U.S. DAIRY PROTEINS AND PERMEATES IN READY-TO-DRINK BEVERAGES

Ready-to-drink beverages offer the advantages of convenience and portability to today's busy consumers. They also provide an opportunity to incorporate innovative and exciting functional ingredients and packaging technologies. While this category includes both refrigerated and shelf-stable beverages, demand is stronger for shelf-stable products which offer ease of distribution and storage. However, refrigerated beverage sales are surging, as they can be perceived by consumers to be more fresh and natural than shelf-stable products. Dairy proteins are often the preferred source for ready-to-drink protein beverages because of their excellent nutritional qualities, mild flavor, ease of digestibility and unique functionality in beverage systems. More in-depth descriptions of the nutritional and functional characteristics of whey and milk protein, as well as whey and milk permeate, are available in online publications from the U.S. Dairy Export Council at www.ThinkUSAdairy.org.

This monograph focuses on the aspects of formulating and manufacturing ready-to-drink (RTD) beverages using proteins from milk, including whey protein isolate (WPI), whey protein concentrate (WPC), milk protein isolate (MPI), milk protein concentrate (MPC) and micellar casein concentrate (MCC) as the sources of protein. It also addresses the use of U.S. milk and whey permeate ingredients in RTD beverage formulations.

The use of dairy proteins in dry mix beverage formulations is common, but the creation of ready-to-drink beverages requires far more technology, processing expertise and careful ingredient consideration.

The Ready-to-Drink Beverage Market

Growth in the beverage market is shifting toward drinks that offer improved nutrition and diverse consumer benefits. Diets high in protein can help promote satiety, curb hunger and preserve lean body mass. Protein is the most sought out nutrient by U.S. shoppers according to the *Food and Health Survey* from the International Food Information Council Foundation,[1] and research shows consumers not only seek out protein beyond traditional meat sources, but also find dairy protein to be a high-quality alternative.[2] Protein drinks and shakes continue to attract new audiences, and non-traditional dairy beverages can help consumers achieve their protein intake goals.

The popularity of sports nutrition drinks, drinkable yogurt and fermented beverages has increased around the globe. Drinkable yogurt and fermented beverages experienced a 12% compound annual growth rate (CAGR) over a five-year period.[3] Additionally, use of permeate as an ingredient is increasing in the global food and beverage industry. The number of new food and beverage launches with permeate has been growing over the last decade, and the growth rate has increased significantly to 41% CAGR between 2010 and 2016. Bakery, dairy and hot drinks are the leading categories for permeate applications.[4]

There are a wide range of protein-containing RTD beverages which serve a variety of consumers with different needs throughout the day. Whey proteins are often added to milk-based infant formulas to make whey-predominant mixtures, hence providing a whey-to-casein protein ratio closer to that of human milk. Beverages developed for the sports nutrition market are particularly likely to contain whey proteins which are incorporated for their unique and well-documented nutritional benefits for athletes. Medical and therapeutic nutritional beverages often include milk proteins because of their abundant supply of essential amino acids for protein synthesis, digestibility and health benefits. Additionally, there are smoothie-type beverages which contain a combination of fruit juice and milk or whey protein, and protein waters which incorporate flavors and colors for product interest. RTD refrigerated coffees and teas are increasingly fortified with protein for added nutrition and consumer appeal. Finally, aging seniors also benefit from dairy protein consumption in neutral pH shake-type beverages fortified with the protein and nutrients they need for complete nutrition.

Beverage Innovation Considerations

The product characteristics of a finished ready-to-drink beverage are all interrelated. Regardless of the particular type of beverage desired, the following factors must be identified and evaluated before beginning product and process development:

1. Define desired packaging, transportation and storage environment, which will determine the appropriate manufacturing process including heat treatment.
2. Describe product in terms of pH range.
3. Determine approximate cost targets/limits.

4. Decide upon general nutritional composition, which is shown on the product nutrition label and required to satisfy a nutrition claim.
5. Identify non-protein ingredients needed or desired.
6. Determine compatibility of items 1, 2, 3, 4 and 5.

The level of protein in the desired beverage will determine the available processing and packaging options. Dairy proteins can be soluble and stable over a wide pH range, yet their natural gelation abilities—in particular with whey proteins—are an important consideration because of their temperature and concentration-dependent behavior. Concentrations of sugars and mineral ions in the beverage solution also affect whey and milk protein behavior during processing and throughout shelf life. The interactions are very formula specific, so it is important to perform benchtop and pilot plant simulations before finalizing a formulation.

ENVIRONMENT SELECTION

Generally, the pH (acidity) of the product determines its processing requirements in terms of safety and storage stability. Except for juice products, there are no U.S. Food and Drug Administration (FDA) thermal processing requirements for high acid (pH< 4.6) products. Please check country specific regulations when formulating such products to ensure compliance with local requirements.

