WHEY PRODUCTS IN ICE CREAM AND FROZEN DAIRY DESSERTS

By Dr. Steven Young, Ph.D.
Steven Young Worldwide, Houston, Texas, USA

Whey and whey protein products have been used successfully in ice cream and other frozen dairy desserts for the past six decades. Sweet whey, whey protein concentrates (34-89% protein) and whey protein isolates (≥90% protein) are among the most commonly used whey products. Other whey ingredients such as 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.

Whey powder was the first whey product added to ice cream and its popularity was associated with its cost benefits when compared to other sources of milk-solids-non-fat (MSNF). Nowadays, the functional properties of the proteins in whey protein concentrates (WPC) and whey protein isolates (WPI) also justify their use in mix formulas.

In global markets, the use of whey products in frozen dairy desserts has become increasingly common. This can be attributed to the greater availability of high quality functional whey products and the increased knowledge about the applications and benefits of whey products.

This monograph focuses on the functional benefits and considerations associated with adding whey ingredients to ice cream and frozen dairy dessert formulations. It is intended as a tool to jump-start product development. For additional information and quicker reach of your goals, please consult with your U.S. whey ingredients supplier and/or other publications available from the U.S. Dairy Export Council (www.usdec.org).

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MARKET TRENDS AND EXPANDING USE OF WHEY PRODUCTS IN FROZEN DAIRY DESSERTS

In the U.S., ice cream (including full-fat and fat-modified products) is still the predominant frozen dairy dessert category by total unit volume. Frozen yogurt, sherbet and sorbet show no indication of significant growth as percent of total sales. Novelties continue to grow but only within the ice cream segment, and within that segment most new novelties are based on full-fat (≥10% milk fat) ice creams rather than fat-modified (<10% milk fat) ice creams.

In the U.S., as in other regions of the world, the term "ice cream" includes fat-modified and/or sugar-modified (no sugar added) frozen dairy desserts – as long as other compositional standards for "ice cream" are met. The market availability for such "nutrient-modified" products shows the increasing demand for a true ice cream eating "experience" with lower fat and/or lower added sugar.

"Ice cream" covers nearly 90% of all frozen dairy desserts in the U.S. Of this, 70% is full-fat product. The remainder is split between fat-modified ("light," "reduced-fat," "low-fat" and "fat-free") and sugar-modified (no-sugar added) "ice creams." Of all new products, nearly two-thirds are full-fat ice creams.

This further highlights and emphasizes the constant consumer demand for nutrient-modified products (low/no-fat; low/no-sugar) that also maintain a classical ice cream eating quality.

Novel products might include truly sugar-free (<0.5 g total sugars per serving) executions and better quality (i.e. better taste, eating quality and texture) executions of fat-free "ice creams," and/or products with "low glycemic index."

Whey and whey products can offer significant functionality benefits, cost-effective functionality for cost avoidance and cost reduction, quality improvement, superior nutritional value and other nutritional benefits such as reducing the glycemic index.

REGULATORY LIMITATIONS

There are no international standards for frozen dairy desserts and, thus, no internationally recognized standards for the use of whey ingredients in frozen dairy desserts. Manufacturers should check local legislation for maximum amounts of specific ingredients allowed in their frozen dairy dessert formulations. However, proposals now being considered in the U.S. may allow use of "total milk protein" (total of all casein and whey proteins) as the basis for regulatory standards rather than "total milk solids" or "total milk-solids-non-fat (MSNF)." Such evolving proposals are more scientifically and technically correct and, inherently, allow the use of more whey protein ingredients if all other functionalities and sensory needs are met in the finished frozen dairy dessert. Of course, individual national regulations, or limitations, on the use of whey and whey protein ingredients need to be considered in this potentially changing regulatory environment.

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 ice cream and frozen dairy desserts include:

- Sweet Whey
- Reduced Lactose Whey
- Demineralized Whey
- Acid Whey (acid flavored sherbet, sorbet only)
- Whey Protein Concentrate (WPC with protein levels ranging from 34% to 89%)
- Whey Protein Isolate (WPI ≥90% protein)
- Other customized products and ready-to-use blends.

Composition of any given whey ingredient can vary based on the supplier, the type of cheese from which it was created and the purification process. Even so, it is relatively easy to formulate whey products into ice cream and frozen dairy desserts with a few key formulation guidelines.

