on low speed and 1 minute on high speed.
5. Add remaining water and mix for 30 seconds on low speed and 1 minute on high speed.
6. Place batter in Pam-sprayed, parchment-lined 20cm (8") round pan and bake for 25 minutes at 190°C (375°F) in a conventional oven, or for 23 minutes at 163°C (325°F) in a convection oven.
7. Cool 10 minutes in pan, then turn out on rack to completely cool.

Baking Powder Biscuits

Ingredients	Usage Level (%)
Flour	45.60
Water	27.64
Shortening	15.00
WPC80	4.00
Skim milk powder, low heat	3.94
Baking powder	2.95
Salt	0.87
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Sift together flour, baking powder, salt, and WPC80 in a bowl.
2. Cut shortening into dry ingredients, using a pastry blender or a fork.
3. Mix skim milk powder with cold water and add all at once to dry ingredients, mixing with a fork just 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 1.25cm (1/2") and cut into 6cm (2-1/2") diameter circles.
6. Bake on ungreased pan in a 232°C (450·F) oven for 10 minutes, or until golden brown.

White Pan Bread

Ingredients	Usage Level (%)
Bread flour	55.94
Water	33.56
WPC34	4.00
Shortening	2.10
Granulated sugar	2.00
Salt	1.40
Yeast	1.00
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Add yeast to water warmed to about 38°C (100°F), containing a pinch of sugar. Set aside for 5 minutes.
2. Combine sugar, salt, WPC34, and shortening with bread flour in mixer bowl of Kitchen Aid mixer equipped with dough hook.
3. Add yeast/water mixture to other ingredients and mix on the lowest speed until combined. Increase speed to medium and knead for 10 minutes.
4. Place in greased bowl and cover lightly with plastic wrap. Proof at 27° to 32°C (80-90°F) for about 1 hour or until doubled.
5. Punch down and shape into loaf, placing in a 22.5 cm x 22.5 cm (9" x 5") greased pan.
6. Proof at 27° to 32°C (80-90°F) for about 30 minutes (or until doubled).
7. Bake in preheated 180°C (350°F) convection oven until browned and loaf sounds hollow when tapped on the bottom (about 32 minutes).

Chocolate Chip Cookies

Ingredients	Usage Level (%)
Flour, pastry	29.00
Butter: margarine (50:50 blend)	20.60
Semi-sweet chocolate chips	16.57
Sugar, granulated	13.58
Sugar, brown	9.96
Water	6.79
WPC80	2.28
Salt	0.52
Bicarbonate of soda	0.41
Vanilla	0.29
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Allow butter/margarine blend to come to room temperature.
2. Mix together flour and bicarbonate of soda in a large bowl. Set aside.
3. Cream butter/margarine together with granulated sugar, brown sugar and salt by beating at medium speed for 4 minutes.
4. Beat in WPC80, water and vanilla at medium speed for 2 minutes.
5. Add flour mixture and mix on medium speed for 2 minutes.
6. Fold in chocolate chips and mix on low just until incorporated.
7. Bake in 176°C (350°F) oven for approximately 10 minutes, or until golden brown.

BEVERAGE APPLICATIONS FOR WHEY AND LACTOSE PRODUCTS 11

Formulary edited by
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11.1 AN OVERVIEW

By KIMBERLEE J. BURRINGTON
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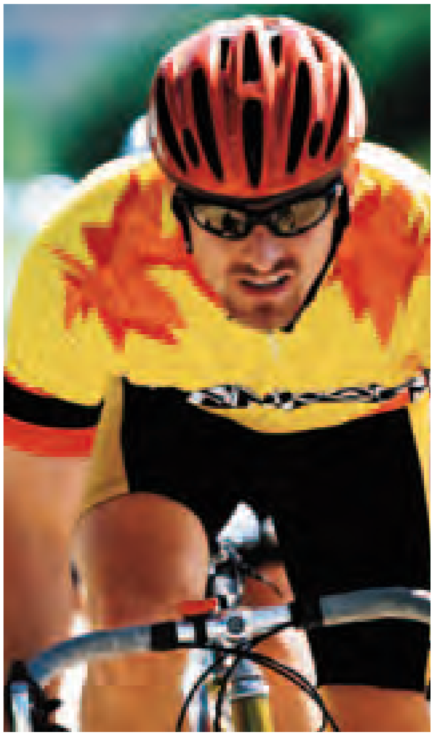
Whether you're interested in meal replacement, bodybuilding, endurance, weight loss or supplementation, there is a protein drink formulated for your specific nutritional goals. Fortified with everything from whey proteins to milk minerals, these drinks come with benefits ranging from "beefing up" to "slimming down" and "immunity enhancement" to "increased endurance." Whether a drink should deliver 15 or 50 grams of protein per serving, there are tricks to fulfilling product claims. Picking the right protein sources and taking a hard look at their nutritional and functional properties are the keys to formulating a protein-packed beverage that consumers will buy again and again.

"Whey proteins are typically the proteins of choice for high-protein sports-drink applications," says Julie Wagner, Director of Applications, Century Foods International, Sparta, WI. Whey protein ingredients often used in high-protein drinks include whey protein concentrate with 80% protein (WPC80), whey protein isolate (WPI) containing greater than 90% protein, hydrolyzed WPC80 and WPI, lactoferrin and glycomacropeptide.

Whey proteins work in high-protein drinks for a number of reasons. Functionally speaking, whey protein ingredients have high solubility over a wide pH range. "Whey proteins are acid stable but they have the best solubility outside of the pH range of 4 to 5 because their isoelectric point falls in this range," says Laurie Nelson, Applications Manager, Davisco Foods International, Inc., Eden Prairie, MN. When considering a dry-mix drink or a ready-to-drink product, whey proteins contribute to a smooth mouthfeel and a mild dairy flavor that blends well with the popular flavors: vanilla, chocolate and strawberry.

A unique property of these proteins is their ability to make a high-clarity beverage. Generally speaking, whey protein ingredients have good dispersibility in water but certain processing modifications can optimize their dispersibility. "Agglomeration is the key to good dispersibility in a high-protein dry mix," says Wagner. Good emulsion stability and foam stability are also included on whey protein's list of important attributes in drink applications. "Most high-protein sports drinks are dry mixes because it is difficult to process a high amount of protein through the retort or UHT process required by a ready-to-drink (RTD) beverage for a good, stable and palatable finished product," says Wagner.



One functional property of whey proteins that makes them very good at forming gels and, in general, good at protein-protein interactions, is their reaction upon heating above 70°C. "These proteins are heat sensitive; you can't go in and change the characteristic of the protein because that is dictated by the primary structure of the protein," says Eric Bastian, Director of Research & Development, Glanbia Nutritionals, Inc., Monroe, WI. "You have to try to control the environment that the whey protein is in, in order to improve the heat stability of the protein." In this case, the environment includes the amount of water, presence of ions such as calcium, pH, and the levels of other ingredients in the drink formulation.

Cellulose- and carageenan-type hydrocolloids work well with whey proteins to provide some stability in an RTD application at a more neutral pH. Pectins can stabilize whey proteins in a low-pH RTD product. Homogenization will also aid the long-term solubility of whey proteins in an acid beverage. Choosing acidulants for a low-pH protein drink requires care; some organic acids taste better than others. "To achieve the best flavor in a low-pH whey protein drink, an 85% solution of phosphoric acid works well as the acidulant," says Nelson. If it is important to pack as much protein as possible into an RTD product, many companies play with the serving size to optimize the functional limitations. "You can easily add 6% to 8% whey protein to a ready-to-drink product, which could translate into 40 grams of protein in a 600 ml serving size," says Nelson. Beyond functionality, the interest in whey proteins quickly becomes a matter of nutrition.

Whey proteins have the highest concentration of branched-chain amino acids (BCAA), leucine, isoleucine and valine, available from any natural protein source. A whey protein isolate would typically supply 26 grams of BCAA per 100 grams protein. Whey has 10 grams of leucine, 6.5 grams of isoleucine and 5.5 grams of valine per 100 grams of protein. The amino-acid composition of whey protein ingredients will vary with the processing methods used to isolate the proteins. Whey protein isolates manufactured by ion exchange or microfiltration contain higher levels of Beta-lactoglobulin, a protein naturally high in BCAA.

Whey proteins are also a good source of the sulfur-containing amino acids, cysteine and methionine, compounds responsible for maintaining the body's antioxidant levels. The high levels of arginine and lysine in whey are thought to stimulate growth-hormone release promoting an increase in muscle mass and decline in body fat. The high level of glutamine in whey proteins might prevent the decline in immune function that may result from overtraining.

Two other proteins with bioactive properties unique to whey are glycomacropeptide and lactoferrin. Lactoferrin makes up about 0.1% of the whey proteins. It can be isolated from whey by ion exchange and added to a protein drink to provide additional benefits. It is classified as an iron-binding protein from the transferrin family. Transferrins bind iron in the blood for energy production and the regulation of red cells and hemoglobin. Whey protein contains glycomacropeptide (GMP) because of the reaction of chymosin with kappa-casein during the cheese-making process. Whey proteins contain about 15% to 20% glycomacropeptides. These proteins stimulate the synthesis and release of cholesystokinin in the body, a regulator of digestive functions. "GMP could be added to a protein drink for its potential appetite-suppressing properties," says Nelson.

Enzyme hydrolysis of whey proteins increases the digestibility, nitrogen absorption and retention, and decreases the allergenicity of the protein. Many high-protein drinks utilize hydrolyzed whey proteins to deliver these benefits. Keep in mind that the nutritional benefits will increase with the level of hydrolysis, but that bitterness from peptides also will increase accordingly.

Whey proteins offer function and nutrition. For this reason, they are increasingly used in meal replacement beverages (mixes and ready-to-drink), and sports beverages as well as a variety of dairy-based beverages such as hot chocolates, coffee and tea drinks.

11.2 WHEY PROTEINS IN DAIRY-BASED DRINKS

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Milk beverages are viewed as convenient, tasty, highly nutritional and digestible health foods associated with a high protein content as well as a high content of bioavailable calcium. As the popularity of dairy drinks increases due to their health benefits, it is critical for product developers to understand milk components composition and functionality, to develop products with high consumer appeal and through a cost-effective approach.

As multifunctional ingredients, whey proteins are used in a wide range of dairy beverages. They can perform as texture modifiers and as a delivery medium for probiotics and other nutraceuticals. U.S. whey products, from sweet whey to whey protein concentrates and high-end whey fractions, are increasingly used in dairy beverages and fermented milk products worldwide. According to major whey protein concentrate (WPC) suppliers, U.S. WPCs can even be tailored for specific end applications to produce the most desirable results, such as WPCs with reduced lactose content or high calcium.

Whey proteins are value-added proteins and provide the following benefits in dairy drinks production:

- "Clean" label and flavor
- Cost reduction
- Buffering capacity
- Texture improvement
- Substitute for non-dairy stabilizers
- Protein and calcium fortification
- Delivery medium for probiotics, lactoferrin and other bioactive or nutraceutical components.

Whey Proteins: "Clean" Label and Flavor for Dairy Beverages

As ingredients derived from pure, fresh milk, whey proteins are perceived by consumers as natural and healthy ingredients. Using WPC in dairy drinks helps displace less desirable additives, simplify the ingredient statement and increase the consumer appeal of the overall product. According to the U.S. National Yogurt Association, "Today, many drinking yogurt producers prefer to avoid stabilizers and starch-like hydrocolloids from the label and use complementary dairy ingredients, like WPC, that fit the nutritional and 'clean-label' image," an important marketing and positioning element for this type of product.

There are many types of dairy beverages available on the market today. One of the fastest growing segments is the drinking yogurt category. Yogurt flavor is multi-dimensional: a composite of volatile components, sugars, polysaccharides, organic acids, amino acids and peptides. A senior scientist at Dannon USA states that "compared with caseins, whey proteins impart less of their own flavor and allow the customer to enjoy the pleasant blend of acids, sugars and flavors." The factors affecting flavor are milk and ingredients quality, culture strains and fermentation, and storage. In plain drinking yogurt, desirable flavor compounds are acetaldehyde, diacetyl, acetone, and volatile fatty acids. The well-known compounds affecting yogurt flavor, such as lactic acid and acetaldehyde, can be controlled by the addition of WPCs. Studies have indicated that diacetaldehyde concentration increased with WPC fortification, and acetaldehyde increased with whey powder fortification in yogurts made with traditional yogurt starter cultures.

The organoleptic scores of drinking yogurts fortified with WPC were higher than scores of yogurts fortified with plain whey powder and controls without whey addition. These results suggest WPC can be incorporated in drinking yogurts as natural dairy additives to improve the flavor profile of the product. Furthermore, skim milk solids can be replaced by WPC80 at about the 2% level (or as 50% of total protein) without affecting the viscosity or the titrable acidity.

In reduced-fat and nonfat drinking yogurt, different flavor systems pose a unique challenge, especially when the product contains fruit. "There is a quick flavor release and then it is gone," explains a major U.S. yogurt producer. For this reason, an increasing number of manufacturers of reduced-fat and nonfat flavored liquid yogurts are incorporating more WPC in their formulas. According to the National Yogurt Association, "U.S. yogurt companies are using WPC in their low and nonfat yogurt lines to provide superior body and mouth feel and to solve the flavor challenge."

Whey Proteins: Cost Efficient Solution for Dairy Beverages

An important element in the cost of dairy beverage production is the cost of milk solids. WPCs are increasingly used to replace or complement part of the milk solids, (between 0.75-2%) in order to increase the total milk solids content of the products. For example, whey protein concentrate 34% (WPC34), with a protein level similar to skim milk powder, is used as a cost effective source of dairy solids in yogurt production. This ingredient is increasingly used in a variety of dairy-based beverages.

Whey Proteins: Yield Buffering Capacity to Beverages

The buffer capacity of the WPC is very important. It helps the probiotic cultures survive the acidity of the stomach and it helps them function in the intestine. The buffer components in milk are protein, phosphate, bicarbonate, lactate, and citrate. The ionizable groups in protein exert considerable buffer action in the pH range of 4.6-8.3. Lactic acid is a monoprotic acid with buffer maxima at pH 3.86. The pH and buffering capacity of drinking yogurts are influenced by the total solids in the yogurt mix and by the amount of lactic acid produced by the culture. The different formulations of yogurt mix result in different buffering capacities, an increase in protein and mineral salt content results in a better buffering capacity of the yogurt.

Whey proteins affect the buffering capacity and pH of milk-based beverages. The main proteins in WPC are Alpha-lactalbumin and Beta-lactoglobulin, which have weaker buffering capacity than casein. Dairy-based beverages produced by partial replacement of skim milk powder by WPC 80 (20%-51%) showed high buffering capacity at low pH (2.0-4.2) and low buffering capacity at high pH (4.1-8.2). These results suggest that the addition of WPC to formulations could provide improved protection for live probiotic bacteria in the acidic stomach and increased Beta-galactosidase enzyme activity in the small intestine. The increase of Beta-galactosidase activity may also make consumption of dairy beverages easier for people with lactose intolerance.

Whey Proteins and Nutritional Profile, Probiotics

Whey protein concentrates are good ingredients for fortifying the protein content of milk-based beverages. For example, drinkable cultured dairy products are ideal foods for young children because of their high nutritional quality. Today, the popularity of dairy beverages as a source of calcium for a variety of individuals is growing. Whey proteins are an excellent source of highly bio-available calcium; some whey products contain in excess of 800 mg of calcium per 100 g. For this reason, they are often used in drinks for children, pregnant women and seniors. Formulators can now also use natural dairy calcium derived from whey products to enrich beverages and other nutritional products. This form of calcium offers several major benefits: it is all-natural, highly bioavailable and has a mild flavor which complements very well other dairy flavors.

Whey is also increasingly used in probiotic drinks. Some studies suggest that whey proteins may help protect probiotic cultures in the product and extend its shelf life. Lactose and lactose derivatives also have a prebiotic effect.

Additional information on this topic and the latest research projects are available from the U.S. Dairy Export Council.

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11.3 BEVERAGE FORMULATIONS

Meal Replacement Beverage Mix

Ingredients	Usage Level (%)
Skim milk powder, instant	22.45
WPC80, instant	22.20
Fructose	15.00
Creamer	11.65
Sucrose	10.25
Canola oil	6.20
Instant coffee	4.20
Cocoa	2.80
Guar/xanthan blend	1.70
Natural flavor	1.40
Milk minerals	1.30
Vitamin/mineral premix	0.85
Total	**100.00**

Formula courtesy of Dairy Management Inc.™

Procedure:

1. Combine sugars and cocoa until well blended.
2. Add guar/xanthan gum blend and mix until well dispersed.
3. Combine with remaining ingredients, except canola oil, and mix well.
4. Add canola oil and mix for five minutes.

Chocolate Drink

Ingredients	Usage Level (%)
Water	85.42
Sugar, granulated	5.00
Fat, spray-dried	5.00
Dry sweet whey	3.00
Cocoa	1.00
Calcium caseinate	0.50
Carrageenan	0.08
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Blend dry ingredients together and then disperse into water with rapid agitation (alternatively, use blender).
2. Rapidly heat to 82°C (180°F) and hold for 20 seconds.
3. Homogenize using a two-stage process of 176 kgf/cm^2 (2000 lb/inch^2) on first stage, and 35 kgf/cm2 (500 lb/inch^2) on the second stage.
4. Cool to 5°C (40°F) and fill.

Coffee Whitener, Spray-Dried

Ingredients	Usage Level (%)
Water	82.70
Coconut oil	10.00
Sugar	5.00
WPC80	2.25
Xanthan gum	0.05
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Pre-hydrate WPC80 with formula water. Let sit overnight at 5°C (40°F).
2. Mix xanthan gum thoroughly with formula sugar.
3. In a jacketed heated vessel, mix together all ingredients until slurry is homogeneous.
4. Bring the slurry up to a temperature of 62-66°C (145-150°F) and hold for 30 minutes with continuous agitation, to insure pasteurization.
5. Spray-dry the slurry.

Chai Tea Mix

Ingredients	Usage Level (%)
Sugar	42.50
Whole milk powder	16.40
Honey powder	13.50
Skim milk powder	11.25
Creamer	9.60
Whey mineral concentrate/ milk calcium	2.70
Black tea	1.90
Natural and artificial flavor	1.20
Spice blend*	0.60
Lactoferrin	0.35
Total	**100.00**

*Suggested: cardamon, clove, anise, cinnamon, ginger.
Formula courtesy of Dairy Management Inc.™ and California Dairy Research Foundation.

Procedure:

1. Blend sugar, honey powder, spices and black tea. Mix until well blended.
2. Add dairy ingredients and mix until well dispersed.
3. Add remaining ingredients. Mix well.
4. Package. Net weight = 31 grams.

Preparation Instructions:

Iced Chai:

1. Mix 31 grams of dry Chai Tea Mix with 170 ml of cold water. Mix well.
2. Pour over ice and enjoy.

CONFECTIONERY APPLICATIONS FOR WHEY AND LACTOSE PRODUCTS 12

Formulary edited by
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Dairy products have been used as valued ingredients by the confectionery industry for many years as they help to achieve the required flavor, color, and texture in many products including chocolate, coatings, caramels, aerated confections and toffee. Whey proteins are multi-functional food ingredients with a high nutritional value. They offer a wide range of functional properties that allow the development of new products and optimization of existing products with considerable cost savings.

Today, the U.S. dairy industry offers a successful range of functional dairy ingredients based on whey for application by confectionery companies worldwide. Commercially, three major categories of products are used by the confectionery industry: sweet whey and modified whey products, whey protein concentrates (WPC) and whey protein isolates (WPI). In addition, lactose and lactose derivatives are important whey-derived functional ingredients for the confectionery industry.

12.1 AN OVERVIEW AND NEW DEVELOPMENTS

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Flavor, color and texture are just three reasons to use dairy products in confections. Whey is a very commonly used ingredient in confections because the various forms of the ingredient impart functional characteristics such as nutrition, flavor, color, texture and stability, as well as fitting into cost parameters. Traditionally, lactose has been more limited in its usage but its potential use is changing as availability has made it a valuable alternative to sucrose. Lactose can be a cost-efficient alternative to sugar, which makes it very competitive and attractive from such standpoint. Some of the most common uses of whey and lactose in the U.S. include sweet whey, WPC or lactose in caramels, whey and lactose in confectionery coatings and lactose in hard candy and chocolate.

In making the decision to use whey and lactose, the food formulator must consider functionality. The basic formulation has to be designed to meet the needs of the marketing concept. With marketing claims that use either inherent or additive nutritional elements, the nutrition claim sometimes has to be considered before everything else in the formulation. Whey offers some excellent nutritional properties, making it a choice ingredient in nutraceutical formulations. Lactose's physical properties and low sweetness offer interesting design opportunities.

Functional Benefits for Confectioners

Flavor

Whey has some wonderful functional attributes that make it ideal for usage in confections. Flavor and color development occurs during both caramelization and the Maillard reaction. Whey contributes both the protein and the reducing sugar to these chemical reactions. Since the Maillard reaction is pH-dependent and proceeds at a faster rate above pH 6.0, pH control may be critical in producing the desired end product. Whey proteins are themselves odorless and have a mild flavor, but they can bind undesirable flavors. It is important to have a high quality, consistent supply of whey.

Color

Color development can at times be used as an indicator of flavor formation. In caramels, optimum color and flavor notes have been found to occur when a combination of liquid whey concentrate and sweetened condensed skim milk are used. Products made with these ingredients have improved flavor with no structural changes to the caramel. Color development is dependent upon how the substitution of whey for other proteins is calculated. When whey is substituted for skim milk powder on a weight for weight basis, a lighter caramel is produced since there is less protein for caramelization and Maillard browning. If whey is substituted on a protein basis, color development is either par or in some cases more pronounced.

Texture

Whey proteins contribute to texture, which can be a major characteristic of a confection. In a nougat or taffy, the protein source is very important. Even though the quantity of proteins in these products is low, texture is directly related to the type of protein used, its usage level and processing conditions. Protein selection goes hand-in-hand with the equipment on the production line. If the selection of protein is incorrect, the formula costs become too high and the product texture changes from a light, fluffy tenderness to a chewy, tough product.

Foams consist of an aqueous phase and a gaseous dispersed phase. In most foams, proteins are the main surface-active agent in the formation and stabilization of the dispersed phase. Whey produces a good foam. In marshmallows, the whey protein Alpha-lactalbumin is utilized as an aerating agent. Whey as the sole protein source in marshmallows may not produce an optimal quality product, so gums or other proteins such as gelatin, soy or milk are commonly used in combination with whey protein concentrates. Good foaming properties and a stable, high quality product can be produced when these ingredients are combined.

The presence of salt can affect the foaming properties of a protein. Divalent cations, such as calcium and magnesium dramatically improve foamability and stability through cross-linking. The use of demineralized whey may be useful where the presence of minerals affect the quality of the product. The importance of the quality and consistency of the whey supply is critical to the operations of a confectionery manufacturer. Lipids also greatly affect the ability of a protein to foam. Lipids present at more than 0.5% greatly impair foaming properties. Because they are more surface-active than protein, they readily absorb at the air-water interface and inhibit adsorption of protein. Lipids lack cohesiveness to withstand the internal pressure of the foam bubble, causing the bubble to collapse during whipping. Monitoring the content of lipids in the whey is important to having a good finished product.

Fat Reduction

Fat imparts unique properties that affect smoothness, flavor, texture, moistness and palatability. Replacing fat in many confections is simply not an option, although reduction using appropriate additives is, to a degree, possible. By substituting sweetened condensed whey for the sweetened condensed milk, a caramel with less than 4% fat can be produced. Whey protein concentrates can also be used as a fat replacement. A substitution of WPC for whole milk powder can be made up to 50% without any effect on production, flavor, color or texture.

New Confectionery Applications for Whey

"Milk chews" originated in Japan and they are becoming popular in many countries. They are basic taffies with milk or whey replacing some of the sugar in the formulations. This substitution results in a soft chewy matrix with a distinct milky flavor. The milky flavor can be enhanced further with natural and artificial milk flavorings. Flavor combinations that are quite successful include coffee and cream, strawberry and cream, and orange and cream. The current trend is toward a fresh milk taste profile. To achieve this effect, it is necessary to use special equipment to reduce the cooked flavor notes.

"Milk high boil" is somewhat similar to "Milk chew" and is also very popular in Asia. In this product too, the desired flavor profile is a fresh milk taste profile. Care must be taken to not overcook and have continuous mixing to prevent Maillard reactions from occurring. A continuous vacuum swept surface cooker is required for this type of product.

Malted milk balls are mostly popular in the U.S. The center is a simple expanded high boiled hard candy. After cooking and forming into small pea-sized shapes, it is reheated and then vacuum puffed. The entrapped air expands when exposed to the reduced pressure environment. During expansion, the product undergoes cooling and results in an expanded hard mass ball. The sphere is then coated with chocolate. Whey works very well in this application for taste and performance reasons, and also provides cost savings.

Confectionery Coatings

Whey can be used to substitute for the milk solids in a confectionery coating to produce a lower cost alternative. There exist formulations where all of the milk solids are replaced by whey without affecting the quality of the final product.

Utilization of Lactose

Lactose's functional properties make it a viable ingredient for the confectionery industry. Lactose is a reducing sugar, while sucrose is a non-reducing sugar. Therefore, lactose carries with it the functionalities associated with reducing sugars, such as browning reactions. In industrial use today, the main applications of lactose are for hard candy and chocolate. Both of these applications use lactose as a cost-efficient ingredient with reduced sweetness. There are two recommended grades of lactose for confectionery use: Alpha lactose monohydrate and amorphous lactose. These are sometimes blended and spray dried to produce a product special for confections.

Benefits of Lactose in Confections

Flavor

Lactose is about one-sixth as sweet as sugar when in solution. While this can be an advantage in reduced-sweetness products, it is also less soluble and has some unique crystallizing properties. Lactose is a flavor-enhancer and is more than twice as effective in absorbing flavor components as compared with other sugars.

Color

The Maillard reaction is enhanced with the addition of lactose. Lactose is a reducing sugar and helps to generate color at an accelerated pace. Refined lactose can be used to control color formation in caramels and usually results in a darker colored caramel. The amount of lactose that generates an acceptable caramel is approximately 5%-6%. Higher levels tend to generate manufacturing issues, shelf life problems and quality defects like grain formation. Lactose also has the ability to attract and absorb natural and synthetic pigments.

Texture

The major use of lactose is in hard candy at typical levels of 1%-5%, but there are occasions where 30% or more are used in some products. For example, good rock candy can be made with 100% lactose as the sugar source. Using lactose in milk chocolate can produce a harder, less sweet chocolate.

Usage levels vary from company to company as well as from formula to formula. Normal usage levels range from a high of 10% to a low of 3%. Lactose can replace 10% of the sugar in marshmallows. Lactose can be used in nougats, chews and other confections. In chewing gum applications, lactose can result in delayed sweetness because of its reduced solubility or reduced sweetness. Graining and an unstable product can be the result along with production issues unless special formulations are used and thorough and proper cleaning takes place to reduce the possibility of any seed crystals being present.

Compound Coatings

Cost reductions can be achieved by substituting up to 10-15% lactose for sucrose in compound coatings. Because of the reduced sweetness level of lactose, the sweetness is also reduced. In formulations of pastel coatings or white chocolate, which are by nature sweeter, even higher levels can be used to reduce the sweetness. Lactose is a good substitute for dextrose or sucrose in tabletted candies although agglomeration is sometimes required when the particle size is important to tabletting efficiency. Substituting lactose for sucrose can also reduce the cost of chewing gum formulas. If a majority of the formula is changed to incorporate lactose for sucrose, a high intensity sweetener may be needed to enhance product sweetness.

12.2 WHEY PRODUCTS AND LACTOSE IN CONFECTIONERY APPLICATIONS

By DR. JORGE BOUZAS
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Dairy Ingredients in Chocolate Confectionery

Milk, in its various forms, has been used as an ingredient in chocolate manufacture since the introduction of milk chocolate in 1876. As a major ingredient, dairy solids are essential to flavor, color and texture. They also provide nutrition and bulk, and contribute to gloss and shelf life. In the formulation of milk and white chocolates, several functional ingredients are used:

- Sweet whey, demineralized sweet whey and partially delactosed whey
- Whey protein concentrates
- Proprietary blends of the above components

The protein content of such ingredients is important because it is a key component in the Maillard reaction between amino acids and sugars. This reaction is important in caramel and toffee manufacturing, although it also takes place during the manufacture of milk chocolate.

Table 12.2.1
Functionality Overview of Various Whey and Whey Protein Products

Product Function	Sweet Whey	WPC*	WPI**
Nutritional value	medium	high	high
Solubility	good	good	good
Viscosity	low	low	low
Water binding	medium	high	very high
Coagulation	>65°C	>65°C	>65°C
pH stability	medium	high	high
Emulsifying capacity	medium	high	high
Foaming	low	high	very high
Gelation	low	high	very high
Ability for fat replacement	medium	good	good

*Whey protein concentrates: 34 to 80% protein.
**Whey protein isolates: >80% protein.

The level of milk solids non fat in milk chocolate varies from 10% to 25%, although a lower limit of 14% applies in most European countries. According to European, Canadian, and Codex standards, functional dairy ingredients can be used to formulate milk chocolate in addition to milk and at a level not higher than 5% of total chocolate mass. This formulation practice has the following purposes:

- To develop specific or signature flavors during conching.
- To reduce manufacturing costs while maintaining high quality.
- To take advantage of the excellent functional and nutritional characteristics of many dairy based ingredients, i.e., whey-based products.
- To provide creamy-milky notes to the finished product.

Recently, conching mechanisms to reduce conching time and avoid agglomeration have been developed, leading the use of new equipment and shorter conching times. The addition of functional whey-based ingredients to a milk chocolate formulation improves the efficiency of the Maillard reaction, yielding better chocolate taste and mouthfeel.

Milk chocolate is consumed in a variety of ways—as a snack item such as the common chocolate bar, as a topping or coating on products such as candy bars, biscuits, cakes, etc. Such diverse application of a single product means that different milk chocolate formulations could be developed for each application to provide both the functional and sensory properties that the manufacturer and consumer expect. The selection of the optimal whey-based ingredient should be determined by taking into consideration:

- The nature of the final application: from solid bar versus enrobing chocolates.
- The desired effect of the ingredient on chocolate functionality and rheology.
- The desired contribution to a specific flavor profile, such as caramelized and toffee notes.
- Cost constraints.

In general terms, replacing milk solids with whey-based ingredients at a 5% level, can produce savings of 8% to 14% on milk powder costs, while maintaining a high quality end product.

Whey Ingredients in Compound Coatings

Chocolate-flavored compound coatings provide an alternative to real chocolate. Other vegetable fats are substituted for the cocoa butter. Compared to chocolate, the resulting products can be less expensive or easier to handle. Sensory quality would not match that of pure chocolate but allows more flexibility in terms of new and novel textures and applications.

Ingredients used in compound coating formulations include sugar, chocolate liquor (mass) and/or cocoa powder, vegetable fat, dairy components, and lecithin.

Whey protein-based ingredients are used as a milk solids source in the formulation of milk chocolate flavored coatings for ice cream, candy bars, and other enrobing applications replacing skim milk powder. Demineralized whey (50%, 90%), whey protein concentrates, or blends are used as total or partial replacement for milk powders in coating formulations.

Reduced-calorie and reduced-fat coatings offer an unique opportunity to use whey based dairy ingredients for flavor enhancement. Reduced calorie fats have fast crystallization rates but minimal contraction. For this reason, these coatings are best employed using powder-type recipes in enrobing applications.

Whey Products in Sugar Confectionery

It is the combination of multiple ingredients and processing options that allows the confectioner to manipulate chemical and physical interactions to produce a wide range of confectionery products.

The range of textures which can be achieved in confectionery is diverse, spanning from hard (high boils) to soft (nougats, marshmallow) and from snappy (chocolate) to chewy (caramel). The principal ingredients that contribute to these characteristics are sugars (including sucrose, invert and glucose syrups), fats and proteins. Dairy components provide protein and play a critical role in the formulation of caramels, aerated confections, health bars, and dulce de leche (a popular South American delicacy with increasing worldwide appeal).

Caramel

Caramel and toffee are complex blends of fat globules evenly dispersed in and surrounded by a high concentration sugar solution in which dairy solids are dispersed. Important characteristics are flavor, color, and texture and these will directly reflect the nature of the ingredients and cooking process used in their manufacture. Both caramel and toffee have the same ingredients, the difference between the two is that the final moisture content is less in toffee than in caramel. Toffee has 3% to 6% moisture and is generally darker whereas caramel has 6% to 12% moisture and is lighter in color.