There are four basic product categories of shelf-stable RTD beverages:

1. Aseptically-processed, commercially sterile beverages.
2. Retort-processed, commercially sterile beverages.
3. Tunnel pasteurized beverages.
4. Hot-filled or pasteurized cold-filled beverages.

The main difference between aseptic and retort processing is:

- In aseptic processing, the container is sterilized and filled with a sterilized beverage inside a sterile chamber where the container is also sealed.
- In retort processing, a container is filled with the beverage and sealed, then the entire container and its contents are heated to achieve sterility.

Generally speaking, the R&D processing and packaging costs for aseptic and retort beverage development are greater than those for hot-filled and cold-filled beverages.

While some beverages can be cold-filled without thermal processing, beverages containing dairy proteins will require some type of thermal process to ensure shelf stability.

WHEY PROTEINS IN NEUTRAL PH BEVERAGES

Low-acid aseptically-processed and retort-processed commercially sterile beverages (categories 1 and 2) are typically represented by the neutral pH, shake-type products. They will generally have a pH between 4.6 and 7.5, depending upon the flavor. For example, strawberry is more acidic than chocolate. These products must either be thermally sterilized (rendered "commercially sterile") via aseptic processing or retort processing, or they must be pasteurized and refrigerated until consumed. Whey proteins are sometimes included in these formulations but are generally not the predominant proteins.

The prevalent proteins are those containing casein proteins such as milk protein concentrate or micellar casein. Often the neutral pH drinks—like shake products—use a retort or UHT process, which is a high heat treatment. Whey proteins that haven't been modified for increased heat stability will not be stable as the sole protein ingredient at levels above 3% protein. Unmodified whey proteins will gel or precipitate under these conditions unless a stabilizing system is used. Using casein proteins in combination with whey proteins will provide some protection and heat stability to the whey proteins. In doing this, the whey proteins will be dispersed among the casein and remain soluble versus interacting only with themselves and risk forming a gel or precipitating.

MILK PROTEINS IN NEUTRAL PH BEVERAGES

Ingredients containing primarily milk-derived proteins such as milk protein concentrate, milk protein isolate and micellar casein are well-suited for low acid beverages because of the inherent heat stability of casein.[5] Milk protein ingredient compositions can be found in Figure 1.

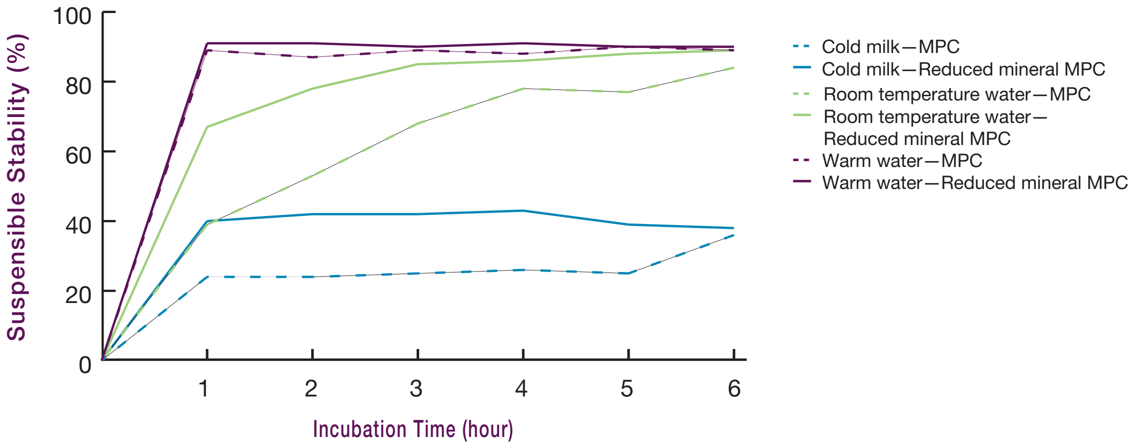
Good hydration of milk protein ingredients is key to their performance in a low-acid beverage. There are several accepted methods for measuring hydration.[6, 7, 8, 9] Dissolving the powders in solution with a high-speed mixer is a good starting point, but allowing time for the powders to absorb water is also important to optimize their heat stability and solubility over the shelf life of the beverage. Depending on the type of drink desired, either milk or water may be the starting point for the addition of milk proteins. The temperature of the milk or water and the time allowed for hydration also contributes to their overall stability.