FUNCTIONAL BENEFITS OF WHEY IN ICE CREAM AND RELATED PRODUCTS

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 transition. Limiting transition of water-to-ice-to-water-to-ice helps maintain small ice crystals which improves resistance to heat shock and helps the finished frozen dairy dessert retain its smooth and creamy eating quality.

Whipping/Foaming

The whipability and foaming function of whey proteins adds to desirable performance during freezing and enhances air incorporation. Furthermore, by increasing the viscosity of the unfrozen portion of the mix, whey proteins help stabilize and strengthen air cells. This helps in retaining air and helps prevent the collapse of structure known as "shrinkage." When small air cells are created and maintained, smooth and creamy ice cream results. Also, resistance to heat shock is enhanced.

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. Milk fat in whey ingredients needs to be taken into account when considering final milk fat targets. Whey products can be a highly economical source of milk fat. Whey can also directly or indirectly influence fat agglomeration during whipping (addition of air) and freezing (creation of ice). Fat agglomeration is critical to superior heat shock resistance and eating quality in terms of body (chew or bite) and texture (smoothness or creaminess).

Flavor

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 a strong "whey flavor" in the finished product. However, if properly selected and applied this can be avoided and positive aspects of whey in relationship to flavor can be maximized. Additionally. 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 or their effects are eliminated. Formulators can easily balance the use of whey products versus any function of overall flavor optimization.

Viscosity

Chew and bite (i.e. body) and texture (i.e. smoothness and creaminess) improvements can be achieved through the addition of whey proteins. Whey proteins help increase viscosity of the unfrozen portion of the ice cream and help maintain both small air cells and small ice crystals. Thus, mouth-feel of frozen dairy desserts with whey proteins tends to be smoother, creamier and less icy or "coarse." Again, resistance to heat shock also results.

Visual Appeal

Depending on the mix type, whey products can add opacity, whiteness and "milkiness" to mixes and finished products. If properly selected, whey products can also help preserve visual appeal by helping maintain structure and/or form in the finished product. Whey products can also indirectly aid in maintaining ice cream structure which helps with visual appeal of flavors with added particulate(s) and/or syrup (ribbons, variegating sauces) inclusions.

Bulking Agent

In some formulations, whey ingredients can be used as low-cost solids bulking agents and replacers of removed functionality (e.g. fat replacement in low-fat frozen dairy desserts). Since whey is not a "fat," fat replacement is best executed in high-fat products and less so in lower-fat products where the need for true fat functionality is greatest.

Freezing Point Management

Whey protein, lactose and mineral salts in any given whey ingredient can be taken into account to efficiently manage water-to-ice freezing performance and transitioning. 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. Proper selection and use of any given whey ingredient are critical to success.

Impact on Added Flavors

High molecular weight proteins such as whey proteins can absorb various chemical components from added flavors such as vanilla extract. The higher the whey protein content, the more impact on added flavorings. This effect can occur with other proteins as well and formulators need to optimize their formulations in terms of protein/flavoring 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 a formulation is done correctly, all whey ingredients can offer cost saving opportunities. Additionally, improvement in yields (i.e. ability to achieve higher overruns) can offer significant secondary cost savings. Whey proteins help achieve higher overruns by allowing more air to be incorporated during freezing and whipping of the mix and by helping to maintain small and strong air cells.

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.

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), sorbets, sherbets
Water binding	• Binds and entraps water • Limits ice-to-water-to-ice transition	• Provides body, texture • Inhibits ice crystal formation and growth • Helps improve smoothness and creaminess
Viscosity	• Thickening effect	• Improves body and texture • Helps stabilize air cell size and strength • Helps improve smoothness and creaminess
Gelation	• Forms gels during heat processing • Helps build viscosity	• Can function as milk fat replacer in low-fat and fat-free frozen dairy desserts • Improves body, texture • Adds heat shock resistance
Emulsification	• Forms stable emulsions	• Can replace part of the casein protein • Prevents oiling off or serum separation in mixes
Foaming	• Forms stable film • Yields stability to whipped systems	• Allows active inclusion of air in mix • Provides structure (aeration of mix) • Provides stable structure
Opacity	• Improves visual appeal	• Adds appeal to low-fat/fat-free foods by providing opacity and "milkiness" • Helps maintain structure and physical appeal
Flavor and aroma	• Bland, sweet dairy flavor	• Highly compatible with sweet dairy flavors • Compatible with virtually all added flavors
Nutritional profile	• Superior amino-acid profile • Prebiotic functions	• Provides protein, calcium in nutritional products • Helps support growth of bifidobacteria
Freezing point depression	• Carbohydrates and salts reduce freezing point	• Facilitates freezing point management • Soft serve applications

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, corn syrup solids or maltodextrin) 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 addition of protein-containing ingredients (e.g. cream, skim, milk, egg solids, etc.). 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 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 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 dairy desserts do not impact 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 whey. In some instances, ultra-high temperatures or ultra-long times can affect 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 any given whey ingredient in any given mix.

