U.S. MILK AND WHEY INGREDIENTS IN ICE CREAM AND FROZEN DAIRY DESSERTS

Ice cream shines as an iconic treat with countless indulgent variations enjoyed around the world. Beyond fluid milk and cream, dairy ingredients such as milk powder, sweet whey, dairy proteins (whey and milk protein concentrates and isolates), as well as whey and milk permeate, are also frequently used in the production of ice cream, frozen novelties and other popular frozen dairy desserts. The driver for selecting a particular dairy ingredient depends on the desired attributes of the finished product, including flavor characteristics, nutritional profile (e.g., protein or fat content), format and price point of the specific ice cream or frozen dessert being produced. Dairy ingredient use can also contribute to product quality enhancements, including improved flavor, body, texture and freeze/thaw stability (contributing to extended shelf life).

This monograph reviews the functional benefits and technical considerations associated with successfully adding milk and whey-derived ingredients to ice cream and frozen dairy dessert formulations.

Ice Cream and Frozen Dessert Market Trends

The ice cream and frozen dessert category is constantly adapting, with both trendy new products and classic flavors and formats concurrently available in the marketplace to satisfy varying consumer cravings and budgets. Premiumization, flavor adventure, and clean label and nutritional enhancements are among the leading forces influencing new product offerings.

Artisan ice cream products made with simple ingredients and sophisticated flavors and inclusions continue to grow in popularity. This rise in unique savory and sweet taste profiles is creating an expansion of consumption occasions beyond just a treat into other day parts.

Sourcing milk from the sustainability-focused U.S. dairy community layers in an additional level of social responsibility, delighting today's discerning consumer with the best of both worlds: indulgence with less guilt. Through the ongoing implementation of new farming practices and technologies, U.S. dairy farmers and dairy ingredient processors continue to produce safe and nutritious products while using fewer resources. U.S. dairy farmers are producing more milk with fewer cows, using less water, producing fewer greenhouse emissions, and using less land than just a few years prior. Since cow's milk is 87% water, with the help of new technologies, processors find ways to recover and reuse it when cheesemaking and milk powder drying is complete. The U.S. dairy industry also has an ongoing commitment to adopt sustainable practices and report progress every five years, further demonstrating the industry's dedication to responsible production practices and continuous improvement across the value chain, from farm to table.

REGULATORY LIMITATIONS

There are no harmonized standards internationally for frozen dairy desserts including ice cream and, thus, for the use of milk and whey ingredients in frozen dairy desserts. Manufacturers should check local regulations to understand the minimum and maximum amounts of specific ingredients or components required or allowed in frozen dairy dessert formulations.

Notably, rising awareness and interest in the benefits of protein for health has propelled the launch of ice creams and frozen desserts with added protein. U.S. dairy proteins readily fit into this growing market opportunity due to advantageous attributes such as science-backed nutritional quality, mild flavor and functional versatility. Dairy proteins are easily digestible, high-quality, complete proteins containing all the essential and non-essential amino acids. Because of this greater efficiency, choosing dairy proteins allows formulators to use a smaller volume of protein to meet the nutritional needs of consumers as compared to many plant-based alternatives—all without negatively impacting final product appearance, functionality, shelf life and/or sensory attributes. This allows for nutritional enhancement without exceeding desired calorie limits or negatively impacting functionality of the finished product.

A Range of Functional Ingredients

Composition and functionality of any given milk or whey-derived ingredient can vary based on the supplier, the starting material and the manufacturing method(s) used for concentration and/or fractionation. Working with your suppliers to select ingredients that meet your functionality needs is very important. Even so, it is relatively easy to include milk and whey-derived ingredients in ice cream and frozen dairy desserts with a few key formulation guidelines based on their functional properties.

FUNCTIONAL BENEFITS OF MILK AND WHEY- DERIVED INGREDIENTS IN ICE CREAM AND FROZEN DESSERTS

Water Binding

Milk and whey proteins bind large volumes of water through physical and chemical means. These interactions with water can increase mix viscosity and product smoothness and aid in achieving finished product freeze/thaw stability. This helps to maximize shelf life by limiting water mobility and ice crystal growth. Limiting ice crystal growth is arguably the best means of increasing frozen dessert shelf life. Smaller ice crystals are less detectable to the human palate, so the finished frozen dairy dessert retains smooth and creamy eating qualities.