FIGURE 1:
TYPICAL COMPOSITION OF WHEY AND MILK PROTEIN INGREDIENTS

	PROTEIN (%)	LACTOSE (%)	FAT (%)	ASH (%)	MOISTURE (%)
WPC34	33	52	4	7	4
WPC55	53	31	6	6	4
WPC80	77	9	6	4	4
WPI	89	2	1	3	5
MPC56	54.4	31.7	1.2	7.6	5.0
MPC70	68.3	18.2	1.2	7.3	5.0
MPC80	78.1	8.4	1.5	7.0	5.0
MPI	87.1	0.5	1.5	5.9	5.0
MCC85	84.5	3.0	3.0	4.5	5.0

(Source: Smith K. Dried Dairy Ingredients. Wisconsin Center for Dairy Research. May 15, 2008)[10]

FIGURE 2:
HYDRATION CHARACTERISTICS OF MPC85



(Testing done by the Wisconsin Center for Dairy Research by the method of Sikand et al, 2011)

Figure 2 compares the solubility (hydration level) of 5% solutions of MPC85 (dotted lines) in room temperature water (RT, 25°C [77°F]), cold milk (CM, 5°C [41°F]), and warm water (WW, 50°C [122°F]). The solutions were stirred continuously over a six-hour time period. The fastest hydration occurs in warm water while the slowest is in cold milk. Even after six hours of hydration, the MPC85 solution in cold milk is not fully solubilized. Published studies have confirmed this issue of poor re-hydration properties with high protein MPC ingredients at 70% protein and above.[11] One way to improve the rate of hydration for MPC ingredients is to reduce the content of minerals, especially calcium.[12] The other three curves shown as solid lines represent an MPC85 ingredient with 25% reduced minerals. The hydration time was much faster for the reduced mineral MPC85 in cold milk and room temperature water.

Heat stability is another functional property that can be measured for milk protein ingredients to help understand their performance in low-acid beverages.[13] Figure 3 compares the heat stability of the same MPC85 samples in a 5% solution. The results show that the reduced mineral MPC85 had less sediment after heating at 85°C (185°F) for three minutes versus the regular MPC85 and therefore had better heat stability. These samples are dissolved and hydrated with stirring for one hour in room temperature distilled water. Samples that hydrate faster will typically show better heat stability because more of the milk protein has been solubilized.

Storage conditions and the age of higher protein MPC ingredients are also a consideration when using them in a beverage application. Studies of MPC85 powder showed that losses in solubility occurred within 60 days at storage temperatures of 30°C (86°F) and above.[6] Milk protein ingredients that have poor rehydration characteristics will show poor solubility and heat stability in a beverage application.

The basic processing instructions to enhance protein stability in a UHT processed high-protein, low-acid beverage are:

1. Mix milk protein in water at 50°C (122°F) with a high-speed mixer.
2. Add other ingredients such as sweeteners, colors, stabilizers and flavors and allow mix to hydrate for one hour with slow agitation.
3. Add pH adjusting ingredients such as buffers to reach pH 7.0.
4. Heat to 140°C (284°F) for six seconds.
5. Homogenize at 2500 psi/700 psi.
6. Cool product to 24°C (74°F).

WHEY PROTEINS IN ACIDIFIED BEVERAGES

Hot-filled or pasteurized cold-filled beverages and tunnel pasteurized beverages (categories 3 and 4) are typically represented by acidified whey protein beverages and are generally formulated to a pH range of 2.8 to 4.0. They are commonly subjected to a mild thermal pasteurization process, after which they are generally considered to be shelf-stable at room temperature.

In the pH range of 2.8–3.5, beverages formulated with WPI will have a high clarity/low turbidity even at high levels of protein. The ability to make a clear protein-fortified beverage is unique only to whey proteins. A low level of fat and minerals in the WPI will deliver the highest clarity and lowest turbidity.

Thermally processed acidic beverages may be filled while hot into containers which can withstand high temperatures (hot-fill). In the acidic environment, the hot liquid product essentially sterilizes the containers, which have already been pre-rinsed with ozonated water or other methods of destroying airborne contaminants. Hot-filled containers may be metal, glass or certain plastic bottles designed to withstand the filling temperatures and the subsequent vacuum created during product cooling.

Cold-fill is similar to hot-fill in that the product is thermally processed. However, unlike hot-fill, a cold-fill product is immediately cooled to less than 38°C (100°F) prior to filling. Cooling the product right away allows less vitamin degradation and variations of flavor that may result from hot-fill processing.

Tunnel pasteurization of sealed metal cans or glass bottles is adequate for acidic protein beverages and is the only practical method for pasteurizing carbonated beverages. Tunnel pasteurization is historically the common method for pasteurizing beer, but it can also be very useful for acidic beverages containing protein. However, few manufacturers other than brewers have this capability.

Dairy Protein Ingredient Considerations

The most important component of a protein-containing RTD beverage is the protein ingredient.