Caramel is one of the most versatile and widely used confectionery products. Caramel in its many forms is consumed as an item, enrobed or used as a component in combination with cookies, nougat, marshmallow, etc.

Caramel is produced by blending water, glucose syrup, refined or brown sugar, emulsifier, milk fat or vegetable fat, and dairy solids. The mix is concentrated to a high solids content by cooking to approximately 116°C. This process helps to develop the characteristic color and flavor through caramelization and the Maillard reaction.

Cooking of the caramel pre-mix is necessary to remove moisture for microbiological stability and to develop color, flavor, and texture. Before the cooking process begins, all sugar crystals must be dissolved to prevent graining upon storage. As a rule of thumb, 500 g of water will dissolve 1000 g of sugar. It is better to slowly heat the pre-mix to 72°C and dissolve the sugar crystals before the high heat of cooking is applied. Then, the other ingredients could be added and the cooking process starts.

It is advisable, that powdered dairy ingredients, i.e., skim milk solids, demineralized sweet whey, WPC, be reconstituted with warm water (50 to 60°C), preferably in a homogenizer prior to addition to the cooking vessel. Pre-blending of the dairy powder with some of the formulation sugar will also prevent lumping during the recombination process. If no homogenizer is available, the dairy ingredients can be reconstituted in the following manner. Place a predetermined amount of warm water heated to 72°C in a vessel. Slowly add the blended dairy powders with enough agitation to give the solution a creamy consistency. Mix for at least 15 to 20 minutes. If the recombined dairy blend shows sign of curdling, it is advisable to add a stabilizer, usually di-sodium phosphate at a level of 0.01% to 0.05% of the total protein.

Normal cook time in an open cook vessel is 20 to 30 minutes. After cooking is completed, agitation should be stopped to prevent possible graining. Caramel is cooled to stop the browning process and to be manageable for further downstream process. For small batches, a simple cooling method is to pour the cooked mass on a slab table. Another solution is a moving chilled belt/cooling tunnel or cooling wheels.

Caramels should be wrapped in moisture proof packaging and stored at less than 50% relative humidity for good shelf life.

Whey Products in Aerated Confectionery

An aerated confectionery product can be described as a dispersion of a gas in an aqueous phase which is in fact a highly concentrated syrup made up from a variety of sugars and whipping agents. The density of the finished product will be reduced by the presence of gas. In most cases the gas is air. Nitrogen can be used when a high amount of fat is present.

Aerated confectionery is produced by vigorous agitation of the syrup. Stability is obtained by the addition of a whipping agent/stabilizer. At the simplest level, the air is incorporated by beating at various speeds in an open pan. Beating creates a series of cavities that entrap air in the form of large bubbles. While continuing beating, the largest air bubbles will be broken into smaller units. The viscosity of the final mix will increase depending on the amount of air incorporated in the product.

Common aerating proteins used in the formulation of aerated confectionery are gelatin, soy, and modified dairy proteins. Within the last category, both, partially denatured WPCs (80% protein) and partially denatured WPIs (>90% protein) offer a cost effective alternative to the confectionery manufacturer when used in combination with the other aerating agents. In addition, partially hydrolyzed WPIs have been proved to also provide interesting functionality.

The texture of the finished product could be broken down by three effects:

- Coalescence: the layer enclosing the air bubbles breaks and creates larger bubbles.
- Drainage: a flow of the syrup continuous phase goes down through various layers of bubbles.
- Disproportionation: air migrates from smaller air bubbles to larger air bubbles.

These defects could be prevented by increasing the viscosity of the syrup by the appropriate choice of foaming agent, and by correct processing conditions.

Nougat

Nougat is basically an aerated high boiled syrup containing fat that has been stabilized by the addition of a whipping agent. The production of nougat can be adjusted to give a range of textures that can vary between a long-eating, chewy, non-grained product and a short-eating, soft, fine-grained product.

The texture of nougat is influenced by:

- The ratio of sugar to glucose syrup to invert sugar syrup.
- The final moisture content of the nougat.
- The ratio of the liquid phase to the solid phase.
- The type of whipping agent.
- The degree of aeration, which can vary between 0.6 and 1.0 g/ml.
- The quantity and type of additions, e.g., fat, nuts, cherries, etc.

Nougat can be produced by either a batch or continuous method, but the batch process is considered a far superior system in terms of flexibility of production, texture consistency, the ability to absorb, rework, and the appearance after cutting. The batch process consists of boiling water, sugar, and a corn syrup under vacuum to a moisture content of about 8% at a temperature of 120°C. The vacuum cooker is used not only to reduce the time of boiling, but also to produce a cooked syrup at a lower temperature- the higher the temperature, the longer the beating time.

The vacuum-cooked syrup is transferred to a robust and powerful atmospheric whipping machine that can operate at two speeds, low for mixing and blending and high for aerating. A whipping solution (gelatin, milk proteins, WPC, WPI) is blended into the cooked mass before being aerated at high speed, when the density is reduced to 0.6 g/ml. A small quantity of icing sugar, to induce graining, is blended into the aerated product at low speed. The nougat is discharged from the whipping machine into metal trays and allowed to condition overnight. Here the induced fine crystal can be developed in the product prior to cutting into the required shapes at a final water content ranging from 8% to 10.5%.

Vacuum aeration is a process whereby a sugar mass is heated, subjected to vacuum in a vacuum vessel, cooled, and/or dried, and released from the vessel to produce a candy exhibiting a honey-combed appearance containing considerable small air bubbles. Malted milk balls are an example of such product. The ingredients used in the formulation consist of mainly corn syrup, sugar, protein, flavor, and color. The quality of the ingredients is critical as it relates to the formation of the air bubbles.

Whey powders, specifically 50% demineralized powders, can be used as protein bulking agents in the formulation of this kind of confectionery. The whey powder should be free from lumps, and of uniform moisture content. A minimum of 10% protein in the demineralized whey is critical to avoid product texture collapse after vacuum processing. For the production of vacuum aerated confections, batching of ingredients is fairly straightforward. Corn syrup and sugar are cooked to the desired solids (approximately 90%) and transferred to a suitable sigma type mixer/blender where the dry ingredients were previously added (whey powder). A thorough mixing process to allow for a uniform mass then occurs. The mass is unloaded into a sheeting device and the sheet conveyed to the forming rolls.

The centers are then stored until ready for expansion. Prior to expansion, the centers must be uniformly heated to a desired temperature of 82°C to obtain the optimum amount of expansion. The preheated centers are then conveyed through a vacuum tube where vacuum is applied. Approximately 1% moisture is removed and the product is cooled sufficiently so that the center will not collapse.

Excessive residual moisture will cause the extremely hygroscopic centers to become wet and sticky, eventually collapsing the cell structure completely. During the panning process the centers should be completely covered with chocolate or compound coating to prevent moisture pickup.

Whey Ingredients in Dulce de Leche

In general, dulce de leche is prepared by boiling whole milk with added sucrose until a 70% (wt/wt) total solids product is obtained. Sucrose, usually, is partially replaced with glucose syrup to prevent crystallization. Due to the prevailing conditions during preparation (temperature-time, pH, reactant species), non-enzymatic browning reactions occur extensively leading to a brown-colored product that has a characteristic and pleasant flavor. Sodium bicarbonate is added to raise pH to increase browning development and prevent protein coagulation. The high solute concentration of dulce de leche results in a water activity usually below 0.85, which constitutes the main preservation factor in this product.

Generally, two distinct types of dulce de leche are produced. The "casero" (for use at home) is shiny, of a reddish brown color and slightly stringy while the "pastelero" (for confectionery and pastry shop use) is lighter in color and very short in texture to avoid running off from cakes, pastries, and other confectionery products.

Whey based dairy ingredients can be used as a cost effective tool to replace milk solids and produce alternative formulations for dulce de leche with consumer appeal. Best suited whey ingredients for this application are WPCs with a protein content of 34% to 40%. Depending on the manufacturing process and formulation, it may be necessary to adjust processing conditions to account for the difference in protein composition between milk and whey. A recommended starting level of milk solids replacement is 25%. In general with up to 50% solids replacement with a WPC34, no processing or formula adjustment is necessary. At higher replacement levels, the consistency, rheology, flavor and color of the finish would be effected in such a way that major changes in formulation and processing would be needed.

In formulations already using a combination of fluid milk and skim milk solids, the latter ingredient could be replaced 100% with a WPC (34% protein) without changes in processing conditions. It is advisable, that powdered dairy ingredients, i.e., skim milk solids, WPC, be reconstituted with warm water (50 to 60°C), preferably in an homogenizer prior to addition to the cooking vessel. Pre-blending of the dairy ingredient with some of the formulation sugar will also prevent lumping during the recombination process. If no homogenizer is available, the dairy ingredients can be reconstituted in the following manner. Place a predetermined amount of warm water heated to 72°C in a vessel. Slowly add the blended dairy ingredients with enough agitation to give the solution a creamy consistency. Mix for at least 15 to 20 minutes.

Whey-based ingredients have many desirable qualities of great importance to the manufacturer of confectionery products: good rate of solubility over a wide range of pH levels, water-binding capacity, gelation properties, ability to emulsify with fats, enhanced whipping and foaming performance, and improved viscosity and texture. Table 12.2.2 (page 131) summarizes the use levels of whey-based ingredients in different applications.

Table 12.2.2
Recommended Use Levels of Whey Proteins in Confectionery Applications:

Product	Recommended Usage Level (%)						Expected Benefit
	Sweet Whey	Demin. Whey	WPC34	WPC80	WPI	Lactose	
Milk chocolate[1]	–	0–5	0–5	–	–	3–7	Cost benefit Flavor development Color improvement
Compound coatings[1]	–	0–20	0–20	–	–	3–7	Cost benefit Flavor development Color improvement Functionality
Caramel[1]							Cost benefit
Standup	0–4	0–4	0–7	–	–	–	Flavor improvement
Cast	0–2	0–2	0–5	–	–	–	Color development
Free flowing	0–2	0–2	0–5	–	–	–	Texture modification
Nougat[1]	–	–	0–1	–	0–3	–	Cost benefit Better quality Better texture Better shelf life
Dulce de leche[2]	–	0–50	0–50	–	–	–	Cost benefit Improved color Improved flavor Signature flavor development Functionality
Nutrition bars[1]	–	–	–	0–20	0–35	–	Nutritional quality Functionality

[1] % of final formula.
[2] % of total milk solids nonfat.

QUESTIONS AND ANSWERS

Q. *Will the addition of demineralized whey to milk chocolate or compound coatings affect its shelf life?*

A. No, the addition of a good quality demineralized whey into milk chocolate will not affect shelf life. However, flavor and color of the chocolate or compound coating will be affected if whey levels exceed 25% of the formulation.

Q. *Can sweet whey give a gritty or grainy texture in caramels and toffees? How could this be avoided?*

A. Yes, gritty caramel could be produced if the crystalline lactose present in the whey is not totally dissolved during processing. The insoluble lactose crystals will act as seed agents and the product will crystallize during storage. To solve the problem, the whey-based ingredient should first be dissolved in water preheated to at least 72 to 82°C.

Q. WPC80 *can replace egg white in some products. Which ones are best suited?*

A. In aerated confectionery, partially denatured WPC80 can be used in combination with gelatin to replace egg white.

Q. *After cutting caramels, they lack body and flatten out. Why?*

A. Probably the formulation does not contain enough milk solids. Increase protein level. In addition, reformulation of the syrup phase could help too.

Q. *My caramel is too thick and has poor elasticity. Could this be due to the use of* WPC *or sweet whey?*

A. Thickness of the caramel is probably not due to the whey component used but to the corn syrup selected for the formulation. Changing corn syrup or using a corn syrup blend with less polysaccharide will help reduce viscosity. The elasticity could also be related to the carbohydrate profile or the syrup phase or could be related to a low concentration or even no casein being present. Again, this problem could be solved by reformulating the syrup phase or by adding additional casein in the form of milk solids.

Q. *Is demineralized whey recommended in a nougat formulation?*

A. Generally no. In nougat applications good whipping and foaming properties are needed. Both are higher in WPC80 and WPI. Demineralized whey could be added at low levels (1% of the formulation) as a milk replacement to add some dairy notes to the formula if that is desirable.

Q. *My vacuum aerated center is not expanding during process. Could this problem be related to my formulation? Why?*

A. Yes, your formulation may be responsible for this problem. The demineralized whey should have at least 10% protein to prevent this from happening.

Q. *While using a* WPC*/milk solids nonfat formulation in the production of caramel,* I *experienced an unacceptable curdling. How could this be avoided?*

A. First check the pH of your product. Sometimes a stabilizer needs to be added to prevent curdling of the proteins that lead to a grainy texture. Usually, disodium phosphate solves the problem at a very low usage level.

12.3 CONFECTIONERY FORMULATIONS

Caramel with 100% WPC

Ingredients	Usage Level (%)
Corn syrup 42/43	30.32
Granulated sugar	25.28
WPC34	4.67
Water	18.71
Butter fat	11.77
Lecithin	0.51
Salt	0.40
Water	8.29
Vanillin	0.05
Total	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Combine the ingredients, except vanillin, under constant agitation and bring to a boil. Cook to 117°C (243°F).
2. Add vanillin.
3. Pour onto slightly oiled table or into container.

Caramel with 10% Calcium

Ingredients	Usage Level (%)
Granulated sugar (sucrose)	34.70
Corn syrup, 42 D.E.	33.40
Partially hydrogenated coconut oil	12.00
Water	5.90
Nonfat dry milk	4.20
WPC34	4.20
Butter	3.00
Milk calcium	2.30
Vanilla extract	0.10
Lecithin	0.10
Salt	0.10
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Pre-hydrate WPC34 as a 40% suspension, milk calcium at a 20% suspension, and nonfat dry milk as a 30% suspension in water and let sit overnight at 4°C (40°F).
2. Mix sugar, corn syrup and water together and dissolve over low heat.
3. Add all remaining ingredients, except vanilla, and continue to stir over low heat until completely mixed.
4. Increase heat, and bring to a boil. Continue to boil with constant stirring until 115°C (238°F) is reached.
5. Remove pan from heat and add vanilla, stirring until completely homogeneous.
6. Pour into a parchment-lined, rectangular 22.5 cm x 32.5 cm (9" x 13") pan. Cool slightly, then remove caramel slab from pan using the parchment to pull it out. Score the pieces using a sharp knife. Cut into squares when completely cool.

Caramel with WPC at 50% Replacement Level

Ingredients	Usage Level (%)
Granulated sugar	25.08
42/43 Corn syrup	30.08
Whole milk powder	3.01
Water	18.56
Butter	11.08
Lecithin	0.51
Salt	0.40
Water	8.22
WPC34	3.01
Vanillin	0.05
Total	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Combine the ingredients, except vanillin, under constant agitation and bring to a boil. Cook to 117°C (243°F).
2. Add vanillin.
3. Pour onto slightly oiled table or into container.

Marshmallow

Ingredients	Usage Level (%)
Solution A	
Gelatin, 250 bloom	2.00
Cold water	9.40
Solution B	
WPC80	0.67
Water	4.76
Solution C	
Sucrose	37.00
Corn syrup, 42 D.E.	16.00
Water	13.50
Mixture D	
Invert sugar	16.00
WPC34	0.67
Total	**100.00**

Formula courtesy of the Wisconsin Center for Dairy Research.

Procedure:

1. Prepare Solution A: Place gelatin in small bowl and add cold water. Let hydrate for 20 minutes.
2. Prepare Solution B: Place WPC80 in water and agitate to mix. Allow several hours or overnight for this to hydrate.
3. Prepare Solution C: Place sucrose, corn syrup and water in a pan and bring temperature to 104°C (220°F) with stirring, until sucrose is completely dissolved.
4. Pour Solution C into a Kitchen Aid mixing bowl and cool.
5. Prepare Mixture D by stirring the invert sugar and WPC34 together. Add Mixture D to Solution C with stirring.
6. When Solution C has reached 60°C (140°F), add Solution A to it first (gelatin solution) and then Solution B (whey solution).
7. Beat at high speed to desired density (0.4-0.5 g/cm3).
8. Add color and flavor as desired.
9. Prepare a mold 22.5 cm x 32.5 cm (9" x 13") rectangular pan by dusting it heavily with cornstarch. Deposit marshmallow mixture into mold and dust the top with more cornstarch.
10. Allow to dry overnight and then cut into desired shapes.

Nougat with WPC34

Ingredients	Usage Level (%)
Granulated sugar	33.01
Corn syrup, 42 D.E.	45.37
Water	8.25
Gelatin, 250 bloom	0.77
Water	2.06
WPC34	4.00
100 Degree vegetable (Palm kernel)	2.05
Glyceryl monostearate	0.26
Fondant 4:1	4.13
Peppermint oil	0.10
Total	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Soak gelatin in water. Set aside.
2. Cook sugar, corn syrup and first water to 117°C (243°F). Place the cooked syrup into mixer. Add the gelatin mixture and beat at high speed for 5 minutes.
3. Make a paste of WPC34, Paramount C and glycerol monostearate.
4. Add the paste mixture, fondant and flavor to the mixer and blend well.
5. Pour onto oiled slab. Cool and cut into pieces. Wrap.

Milk Chews

Ingredients	Usage Level (%)
Corn syrup, 42 D.E.	40.19
Granulated sugar	28.04
Water	9.35
Sweetened condensed whey	9.35
Gelatin, 225 bloom	0.93
Water	0.93
Sweet whey	6.54
Butter	4.67
Total	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Soak gelatin in 0.93% water. Set aside.
2. Paste together sweet whey and butter in mixer.
3. Cook corn syrup, sugar and remaining water to 126°C. Stir in sweetened condensed whey. Bring to 118°C while stirring constantly.
4. Pour cooked mix into mixer with butter and milk. Mix until thoroughly blended. Add gelatin and mix well.
5. Pour onto slab table to cool.

Malted Milk Balls

Ingredients	Usage Level (%)
Corn syrup, 42 D.E.	33.69
Hard fat	2.30
Lecithin	0.10
Salt	0.10
Sweet whey	23.20
Granulated sugar	22.74
Corn syrup solids	7.58
Malted milk powder	9.19
Malted milk flavor	0.18
Cocoa powder	0.92
Total	**100.00**

Formula courtesy of Hershey Foods Corporation.

Procedure:

1. Preheat sigma blade mixer. Add corn syrup and hard fat to the mixer and heat to 60-71°C while continuously mixing.
2. Premix the powders and add slowly to the mixer. When the batch is uniformly mixed, remove from mixer and run through 9mm drop rolls to form balls.
3. Remove the webbing from the formed balls. Warm the formed balls and vacuum expand.
4. Pan in milk chocolate or chocolate compound, following standard panning procedures.

Chocolate Product with WPC34

Ingredients	Usage Level (%)
Chocolate liquor	13.00
WPC34	12.30
Cocoa butter	20.85
Anhydrous milk fat	3.70
Lecithin	0.30
6X Sugar	49.75
Vanillin	0.10
Total	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Combine dry ingredients in a Hobart mixer with paddle attachment.
2. Melt fat and add the lecithin.
3. Add enough of the melted fat mixture to the dry ingredients to make refiners paste.
4. Pass the refiners paste through a 3 roll refiner (set at 375-450psi) twice.
5. Pass the paste back into the mixer bowl and with low heat, conch into a paste.
6. Slowly add the remaining fat mixture into the batch and mix until uniform.
7. Place the chocolate into a chocolate melter for at least 24 hours to develop flavors.
8. The chocolate is ready to be tempered for use.

Whey Hard Candy

Ingredients	Usage Level (%)
Granulated sugar	40.29
Water	21.57
High maltose corn syrup	21.05
Sweetened condensed milk replacer	4.80
Butter	11.98
Lecithin	0.07
Whipped cream flavor	0.24
Total	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Dissolve the sugar in the water and bring to a boil.
2. Wash all traces of sugar crystals from the sides of the pan. Add the corn syrup and sweetened milk replacer. Bring to 145°C (290-295°F).
3. Add butter, lecithin, and flavor.
4. Pour onto oiled table and cool until plastic, but still soft and mobile. Feed into drop roller.

Lactose Rock Candy

Ingredients	Twirls and Dummies Usage Level (%)	Lollipops Usage Level (%)
Lactose	15	21
Granulated white sugar	45	39
Glucose syrup, 42 D.E.	40	40
Flavoring and colors	–	–
Total	**100.00**	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Boil the mix to 138°C in winter and 143-153°C in summer. The boiling process takes about 30 minutes.

Reduced-Cost Chocolate

Ingredients	Usage Level (%)
Chocolate liquor	30.00
Butter oil	1.00
Cocoa butter	15.10
10X Sugar	46.45
Lactose	7.00
Lecithin	0.35
Vanillin	0.10
Total	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Melt cocoa butter and butter oil together and mix in 1/3 of the lecithin.
2. Combine dry ingredients in Hobart bowl with paddle and mix.
3. Melt chocolate liquor and mix into dry ingredients. Add enough cocoa butter to mix to create a refiners paste.
4. Refine on a 3-roll refiner until desired particle size is achieved (between 20-30 microns). Place refined powder back into Hobart bowl with low heat being applied.
5. Conch into a paste and slowly add remaining cocoa butter and lecithin.
6. Scrape down bowl. Transfer to chocolate melter and rotate for 24 hours at 49°C (120°F).
7. Temper chocolate and mold into bars. Cool and wrap.

Strawberry Bubble Gum with Lactose

Ingredients	Usage Level (%)
Gum base	25.5
Corn syrup 43/42	9.0
Powdered sugar (6X)	36.8
Lactose	10.0-20.0
Glycerin (99.6%)	2.0
Citric acid, powdered	0.7
Flavor, N&A	0.93
Color, red #40 lake	Trace
Total	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Warm the gum base and 1/3 of the glycerin in a Z-blade mixer to 54-60°C (129-140°F), for about 7 minutes. Mix 3 minutes.
2. Screen the powders through a 20-mesh screen.
3. Add 1/3 of the corn syrup slowly and alternate with 1/3 of the dry ingredients. After 5 minutes, stop the mixer and scrape the sides and the mixer blades.
4. Add another 1/3 of the corn syrup and dry ingredients and mix for 3 minutes.
5. Stop the mixer and scrape down the sides and the mixer blades.
6. Add the balance of the corn syrup and dry ingredients along with another 1/3 of the glycerin and mix for 2 minutes.
7. Stop the mixer and scrape the sides and the blades of the mixer. Mix for 10 minutes.
8. Add the remaining glycerin. Mix for 3.5 minutes and add the flavor and color. Mix 1.5 minutes. The product temperature should be between 43-49°C (109-120°F).
9. Form the chewing gum with a rolling pin and 0.6cm (1/4"), shim aluminum rod and score lines using a rolling knife.

Reduced Hygroscopicity Hard Candy, Lower Solubility and Increased Strength

Ingredients	Usage Level (%)
Sucrose	40.12
Lactose	2.36
Corn syrup, 43 D.E.	34.99
Flavor, lemon oil	0.33
Citric acid, anhydrous	0.94
Color, FD&C yellow #5, 10% solution	0.02
Water	21.24
Total	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Combine sucrose, corn syrup, water and color.
2. Cook to 138°C (280°F) quickly.
3. Place under vacuum at 650mm (26") for 3.5 minutes. Pour onto table and add flavor, acid and fold in.
4. Form.

Benefits:

- Reduced hygroscopicity
- Lower solubility, increased strength

Lactose Tablets

Ingredients	Usage Level (%)
Lactose, coarse grade (20-80 mesh average particle size)	97.39
Citric acid, anhydrous	1.50
Color, FD&C yellow #5	0.06
Calcium or magnesium stearate	1.00
Lemon flavor, spray dried	0.05
Total	**100.00**

Formula courtesy of Knechtel Laboratories.

Procedure:

1. Mix all ingredients, except calcium stearate, in a Hobart mixer for 10 minutes or until uniformly blended.
2. Add calcium stearate and mix for an additional 2 minutes.
3. Run through tablet press to form centers.

Milk Chocolate with WPC34

	Usage Level (%)	
Ingredients	**Standard**	**WPC34**
Sucrose	47.53	47.53
Cocoa butter	20.00	20.00
Skim milk powder	15.12	10.12
WPC34	–	5.00
Butter oil	4.00	4.00
Cocoa liquor (mass)	12.90	12.90
Lecithin	0.40	0.40
Vanillin	0.05	0.05
Total	**100.00**	**100.00**

Formula courtesy of Hershey Foods Corporation.

Please refer to text of section for procedure or recommendations.

Milk Chocolate with Demineralized Whey

	Usage Level (%)		
Ingredients	**Standard**	**Demineralized Whey—50%**	**Demineralized Whey—90%**
Sucrose	45.25	45.25	44.75
Cocoa butter	20.30	20.30	20.30
Whole milk powder (28% fat)	21.00	16.00	16.00
Demineralized whey	–	3.60	5.00
Butter oil	–	1.40	1.40
Cocoa liquor (mass)	12.90	12.90	12.00
Lecithin	0.50	0.50	0.50
Vanillin	0.05	0.05	0.05
Total	**100.00**	**100.00**	**100.00**

Formula courtesy of Hershey Foods Corporation.

Please refer to text of section for procedure or recommendations.

Vanilla Cake Icing

Ingredients	Usage Level (%)
Sugar, confectioner's	58.08
Emulsified shortening	21.83
Water	10.92
WPC34	7.86
Salt	0.66
Vanilla	0.65
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Use blender to mix WPC34, salt and vanilla into a suspension.
2. Beat shortening in a mixing bowl until light and fluffy.
3. Add sugar gradually, alternating WPC34 mixture with sugar, and continue to mix until a smooth, creamy consistency is reached.
4. Continue to beat for 3 to 4 minutes.

Reduced-fat Vanilla Icing

Ingredients	Usage Level (%)
Sugar, powdered	68.60
Water	14.30
Shortening	9.50
NFDM	4.00
WPC80	1.70
Starch	1.30
Butter flavor	0.30
Vanilla	0.30
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Blend dry ingredients on low speed in a mixer fitted with a paddle attachment.
2. Add shortening and blend until uniform.
3. Add hot tap water (60°C or 140°F) and vanilla. Mix on medium speed until mixture is of a smooth, creamy consistency.

Milk Chocolate Compound Coatings

	Formula I Usage Level (%)		
Ingredients	Tempering		Non-Tempering
Sugar	48.00	44.12	44.50
Vegetable fat (CBE)	27.00	28.00	–
Vegetable fat (CBR)	–	–	35.00
Chocolate liquor (mass)	–	11.20	–
Demineralized whey (50%)	7.00	7.00	7.00
WPC34	7.00	7.00	7.00
Cocoa powder (12% fat)	7.50	–	6.00
Butter oil	2.00	2.00	–
Lecithin	0.50	0.50	0.30
Vanillin	To taste	To taste	To taste
Salt	0.06	0.06	0.06
Total	**100.00**	**100.00**	**100.00**

Formula courtesy of Hershey Foods Corporation.

Please refer to text of section for procedure or recommendations.

White Chocolate Compound Coatings

	Formula I Usage Level (%)	
Ingredients	Tempering	Non-Tempering
Sugar	50.00	49.50
Vegetable fat (CBE)	38.00	–
Vegetable fat (CBR)	–	40.00
Lecithin	0.30	0.35
Vanillin	0.10	0.15
Demineralized whey	5.00	5.00
WPC34	5.00	5.00
Butter oil	1.60	–
Total	**100.00**	**100.00**

Formula courtesy of Hershey Foods Corporation.

Please refer to text of section for procedure or recommendations.

Chocolate Compound Coating

Ingredients	Usage Level (%)
Powdered sugar	43.83
Hard butter oil	40.02
Dutched cocoa	7.62
WPI	7.62
Sorbitan tri-stearate	0.57
Soy lecithin	0.19
Vanilla extract	0.09
Flour salt	0.06
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Weigh butter oil, sorbitan tri-stearate, and soy lecithin in a double boiler. Melt on low heat at 70°C (162°F).
2. Weigh all remaining dry ingredients into a bowl. Sift and then mix lightly.
3. Incorporate dry ingredients into butter oil using a whisk, mixing until completely smooth.
4. Keep coating warm, and submerge items completely in the coating, gently wiping underside once coated, in order to remove excess coating.
5. Place on parchment-lined pans and allow 20-30 minutes for coating to set up.

Caramel Center for Molded Shells (Typical final moisture 10%)

	Usage Level (%)		
Ingredients	**Control**	**Variant I**	**Variant II**
Corn syrup, 42 or 62 D.E.	50.00	50.00	50.00
Sugar, granulated	15.00	25.00	25.00
Sweetened condensed whole milk	22.30	–	–
Sweet whey	–	–	2.00
WPC34	–	6.20	4.30
Vegetable fat	2.00	2.00	2.00
Butter oil	–	1.40	1.40
Mono- and di-glycerides	0.10	0.10	0.10
Vanillin	0.20	0.20	0.20
Salt	0.40	0.10	–
Water	10.00	15.00	15.00
Total	**100.00**	**100.00**	**100.00**

Formula courtesy of Hershey Foods Corporation.

Please refer to text of section for procedure or recommendations.

Standup Caramel (Typical final moisture 10%)

	Usage Level (%)		
Ingredients	**Control**	**Variant I**	**Variant II**
Sugar, granulated	31.20	37.17	30.00
Corn syrup, 42 D.E.	26.65	26.65	30.30
Sweetened condensed whole milk	28.40	14.20	–
Demineralized whey	–	3.74	–
WPC34	–	–	6.70
Skim milk solids	–	–	6.70
Partially hydrogenated vegetable fat	12.27	12.20	8.0
Butter oil	–	1.00	1.00
Water	–	3.85	16.20
Lecithin	0.79	0.79	0.70
Vanillin	0.20	0.20	0.20
Salt	0.49	0.20	0.20
Total	**100.00**	**100.00**	**100.00**

Formula courtesy of Hershey Foods Corporation.

Please refer to text of section for procedure or recommendations.

Dulce de Leche

Ingredients	Usage Level (%)
Whole milk	37.08
Sucrose	26.68
Corn syrup, 42 D.E.	19.27
WPC34	11.12
Heavy cream	5.56
Vanilla	0.07
Sodium bicarbonate*	0.22
Total	**100.00**

Formula courtesy of the Wisconsin Center for Dairy Research.
*Increasing or decreasing sodium bicarbonate controls the color of the final product.

Procedure:

1. Pre-hydrate WPC34 in water to make a 30% solution and let sit overnight at 5°C (40°F). (Note: Excess water will be boiled away during the cooking process.)
2. Place milk and cream in a steam-jacketed kettle. Add sodium bicarbonate to this mixture. The pH of this mixture should be 6.2-6.4 to avoid precipitation of the proteins. Heat mixture to 60°C (140°F).
3. Add hydrated WPC34, sugar, and corn syrup to milk mixture.
4. Cook to 70% to 71% solids (approximately 108°C or 220°F) with constant stirring.
5. Stir in vanilla.
6. Fill containers with hot mixture, cover and cool.

Free Flowing Caramel for Layers in Candy Bars (Typical final moisture 15%)

	Usage Level (%)		
Ingredients	**Control**	**Variant I**	**Variant II**
Corn syrup	45.00	45.00	45.00
High fructose corn syrup 55	5.00	5.00	5.00
Sugar, granulated	15.00	19.40	21.60
Sweetened condensed whole milk	22.30	11.00	6.00
Sweet whey	–	–	1.40
WPC34	–	3.20	3.20
Vegetable fat	2.00	2.00	2.00
Butter oil	–	1.00	1.20
Mono- and di-glycerides	0.10	0.10	0.10
Vanillin	0.20	0.20	0.20
Salt	0.40	0.10	0.10
Water	10.00	13.00	14.20
Total	**100.00**	**100.00**	**100.00**

Formula courtesy of Hershey Foods Corporation.

Please refer to text of section for procedure or recommendations.

Dulce de Leche "Casero"

Ingredients	Formula I	Formula II
Fluid whole milk, Liters	500	1500
WPC34, Kg	150	–
Demineralized whey, Kg	–	65
Sugar, Kg	360	360
Cream, 60% fat, Kg	75	–
Glucose syrup, 84° Brix, Kg	260	260
Sodium bicarbonate, g	100	100
Vanilla extract, Liters	0.3–0.6	0.3–0.6
Product yield: 1000 Kg @ 69–70% total solids		

Formula courtesy of Hershey Foods Corporation.

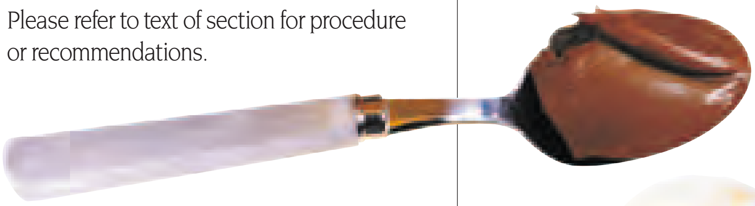
Please refer to text of section for procedure or recommendations.