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

Freezing (Batch or Continuous; -5 to -6°C)

The actual "draw" temperature from the freezer is dependent on the mix composition and functionality and what needs to be done with the finished frozen dairy dessert. Normally, the lowest possible draw temperature is desirable (greatest amount of ice made in the barrel of the ice cream freezer) as long as the finished ice cream can be handled for whatever purpose (packaged, molded, extruded) it is to be used. By managing the freezing point of the mix, inclusion of whey products can impact the "draw" temperature and the "draw" 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, whey and whey ingredients can help in the freezing of many small ice crystals that impact the eating quality of the finished dairy 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. As ice-to-water-to-ice transition occurs due to temperature fluctuation during distribution, whey products help since they add heat shock resistance and maintain the body (bite, chew) and texture (smoothness, creaminess) of the frozen dairy dessert.

FORMULATING WITH WHEY PRODUCTS

Care is necessary to manage protein (amount and functionality), lactose and salts to insure proper freezing performance (i.e. maximize creation of large number of small ice crystals) and eliminate potential for "sandiness" defects. This is true in super-premium ice creams as well as nutrient-modified ice creams.

In general, whey products, when applied on a protein-to-protein basis, can replace up to 50% of natural occurring casein in most ice cream mixes. This helps retain the unique functional properties of casein that add body (chew), texture (smoothness) and resistance to heat shock. The effects of lactose and salts must also be carefully considered.

Typical starting formulas for full-fat, fat-modified (reduced-fat, low-fat and fat-free) and sugar-modified (no-sugar added) ice creams using sweet whey, whey protein concentrates and whey protein isolate are presented.

Formulations for Ice Cream using Sweet Whey

Ingredients	Regular Ice Cream	Premium Ice Cream	Super-Premium Ice Cream
Milk fat	10.00%	12.00%	16.00%
Milk-solids-non-fat	7.50%	7.50%	6.00%
Sweet whey*	**2.50%**	**2.50%**	**2.00%**
Sucrose	12.00%	12.00%	12.00%
Corn syrup 36 DE	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.

Reduced-fat, Low-fat and Fat-free Ice Cream Formulations with Whey Protein Concentrates (34-80% protein)

	Control	Reduced-fat Ice Cream with			Low-fat Ice Cream with			Fat-free Ice Cream with		
Ingredients		**WPC 34**	**WPC 60**	**WPC 80**	**WPC 34**	**WPC 60**	**WPC 80**	**WPC 34**	**WPC 60**	**WPC 80**
Milk fat	5.00%	5.00%	5.00%	5.00%	4.00%	4.00%	4.00%	0.35%	0.40%	0.40%
Milk-solids-non-fat	11.00%	8.90%	9.35%	9.50%	8.00%	9.00%	9.25%	8.25%	8.40%	8.80%
WPC 34		**1.10%**			**2.50%**			**2.75%**		
WPC 60			**0.65%**			**1.00%**			**1.60%**	
WPC 80				**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 DE	5.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.50%	6.50%
Maltodextrin 4 or 10 DE	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%	37.80%	37.80%	36.05%	36.05%	36.10%

Mix: approximately 0.59 kg/liter of finished product.

No-sugar Added Ice Cream using Whey Protein Isolate (WPI)

	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%
Milk-solids-non-fat	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 DE	6.00%		6.00%		10.00%	
Polydextrose		6.00%		6.00%		8.00%
Sorbitol		6.00%		6.00%		6.00%
Maltodextrin 4 or 10 DE		6.00%	3.00%	8.00%	4.00%	8.00%
Aspartame*		0.08%		0.08%		0.08%
Stabilizers and emulsifiers	0.30%	0.30%	0.70%	0.70%	0.25%	1.00%
Total solids	38.30%	38.38%	36.70%	35.78%	38.60%	36.58%
Final kg/liter of finished product	0.536	0.536	0.596	0.596	0.782	0.596

*Aspartame, acesulfame-k and/or sucralose can be used to achieve appropriate sweetness levels. Aspartame and acesulfame-k are approximately 200 times as sweet as sucrose (sugar); sucralose is approximately 600 times as sweet as sucrose (sugar). Combination of two or all three sweeteners may be desirable to minimize aftertaste effects.