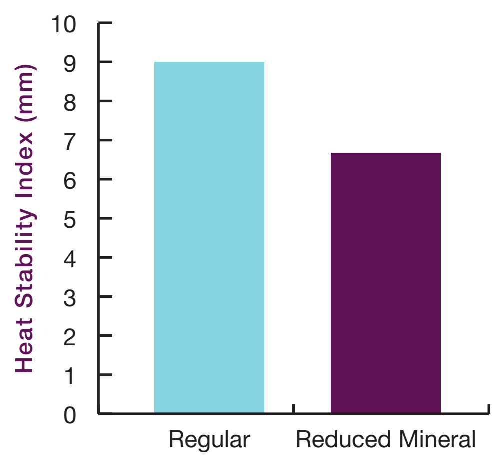
The source of protein may be dairy protein concentrates (defined as having 34–89% protein), isolates (containing 90–92% protein) or peptides, which provide distinct nutritional and functional advantages. In some cases, dairy proteins are combined with other proteins such as vegetable-based ingredients to create a particular overall amino acid composition or textural character, but the vegetable-derived proteins in particular may present serious flavor and mouthfeel challenges for the formulator. These mixtures can be very difficult to stabilize due to multiple ingredient interactions before or after thermal processing. Dairy proteins themselves display a wide range of isoelectric points and molecular sizes, and commercial dairy protein ingredients are comprised of several different molecular species.

Two key factors to be considered when selecting a dairy protein are a) the protein's method of separation from the remaining milk components which determines the composition of the WPC, WPI, MPC, MPI or MCC and b) a consistent source and manufacturing process to produce the ingredient.

Whey protein concentrate 80% (WPC80) and milk protein concentrates and isolates are manufactured using membrane filtration which is a physical separation process. Fat and ash contents can vary among ingredient suppliers, as can flavor profiles, but overall composition is fairly consistent.

For WPI, the two main manufacturing processes are ion exchange (a chemical manipulation) and membrane filtration. Compositional differences between ion exchange and membrane filtered products do exist, including differences in mineral composition, carbohydrate level and the glycomacropeptide content, all of which may affect suitability for a particular application.

FIGURE 3:
HEAT STABILITY INDEX OF MPC85



From a nutritional standpoint, food manufacturers will want to select the ingredient which best matches their requirements from total protein or mineral concentration to the presence of a particular protein fraction or amino acid. The best strategy for manufacturers is to work closely with dairy protein suppliers at the very early stages of the development process. Many U.S. suppliers offer guidance, typical formulations and technical assistance to support their customers when developing products.

Lot-to-lot ingredient consistency is important, and it may be necessary to develop a simple test to correlate with performance relative to the intended use, which goes beyond information provided in a standard specification or certificate of analysis. This is particularly true if the product and process are less robust to variations and if the beverage contains a protein level on the high end of the practical range. Again, close and early collaboration with a U.S. dairy protein supplier is an important success factor.

Dairy Permeate Ingredient Considerations

Permeate (also called dairy product solids, deproteinized whey or modified whey) refers to the lactose and mineral coproduct generated during ultrafiltration of milk or whey to produce milk or whey proteins. The name permeate refers to those components that "permeate" or go through the ultrafiltration membrane due to their small molecular size. The proteins and fat found in milk and whey are much larger in size than lactose or minerals, so they are retained in the membrane and become the ingredients commonly known as whey protein concentrate or milk protein concentrate.

The composition of milk and whey permeates are listed in Figure 4. Both types of permeate have a similar

FIGURE 4:
COMPOSITION OF MILK AND WHEY PERMEATE

COMPONENT	WHEY PERMEATE	MILK PERMEATE
Protein[*a]	Typical 2–7% (max. 7%)	Typical 3–5% (min. 2%)
Fat[a]	Typical 0–1.0% (max. 1.5%)	Typical 0–1.0% (max. 1.5%)
Lactose[a]	Typical 76–85% (min. 76%)	Typical 78–88% (min. 76%)
Ash[a]	Typical 8–11% (max. 14%)	Typical 8–11% (max. 14%)
Moisture[a]	Typical 3–4.5% (max. 5%)	Typical 3–4.5% (max. 5%)
Sodium[b]	0.70–0.89%	0.38–0.66%
Calcium[b]	0.36–0.62%	0.36–0.46%
Magnesium[b]	0.10–0.13%	0.10–0.12%
Potassium[b]	2.18–5.36%	1.91–2.58%

[a] American Dairy Products Institute. Dairy Permeate Standard | [b] Commercial specification | * Nonprotein nitrogen

composition with whey permeate having a slightly higher sodium and potassium content.

The primary benefit of using permeate in a beverage is for the nutritional benefits of the minerals. Permeate can contribute to a clean label by providing milk minerals to a beverage without the addition of individual minerals such as calcium carbonate or potassium phosphate. The lactose in permeate provides a source of carbohydrates that has less sweetness than sucrose (about 70% less sweetness) but the lactose can be hydrolyzed with ß-galactosidase (lactase) into glucose and galactose to provide more sweetness without adding more sugar.