Dulce de Leche for Ice Cream Use

Ingredients	Formula I
Fluid whole milk, Liters	1000
WPC34, Kg	100
Sugar, Kg	400
Cream, 60% fat, Kg	50
Glucose syrup, 84° Brix, Kg	125
Sodium bicarbonate, g	1000
Vanilla extract, Liters	0.3–0.6
Product Yield: 1000 Kg @ 70–71° Brix	

Formula courtesy of Hershey Foods Corporation.

Please refer to text of section for procedure or recommendations.



Dulce de Leche for Confectionery and Bakery Use

Ingredients	Formula I	Formula II	Formula III
Fluid whole milk, Liters	700	700	–
WPC34, Kg	75	75	110
Sweet whey, Kg	75	75	110
Water	–	–	750
Sugar, Kg	400	300	400
Cream, 60% fat, Kg	67	67	100
Glucose syrup, 82° Brix, Kg	70	–	70
HFC syrup, 42%, Kg	–	180	–
Sodium bicarbonate, g	100	100	100
Vanilla extract, Liters	0.25–0.35	0.25–0.35	0.25–0.35
Agar, Kg	1.25	1.5	1.5
Product Yield: 925 Kg @ 72–74% total solids			

Formula courtesy of Hershey Foods Corporation.

Please refer to text of section for procedure or recommendations.

Sweetened Condensed Milk Replacer

Ingredients	Usage Level (%)
Sugar	42.00
Water	28.00
Sweet whey	18.25
Vegetable fat, partially dehydrogenated	7.50
Calcium caseinate	2.50
Sodium caseinate	1.25
Lecithin	0.25
Sodium bicarbonate	0.25
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure for Non-Homogenized Blend:

1. Melt vegetable fat and lecithin to 65° to 75°C (150° to 165°F).
2. Dry blend sweet whey, caseinates and sodium bicarbonate, and slowly add to the fat mixture at 65° to 75°C (150° to 165°F) under rubbing agitation to form a uniform mixture.
3. Blend sucrose slowly into melted fat/whey-caseinate mixture, and mix until uniform.
4. Add about one third of the water with agitation, to form a thick, homogeneous paste. Continue stirring until sucrose is dissolved.
5. Slowly add the remaining water and continue stirring until mixture is smooth and creamy.
6. Store in the mixer vat at cool temperatures 15° to 18°C (60° to 65°F) until use, or transfer immediately to a confection cooker with the remainder of the candy ingredients.

Procedure for Homogenized Blend:

1. Melt vegetable fat and heat together with water and lecithin in a vat at 65° to 70°C (150° to 165°F).
2. Dry blend sucrose, whey, caseinates and sodium bicarbonate, and slowly add fat/water mixture to the dry ingredients. Agitate to completely disperse dry and wet ingredients, mixing until uniform.
3. Raise temperature of the batch to 70°C (165°F).
4. Homogenize at 70°C (165°F) in a two-stage homogenization with pressures of 141 kgf/cm^2 (2500 psi) on the first stage and 35 kgf/cm^2 (500 psi) on the second stage.
5. Cool to 15° to 18°C (60° to 65°F) and store for use.

Bakery Cream Filling

Ingredients	Usage Level (%)
Water	64.27
Sugar	8.76
Heavy cream (36% fat)	8.11
WPC34	5.33
Corn starch	5.26
Butter, melted	4.38
Egg yolk solids	2.37
Vanilla	1.05
Salt	0.47
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Blend the dry ingredients (sugar, WPC34, corn starch, salt and egg yolk solids) together in a container.
2. Add a small amount of the measured water to the dry ingredients and, using a whisk, mix until a smooth paste is formed.
3. Heat remaining water to boiling and gradually add the paste to the water, stirring constantly.
4. Continue mixing and heating over medium heat, until a thick gel-like consistency develops.
5. Remove from the heat but continue mixing while adding the cream, melted butter, and vanilla.
6. Cool to 7°C (45°F) and refrigerate until use.

Formulary edited by
KATHY NELSON
Wisconsin Center for Dairy Research, Madison, WI

13.1 AN OVERVIEW

By DR. PHILLIP S. TONG
Dairy Products Technology Center, California Polytechnic State University, San Luis Obispo, CA

The dairy industry produces a wide range of products including fermented milks, dairy based beverages, cheeses, frozen desserts, concentrated dairy products, and dry food products. Consumers have grown accustomed to expect high quality, wholesome and nutritious dairy products of good value that are available at anytime. Hence, ingredients utilized in such foods must reflect these expectations while providing the wide range of functionality that is demanded by the manufacturers of this diverse range of dairy food products.

In the United States, the dairy industry has accounted for approximately 50%-70% of the dry whey product sold for human consumption in recent years. The use of whey protein concentrates in dairy foods has also increased significantly.

Advances in the technologies used to produce whey-based dairy ingredients have enhanced their desirability for use in dairy applications. Such technologies have improved product quality and consistency while keeping their costs competitive with alternative functional ingredients. This is particularly important since whey-based ingredients have traditionally been widely used as an effective substitute for higher cost milk solids in dairy applications.

However, more recently these ingredients are being selected for use in dairy foods because they impart desirable finished product attributes. Many of the dairy ingredients produced from whey provide the kind of ingredient functionality (viscosity, gelation, water binding, solubility, sensory properties, emulsification, foaming, acid stability, bulking, etc.), microbiological quality, nutrition and availability that is demanded by dairy processors. Because the flavor profile of such ingredients is complementary to most dairy foods, whey-based ingredients can be included in most dairy foods quite easily at levels legally allowed. The ability of whey based ingredient suppliers to cater functionality of whey products for specific end-use needs has also attracted dairy foods manufacturers to utilize such ingredients.

There is emerging information on the health benefits of consuming certain compounds that are present in many whey-based dairy ingredients. Hence the utilization of these ingredients in dairy foods allows additional opportunities for marketing of additional beneficial health aspects of consuming dairy foods containing whey-based ingredients.

Finally changes in the regulatory climate for dairy foods and related products worldwide are providing new opportunities for utilization of high price/value whey-based ingredients. Such changes can provide unique product opportunities for dairy foods processors to gain market share in highly profitable product categories.

The following sections provide information on four key dairy foods categories where whey-based ingredients can help dairy foods processors produce desirable value-added foods (processed cheese, frozen desserts, fermented milks/yogurt, and standardization of dairy ingredients). Such information can serve as a useful guide on the rationale and practical approaches to using whey-based ingredients in dairy foods applications.

13.2 WHEY PRODUCTS IN COLD PACK AND PASTEURIZED PROCESSED CHEESES

By DR. STEVEN YOUNG
Steven Young Worldwide,
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Whey-based ingredients in processed cheese:

- Improve sheeting, slicing, shredding and spreading.
- Enhance melting characteristics.
- Yield superior flavor and body.
- Provide high quality proteins and calcium.
- Are cost-effective and reduce ingredient costs.

Whey and whey products have been used successfully in cold pack "club" cheese foods and spreads and pasteurized processed cheese foods/spreads for years. Sweet whey, whey protein concentrates (34%-80% protein WPC), reduced-lactose whey, demineralized whey and whey protein isolates (>90% protein, WPI) are among the most commonly used whey products.

Cost effectiveness is a key driver in using whey products in processed cheeses, since qualitative attributes such as flavor enhancement and functionality justify using optimal amounts of whey products in virtually every formula type.

Processed Cheese Products—Classifications/Types

There are two basic types of processed cheese products: cold pack and pasteurized processed products. The term "processed" is commonly associated with pasteurized (i.e., hot processed) cheese products, but it can also include cold packed or "club" cheeses. (Regulations and definitions vary from country to country. Please consult country-specific food codes for further information.)

There are several types of classifications of processed cheeses and cheese foods that reflect commercial uses and practices. Fundamental differences between these classifications are based on:

- Compositional differences
- Amount and type of cheese(s) that can be used
- Ingredients allowed
- Finished milk fat and moisture targets and allowances
- Flavor and color (i.e., cheese type) profile desired
- Nutrient content claims to be made, where allowed and applicable
- How the finished cheese is to be used (individual slices, block or loaves for shredding, spreads, sauces, fillings or pastes as industrial food ingredients)

It is important to note that regulations concerning whey and whey products in processed cheese products vary country-to-country. Whey products generally allowed for use in processed cheeses include sweet whey, reduced lactose whey, demineralized whey, acid whey, whey protein concentrates and whey protein isolates. (Classifications based on nutritional content and claims are also country-specific. Please check local product legislation.)

How to Select Whey Ingredients

Key considerations when selecting a particular type of whey product include:

- Functional properties
- Flavor impact
- Ingredient costs
- Lactose content
- Acidity

Whey Products and Functionality

Depending on the type of product to be made and its intended use, more or less whey protein functionality may be desirable. (Table 13.2.1 summarizes the function(s) of whey products in processed cheese foods and spreads.)

Melt and Body

Lower protein whey products (e.g., sweet whey) have a tendency to yield weak structure to processed cheese food loaves and increase spread during melt, a desirable feature in some applications. Whey protein concentrates (WPCs), if properly selected and applied, can yield smooth-textured and firm loaves for shredding. However, in such loaves, melt and spread might be limited due to water binding by the whey proteins. Additionally, these latter formulas which have increased viscosities while still hot, may, or may not, be compatible with the manufacture of slices or with finished packaging options. It is normally desirable to use WPCs where proteins are less denatured (low heat process treatments) and, thus, have lower impact on product viscosity and other functional traits of finished cheese.

Flavor profile

Whey products can affect finished product flavors in several ways.

- Whey ingredient flavor quality
- Sweetness
- Whey protein impact on flavor chemicals (added and/or natural)

U.S. whey products have a bland, sweet dairy flavor, compatible with many other savory flavorings used in processed cheese products.

Ingredient Costs

The most expensive ingredients in cold pack or hot processed cheese foods and spreads are natural cheese, skim milk solids and milk fat. Whey products can help to keep costs low and still allow for fine flavor, functional performance, and formula versatility (i.e., nutrient content and other labeling claims.) The choice of which whey ingredient(s) to use can be optimized to allow for these objectives to be met.

Lactose Composition

Lactose crystallization (sandiness) can occur in improperly formulated cold pack and hot processed cheese foods and spreads. Lactose's ability to crystallize and form hard sand-like crystals can be controlled by limiting the concentration of lactose in the aqueous phase of products to be <16% (~<7.5% as is basis).

Lactose can participate in Maillard non-enzymatic browning during manufacture and during distribution of finished processed cheese products. This reaction can affect both color (darkening) and flavor (caramel, cooked, burnt type flavors). Therefore, keeping lactose concentrations under control is critical. Lactose-reduced whey products such as reduced-lactose whey, whey protein concentrate, and whey protein isolate help minimize lactose crystallization and non-enzymatic Maillard-type browning.

Acidity

Acidifying agents are allowed and used in both cold pack and hot processed cheese foods and spreads. Too much acid, or acid added improperly during processed cheese manufacture can cause coarse, gritty mouthfeel from precipitated casein. This is why acidity in many processed cheese foods and spreads is limited to pH's >4.5-5.0. Acidity comes from both added acids and dairy ingredients including whey, and it must be controlled appropriately.

Impact of Whey Ingredients on the Manufacture of Processed Cheese

Addition of Optional Ingredients (including flavorings)

Optional ingredients can be added at the same time as comminuted cheese. When adding whey ingredients care must be taken to minimize lumping. Whey ingredients may need to be added to available process water to allow hydration during mixing and cooking. This can be accomplished by pre-blending whey ingredients into a slurry including all, or part, of the added water. This is most critical in higher protein, higher viscosity whey ingredients. Flavors, acidifying agents, and colors may be added last to insure proper incorporation and reduce flavor loss through the cooking process.

Solubility

Fresh whey products (i.e., proteins) are highly soluble across a wide pH range and stable to added acid. This helps create creamy, smooth, non-gritty textures with little or no powder taste.

Emulsification

Whey proteins are very efficient emulsifiers of fat and oil in aqueous food systems. They form stable emulsions easily and can be used to replace chemical emulsifiers in certain systems. Additionally, the bound fat in whey products is relatively high in phospholipids (e.g., lecithin) adding to the emulsification capacity of whey ingredients. Stable emulsions are highly desirable during grinding, cooking, packaging, and cooling of the cheese mass.

Water Binding

Whey proteins also bind high amounts of water through physical and chemical means. This tends to increase mix viscosity. The precise nature of this viscosity increase can be used to specifically manage final mix viscosity. Because of the water binding properties of whey proteins, melt, stretch, spread, and smoothness of finished processed cheeses can be negatively impacted. Thus, low heat-treated whey ingredients are normally desirable for most processed cheese applications.

Bulking Agent

Whey ingredients can be used as low cost solids replacers (e.g., cheese, milk solids non fat, milk fat) and fat replacers.

Viscosity

Whey proteins add body (improve chew and bite) and improve texture (increase smooth/creamy; reduce grainy, coarse textures). However, whey proteins do not melt, stretch, spread, or retain finished cheese firmness as do milk caseins. This can be managed by proper selection of the type and amount of whey product used. Viscosity also impacts extrudability, sheeting, slicing, shredding, and packaging fill.

Visual Appeal

Depending on the cheese blend, whey products add opacity, whiteness, and "milkiness" to mixes and finished products.

Cost Effectiveness

Much of whey product performance in processed cheeses is the ability to minimize mix ingredient costs. Significant savings can be achieved by properly selecting the right whey products. Many whey ingredients can offer these savings opportunities.

Nutrition

Whey is a great source of nutrients, including high-quality proteins, minerals and vitamins. The price-value relationship is such that there are few equivalent sources of key nutrients. Whey products contain nutrients like calcium and a variety of biologically active components. High protein, low lactose whey ingredient options (WPC80, WPI) can also be used to create cold or hot pack products with low carbohydrate or fat levels.

Table 13.2.1
Benefits of Whey Products in Processed Cheese Foods and Spreads

Functionality	General Impact	Specific Impact on Processed Cheese Products
Solubility	Smooth texture at most use levels	• Creamy texture at high use rates • Reduced gritty or "powdery" taste
Solubility at various pHs	High solubility across wide pH range	• Stable solutions to addition of acid
Water binding	Bind and entrap water	• Provide body, texture
Viscosity	Thickening	• Provide body, texture
Gelation	Form gel during heat processing	• Milk fat replacement
Emulsification	Form stable fat/oil emulsions	• Casein protein replacement • Prevent oiling off
Foaming	Form stable film	• Provide structure
Foam stability	Yield stable structure to whipped foods	• Provide stable structure
Opacity	Give opacity to low-fat foods	• Add color and appearance improvements
Flavor, aroma	Mild dairy or no flavor	• Compatible with other dairy flavors • Low flavor impact at recommended usage levels
Nutrition	Source of high quality proteins and calcium	• Excellent for enrichment and fortification purposes
Freezing point depression	Salts and lactose reduce mix freezing point	• Allows freezing point management for frozen prepared foods

Typical Usage Levels for Whey Ingredients

Typical use levels are noted below. All are dependent on the flavor and functional performance of each whey ingredient and any formula specific considerations:

- Sweet Whey 4%–8%
- Reduced Lactose Whey 5%–8%
- Whey Protein Concentrate (WPC34, WPC80) 1%–5%
- Whey Protein Isolate 0.5%–1%

Recommendations—Product and Process Modifications

When considering a whey ingredient to use, it is important to note the following:

- Balance the viscosity and flow performance of the mix with the whey ingredient of choice and finished product applications (slice, shred, spread, etc.).
- Control total lactose in formulas to minimize lactose crystallization resulting in "sandy" defects and any undesirable non-enzymatic browning (during processing and storage).
- Understand fully the process conditions (time, temperatures, etc.) being used.
- Regulatory limitations and allowances. Indirect impact of fat, moisture, and total cheese content on whey ingredient use rates.
- How the finished food is to be used, distributed, and marketed. That is, is finished food to be consumed as slice, shred, spread, flavoring, or dry powder?
- Sweet whey (including reduced-lactose whey and demineralized whey) may be the most economic whey ingredient. However, WPCs and WPIs can be effective ingredient choices to manage mix ingredient cost and finished product yields.
- When all product and process considerations are taken into account, whey products are viable and valuable ingredients for use in virtually all processed cheese and cheese food mixes.

QUESTIONS AND ANSWERS

Q. *What is the proper time and place to incorporate whey ingredients into mixes?*

A. Whey ingredients can be added with other optional dairy ingredients. To prevent lumping with products where high viscosity is expected (high protein or pre-denatured whey products), it is advisable to prepare a slurry of whey and available process water. This slurry can then be added to the cooking vessel before final cook temperatures are achieved.

Q. *Can I use the same process protocol for the manufacture of low fat or non-fat processed cheese products?*

A. Basically, yes--with considerations for other ingredients required for successful formulation. Care is necessary when incorporating microcrystalline cellulose, carrageenan, and skim milk cheese. Hydrocolloids may need to be pre-blended with other dry ingredients and pre-hydration might be required before the cheese and other ingredients are added. Cooking times and temperatures can remain the same.

Q. *The term whey flavor sometimes refers to a flavor defect. What is it?*

A. "Whey flavor"—also called "cardboard," "oxidized" or "cheesy" flavors—can originate from some whey ingredients, particularly if they have been stored under non-ideal conditions (>30°) for extended time periods (>12 months). Please consult your supplier if such a defect occurs. Sweet whey should have a mild, dairy and pleasant flavor. When properly selected, stored, and used, whey ingredients can have a wonderful pleasant dairy flavor (or no flavor) highly compatible with a variety of cheese flavors.

Q. *How can* WPC80, *which carry cost premiums to skim milk solids, be cost effective?*

A. Several factors impact the cost effectiveness of WPC80 or WPI. The key is to know that these highly functional ingredients can be used at significantly lower levels (0.5%-1.0%) than standard sweet whey (3%-4%). Secondly, when properly formulated, other more expensive ingredients (hydrocolloid stabilizers, some emulsifiers) can be totally or partially removed from formulas, thereby reducing total formula costs.

Q. *Must whey products be added pre-pasteurization?*

A. It is always desirable to add whey to mixes pre-pasteurization. This insures proper control of the microbiological quality of the finished mix. Under certain conditions, where finished product water activity is low, whey ingredients can be added during the cold process to produce cold packed cheese foods and spreads.

Q. Is *there a difference between cold and hot pack processes as it relates to whey protein functionality?*

A. Whey protein functionality is virtually left unchanged during cold pack processes. Temperatures for hot process can either adversely or positively affect whey protein functionality. Color and flavor defects can result during unusual heating and slow cooling of products.

13.3 WHEY PRODUCTS IN YOGURT AND FERMENTED DAIRY PRODUCTS

By DR. ALAN HUGUNIN
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There are many benefits resulting from the addition of selected whey products in yogurt formulations. These benefits include:

- Improved flavor
- Texture improvement
- Nutritional enrichment
- Reduced syneresis, extended shelf-life
- Prebiotic effect
- Nutraceutical benefits
- Cost-effectiveness

The U.S. dairy industry offers an ever wider range of whey products, specially designed to optimize consumer preference of yogurt products, as well as shelf-life and overall quality profile, in a cost-effective way.

Whey products offer multiple functional benefits and can help formulators replace less desirable ingredients. Their use helps processors deliver all-milk formulas with "clean" labels, an important factor for many consumers worldwide. The prebiotic functions of whey products are of critical importance to manufacturers of probiotic or nutraceutical fermented milk products.

Whey products can provide non-fat milk solids in many yogurt formulas. Whey products not only allow the processor to reduce the ingredient costs, most importantly, they also provide unique functional properties and a concentrated source of milk nutrients (highly nutritional proteins, calcium). Flavors and fruits are added to yogurts to offer products that can compete with carbonated soft drinks. Now yogurt is also recognized as a delivery medium for probiotic bacteria as well as other health-enhancing compounds. Included among these compounds are lactoferrin, and milk minerals that are being commercially concentrated in, or isolated from, whey.

Effect of Whey Fortification on Yogurt Flavor

The flavor of yogurt is the blend of the flavors created by the base compounds produced during the fermentation and added flavoring ingredients. The acidity of yogurt, produced by the lactic cultures, complements its flavor. Hydrolysis of the lactose in milk, for the lactose intolerant, can produce a slightly sweet flavor that is objectionable to some consumers. This same sweetness can improve the flavor balance of yogurt and reduce the need for added sugar in sweetened yogurt. The acidity will enhance many added flavors and it is most complimentary to fruit flavors.

Whey proteins are bland in flavor. Compared to the caseins in skim milk, they have fewer tendencies to mask added fruit flavors. More flavor can be expected in a fruit-flavored yogurt when solids from whey protein concentrate (WPC) partially replace the skim milk solids. When whey proteins are used to stabilize yogurt, and to replace starch or other thickeners, additional improvement in flavor can result.

The soluble salt concentration of whey has been linked to off-flavors when sweet whey is added to yogurt. The salt concentration of whey can be reduced by electrodialysis or ion exchange to produce demineralized whey. Soluble salts and lactose can also be separated and WPC produced by ultrafiltration. Furthermore, the inhibition of the fermentation process that may occur when whey solids partially replace skim milk solids in a yogurt base is not seen when either demineralized whey or WPC is utilized instead. Yogurt with excellent flavor is produced with either demineralized whey or WPC. The concentration of lactic acid, acetaldehyde and diacetyl (compounds associated with good yogurt flavor) are equal or greater in yogurt samples in which WPC partially replace the skim milk solids.

Substituting whey powder (sweet whey) for skim milk solids in yogurt mixes can result in a lower quality product if not done properly. Comparative tests show that the pH value of the yogurt is consistently higher and the titratable acidity (TA) is consistently lower when sweet whey replaces 25% and 50% of the skim milk solids in a yogurt base. The lower protein content (skim milk solids have more that two and one-half times as much protein as sweet whey powder) and the lower buffer capacity of the whey proteins compared to the casein in the skim milk solids may enhance the differences in TA. However, an improved product can be produced by hydrolyzing the lactose in the yogurt mix with added lactase enzyme. Hydrolysis of the lactose increases the available monosaccharides, accelerates the fermentation, and results in yogurt with lower pH and a correspondingly higher TA. For this reason, most formulators prefer to use higher-protein whey protein concentrates in high quality products.

When Bifidobacterium bifidum is added to the standard yogurt culture (S*treptococcus salavarius subs. thermophilus and* L*actobacillus del bruechii ssp. bulgaricus*), the viable count of B. bifidum is significantly higher in the samples fortified with sweet whey and whey protein. Whereas addition of B. bifidum can significantly reduce the concentration of diacetyl and acetaldehyde in the skim milk fortified yogurt, the yogurt with B. bifidum and fortified with the whey protein has slightly higher diacetyl and nearly as high acetaldehyde concentrations as the control. Higher acetaldehyde concentrations in yogurt produced with whey proteins may result from the higher concentrations of non-protein nitrogenous compounds in whey and lower protein WPC.

If the salt content of the WPC is significantly reduced, such as occurs when 80% protein WPC (WPC80) is produced by ultrafiltration, the buffer capacity of the yogurt may be reduced. The addition of phosphates will restore the buffer capacity and the TA of yogurt formulated with WPC80. The added phosphates can also increase the viscosity of the yogurt, most likely a result of their effect on calcium ions. Alternatively, citric acid can be added to the fermented yogurt to establish the desired titratable acidity and acid flavor.

Effect of Whey Fortification on Yogurt Texture

The appearance and texture of yogurt are dependent upon numerous factors: total solids, protein content, type of protein, and the type and concentration of any thickeners or stabilizers that are added. Researchers have studied the effect of treatment temperature and skim milk replacement with demineralized whey, and reported that instrumental consistency of the yogurt increased as (1) the process temperature increased (from 85°C to 95°C, with five-minute hold) and (2) the concentration of demineralized whey decreased. However, researchers also report that it is possible to match the consistency of commercial yogurts using a mix that contains 12.5% milk solids (with 1.5/5-3.0% of the solids provided by demineralized whey) if the mix is heated and held at 91°C for five minutes.

When milk is fortified with WPC and heat-treated, fine protein floccules are observed. When casein, skim milk powder, or milk protein concentrates are added, no floccules are observed. When milk is heated, Beta-lactoglobulin is denatured and reacts with k-casein to form an insoluble complex. When milk is fortified with WPC, the concentration of Beta-lactoglobulin greatly exceeds the concentration of k-casein. As a result other protein complexes, such as Beta-lactoglobulin and Alpha-lactalbumin complexes will form. In yogurts fortified with WPC, it is the Beta-lactoglobulin and Alpha-lactalbumin complex, rather than the casein complex that probably stabilizes the yogurt, resulting in different consistency. Fortification of milk for yogurt with WPC results in yogurt with better texture and consistency. Yogurts fortified with casein or skim milk protein often have a firmer gel, but yogurts fortified with WPC tend to be smoother and to have better appearance.

One of the most significant benefits of WPC is its effect on separation or syneresis during storage of yogurt (shelf life). When properly heat-treated, yogurts fortified with WPC have higher viscosity and better water-holding properties. Data in the following table was generated for yogurts produced with milk, milk fortified with 2% skim milk powder and milk fortified with 2% WPC34.

Table 13.3.1
Effect on Viscosity and Syneresis of Fortification with WPC34 and Skim Milk Powder

	Consistency (Apparent Viscosity) (Centipoise)	Syneresis (ml)*
Control	57.5	22
Fortification with 2% SMP	94.5	17
Fortification with 2% WPC34	117.0	7

*Reduced syneresis ("water separation") is a desirable consumer attribute.
Source: Proliant, Inc.
Data reproduced with permission from the authors (contact USDEC for further information).

Table 13.3.2
Effect of WPC80 Addition on Yogurt Viscosity

	Control	WPC80 with Enhanced Gelling Properties	WPC80
Skim milk	95.25%	97.26%	97.26%
Skim milk powder	3.08%	–	–
WPC80	–	1.44%	1.44%
Starch	1.30%	1.30%	1.30%
Gelatin	0.37%	–	–
Skim milk protein	4.19%	3.21%	3.21%
Whey protein	–	1.15%	1.15%
Set viscosity	60,200 cps	76,000 cps	70,700 cps
Stirred viscosity	8,900 cps	8,800 cps	8,000 cps

Source: Proliant, Inc.
Data reproduced with permission from the authors (contact USDEC for further information).

Reports indicate that syneresis is cut in half when milk for yogurt is fortified with 4% WPC compared to 4% skim milk powder. The higher protein whey protein concentrates (≥80% protein: WPC80) also provide textural benefits in yogurt. These functional protein products include products that are processed to enhance gel-forming properties. Some differences are seen in the textures of yogurts prepared with different WPC80, however they are generally less than might be anticipated. The above table shows the results of a study to partially replace skim milk solids and totally replace gelatin in a stirred yogurt with two types of WPC80.

Developing the viscosity needed to suspend fruit pieces, developing the smooth creamy texture, preventing the separation and syneresis that occur during storage and distribution are all possible with a milk system that includes whey protein concentrates and milk.

Whey Products in Yogurt and Acidified Protein Beverages

Viscosity, age, thickening and separation problems are enhanced in lower viscosity beverage products. The protein floccules that result when the ratio of whey proteins to caseins is increased in the yogurt base can precipitate if the viscosity is reduced. Using high shear to reduce the size of the floccules and blending high-methoxyl pectin into the fermented yogurt helps control separation and sedimentation.

Whereas undenatured whey proteins have an advantage over caseins with regards to solubility at low pH, the combination of acid and heat can cause precipitation of whey proteins. Heat stability of whey proteins is lowest in the pH 3.5-5.5 range. Acidification of whey protein drinks to pH 3.5 reduces the tendency of protein precipitation during post-fermentation pasteurization or sterilization. Yet, some thickening and sedimentation has been reported in a UHT-processed long shelf-life whey protein and fruit juice beverage acidified to pH 3.65 before sterilization and packaging. U.S. processors now offer whey products specially formulated to withstand high temperature treatments.

Effect of Whey Products on Yogurt Fermentation and Probiotic Cultures

Most researchers have determined that fortification or partial replacement of skim milk solids with solids of ultrafiltered WPC has no effect on yogurt fermentation as indicated by pH, TA or number of bacteria. Mineral salts and other compounds that can inhibit the cultures pass through the membrane and are separated from the whey proteins. Others have reported that ultrafiltered WPC can positively stimulate the rate of fermentation and the growth of L. *acidophilus*.

About 20% to 30% of the lactose in the yogurt base is broken down to glucose and galactose, and the glucose is converted to lactic acid during yogurt fermentation. Bacterial enzymes can help breakdown the remaining lactose in the intestinal tract. However, gastric acids in the stomach can destroy probiotic culture organisms and the bacterial Beta-galactosidase enzymes that breakdown the lactose. The ease by which the acids are neutralized in the duodenum will also influence the bacterial enzyme activity and the utilization of the lactose.

Researchers have determined that the type of cultures and the lactic acid, total solids, protein and salt (phosphates, citrates, lactates) content of the yogurt base affect the buffer capacity of the yogurt. Fortification of the yogurt base with WPC, compared to fortification with skim milk powder, results in a high buffer capacity at low pH and a lower buffer capacity at high pH. Thus, fortification of yogurt with WPC will:
a) minimize destruction of the probiotic cultures and lactase enzyme in the stomach and b) enhance the enzyme activity in the intestinal tract.

Using Whey Fractions and Minerals for Nutraceutical Benefits

There is increasing evidence that some of the therapeutic benefits of yogurt cultures may be linked to the proteins. Bioactive peptides, produced during fermentation, are effective in decreasing cell proliferation in a cell culture model system. When the proteins were separated and fermented, Alpha-lactalbumin inhibited cell division, but Beta-casein did not. The effect is a hypothesized explanation for the association between the reduced incidence of colon cancer and yogurt consumption.

Another study compared the effect of diets with soybean protein, casein and whey proteins on blood cholesterol levels of rats. The reported results were a three times increase over the pretreatment level in the group fed the casein diet, a two fold increase in the group fed the soy protein diet and a 30% reduction in the group fed the whey protein diet. A substantially elevated rate of cholesterol excretion was observed when rats on high fat diets were fed whey proteins. Suppressed cholesterol synthesis was observed when rats on fat-free diets were fed whey proteins.

Lactoferrin, a milk protein that is now being commercially isolated from whey, has been identified as one of the most interesting nutraceutical food ingredients. It is reported to stimulate intestinal cell growth and growth of bifidobacteria. Lactoferrin is also a selective antimicrobial agent. Through its ability to chelate free iron, it controls the organisms that needs iron for growth. It can be converted by digestive proteases to lactoferricin, a peptide that is active against Gram negative bacteria and yeast. The iron binding ability and the ability to transport iron are other recognized benefits of lactoferrin.

Table 13.3.3
Effect of 40% Replacement of Skim Milk Protein by Whey Proteins in a Yogurt Beverage

Formula	Control	Test A	Test B	Test C
Skim milk powder, %	10.40	6.24	6.24	6.24
WPC80 (gelling type), %	–	1.88	–	–
WPC80, %	–	–	1.92	–
WPC34, %	–	–	–	4.16
Lactose, %	–	2.28	2.24	–
Water, %	89.60	89.60	89.60	89.60
Viscosity				
Freshly sheared (cps)	82	758	315	22
After 24 hours (cps)	95	1,982	845	30
Sensory Scores				
Thickness	3.4	7.0	0=thin to 10=thick	
Chalkiness	3.8	3.8	0=not chalky to 10=very chalky	
Flavor	5.3	6.8	0=poor to 10=good	

Source: Proliant, Inc.
Data reproduced with permission from the authors (contact USDEC for further information).

High mineral content will inhibit yogurt culture activity. However, the milk mineral concentrates that are being processed from whey are another potential ingredient for yogurts. These products, that typically contain 20%-25% calcium, can be used to enhance the calcium content of foods, and the viscosity of yogurt lends itself to minimizing any sedimentation of the mineral salts. However, the concentration of the monovalent salts (sodium, potassium and chlorides), protein and non-protein nitrogenous compounds can vary depending upon the process used for manufacture. Levels of addition need to be controlled to avoid flavor impact, and viscosity of the yogurt must be adequate to suspend any insoluble salts.

For those concerned about calorie consumption, researchers reported that panelists initially preferred yogurt fortified to a higher protein content with whey protein concentrates. However, after consuming equal calorie servings of low protein and high protein yogurt, panelists' hunger was significantly less (indicated by significantly lower liking rating) after consuming the high protein product.

QUESTIONS AND ANSWERS

Q. *How can whey products help yogurt processors meet consumer expectations?*

A. Many of the nutrients and bioactive compounds in milk are separated with the whey during cheesemaking. New processing technologies enable whey processors to modify, fractionate and concentrate these into highly nutritious and/or functional ingredients.