Whipping/Foaming

Most typical frozen desserts rely upon the creation and maintenance of foam structure to provide desirable textural and functional qualities. Given

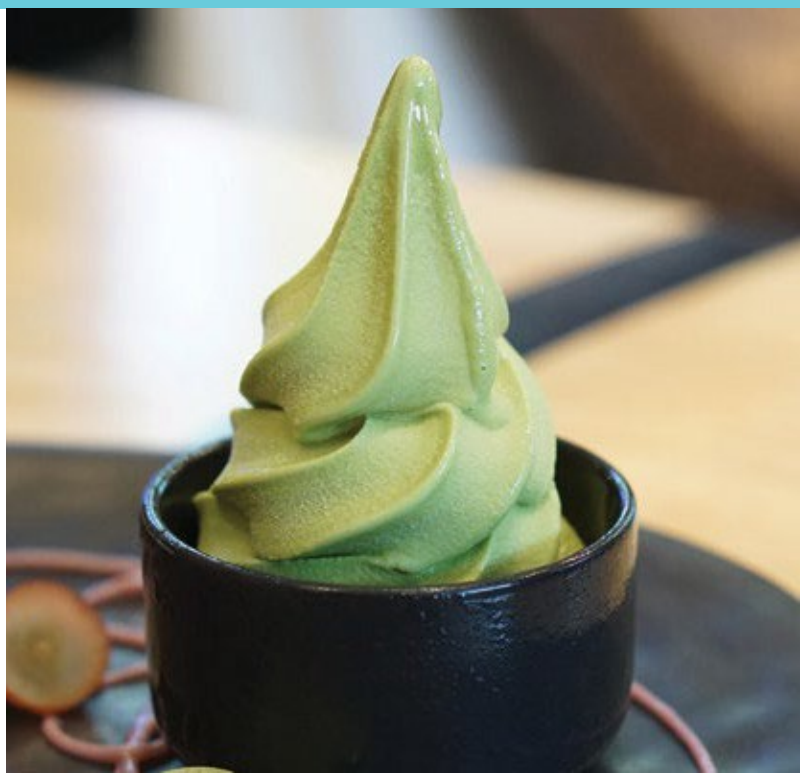
their unique chemical structures, milk and whey-derived ingredients are natural aids in contributing whipping and foaming ability as air is incorporated. Furthermore, as the viscosity of the unfrozen portion of the mix increases, milk and whey proteins help stabilize and strengthen the resulting air cells, thus limiting the collapse or shrinkage of the foam structure which is known as "shrinkage." When small air cells are created and maintained, ice crystals are small, and ice cream texture is smooth and creamy. This enhances resistance to heat shock, which is caused by temperature fluctuations during product distribution.

Emulsification

Select milk and whey-derived ingredients are very efficient emulsifiers of fat and oil. They can exist at crucial interfaces between water and lipid phases in frozen desserts and can easily participate in emulsion structure. This dual functionality allows milk and whey-derived ingredients to either partially or totally replace chemical emulsifiers in frozen dairy desserts. Additionally, milkfat-containing ingredients contain significant amounts of phospholipids (a naturally occurring component of milkfat that chemically behaves much like lecithin), adding to the emulsification capacity of the mix. Each dairy ingredient must be carefully considered during product formulation for purposes of performance, standardization, consistency and labeling accuracy. Milk and whey-derived ingredients can directly or indirectly influence fat agglomeration during whipping (addition of air) and freezing (creation of ice). Studies have shown that some agglomeration is critical for superior heat shock resistance and eating quality in terms of body (chew or bite) and texture (smoothness and creaminess).

Flavor

Milk and whey protein isolates have mild flavor profiles, making them ideal choices for formulations as compared to many non-dairy protein sources available on the market. High levels of sweet whey and whey concentrates may, in some formulations, result in a whey flavor especially noticeable in delicate flavor systems, such as vanilla. However, if properly selected and used at the correct levels, positive aspects of both milk and whey in relationship to flavor can be maximized—especially in applications where complex, strong flavor systems are employed. Additionally, the use of organic acids (such as citric, malic and lactic) and fruit flavors, which are common in frozen desserts, help attenuate milk and whey flavors.



Viscosity

Body and texture improvements can be achieved through the addition of milk and whey proteins. Milk and whey proteins help increase the viscosity of the unfrozen portion of the frozen dairy dessert and help maintain both small air cells and small ice crystals through interactions involving protein structure and water. As a result, the mouthfeel of frozen dairy desserts with milk and whey proteins tends to be smoother, creamier and with less icy or coarse texture. Additional benefits include resistance to heat shock and improved shelf life.

Visual Appeal

Depending on the type of mix, milk and whey ingredients can add opacity, whiteness and milky appearance to mixes and finished products. For example, milk permeates appear whiter than whey permeates, making them more appropriate in vanilla and other lighter-colored finished products. If properly selected, milk and whey ingredients can also help preserve visual appeal by helping to maintain structure and/or form in the finished product, even during conditions when the product is melting during consumption. Milk and whey ingredients can also aid in maintaining the product structure, which helps with the visual appeal of flavors with added particulate(s) such as cookie and candy pieces, fruit particulates, nuts and/or syrup inclusions (e.g., ribbons, variegating sauces).