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 kg**	**Cost per 100 kg**	**% dry basis**	**Cost per kg**	**Cost per 100 kg**
Milk-solids-non-fat	10.00%	$3.86	$38.58	7.50%	$3.86	$28.94
Sweet whey				**2.50%**	**$0.88**	**$2.20**
Milk fat	10.00%	$6.61	$66.14	10.00%	$6.61	$66.14
Sugar	12.00%	$0.77	$9.26	12.00%	$0.77	$9.26
Corn syrup 36 DE	5.00%	$0.22	$1.10	5.00%	$0.22	$1.10
Stabilizers and emulsifiers	0.30%	$4.41	$1.32`	0.30%	$4.41	$1.32
Total solids	37.30%			37.05%		
Ingredient costs			$116.40			$108.96
$/kg of mix			$1.16			$1.09
$/liter of finished ice cream			$0.63			$0.59
Savings						6.97%

*U.S.-based ingredients costs, Fall 2006. All calculations are for demonstration purposes only. Prices for specific ingredients will vary in different locations and situations.

Whey Protein Concentrate 80% (WPC 80) Addition in Premium Ice Cream: Cost-effectiveness Demonstration (Sample calculations*)

	Control Formulation			Formulation with 1.5% WPC 80		
Ingredients	**% dry basis**	**Cost per kg**	**Cost per 100 kg**	**% dry basis**	**Cost per kg**	**Cost per 100 kg**
Milk-solids-non-fat	10.00%	$3.86	$38.58	7.00%	$3.86	$27.01
WPC 80		**$0.00**	**$0.00**	**1.50%**	**$4.19**	**$6.28**
Milk fat	14.00%	$6.61	$92.59	12.00%	$6.61	$79.37
Sugar	12.00%	$0.77	$9.26	12.00%	$0.77	$9.26
Corn syrup 36 DE	5.00%	$0.22	$1.10	5.00%	$0.22	$1.10
Stabilizers and emulsifiers	0.30%	$4.41	$1.32`	0.30%	$4.41	$1.32
Total solids	41.30%			37.80%		
Ingredient costs			$142.86			$124.34
$/kg of mix			$1.43			$1.24
$/liter of finished ice cream			$0.77			$0.67
Savings						15.00%

*U.S.-based ingredients costs, Fall 2006. All calculations are for demonstration purposes only. Prices for specific ingredients will vary in different locations and situations.

CONSIDERATIONS WHEN USING WHEY IN FROZEN DAIRY DESSERTS

Selection of the exact amount and type of whey ingredients to use is based on the following considerations:

Final Use of the Mix

Retail Packs: Two-, one-, half-liter and other small packs for home consumption, where significant freeze/thaw stability is necessary due to temperature abuse. WPC or WPI can add significant freeze/thaw stability when distribution abuse is a potential concern.

Bulk Packs: Ten-liter packs or larger for food service or "dip shops," where repeated dipping and sampling can physically punish the finished frozen dairy dessert. Again, WPC or WPI can add physical strength to the finished frozen dairy dessert and add both heat shock resistance and resistance to punishment due to physical abuse of the frozen dairy dessert.

Direct-fill Novelties: This is the direct filling of cups, cones, "push-ups," etc. 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. Sweet whey is 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: These are novelty items that are extruded through shaped orifices and cut to the proper size and shape. Frozen dairy dessert needs to be flowable, yet stiff enough to extrude and hold a shape. Both WPC and WPI 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: Normally, very fluid (as compared to stiff) frozen mix is deposited into molds, which, in turn, are frozen to create the molded form. Frozen dairy 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 coating applications.) If molds are not filled adequately, voids are created which can cause a variety of undesirable defects. Sweet whey (or demineralized whey) is typically used.

