

WHEY PRODUCTS IN YOGURT AND FERMENTED DAIRY PRODUCTS

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There are many benefits resulting from the addition of selected whey products in yogurt formulations. These benefits include:

- *Improved flavor*
- *Texture improvement*
- *Nutritional enrichment*
- *Reduced syneresis, extended shelf-life*
- *Prebiotic effect*
- *Nutraceutical benefits*
- *Cost-effectiveness.*



The U.S. dairy industry offers an ever wider range of whey products especially designed to optimize consumer preference of yogurt products, as well as shelf-life and overall quality profile, in a cost-effective way.

Whey products offer multiple functional benefits and can help formulators replace less desirable ingredients. Their use helps processors deliver all-milk formulas with “clean” labels, an important factor for many consumers worldwide. The prebiotic functions of whey products are of critical importance to manufacturers of probiotic or nutraceutical fermented milk products.

Whey products, co-products of cheese production, can provide non-fat milk solids in many yogurt formulas. The processes used for the manufacture of the products have been recently reviewed. Whey products not only allow the processor to reduce the ingredient costs, most importantly, they also provide unique functional properties and a concentrated source of milk nutrients: highly nutritional proteins, calcium.

Flavors and fruits are added to yogurts to offer products that can compete with carbonated soft drinks. Now yogurt is also recognized as a delivery medium for probiotic bacteria as well as other health-enhancing compounds. Included among these potential compounds are a milk protein, lactoferrin, and milk minerals such as calcium that are being commercially concentrated in, or isolated from, whey.

EFFECT OF WHEY FORTIFICATION ON YOGURT FLAVOR

The flavor of yogurt is the blend of the flavors created by the base, the compounds produced during the fermentation and added flavoring ingredients. The acidity of yogurt, produced by the lactic cultures, complements its flavor. Hydrolysis of the lactose in milk, for the lactose intolerant, can produce a slightly sweet flavor that is objectionable to some consumers. This same sweetness can improve the flavor balance of yogurt and reduce the need for added sugar in sweetened yogurt. The acidity will enhance many added flavors and it is most complimentary to fruit flavors.

Whey proteins are bland in flavor. Compared to the caseins in skim milk, they have less tendency to mask added flavors. More fruit flavor can be expected in a fruit-flavored yogurt when solids from whey protein concentrate (WPC) partially replace the skim milk solids. When whey proteins are used to stabilize yogurt, and to replace starch or other thickeners, additional improvement in flavor can result.

The soluble salts concentration of whey has been linked to off-flavors when sweet whey is added to yogurt. The salt concentration of whey can be reduced by electro dialysis or ion exchange to produce demineralized whey. Soluble salts and lactose can also be separated and WPC produced by ultrafiltration. Furthermore, the inhibition of the fermentation process that may occur when whey solids partially replace skim milk solids in a yogurt base, is not seen when either demineralized whey or WPC are utilized



Effect of 40% replacement of skim milk protein by whey proteins in a yogurt beverage.

Formula	Control	Test A	Test B	Test C
Skim milk powder,%	10.40	6.24	6.24	6.24
WPC80 (gelling type), %	–	1.88	–	–
WPC80, %	–	–	1.92	–
WPC34, %	–	–	–	4.16
Lactose, %	–	2.28	2.24	–
Water, %	89.6	89.6	89.6	89.6
Viscosity				
Freshly sheared (cps)	82	758	315	22
After 24 hours (cps)	95	1,982	845	30
Sensory Scores				
Thickness	3.4	7.0	0 = thin to 10 = thick	
Chalkiness	3.8	3.8	0 = not chalky to 10 = very chalky	
Flavor	5.3	6.8	0 = poor to 10 = good	

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instead. Yogurt with excellent flavor is produced with either demineralized whey or WPC. The concentration of lactic acid, acetaldehyde and diacetyl (compounds associated with good yogurt flavor) are equal or greater in yogurt samples in which WPC partially replace the skim milk solids.