Bulking Agent

In low-cost or economy formulations, milk, whey and permeate ingredients can be used as bulking agents and/or fat replacers, imparting sensory improvements related to product density. Compared to other options in this category of bulking agents, dairy-derived ingredients provide natural, familiar-sounding, clean label options for discerning consumer markets. Permeates are cost-effective dairy ingredients that enhance flavor and increase water-holding capacity. They can contribute sweetness, making them ideal for soft serve ice cream as well as for chocolate, salty and savory flavors, such as salted caramel. Whey or milk permeate can be readily incorporated into frozen dessert applications using basic formulation software. Careful review of ingredient selections and specifications is recommended to ensure accurate formula calculations.

Freezing Point Management

A key step in manufacturing a successful frozen dessert is the management and calculation of the freezing point depression of the mix. Milk and whey proteins, lactose and permeate (which contains mineral salts) can be customized or selected to efficiently manage freezing performance and water-to-ice phase transition. This, in turn, affects freezing conditions, mix performance and finished product qualities, such as body and texture. Milk and whey proteins play a key role in managing ice crystal growth during heat shock and other storage/distribution challenges. Superior freeze-thaw stability can be achieved using milk and whey proteins. The proper selection and use of milk, whey and permeate ingredients are critical to formulation success. Contact your U.S. dairy ingredient supplier to identify the best options.

Impact on Added Flavors

High molecular weight proteins, such as milk and whey proteins, can absorb various chemical components from added flavors such as vanilla extract. In general, increased levels of nearly any protein or lipid source will attenuate the perception of volatile flavors such as vanilla. When changes in the concentrations of protein or lipid fractions are being considered, thoughtful re-design of product formulations, including flavor systems, is encouraged.

Cost Effectiveness

An important factor in the use of milk, whey and permeate products in ice cream and other frozen dairy desserts is the ability to optimize the mix ingredient costs. Proper selection of dairy ingredients to maximize functionality and sensory properties can result in significant cost savings. The use of milk and whey proteins allows more air to be incorporated during freezing and whipping of the mix and by helping to maintain small and strong air cells. Increasing the amount of air incorporated, known as overrun, will increase yield and offer secondary cost savings.

NUTRITIONAL BENEFITS OF MILK AND WHEY-DERIVED INGREDIENTS IN ICE CREAM AND FROZEN DESSERTS

While nutrition attributes are not necessarily top-of-mind in the ice cream and frozen dessert category, there is increasing diversity in better-for-you options. Today's consumers are opting for personalized nutrition, such as adopting dietary habits like high protein or low-carb eating plans based on what they feel is right for their body and health goals. Frozen desserts and snacks that contain high-quality protein

and clean label ingredients are valued and sought after by health-conscious consumers. Examples may include frozen yogurt or ice cream products with added probiotics, botanicals, a protein boost for muscle health and maintenance, or added coffee or green tea to address a mid-day energy slump.

Incorporating dairy ingredients into ice cream products can help meet the body's needs for calcium, magnesium, selenium, riboflavin, vitamin B12 and pantothenic acid. Dairy ingredients like whey and milk proteins can provide a variety of health and wellness benefits related to muscle health, weight management and satiety, depending upon the usage level at which they are added. Dairy's nutrient-rich package is recognized as an important part of well-rounded, healthy diets.

Note that ice cream is an extremely complex food and that changes in the base mix formulation to meet a nutritional goal or target must be done with an understanding of how those changes will affect other parameters of the frozen dessert. Consulting an expert on ice cream formulation is suggested.

Manufacture of Frozen Dairy Desserts with Milk and Whey Ingredients

ASSEMBLY OF INGREDIENTS/ MIX PREPARATION

Milk and whey ingredients are added with other liquid and dry ingredients to each individual mix. Milk, whey and/or permeate ingredients must be added during the assembly of the mix prior to pasteurization to ensure the microbiological quality and safety of the finished mix. They should be added under high shear to the totality of liquid ingredients (water, milk, skim milk, cream, whey, permeate, liquid sugar and/or sweeteners) to prevent lumping and pre-gelation. Under these conditions, it is not necessary to pre-blend with other dry ingredients, but agitation time should not be less than 20 minutes to allow for adequate hydration of the proteins to ensure heat and shelf stability.

For small batch sizes, high shear conditions are less critical. In these cases, amounts of milk, whey and permeate ingredients can be added via simple pre-blending with other dry ingredients (such as sugar, corn syrup solids or maltodextrin) to improve dispersion or through a powder funnel or powder horn with recirculation through the funnel pump and batch tank. With either high or low shear preparation, care is necessary to prevent excess foaming (air incorporation) in the mix. Foaming is not just due to addition of protein-containing ingredients such as milk, whey and egg solids. More protein and less fat in any given mix increases the potential for foaming. Foaming leads to burn-on in batch and continuous pasteurizers, low yields, increased costs, poor freezer performance and other undesirable effects, such as the development of oxidized and/or burnt flavors. Foaming is easily controlled through properly engineered mix preparation systems.