Coated Novelties: Whether a frozen item is to be coated or not is critical to mix ingredient selection and mix formulation. Whey can add significant functional characteristics that assist application and retention of coatings onto the finished frozen novelty. Lactose is a desirable ingredient in many compounded novelty coatings as it provides 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. To minimize lactose crystallization (also known as "sandiness" in frozen dairy desserts), it is advisable to reduce the lactose content of mixes to below 7.5%. Lactose solubility

is limited and varies with a number of factors. Although there must be lactose crystallization in virtually all dairy-based frozen dairy desserts, the amount of lactose and the size of the actual lactose crystals are critical to detection of "sandiness." By managing the lactose content, both the likelihood of lactose crystallization and the size of the lactose crystals can be reduced. This simple recommendation can help prevent sandy defects. Of course, the lower the lactose content the less likely it is that the lactose can or will contribute to "sandiness." 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. However, in most instances sweetness from the lactose (only 20% as sweet as sucrose) in dairy ingredients can be ignored. If sweetness from lactose is to be considered, it must be considered for all mixes that are being compared.

Bulking Agents, Stabilizers and Emulsifiers: 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 WPC or WPI 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 from whey and low methoxyl pectin). Such interactions can result in sticky and/or gummy frozen dairy dessert if the mix is "over stabilized."

Processing Conditions: Typically, pasteurization conditions impact very little on whey protein functionality in mixes. However, if aggressive (high temperature, long time) pasteurization is considered, whey protein functionality can be affected, depending on the processing of the specific whey ingredient. Whey products, particularly WPC (with 60 to 85% protein) and WPI may become more hydrated during aging and can significantly effect 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 (e.g. for packaged ice cream, extruded novelties, molded novelties, direct-filled novelties, etc). Modern continuous hardening systems maximize the use of whey products by quickly freezing the remaining free water as ice. This allows the use of either the maximum acceptable sweet whey or reduces the amount of WPC or WPI needed for any given purpose.

If severe 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 sample formulations and cost tables).

WHEY PERMEATE AS AN INGREDIENT IN SOFT-SERVE ICE CREAM

C.S. Otte,* K. Lim,** K.E. Smith,**
V. Jusuf,* L. Jensen,* S.A. Rankin*
Department of Food Science and Center for Dairy Research,** University of Wisconsin-Madison, WI*

Soft-serve ice cream is smooth, soft and has a similar flavor to hard ice cream, yet contains less milk fat. To reduce the production cost, whey ingredients can be added to replace some of the milk solids.

A study was conducted by researchers at the University of Wisconsin-Madison to determine the influence of whey permeate on the texture and flavor of soft-serve ice cream. In the study, three vanilla soft-serve ice creams were made:

1) Control – with 11.3% nonfat dry milk
2) Replacement of 25% milk-solids-non-fat (MSNF) with sweet whey powder
3) Replacement of 25% MSNF with whey permeate*

The mixes were pasteurized (84°C for 15 seconds), homogenized (2000/500 psi) and aged for 24 hours at 4°C. Prior to freezing, 127 ml/L of natural vanilla was added to each mix. Each mix was frozen to identical draw temperatures on a soft-serve ice cream freezer.

Colorimetric tests showed that the whey permeate sample was more similar to the control than the sample with sweet whey powder. There were no significant differences in the melting rates, fat destabilization and overrun. The trained sensory panel showed significant differences in the vanilla flavor intensity and salt flavor intensity of all three products. The consumer panel found no significant differences in preference.

These results show that sweet whey powder and whey permeate can successfully replace a portion of the MSNF in soft-serve ice cream while maintaining consumer satisfaction.

*Whey permeate (also called high lactose whey or dairy products solids) generally contains 65% to 85% lactose, 3% to 8% protein, less than 1.5% fat, 8% to 20% ash and less than 5% moisture.

RECOMMENDATIONS FOR THE USE OF WHEY PRODUCTS IN FROZEN DAIRY DESSERTS

When considering using a whey ingredient, note the following:

- Balance the freezing performance of the mix with that of 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 lower the lactose, the less likely it is that "sandiness" will result.
- 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 significant savings can be achieved.
- Sweet whey may be the most economic whey ingredient. However, WPCs and WPIs can be more cost-effective ingredient choices to achieve quality, consistency and desired nutritional profile. WPCs and WPIs 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 dairy dessert mixes.