Substituting whey powder (sweet whey) for skim milk solids in yogurt mixes can result in a lower quality product if not done properly. Comparative tests show that the pH value of the yogurt is consistently higher and the titratable acidity (TA) is consistently lower when sweet whey replaces 25% and 50% of the skim milk solids in a yogurt base. The lower protein content (skim milk solids have more than two and one-half times as much protein as sweet whey powder) and the lower buffer capacity of the whey proteins compared to the casein in the skim milk solids may enhance the differences in TA. However, an improved product can be produced by hydrolyzing the lactose in the yogurt mix with added lactase enzyme. Hydrolysis of the lactose increases the available monosaccharides, accelerates the fermentation, and results in yogurt with lower pH and a correspondingly higher TA. For this reason, most formulators prefer to use higher-protein whey protein concentrates in high quality products.

When *Bifidobacterium bifidum* is added to the standard yogurt culture (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*), the viable count of *B. bifidum* is significantly higher in the samples fortified with sweet whey and whey protein. Whereas, addition of *B. bifidum* can significantly reduce the concentration of diacetyl and acetaldehyde in the skim milk fortified yogurt, the yogurt with *B. bifidum* and fortified with the whey protein has slightly higher diacetyl and nearly as high acetaldehyde concentrations as the control. Higher acetaldehyde concentrations in yogurt produced with whey proteins may result from the higher concentrations of non-protein nitrogenous compounds in whey and lower protein WPC.

If the salt content of the WPC is significantly reduced, such as occurs when 80% protein WPC (WPC80) is produced by ultrafiltration, the buffer capacity of the yogurt may be reduced. The addition of phosphates will restore the buffer capacity and the TA of yogurt formulated with WPC80. The added phosphates can also increase the viscosity of the yogurt, most likely a result of their effect on calcium ions. Alternatively, citric acid can be added to the fermented yogurt to establish the desired titratable acidity and acid flavor.

EFFECT OF WHEY FORTIFICATION ON YOGURT TEXTURE

The appearance and texture of yogurt is dependent upon numerous factors: total solids, protein content, type of protein, and the type and concentration of any thickeners or stabilizer that are added. Penna et al. studied the effect of treatment temperature and skim milk replacement with demineralized whey, and reported that instrumental consistency of the yogurt increased as (1) the process temperature increased (from 85°C to 95°C, with five minute hold) and (2) the concentration of demineralized whey decreased. However, researchers also report that it is possible to match the consistency of commercial yogurts using a mix that contains 12.5% milk solids (with 1.5 - 3.0% of the solids provided by demineralized whey) if the mix is heated and held at 91°C for five minutes.

Modler and Kalab report that the casein micelles in yogurt form different matrices depending upon the concentration of the other proteins. When milk is fortified with WPC and heat treated, fine protein floccules are observed. When casein, skim milk powder, or milk protein concentrates are added, no floccules are observed. When milk is heated, β -lactoglobulin is denatured and reacts with α -casein to form an insoluble complex. When milk is fortified with WPC, the concentration of β -lactoglobulin greatly exceeds the concentration of α -casein. As a result other protein complexes, such as β -lactoglobulin and α -lactalbumin complexes will form. In yogurts fortified with WPC, it is the β -lactoglobulin and α -lactalbumin complex, rather than the casein complex, that probably stabilizes the yogurt, resulting in different consistency. Fortification of milk for yogurt with WPC results in yogurt with better texture and consistency. Yogurts fortified with casein or skim milk protein often have a firmer gel, but yogurts fortified with WPC tend to be smoother and have a better appearance.

Effect on viscosity and syneresis of fortification with WPC34 and skim milk powder.

	Consistency (Centipoise)	Syneresis (ml)*
Control	57.5	22
Fortification with 2% SMP	94.5	17
Fortification with 2% WPC34	117	7

* Reduced syneresis ("water separation") is a desirable consumer attribute. Data reproduced with permission from the authors (see reference for further information).

