WHEY PRODUCTS IN BAKED GOODS

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Whey-based ingredients in bread:

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

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

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

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

FUNCTIONAL BENEFITS

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

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

FUNCTIONALITY

Whey protein concentrates (WPCs) have many functional properties most of which are associated with the whey proteins. Some of the basic functionalities that a WPC can provide are whipping/foaming, emulsification, high solubility, gelation, water binding, and viscosity development. Generally, WPCs with higher protein content have improved functionality over those with lower protein content. Other factors that influence their functionality are the whey source, amount of heat treatment received during manufacture, and lipid and mineral content. Whey protein conformation and functionality are interrelated and dictated by changes in their globular folded structure. Their functional properties are affected by several factors within a food application, including concentration, state of the whey proteins, pH, ionic environment, (pre-) heat treatment, and the presence of lipids. In the native state, whey proteins are highly soluble and adeptly perform emulsification and whipping functions in a food application. Heating whey proteins can result in a loss of solubility due to the denaturation of the proteins, especially in the pH range of 4.0-6.5. While solubility is adversely affected by heat, emulsification can be improved through controlled heat denaturation. As the whey protein unfolds, hydrophobic amino acid residues are exposed, which enhance the ability of the protein to orient at the oil/water interface. The presence of salts during the emulsification process influences whey protein conformation and solubility. In their undenatured form, whey proteins can form rigid gels that hold water and fat and provide structural support. The formation of disulfide bonds and ionic bonding controlled by calcium ions appears to determine gel structure.

The water-binding abilities of whey proteins can help reduce formula costs as the proteins hold additional water. Viscosity development is closely related to gelation and other protein-protein interactions. Foaming properties are best when the whey proteins are undenatured, not competing with other surfactants at the air/water interface, and stabilized by an increase in viscosity when foam formation occurs. Whey proteins also contribute to browning by reacting with lactose and other reducing sugars present in a formulation, providing color to heated products. WPCs are also bland tasting and contribute no foreign or off-flavors when used as an ingredient.

Modified whey can also improve the flavor and texture of reduced fat, low fat and fat free baked goods.

NUTRITION

Whey protein concentrates contribute nutrition to a food application through their mineral content as well as their protein content (see Nutrition section of the Reference Manual). Whey proteins contain a high level of essential amino acids and are considered to be a high quality protein source. WPCs also contain significant amounts of calcium and other minerals that can be added advantages when fortifying food products.

WHEY PROTEIN CONCENTRATES IN BAKED PRODUCTS: FUNCTIONALITY IN SPECIFIC PRODUCTS

BREADS

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

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

CAKES

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

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

COOKIES

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

CRACKERS

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

PIE CRUSTS

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

BAKERY MIXES

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

BAKERY GLAZES

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

NUTRITIONAL PRODUCTS

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

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

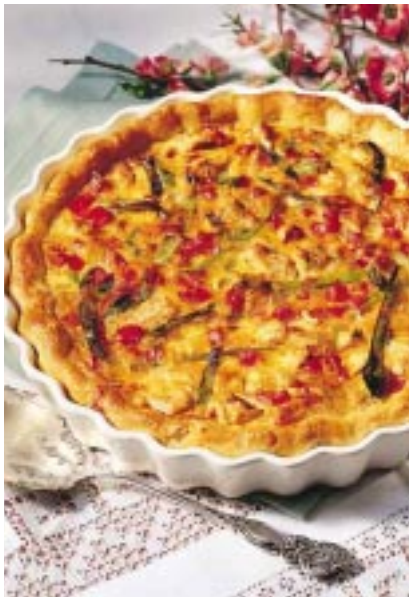
PROCESSING CONSIDERATIONS

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

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

LACTOSE FUNCTIONALITY IN BAKED PRODUCTS

In baking, lactose is often used to replace sucrose for a variety of functional benefits. Compared to other sugars, lactose results in low relative sweetness, increased browning, enhanced emulsification action, moisture retention, non-hygroscopicity and enhanced flavors. When replacing sucrose (up to 50%), lactose can contribute to improved crumb texture and freshness, increased volume, reduced fat levels, improved gas retention, and enhanced flavor.



Use of lactose in bakery products

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

Level is based on flour weight (100%), except for cakes and muffins where use level is based on replacement of other sugars.