Q&A

Q: *What are "typical" recommended use rates for sweet whey, WPCs and WPIs in frozen dairy desserts?*

A: Actual use rates are very much dependent on all the key considerations affecting frozen dairy 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	1.5-3.0%
WPC 60 to 85	0.5-2.0%
WPI	0.5-1.0%

If total milk protein (total of casein and whey proteins) is used as a regulatory standard, then it is recommended that at least 50% of the total milk protein be as naturally occurring casein. Thus, the amount of any given whey ingredient can be simply calculated based on this target and the percent protein in the specific whey ingredient. This retains the functionality of casein in the conditioning of the fat globule during aging of ice cream mix in preparation for fat agglomeration during freezing and whipping but allows significant use of whey protein for function, quality and cost savings opportunities. Fat agglomeration is necessary to build air cell strength and subsequent resistance to heat shock. The following tables demonstrate how to formulate using this and other guidelines.

Standard Ice Cream – 11% Milk Fat

	Ingredient Cost USD per kg	Control	Using Sweet Whey	Using WPC 34	Using WPC 80
Vegetable fat	$0.63	11.00%	11.00%	11.00%	11.00%
Skim milk solids	$2.30	11.00%	8.25%	7.50%	6.25%
Sweet whey	$0.65		**2.75%**		
WPC 34	$2.75			**1.00%**	
WPC 80	$7.33				**1.00%**
Sugar	$0.48	14.00%	14.00%	14.00%	14.00%
Maltodextrin 10 DE*	$0.80			2.50%	3.55%
Stabilizer/emulsifier	$5.20	0.45%	0.45%	0.45%	0.45%
Total solids		36.45%	36.45%	36.45%	36.25%
Cost per 100 kg mix		$41.24	$36.70	$33.64	$40.48
% Savings vs current**			11.00%	18.42%	1.83%
	Target				
Milk protein %	3.0% minimum	3.96%	3.33%	3.05%	3.05%
% Casein	≥1.6% casein	3.2%	2.4%	2.2%	1.8%
% Milk protein as casein	≥50%	80.0%	71.4%	70.8%	59.0%
Total fat %	Per need	11.11%	11.11%	11.11%	11.12%
Lactose %	Minimize	6.2%	6.5%	4.7%	3.6%
% Sweetness	14-15%***	14.00%	14.00%	14.25%	14.36%

* Either corn syrup solids (CSS) 36 DE or maltodextrin (MDX) 10 DE are acceptable; MDX 10 DE = smoother, creamier texture; CSS 36 DE = sweeter, smooth/creamy texture.
** Save more by increasing non-fat solids; increase mix density; increase yield.
*** Based on control.

Low-fat Ice Cream – 5% Milk Fat

	Ingredient Cost USD per kg	Control	Using Sweet Whey	Using WPC 34	Using WPC 80
Milk fat	$3.95	5.00%	5.00%	5.00%	5.00%
Vegetable fat	$0.63	5.50%	5.50%	5.50%	5.50%
Skim milk solids	$2.30	7.65%	5.10%	5.10%	5.10%
Sweet whey	$1.00	2.55%	**5.10%**		
WPC 34	$2.75			**2.50%**	
WPC 80	$7.33				**1.00%**
Sugar	$0.48	15.20%	15.20%	14.00%	14.00%
Corn syrup solids 36 DE*	$1.60				
Maltodextrin 10 DE*	$0.80			2.50%	3.55%
Stabilizer/emulsifier	$5.20	0.82%	0.82%	0.82%	0.82%
Total solids		36.72%	36.72%	35.42%	34.97%
Cost per 100 kg mix		$51.46	$48.14	$51.34	$52.63
% Savings vs current**			6.44%	0.23%	-2.29%
	Target				
Milk protein %	3.0% minimum	3.09%	2.50%	2.71%	2.64%
% Protein as casein	≥50% casein	69.4%	57.1%	52.7%	54.2%
Total fat %	Per need	5.10%	5.10%	5.14%	5.11%
Lactose %	Minimize	6.0%	6.4%	4.1%	2.9%
Sweetness %	15%***	15.20%	15.20%	14.25%	14.36%

* Either corn syrup solids (CSS) 36 DE or maltodextrin (MDX) 10 DE are acceptable; MDX 10 DE = smoother, creamier texture; CSS 36 DE = sweeter, smooth/creamy texture.
** Save more by increasing non-fat solids; increase mix density; increase yield.
*** Based on control.