One of the first beverage applications for liquid milk permeate published in the early 1990s was an electrolyte beverage.[14] The researchers used the addition of lactase to hydrolyze the lactose to provide sweetness. Whey permeate can be used for the same application but it will have sour (whey-like) flavor notes from the cultures used during the cheese making process. Later whey permeate research showed that beverages made with 75–100% liquid permeate had brothy and sour dairy flavors.[15] The whey permeate beverages also had a salty taste but at similar levels found with commercial sports (isotonic) beverages. Sports drinks designed for rehydration are not the only opportunity for permeate ingredients. Permeate is currently used in both dry mix hot cocoa and cappuccino drinks as well as ready-to-drink chocolate and fruit flavored drinks for children.

Because of the lack of protein, permeate ingredients have greater heat stability than dairy protein ingredients. The primary formulation issues that could arise with permeate are related to the high levels of minerals. The calcium in permeate can settle when high levels (>7% added dry permeate) are used in a dry mix application at neutral pH. Calcium has higher solubility in acid conditions, so a high acid beverage will be easier to formulate with levels of permeate above 7%. There are more opportunities for permeate to be used in the beverage category that have yet to be explored, such as combinations with juice in a ready-to-drink form or as a dry mix nutritional drink for children.

Non-Dairy Ingredient Considerations

Here are some other categories of ingredients frequently required or desired in RTD protein beverages. Their careful selection and laboratory evaluation are important when developing a shelf-stable product with excellent flavor and good consumer appeal. In all cases, please check country specific regulations when formulating these products to ensure compliance with all local requirements.

ACIDULANTS

Whey protein in particular has strong buffering capacity and requires the use of considerable amounts of acid in the formula to bring the starting pH from around 6.5

Packaging Selection

Packaging selection (glass, plastic, multilayer, flexible or rigid metal) is an important determinant of beverage processing conditions and product stability, and it influences the costs of manufacturing and distribution. In summary, the possibilities are:

	PROCESS				
Bottle	COLD-FILL	HOT-FILL	TUNNEL PASTEURIZATION	RETORT STERILIZATION	ASEPTIC STERILIZATION
Glass	•	•	•	•	
Hot-fillable plastic	•	•			
Cold-fillable plastic	•				
Retortable plastic				•	
Multilayer					•
Metal		•	•	•	•

down to 3.5 or lower. The most common acids used for making low pH whey protein beverages are:

1. Phosphoric—a strong acid with minimal flavor impact.
2. Hydrochloric—a strong acid with less desirable palatability, but may be used in medical nutritionals because it is the same acid found in the gastric system.
3. Citric—a weaker acidulant but very desirable for its contribution to the overall flavor profile of a fruit-flavored beverage. Citric acid is not recommended as the sole acidulant for very high protein drinks because of the extreme tartness imparted when used at high levels.
4. Malic—a weaker acid similar to citric acid but useful as an adjunct to formulas with apple or berry flavors, due to its natural presence in those fruits.

CARBON DIOXIDE (CARBONATION)

Carbonation is included in this section because it functions as an ingredient, as much as a process, and because of its impact on acidity. There is increasing interest in improving the nutritional profile of carbonated soft drinks by adding dairy protein.

FLAVORS

Dairy proteins, unlike some plant protein sources, are widely compatible with, and even complementary to, many popular flavors. Protein beverages do require higher flavor usage as proteins absorb flavor over the shelf life of the beverage. However, plant proteins are more prone to this effect than dairy proteins, requiring heavier flavor usage and cost.

SWEETENERS

There are many choices of caloric and non-caloric sweeteners, both natural and artificial, that are suitable for use in protein beverages. As many health and wellness-focused consumers continue to be vigilant about sugar intake, more sweetener ingredients continue to be developed.

These include:

1. Traditional sweeteners such as sucrose, fructose and high fructose corn syrup.
2. Other natural sweeteners including honey, maple syrup and fruit puree.
3. Sugar alcohols such as lactitol and erythritol.
4. Artificial high-intensity sweeteners including sucralose and acesulfame potassium (K).
5. Natural high-intensity sweeteners such as stevia, monk fruit and chicory root extract.

The selection of sweeteners can impact mouthfeel and protein stability in a formula-specific manner. However, the choice of a sweetener is usually directed by calorie and flavor requirements. Note that in any particular RTD protein formulation, one sweetener may work well as the sole source of sweetness, but a combination of two often provides the best overall sweetness impact and compatibility with the base flavor.

COLORS

Colors may be either artificial or natural, with light stability as an important consideration when using transparent or translucent bottles. The slow degradation of ascorbic acid (vitamin C) in beverages can, via its peroxide breakdown product, slowly decolorize beverages during shelf life. Color suppliers can offer guidance to manufacturers during the development process.