PASTEURIZATION (BATCH OR CONTINUOUS)

Pasteurization can potentially impact milk and whey ingredient functionality in finished mixes. This is dependent on the specific mix, composition, ingredient(s) used and the exact times and temperatures applied during pasteurization. Typical pasteurization conditions for frozen dairy desserts do not impact milk and whey product functionality. However, if heating systems are uncontrolled, burn-on can occur, which can result in off flavors and varying functionality from added protein ingredients such as milk and whey concentrates/ isolates. In some instances, pasteurizing using ultra-high temperatures or ultra-long times can affect milk and whey protein functionality, both positively and negatively. Again, care is necessary when considering these temperature and time options to maximize water-binding or gelling characteristics of milk or whey ingredients in any given mix.

HOMOGENIZATION

Milk and 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. This is particularly helpful in a mix that is to be packaged for freezing at another location and/or time.

AGING

Once a frozen dessert mix is made, it is customary to allow the mix to sit or "age" for a duration ranging from several hours to overnight. Given the complex nature of frozen dessert mix, this aging period allows the mix to fully hydrate and to complete the relatively slow reactions and interactions. Aging of the mix involves holding the mix at refrigeration temperature with agitation just sufficient to enable the maintenance of product temperature (e.g., <7˚C/45˚F). In general, aging results in a smoother product with improved processing performance and finished product quality.

FREEZING (BATCH OR CONTINUOUS -5 TO -6˚C/21 TO 23˚F)

The draw temperature is the temperature of the mix upon discharge from the freezer. It is dependent on the mix composition, functionality and the packaging and storage plan for the finished frozen dairy dessert. Normally, the lowest possible draw temperature (greatest amount of ice made in the barrel of the ice cream freezer) that allows handling of the finished ice cream for its required purpose (packaged, molded, extruded) is desired. By helping to manage the freezing point of the mix, inclusion of milk, whey and/or permeate ingredients can impact the draw temperature and the viscosity (weak and fluid versus stiff and dry). Weak viscosity may be adequate and desirable for molded novelties but unacceptable for extruded novelties or packaged ice cream. Additionally, milk, whey and/or permeate ingredients can help in the freezing of many small ice crystals to improve the eating quality of the finished dairy dessert.

HARDENING

Once the product is frozen and packaged, it is critical that it is more fully hardened under conditions of extreme cold and air circulation. This step freezes much of the remaining water and allows for the best long-term storage performance, typically 18 months

DISTRIBUTION (<-28˚C/-18.4˚F)

Finished frozen dessert temperature will fluctuate with specific conditions encountered in the distribution chain. As ice-to-water-to-ice transition occurs due to temperature fluctuation during distribution, milk and whey proteins increase stability by adding heat shock resistance to protect and maintain the body and texture of the frozen dessert.

Considerations When Formulating with Milk and Whey Products

Care is necessary to manage protein, lactose and salts to ensure proper freezing performance (maximize creation of small ice crystals) and eliminate potential for lactose crystallization known as sandy texture defect. This is true in super-premium ice creams as well as in nutrient-modified ice creams. In general, milk and whey protein ingredients, when applied on a protein-to-protein basis, can replace up to 50% of naturally occurring casein in most ice cream mixes. This helps retain the unique functional properties of casein that add body, texture and heat shock resistance. The effects of lactose and salts must also be carefully considered.

U.S. DAIRY INGREDIENTS: COMPOSITIONS AND ADVANTAGES IN FROZEN DESSERTS

INGREDIENT	PROTEIN (%)	LACTOSE (%)	FAT (%)	ASH (%)	MOISTURE (%)	APPLICATION ADVANTAGE
Skim Milk Powder	34 to 37	49 to 52	0 to 1	8 to 9	3 to 4	Stable source of dairy solids; cost-effective
Evaporated, Condensed Skim Milk	7	11	0	1	80	Cost-effective source of dairy solids
Milk Protein Concentrate	42 to 85	8 to 50	1 to 2	8 to 10	<5	Common source for milk protein fortification
Milk Protein Isolate	> 90	0.5	< 2	<8	5	Source of highly concentrated milk protein
Casein*	80 to 85	0.5	1	4 to 8	5	Concentrated casein protein with various functional properties
Sweet Whey Powder	10	> 70	1	9	5	Cost-effective source of milk solids
Whey Protein Concentrate	34 to 80	10 to 50	4 to 6	3 to 7	4	Highly functional, nutritional protein
Whey Protein Isolate	> 90	<1	<1	3	4	Concentrated source of highly functional, nutritional protein
Whey Permeate	2 to 6	70 to 85	<1	10	4	Cost-effective source of milk solids
Lactose	<1	95+	< 0.1	< 0.5	5	Source of milk sugar: Contributes total solids and freezing point
Whey Protein Phospholipid Concentrate	> 50	1 to 5	> 12	<8	<6	Source of protein and milk phospholipid for emulsification and foaming
Dry Buttermilk Powder**	34	45 to 50	5	8 to 9	<4	Cost-effective source of protein and milk phospholipid for emulsification and foaming

*There are various forms of casein including acid, rennet, and caseinates that have specific compositions and funtional properties.
**Derived from butter manufacturing.