Lactose also shortens proofing times, especially where the overall sugar level is high. Doughs containing lactose show a tendency to rise faster during the initial stages of proofing and show improved stability and gas retention. Lactose readily reacts with proteins (Maillard reaction) giving baked goods a highly flavored, desirable golden-brown color. Caramelization by heat during baking also contributes flavor and color. Lactose influences and enhances the controlled browning of bakery goods, leading to shorter baking times and lower temperatures to achieve even, stable, golden brown colors. This is a particular benefit in products targeted for microwave finishing. Lactose has unique, volatile flavor binding and enhancing properties, which are particularly useful in products with delicate flavors. Lactose has a strong affinity for flavorings and flavors. It is able to absorb and accentuate flavors. This enables a reduction in added flavors.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Q: *When using* WPC 34 *in cookie dough, it makes the dough too sticky. Furthermore, the cookie spreads out too much. Any tips on preventing this from happening?*

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

Q: *Adding* WPC 80 *in cookie and cake dough makes the dough too sticky. How can this be prevented?*

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

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

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

Abboud, A. 1995. "Technical Bulletin: Systems approach to reducing fat in baked goods," *American Institute of Baking*, Manhattan, KS, 17(12).

Anonymous. 1996. *Dairy Ingredient Application Guide. Whey Ingredients*. Dairy Management, Inc., Rosemont, IL.

Asp.E.H., 1996. *The effects of milk derived ingredients on doughs and bread*. M.S. thesis, University of Minnesota.

Burrington, K.J. January, 1998. "More than just milk." *Food Product Design*.

Chandan, R. 1997. *Baked Products, In Dairy-Based Ingredients*. Eagan Press, St. Paul, MN.

Corliss, G.A. 1992. "Technical Bulletin: Protein-based fat substitutes in bakery foods," *American Institute of Baking*, Manhattan, KS, 14(10).

Haines, B. 1998. "Dairy ingredients and their use in bakery foods." *American Institute of Baking Technical Bulletin*, XX(3).

Harper, W.J., 1991. "Whey protein functionality in model foods systems." *Proceedings of CDR/ADPI Whey Protein Workshop*, October 21-23, Madison, WI.

Harper, W.J. and Zadow, J.G. 1984. "Heat induced changes in whey protein concentrates as related to bread manufacture." *New Zealand Journal of Dairy Science and Technology*, 19, p. 229-237.

Hegenbart, S September, 1998. Maximizing convenience with bakery mixes: *Food Product Design*.

Kulp, K. 1994. "Cookie Chemistry and Technology." *American Institute of Baking*.

McWard, C. "Balancing act." *Baking and Snack*, January, 1998.

O'Donnell, K. 1996. "Technical Bulletin: Methods of bread dough making," *American Institute of Baking*, Manhattan, KS, 18(12).

Pyler, E.J. 1988. *Baking Science and Technology*, Third edition, Sosland Publishing Company, Merriam, Kansas.

Sherwin, C. 1995. "Technical Bulletin: Use of whey and whey products in baked goods," *American Institute of Baking*, Manhattan, KS, 17(11).

Appendix I
Recommended Level of Addition as % of Total Formula

	Sweet Whey	WPC34 to WPC50	WPC80	Demineralized Whey, Modified Whey
White Bread	1–5%	1–4%	1–3%	2–6%
Sweet Rolls	2–5%	1–4%	1–3%	2–6%
Cookies and Biscuits	1–5%	1–5%	1–4%	2–5%
Crackers	1–5%	1–4%	1–3%	2–6%
Pizza Dough	1–5%	1–4%	1–3%	2–6%
Cakes	1–6%	1–4%	1–3%**	1–6%
Icings & Fillings	1–3%	1–2%	1–2%	1–3%
Low Fat, Low Sugar Baked Goods	2–10%~	3–9%*	3–5%*	2–10%~

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

	Lactose	Low Protein Whey	Expected Benefit for all categories of whey ingredients to varying degrees depending on protein level
White Bread	1–5%	1–5%	Extend shelf-life, improve crumb structure and softness, provide crust browning.
Sweet Rolls	1–5%	1–5%	Extend shelf-life, improve crumb softness, provide surface browning.
Cookies and Biscuits	1–5%	1–5%	Provide surface browning, improve tender texture, provide partial egg replacement.
Crackers	1–5%	1–5%	Contribute to cracking stability and surface color.
Pizza Dough	1–5%	1–5%	Provide structure, freeze-thaw stability, crust browning.
Cakes	1–6%	1–6%	Provide soft crumb, partial egg replacement, add surface browning.
Icings & Fillings	1–3%	1–3%	Partial replacement for sugar, add water-binding capabilities for overall stability, reduces sweetness.
Low Fat, Low Sugar Baked Goods	2–10%~	2–10%~	Partial replacement for fat and/or sugar, adds water-binding and some emulsifying capabilities, reduces sweetness.

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