Q. *Which whey products are used as ingredients in yogurt?*

A. Whey protein concentrates are successfully used in yogurt production. New commercially available whey products with potential application in yogurt include lactoferrin and milk protein concentrates.

Q. *How are whey protein concentrates used?*

A. They fortify the protein content in the yogurt milk and/or practically replace skim milk protein in the milk. Replacing 15%-35% of the skim milk protein with 0.75%-2% whey protein is common. The high protein whey products, such as WPC, are also added to replace stabilizers.

Q. *Which process changes are required when producing yogurt with whey protein concentrates?*

A. The functional benefits of whey proteins result from protein-protein interactions. These interactions are initiated during the preheating and pasteurizing of the yogurt, before fermentation. Pasteurization temperatures of 85-90°C, with hold times of 5-30 minutes are common in yogurt production. These are generally appropriate for formulas with added whey protein concentrates. If textural problems occur, try adjusting the temperature and minimize the free calcium ions in the mix.

Q. *Are there other benefits of adding whey protein concentrates to yogurt?*

A. Laboratory studies suggest improved buffer capacity for probiotic cultures and Beta-galactosidase activity in the intestine. Peptides produced from whey proteins may help control proliferation of tumor cells in the colon and whey proteins may help reduce blood cholesterol levels.

Q. *How is milk calcium concentrate or milk minerals used?*

A. Several whey products can be used as a source of natural, highly bioavailable calcium. Because high calcium and salt concentrations can affect protein-protein interactions and activity of cultures, it is recommended to mix these products in the yogurt after fermentation.

Q. *Can lactoferrin be used in yogurt?*

A. Lactoferrin is a milk protein that is present at comparatively high concentrations in early human milk and at lower levels in cow's milk. It is identified with improved iron transport, stimulation of bifidobacteria, stimulated growth of intestinal cells and antimicrobial activities against pathogenic bacteria. It should be added after pasteurization and fermentation of yogurt.

13.4 WHEY PRODUCTS IN ICE CREAM AND FROZEN DESSERTS

By DR. STEVEN YOUNG
Steven Young Worldwide, Houston, TX

Whey and whey products have been used successfully in ice cream and other frozen dairy desserts for years. Sweet whey, whey protein concentrates (34-80% protein), and whey protein isolates (>90% protein) are among the most commonly used whey products. Delactosed and demineralized whey can also be used. Cost efficiency and quality improvement are key drivers in using whey products. The nutritional value of whey products is also an important reason why an increasing number of manufacturers worldwide include U.S. whey products in their formulations.

Individual national regulations, or limitations, on the use of whey need to be considered. Manufacturers should check local legislation for maximum amounts of specific ingredients allowed in their frozen dessert formulations.

The use of judicious amounts of the appropriately selected whey product(s) typically results in superior finished product quality—flavor, body, texture, and freeze/thaw stability while improving the nutritional content at reduced ingredient costs.

A Range of Functional Ingredients

The U.S. whey products most often used in frozen desserts include:

- Sweet Whey
- Reduced Lactose Whey
- Demineralized Whey
- Acid Whey (acid flavored sherbet, sorbet only)
- Whey Protein Concentrate (WPC 34% protein: WPC34)
- Whey Protein Concentrate (WPC 50% protein: WPC50)
- Whey Protein Concentrate (WPC 80% protein: WPC80)
- Whey Protein Isolate (90% protein: WPI)
- Other customized products, ready-to-use blends and calcium-rich whey-based products

Functional Benefits of Whey in Ice Cream and Related Products

Emulsification

Whey proteins are very efficient emulsifiers of fat and oil. They easily form stable emulsions and can be used to totally or partially replace chemical emulsifiers in frozen dairy desserts. Additionally, the "bound" fat in whey products is relatively high in phospholipids (e.g., lecithin) adding to the emulsification capacity of whey ingredients.

Water Binding

Whey proteins bind high amounts of water through physical and chemical means. This tends to increase mix viscosity but also aids in achieving finished goods freeze/thaw stability by limiting water-ice-water movement.

Bulking Agent

In some formulations, whey ingredients can be used as low cost solids replacers and replacers of removed functionality (e.g., fat replacement in low-fat frozen desserts).

Whipping/Foaming

The whipability and foaming function of whey proteins adds to desirable performance during freezing and enhances air incorporation.

Viscosity

Whey proteins add body to frozen desserts and have been shown to improve chew and bite. Texture improvements can be achieved through the addition of whey proteins—the mouthfeel of frozen desserts tends to be smoother, more creamy, and icy or "coarse" textural problems minimized.

Visual Appeal

Depending on the mix type, whey products can add opacity, whiteness, and "milkiness" to mixes and finished products.

Freezing Point Management

Whey, lactose and mineral salts can be taken into account to manage water-to-ice freezing performance. This, in turn, affects freezing conditions, mix performance and finished product qualities such as body (chew, bite) and texture (smoothness). Whey proteins play a key role in managing ice crystal growth during heat shock and other distribution abuses. Superior freeze-thaw stability can be achieved through the use of whey proteins.

Flavor

Fresh whey products have a sweet/dairy flavor (sweet whey) with virtually no perceivable flavor profile of their own (whey protein concentrates and isolates). Using high levels of sweet whey may, in some formulations, result in too strong a whey flavor in the finished product. However, when organic acids (e.g., citric, malic, lactic) and fruit flavors are used as in some ice creams, most sherbets and sorbets, many typical "whey" flavors are eliminated. Formulators can balance levels of whey product addition as a function of overall flavor optimization.

Impact on Added Flavors to Finished Product Flavor

High molecular weight proteins such as whey proteins can absorb various chemical components of added flavors such as vanilla extract and reduce perceived vanilla flavor. The higher the whey protein content, the more impact on added flavorings. This effect can occur with other proteins and formulators need to optimize their formulations in terms of protein/flavorings addition.

Cost Effectiveness

An important factor in the use of whey products in ice cream and other frozen dairy desserts is the ability to manage or reduce mix ingredient costs. By properly selecting the best whey product, significant savings can be achieved. When formulation is done correctly, whey ingredients can offer cost savings opportunities.

Nutrition

Whey is a great "nutrient buy." The price-value relationship is such that there are few equivalent sources of key nutrients such as high quality protein, calcium and a variety of health-enhancing components such as whey fractions. Indirect impact on the nutrient content of mixes such as in "reduced" or "low" fat products also adds value.

13.4.1
Functionality and Benefits of Whey Products in Frozen Dairy Desserts

Function	General Impact	Specific Benefit in Frozen Dairy Desserts
Solubility	• Smooth texture at most use levels • Soluble over wide pH range	• Creamy texture at high use rate • Reduced "gritty," "powdery" taste • Remains soluble in acidic mixes, including cultured systems (frozen yogurt)
Water binding	• Binds and entraps water	• Provides body, texture • Inhibits ice crystal formation and growth
Viscosity	• Thickening effect	• Improves body and texture
Gelation	• Forms gels during heat processing	• Can function as milk fat replacer in low-fat and fat-free frozen desserts
Emulsification	• Forms stable emulsions	• Can replace casein protein • Prevent oiling off
Foaming	• Forms stable film • Yields stability to whipped systems	• Provides structure
Opacity	• Improves visual appeal	• Adds appeal to low-fat, fat-free foods by providing opacity
Flavor and aroma	• Bland, sweet dairy flavor	• Highly compatible with sweet dairy flavors
Nutritional profile	• Good amino-acid profile • Prebiotic functions	• Provides protein, calcium in nutritional products • Helps support growth of Bifidobacteria
Freezing point depression	• CHOs and salts reduce freezing point	• Facilitates freezing point management • Soft serve applications

Formulating with Whey Products

Care is necessary to manage protein (amount and functionality), lactose, and salts to insure proper freezing performance and eliminate potential for "sandiness" defects.

Typical starting formulas for full fat ice cream, fat modified ("reduced fat," "low fat" and "fat free") ice creams, and sugar modified ("no sugar added") ice creams using sweet whey, whey protein concentrates and whey protein isolates are presented in the dairy formulations section.

Manufacturing of Frozen Dairy Desserts with Whey Ingredients — Impact of Whey Ingredients on Specific Manufacturing Steps

Assembly of Ingredients, Mix Preparation

Whey products are added with other liquid and dry ingredients to each individual mix. Whey products must be added to the mix prior to pasteurization to assure the microbiological quality and safety of the finished mix. Whey and whey ingredients are always added during the assembly of mix ingredients. Dry whey should be added under high shear to the totality of liquid ingredients (water, milk, skim milk, cream, liquid sugar, sweeteners) to prevent lumping and pre-gelation. Under these conditions, it is not necessary to pre-blend whey with other dry ingredients to aid dispersion. Under less than high shear conditions (normally for small batch sizes), amounts of whey and whey products can be added via simple pre-blending with other dry ingredients (such as sugar) to improve dispersion or through a "powder funnel" with recirculation through the funnel pump and batch tank. In either high or low shear preparation, care is necessary to prevent excess foaming (air incorporation) in the mix. Foaming is not just due to all protein containing ingredients (cream, skim, milk, egg solids, etc.). The more protein and less fat in any given mix the increased potential for foaming. Foaming leads to low yields, increased costs, inefficient pasteurization and homogenization, poor freezer performance and other undesirable effects. Foaming is easily controlled through properly engineered mix preparation systems.

Pasteurization (Batch or Continuous)

Pasteurization can potentially impact whey product functionality in finished mixes. This is dependent on the specific mix, composition, whey ingredient(s) used, and the exact times and temperatures applied during pasteurization. Typical pasteurization conditions for frozen desserts do not impact whey product functionality.

Homogenization

Whey proteins help form a stable emulsion at the fat/water interface of the mix and add stability to the serum (non-fat) phase of the mix.

Freezing (Batch or Continuous: -5° to –6°C)

The actual "draw" temperature from the freezer is dependent on mix composition and functionality. Thus, inclusion of whey products can impact the "draw" temperature and the "draw" viscosity (weak and "wet" versus stiff and "dry"). Weak viscosity may be adequate for molded novelties, but unacceptable for extruded novelties or packaged ice cream. Additionally, whey and whey ingredients can help in the freezing of many small ice crystals that impact the eating quality of the finished dessert.

Distribution (<-28°C)

Temperatures will fluctuate with specific conditions and hardware used in the distribution chain. Whey and whey products can offer significant benefits and increase stability by managing the transition of ice-to-water-to-ice during freeze/thaw abuse. This helps maintain the body (bite, chew) and texture (smoothness, creaminess) of the frozen dessert.

Considerations When Using Whey in Frozen Desserts

Selection of the exact amount and type of whey ingredient to use is based on the following considerations. The following aspects should be considered:

1. Final Use of the Mix

- Retail packs (Two-liter, 1 liter, 1/2 liter, etc, for home consumption, where significant freeze/thaw stability is necessary due to distribution abuse. WPC at 34% or more protein can add significant freeze/thaw stability when distribution abuse is a potential concern.)
- Bulk packages (Ten liter packs or larger for food service, where repeated dipping and sampling can physically punish the finished frozen dessert. Again, a protein enhanced whey product (WPC or WPI) can add physical strength to the finished frozen dessert.)
- Novelties (Direct fill- this is the direct filling of cups, cones, and "push-ups." Because the ultimate shape of the product is determined by the package, the frozen dessert must be able to flow into the package before final hardening, this concern is given to mix composition, viscosity, and processing. Sweet whey is a normal ingredient selection for these direct filled novelty applications.)
- Extruded (These are novelty items that are extruded through shaped orifices and cut to the proper size. The frozen dessert needs to be flowable, yet stiff enough to extrude and hold a shape. Both WPC and WPI offer significant functionality to withstand the physical treatment an extruded piece must undergo during manufacturing.)
- Molded (Normally, very fluid frozen mix is deposited into molds, which, in turn, are frozen to create the molded form. Frozen dessert mixes need to be created to withstand air incorporation and freezing, yet allow flow, rapid hardening (to hold inserted stick, if desired), surface thaw to release items from the molds, and secondary treatments (liquid or dry applications). Again, sweet whey (or demineralized whey) is typically used.

2. Amount and Type of Mix Ingredients Available

- *Lactose Content*
  An important factor is the total lactose content of the mix. To minimize lactose crystallization (also know as "sandiness" in frozen dairy desserts), it is advisable to reduce the lactose content of mixes to below 7.5%. This simple recommendation can help prevent sandy defects in ice cream. The contribution of lactose from all dairy ingredients must be known, calculated, and controlled.
- *Sweetness*
  Whey, particularly sweet whey, adds some degree of sweetness to the mix. Depending on mix specifics, it may be possible to reduce sweetness using whey for improved consumer acceptability.
- *Bulking Agents, Stabilizers and Emulsifiers*
  Whey proteins can interact with several large molecular weight bulking agents (starches, hydrocolloids) to add or detract from the performance of a given mix. Thus, care is necessary when adding WPCs (34-80% protein) to specialty mixes with relatively large amounts of "bulking agents." Whereas there is very little interaction between components of whey ingredients and added chemical emulsifiers, there can be significant interaction between components of whey and stabilizer gums (e.g., free calcium and low methoxyl pectin).

3. Processing Conditions

Typically, pasteurization conditions (other than 83°C, 30 minutes or equivalent) impact very little on whey protein functionality in mixes. However, if aggressive (high temperature, long time) pasteurization is considered, then whey protein functionality can be affected, depending on the processing of the specific whey ingredient.

Whey products, particularly WPCs (60-80%) and WPIs (90% protein), become more hydrated during aging and can significantly effect mix viscosity and mix performance.

Modern continuous hardening systems maximize the use of whey products by quickly freezing the remaining free water as ice. This allows use of either maximum allowable sweet whey or reducing the amount of WPC or WPI needed for any given purpose. If thermal abuse during distribution is expected, selecting a proper whey protein product can add significant freeze/thaw stability.

Whey products offer significant mix ingredient and yield improvement cost savings. Whey products play a significant role in reducing ingredient costs and improving finished product yields (see Tables 13.4.2 and 13.4.3).

Table 13.4.2
Sweet Whey Addition in Standard Ice Cream (10% milk fat): Cost-effectiveness Demonstration (Sample calculations*)

	Control Formulation			Formulation with 2.5% Sweet Whey		
Ingredients	**% Dry Basis**	**Cost Per Lb.****	**Cost Per Cwt Mix**	**% Dry Basis**	**Cost Per Lb.****	**Cost Per Cwt Mix**
Milk solids nonfat	10.00	$ 1.10	$ 11.000	7.25	$ 1.10	$ 7.975
Sweet whey				2.50	$ 0.25	$ 0.625
Milk fat	10.00	$ 3.00	$ 30.000	10.00	$ 3.00	$ 30.000
Sugar	12.00	$ 0.30	$ 3.600	12.00	$ 0.30	$ 3.600
Corn syrup 36 D.E.	5.00	$ 0.13	$ 0.625	5.00	$ 0.13	$ 0.625
Emulsifiers and stabilizers	0.30	$ 2.00	$ 0.600	0.30	$ 2.00	$ 0.600
Total solids	37.30			37.05		
Ingredient costs			$ 45.825			$ 43.425
$/kg of mix			$ 1.107			$ 1.063
$/liter of finished ice cream			$ 0.542			$ 0.514
Savings						**5.3%**

*All calculations are for demonstration purposes only. Prices for specific ingredients will vary in different locations and situations.
**1lb = 0.453kg.
Source: Steven Young Worldwide, Houston, TX.

Table 13.4.3
Whey Protein Concentrate 80% (WPC80)
Addition in Premium Ice Cream: Cost-effectiveness Demonstration (Sample calculations*)

	Control Formulation			Formulation with 2.5% Sweet Whey		
Ingredients	**% Dry Basis**	**Cost Per Lb.****	**Cost Per Cwt Mix**	**% Dry Basis**	**Cost Per Lb.****	**Cost Per Cwt Mix**
Milk solids nonfat	10.00	$ 1.10	$ 11.000	7.00	$ 1.10	$ 7.700
Sweet whey				1.50	$ 1.50	$ 2.250
Milk fat	14.00	$ 3.00	$ 42.000	12.00	$ 3.00	$ 36.000
Sugar	12.00	$ 0.30	$ 3.600	12.00	$ 0.30	$ 3.600
Corn syrup 36 D.E.	5.00	$ 0.13	$ 0.625	5.00	$ 0.13	$ 0.625
Emulsifiers and stabilizers	0.30	$ 2.00	$ 0.600	0.30	$ 2.00	$ 0.600
Total solids	41.30			37.80		
Ingredient costs			$ 57.825			$ 43.425
$/kg of mix			$ 1.421			$ 1.248
$/liter of finished ice cream			$ 0.684			$ 0.601
Savings						**12.2%**

*All calculations are for demonstration purposes only. Prices for specific ingredients will vary in different locations and situations.
**1lb = 0.453kg.
Source: Steven Young Worldwide, Houston, TX.

Summary for the Use of Whey Products in Frozen Desserts

When considering a whey ingredient to use, note the following:

- Balance the freezing performance of the mix with the whey ingredient of choice.
- Be sure to control total lactose in formulas to <7.5% of total mix to minimize lactose crystallization resulting in "sandy" ice cream.
- The functionality (including flavor) of the whey ingredient itself and its impact on added flavors should be assessed for each individual mix.
- Regulatory limitations: check local legislation for usage limits of all ingredients.
- Consider how the finished food is to be used, distributed, and marketed.
- Add dry whey to the totality of all liquid ingredients under high shear, or as a pre-blend (small batch sizes) together with high solubility dry ingredients.
- Minimize foam through a properly engineered batching system. Other process considerations can be managed through proper formulation.
- Economics: when properly formulated more than just significant savings can be achieved.
- Sweet whey may be the most economic whey ingredient. However, WPCs can be more cost-effective ingredient choices to achieve quality, consistency and desired nutritional profile. Whey protein concentrates are multi-functional ingredients, which may help reduce or displace less desirable ingredients or additives.
- When all product and process considerations are taken into account, whey products are viable and valuable ingredients for use in virtually all frozen dessert mixes.

QUESTIONS AND ANSWERS

Q. *What are "typical" recommended use rates from sweet whey, WPCs and WPIs in frozen desserts?*

A. Actual use rates are very much dependent on all the key considerations affecting frozen dessert composition and the individual functionality of the specific whey ingredient to be used. However, in general, the following initial recommendations can be considered guidelines:

Sweet Whey	2.0-3.0%
WPC–34% Protein	1.5-3.0%
WPC–60-80% Protein	0.5-2.0%
WPI–90% Protein	0.5-1.0%

Q. *Whey "flavor" is typically a defect of ice cream and other frozen desserts. Does using whey add "whey flavor" to frozen desserts?*

A. "Whey flavor" or other flavor defects called "cardboard," "oxidized" or "cheesy" flavors—can be sourced from whey ingredients, particularly sweet wheys. This defect may occur in low-quality or poorly processed ingredients. U.S. whey ingredients typically have a wonderfully pleasant dairy flavor, which is highly compatible with frozen dessert mixes.

Q. *How can WPC at 80-90% proteins, which carry cost premiums to skim milk solids, be cost effective?*

A. Several factors impact the cost effectiveness of 80-90% WPC/WPI. The key is to know that these highly functional ingredients can be used at significantly lower levels (0.50%-1.0%) than standard sweet whey (2.50%-2.75%). In addition, these highly functional ingredients can totally or partially replace other more expensive ingredients (hydrocolloid stabilizers and some emulsifiers) from formulas. Finally, because ice cream is sold by weight, as well as volume, increased yields can be achieved by producing quality product at higher overruns. Minor increases (5%-6%) in overrun (producing more finished ice cream from a given volume of mix) can return major cost reductions (10%-12%) in ingredient and process costs when premium whey products are used.

13.5 LACTOSE AND OTHER WHEY PRODUCTS IN PROTEIN STANDARDIZATION OF MILK

By DR. PHILLIP S. TONG
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What is Protein Standardization?

Protein standardization is a means to improve the consistency of the composition of dairy foods. Specifically protein standardization will improve the consistency of the absolute protein content and the protein to lactose, protein to solids nonfat and/or protein to fat ratio of milk products. Like all natural biological products, milk can vary in its composition over the course of the year. The two components of milk that vary most are fat and protein. For years, dairy processors have used centrifugal separation to standardize the fat content of milk. This has benefited consumers and processors of milk. Now, with the development and availability of various technologies and products, it is possible to standardize (adjust upwards or downwards) the protein content of milk within a very narrow range.

Why Would it be Valuable to Standardize Protein?

The key advantage of protein standardization is to improve the consistency of milk and milk product composition. Improving composition control ultimately means more reliable delivery of product quality (i.e., nutrition, functionality, sensory properties, processability).

Nutrition

Milk proteins are one of the key nutrients in dairy foods. Nutritional labeling is sufficiently lenient to allow for normal biological variations in milk protein content in non-protein fortified dairy foods. Nevertheless, by using protein standardization, dairy and food processors can insure that consumers of dairy foods and ingredients get a more consistent amount of milk protein per serving.

Ingredient Performance

Milk proteins increasingly serve as key functional components of dairy ingredients for food formulations. The milk proteins contribute to emulsification, gelation, viscosity control, water binding, aeration, etc. For example, a low protein content skim milk powder used to fortify milk for yogurt manufacture would result in a weaker gel. On the other hand, too high a protein content in dairy ingredients used for manufacture of condensed/evaporated milk products could result in excessive finished product viscosity and increased susceptibility to age gelation. In addition, milk proteins contribute to the sensory properties (texture, flavor, appearance) of a food. Hence, providing dairy ingredients with a more constant milk protein content will help to insure that the dairy ingredients will perform consistently in food formulations.

Because protein content varies, absolute lactose levels will go up or down also to meet final total solids targets in finished products (meet target moisture). Changing lactose content may also impact on functionality. Lactose can effect freezing point depression and perceived sweetness. Hence, standardization will not only improve protein consistency but also consistency of lactose content and ideally set the protein to lactose ratio in the final product as a constant.

Economics

The economic value of the protein content of the milk supply continues to increase. Hence, protein standardization (downwards) can be utilized to insure that this high cost milk component is maximized in the production of dairy foods and ingredients. In addition, lower cost dairy components (e.g., permeate and lactose) would be utilized for standardization of higher value products/ingredients. Such improvements in the utilization of milk components should maximize product/ingredient quality and efficiency of conversion of raw materials (milk) to value added dairy products/ingredients, which should benefit ingredient manufacturers and ingredient end-users.

How Do We Technologically Achieve Protein Standardization?

A few general guidelines for protein standardization should be followed:

1. Protein standardization techniques should not significantly alter the natural ratio of whey proteins to caseins in the dairy product or dairy ingredient.
2. Protein standardization must be consistent with regulatory guidelines for the dairy food, dairy ingredients, and/or finished food products in the market of interest.

For marketing of products containing a standard of identity (in the U.S.) or any other type of definition (other countries), standardization and the methods of standardization must comply with the U.S. Code of Federal Regulations, or local regulations. In addition, in the U.S. many plants maintain USDA grade A status and are required to comply with the USDA Inspection Guidelines for Dairy Plants.

Currently in the U.S., standards for most dairy products do not specify a minimum protein content, and do not contain provisions for protein standardization. However, standards for dairy products for international trade follow Codex Alimentarius. Codex Alimentarius Section 206 recognizes that "milk" can be protein adjusted. Further, Codex Standard 207 recognizes a minimum of 34% protein in solids nonfat for skim milk powder and specifies that retentate (from ultrafiltration of milk or skim milk), permeate (from ultrafiltration of milk or skim milk) and lactose can be utilized for standardization purposes. It also states that the normal ratio of casein to whey protein for that milk supply must not be altered by the standardization process.

Case 1. Target desired protein content of the finished product/ingredient is higher than the protein content of the finished product if the starting material is not standardized (i.e., need to standardize upwards). In this case, retentate from the ultrafiltration of milk can be added to the original milk, concentrate, or finished product to increase the protein to lactose ratio and achieve the target protein content in the finished product.

Case 2. Target desired protein content of the finished product/ingredient is lower than the protein content of the finished product if the starting material is not standardized (i.e., need to standardize downwards). In this case, allowable ingredients (e.g. lactose, permeate) are added to the original milk, concentrate and/or finished product to lower the protein to lactose ratio and achieve target protein content in the finished product. Standardization in the more dilute fluid milk prior to concentration and drying insures product uniformity.

Other Considerations

- Depending on the method of standardization, the amount of non-protein nitrogen components (NPN, nitrogen fraction soluble in 12% Trichloroacetic acid) may vary. NPN contains urea, small peptides, free amino acids and other low molecular weight nitrogenous components, which may or may not effect the nutritional and functional properties of foods. In addition, variation in NPN may be important if protein determination (and/or calibration of infra-red milk analyzers) are based on total nitrogen analysis.
- In order to confirm that the ratio of whey to casein in standardized milks are being maintained after protein standardization, it will be important to develop baseline information on the current whey to casein ratio in milk supplies.
- Some minerals are present in permeate which may or may not be present in lactose. These minerals can influence ingredient functionality and stability and potential interactions in food formulations.
- Standardization can be accomplished by addition or removal of milk constituents in the milk, concentrate or finished dried product. However, protein standardization may be preferable in liquids to insure optimal uniformity during drying. For nonfat dry milk powder, standardization of milk prior to fat removal could alter the composition of cream. Reconstitutions of lactose or dry permeate solids prior to addition to skim milk or skim milk concentrate will improve product uniformity.

Summary

Today's technology can allow for protein standardization of dairy products and ingredients to insure more consistent product quality and nutrition. The full use of the technology can result in a wider range of products with different protein to lactose ratio and more tailored functionality.

References

Codex Standard 206–Codex General Standard for the Use of Dairy Terms, FAO/WHO Food Standards, Codex Alimentarius, 1999.

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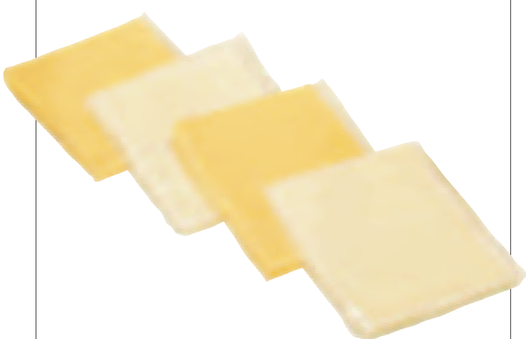
13.6 DAIRY FORMULATIONS



Typical Processed Cheese Food Formulations with Whey Ingredients

Ingredients	Formula using Usage Level (%) Sweet Whey	Reduced-lactose Whey	WPC34 and Sweet Whey	WPI and Reduced-lactose Whey
Full fat Cheddar cheese	67.00	66.00	65.00	65.00
Disodium phosphate	1.80	1.80	1.80	1.80
Trisodium phosphate	0.54	0.54	0.54	0.54
Salt	0.50	0.50	0.50	0.50
Skim milk powder	7.63	7.63	4.63	4.10
Sweet whey	4.50	–	5.50	–
Reduced-lactose whey	–	5.50	–	7.50
WPC34	–	–	4.00	–
WPI	–	–	–	1.50
Cream, 40% fat	2.00	2.00	2.00	2.00
Water	4.00	4.00	4.00	5.03
Water as steam	8.00	8.00	8.00	8.00
Lactic acid, 20%	4.00	4.00	4.00	4.00
Color	0.03	0.03	0.03	0.03
Total	**100.00**	**100.00**	**100.00**	**100.00**

Formula courtesy of Steven Young Worldwide.

Please refer to text for procedure or recommendations.

Reduced-fat (50%) Processed Cheese Food Formulations with Whey Ingredients

Ingredients	Formula using Usage Level (%) Sweet Whey	Reduced-lactose Whey	WPC34 and Reduced-lactose Whey	WPI and Sweet Whey
Full fat Cheddar cheese*	35.00	35.00	35.00	35.00
Low-fat cheese*	27.00	27.00	26.00	26.00
Disodium phosphate	1.80	1.80	1.80	1.80
Trisodium phosphate	0.54	0.54	0.54	0.54
Salt	1.00	1.00	1.00	1.00
Skim milk powder	8.63	7.63	6.13	5.13
Sweet whey	7.50	–	–	8.00
Reduced-lactose whey	–	8.50	6.00	–
WPC34	–	–	2.00	–
WPI	–	–	–	0.50
10 D.E. maltodextrin	3.00	3.00	3.00	3.00
Water	3.00	3.00	6.00	7.03
Water as steam	8.00	8.00	8.00	7.50
Lactic acid, 20%	4.00	4.00	4.00	4.00
Color	<0.50	<0.50	<0.50	<0.50
Enzyme-modified cheese	<0.50	<0.50	<0.50	<0.50
Total	**100.00**	**100.00**	**100.00**	**100.00**

*Or use blends of full fat cheddar, low-fat cheddar, “skim” cheese.
Formula courtesy of Steven Young Worldwide.

Please refer to text for procedure or recommendations.

Cheese Spread, Pasteurized Process American

Ingredients	Usage Level (%)
Cheddar cheese	54.77
Water	24.20
Dry sweet whey	7.20
Sweet cream	5.40
WPC35	5.00
Disodium phosphate	2.30
Salt	0.60
Trisodium phosphate	0.45
Annatto	0.08
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Grade, clean and pass cheese through a grinder of approximately 6 mm (1/4") diameter opening.
2. Blend the ground cheese with coloring agent and cream in an industrial mixer. Blend until uniform.
3. Add 1/3 of the water to the blender and mix until uniform.
4. Prepare a slurry of dry sweet whey and WPC with 1/3 water.
5. Transfer the uniform cheese blend to a heating vessel. Add phosphate emulsifiers and salt. Agitate constantly while the blend is being heated.
6. When the blend is about 60°C (140°F), slowly add the remaining water and whey slurry. Continue agitation.
7. Heat sufficiently to insure pasteurization.
8. Pour molten cheese spread into a form. Cover. Seal. Cool.
9. Keep refrigerated at 5°C (40°F) during transfer, storage and distribution.

Cold Pack Cheese Food

Ingredients	Usage Level (%)
American cheese	85.00
Water	7.40
Reduced-lactose whey	5.00
Citric acid	1.50
Salt	0.50
Xanthan gum	0.30
Sorbic acid	0.30
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Grind cheese in cold-pack processing machine.
2. Mix in other ingredients using the chopper.
3. Package and distribute.

Typical "Fat-free" (<1.7% fat) Processed Cheese Food Formulations with Whey Ingredients

	Formula using Usage Level (%)			
Ingredients	Sweet Whey	Reduced-lactose Whey	WPC34 and Reduced-lactose Whey	WPI and Sweet Whey
Fat-free cheese	60.96	60.92	58.98	56.44
Disodium phosphate	2.00	1.80	1.80	1.80
Trisodium phosphate	0.60	0.64	0.65	0.54
Salt	1.00	1.00	1.00	1.00
Skim milk powder	9.00	7.00	3.50	5.60
Sweet whey	8.00	–	–	10.50
Reduced-lactose whey	–	7.00	3.50	–
WPC34	–	–	5.00	–
WPI	–	–	–	0.50
10 D.E. maltodextrin	3.30	3.30	2.00	3.00
Microcrystalline cellulose	2.00	2.00	2.00	2.00
Water	4.04	7.24	9.50	11.40
Water as steam	4.00	4.00	6.97	7.00
Lactic acid, 20%	4.00	4.00	4.00	4.00
Color	<0.10	<0.10	<0.10	<0.10
Enzyme-modified cheese	1.00	1.00	1.00	1.00
Total	**100.00**	**100.00**	**100.00**	**100.00**

Formula courtesy of Steven Young Worldwide.

Please refer to text for procedure or recommendations.

Formulations for Ice Cream using Sweet Whey

Ingredients	Dry Basis Usage Level (%) Regular Ice Cream	Premium Ice Cream	Super Premium Ice Cream
Milk fat	10.00	12.00	16.00
Skim milk powder	7.50	7.50	6.00
Sweet whey*	2.50	2.50	2.00
Sucrose	12.00	12.00	12.00
Corn syrup, 36 D.E.	6.00	4.00	4.00
Stabilizers and emulsifiers	0.30	0.25	0.25
Total Solids	**38.30**	**38.25**	**40.25**

*Reduced-lactose or demineralized whey can also be used.
Formula courtesy of Steven Young Worldwide.

Please refer to text for procedure or recommendations.