Mellorine – 10% Vegetable Fat

	Ingredient Cost USD per kg	Control	Using Sweet Whey	Using WPC 34	Using WPC 80
Palm oil	$0.63	6.30%	5.00%	7.00%	5.00%
Coconut oil	$0.68	4.20%	3.00%	3.00%	3.00%
Buttermilk powder	$2.13	6.00%	3.00%	3.00%	3.00%
Sweet whey	$1.60		**3.00%**		
WPC 34	$2.50			**1.50%**	
WPC 80	$6.32				**0.80%**
Sugar	$0.90	15.00%	14.00%	13.00%	14.00%
Fructose syrup (42% HFCS)	$0.40	2.80%	2.50%	3.00%	2.50%
Corn syrup solids 36 DE*	$1.58				
Maltodextrin 10 DE*	$0.79		5.00%	6.00%	5.00%
Stabilizer/emulsifier	$1.65	0.55%	0.30%	0.55%	0.30%
Total solids		34.85%	35.80%	37.05%	33.60%
Cost per 100 kg mix		$33.98	$33.40	$33.90	$33.66
% Savings vs current**			1.71%	0.23%	0.96%
	Target				
Milk protein %	3.0% minimum	2.04%	1.41%	1.55%	1.66%
% Casein	≥1.6% casein	1.6%	0.8%	0.8%	0.8%
% Milk protein as casein	≥50%	80.0%	57.9%	52.8%	49.2%
Total fat %	Per need	10.77%	8.17%	10.19%	8.18%
Lactose %	Minimize	3.4%	3.8%	2.4%	1.7%
Sweetness %	15-18%***	17.80%	17.00%	16.60%	17.00%

* Either corn syrup solids (CSS) 36 DE or maltodextrin (MDX) 10 DE are acceptable; MDX 10 DE = smoother, creamier texture; CSS 36 DE = sweeter, smooth/creamy texture.
** Save more by increasing non-fat solids; increase mix density; increase yield.
*** Based on control.

Premium Ice Cream – 16% Milk Fat

	Ingredient Cost USD per kg	Control	Using Sweet Whey	Using WPC 34	Using WPC 80
Milk fat	$3.95	16.00%	16.00%	15.30%	15.50%
Skim milk solids	$2.30	10.20%	7.65%	7.50%	6.25%
Sweet whey	$0.65		**2.55%**		
WPC 34	$2.75			**1.00%**	
WPC 80	$7.33				**1.00%**
Sugar	$0.48	14.00%	14.00%	14.00%	14.00%
Maltodextrin 10 DE*	$0.80			2.50%	3.55%
Egg yolk solids	$2.00	1.70%	1.70%	1.70%	1.70%
Total solids		41.90%	41.90%	42.00%	42.00%
Cost per 100 kg mix		$96.78	$92.57	$92.56	$95.89
% Savings vs current**			4.35%	4.37%	0.92%
	Target				
Milk protein %	3.0% minimum	3.67%	3.09%	3.05%	3.05%
% Casein	≥1.6% casein	2.9%	2.5%	2.5%	2.6%
% Protein as casein	≥50% casein	80.0%	82.1%	82.3%	85.2%
Total fat %	Per need	16.10%	16.10%	15.41%	15.62%
Lactose %	Minimize	5.7%	6.0%	4.7%	3.6%
Sweetness %	14-15%***	14.00%	14.00%	14.25%	14.36%

* Either corn syrup solids (CSS) 36 DE or maltodextrin (MDX) 10 DE are acceptable; MDX 10 DE = smoother, creamier texture; CSS 36 DE = sweeter, smooth/creamy texture.
** Save more by increasing non-fat solids; increase mix density; increase yield.
*** Based on control.

Q: *How can* WPC 80-85 *and* WPI, *which carry cost premiums to skim milk solids, be cost-effective?*

A: Several factors impact the cost-effectiveness of high protein WPC and WPI. The key is to know that these highly functional ingredients can be used at significantly lower levels (0.50-2.0%) than standard sweet whey (2.0-3.0%). 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 reductions (10-12%) in ingredient and process costs when premium whey products are used.

Q: *Can whey permeate be used in ice cream and other frozen dairy desserts?*

A: Permeate, which is the by-product of the process to make whey protein concentrates and isolates, is ultra-high in salts and lactose. These latter components negatively affect freezing point of ice cream mix, heat shock resistance and add unusually high percent of lactose (which can increase the sensitivity to "sandiness") to mixes. Thus, permeate is typically not recommended for ice cream. If considered, care must be taken.