FINISHED PRODUCT TO BE MADE FROM THE MIX

Retail Packs

Two-liter or smaller packs for home consumption will undergo more temperature abuse during distribution, so freeze/thaw stability is important. Milk and whey protein concentrates and isolates can add significant freeze/thaw stability when distribution abuse is a potential concern.

Bulk Packs

Repeated dipping and sampling into 10-liter packs or larger for food service or dip shops can physically damage the finished frozen dairy dessert. Again, milk and whey protein concentrates and isolates can add physical strength to the finished frozen dairy dessert and add resistance to both heat shock and physical abuse.

Direct-fill Novelties

This is the direct filling of cups, cones and novelties such as push-ups. Because the ultimate shape of the product is determined by the package, the frozen dairy dessert must be able to flow evenly into the package before final hardening, thus concern is given to mix composition, viscosity and processing. Milk or whey permeates could be a normal ingredient selection for these direct-filled novelty applications. Draw temperatures are selected to reflect need of the final frozen dairy dessert to flow into the package without voids.

Extruded Novelties

Frozen dairy dessert mixes intended for novelty items that are extruded through shaped orifices and cut to the proper size and shape need to be flowable, yet stiff enough to extrude and hold a shape. Both milk and whey protein concentrates and isolates offer significant functionality to bind water, stiffen the frozen dairy dessert and help an extruded piece withstand the physical abuse it must undergo during manufacturing.

Molded Novelties

Molded novelties require a very fluid frozen mix that is deposited into molds and then frozen. The frozen mix must withstand air incorporation and freezing, flow readily, harden rapidly (to hold inserted stick, if desired), promote surface thaw to release items from the molds, and allow secondary treatments (liquid or dry coating applications). If molds are not filled adequately, voids are created, which can cause a variety of undesirable defects. Sweet whey and/or permeates may be used.

Coated Novelties

If a frozen item is to be coated, ingredient selection and mix formulation are critical. Milk and whey proteins can add significant functional characteristics that assist application and retention of coatings onto the finished frozen novelty. Lactose and permeate may also be desirable ingredients in many compounded novelty coatings, as they provide sweetness control and low-cost solids. This includes dry as well as liquid coatings.

AMOUNT AND TYPE OF MIX INGREDIENTS AVAILABLE

Lactose Content

An important factor is the total lactose content of the mix. The contribution of lactose from all dairy ingredients must be known, calculated and managed. To minimize lactose crystallization (sandiness) in frozen dairy desserts, it is advisable to keep the lactose content of mixes below 7.5%. The lower the lactose content, the less likely it is that the lactose can or will contribute to sandiness. Lactose solubility is limited and varies with several factors. Although there will be some degree of lactose crystallization in virtually all dairy-based frozen dairy desserts, managing the lactose content will reduce both the likelihood of lactose crystallization and the size of the lactose crystals that do form. Permeate—with its higher lactose content—may be more suitable for formulating soft serve ice cream mixes, which are somewhat more forgiving than hard pack ice cream.

Sweetness

Some manufacturers use various enzyme hydrolysis technologies to fully eliminate or reduce lactose to its sugar monosaccharides, which can contribute sweetness. There are numerous implications of such technologies, most of which are advantageous to frozen dessert applications. Two examples are the ability to add less sugar to the formula and the ability to market a reduced lactose product.

Bulking Agents, Stabilizers and Emulsifiers

Milk and whey proteins can interact with several large molecular weight bulking agents (starches, starch hydrolysates, hydrocolloids, etc.) to add or detract from the performance of a given mix. Thus, care is necessary when adding milk or whey protein concentrates and isolates to specialty mixes with relatively large amounts of bulking agents. Components of milk and whey ingredients don't interact significantly with added chemical emulsifiers, but there can be significant interaction between the free calcium in milk and whey with stabilizers, such as low methoxyl pectin. Such interactions can result in sticky and/or gummy frozen dairy dessert. Given the broad array of customized U.S. dairy ingredients, be sure to check with your supplier for guidance on which one to use in your formulation.

PROCESSING CONDITIONS

Typically, pasteurization conditions have little impact on milk and whey protein functionality in mixes. However, if aggressive pasteurization (high temperature-long time, UHT) is considered, milk and whey protein functionality can be affected, depending on the processing of the specific milk and whey ingredient. Milk and whey ingredients, particularly whey protein concentrate with 60% to 85% protein and whey protein isolate, may become more hydrated during aging and can significantly impact mix viscosity and mix performance. Freezer draw temperatures become critical. Recommended draw temperatures are typically those that are as low as possible and still allow the manufacturer to handle the frozen dairy dessert as necessary for packaging. Modern continuous hardening systems that quickly freeze the remaining free water as ice are optimal when mix formulas contain milk and whey ingredients. Protein blends may also be used to optimize draw temperatures and handling. If severe thermal abuse during distribution is expected, selecting a proper milk and whey protein ingredient can add significant freeze/thaw stability and yield improvements for cost savings.