FRUIT JUICES

Juices are an excellent choice for creating flavorful dairy protein beverages with consumer appeal. Juices can be used to add both flavor and sweetness. The use of natural juices may affect pasteurization requirements. The dairy protein should be sufficiently hydrated in water before adding the juice, acidulants and other beverage components.

MINERALS

The stability and clarity of acidified whey protein beverages is believed to be affected by the mineral ion concentration (sodium or calcium) present in the system. Therefore, mineral selection and level of fortification may be limited by their effect on the final beverage. In general, adding salts increases aggregation in thermally processed whey beverages, thus decreasing stability.

VITAMINS

As with any food or beverage product, vitamins must be chosen and formulated according to their compatibility with the overall system. Most water-soluble vitamins are fairly stable in acid environments.

However, consideration must be given to color and flavor contribution, processing losses and light stability for a RTD beverage in a transparent or translucent bottle. Ingredient interactions should also be considered.

STABILIZERS AND EMULSIFIERS

Stabilizers and emulsifiers can be very important to neutral, shake-type beverages, especially when mixtures of proteins and/or cocoa powder are used. Carrageenan, cellulose gel and cellulose gum are common stabilizers used in neutral beverages with added protein. Pectin is used for whey protein beverages in the pH range between 3.5 and 4.6 to protect and stabilize the proteins during thermal processing and throughout their shelf life. Stabilizers are generally not needed below pH 3.5 in acidified whey protein isolate RTD beverages.

Emulsifiers like mono- and diglycerides and buffers such as tetrasodium pyrophosphate are commonly used in neutral pH beverages using whey proteins along with other milk proteins. Establishing the ideal levels of stabilizers, buffers and emulsifiers is especially important to ensure long-term stability of protein fortified beverages in the acid and neutral pH category.

PRESERVATIVES

Some acidified protein beverage formulas include chemical preservatives such as sorbates and benzoates to control the growth of yeast, mold and bacteria that could lead to product spoilage.

NUTRACEUTICALS

RTD protein drinks are high-value nutritional beverages that can be fortified with additional nutritional components such as plant sterols to lower cholesterol, lutein for eye health or energy boosting ingredients. Live and active cultures are frequently incorporated into cultured protein-containing dairy beverages. These beverages are usually pasteurized, cultured and stored refrigerated, although some products do receive heat treatment and are thus shelf-stable. The choices of beverages with added nutraceuticals is continually evolving with consumer trends and demands.

Processing Considerations

Attention should be given to the development of a validated, definable and repeatable process for preparing each batch of beverage. This includes batching temperatures, mixing procedures, order of ingredient addition (in particular acidulants) and, of course, the thermal process used for pasteurization or sterilization.

Use of Whey Proteins in Retort Beverages

The objective of the following research by Dr. Ron Richter, Department of Animal Science, Texas A&M University, Texas, USA was to develop beverages with high whey protein content that could withstand commercial retort sterilization and to examine shelf life.

Heat Stability

Heat treatment necessary to sterilize beverages caused instability and aggregation of the whey proteins when the concentration was greater than 1%. The addition of some food additives improved beverage stability.

Casein: Caseins such as in MPC, MPI and MCC have a disordered molecular structure and can protrude longer distances from the fat droplet interface increasing the steric repulsion and improving both the heat and emulsion stability.

Phospholipids: In fat-containing beverages, regular, hydrolyzed and acetylated lecithins improved the heat stability of emulsions containing up to 5% whey proteins. Modified lecithins with higher hydrophilic-lipophilic balance (HLB) values provided more protection against heat denaturation than regular lecithin.

Polyphosphates: Polyphosphates improved the heat stability of whey protein beverages allowing clear retorted beverages to contain up to 5% whey protein without added fat.

Hydrocolloids: Hydrocolloids had a detrimental effect on the heat stability of whey protein emulsions, most probably through thermodynamic incompatibility that locally increased the concentration of proteins and promoted heat aggregation.

Emulsion Stability

Homogenization pressure had the greatest impact on the fat droplet particle size and surface area, which both influence the emulsion stability. Emulsions containing acetylated lecithins were the most stable against creaming.

Storage Stability

Emulsions containing 5% protein and 3% fat formulated with 0.3% lecithin and homogenized at 90 megapascals (MPa) had the best stability when tested over 28 days of storage. However, creaming of the emulsions was still evident.

In summary, to improve creaming stability of whey protein retort beverages, additives must increase the viscosity without affecting the heat stability. The selection of ingredients to increase heat and emulsion stability depends on the beverage composition, and many options are available. Please contact your U.S. supplier of dairy ingredients for assistance in developing successful beverage products.

Adequate Hydration Time Means Increased Clarity of WPI Beverages

A challenge of incorporating WPI into clear beverages is that heating often causes cloudiness of the beverage. But a simple and inexpensive way to increase clarity is to allow adequate hydration time of the WPI in solution before heat treatment. Turbidity less than about 40 NTU† is considered clear to the consumer.