Reduced and Fat-free Ice Cream Formulations with Whey Protein Concentrates (34–80% protein)*

		Dry Basis Usage Level (%)								
		Reduced-fat Ice Cream with			Low-fat Ice Cream with			Fat-free Ice Cream with		
Ingredients	**Control**	**WPC34**	**WPC60**	**WPC80**	**WPC34**	**WPC60**	**WPC80**	**WPC34**	**WPC60**	**WPC80**
Milk fat	5.00	5.00	5.00	5.00	4.00	4.00	4.00	0.35	0.40	0.40
Skim milk powder	11.00	8.90	9.35	9.50	8.00	9.00	9.25	8.25	8.40	8.80
WPC34		1.10			2.50			2.75		
WPC60			0.65			1.00			1.60	
WPC80				0.50			0.50			0.50
Sucrose	12.00	12.00	12.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00
Corn syrup, 36 D.E.	5.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.50	6.50
Maltodextrin 4 or 10 D.E.	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.50	5.50
Stabilizers and emulsifiers	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.70	0.70	0.70
Total Solids	**38.30**	**38.30**	**38.30**	**38.30**	**37.80**	**37.30**	**37.05**	**36.05**	**36.10**	**35.40**

*Mix: approximately 0.59 kg/liter of finished product.
Formula courtesy of Steven Young Worldwide.

Please refer to text for procedure or recommendations.

No-sugar Added Ice Cream using Whey Protein Isolate (WPI)

	Dry Basis Usage Level (%)					
	Standard Ice Cream		Low-fat Ice Cream		Fat-free Ice Cream	
Ingredients	**Control**	**No Sugar Added**	**Control**	**No Sugar Added**	**Control**	**No Sugar Added**
Milk fat	10.00	10.00	4.00	4.00	0.35	0.50
Skim milk powder	10.00	9.00	11.00	10.00	12.00	12.00
WPI		1.00		1.00		1.00
Sucrose	12.00		12.00		12.00	
Corn syrup, 36 D.E.	6.00		6.00		10.00	
Polydextrose		6.00		6.00		8.00
Sorbitol		6.00		6.00		6.00
Maltodextrin 4 or 10 D.E.		6.00	3.00	8.00	4.00	8.00
Aspartame		0.10		0.08		0.08
Stabilizers and emulsifiers	0.30	0.30	0.70	0.70	0.25	1.00
Total Solids	**38.30**	**38.40**	**36.70**	**35.78**	**38.60**	**36.58**
Final Kg/liter finished product	0.536	0.536	0.596	0.596	0.782	0.596

Formula courtesy of Steven Young Worldwide.

Please refer to text for procedure or recommendations.

Ice Cream, Hard Pack

Ingredients	Usage Level (%)
Water	45.81
Heavy cream (40%)	24.98
Sugar	15.99
Skim milk powder	10.31
Dry sweet whey	2.58
Stabilizer/Emulsifier	0.25
Vanilla extract (2X)	0.08
Total	**100.00**

Formula courtesy of the Wisconsin Center for Dairy Research.

Procedure:

1. Pre-hydrate sweet whey by blending with formula water. Let sit overnight at 4°C (40°F).
2. Mix dry gelatin thoroughly with sugar.
3. Blend hydrated whey, sugar/gelatin mixture and all remaining ingredients, except vanilla, into a uniform suspension in a batch tank.
4. Pasteurize the mixture for a minimum of 30 minutes at 62 to 66°C (145 to 150°F), or 25 seconds at 80°C (175°F).
5. Homogenize the mixture at 66-85°C (150-185°F). Use homogenization pressures of 176 kgf/cm^2 (2000 lb/inch^2) in the first stage and 35 kgf/cm^2 (500 lb/inch^2) in the second stage.
6. Cool rapidly to 0-5°C (32-40°F).
7. Age the mix overnight or at least 4 hours.
8. Disperse flavorings in aged mixture prior to freezing.
9. Freeze in two stages in an ice cream freezer: In first stage, freeze to around 0°C (30-32°F) and approximately 100% overrun. In the second stage, harden the ice cream as quickly by reducing the temperature to at least -18°C (0°F) in the center of the package.
10. Maintain a warehouse, transportation, and transfer temperature of -26° to -32°C (-15° to -25°F).

Soft-serve Frozen Yogurt Dessert Mix

Ingredients	Usage Level (%)
Water	67.00
Sugar	10.00
Corn syrup solids, 36 D.E.	8.00
Skim milk powder	6.00
WPC34	3.00
Sweet whey powder	3.00
Milkfat or vegetable fat	3.00
Stabilizer*	–
Flavor*	–
Total	**100.00**

*Varies with type used.
Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Calculate the weight of ingredients, including necessary water.
2. Add liquid ingredients to tank.
3. Add dry ingredients, using adequate agitation to disperse and dissolve the powders.
4. Pasteurize and homogenize the mix.
5. Add appropriate flavors, cool to 4°C.
6. Store and distribute at 4°C or less.
7. Freeze in commercial soft-serve freezer.

Raspberry Sherbet

Ingredients	Usage Level (%)
Raspberry puree, deseeded	62.90
Sucrose	17.00
Corn syrup solids, 36 D.E.	9.60
Lactose	5.00
De-mineralized whey (10% minerals)	3.50
Butter fat	1.50
Stabilizer (gelatin)	0.50
Water	(As needed)
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Blend all ingredients into a uniform suspension in a batch tank, using adequate agitation to disperse and dissolve.
2. Pasteurize the mix for a minimum of 30 minutes at 70°C (158°F) or 25 seconds at 80°C (175°F).
3. Homogenize the mix at 49°C (120°F), using pressures of 176 kgf/cm^2 (2000 lb/inch^2) for the first stage, and 35 kgf/cm^2 (500 lb/inch^2) for the second stage.
4. Cool rapidly to 0-5°C (32-40°F).
5. Freeze in commercial ice cream freezer.
6. Package and harden at -40°C (-40°F).
7. Store and distribute at -23.3°C (-10°F).

Yogurt Drink

Ingredients	Usage Level (%)
Sweetener/flavor	–
Water	89.60
Whole milk powder	6.24
Lactose	2.26
WPC80	1.88
Yogurt culture	0.02
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Pre-hydrate whole milk powder and WPC80 in separate containers using part of the formula water. Let mixture stand overnight at 5°C (40°F), allowing hydration to take place.
2. Combine milk, lactose, WPC80 and any remaining water in a heating vessel. Heat to 82°C (180°F), holding at that temperature for 15 minutes.
3. Cool to 37°C (98.6°F) and inoculate with yogurt culture. Allow yogurt to incubate for approximately 6 hours, or until a pH of 4.25 to 4.35 is reached.
4. Cool to 7°C (45°F) and sweeten/flavor to desired levels with sweetener/flavor of choice.
5. Store at 5°C (40°F) until use.

Blended Yogurt

Ingredients	Usage Level (%)
Skim milk	97.43
Waxy maize modified cook-up starch	1.30
WPC80	0.50
Yogurt culture	0.40
Gelatin	0.37
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Mix all ingredients, except culture, together in a batch kettle.
2. Heat to 86°C (185°F) and hold for 30 minutes.
3. Cool mixture to approximately 40°C (104°F) and inoculate with culture.
4. Allow mixture to incubate at 40°C (104°F) until a pH of 4.5 is reached (approximately 3 to 4 hours).
5. Cool to 5°C (40°F) and hold overnight in cooler.

Fat-free Sour Cream

Ingredients	Usage Level (%)
Skim milk	64.25
Whole milk	30.00
WPI	3.44
Waxy maize modified cook-up starch	0.76
Dent modified instant starch	0.75
Sodium phosphate	0.27
TiO_2	0.27
Culture	0.20
Sodium citrate	0.06
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Mix all dry ingredients together in a bowl.
2. Place skim and whole milk together in a pan, and disperse dry ingredients in milk, using a mixer.
3. Heat to 85°C (185°F), and hold for 30 minutes to pasteurize.
4. Homogenize at 70°C (158°F), using two stages: 176 kgf/cm^2 (2000 $lb/inch^2$) in the first stage and 35 kgf/cm^2 (500 $lb/inch^2$) in the second stage.
5. Cool to 21°C (70°F) and inoculate with culture.
6. Incubate at 24°C (76°F) approximately 18 hours, or until pH of 4.5 to 4.6 is reached.
7. Cool to 4°C (40°F) and store for at least 48 hours to allow starch to set up and full viscosity to be developed.

PROCESSED MEAT AND FISH APPLICATIONS FOR WHEY AND LACTOSE PRODUCTS 14

Formulary edited by
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Whey proteins are widely used in meat, poultry, and chicken products as binding, extending, and texture modifying agents. In addition to their functional characteristics, they also have a high nutritive value: they contain readily digestible and bio available essential amino acids.

A range of uses for U.S. whey proteins in meat, poultry and seafood include, regular and high gelling WPC34, WPC50, WPC80, WPI and whey protein isolate blends, and other specialized tailor-made WPCs and WPIs. However, since no WPC and/or WPI meet all functional properties in a single ingredient, it is necessary to match the application requirements with the specified functionality the WPC and/or WPI have been manufactured to. Whey proteins can be used as stand-alone proteins or for partial and/or total replacement of other non-meat ingredients.

U.S. whey proteins can be successfully used in:

- Processed meats (ground meats, emulsion products, coarse ground products, whole muscle products, meat loaves, ground meat patties, sausage products, cured ham, pre-packaged cold cuts, etc.)
- Poultry meat products (meat batters, chicken "nuggets" or patties, chicken sausage, etc.)
- Seafood (fish sticks or balls, fish-based fillings, surimi-based seafood, etc.)

14.1 AN OVERVIEW

By DR. G. PRABHU
Proliant Inc., Ames, IA

The use of 80% whey protein concentrate in processed meat systems is increasing due to changing attitudes of consumers, processors and regulatory agencies. Whey protein concentrates are used as partial replacements of meat, binders, flavor enhancers, emulsifiers, brine ingredients and meat analogs and contribute to nutrition, flavor and critical functional properties. Most of the applications of 80% whey protein concentrates are in the area of coarse ground, comminuted and whole muscle meat products. They are mainly used to increase cook yields, reduce product purge, reduce formulation costs, improve product texture, or enhance product flavor.

Comminuted (Emulsified) and Coarse Ground Meat Products

Typically, about 1%-2% of whey protein concentrate 80% is used in comminuted meat products on a pre-hydrated basis depending on the type of product, resulting in substantial savings without reducing nutritional or eating quality. Whey protein concentrates are used in emulsified meats (e.g., bologna and frankfurters) for their moisture and fat-binding, emulsifying, and emulsion-stabilizing properties. These properties make whey protein concentrate ideal for use in coarse ground products such as loaves, patties and sausages.

Whole Muscle Meats

In whole muscle or large pieces of muscle tissue such as fish, ham, poultry or roast beef, it is possible to incorporate 80% whey protein concentrate. Usually, the brine solution containing the protein is injected or massaged directly or tumbled into the muscle using conventional cure meat technology. Upon cooking, the resulting product shows improved firmness, enhanced slicing characteristics, and less purge under vacuum packaging. Whey protein concentrate can also be used as binders (adhesives or glues) in formed products resulting in a firmer texture, increased juiciness and acceptable flavor after cooking.

Canned Meats

Whey protein concentrate 80% can also be used in retorted meat products to absorb juices and reduce fat separation during canning resulting in firmer products. These products include chili, meatballs, meat loaf mixes, minced hams, corned beef and Vienna sausages.

Poultry Products

Processed products have become the fastest growing section of the poultry market. Whey protein concentrate 80% can play a key role in making high-quality processed poultry products. They are used to bind meat cuts and trimmings in nuggets and patties, poultry rolls and pressed loaves. Poultry breasts pumped with a slurry of 80% whey protein concentrate, salt and flavors will result in increased cook yield, reduced freeze-thaw purge and improved juiciness.

Seafood Products

Whey protein concentrate 80% can be used in a variety of traditional Japanese fish-based products. Most of these products are based on surimi (a minced fish flesh), a portion of which, usually 1%-3%, can be replaced with 80% whey protein concentrate without affecting the traditional quality. Hydrated 80% whey protein concentrate can also be used in preparing fish blocks, fish cakes and fish patties as binders taking advantage of their water absorption and retention properties.

14.2 WHEY PROTEIN AND LACTOSE PRODUCTS IN PROCESSED MEATS

By DR. JIMMY KEETON
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Whey Proteins and Meat Products: Functional Benefits

Numerous researchers have reported the textural and nutritional benefits of non-meat protein additives, such as whey protein concentrates, on meat products. The use of non-meat dairy proteins in the manufacture of restructured cured meats is of commercial interest due to their ability to improve final product quality and yield. Among dairy ingredients, whey proteins and skim milk powders are used as fillers, binders, and extenders to improve the flavor, texture, appearance, cook yields, mouthfeel, and nutritional value of comminuted meat products such as sausages, turkey rolls, meat loaves, and ground meat patties.

Binding Properties

WPCs are effective as a meat binder, extender, and/or texture modifier in the manufacture of restructured meat products. Restructured meat products are complex food systems in which water absorption, gelation and emulsion formation influences stability and texture of the cooked product. Effective adhesion between meat pieces is an important quality characteristic in the manufacture of these meat products. Binding is used to describe both the adhesion of meat particles and water binding (holding) by the meat proteins. The actual binding depends on factors such as the type and concentration of salt, the extraction temperature and pH of the raw meat.

Table 14.2.1
Function, Benefit and End-Use of WPC in Meat, Poultry and Seafood

Function	Benefit	End-Use
Adhesion	• Improves food product's homogeneous texture	• To adhere bread crumbs or batters to meat, poultry and fish • To adhere pieces of meat, poultry and fish
Gelation	• Forms irreversible gels by restructuring into extended three dimensional networks • Entraps water within capillaries of gel matrix, and provides additional water binding capacity	• To improve yield value for ham, surimi, etc. • To prevent moisture loss for ham, surimi, etc. • To modify textural properties such as hardness, cohesiveness, and elasticity of processed meats, poultry and seafood
Viscosity and water binding	• Heating increases viscosity and provides additional water-binding sites • Provides body and texture • Adds chew, bite and firmness • Improves lubricity, juiciness and mouthfeel • Improves sliceability	• To replace fat in low fat and nonfat processed meat and poultry products
Browning	• Enhances Maillard and non-enzymatic Maillard reactions • Improves visual appeal • Adds color	• To increase the redness of low fat and nonfat meat and poultry products
Flavor	• Enhances flavor due to presence of lactose • Masks bitter aftertaste of salts and phosphates • Acts as a flavor carrier of volatile flavors	• To enhance flavor in some meat products such as sausages
Nutrition	• Good source of calcium fortification • Excellent source for readily digestible and bio-available amino acids	• To improve health image of nonfat and low fat processed meat products

The principal mechanism of binding in meat systems is attributed to heat induced gelation of myofibrillar proteins. The actual meat particle binding occurs during cooking as the heat setting of the proteins takes place. Binding decreases during cooking due to protein denaturation. Under appropriate heating conditions, WPCs form irreversible gels by restructuring into extended three-dimensional networks. Gelation entraps water within the capillaries of the gel matrix; thus providing additional water binding capacity. A strong gel network helps hold this water and prevents moisture loss. This can improve the yield value of processed meat products.

Gelation profiles of crude meat extrudates, obtained from restructured and whole muscle meat products on the use of WPCs and their influence on bind characteristics, have been examined by researchers. Meat extrudates made from cured porcine muscle were used to observe changes in gelation properties due to the incorporation of commercially available non-meat proteins including high gelling WPCs and regular WPCs. This study demonstrated that, in both the heating and cooling cycles, all levels (1%-3%) of WPCs resulted in increased storage modulus values in meat extrudates compared to controls (no WPC). A comparison of nondairy proteins with WPCs suggested WPCs were more effective gelling agents. Recently other researchers suggested the water holding capacity and cook yield of a processed meat product could be increased by replacing salt-soluble proteins with WPI.

As an Additive in Blends

In addition to being used by themselves, a variety of WPCs with different protein contents and gelling capacities can be used as effective gelling additives with a blend of polysaccharides, such as starch or carrageenan in the formulation of restructured meat products.

Researchers have investigated the influence of the addition of carrageenan, WPC and carrageenan blends on bind characteristics in cured restructured meat products. Results showed the addition of a variety of WPCs (from WPC34 to WPC80) at 2% residual powder level in the final meat increased storage modulus values. The addition of 2% regular WPC with a combination of carrageenan blends increased cook yields and water binding capacity by 5% to 8%, as well as organoleptic scores for juiciness. However, the addition of high gelling WPC at a 2% level in combination with the same carrageenan blend produced the best results for use in restructured meat formulations.

As an Edible Film

Research recently conducted by the Northeast Dairy Foods Research Center at the University of Vermont demonstrated that a film made from polymerized WPC could help meat retain moisture during heating without affecting its rheological properties such as texture. In addition, researchers showed that when the WPC film systems were integrated with antimicrobial agents, they effectively inhibited the growth of pathogenic and spoilage microorganisms, including *Listeria monocytogenes*.

As a Bulking Agent in Nonfat/Low-fat Formulations

Restructured meats are good candidates for nonfat and low-fat formulations. The eating quality of these meats is dependent on the fat content, because fat contributes flavor, texture and juiciness to such products. WPC has been reported in many studies to exhibit functional properties useful in fat replacement in nonfat and low-fat processed meat formulations. In low-fat meat products WPC enhances moisture content and fat entrapment, resulting in increased cook yield, moisture retention and increased resistance to shrinkage.

The increase in consumer interest in reduced fat foods has created a growing need for marketable nonfat and low/reduced fat meat products. Developing the leanest meat product, while assuring the necessary palatability demanded by consumers is not as easy as just removing fat. The active approach to fat replacement is to add fat-mimetic ingredients, which either replace fat or modify the interactions of the remaining components while maintaining good taste.

Proteins are primarily used as fat substitutes due to their ability to bind water and form gels. In addition, they act as emulsifying agents and are used to alter the appearance, flavor and texture of food products. Specifically, WPCs improve lubricity and mouthfeel of the end product by providing a smooth and creamy texture. WPCs are also ingredients that contribute to the healthful image of a low calorie profile through enhancement protein content and a lower level of saturated fatty acids.

Typical Applications in Meat Products

Low-fat Beef Patties

WPC80 at a 4% level can be effectively used as a functional ingredient in low-fat beef patties due to its heat gelation and emulsification properties. Low-fat ground beef patties (10%-11% fat) formulated with 10% water, 0.5% salt, and 1%-4% WPC80 show an increase in cook yield and reduced shrinkage with increasing levels of WPC over beef patties without WPC. The addition of 4% WPC in combination with 10% water produced the highest cooked yield (125% of the high fat control) and the least shrinkage (49% of the high fat control) compared with controls of higher fat content. The addition of 0.3% tripolyphosphate enhances the effectiveness of WPC in terms of texture, while the addition of about 1% lactose improves the flavor profile and overall sensory properties of low-fat beef patties. Sensory analysis indicates the 4% WPC level is an optimal level with respect to juiciness and overall acceptability of the low-fat beef patties.

Low-fat Frankfurter/Hot Dog/Sausage

The use of WPC in frankfurters/hot dogs may contribute to a healthful image because of the low calorie profile, enhanced protein content and a lower level of saturated fatty acids in the finished product. Due to market demand, reduced fat processed meat products are the focus of many developmental efforts. Reduced/low-fat meat products must be perceived by consumers as being of good economic value with desirable palatability.

It is well established that decreasing fat content significantly increases the cook loss in sausages. Investigators have evaluated the effects of fat level (5% and 12%), tapioca starch and WPC35 on the hydration/binding properties, color, textural and sensory characteristics of frankfurters. They reported that the addition of 3% tapioca starch and 3% WPC to frankfurter formulas significantly decreased the cook loss at both 5% and 12% fat levels. But, compared to tapioca starch, WPC reduced the cook loss further at 5% fat levels. This suggests WPCs are more effective than tapioca starch in reducing the cook loss at lower fat reduction levels.

Reducing the fat content of sausages can significantly decrease emulsion stability without appropriate water binders. The addition of WPC significantly increases emulsion stability at both 5% and 12% fat levels. It is known that reduced fat products require a high protein content for emulsion stability and the beneficial effects of whey proteins can be improved at higher usage levels. Low fat bologna is more stable when formulated with 13% protein compared to 11% protein, due to increased availability of extracted protein, which encapsulates fat to form a stable emulsion. Whey proteins are effective fat stabilizers, suggesting that whey proteins do affect the percentage of fat released from the emulsion.

Fat is known to influence the color of meat products: reducing the fat level from 12% to 5% decrease lightness and increases redness of sausages. In contrast, WPC addition increases lightness and decreases both redness and yellowness.

Researchers also established that reducing fat levels from 12% to 5% at constant protein levels significantly decreases cohesiveness and gumminess of the frankfurters, but does not significantly affect hardness, springiness, adhesiveness or chewiness.

Reduced fat frankfurters release flavor compounds more rapidly than higher fat frankfurters. Therefore, an ideal fat substitute should retain flavor compounds with the food matrix and release them at a rate comparable to that of their full fat counterparts. It has been demonstrated that WPC does not affect the rate of flavor release from low-fat frankfurters, suggesting that WPC can be an effective fat substitute.

Whey Proteins in Poultry Products

WPC and WPI can be effectively used to increase cook yield, water binding capacity and emulsification stability in poultry meat formulations with regular, low, and no-salt content. Studies of gels composed of 4% isolated salt-soluble protein from chicken meat and 12% WPC mixtures (16% protein) in 0.6 M NaCl and 0.05 M sodium phosphate buffer have suggested that WPC can form a composite gel, in which the whey protein aggregates exist as dispersed particles within the salt-soluble protein gel matrix.

In other studies, the addition of high gelling WPC80 or WPI to exhaustively washed chicken breast muscle improved the emulsion stability of heated emulsions. This may relate to the prevention of cook yield loss after emulsification. These results suggest the incorporation of WPC and WPI into exhaustively washed chicken breast muscle performed very well. In heated mixtures, the addition of WPC or WPI of the meat system reinforced the protein matrix. Also, WPC and WPI improved water and fat retention within the meat protein network when compared to caseinates and other milk proteins.

Pre-heated WPI can form a gel at a low protein concentration (6%) and low temperature (1°C) when salt is added to chicken breast meat batters. Gels formed at a low temperature are more transparent, more rigid and have better water holding properties than heat induced gels. Researchers have also shown substituting 2% of chicken meat protein with preheated WPI improved textural parameters and reduced cook loss compared to no substitution or 2% regular WPI addition. It was also observed that a stronger gel could be formed when the salt level was 1.5% or less, indicating that changing the ionic strength can modify gel characteristics.

Other studies have reported the combined effects of pre-heated WPI substitution level (0%-4%), and salt level (0%-2.5%) on the physical characteristics of raw and cooked chicken breast meat batters. Pre-heating of WPI resulted in cold set gelation overnight at 1°C, which significantly increased water holding capacity, reduced cooking loss and improved rheological properties of raw and cooked chicken breast meat batters, particularly at 1.5% or less NaCl. This suggests that pre-heated WPI substitution and NaCl concentration could have a significant effect on water holding capacity, and the rheological characteristics of raw poultry meat batter.

Whey Proteins and Seafood Applications

The utilization of whey protein concentrates in seafood depends on their functional properties and economic viability. The use of WPCs in seafood is mainly due to their gel forming and water binding abilities. The growing demand for surimi-based fish and shellfish analog products has resulted in continued efforts to improve the textural quality of these products by the addition of gel forming and water binding non-fish ingredients such as starch and protein.

As a Texture Modifier

Whey proteins such as whey protein concentrates and whey protein isolates can be used effectively to improve the textural properties of surimi-based seafood, fish balls, fish and shellfish, and other similar products. WPCs are cost-efficient ingredients in these types of seafood.

Pacific whiting (*Merluccius productus*) is the largest trawl fish caught off the West Coast of the U.S. This fish is processed to produce surimi. The surimi is further processed into various gelled products, such as crabmeat analogs, which are very popular in the U.S., Japan and Korea.

Shear strain is the most important measure of surimi gel strength and it is dependent on the structure of the myosin molecule. Shear strain is easily lost by proteolysis or the denaturation of myofibrillar proteins. Pacific whiting surimi made with 4% WPC and cooked rapidly at 90°C, demonstrated an improved shear strain. The addition of 4% WPC produces surimi with a commercially acceptable gel strength. Binding "meat" particles in the raw stage is essential in the production of surimi-based seafood. (A U.S. patent describes a process using whey proteins to form a self-supporting cold gel in surimi.) Researchers have used a commercial nonlinear programming technique ('optimization program') to develop least cost formulations for WPC with 34% to 80% protein in the surimi seafood base. In the least cost formulation, surimi gels with WPC34 and WPC80 at 4.08% and 2.98% levels, respectively, remained economically competitive with potato starch and beef plasma protein. This finding suggests WPC could be used as a cost effective texture modifier to replace, or complement, beef plasma proteins and potato starches.

Fish crackers are popular snacks in Southeast Asian countries, and are classified as 'intermediate products.' It is reported that the addition of up to 9% WPC to a fish cracker formulation, consisting of tapioca starch, minced fish and salt, produced a nutritious product with good overall acceptability. For fish balls, important quality parameters are 'springiness/bounce', color and flavor. It has been reported that the addition of 2-5% WPC can improve texture, color and flavor in fish balls.

As a Protein Inhibitor

Whey proteins have been characterized by a number of researchers as effective autolytic proteinase inhibitors controlling the autolysis of Pacific whiting surimi at 3% addition level. Therefore, WPCs are widely used as proteinase inhibitors in surimi processing of Pacific whiting. Proteinase inhibitors are heat-stable compounds, which break down muscle proteins. Commonly used food-grade inhibitors are beef plasma proteins, egg white, and potato powder. Some of these inhibitors have negative effects on quality, thus inhibiting their applications in surimi. For example, some forms of beef plasma proteins may result in off-flavors at concentrations higher than 1%. Similarly, egg white is typically more expensive and tends to give an undesirable egg-like odor at levels required for protease inhibition. Potato powder causes off-color problems.

14.3 PROCESSED MEAT AND SEAFOOD FORMULATIONS

Chicken Breast Formula with WPC

	Usage Level (%)	
Ingredients	**Control**	**WPC80**
Chicken breasts	85.65	84.65
Water	12.00	12.00
Starch	1.50	1.50
Salt	0.50	0.50
Phosphate	0.35	0.35
WPC80	–	1.00
Total	**100.00**	**100.00**

Formula courtesy of Proliant Inc.

Procedure:

1. Dissolve salt, phosphate, starch and WPC80 in water and tumble with chicken breasts for 45 minutes continuously.
2. Thermally process to 74.5°C internal temperature at 40% relative humidity (94.5°C dry bulb, 69°C wet bulb).
3. Chill overnight, vacuum package and freeze.

Benefits:

1. Enhances cooked yield based on both raw weight and tumbled weight without significantly affecting sensory attributes.
2. Cost reduction of about 7% while maintaining the whole muscle texture of the finished product.

Restructured Chicken with WPC

	Usage Level (%)	
Ingredients	**Control**	**WPC80**
Chicken breasts	77.00	73.00
Water	18.10	20.60
Salt	2.00	2.00
Sodium phosphate	0.40	0.40
Spices	1.00	1.00
Modified starch	1.50	1.50
Chicken broth	0.00	0.50
WPC80	–	1.00
Total	**100.00**	**100.00**

Formula courtesy of Proliant Inc.

Procedure:

1. Remove fat from whole chicken breast pieces and macerate trimmed breasts.
2. Take 20% of trimmed breasts and chop into a coarse paste.
3. Add meat and other ingredients to tumbler and tumble under vacuum for at least 2 hours at 14 rpm.
4. Refrigerate and hold for 16 to 24 hours.
5. Stuff into pre-stuck fibrous casings and cook, using high relative humidity, to an internal temperature of 67°C.

Benefits:

- WPC with chicken combination improves flavor, texture, juiciness, and reduces cost in processed chicken products.

Benefits	**Control**	**WPC80**
Blend cost ($/cwt)	135.28	132.29
Cook yield (%)	96.40	96.51
Yielded blend cost ($/cwt)	140.33	137.07
Cost savings ($/cwt)	Base	3.26

Fresh Chicken Breakfast Sausage

Ingredients	Usage Level (%) Control	0.5% WPC80	1.0% WPC80
Chicken thigh meat	79.06	77.06	77.06
Spice blend	2.25	2.25	2.25
Synergy pork stock	0.00	1.50	1.50
Synergy chicken stock	0.00	0.50	0.50
Water	16.35	15.85	15.35
Salt	1.84	1.84	1.84
Modified food starch	0.50	0.50	0.50
WPC80	0.00	0.50	1.00
Total	**100.00**	**100.00**	**100.00**

Formula courtesy of Proliant Inc.

Procedure:

1. Grind chicken thigh meat through a 0.635 cm plate.
2. Mix meat, water, and spices for not more than 3 minutes.
3. Regrind meat mixture through a 0.476 cm plate.
4. Stuff into 5.08 cm collagen casings.
5. Freeze product and then temper out partially.
6. Slice chubs into 56.7 g patties.
7. Package and store in freezer.

Benefits:

- WPC increases cooking yields significantly and provides cost savings of about 3.6% with 0.5% WPC and 2.3% with 1.0% WPC additions.
- Addition of synergy stocks enhances and improves flavor by providing a subtle blend of meaty, browned and roasted notes.

Benefits	Control	0.5% WPC80	1.0% WPC80
Blend cost ($/cwt)	0.450	0.491	0.501
Cook yield (%)	78.300	84.400	86.020
Yielded blend cost ($/cwt)	0.575	0.554	0.562
Cost savings ($/cwt)	Base	0.021	0.013

Smoked Sausage

Ingredients	Usage Level (%)
Collagen casings	–
Meat blends	76.25
Water	17.25
Salt	1.75
Skim milk powder	2.50
WPC80	1.25
Spice and cure	1.00
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Grind meats through 0.95 cm (3/8 inch) plate.
2. Blend meats and other ingredients together in a mixer for 5 minutes.
3. Regrind through 0.48 cm (3/16 inch) plate.
4. Stuff into edible collagen casings.
5. Place in smoke and heat. Cook to an internal temperature of 62°C (145°F).

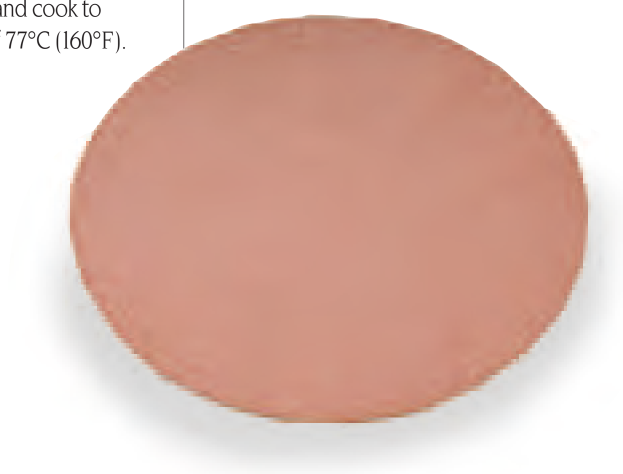
Pork and Beef Bologna

Ingredients	Usage Level (%)
Cellulose casing	–
Pork (50% lean)	38.08
Ice/Water	29.00
Beef (90% lean)	26.06
WPC80	3.00
Salt	2.30
Sugar	1.00
White pepper	0.30
Nutmeg	0.13
Ginger	0.13
Sodium erythorbate	540 ppm
Sodium nitrite	154 ppm
Total	**100.00+**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Add meat, salt, curing ingredients, WPC80 and half of the ice to cutter. Drop the temperature to about 4°C (40°F). Chop until a stable emulsion forms.
2. Add the remaining ice and spices.
3. Heat to about 13°C (55°F).
4. Stuff in cellulose casings and cook to an internal temperature of 77°C (160°F).



97% Fat-free Turkey Breakfast Sausage

Ingredients	Usage Level (%) Control	WPC80
Line run turkey thigh meat	86.90	84.90
Spice blend	2.25	2.25
Synergy pork stock	0.00	1.50
Synergy turkey stock	0.00	0.50
Water	10.35	9.85
Modified starch	0.50	0.50
WPC80	0.00	0.50
Total	**100.00**	**100.00**

Formula courtesy of Proliant Inc.

Procedure:

1. Grind turkey thigh meat through a 0.635 cm plate.
2. Mix meat, water and other ingredients for not more than 1 minute.
3. Stuff mixture into a 5.08 cm collagen casing.
4. Freeze meat and then temper out partially.
5. Slice chubs into 28-30 g (1-1/4 ounce) patties.
6. Package and store the patties in freezer.

Benefits:

- Addition of WPC significantly increases cook yield and reduces diameter shrink loss.
- Addition of synergy stocks enhances savory and meaty notes in 97% fat free breakfast sausage.