Recommendations for the Use of Milk and Whey Ingredients in Ice Cream and Frozen Dairy Desserts

When considering using a milk, whey or permeate ingredient, note the following:

- Balance the freezing performance of the mix with that of the ingredient of choice.
- Control total level of lactose in formulas to <7.5% of total mix to minimize lactose crystallization, which can result in sandy ice cream texture. The lower the lactose, the less likely it is that sandiness will result.
- Consider the impact of the functionality (including flavor) of the milk, whey or permeate ingredient itself on each individual flavor of every mix.
- Check local legislation for regulatory usage limits of all ingredients.
- Consider how the finished product is to be used, distributed and marketed.
- Add milk, whey and permeate ingredients to the totality of all liquid ingredients under high shear or as a pre-blend (for small batch sizes) together with high solubility dry ingredients to ensure proper mixing and hydration.
- Minimize foam development by using a properly engineered batching system. Other process considerations can be managed through proper formulation.
- Consider that because dairy protein isolates and concentrates are multifunctional ingredients, they may help reduce or replace other ingredients for a cleaner label.

When all product and process options are considered, dairy ingredients, including milk and whey proteins, milk powder, sweet whey, and whey and milk permeates, are viable and valuable ingredients for use in ice cream, frozen dairy desserts and novelties.

Common Q & A

Q: How can I successfully incorporate a milk- or whey-derived ingredient into a complex food such as ice cream?

A: Your ingredient supplier should be able to provide you with a clear compositional profile of the ingredient you are seeking to purchase. Each of these components, such as protein, milkfat, lactose and minerals, will influence the behavior of the product. We encourage you to work with someone experienced in standardizing ice cream mixes to account for all changes to ensure product performance is maintained and/or improved.

Q: What should I consider when purchasing dairy ingredients?

A: We encourage you to work with your supplier to identify and agree upon clear specifications for product consistency and performance in the finished product. Important aspects include composition, microbial standards, color and flavor. Remember, ice creams and other frozen desserts are complex foods. As a result, ingredient deviations will most likely impact product quality.

Q: There are multiple suppliers for my desired ingredient—how do I select the right one?

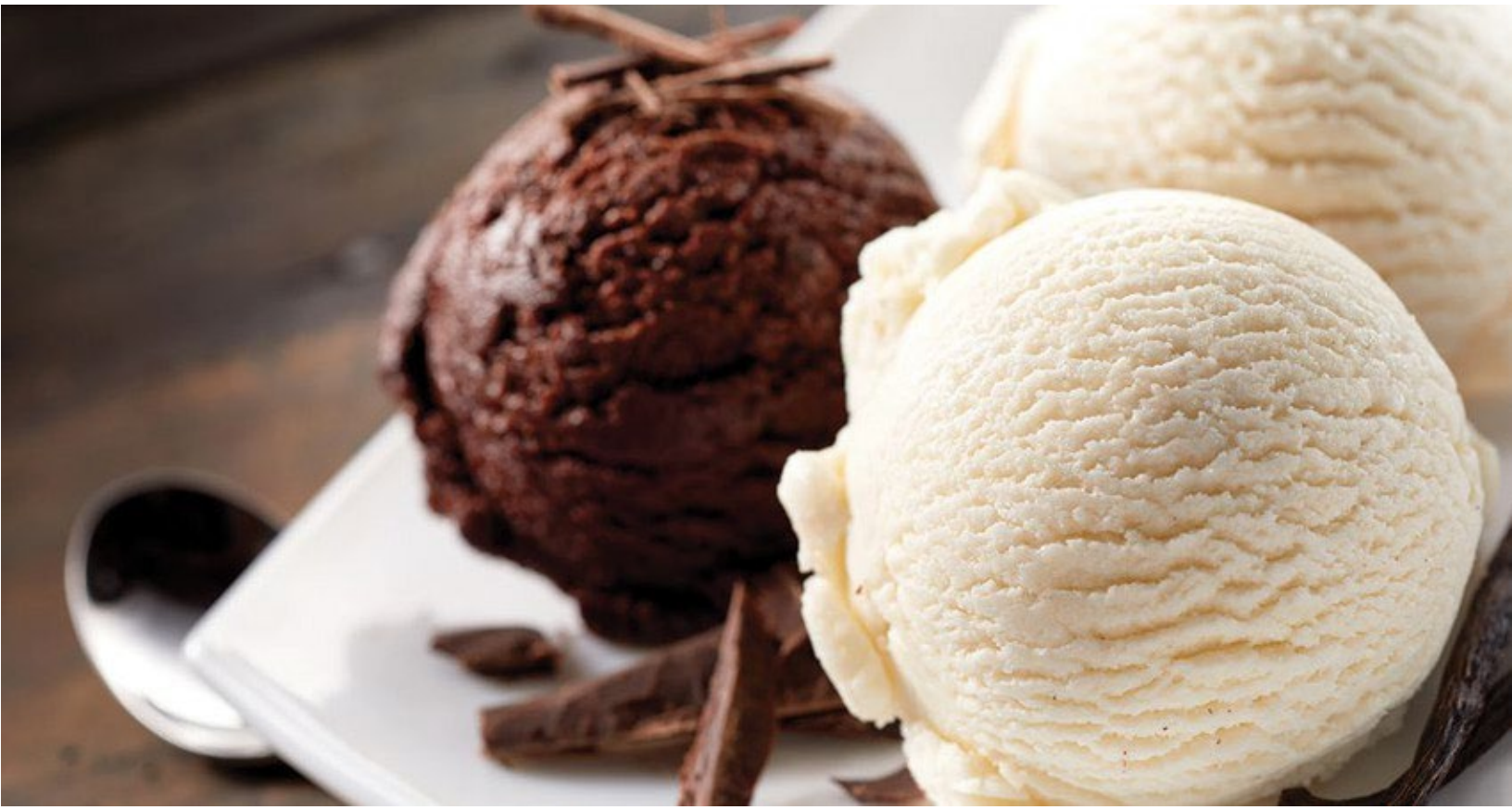
A: Contact several U.S. suppliers to help guide your decisions and meet your targets for functionality and cost. Ask each supplier to send you product samples and conduct trial assessments of important characteristics, such as color, flavor and solubility. Some suppliers may be able to provide sample application formulations using their ingredients.