Procedure:

- Blend dry ingredients.
- Mix with water.
- Allow mixture to hydrate 20 minutes.
- Heat solution to 88°C (190ºF) for two minutes.

Benefit:

- By using adequate hydration time, turbidity of the solution after heat treatment is reduced about 50%.

WPI Solution Turbidity Over Time
(Solution of 25 g/L protein, pH 3.2, heat treatment 88ºC [190ºF] for two minutes)

HYDRATION TIME (MIN)	BEFORE HEATING (NTU)†	AFTER HEATING (NTU)†
0	55	79
10	52	39
20	49	38
30	49	37
40	47	39
50	47	38
60	47	37
70	47	39
80	46	37
130	46	38

†NTU= Nephelos Turbidity Units
Data courtesy of UW-Madison, D. M. Etzel

Consistent use of the dairy protein ingredient in the preparation of each batch for example, the method of pH adjustment and temperature exposures/treatments is also very important and should be carefully monitored and controlled to ensure success.

The first step is usually the rehydration of the powdered protein. This lengthy step can result in foaming. The manufacturer should be careful to minimize air incorporation during all steps of processing. The formation of excessive foam can lead to flocculation when the drink is heat-treated and in the case of stabilized beverages, some syneresis or separation may occur. It is recommended to blend dairy protein ingredients with a high-speed mixer and to allow hydration in roughly half of the formula water at temperatures less than 38°C (100°F), with slow agitation. The protein ingredients can be mixed in with sugars and other dry ingredients during the hydration step. Hydration time should not be less than 20 minutes to maximize heat stability and shelf stability of the dairy protein ingredient.

Order, method and rate of addition of ingredients are important to a specific formula. This is particularly critical for the acidification step, which generally takes a protein solution at around pH 6.5 and passes it through the zone of isoelectric points of the major proteins around pH 4.5. Whey proteins have a high buffering capacity so formulations with high levels of protein will require high levels of acid for pH adjustment.

The pH of acidified whey protein drinks typically decreases after heat treatment. This pH drop is likely due to the following: 1) initial stages of Maillard browning, 2) unfolding of proteins causing a change in the dissociation constant of some functional groups and 3) aggregation of proteins which alters the dissociated state. The pH shift that occurs will depend on the level of protein used.

For example, if a final pH of 3.2 is desired for a beverage containing 5% protein, then it is recommended that the drink be adjusted to pH 3.3–3.35 prior to heat treatment.

Finished Product Handling: Environmental Conditions During Distribution, Storage

Marketers of protein beverages must be familiar with the possible exposure to environmental extremes throughout various distribution channels, locations and climates. Not only are extremes of heat and cold undesirable, but repeated cycling between lesser extremes of heat and cold may have unexpected and unwelcome effects on product stability. Manufacturers new to a market may want to consult with representatives from their regional distribution and storage partners early in the development process to obtain information on typical conditions. Accelerated storage studies at various temperatures will help model shelf life and help predict changes in nutritional contents, flavor, acceptability, stability and other physical or chemical parameters.

Sample Beverages Formulations

The formulations in this section are provided as a starting point for product development purposes. Adjustments may be necessary, depending upon the exact nature of ingredients used, processing and storage variables, local regulations and target consumer preferences in each market.

Please consult your U.S. dairy ingredient supplier for additional information. Also check local regulations for use of additives and labeling requirements.

DAIRY MINERAL THIRST QUENCHER

INGREDIENTS

	Usage Levels (%)
Milk permeate (dairy product solids)	77.38
Sugar	18.05
Malic acid	2.58
Natural lemon flavor – WILD flavor	1.99
Yellow 5	.001
Total	**100.00**

PREPARATION

1. Mix all ingredients.
2. Add 20 grams to 8 ounces of cold water and stir.

NUTRITIONAL CONTENT

	per 100 g
Calories	28 kcal
Total Fat	0 g
Saturated Fat	0 g
Trans Fat	0 g
Cholesterol	0 mg
Total Carbohydrates	7 g
Dietary Fiber	0 g
Sugars	7 g
Protein	0 g
Calcium	32 mg
Potassium	162 mg
Sodium	40 mg
Iron	0 mg
Vitamin A	0 IU
Vitamin C	0 mg

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

RAZZ-A-TAN FROZEN FITNESS SMOOTHIE

INGREDIENTS

	Usage Levels (%)
Water	97.96
Raspberry base – Fruitcrown – 60 Brix	0.49
Whey protein isolate	0.49
Erythritol powder – Cargill 16952	0.30
Soluble fiber – Tate and Lyle Promitor (Soluble corn fiber 70)	0.30
82% Phosphoric acid	0.07
Tangerine flavor WONF – Biosun MZ6187815	0.06
Total	**100.00**

PROCEDURE

1. Combine the water, whey protein isolate and soluble fiber in a tank. Mix with a lightening mixer and hydrate for more than 30 minutes.
2. Combine rehydrated fiber/WPI and remaining ingredients in a mixer, and combine with slow agitation. Adjust the pH to 3.4 with phosphoric acid.
3. Heat to 85˚C (185˚F) for 30 seconds and cool to about 15.5˚C (60˚F).
4. Collect the pasteurized cooled product into sanitized containers and store at 2.2˚C (36˚F).
5. Place a portion of the product in a “Frozen Slushy” machine, freeze and dispense.