Ground Meat Patties with WPC

Ingredients	Usage Level (%) Control	1.0% WPC80	2.0% WPC80
Ground meat (0.3175 cm grind)	99.50	87.00	86.00
Water	0.00	11.50	11.50
WPC80	0.00	1.00	2.00
Salt	0.50	0.50	0.50
Total	**100.00**	**100.00**	**100.00**

Formula courtesy of Proliant Inc.

Procedure:

1. Mix ground beef with other dry ingredients in 600 ml beaker.
2. Add water and mix 30 seconds.
3. Press into patties at bottom of beaker.
4. Cook in an oven at 187°C for 20 minutes.
5. Measure free liquid and evaluate for sensory.

Restructured 60% Extended Ham with WPC

	Usage Level (%)	
Ingredients	**Control**	**WPC80**
Lean ham	100.00	100.00
Water	56.00	53.12
Salt	3.30	3.30
Sodium phosphate	0.63	0.63
Erythorbate	0.05	0.05
Sodium nitrite	0.02	0.02
WPC80	0.00	2.88
Total	**160.00**	**160.00**

Formula courtesy of Proliant Inc.

Procedure:

1. Macerate heavily the fresh raw ham.
2. Add meat and ingredients to tumbler.
3. Tumble under vacuum at 10 rpm's for 4 hours.
4. Refrigerate for 12 to 16 hours.
5. Stuff under vacuum into pre-stuck fibrous casings.
6. Cook in smokehouse to 70°C internal temperature about 6 to7 hours.

Benefits:

- WPC80 provides higher cook yields.
- WPC80 provides a juicier ham.
- WPC80 improves the flavor profile of the ham by reducing the harsh salty characteristic typically seen in ham products.

Hot Dogs with WPC

	Usage Level (%)	
Ingredients	**Control**	**WPC80**
Beef	15.50	7.50
Pork	40.00	40.00
Chicken	21.00	21.00
Water	19.13	25.13
Salt	2.39	2.39
Sugar	1.00	1.00
Sodium tripolyphosphate	0.42	0.42
Spice	0.50	0.50
Sodium erythorbate	0.04	0.04
Sodium nitrite	0.02	0.02
WPC80	0.00	2.00
Total	**100.00**	**100.00**

Formula courtesy of Proliant Inc.

Procedure:

1. Chop lean meat with salt, nitrite, and half of water until a temperature of 6 to 8°C is reached.
2. Add remaining dry ingredients while chopping at low speed.
3. Add fat, meats and remaining water, and then chop on high speed until temperature reaches between 13 and 15°C.
4. Stuff emulsion into cellulose casings.
5. Cook hot dogs in smokehouse or hot dog cooker.
6. Shower product for 20 minutes and store at <4°C.

Benefits:

- Similar cook yield, indicating WPC80 bound additional 3 l (6 lbs) of water.
- WPC addition reduced yield costs by $3.37/cwt.
- Comparable texture expected with replacement of 4 parts lean meat with 1 part of WPC80 and 3 parts water, providing savings up to $2.00 cwt.

Low-fat Hot Dog

Ingredients	Usage Level (%)
Pork trim	36.88
Ice water	30.26
Beef trim	24.58
Fatfree spice blend	5.00
WPC80	2.83
Heller's modern cure	0.20
Paprika	0.14
Salt	0.00
Liquid smoke	0.11
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Add pre-ground (1/8") beef trim, cure and 1/2 ice water mixture (75% ice: 25% water) into a chopper.
2. Add spice mix, WPC80, paprika, salt, and liquid smoke. Additional ice water may be added so that the batter is easier to chop. Chop until temperature reaches 6°C (42°F).
3. Add pork trim and remaining ice water and chop until 7°C (45°F).
4. Place mixture in an emulsifier (desired emulsifier output temperature is 17°C or 62°F). The emulsifier must be cleaned between batches.
5. Preheat processing oven equipped with a smoke generator filled with white hickory smoke bits.
6. Stuff into collagen casings with a sausage stuffer and smokehouse cook until internal temperature of 76°C (162°F).
7. Shower 10 minutes until 27°C (80°F), cool to 14°C (57°F), peel and vacuum.

Surimi Seafood Formula with WPC

Ingredients	Usage Level (%)
Alaska Pollack	66.70
Ice	29.80
Salt	2.00
WPC80	1.50
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Mix all ingredients together for 4 minutes in a vacuum chopper.
2. Transfer paste to sausage stuffer and extrude into stainless steel tubes.
3. Seal both ends of the tubes.
4. Cook at 90°C (195°F) for 15 minutes.
5. Chill in ice water for 15 minutes.
6. Remove from tubes and store at 4°C (40°F).

Formulary edited by
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During the past few decades, there has been a proliferation of convenience foods snacks, and processed foods, which require very little preparation by the consumer. In a variety of processed foods and snacks, whey protein products provide a number of useful functions such as flavor enhancement, whitening, emulsification, thickening and whipping.

Cream soups, white sauces and gravies are oil-in-water emulsions, which are available either as a liquid or as dry mix. A variety of milk protein products are used to provide both an emulsifying function and a stabilizing effect. Gravy mixes also benefit from the use of whey-containing dairy blends as whitening or opacifying agents. Whey solids impart a nice, mild dairy flavor and are well known as flavor enhancers in dry sauces. In some applications, mineral-concentrated whey products are used as flavor enhancers as well as bulking and dispersing agents in flavoring and dry mixes. Whey protein concentrates may be used advantageously in acid-processed foods and snacks because of their good acid solubility.

Salads dressing are oil in water emulsions with a low pH (close to 4) which may contain egg yolk as an emulsifier, vinegar as an acidulant, along with coloring and flavoring materials. Unlike mayonnaise, pourable dressing often also contains starches or gums as an extra emulsifier and texture agent. The principal emulsifying agent in salad dressings is egg yolk, which also affect the stiffness and stability of the emulsion. For economic and bacteriological reasons, there is much interest in replacing egg yolk with natural whey proteins that have suitable emulsifying and stabilizing properties at low pH values. Research has shown that the emulsifying capacity and stability in terms of serum separation in pourable salad dressing are very important parameters, and that the method of preparing the dressing (such as order of ingredient) is one of the most important factors to consider. U.S. suppliers have developed customized whey protein concentrates that offer superior performance in salad dressing and can help replace all or part of the eggs in formulations.

Whey's high quality proteins and calcium content are also important factors when designing convenience foods or fortified snacks. Whey products are also seen as desirable, all-natural ingredients by consumers and their use helps manufacturers offer "clean labels." Whey protein concentrate's ability to displace eggs offers significant benefits in terms of microbiological quality, product safety and shelf life.

15.1 WHEY PRODUCTS IN SNACK APPLICATIONS

By DR. B. JOHNSON
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Snacks include a wide array of foods from crackers to cheese curls and potato chips to cookies. Their flavor may be sweet or savory and texture from soft to crunchy and crisp. A wide variety of snacks are formulated with dairy ingredients, in particular whey products. The primary application of whey-based products in snack foods is for seasonings, since whey products can enhance the flavor and appearance of snacks. In addition, whey products are increasingly used in crackers and masa dough, and new applications include their utilization as coating for nuts and other snacks. Whey products enhance the texture, color and flavor of many types of snacks, can increase shelf-life, and provide cost-efficient solutions as they can partially substitute eggs and shortenings in many formulations.

Another key reason why manufacturers now select U.S. whey products as ingredients in snacks is that they provide valuable nutrients. Whey proteins are exceptionally rich in branch-chain amino-acids—important nutrients in sports nutrition and they are rated among the top quality proteins available. Whey products are also a source of highly bioavailable dairy calcium, other minerals and vitamins. Whey protein concentrates and whey protein isolates are now the ingredient of choice in healthy and sports snacks.

Flavored salty or savory snacks are produced by topically coating the "chip" with flavored seasonings. Flavor impact, uniformity and visual appeal are key factors to control to optimize consumer acceptance. In the U.S., some of the most popular flavor types are cheese, "nacho," "ranch" sour cream and onion, and barbecue. Four of the top five snack seasonings are dairy-based and generally contain a significant level of whey solids. These dairy compounds are available as individual ingredients or in a varying array of blends to provide the snack industry with versatile building blocks for snack seasonings.

An Overview of Whey Products Functions in Snacks

- Flavor carrier and volume agent.
- Sweet whey is an ideal clean, low-flavor carrier that blends very well with cheese powders, other savory flavors and oleoresins.
- Whey products increase the volume and coating of snack seasonings, and provide uniform coating with excellent visual appeal.
- The non-hygroscopic properties of whey-containing seasonings are important for non-caking effect and quality preservation.
- The use of whey products can help extend shelf-life and preserve functionality in some applications by physically separating some reactive components from each other.

Table 15.1.1
Cheese Blend Seasonings

Ingredients	High Cheese	Blended	"Economy"
Cheese	>90%	70%	<50%
Sweet whey	4%	10–20%	20–35%
Acid whey	3%	5%	5%
WPC34	3%	3%	5%
Enzyme modified cheese	–	1–2%	1–3%

Whey Products in Cheese Blend Seasonings

Dairy powders used in snacks are almost exclusively spray-dried. Cheeses, sour cream, cream cheese and various dry milk powders are dried in this fashion. The process is similar for all, but emulsifying salts and extenders are sometimes added to fat-containing seasonings when needed. Emulsifying salts such as citrates and phosphates are added to condition the cheese protein and to form an emulsion of the dairy fat. This smoothes the texture and prevents oiling-off of the cheese powder. When well-aged cheeses or vegetable oil are used, additional functional protein such as WPC34 or sweet whey can be added to aid in the emulsification and drying process. The emulsifying salts, water and cheese are blended and heated to sterilization temperatures, homogenized and spray dried to produce a cheese powder. The resultant product has a moisture level of around 4%, providing good storage quality and stability.

Depending on the target use of the cheese powder, manufacturers produce cheese powders with a range of cheese solids ranging from high (95%), moderate (more than 50%) to low (less than 50% cheese solids). Cheese powders are formulated with other dairy ingredients such as whey, buttermilk, skim milk solids, flour, maltodextrin and dextrose, depending upon the application and end-user needs. Sweet whey and whey protein concentrates act as cost-efficient flavor carriers and enhancers.

Salted snack foods are the major cheese powder use in the U.S. cheese powders and blends, along with other dairy powders, are the essential flavor base for topical applications on potato chips, extruded snacks and popcorn. Cheese powders can be more cost-efficient in snack fillings than natural cheese because of their functionality, flavor intensity and shelf-stability. Baked, reformed and extruded snacks generally require cheese powders which are formulated for increased heat stability, and also often require topical applications to get desired initial and lasting flavor impacts.

Snack seasoning manufacturers use whey products in various ways in dairy-flavored seasonings. Cheese blends are popular and will typically contain cheddar, whey solids, buttermilk solids, blue cheese, phosphates, color and salt. This type of blend is then often customized by adding additional whey solids, salt, monosodium glutamate, color, etc.

Application of Seasonings to Snack Foods

The majority of snack flavorings are applied topically. In a limited number of products, flavorings or flavorful ingredients such as cheese, are added to the snack formulation prior to cooking. In addition topical seasonings are used to provide the initial flavor impact that complements the internal base flavor. Topical seasonings are applied to snacks primarily by one of three methods: (1) dusting or dry coating, particularly for fried snacks, (2) spraying onto the snack surface of a flavoring blend suspended in vegetable oil and, (3) oil spraying of baked products followed by dusting of seasonings.

Cheese seasonings for extruded snacks are typically applied as a suspension in an oil slurry. The seasoning is sprayed onto the product giving a more uniform and tightly bound surface coating. Such seasoning is used on popcorn, expanded, extruded snacks and related products. Three different formulations are presented in Table 15.1.2. Blends A and B are traditional blends, with B as a cost-reduced formulation where whey solids and enzyme modified cheese flavor replace 15% of the cheese. These can be used as an oil suspension on cheese "curls" (extruded snacks) with a pick-up of 30%-35% by weight. Blend C is a cost-reduced formulation that uses whey, enzyme-modified cheese and various flavor enhancers. It can also be suspended in vegetable oil (one part to two parts oil), and the recommended application rate is 30%-35% by weight.

Tortilla and corn chips have unique flavors of their own and stronger-flavored seasonings are needed to adequately flavor corn-based chips. "Nacho" and "Ranch" flavors are the most commonly used because of their high consumer acceptance. Higher color and coating levels are often necessary to increase consumer appeal. Three variations for a "Nacho" seasoning for tortilla chips are presented. Formulations B and C use dried acid whey and enzyme-modified flavors to minimize cost.

These seasonings can be used at 6%-8% on tortilla chips while still hot, using dusting or tumbling for uniform coating. An oil slurry can be used for popcorn or corn-based collets. Cracker dough usage is 8%-10% of the flour weight, while cracker fillings will require 30%-35% of the filling weight. Baked snack crackers can be sprayed with oil before salt and seasonings are added to increase coating adhesion.

Whey products are multi-functional ingredients in co-extruded snacks. In the outer shell of both snacks, WPC34 is used to partially replace other solids. In the fillings whey acts as a dairy flavor source and a cost-effective ingredient. Filled pretzels are an example of cheese-filled co-extruded snacks.

Table 15.1.2
"Nacho" Flavorings for Corn and Tortilla Chips, Popcorn and Crackers

	Formula (%)		
Ingredients	**A**	**B**	**C**
Romano cheese powder	34.00	29.00	26.00
Parmesan cheese powder	10.00	10.00	10.00
Cheddar cheese powder	5.00	5.00	5.00
Salt, flour	18.90	18.90	18.90
Maltodextrin	18.10	18.10	18.10
Tomato flavor	5.00	5.00	5.00
Acid whey	–	5.00	8.00
Monosodium glutamate	3.00	3.00	3.00
Onion powder	1.50	1.50	1.50
Romano (enzyme modified) flavor	1.00	1.00	1.00
Citric acid	1.00	1.00	1.00
Mustard powder	1.00	1.00	1.00
Garlic powder	0.50	0.50	0.50
Yellow coloring	0.70	0.70	0.70
Red pepper	0.30	0.30	0.30

Benefits of Whey Products in Sweet Snacks

Sweet whey and whey protein concentrates are widely used in sweet and baked snacks. Such snacks included cereal bars (granola, muesli, rice), a wide variety of cookies, biscuits and wafers as well as nutrition, sports and candy bars.

In general whey products are used because of the mild and smooth dairy flavor they provide. In baked snacks, a typical usage level of 5% (flour basis) is recommended for achieving the functional benefits of whey products. Crust color and gloss are typically improved with the addition of whey and dough stiffness or stickiness reduced. Whey protein concentrates and isolates are also used as partial replacement of egg white or gelatin and as gelling/ binding agents. Whey ingredients are multi-functional and cost-efficient.

In confections such as nougat and malted milk balls, the aeration properties of whey proteins help control ingredient costs. The protein network within the foam structure helps stabilize the final aerated product. In the syrup or continuous phase of the confection, the protein network surrounds each of the air cells and prevents collapse. Whey protein concentrates are also used in toffee, caramel, fudge and other confections as a partial casein replacement. (Please refer to confectionery chapter for more details).

Table 15.1.3
Whey Products Usage and Benefits in Snack Applications

	Typical Usage Level (%)				
Product	**Sweet Whey**	**Acid Whey**	**WPC34**	**Demineralized Whey**	**Benefit**
Cheese blends	5–30	0–10	0–5	–	• Cost control • Functionality • Flavor carrier
Cheese powder	0–20	0–2	0–3	–	• Cost control • Functionality • Mild dairy flavor
Seasonings	0–50	0–8	0–5	–	• Cost control • Flavor carrier • Mild dairy flavor • Effective coating
Savory crackers	0–4	0–2	0–4	–	• Color development • Texture modification • Cost control
Milk chocolate*	–	–	0–5	0–5	• Flavor development • Mild dairy flavor • Cost control
Compound coatings*	–	–	0–20	0–20	• Flavor development • Color development • Cost control
Granola bars, chewy	0–3	–	0–3 WPI also used	0–3	• Cohesiveness • Egg, gelatin replacement • Flavor contribution
Caramel*	0–4	–	0–7	0–4	• Texture improvement • Color development • Flavor development
Biscuits, cookies**	>5% fb	–	>5% fb	>5% fb	• Texture improvement • Color and flavor development • Mild dairy flavor

*For additional information and formulations, please consult the chapter on confectionery in this manual.
**For additional information and formulations, please consult the chapter on bakery in this manual.

15.2 WHEY PROTEIN FILMS IN SNACK APPLICATIONS

Copy contributed by:
Dairy Management Inc.

In the evolving world of food formulations, dairy ingredients continue to meet formulation challenges by expanding their repertoire of value-added functional properties and applications potential. Currently, a researcher at Cornell University is introducing a new whey-based polymer that combines the best qualities of starch and protein to offer functional benefits beyond those typically found in a whey protein or starch alone. This opens up new applications and marketing opportunities for snack manufacturers looking for a nutritional, stable, functional gelling agent. Dairy Management Inc., the parent organization of the U.S. Dairy Export Council, funded this innovative research.

Steven Mulvaney, Ph.D., Associate Professor in the Department of Food Science at Cornell University, in Ithaca, NY, created a unique composite gel by combining and heating corn starch and whey proteins above their respective gelatinization and denaturation temperatures. The gel properties can be manipulated to suit an individual manufacturer's needs by modifying process conditions and varying the formulation.

Once created, the polymer is a wet gel, although Mulvaney indicates that the polymer gel can be dried and ground into flour, lending itself to applications in snacks. In addition, whey offers significant nutritional and technological advances over other simple, starch-based gels. Food manufacturers can utilize existing equipment for the process, with standard, readily available ingredients, and produce this composite polymer by controlling the process conditions such as pH and heat exposure. The polymer mixture in flour form acts like a pregelatinized starch and will form dough upon mixing with water. This opens up additional possibilities for use with baked and/or extruded snacks.

"Gels and edible films have many applications for the food industry," says John M. Krochta, a researcher with the California Dairy Foods Research Center at the University of California-Davis. "For instance, whey protein film can be formed as a coating on nuts or other products which suffer from oxygen intrusion. By inhibiting oxidation, whey protein protective coatings help improve the quality and shelf life of nuts and such nut-containing products as confections and baked goods. These whey protein coatings can also prevent oil migration from nuts into surrounding food ingredients. Coatings made from polymerized whey protein register no discernible taste." The innovative use of U.S. whey proteins allows manufacturers to formulate all-natural snacks with improved flavor and consumer appeal.

QUESTIONS AND ANSWERS

Q. *Is it recommended to use only one type of cheese seasoning on all varieties of cheese-flavored snacks?*

A. The flavor requirements vary with the snack background flavor so it is preferable to use different types of cheese flavorings. Stronger flavor types and different profiles complement corn or tortilla chips better than potato chips for instance. Rice-based snacks may also require a different flavoring. Pre-salted chips will require a different coating level and formula to account for the salt already present. In addition, children or adults may have different flavor preferences. In general, children prefer mild cheese flavors and like the slightly sweet dairy flavor of whey. Adults often have a preference for snacks with high seasoning levels and the use of whey products is critical to carry and extend the cheese flavor, thereby maximizing the visual appeal of the product.

Q. *Will the use of whey modify the nutritional profile of my product?*

A. Whey protein concentrates contain significant levels of high-quality proteins and minerals such as calcium. Depending upon the level of usage, formulations with whey products may contain higher levels of proteins and calcium, a desirable attribute that can be promoted to consumers. In some baked snack formulations, whey products can be used as partial fat-replacers. In addition to cost-savings, this property is desirable when formulating healthy, fat-reduced snacks.

Q. *The seasoning powder is not adhering well to the snack, what can be done to correct this?*

A. Care must be taken to apply the dry seasoning when the surface oil from frying or spraying is still fluid and present on the surface. This often occurs when the product is still very warm. In the case of tortilla chips, with lower surface fat, smaller particle seasonings are recommended since they are lighter and adhere better. In low fat products, spraying with aqueous solution of gums and/or maltodextrins is required to ensure that the seasonings adhere well to the surface.

Q. *In a confectionery application is there a preference for using sweet whey or other types of whey?*

A. Yes, in some applications, the use of whey protein concentrates rather than sweet whey is recommended as they have less flavor of their own and do not mask other flavors in the confection. Whey protein concentrates are highly functional because of their gelling, binding and emulsification properties. Whey protein isolates are sometimes preferred to replace egg white or gelatin. Combinations of more than one type of whey products should be tested through sensory evaluation to optimize the formulation and cost efficiencies.

Q. *What are the advantages and disadvantages of self-blending vs. purchasing complete seasoning mixes?*

A. There are usually cost advantages from self-blending of a seasoning but maintaining the consistency of the flavor requires considerable expertise. Some snack manufacturers prefer to buy the co-dried blend and custom mix the remaining seasoning components such as sweet whey and whey protein concentrates. The decision is often based on a total evaluation of process costs and scale of the operation. In most cases, snack manufacturers work closely with U.S. whey and seasonings suppliers to develop unique mixes that are optimized based on consumer preference.

Q. *I am having some flavor uniformity problems with seasonings, what are the possible causes?*

A. Any liquid oleoresin should be pre-blended thoroughly with a dry ingredient like whey powder and dry blended in with the remaining dry ingredients to assure uniform dispersion. If there are ingredient particle size differences between components, stratifying of the components may occur during transport and handling. It is important to ensure that all ingredients have similar particle sizes. Particle sizes can also greatly affect oil slurry-applied seasonings, creating non-uniform suspensions and plugging the spray nozzle. In most instances, adequate agitation of the slurry helps solve the problem.

Q. *Will using a fat substitute in fat-free snacks work the same for seasoning coatings?*

A. Yes, it should provide the same adherence as a spray oil or as a surface oil from frying just like vegetable oils and shortening. Contact the manufacturer if unusual results occur in a specific application.

15.3 WHEY PRODUCTS IN LOW-FAT FOODS

By DR. B. JOHNSON
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Stillwater, OK

Whey products contribute to creaminess, texture, water binding, opacity and adhesion in a variety of food systems. They are multifunctional food ingredients, which are increasingly used in low-fat systems as fat replacers. Their high nutritional quality and unique range of functional properties make them valuable in a wide range of low-fat products including soups, sauces, salad dressings and meats.

Whey Proteins as Fat Mimetics

Currently the most widely used approach for producing reduced-fat products is using fat mimetics in food emulsions. A systems approach using a combination of two or more carefully selected fat replacers along with formula and process changes appears to be the best current strategy. Fat mimetics are the most widely used ingredients for producing emulsion-based reduced-fat products. Whey protein concentrates (WPCs) are considered as fat mimetics and they have found extensive use in reduced-fat foods, either alone or in combination with other mimetics.

The whey protein concentrates used as fat mimetics are typically WPC34 and WPC80 and their use in low-fat foods offer many advantages. Their multifunctional characteristics provide several fat-like attributes. Their major functions are gelling, water binding, emulsification, viscosification and adhesion. Modifying processing conditions during the manufacture of WPCs can also selectively enhance specific functional aspects.

A majority of fat mimetic applications for WPCs involve emulsification within applications such as salad dressings, mayonnaise, cream soups, sauces and processed meats. In addition, WPCs offer cost-efficiency benefits when replacing or extending egg whites, hydrocolloid gums, soy proteins and modified starches.

WPCs retain their functionality in low pH environments, achieving good emulsification in highly acidic systems. Thus, in low-fat salad dressings, the important function of efficient fat dispersion and high water binding can be achieved. WPCs enhance water binding and allow for cost reductions through the addition of extra water, while yielding a product with good viscosity and opacity. For example, reduced-fat soups and sauces benefit from the efficient dispersion of fat and the excellent emulsifying properties of whey proteins. Furthermore, the gelling properties of WPCs impart creaminess and a superior texture to low-fat soups and sauces. Another key function provided by WPCs in low-fat applications is increased opaqueness, which otherwise is significantly reduced with decreasing fat content. Whey proteins also function well in sausage and processed meat applications by binding water and pieces of meat to each other. Cost reduction, improved texture, mouthfeel and superior nutritional profile are provided by WPCs.

When fat is removed in a low-fat product, many physical and sensory attributes (viscosity, mouthfeel, shear, color and flavor) are typically affected. As a result, food formulators often need to add a mimetic to produce the textural characteristics found in the full-fat product. Whey proteins fill this role cost-effectively since they are multifunctional, performing as both an emulsifier and a stabilizer. Whey proteins migrate to the oil-water interface to produce protein-stabilized emulsions. They undergo interfacial denaturation and form viscoelastic films at the oil-water interface. Heat gelation of the whey protein emulsion adds further stability by limiting the tendency of emulsions to coalesce, cream or oil-off.

Whey Protein Concentrates and Functional Enhancements

Some of the special functional aspects of WPCs are emulsification, high solubility, gelling, whipping/foaming, water binding and viscosity. Whey proteins in their native form are globular folded structures. As such they are highly soluble and efficient in whipping and emulsification functions. The pH, ionic environment, concentration, presence of lipids and heat treatments influence their functional properties in food applications. Controlling various parameters during production of WPCs allows for selective enhancement of specific physical properties. A number of unique functionally-enhanced WPCs are available from U.S. suppliers for specialized applications.

High Gelation

An important function of WPCs is their ability to form heat-induced gels. These gels can hold water and other non-protein components of food systems. Calcium is required for gelling to occur and free calcium concentration is critical in determining gel hardness and water retention properties. In some cases chelating agents are effective in reducing free calcium to optimal levels. Heating time, heating temperature, pH, and NaCl all influence the texture of WPC gels, affecting heat-induced changes to the secondary structure of the whey protein. High-gelling WPCs function particularly well in reduced-fat meats. For example, studies have shown that high-gelling WPCs, when combined with a gum and starch, yield a low-fat (3%) pork sausage that has similar textural characteristics to a full-fat (20%) control.

Cold Gelation

Studies have demonstrated that whey proteins have to be pre-treated by heating to at least 70°C to achieve cold-gelling ability. Cold-gelling WPCs are now commercially available, and they can find good applications in salad dressings and mayonnaise type products. In meat applications using vacuum tumbling, cold-gelling WPCs can be added until the protein is in the meat, to be followed by the addition of salt to gel the WPC. Tests have shown that such method improves meat quality and yields.

Heat Stability

Heating WPCs leads to the unfolding of globular proteins followed by association to form aggregates. Researchers have shown that Alpha-lactalbumin heated alone did not form aggregates while Beta-lactoglobulin formed large aggregates with no evidence of intermediates. However, the two proteins interact to form soluble aggregates, as well as larger particles, by means of both disulfide bonds and hydrophobic interactions. This step can lead to the formation of small aggregate precipitates or gel lattice structures. Small aggregates remain soluble, they bind increased amounts of water, increase viscosity and add body or improve the product texture. However, gelation and some flocculating can occur. Heat stability of WPCs can be increased during manufacture by using a demineralization step along with some controlled heat denaturation. Lowering the pH of WPCs has been shown to inhibit unfolding of the protein and to increase their stability to thermal denaturation. Controlling the heat denaturation process in low-fat systems to prevent defects is important. Some precautions to follow include keeping the temperature below 75°C while the system is dilute. Denaturation of WPCs decreases from 80% to 40% when solids increase from 9% to 44% (with heating at 80°C for 20 minutes). Finally, adjusting calcium levels with chelators can be effective in some systems.

Water Binding

Efficient water binding is an important function provided by WPCs in reduced and fat-free salad dressings. The retained water improves texture and reduces cost by replacing oil with water. This function is also valuable in reduced-fat chopped meat and seafood products, providing improved texture and mouthfeel.

Increased Solubility, Modified Properties

Selected modifications to WPCs by proteases (protein cleaving enzymes) can be done to modify their properties. The degree of hydrolysis is carefully controlled to enhance desired functions. Such treatments can optimize different functional properties: increased solubility over pH ranges, decreased viscosity and significant changes in foaming, gelling and emulsifying properties. These new functional properties of the hydrolyzed proteins are related, to a large degree, to their molecular size and hydrophobicity. U.S. suppliers of these products offer additional information on their characteristics, benefits and applications.

Benefits of U.S. Whey Ingredients in *Low-fat Meat Products*

- Whey proteins possess both hydrophilic and hydrophobic regions, which account for their good emulsification properties. This capability permits interaction with meat pieces, fat and other ingredients, and retaining water and fat, which are essential for moistness and mouthfeel in low-fat products.
- Heat-induced gelation develops three-dimensional networks, providing binding of meat juices and added formula water. Retention of fat is especially important in reduced-fat products to prevent dryness and maintain some lubricity. Significant economical advantages are realized with higher water retention.
- Whey proteins are compatible with other meat ingredients and fat mimetics, allowing increased flexibility in formulating reduced-fat meat products. Synergistic effects are observed with other fat replacers and yield cost-effective formulation solutions.

In meat processes which utilize injection or vacuum tumbling to introduce proteins and other ingredients into the meat pieces, proteins serve to increase yields, reduce cook shrinkage by binding water and fat, and help bind meat pieces. Comparatives studies indicate that widely used soy isolates and caseinates may be less optimal than some functionally enhanced WPCs in many meat applications. The use of WPCs can help decrease ingredient costs, increase process efficiency and help optimize product quality and consumer preferences.

Benefits of U.S. Whey Ingredients in *Reduced-fat Salad Dressings*

- Efficient dispersion of fat from the high emulsification properties aids in low-fat applications. This yields high opacity to salad dressings and the appearance of regular, high-fat products. This function is particularly critical to increase the consumer appeal and acceptability of this type of product.
- Water binding enhancement by whey proteins is important in reduced-fat and fat-free formulations. This is important to retain the increased water in the formula, to replace fat and maintain texture and yield.
- Stable emulsions are formed in extended shelf-life products, even in acid systems as in salad dressings.
- Full and partial egg yolk replacement gives equivalent product qualities and provides cost-saving opportunities. Heat treatments generally increase the functionality of WPCs, even in acidic dressings, whereas egg yolks tend to break down.

Benefits of U.S. *Whey Protein Concentrates in Reduced-fat Soups and Sauces*

- Whey proteins provide fat-like functions of lubricity and significantly improve the mouthfeel of low-fat soups and sauces.
- Whey proteins contribute to increased opacity and help reduced-fat soups and sauces retain a good visual appeal, with the creamy appearance of regular products.
- Emulsification properties of whey proteins aid in efficient dispersion of fat by forming interfacial membranes around oil globules that prevent creaming, coalescence, and oiling off. Whey proteins contribute to increased shelf-life in terms of product appearance and consumer acceptability.
- Thermal gelation adds viscosity and texture to condensed ready-to-serve and frozen soups and sauces. This helps retain a desirable creaminess and pleasant mouthfeel. By enhancing thickening and viscosity, WPCs aid in emulsion stability in the final product.
- WPC34 adds a clean dairy flavor and higher protein WPCs have a clean, bland flavor that blends well with other flavors present in the system.

QUESTIONS AND ANSWERS

Q. Do WPCs *have any flavor impact in low-fat products?*

A. WPCs generally have very little flavor of their own, but WPC34 may have slight dairy notes with some light sweetness. The whey proteins do bind some flavors and this can be apparent in low-fat systems since the fat that normally carries flavors is reduced. Depending on the application it is often necessary to increase added flavors to compensate for this type of interaction. The "whey flavor defect" is not found in WPCs.

Q. *Does using* WPCs *in low-fat products increase costs?*

A. Generally, low-fat products do cost more and sell for a higher price. The WPC cost, along with other mimetics and flavors can increase the price of the product, compared to a simple, lower quality product. However, these highly functional ingredients are effective at low levels and replace or displace other more expensive ingredients such as modified starches, hydrocolloids and emulsifiers. Furthermore increased yields are often realized by water and fat retention, yielding increased product quality and cost adjustments. Ingredient cost savings of 10%-20% can be achieved using WPCs, depending upon the cost of other ingredients and processing variables.

Q. *Are processing changes required when using* WPCs *in low-fat applications?*

A. Each application has its unique requirements that also dictates which WPC should be selected for a specific application. For heat-processed soups and sauces where the WPC is an emulsifier and texturizer, some caution is required when blending the product, taking care with the heating conditions to avoid forming large insoluble precipitates. Selecting a more heat stable WPC will reduce this caution, careful control of the heat treatment is also recommended.

In salad dressing applications, a cold gelling WPC may have little heat stability, and in meat applications attention to salt sensitivity and viscosity may be important. U.S. WPC manufacturers and suppliers will have specific application guidelines for their ingredients.

Q. *Is there a guideline to determine which type of* WPC *is needed for an application?*

A. If cost-effectiveness is a primary concern, the lowest protein level that will provide the functionality is generally best. Each application is unique, but as the level of protein increases in the WPC, less may be required to perform the desired function and yield the best end-result. In some applications, one way to increase price/value of WPC is to add a heat treatment to a standard WPC34 or WPC50 thereby increasing its functionality. In emulsion-based low-fat applications this can be accomplished by heating the pre-emulsion blend to 60-80°C for 5 minutes, followed by homogenization. Significant viscosity and texture increases are obtained.