Q: *Whey "flavor" is typically a defect of ice cream and other frozen dairy desserts. Does using whey add "whey flavor" to frozen dairy desserts?*

A: "Whey flavor" or other flavor defects – called "cardboard," "oxidized" or "cheesy" flavors – can be attributed to whey ingredients, particularly sweet wheys. This defect may occur in low-quality or poorly processed ingredients. U.S. whey ingredients typically have a pleasant dairy flavor which is highly compatible with frozen dairy dessert mixes.

Q: *Can I use whey or whey ingredients in sorbet?*

A: Yes. A judicious amount of a whey ingredient (limit the lactose content at or below 7%) can offer smoother body and texture and still retain a low- or no-fat claim. Since sorbets have little or no added dairy ingredient, added whey's impact is to improve bulk, whipping performance and stability. Additionally, whey protein gives increased mix viscosity resulting in smoother, more refreshing finished products. In non-fruit flavored sorbets (e.g. chocolate), whey adds low-cost dairy background flavor and appearance (opacity) characteristics.

Q *What is "gelato"? Can whey ingredients be used successfully?*

A. There is no uniform definition or standard for "gelato" (Italian for ice cream). However, gelato typically refers to ice cream of high solids (milk fat levels can vary), extremely low overrun, bright, bold colors and strong flavors. Again, rules outlined above for replacement of milk-solids-non-fat with whey protein ingredients hold. Remember, gelato is ice cream.

Q: *What about whey and whey protein concentrates in variegating syrups and other ice cream inclusions?*

A: Whey and whey protein concentrates can be used where applicable in flavoring swirls, ribbons, etc. and in particulate inclusions such as baked pieces, candies, etc. that are added post-pasteurization; as long as the inclusion has one of the following characteristics:

- Has a pH below 4.7.
- Has been baked, roasted, pasteurized or in any other way heat treated.
- Has a water activity of <0.85.
- Contains high levels of alcohol (such as vanilla extracts and other liquid flavors).
- Is a bacterial culture (freeze-dried lactic acid bacterial) that is pathogen-free.
- Is subjected to any other process which renders the inclusion pathogen-free.

This also holds for functional (e.g. mousse, whipping) bases and compounded flavoring bases that may contain whey products as ingredients to be added at the flavor tank before freezing.

Q: *What about frozen yogurt?*

A: Standards for frozen yogurt may, or may not, exist in any given market. Whey products can be added to frozen yogurts in much the same manner as for standard ice creams. Rules related to total milk protein, percent of casein and lactose still hold. However, any modification of osmotic pressure on the culture side of mixes can result in poor fermentation, flavor and functionality.

Frozen yogurt mix can be processed in several ways:

1. Culture the entire ice cream mix. The original way of making frozen yogurt is not recommended. This approach results in atypical fermentation leading to bitter and tart off flavors.
2. Cold incubation. In some countries the addition of live and active bacterial cultures to pasteurized and refrigerated ice cream mix is allowed. No culturing of the actual mix is made. Cultures can be added at the flavor tank. The amount and type of culture determines function and flavor of resulting frozen yogurt.
3. Partial culturing of dairy ingredients:
   a. Two-way blend of cultured dairy (milk fat & milk-solids-non-fat) and uncultured non-dairy ingredients (sugar, corn syrup, stabilizer, etc). Whey can be added to partially replace milk solids-non-fat using rules noted previously.
   b. Two-way blend of cultured mix (a specific percent of the total mix) and remaining percent of uncultured mix. Again, whey can be used following rules for standard ice cream.
   c. Two-way cultured dairy (milk-solids-non-fat) and uncultured sugar/dairy blend. Whey ingredients can be used as appropriate in either side to partially replace skim milk solids.
   d. Three-way blend of yogurt (milk fat, milk-solids-non-fat and/or sugar), uncultured dairy and sugars. Use of whey ingredients again is determined by guidelines for standard ice cream.

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Published by U.S. Dairy Export Council®
2101 Wilson Boulevard / Suite 400
Arlington, VA 22201-3061 U.S.A.

Tel U.S.A. (703) 528-3049
Fax U.S.A. (703) 528-3705
www.usdec.org