EVALUATION OF PHYSIOCHEMICAL AND SENSORIAL PROPERTIES OF PEA, SOY AND MILK PROTEIN ICE CREAM

As interest in protein-boosted products has grown for health and wellness, the range of protein options has expanded to include plant-based options in addition to dairy-based sources. As with other food and beverage products, choosing the right protein ingredient is essential when formulating protein-fortified ice creams to deliver the functional performance and sensory characteristics consumers expect. It is also important from a nutritional perspective, as many plant based sources besides soy are incomplete proteins missing some of the key essential amino acids.

In a 2021 capstone project conducted by Singapore Institute of Technology student Leng Wei Qi, supervised by faculty member Assistant Professor Du Juan, PhD, pea, soy and milk protein concentrates were included in traditional ice cream formulations, and samples were comparatively evaluated for functionality, physiochemical and sensorial properties, and amino acid composition. Viscosity, overrun, firmness and shrinkage were all recorded.

The study found that milk protein concentrate 80 (MPC80) produced the closest protein-enriched product to traditional ice cream. The meltdown rate, firmness and sensory attributes evaluated were relatively close to the control. Reformulation of the pea protein and soy protein samples would be required to improve flavor and textural properties and palatability. A combination of protein sources may be necessary to mask the undesirable pea and beany notes and to improve upon the protein quality in terms of essential amino acids.



Sample Formulations

FROZEN DESSERT: NONFAT DAIRY SOURCE

INGREDIENTS

	Usage Level (%)
Skim Milk, Liquid	73.56
Sugar (Sucrose)	13.00
Milk Protein Concentrate, 80%	5.00
Vegetable Oil	4.94
Corn Syrup Solids, 42DE	2.00
Skim Milk Powder	1.00
Stabilizer	0.35
Polysorbate 80	0.15
Total	**100.00**

PROCEDURE

1. Pre-blend all dry ingredients.
2. Mix all wet ingredients and warm to 55˚C (131˚F).
3. Under agitation, carefully add all dry ingredients to wet; avoid excessive clumping.
4. Under moderate agitation, allow ingredients to continue to blend and hydrate for 30 min. at 55˚C (131˚F).
5. Pasteurize (HTST) mix at 85˚C (185˚F) for 20 seconds.
6. Homogenize with 17.2 and 3.4 MPa of pressure on the first and second stages.
7. Cool to <7˚C (45˚F) and allow to age (let sit with slow agitation) for 4 to 8 hours.
8. Flavor and freeze as desired at overruns from 60% to 80%.