Q. Do WPCs *provide nutritional benefits?*

A. Whey protein concentrates help increase the protein content of low-fat foods. Furthermore, these high-quality proteins will help boost the Protein Efficiency Ratio of soups and sauces. They are highly desirable in diet foods, formulations for athletes, senior citizens and children. The calcium content of whey protein concentrates, that can be as high as 800 mg/100 g or more (equivalent to high-calcium cheeses), should be taken into account when calculating the nutrient content of formulations. WPCs are valuable ingredients in calcium-enriched foods for children, pregnant women or older consumers.

When designing "low-carbohydrate" reduced-fat products, WPC80 and whey protein isolates should be selected as they contain very low amounts of lactose.

15.4 WHEY PRODUCTS, EDIBLE FILMS AND COATINGS

Edited by
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Edible films made from WPI or WPCs have many potential applications for the food industry. Research into WPI and WPC edible films is providing the information necessary to realize some of these applications, including the formation of edible films as oxygen-barrier coatings on nuts and nut-containing products; glossy coatings on chocolate, chocolate-covered confections and yogurt-covered products; atmosphere-modifying coatings on fresh fruits and vegetables; mold-reducing coatings on cheese; and integrity-enhancing (i.e., damage preventing) coatings on fragile freeze-dried foods. Additional research into the formation of edible films by extrusion for making pouches and bags for dry milk powders, dry soup mixes and dry drink mixes is also under way. Besides improving food quality, use of edible films and coatings generally reduces the amount of packaging required and improves recyclability of the resulting simpler, cheaper package.

Whey protein gels, which are constructed from WPIs or whey protein concentrates are a growing area of application research. Whey protein gel has the potential to be a cost-effective alternative to other gelation products, including egg whites, soy protein and gelatin in foods such as surimi, meat products and dairy-based foods. In addition, whey protein ingredients may have distinct advantages and allow processors to use an "all-dairy" food ingredient label. Research into whey polymers formed through thermal polymerization shows that whey protein polymers will form gels at room temperature and higher when salts are added. This avoids the problem of the high temperature needed for gelation without salts. Due to the unique characteristics of whey protein polymers, there is a possibility they could be used in ways similar to hydrocolloids—as stabilizers in ice cream or to modify viscosity characteristics in foods.

15.5 PROCESSED FOODS AND SNACKS FORMULATIONS

Reduced-fat Processed Cheese Sauce

Ingredients	Usage Level (%)
Cheddar cheese, 100 day	39.72
Low fat milk (1.0%)	24.81
Skim milk	24.81
WPC50	7.88
Salt	1.50
Carrageenan	0.70
Cheddar-type flavor	0.50
Annatto	0.08
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Add cheddar cheese to Blentech apparatus.
2. Add all dry ingredients and blend until well mixed.
3. Add milk and cream to mixer.
4. Agitate continuously while heating, until temperature reaches 85°C (185°F).
5. Hold at this temperature for 5 minutes, to insure pasteurization.
6. Fill containers and cool.
7. Store at refrigeration temperatures.

Fat-free Thousand Island Dressing

Ingredients	Usage Level (%)
Fraction 1a	
Water	50.47
Sugar	10.00
Salt	1.00
Fraction 1b	
WPC80	2.00
WPC70	3.00
Modified starch	2.00
Xanthan gum	0.10
Guar gum	0.10
Fraction 2	
Vegetable oil	1.00
Fraction 3	
Sweet pickle	10.50
Tomato paste	10.50
Vinegar 12%	5.00
Mustard	2.30
Onion powder	1.50
Flavoring	0.2–1.0
Total	**100.00**

Formula courtesy of FS&T Consulting.

Procedure:

1. Add Fraction 1a to emulsifying equipment.
2. Mix Fraction 1b with part of oil in Fraction 2 then add to Fraction1a.
3. Homogenize until the optimum viscosity is produced.
4. Emulsify Fraction 2 into Fraction 1.
5. Mix Fraction 3 into the emulsion.

Benefits:

- Full functionality in cold-processed high acid dressing.
- Egg yolk replacement is cost-efficient and desirable from a bacteriological standpoint.
- WPCs have excellent emulsifying properties, yield smooth and creamy texture.
- WPCs increase product opacity, appearance and consumer appeal.
- WPCs have a neutral taste.

Reduced-fat "French" Salad Dressing

Ingredients	Usage Level (%)
Tomato puree	10.00
Water	14.50
Seasoning Dry Blend	
Paprika	0.05
Oregano	0.02
Ground mustard	0.30
Xanthan gum	0.30
Propylene glycol alginate	0.10
Salt	1.30
Sugar	19.93
Vinegar	22.50
WPC Solution	
Water	7.50
WPC80	3.50
Vegetable oil	20.00
Total	**100.00**

Formula courtesy of Calpro Ingredients/DFA.

Procedure:

1. Mix at medium speed tomato puree and water.
2. Add dry blended seasonings.
3. Add vinegar.
4. Add WPC80 solution.
5. Slowly add vegetable oil at increased mixing speed.
6. Deaerate using 750 mm vacuum.

Low-fat Cream of Celery Soup

Ingredients	Usage Level (%)
Emulsion Fraction	
WPC75	0.70
Buttermilk powder	0.60
Cream (30% fat)	1.55
Vegetable oil	1.50
Water	12.00
Condiments	
Celery, diced	18.00
Water	22.00
Salt	1.30
Flavors	0.50
Sugar	1.20
Thickener Fraction	
Modified starch	3.50
Wheat flour	1.40
Corn starch	1.80
Water for slurry	14.00
Steam condensate and final dilution	**19.95**
Total	**100.00**

Formula courtesy of FS&T Consulting.

Procedure:

Emulsion Preparation:

1. Hydrate dairy powders in water at 38°C.
2. Add oil and cream to hydrated milk proteins and blend.
3. Heat to 60°C and homogenize at 211 kgf/cm sq.

Soup Preparation:

1. Blanch celery in formula water for 3-4 minutes at 90-95°C.
2. Add salt, sugar and flavors.
3. Heat with live steam to 60°C.
4. Add emulsion to the kettle.
5. Add the thickener slurry and heat with live steam to expand the starch (88-92°C).
6. Adjust to final weight with hot water, mix thoroughly.
7. Fill into cans while hot.

Premium Reduced-fat Cream of Mushroom Soup

Ingredients	Usage Level (%)
Emulsion Fraction	
WPC75	0.60
Skim milk powder	1.40
Vegetable oil	1.75
Cream (30% fat)	1.85
Disodium phosphate	0.50
Water	14.00
Condiments	
Mushrooms, diced	14.00
Salt	1.80
Dairy flavors	0.40
Flavor enhancers	1.05
Water	19.00
Thickener Fraction	
Wheat flour	1.00
Modified starch	3.30
Corn starch	1.60
Water to slurry	15.00
Steam condensate and final dilution water	**22.75**
Total	**100.00**

Formula courtesy of FS&T Consulting.

Procedure:

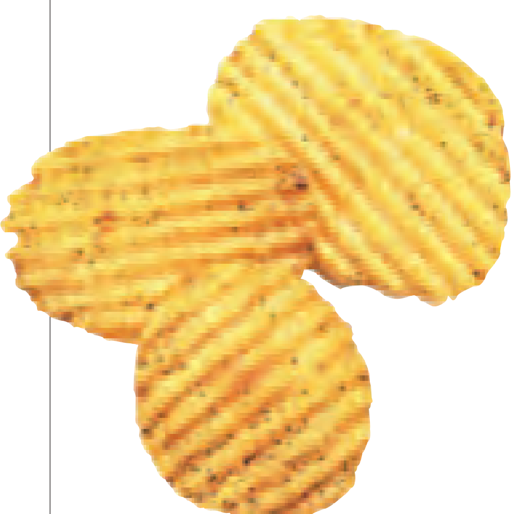
Emulsion Preparation:

1. Hydrate dairy powders in water at 38°C.
2. Add oil and cream to hydrated milk proteins and blend.
3. Heat to 60°C and homogenize at 211 kgf/cm sq.

Soup Preparation:

1. Blanch mushrooms in formula water for 3-4 minutes at 90-95°C.
2. Add salt, flavors and flavor enhancers.
3. Heat with live steam to 40°C.
4. Add emulsion to the kettle.
5. Add the thickener slurry and heat to expand the starch (88-92°C).
6. Adjust to final weight with hot water, mix thoroughly.
7. Fill into cans while hot.

15.6 FORMULATIONS FOR SNACKS



Sour Cream and Onion Seasoning for Potato-based Snack

Ingredients	Usage Level (%)
Sour cream powder	25.00
Sweet whey powder	25.00
Skim milk powder	10.00
Salt	12.00
Dextrose	10.00
Onion, dried	10.00
Monosodium glutamate	5.00
Parsley, dried	1.50
Citric acid	1.00
Free flow agent	0.50
Total	**100.00**

Formula courtesy of FS&T Consulting.

This formula is an example of a sour cream and onion seasoning for potato chips. The flavoring is dusted directly onto the chips while they are hot after emerging from the fryer. The surface coating of oil is essential for the coating to adhere. Pickup (coating level) is targeted at 6%-8% by weight of the finished product. Salt levels must be considered to balance desired salt levels of 1.5%-2.0% with the required flavor intensity. Adjustments must be made on pre-salted chip applications to give adequate coverage for appearance and not exceed salt targets.

This formula is a cost-reduced formula, which uses sweet whey powder to extend sour cream powder and enhance flavor. This formulation can be used on fabricated potato chips, extruded potato sticks and snack crackers, for example.

"Ranch" Seasoning for Corn-based Chips

Ingredients	Usage Level (%)
Salt, flour	20.00
Whey solids	12.00
Buttermilk solids	16.00
Maltodextrin	10.00
Cornstarch	10.00
Shortening powder	5.00
Dextrose	6.00
Tomato powder	3.00
Cheese solids	2.00
Monosodium glutamate	5.00
Onion powder	3.50
Garlic powder	1.20
Flavors	1.00
Lactic acid	1.00
Citric acid	0.80
Parsley	1.50
Paprika	0.50
Anticaking agent	0.50
Buffers, di-sodium phosphates	1.00
Total	**100.00**

Formula courtesy of FS&T Consulting.

This formula is for a topical "Ranch" seasoning blend for unsalted tortilla chips. A recommended application level of 8% gives good color contrast on a darker chip, relative to potato chips. The whey solids complement and enhance the buttermilk and cheese solids, yielding a mild milky flavor. This formula uses three cost-efficient carriers (whey, maltodextrin and corn starch) to add volume and allow for higher usage. The highly visible seasoning adds consumer appeal. The particle size of all the ingredients must be very fine to get good adherence to the lower oil content of tortilla chips.

Cheese Seasonings for Extruded Snacks

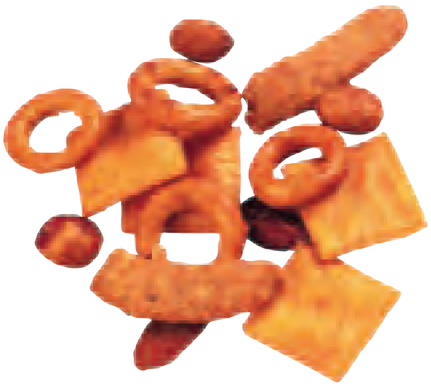
	Usage Level (%)		
Ingredient	**Formula A**	**Formula B**	**Formula C**
Cheddar cheese powder	80.00	68.00	15.00
Whey solids	8.50	19.50	25.00
Buttermilk solids	–	–	15.00
Maltodextrins	–	–	12.50
Dextrose	–	–	8.00
Salt, flour	6.20	6.20	8.00
MSG	4.00	4.00	4.00
Torula yeast	–	–	3.00
Autolyzed yeast	–	–	3.00
Lactic acid	0.30	0.30	1.00
Enzyme modified cheese flavor	1.00	1.00	1.50
Encapsulated butter flavor	–	1.00	1.00
Disodium phosphate	–	–	0.80
Disodium inosinate and guanylate	–	–	0.20
Yellow coloring	–	–	1.00
Flow/anticaking agent	–	–	1.00
Total	**100.00**	**100.00**	**100.00**

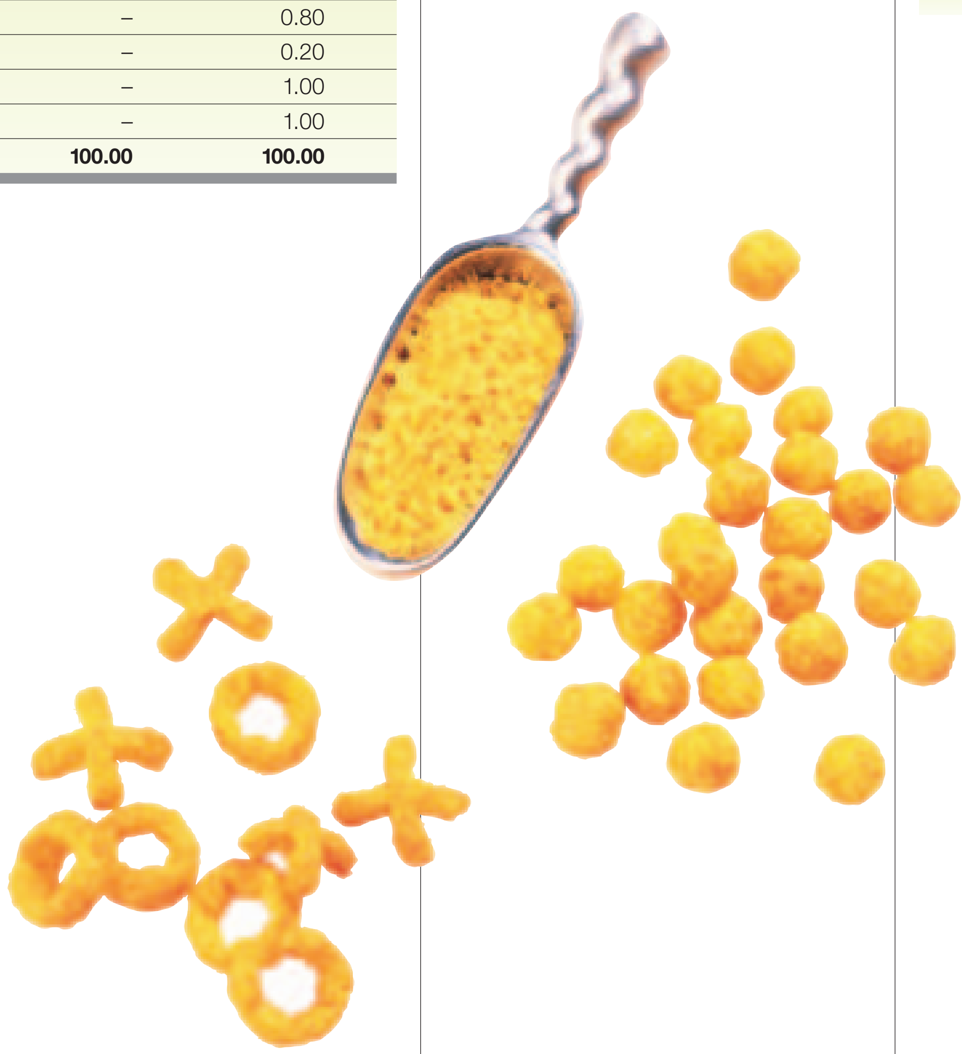
Formula courtesy of FS&T Consulting.

Procedure:

1. Mix dry ingredients thoroughly and blend with vegetable oil in ratio of 1 part to 2 parts oil.
2. Spray uniformly on cheese curls or other extruded snack.

This formula is provided for demonstration purposes and as a starting point for product development efforts. Adjustments may be required. Please check local regulations for the use of product names and specific ingredients.





15.7 CO-EXTRUDED SNACK FORMULATIONS

Savory Snack

Ingredients	Usage Level (%)
Corn meal	80.00
Wheat bran	10.00
Skim milk powder	6.00
WPC34	3.00
Salt	1.00
Filling	
Cheese powder	24.00
Vegetable oil	30.00
Shortening	14.00
Corn starch	10.00
Skim milk powder	10.00
Whey powder	10.00
Salt	2.00
Total	**100.00**

Formula courtesy of FS&T Consulting.

This formula is provided for demonstration purposes and as a starting point for product development efforts. Adjustments may be required. Please check local regulations for the use of product names and specific ingredients.

Sweet Snack

Ingredients	Usage Level (%)
Wheat flour	70.00
Sugar	20.00
Skim milk powder	6.00
WPC34	3.00
Salt	1.00
Filling	
Powdered sugar	50.00
Vegetable oil	21.00
Shortening	11.00
Corn starch	11.00
Cocoa powder	7.00
Total	**100.00**

Formula courtesy of FS&T Consulting.

This formula is provided for demonstration purposes and as a starting point for product development efforts. Adjustments may be required. Please check local regulations for the use of product names and specific ingredients.

15.8 FORMULATIONS FOR OTHER PROCESSED FOODS

Refrigerated Pasta

Ingredients	Usage Level (%)
Durum semolina	68.32
Water	30.31
WPC80	1.37
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Mix WPC80 and semolina together in a mixer bowl.
2. Add water and mix for 3 minutes on low speed.
3. Allow to rest at room temperature for 15 minutes.
4. Put through a pasta machine to sheet and cut.
5. Cook in boiling water until tender. Store remaining in refrigerator.

Cheddar Cheese Sauce

Ingredients	Usage Level (%)
Water	63.20
Cheddar cheese	17.50
Anhydrous butterfat	5.82
Dry reduced-lactose whey	4.45
Starch, modified waxy maize	4.20
Disodium phosphate	1.80
Flavors*	1.30
Salt	1.00
Monosodium phosphate	0.40
Lactic acid (88%)	0.30
Annatto	0.03
Total	**100.00**

*Flavor of final product is determined by choice of flavors.
Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Place reduced-lactose whey, starch, salt, lactic acid and flavors on top of cheese mixture.
2. Melt the anhydrous butterfat and combine it with color. Add this mixture to the solubilize cheese.
3. Begin mixing, while heating to 70°C (160°F).
4. Heat sufficiently to insure pasteurization of the cheese sauce.
5. Fill containers at 80°C (175°F).
6. Cool immediately. Keep refrigerated at 5°C (40°F) during transfer, storage and distribution.

Dry Mix Cheese Sauce

Ingredients	Usage Level (%)
Dry cheese powder*	40.00
Sweet whey powder	25.00
Starch, modified, cook-up**	22.40
WPC35	9.00
Salt	3.60
Total	**100.00**

*Choice of cheese powder based on desired profile of end product.
**Choice of cook-up or instant starch based on method of sauce preparation.
Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

Dry Sauce Mix:

1. Dry blend all ingredients until homogeneous.
2. Place 43g per package.

Cheese Sauce Preparation:

1. Add 43g sauce mix to sauce pan with 2 cups milk and stir until dispersed.
2. Cook over medium-low heat until thick and bubbly. Serve immediately.

Creamy Italian Dressing—Nonfat Dry Mix

Ingredients	Usage Level (%)
Salt	14.49
Powdered vinegar	13.50
Fructose	13.48
Dry sweet whey	13.26
Sugar	12.15
Fat replacer instant starch	12.15
Starch	4.42
Garlic powder	3.85
Citric acid	3.31
Dry mustard	1.55
Basil	1.55
Parsley	1.24
Xanthan gum	1.10
Onion powder	0.93
Black pepper	0.93
Guar gum	0.77
Paprika	0.50–1.00
TiO_2	0.33
Oregano	0.50
Dill	<0.50
Total	**100.00**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

Dry Mix:

1. Mix together all ingredients thoroughly.
2. Place 50g of dry mixture per package.

Salad Dressing:

1. Mix 50g dry mix salad dressing with 1/2 cup water using a whisk or electric mixer, or shake in a bottle.
2. Add 1/2 cup skim milk and mix vigorously.
3. Store in refrigerator for at least 1 hour before serving.

NUTRITIONAL PRODUCTS APPLICATIONS FOR WHEY PRODUCTS 16

Formulary edited by
KATHY NELSON
Wisconsin Center for Dairy Research, Madison, WI

16.1 WHEY PRODUCTS IN INFANT FORMULA/ CHILD NUTRITION

By DR. BEATE LLOYD
Global Research Solutions, Johnstown, OH

Whey proteins are widely used as a high quality protein source and as a source of active peptides in healthy foods. Infant formula manufacturers are increasingly adding whey proteins to cow milk-based infant formulas to match the high concentration of whey in human milk, and to formulas for infants with special needs including fussiness, colic and allergy to cow milk protein. While literature supportive of the use of whey proteins in infant formula for fussiness and colic is limited, there are numerous peer-reviewed reports on the use of hydrolyzed whey protein for milk protein allergy. In the case of milk protein allergy, sole source use of hydrolyzed whey protein is being motivated by its high biologic value and superior taste and smell compared to casein hydrolysates. Benefits of supplementing infant formulas with whey protein are discussed in the following sections.

Human milk is widely considered to be the ideal feeding for newborn infants. Its uniquely suited composition is thought to have resulted from the effects of time and evolution on nutritional compromise between mother and infant. Thousands of years ago antibodies directed at pathogens encountered by the mother were certainly important for the survival of the infant. Human milk also contains an incredible array of functional enzymes, growth factors, gastrointestinal protective factors, functional immune cells and non-protein nitrogen sources. Changes in composition occurring over the course of lactation render human milk a remarkably complex infant food.

The ultimate goal of an infant formula manufacturer cannot possibly be to match this amazing complexity using industrial cow milk preparations. Rather, their goal is to make the second best infant feeding available by targeting the major differences between human milk and infant formulas. Cow milk protein-based infant formulas are relied upon to provide optimal nutritional support for infants that, for a variety of reasons, cannot be, or are not, breastfed. Comparatively limited numbers of infants are fed formulas based on protein sources other than milk (O'Connor et al., 1997). Yet some of the desirable components of human milk (pathogen-specific human milk IgA) are either too variable or too costly to be considered for addition to infant formula. Cow milk itself does not match the superb, evolutionary adaptation of human milk to the nutritional needs of the infant. One of the primary compositional gaps between human milk and cow milk-based infant formula is the difference in whey protein content. Technical advances in milk protein chemistry have led to a number of economical solutions to this "deficiency" in cow milk-based infant formulas.

The question for the infant formula manufacturer is, to what degree does infant formula need to be humanized? Plausible answers to this question range from humanizing the whey to casein ratio to the use of modified whey protein to serve a particular, and sometimes critical, function in infants. Examples of the latter are hydrolyzed whey protein for cow milk protein allergy and an increased whey to casein ratio to support favorable metabolic balance in premature infants.

Compositional Strategy for the Use of Whey Protein

The milks of most mammals contain the same general classes of proteins, casein and whey. However, these are functional definitions based on whether the respective proteins precipitate or remain soluble in response to manipulations in milk pH. Whereas, whey proteins are soluble at lower pH, casein proteins are insoluble and precipitate. The species-dependent compositional heterogeneity within these functional classes is most dramatic in whey proteins. While, human milk is whey predominant, cow milk is casein predominant. The whey to casein ratio of mature human milk is 60:40 and that of cow milk is 18:82. As a result, some infant formula manufacturers have chosen to enrich their cow milk-based formula by adding whey protein. This requires the addition of enough whey protein to consist of 42% of the total protein provided by the formula. Approximately 6 g of whey protein would need to be added to 9 g cow milk protein in a typical cow milk-based formula delivering 15 g protein/L. This strategy has been popular throughout the world and has the advantage of a simple marketing message that can easily be comprehended by parents.

The whey to casein ratio of human milk changes as a function of the stage of lactation from 90:10 in early lactation, to 60:40 in mature milk and 50:50 in late lactation (Kunz and Lonnerdahl, 1992). Which of the human milk ratios is the correct target for an infant formula manufacturer? The industry has decided that the whey to casein ratio of mature human milk is the most appropriate composition for an infant formula. However, the relative amounts of the whey proteins are dramatically different in human and cow milk. Another approach would be to increase the concentration of Alpha-lactalbumin and lactoferrin in cow milk using fractionation technology. However, this approach is not currently feasible for most infant formula markets. In the end, the compositional strategy is undermined by species-dependent heterogeneity in whey proteins and technical/cost limitations.

Plasma Amino Acid Strategy for the Use of Whey Proteins

One can argue that generations of infants have grown perfectly well, without ill effects, on formulas made from unmodified cow milk. However, taurine, for example, was not included in infant formulas for decades, only to be suspected to be essential in the infant (Gaull, 1989). In this context, human milk produces a different plasma essential amino acid profile in the infant than unmodified cow milk or whey protein infant formulas (Paule et al., 1996). Infants are known to be particularly sensitive to alterations in plasma amino acid profiles (O'Tuama et al., 1991). Perhaps reflecting this sensitivity, total amino acid requirements of the human infant are much higher than those at other stages of life (Munro, 1972). These elevated requirements reflect the rapid rate of growth and development of the infant. In this context, it is important to consider that a formula-fed infant consumes all of its protein from a sole source until the introduction of solid foods. This means that formula-fed infants are uniquely susceptible to nutritional insufficiencies, the results of which could be devastating.

Given the widespread use of cow milk-based infant formula, infants will benefit from improvements that more closely match the plasma essential amino acid profile of the breastfed infant. Amino acids have functions beyond serving as substrate for protein synthesis, including the synthesis of hormones, bile acids, and neurotransmitters. An example of the effect of a dietary amino acid on neurotransmitters and behavior is provided by tryptophan. Sleep latency was reduced in infants fed supplemental tryptophan (Yogman and Zeisel, 1983; Steinberg et al., 1992). Plasma tryptophan concentration (Steinberg et al., 1992) was increased and is thought to increase the transport of tryptophan across the blood brain barrier (Pardridge, 1983; Smith, 1991) leading to elevated conversion of tryptophan to serotonin and melatonin in the brain, ultimately leading to changes in sleep behavior. Based on this evidence, the goal of this strategy is to match the plasma amino acid profile of the breast-fed infant as closely as possible.

A mathematical equation that yields a single value summarizing the closeness of a formulation to the plasma essential amino acid profile of a breast-fed infant has been developed (Paule et al., 1996; O'Connor et al., 1997). These data revealed that a formula with a whey to casein ratio of 48:52 yielded a plasma essential amino acid profile closer to that of human milk than either a formula with a 60:40 whey to casein ratio, or a formula with 100% whey protein. Thus, the formula with the 60:40 whey to casein ratio of human milk did not match the human milk plasma essential amino acid profile as well as formulas with less whey. This equation can predict the plasma essential amino acid profile of any protein mixture, as long as the amino acid profiles of the constituent proteins are known.

Premature Infants

The vast majority of formulas marketed for premature infant formulas are whey predominant with a whey to casein ratio of 60:40. It is thought that casein predominant formulas lead to excessive plasma concentrations of tyrosine and phenylalanine (Rigo and Senterre, 1987; Axelsson et al., 1989). In addition, those fed whey predominant formulas had metabolic responses more similar to those observed in premature infants fed pooled human milk (Raiha et al., 1976; Kashyap et al., 1988). In order to meet the high protein requirements of premature infants these formulas typically contain a total of 20 to 24 g protein/L.

Use of Modified Whey Protein

There has been an interest in the use of cow milk whey protein enriched in Alpha-lactalbumin due to its high concentration in human milk and its beneficial amino acid profile. In particular, it is hypothesized that an Alpha-lactalbumin-enriched acid whey protein concentrate would facilitate a very close plasma amino acid profile match for human milk. Alpha-lactalbumin has high concentrations of cystine and unusually high concentrations of tryptophan (Heine, 1999). Increased concentrations of Alpha-lactalbumin in protein-reduced cow milk-based infant formula elevated plasma tryptophan concentration to the same level seen in breast-fed infants (Heine et al., 1996). Protein reduced formulas were fed to enhance the plasma ratio of tryptophan to the other large neutral amino acids, as discussed above. Recent technological advances would likely obviate the requirement for protein reduction in order to see breast-fed plasma concentrations of tryptophan.

While the incidence of allergy to cow milk protein is rare, the symptoms are severe and in some cases life threatening. The symptoms include vomiting, diarrhea, gastrointestinal disturbances, excessive crying, eczema, loss of weight and even anaphylactic shock. Traditionally, formulas made with extensively hydrolyzed casein have been used to manage infants with severe milk protein allergies. In the 1990's, extensively hydrolyzed whey protein formulas have been found to be an effective treatment in infants and children with cow milk allergy (Ragno et al., 1993; Halken et al., 1993; Odelram et al., 1996). These formulas tend to have significant cost, taste and odor advantages over their casein counterparts. In addition, recent evidence suggests that extensively hydrolyzed whey protein formulas are an effective means of treating the symptoms of colic in milk allergic infants (Lucassen et al., 2000).

Cow milk whey protein plays a prominent role in infant nutrition. As researchers discover new nutritional and health benefits hidden within this wonderful and plentiful protein source, its use in infant nutrition continues to broaden.

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16.2 WHEY, LACTOSE AND THEIR DERIVATIVES IN NUTRITIONAL AND SPORTS FOOD PRODUCTS

By DR. KWOK-MAN LEE
Proliant, Inc.

Whey proteins, including whey protein concentrates, whey protein hydrolysates (WPH), and whey protein isolates, are commonly used in nutritional and sports food products. Whey proteins provide an outstanding protein source for nutrition-conscious consumers and body builders in order to obtain better nutritional values and to gain lean muscle. The protein efficiency ratio (PER) and protein digestibility corrected amino acid score (PDCAAS) of whey proteins are 3.2 and 1.0, respectively, which indicate that whey protein is a excellent source of essential amino acids. Whey protein can be easily formulated in dietetic and health foods, such as nutritional supplements, protein drink mixes, sports meals, protein bars, high-protein cookies, and even in tablet forms.

In a beverage application, solubility of whey protein is a primary requisite. Native (undenatured) protein is highly soluble in a wide range of pH from 3 to 8, which is a unique functional attribute for either acidic or neutral pH beverages.

Whey protein is commonly used in acidic beverages, such as fruit flavored beverages, and acidic protein drinks. The protein structure of whey protein with dynamic hydrophilic and hydrophobic regions acts as an emulsifier interacting with oil and aqueous phases.

Most of the dry protein drink mixes are formulated with a protein blend of instantized whey protein, WPH, or other protein sources. Dry protein drinks made with instantized WPC and WPH provide not only nutritional benefits but also excellent dispersibility. WPH, which is created by using a protease to break up the protein into smaller peptides, is considered one of the most digestible forms of protein. The hydrolyzed protein has small peptides, so people digest and absorb the proteins more easily. The functional properties of WPC and WPH in protein mixes are solubility, dispersibility, opacity, suspension stability, smooth mouth feel, bland flavor.

16.3 WHEY APPLICATIONS IN SPORTS AND NUTRITION BARS

By DR. J. BOUZAS
Hershey Foods Corporation, Hershey, PA

Nutrition bars are showing the fastest and most explosive growth in the sports nutrition market. Nutrition bars can be baked or extruded with textures ranging from that of brownies or cookies to a chewy/nougat like texture.

Dairy proteins have a special place in the formulation of these products. Because of good functionality and also excellent nutritional characteristics, whey derived ingredients play a critical role when a nutritional bar is formulated. High protein whey protein concentrates (80%) and whey protein isolates (90%) are key elements in the formulation of these bars. WPIs also provide a balanced amino acid profile.

The sensory characteristics of nutrition bars such as appearance (smoothness and shininess), texture (flexibility, firmness, moistness, graininess, stickiness, chewiness, mouthfeel, and chalkiness), and positive or negative flavor attributes (protein, vitamin, milky, bitter, wheaty, stale) could all be effected by the ingredients used, especially the source of protein. Generally speaking, WPCs and WPIs offer blander, milkier flavor profiles, considerably better than those provided by soy protein, with its wheaty, beany notes or egg albumin, which contributes a moderate stale taste.

Texture is notably affected by the type of protein used in the formulation. Bars made with dairy proteins, especially WPIs, are more pliable and moderately firm, than slightly less chewy bars made with other protein sources. Formulations and processing conditions for nutrition bars can be found in the formulation section of this chapter.