NUTRITIONAL CONTENT

	per 100 g
Calories	66 kcal
Total Fat	0 g
Saturated Fat	0 g
Trans Fat	0 g
Cholesterol	0 mg
Total Carbohydrates	23 g
Dietary Fiber	1 g
Sugars	11 g
Protein	4 g
Calcium	9 mg
Sodium	31 mg
Iron	0 mg
Vitamin A	0 IU
Vitamin C	1 mg

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VEGGIE BURST

INGREDIENTS

	Usage Levels (%)
Water	70.40
Carrot juice concentrate	10.00
Sweet potato concentrate	6.30
Whey protein isolate	4.50
Spinach juice concentrate	4.20
Celery juice concentrate	2.10
Romaine lettuce juice concentrate	0.80
Butternut squash juice concentrate	0.80
Ginger puree	0.40
Milk minerals	0.30
Beet puree	0.20
Total	**100.00**

PROCEDURE

1. Weigh all the ingredients.
2. Hydrate whey protein isolate (WPI) and milk minerals with formula water at room temperature while occasionally stirring for two hours.
3. Mix all the juices together with WPI and milk minerals solution.
4. Pasteurize the mixture (prepared in step 3) at 73°C (163°F) for 15 seconds followed by homogenization (2,000/500 psi).
5. Bottle and refrigerate.
6. Serve cold.

NUTRITIONAL CONTENT

	per 100 g
Calories	53 kcal
Total Fat	0 g
Saturated Fat	0 g
Trans Fat	0 g
Cholesterol	0 mg
Total Carbohydrates	8 g
Dietary Fiber	0 g
Sugars	7 g
Protein	5 g
Calcium	128 mg
Magnesium	4 mg
Phosphorus	9 mg
Potassium	433 mg
Sodium	65 mg
Iron	0 mg
Vitamin A	6,476 IU
Vitamin C	5 mg

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

CAFÉ MOCHA

INGREDIENTS

	Usage Levels (%)
Water	92.26
Milk protein concentrate 85	4.52
Sugar, white, granulated	1.54
Autocrat Columbian freeze dried coffee	0.77
Vanilla powder	0.09
Salt, table	0.04
Barry Callebaut Cocoa processed with alkali	0.77
Stevia	0.01
Total	**100.00**

PROCEDURE

1. Combine all dry ingredients (milk protein concentrate, sugar, coffee, vanilla, salt, cocoa and stevia).
2. Mix 20 grams of dry mix with 8 ounces of hot water.
3. Mix well.
4. Enjoy.

NUTRITIONAL CONTENT

	per 100 g
Calories	28 kcal
Total Fat	0 g
Saturated Fat	0 g
Trans Fat	0 g
Cholesterol	4 mg
Total Carbohydrates	2 g
Dietary Fiber	0 g
Sugars	2 g
Protein	4 g
Calcium	101 mg
Sodium	22 mg
Iron	0 mg
Vitamin A	0 IU
Vitamin C	0 mg

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

CHAI TEA LATTE

INGREDIENTS

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

PROCEDURE

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

NUTRITIONAL CONTENT

	per 100 g
Calories	46 kcal
Total Fat	0 g
Saturated Fat	0 g
Trans Fat	0 g
Cholesterol	2 mg
Total Carbohydrates	7 g
Dietary Fiber	0 g
Sugars	6 g
Protein	4 g
Calcium	96 mg
Phosphorus	58 mg
Sodium	6 mg
Iron	0 mg
Vitamin A	0 IU
Vitamin C	0 mg

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About the U.S. Dairy Industry

As the world's largest single-country producer of cow's milk with an ample, rising milk supply and a competitive, evolving product portfolio, the U.S. dairy industry is well-positioned to satisfy the world's growing appetite for dairy. Continuous investments in research and innovation, combined with a long, rich heritage of skilled craftsmanship, support the United States' emergence as a leading global supplier of quality dairy products and ingredients. The entire U.S. dairy supply chain—farm families, milk processors, product and ingredient manufacturers and dairy institutions—works together to provide high-quality, nutritious products to fulfill customers' needs and drive their businesses forward.

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