NUTRITIONAL CONTENT

	per 100 g
Calories	150 kcal
Total Fat	5 g
Saturated Fat	4 g
Trans Fat	0 g
Cholesterol	5 mg
Sodium	45 mg
Total Carbohydrates	19 g
Dietary Fiber	0 g
Total Sugars	18 g
Added Sugars	14 g
Protein	7 g
Calcium	25%
Iron	0%
Vitamin A	10%
Vitamin C	2%
Vitamin D	6%

HARD-PACKED ICE CREAM

INGREDIENTS

	Usage Level (%)
Water	45.85
Cream, 40% Fat	**25.00**
Sucrose, Granulated	16.00
Skim Milk Powder	**10.32**
Sweet Whey Powder	**2.58**
Stabilizers and Emulsifiers	0.25
Total	**100.00**

PROCEDURE

1. Blend all ingredients into a uniform suspension in a batch tank.
2. Test the mix and re-standardize if necessary.
3. Pasteurize the mixture at 82˚C (180˚F) for 23 seconds.
4. Homogenize the mixture. A two-stage homogenization is recommended with 14.1 MPa (2045 psi) in the first stage and 3.5 MPa (508 psi) in the second stage.
5. Cool rapidly to 0-4˚C (32-39˚F).
6. Age the mix for at least 4 hours.
7. Optional: Completely dispersible flavorings can be added to the mix prior to freezing.
8. Freeze in two stages. Freeze to -1 to 0˚C (30-32˚F) in the first stage in an ice cream freezer at a rapid rate to a discharge temperature of -7 to -6˚C (19-21˚F).
9. Optional: Add particulate materials or syrups through a fruit feeder.
10. In the second stage, harden the ice cream by reducing the temperature of the product to at least -18˚C (0˚F) in the center of the packages as quickly as possible.

NUTRITIONAL CONTENT

	per 100 g
Calories	200 kcal
Total Fat	9 g
Saturated Fat	6 g
Trans Fat	0 g
Cholesterol	35 mg
Total Carbohydrates	24 g
Dietary Fiber	0 g
Total Sugars	23 g
Protein	5 g
Calcium	187 mg
Magnesium	19 mg
Phosphorus	130 mg
Potassium	200 mg
Sodium	100 mg
Iron	0 mg
Vitamin A	368 IU
Vitamin C	2 mg

SOFT SERVE FROZEN DESSERT WITH MILK PERMEATE

INGREDIENTS

	Usage Level (%)
Skim Milk, Liquid	64.91
Cream, 36% Milkfat	13.71
Sugar (Sucrose)	12.50
Milk Permeate	3.00
Skim Milk Powder	3.00
Corn Syrup Solids, 42DE	2.50
Stabilizer	0.28
Polysorbate 80	0.10
Total	**100.00**

PROCEDURE

1. Pre-blend all dry ingredients.
2. Mix all wet ingredients and warm to 55˚C (131˚F).
3. Under agitation, carefully add all dry ingredients to wet; avoid excessive clumping.
4. Under moderate agitation, allow ingredients to continue to blend and hydrate for 30 min. at 55˚C (131˚F).
5. Pasteurize (HTST) mix at 85˚C (185˚F) for 20 seconds.
6. Homogenize with 17.2 and 3.4 MPa of pressure on the first and second stages.
7. Cool to <7˚C (45˚F) and allow to age for 4 to 8 hours.
8. Flavor and freeze according to the soft serve freezer directions.

NUTRITIONAL CONTENT

	per 100 g
Calories	140 kcal
Total Fat	5 g
Saturated Fat	3 g
Trans Fat	0 g
Cholesterol	20 mg
Sodium	50 mg
Total Carbohydrates	20 g
Dietary Fiber	0 g
Total Sugars	18 g
Added Sugars	13 g
Protein	4 g
Calcium	15%
Iron	0%
Vitamin A	15%
Vitamin C	2%
Vitamin D	6%

HIGH PROTEIN FROZEN DESSERT: CLEAN LABEL, LOWER CALORIE

INGREDIENTS

	Usage Level (%)
Water	64.18
Lemon Juice	12.00
Whey Protein Isolate	10.55
Honey	5.00
Sugar, Granulated (Sucrose)	5.00
Spice Ginger, Paste	3.00
Lemon Flavor, Natural	0.15
Polysorbate 80	0.12
Total	**100.00**

PROCEDURE

1. Pre-blend all dry ingredients.
2. Add the blended ingredients to pre-weighed water and lemon juice.
3. Mix slowly until all the dry ingredients are dissolved.
4. Allow to mix in a Hot Thermo mixer for 10-15 minutes, applying low to medium shear.
5. Add the ginger paste, flavor and color.
6. Pasteurize at 93˚C (200˚F) for 3 seconds.
7. Fill into form and freeze.
8. Store and serve frozen.

NUTRITIONAL CONTENT

	per 100 g
Calories	170 kcal
Total Fat	12 g
Saturated Fat	8 g
Trans Fat	0 g
Cholesterol	40 mg
Sodium	50 mg
Total Carbohydrates	14 g
Dietary Fiber	0 g
Total Sugars	7 g
Added Sugars	2 g
Protein	7 g
Calcium	20%
Iron	0%
Vitamin A	25%
Vitamin C	2%
Vitamin D	6%

References:

During development of this monograph, the following sources were consulted:

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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 environmental stewardship and skilled craftsmanship, support the United States' emergence as a leading global supplier of quality, sustainably produced 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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