16.4 WHEY PRODUCTS, CALCIUM AND WEIGHT LOSS

By DR. MICHAEL B. ZEMEL
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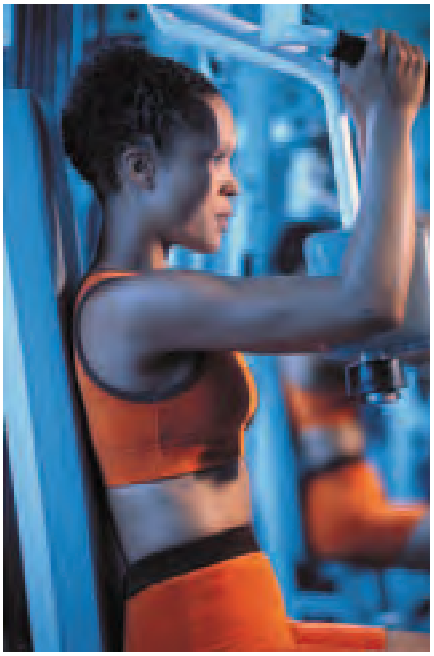
Dietary calcium and dairy products are well recognized to play an important role in the prevention of chronic disease, including hypertension, cardiovascular disease, osteoporosis and colon cancer. Among these, the practical relevance of the blood pressure benefits of dairy products was clearly demonstrated in the DASH (Dietary Approaches to Stop Hypertension) trial, which demonstrated that increasing consumption of low-fat dairy products exerts profound effects on blood pressure regulation (1-3). Although this effect is largely attributable to the calcium contained in dairy products, an evaluation of multiple food-based versus supplement-based trials demonstrates that dairy sources of calcium exert approximately two-fold greater, and more consistent, antihypertensive effects than found with calcium supplements (1). An accumulating body of recent evidence now suggests that dietary calcium plays a pivotal role in the regulation of energy metabolism and, consequently, reduces body weight and fat. Thus, dairy-rich diets not only reduce cardiovascular risk by exerting an antihypertensive effect, but also by reducing the risk of obesity (4). Dairy-rich diets produce metabolic effects, which result in a significant reduction of body fat. A clinical trial of the antihypertensive effect of calcium in obese African-Americans in which dietary calcium was increased from approximately 400 to approximately 1,000 mg/day by feeding two cups of yogurt/day resulted not only in lower blood pressure, but also a significant 4.9 kg reduction in body fat (5). Although the data were inexplicable at the time, they have recently been re-evaluated and placed in a logical theoretical framework based upon recent research describing the role of intracellular calcium in the regulation of adipocyte metabolism. This work, described below, shows that dairy-rich diets are likely to play an important role in the prevention of obesity in both children and adults, as well as in the management of adult obesity. Interestingly, as with the antihypertensive effect of calcium described above, dairy sources of calcium are markedly more effective than calcium supplements in the management of obesity and available evidence suggests that the additional "anti-obesity" bioactivity is found in whey.



Mechanisms

The theoretical framework for this work emerged from studies of the mechanism of action of agouti, an obesity gene expressed in human adipocytes. These studies demonstrate that agouti stimulates calcium influx into adipocytes and that the increase in intracellular calcium is directly responsible for promoting fat storage in human adipocytes by coordinately stimulating fat synthesis and inhibiting net fat breakdown (6-9). Conversely, pharmacological treatment of either human adipocytes or intact mice to inhibit calcium influx results in significant reductions in adipose tissue lipid stores, total fat mass and body weight (8-10). This observation demonstrates that adipocyte calcium modulates energy storage and may be a logical target for interventions to control adiposity and manage obesity. However, this proposal also introduces a paradox: that increasing intracellular calcium promotes obesity while increasing dietary calcium inhibits obesity. Similarly, the calcium paradox of essential hypertension indicated that dietary calcium reduced blood pressure despite the fact that increased intracellular calcium was responsible for increases in blood pressure. The resolution of this paradox emerges from an understanding of the endocrine systems, which regulate the body's "calcium economy" during periods of suboptimal calcium intake.

Parathyroid hormone and calcitriol, both of which are elevated in response to low calcium diets, stimulate calcium influx into multiple cell types. Accordingly, it is possible that one or both calcitrophic hormones increase intracellular calcium in adipocytes as well. Indeed, both parathyroid hormone and calcitriol elicit rapid, sustained increases in intracellular calcium in human adipocytes (5,11), and calcitriol stimulates marked increases in human adipocyte lipogenesis and inhibition of lipolysis (11). Accordingly, suppression of calcitriol by increasing dietary calcium is an attractive target for the prevention and management of obesity. Thus, low calcium diets, by virtue of eliciting a calcitriol response, promote adipose tissue lipid storage, while high calcium diets suppress calcitriol levels and inhibit lipogenesis, increase lipolysis and net lipid mobilization, thereby resulting in a shift in energy partitioning from adipose to lean tissue, resulting in a leaner phenotype at any given level of energy intake and acceleration of weight and fat loss during caloric restriction (5,11-13).

Role of Calcium and Dairy in the Regulation of Body Weight and Adiposity

These concepts have been confirmed in transgenic mice engineered to exhibit a human pattern of obesity-related gene expression. These are P2-agouti transgenic mice, which express agouti in adipose tissue, similar to humans, and exhibit a normal level of leptin expression (5,12) and moderate adult-onset obesity. Placing these mice on low calcium/high fat/high sucrose diets for six weeks caused marked increases in adipocyte lipid storage, body weight and adipose tissue mass. However, high calcium diets inhibited these effects and caused 26%-39% reductions in body weight and adipose tissue mass (5). The magnitude of these effects depended upon the source of dietary calcium, with dairy calcium exerting significantly greater effects than supplemental calcium carbonate despite identical levels of protein, carbohydrate, fat and energy intake (5).

The relevance of these findings at the population level has been confirmed via analysis of the U.S. National Health and Nutrition Examination Survey (NHANES III), a large database of nutrient intake and clinical data in the U.S. population. The odds of being in the highest quartile of body fat was reduced from 1.0 for the first quartile of calcium intake to 0.75, 0.40 and 0.16 for the second, third and fourth quartiles of calcium intake, respectively (5), and this relationship was strengthened with the inclusion of dairy sources of calcium. Thus, moving from the lowest 25% of calcium and dairy intake (0-1 servings per day) to the highest 25% of dairy intake (more than three servings per day), while controlling for energy intake and physical activity reduced the risk of being in the highest quartile of body fat by over 80% (5).

These data have significant implications for the prevention or attenuation of diet-induced obesity but do not directly address the issue of whether high calcium diets will exert any effect on established obesity. Accordingly, a follow-up study was conducted to determine whether increasing dietary calcium would reduce metabolic efficiency and accelerate fat loss secondary to caloric restriction following dietary induction of obesity (12). Administration of the same low calcium/high fat/high sucrose diet to the transgenic mice for six weeks resulted in a ~100% increase in adipocyte intracellular Ca^{2+} and a corresponding two-fold increase in total fat pad mass, demonstrating that dysregulation of adipocyte intracellular Ca^{2+} is associated with increased adiposity in these mice. The animals were then placed on energy restriction (70% of an ad libitum fed control group) for an additional six weeks. Energy restriction on the low calcium diet failed to reduce intracellular Ca^{2+} and only reduced body weight and fat pad mass by 11% and 8%, respectively. In contrast, energy restriction in conjunction with high calcium diets normalized intracellular calcium and resulted in 19-29% reductions in body weight and 42%-69% decreases in fat pad mass, depending upon the calcium source (calcium carbonate versus dairy).

Notably, dairy calcium (non-fat dry milk) was markedly more effective, exerting approximately twice the effect of a calcium supplement. Interestingly, the animals on the low calcium diets were unable to increase adipocyte lipolysis or suppress lipogenesis despite being on an energy-restricted regimen. In contrast, the high calcium diets caused marked reductions in fat synthesis and two to three fold increases in lipolysis during energy restriction (12). These data demonstrate that high calcium diets and especially dairy-rich diets cause an important shift in the partitioning of dietary energy from energy storage to energy expenditure. The inclusion of dairy as a source of calcium is critical to maximizing this effect. For example, a calcium-fortified breakfast cereal attenuated the development of obesity and accelerated weight and fat loss during caloric restriction in mice, similar to the effects of calcium carbonate noted above (13). However, the rate of fat loss was increased two-fold when a small quantity of non-fat dry milk was included (with total protein, carbohydrate, fat and energy content of the diets identical) in the diets of these mice (13).

This beneficial role for calcium in weight control has been confirmed in human trials. In a two-year prospective study of 54 normal weight women participating in an exercise intervention, the dietary calcium to energy ratio was a significant negative predictor of changes in both body weight and body fat (14); moreover, increased total calcium and dairy calcium intakes predicted fat mass reductions independently of caloric intake for women at lower energy intakes (below the mean of 1,876 kilocalories per day) (14). A similar beneficial effect of dietary calcium on body fat mass accumulation was shown in growing children, with a significant inverse relationship between dietary calcium and body fat reported in a five-year longitudinal study of preschool children ($R2 = 0.51$) (15). Similarly, a case-control study conducted to identify predictors of obesity among Puerto Rican children demonstrated a significant negative correlation between dairy intake and body mass index, and multivariate analysis identified low dairy intake as an important predictor of obesity in this population (16). Further, a significant inverse relationship between dietary calcium and body fat was recently reported in pre-menopausal African-American women (17). Finally, Davies et al (18) recently re-evaluated a series of calcium intervention studies originally designed with primary skeletal endpoints, but now re-analyzed with a body weight endpoint.

This analysis of 780 women involved in five clinical trials (four observational and one double-blind, placebo-controlled randomized trial) demonstrated significant negative associations between calcium intake and body weight for all age groups studied (3rd, 5th, and 8th decades of life), and an odds ratio for being overweight of 2.25 for young women in the lower half versus the upper half of calcium intake (18). Data from the randomized controlled trial demonstrated a calcium treatment effect of approximately 0.5 kg per year weight loss over four years with no intentional change in caloric intake. Overall, the relationships derived from this re-analysis indicate that a calcium intake increase of 1,000 mg/day in women otherwise consuming low calcium diets is associated with an 8 kg reduction in body weight (18).

Role of Whey in Weight Loss

While a similar association between whey and body weight/composition has not been shown directly, many whey products provide a quantity and composition of minerals comparable to that found in fat-free milk. Moreover, replacing casein in mouse diets with skim milk produces significantly greater effects on body composition at each level of calcium intake, suggesting that the additional bioactivity in improving body composition resides in the whey fraction. Whey is recognized as a rich source of bioactive compounds (19) which may act either independently or synergistically with the calcium to attenuate lipogenesis, accelerate lipolysis and/or favorably affect nutrient partitioning between adipose tissue and skeletal muscle. For example, whey proteins have recently been reported to contain significant angiotensin converting enzyme (ACE) activity (20,21). Although ACE inhibitory activity may appear to be more relevant to an anti-hypertensive effect than to an anti-obesity effect of dairy, recent data demonstrates that adipocytes have an autocrine/paracrine renin-angiotensin system, and that adipocyte lipogenesis is regulated, in part, by angiotensin II (reviewed in 22). Indeed, inhibition of the renin-angiotensin system mildly attenuates obesity in rodents, and limited clinical observations support this concept in hypertensive patients treated with ACE inhibitors (22). Thus, it is possible that whey-derived ACE-inhibitory activity may contribute to the anti-obesity effect of dairy. However, it is also possible that other whey bioactive compounds may contribute or, alternatively, that a synergistic effect of multiple factors, along with the aforementioned effects of the calcium, are responsible.

The Role of Milk Calcium and Whey as Ingredients

A substantial body of evidence from both experimental animal and human studies provide a theoretical framework and clinical data to support a significant, beneficial role for dietary calcium in weight management. Notably, dairy sources of calcium exert markedly greater (approximately two-fold) effects than supplemental calcium sources, indicating an important role for dairy products in both the prevention and treatment of obesity. Further, available evidence suggests that the additional anti-obesity bioactivity of dairy may reside in whey. Thus, these findings make dairy, non-fat dry milk, whey minerals, and whey isolates logical ingredients in functional products designed to elicit a favorable pattern of energy partitioning and body composition.

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16.5 INGREDIENTS AND MILK MINERALS IN FORTIFIED FOODS

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A number of different ingredients are available from U.S. suppliers to be used by international manufacturers for fortification purposes. Studies show that consumers prefer dairy calcium-enriched products to non-dairy calcium-enriched products because of dairy's positive image and its health value. Market research studies also indicate that consumers are willing to pay more for products enriched with a natural, dairy source of calcium. The high awareness of, and preference for, dairy calcium-enriched products in many countries of the world offer unique marketing opportunities and selling points to help manufacturers around the world launch successful new products.

Milk Minerals Applications

Milk minerals are a natural source of calcium derived from milk. This ingredient has the advantage of also supplying phosphorus, magnesium, other minerals, lactose and proteins, all of which are important for absorption of calcium and utilization by the body. Typical applications include nutritional supplements, diet, sport and isotonic beverages, nutritional bars, and nutraceutical products.

Using Mineral-concentrated Whey for Fortification and Functional Purposes

Mineral-concentrated whey also functions to improve texture, flavor, solubility, and nutritional profile in food formulations. Foods containing mineral-concentrated whey will have a higher nutritional density than other comparable products. The functions and benefits of the ingredient are:

- Good solubility, heat stability and cost-efficiency.
- Lower lactose content that help minimize texture problems caused by lactose crystallization.
- High protein and minerals content help provide the flavor and smooth texture desired in food products.
- Conveys a milky flavor, helps emulsify added fats, provides good stability and heat stability in sauces and gravies.
- A rich source of calcium, magnesium and phosphorus, which enhances nutritional value and flavor profile in comminuted meat products and sauces.

Typical Applications

For dairy, meat, confectionery, bakery, snack, seasonings, soups, sauces, follow-up formula, frozen desserts and nutritional drinks as:

- A cost efficient source of dairy solids with a high mineral content.
- An alternative to other calcium sources when lower lactose concentrations are desired and higher mineral concentration is required.
- A nutraceutical ingredient in powdered beverages, nutritional drinks, dairy products, powdered soups and desserts and baked goods.

Making Nutritional Claims

A nutritional claim is any statement that indicates, suggests or implies that a food has special nutritional properties. Generally, three types of claims can be made: (1) a claim about the content of calcium simply describing the level of a nutrient in the food (see Table on Codex Recommendations), (2) a comparative claim comparing the levels of calcium in two or more foods and (3) a functional claim that describes the physiological role of calcium during growth, development and normal bodily functions. The specific types of functional claims allowed vary from country to country. Please check local legislation for more information.

Table 16.5.1
Claims for Calcium, Codex Recommendations

To be entitled to claim:	The food must contain at least	So, in the case of calcium, the following threshold values:
"Source of"	15% of NRV/100 g (solids) or 7.5% of NRV/100 ml (liquids) or 5% of NRV/100 kcal or 15% of NRV/portion	120 mg of Ca/100 g or 60 mg of Ca/100 ml or 40 mg of Ca/100 kcal or 120 mg of Ca/portion
"High content of"	Twice the "source" value	240 mg of Ca/100 g or 120 mg of Ca/100 ml or 80 mg of Ca/100 kcal or 240 mg of Ca/portion

Source: Codex Alimentarius/Danone World Newsletter No. 19.
Note: NRV stands for Nutrient Reference Value.

Typical Composition of Milk Minerals

Component	
Total mineral content	79.00%
Ash	70.00%
Calcium	25.00%
Phosphorus	14.00%
Ca/P	1.79
Ca/PO_4	0.58
Magnesium	1.50%
Sodium	0.65%
Potassium	0.83%
Zn (mg/100 g)	27.40
Cu (mg/100 g)	0.37
Fe (mg/100 g)	1.88
Organic mineral (citrate)	9.00%
Protein	5.00%
Fat	1.00%
Lactose	8.00%
Total moisture	7.00%
Bound moisture	3.00%
Free moisture	4.00%
Mineral dry basis	88.00%
Hydrous mineral	89.00%

Information courtesy of Glanbia Nutritionals USA. Specifications may vary between suppliers.

16.6 NUTRITIONAL PRODUCTS FORMULATIONS

Dry Protein Drink made with Instantized WPC80

Ingredients	Usage Level (%)
WPC80	12.86
Fructose	3.00
Cocoa powder	1.50
Vanilla flavor	0.50
Salt	0.10
Acesulfame K	0.02
Vitamin/mineral premix	0.02
Water	82.00
Total	**100.00**

Formula courtesy of Proliant, Inc.

Procedure:

1. Dry blend ingredients to prepare nutritional beverage.
2. Add 52 g of finished product to a 225 ml glass of cold water. Stir well.

Benefits:

Whey proteins provide multifunctional properties, including solubility, emulsification, and nutritional benefits in beverage application. Native whey proteins are highly soluble in beverages in a wide range of pH. Most of the proteins are precipitated at their respective isoelectric points; however, whey protein remains soluble at its isoelectric point. Some whey protein products are available in instantized forms for common use in the formulation of instant beverage mixes. Additionally, whey protein is commonly used in acidic beverages, such as fruit flavored beverages and acidic protein drinks. The protein structure of whey protein with dynamic hydrophilic and hydrophobic regions acts as an emulsifier interacting with oil and aqueous phases. Most of the dry protein drink mixes are formulated with instantized whey protein, which is agglomerated and lecithinated. Dry protein drinks made with instantized WPC provide not only nutritional benefits but also excellent dispersibility. The functional properties of WPC in protein mixes are solubility, dispersibility, opacity, suspension stability, smooth mouth feel, and bland flavor.

Protein Drink made with Instantized WPC80 and Whey Protein Hydrolysate

Ingredients	Usage Level (%)
WPC80	10.38
Whey protein hydrolysate	2.59
Crystalline fructose	3.00
Cocoa powder	1.48
Vanilla flavor	0.50
Acesulfame K	0.04
Vitamin/mineral premix	0.02
Water	81.99
Total	**100.00**

Formula courtesy of Proliant, Inc.

Procedure:

1. Dry blend ingredients to prepare nutritional beverage.
2. Add 52 g of finished product to a 225 ml glass of cold water. Stir well.

Benefits:

Whey protein concentrate and whey protein hydrolysate (WPH) provide multifunctional properties, including solubility, emulsification, and nutritional benefits in beverage application. Native whey proteins are highly soluble in beverages in a wide range of pH. Most of the proteins are precipitated at their respective isoelectric points; however, whey protein remains soluble at its isoelectric point. Some whey proteins are available in instantized forms for common use in the formulation of instant beverage mixes.

High-Protein Pudding

Ingredients	Usage Level (%)
WPC80	10.00
Sugar	10.20
Dextrose	5.70
Food starch (modified)	3.00
Tetra sodium pyrophosphate	0.25
Disodium phosphate	0.13
Vanilla flavor	0.20
Skim milk	70.52
Total	**100.00**

Formula courtesy of Proliant, Inc.

Procedure:

1. Mix dry ingredients at low speed.
2. Pour a cup skim milk into a 400-ml container.
3. Add the pudding mix slowly to skim milk with continuous stirring until completely dissolved.
4. Pour pudding sample into serving cups.
5. Refrigerate at 4-8°C for overnight.

Benefits:

This high protein pudding made with WPC80 provides approximately 3.4 times the protein level of a commercial instantized pudding prepared with skim milk. WPC80 is an instantized product, ideal for dry mixes with purposes of creamy textures and quality flavor profiles.

Protein Bar

Ingredients	Usage Level (%)
High fructose corn syrup	42.11
WPC80	7.89
Whey protein hydrolyzate	2.63
Calcium caseinate	10.53
Soy protein isolate	10.53
Canola oil	8.95
Maltodextrin	10.53
Cocoa powder	4.20
Vanilla	2.10
Lecithin	0.53
Total	**100.00**

Formula courtesy of Proliant, Inc.

Procedure:

1. Mix the high fructose corn syrup, oil, and lecithin at low speed for 2 minutes.
2. Add remaining ingredients. Continue mixing for additional 5 minutes.
3. Store in a sealed plastic bag overnight.
4. Form bar into desired shape and size.
5. Package and seal.

Benefits:

Whey protein hydrolyzate can be used as a textural modifier when replacing a partial amount of whey protein concentrate in protein bar systems. By reducing firmness and chewiness, whey protein hydrolyzate offers more desirable texture and potentially extended shelf life. Its relatively bland flavor has minimal impact on the flavor profile in this type of system. Pre-digested peptides from WPH in combination with the nutritional profile of WPC is an ideal source of proteins.

High-Protein Cookie

Ingredients	Usage Level (%)
WPC80	16.00
Soy protein isolate	3.00
Egg white powder	3.00
Brown sugar	14.00
White sugar	14.00
Peanut butter	12.00
Shortening	7.00
Water	7.00
Mini peanut butter morsels	7.00
Cake flour	5.00
Whole egg	5.00
High fructose corn syrup	5.00
Vanilla extract	1.00
Peanut butter flavor	0.50
Salt	0.30
Baking powder	0.20
Total	**100.00**

Formula courtesy of Proliant, Inc.

Procedure:

1. Cream shortening, corn syrup, egg, and sugar at low speed.
2. Add dry powders, other ingredients, and water. Mix for an additional 60 seconds.
3. Fold in peanut butter mini morsels.
4. Portion dough onto a cookie sheet and bake at 175°C (350°F) for 10 minutes.

16.7 WHEY AND LACTOSE FORMULATIONS FOR INFANT FORMULA AND CHILD NUTRITION

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

Demineralized Whey–based Infant Formula

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

*As per manufacturer's usage levels/ Nutrition Labeling and Education Act requirements. Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Add enough water to the de-mineralized whey, skim milk powder, and lactose to make a concentrated liquid that will still pour easily.
2. Heat solution to approximately 60°C (140°F) and mix in the lecithin, fat blend, and vitamin/mineral premix.
3. Continue to heat until pasteurized. Homogenize using a two-stage process of 176 kgf/cm^2 (2000 $lb/inch^2$) for the first stage, and 35 kgf/cm^2 (500 $lb/inch^2$) for the second stage.
4. Spray-dry and agglomerate for easier reconstitution.
5. To re-hydrate, blend 10% dry formula and 90% potable water by weight. Heat to pasteurize, and cool to feeding temperature.

Whey Protein Concentrate-based Infant Formula

Ingredients	Usage Level (%)
Lactose	37.00
Fat blend	27.00
WPC34	18.50
Skim milk powder	16.00
Vitamin/mineral premix*	1.00
Lecithin	0.50
Total	**100.00**

*As per manufacturer's usage levels/ Nutrition Labeling and Education Act requirements. Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Weigh out WPC34, skim milk powder, and lactose. Add these dry components to a quantity of water that will produce a concentrated liquid that is flowable.
2. Heat the solution to approximately 140°C (285°F) and mix in the lecithin, fat blend, vitamins and minerals.
3. Continue heating to pasteurize. Homogenize using a two-stage process with pressures of 141 kgf/cm^2 (1600 $lb/inch^2$) in the first stage and 35 kgf/cm^2 (500 $lb/inch^2$) in the second.
4. Spray dry, and agglomerate for easier reconstitution.
5. To re-hydrate, blend 10% dry formula and 90% potable water by weight. Heat to pasteurize, and cool to feeding temperature.

16.8 WHEY AND LACTOSE FORMULATIONS IN SPORTS PRODUCTS

Intensive Sport Beverage

Ingredients	Usage Level (%)
Fructose	77.24
WPI	20.00
Citric acid, anhydrous	0.85
Sodium chloride	0.50
Sodium citrate	0.50
Potassium phosphate, monobasic	0.40
Lemon/lime flavor	0.35
Blue color	0.06
Sodium benzoate	0.05
Yellow color	0.04
Antifoaming agent	0.01
Total	**100.00**

Formula courtesy of Proliant, Inc.,
Testing by Wisconsin Center for Dairy Research.

Procedure:

1. Blend all dry ingredients well.
2. Disperse 18% dry mix into 82% water, stirring until fully hydrated.
3. Using a 25% phosphoric acid solution, adjust pH to 3.0 to 3.5.
4. Cold-fill bottles and pasteurize to 88°C (192°F).

Sport Beverage

Ingredients	Usage Level (%)
Water	76.53
Maltodextrin, 18 D.E.	10.00
Fructose, crystalline	9.15
WPC80	3.60
Citric or phosphoric or malic acid	0.56
Flavor	0.09
Sodium, citrate, dihydrate	0.06
Color	0.01
Total	**100.00**

Formula courtesy of Proliant, Inc.,
Testing by Wisconsin Center for Dairy Research.

Procedure:

1. Add water to large mixing tank at 15° to 25°C (60° to 77°F).
2. With good agitation, add WPC80, avoiding entrapment of air. Allow mixture to sit for 15-30 minutes, so that WPC80 can become hydrated.
3. Mix in fructose, maltodextrin and sodium citrate with good agitation.
4. Add flavor and color. Allow to hydrate 10 minutes.
5. Adjust pH to 3.5-3.7 using a 50% solution of the appropriate acid while continuously mixing.
6. Each processor must determine the appropriate heating conditions to insure a safe product. Approximately 80-85°C (172-185°F) for 15-30 seconds should serve as a starting point for low pH beverages.
7. Hot-fill containers.
8. Cool beverages immediately.

Protein-Fortified Fruit Beverage

Ingredients	Usage Level (%)
Water	80.00
Fructose	9.98
WPC80	6.26
Corn syrup solids	2.25
Citric acid	0.78
Milk calcium	0.59
Raspberry flavor	0.13
Red color #40	0.01
Total	**100.00**

Formula courtesy of Proliant, Inc.,
Testing by Wisconsin Center for Dairy Research.

Procedure:

1. Blend all dry ingredients well.
2. Disperse one bag (32 oz or 908 g) of dry mix in 3.8 l (1 gal) water, stirring or shaking until fully hydrated.
3. Finished pH is about 4.0.
4. Cold-fill bottles and pasteurize to 88°C.

Nutrition Bars

	Usage Level (%)	
Ingredients	**Variant I**	**Variant II**
WPI (90% Protein)	32.00	–
Milk minerals	2.00	2.00
Soy protein isolate (90% Protein)	–	16.00
WPC80	–	18.00
Citric acid	0.35	0.35
Lecithin	0.40	0.40
Sorbitol	9.25	9.25
Vegetable fat	7.00	7.00
Fructose	16.50	14.50
Figs	3.00	3.00
Corn (42 D.E.)	23.92	23.92
Water	5.50	5.50
Flavor	<0.20	<0.20

Formula courtesy of Hershey Foods Corporation.

Procedure:

1. Mix the dry ingredients.
2. Mix the lecithin in the melted fat phase.
3. Knead the fat phase with the dry ingredients.
4. Add and knead the liquid phase, add flavor, if any.
5. During the process the kneading temperature must be 40-42°C.
6. Form the kneaded mass into bars.
7. Coat with chocolate or compound coating.

16.9 WHEY AND LACTOSE FORMULATIONS IN WEIGHT LOSS, HEALTH AND FITNESS PRODUCTS

Chocolate-flavored Meal Replacement Beverage

Ingredients	Usage Level (%)
Sucrose	39.00
WPC34	19.00
Dutch processed cocoa (16-18% fat)	11.50
Corn syrup solids, 24 D.E.	11.50
Sodium caseinate	11.00
Calcium caseinate	5.00
Vitamin/mineral premix*	1.00
Vanillin	0.90
Lecithin	0.80
Xanthan gum	0.20
Carboxy methyl cellulose	0.10
Total	**100.00**

*Adjusted to provide 25%-30% of daily recommended intake.
Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Dry blend all ingredients and package as desired.
2. To serve, mix 40 g of dry mixture into 225 ml milk.

Dry Acidic Nutritional Beverage (Orange Flavor)

Ingredients	Usage Level (%)
Instantized whey protein concentrate 80%	61.6800
Fructose	23.4222
Dry sweet whey	8.9800
Citric acid, anhydrous	5.0800
Orange flavor	0.6300
Vitamin/mineral premix*	0.1200
Aspartame	0.0400
Acesulfame K	0.0400
FD&C red #40	0.0039
FD&C yellow #5	0.0039
Total	**100.0000**

*Adjusted to provide 30%-35% of daily recommended intake.
Formula courtesy of Proliant, Inc.,
Testing by Wisconsin Center for Dairy Research.

Procedure:

1. Blend all dry ingredients together in a mixing bowl until homogeneous.
2. Reconstitute by mixing 28 g (1 oz) dry mix in 220 g (8 oz) water, stirring or shaking until fully hydrated.

Dry Acidic Nutritional Beverage Meal Replacement Beverage Mix

Ingredients	Usage Level (%)
Skim milk powder	22.46
WPC	22.19
Fructose	15.00
Sucrose	10.25
Creamer	11.64
Canola oil	6.19
Cocoa	2.82
Guar/xanthan blend	1.68
Natural flavor	1.40
Instant coffee	4.21
Milk minerals	1.32
Vitamin/mineral premix	0.84
Total	**100.00**

Formula courtesy of California Polytechnic State University.

Procedure:

1. Mix sucrose, fructose, and gum blend.
2. Add coffee, mix well.
3. Add the remaining ingredients, except the canola oil, mix for 5 minutes.
4. Slowly add oil, mix for an additional 5 minutes.

Fruit Smoothie

Ingredients	Usage Level (%)
Seedless strawberry puree, 7° Brix	48.50
Water	20.00
Liquid fructose	12.00
Seedless banana puree, 22° Brix	8.00
WPC80	7.00
Corn syrup, 42 D.E.	4.00
Milk calcium	0.40
Citric acid	0.10
Total	**100.00**

Note: Batch size depends on size of dispenser (above is for 2 gal or 7263 g).
Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Mix all ingredients in order listed.
2. Place in refrigerated circulating dispenser.

Creamy Meal Replacement Beverage (Raspberry Flavor)

Ingredients	Usage Level (%)
Water	79.498
Fructose	6.150
WPC80	4.690
Fruit juice, 65° Brix	4.090
Sucrose	3.070
Fiber (Rice bran)	1.640
Citric or phosphoric acid	0.170
Carrageenan	0.610
Dry raspberry flavor	0.060
Vitamin/mineral premix	0.020
Color, red #40	0.002
Total	**100.000**

Formula courtesy of Wisconsin Center for Dairy Research.

Procedure:

1. Add water to batch mixing tank and bring to 15-25°C (59-77°F). Add WPC80 to warm water with good agitation, mixing until well dispersed. Allow mixture to stand for 15-30 minutes, so that hydration can take place.
2. When 30 minutes has elapsed, add fruit juice and mix until homogeneous.
3. Blend dry ingredients together. Add dry ingredients to liquid mixture while mixing continuously. Allow this mixture to hydrate for 10 minutes.
4. Add flavor and color, and mix until blended.
5. Check pH and adjust, if necessary, to pH 3.5 with a 50% solution of the acid chosen.
6. Heat process at approximately 80-85°C (176-185°F), although each processor must determine conditions to insure a safe product.
7. Cool beverages immediately.

Whey and Peanut Butter Cardiovascular Health Bar*

Ingredients	Usage Level (%)
Honey	18.29
High fructose corn syrup	16.17
Chocolate coating	14.89
WPI	11.12
Hydrolyzed whey protein isolate	9.79
Peanut butter	8.33
Peanut flour	7.33
Chopped peanuts	7.24
Maltodextrin	3.52
Vitamin/mineral blend	1.68
Vanilla extract	1.03
Soy fiber	0.61
Total	**100.00**

*40% Carbohydrate/30% Protein/30% Fat.
Formula courtesy of Davisco Foods.

Procedure:

1. Place honey, high fructose corn syrup, peanut butter and vanilla extract into mixer with paddle attachment. Blend for 1 minute on medium.
2. Dry blend remaining ingredients, except for chocolate coating. Add to mixer and mix on low speed until all ingredients are evenly incorporated.
3. Extrude or form as desired. Enrobe with chocolate coating.

High Protein Chocolate Chip Cookie

Ingredients	Usage Level (%)
WPC80	17.85
Pasty flour	17.85
Brown sugar	20.85
Butter	12.65
Skim milk powder	1.25
Chocolate chips	17.35
Eggs	2.50
Vanilla extract	0.30
Salt	0.20
Sodium bicarbonate	0.20
Water	9.00
Total	**100.00**

Formula courtesy of California Polytechnic State University.

Procedure:

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

High Protein Energy Bar

Ingredients	Usage Level (%)
Protein blend (WPI, WPC80)	23.95
Rice syrup	16.95
Enrobing chocolate	16.10
Oats	8.40
Honey	8.10
Skim milk powder	7.80
Raisin paste	7.80
Soy nuts	4.25
Peanut flour	4.20
Soy oil	2.25
Milk minerals	0.20
Total	**100.00**

Formula courtesy of California Polytechnic State University.

Procedure:

1. Mix the protein blend, skim milk powder, milk minerals and peanut flour at low speed for approximately 5 minutes until well blended.
2. Continue mixing and add the liquid ingredients (rice syrup, honey, soybean oil and raisin paste). Mix until uniform.
3. Add oats and soy nuts and mix at low speed until uniformly blended.
4. Form bar into desired size by extruding or pressing. Coat in enrobing chocolate.
5. Package.

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