Effect of WPC80 addition on yogurt viscosity

	Control	WPC80 with enhanced gelling properties	WPC80
Skim milk	95.25%	97.26%	97.26%
Skim milk powder	3.08%	–	–
WPC80	–	1.44%	1.44%
Starch	1.30%	1.30%	1.30%
Gelatin	0.37%		
Skim milk protein	4.19%	3.21%	3.21%
Whey protein	–	1.15%	1.15%
Set viscosity	60,200 cps	76,000 cps	70,700 cps
Stirred viscosity	8,900 cps	8,800 cps	8,000 cps

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One of the most significant benefits of WPC is its effect on separation or syneresis during storage of yogurt (shelf-life). When properly heat treated, yogurts fortified with WPC have higher viscosity and better water-holding properties. Data in the table was generated for yogurts produced with milk, milk fortified with 2% skim milk powder and milk fortified with 2% WPC34.

Morris et al. reports that syneresis is cut in half when milk for yogurt is fortified with 4% WPC compared to 4% skim milk powder.

The higher protein whey protein concentrates ((80% protein: WPC80) also provide textural benefits in yogurt. These functional protein products include products that are processed to enhance gel forming properties. Some differences are seen in the textures of yogurts prepared with different WPC80, however they are generally less than might be anticipated.

The following table shows the results of a study to partially replace skim milk solids and totally replace gelatin in a stirred yogurt with two types of WPC80.

Developing the viscosity needed to suspend fruit pieces, developing the smooth, creamy texture, preventing the separation and syneresis that occur during storage and distribution are all possible with a milk system that includes whey protein concentrates and milk.

EFFECT OF WHEY PRODUCTS ON YOGURT FERMENTATION AND PROBIOTIC CULTURES

Most researchers have determined that fortification or partial replacement of skim milk solids with solids of ultrafiltered WPC has no effect on yogurt fermentation as indicated by pH, TA or number of bacteria. Mineral salts and other compounds that can inhibit the cultures pass through the membrane and are separated from the whey proteins. Others have reported that ultrafiltered WPC can positively stimulate the rate of fermentation and the growth of *L. acidophilus*.

About 20 to 30% of the lactose in the yogurt base is broken down to glucose and galactose, and the glucose is converted to lactic acid during yogurt fermentation. Bacterial enzymes can help break down the remaining lactose in the intestinal tract. However, gastric acids in the stomach can destroy probiotic culture organisms and the bacterial β -galactosidase enzymes that breakdown the lactose. The ease by which the acids are neutralized in the duodenum will also influence the bacterial enzyme activity and the utilization of the lactose. Kailasapathy et.al. determined that the type of cultures and the lactic acid, total solids,

protein and salt (phosphates, citrates, lactates) content of the yogurt base affect the buffer capacity of the yogurt. Fortification of the yogurt base with WPC, compared to fortification with skim milk powder, results in a high buffer capacity at low pH and a lower buffer capacity at high pH. Thus, fortification of yogurt with WPC will: a) minimize destruction of the probiotic cultures and lactase enzyme in the stomach and b) enhance the enzyme activity in the intestinal tract.

WHEY PRODUCTS IN YOGURT AND ACIDIFIED PROTEIN BEVERAGES

In some markets, consumers prefer drinking yogurt rather than spoonable formulas. Viscosity, age thickening and separation problems are enhanced in the thinner viscosity beverage products. The protein floccules that result when the ratio of whey proteins to caseins is increased in the yogurt base can precipitate if the viscosity is reduced. Using high shear to reduce the size of the floccules and blending high-methoxyl pectin into the fermented yogurt helps control separation and sedimentation.

Whereas undenatured whey proteins have an advantage over caseins with regards to solubility at low pH, the combination of acid and heat can cause precipitation of whey proteins. Heat stability of whey proteins is lowest in the pH 3.5 -5.5 range. Acidification of whey protein drinks to pH ≤ 3.5 reduces the tendency of protein precipitation during post-fermentation pasteurization or sterilization. Yet, some thickening and sedimentation has been reported in a UHT-processed long shelf-life whey protein and fruit juice beverage acidified to pH 3.65 before sterilization and packaging. U.S. processors now offer whey products specially formulated to withstand high temperature treatments.



OTHER POTENTIAL NUTRACEUTICAL BENEFITS OF WHEY PRODUCTS

Whey proteins are recognized as being of very high nutritional quality. They are easily digested and the essential amino acid profile meets or exceeds all the nutritional requirements of the FAO/WHO.

There is also increasing evidence that some of the therapeutic benefits of yogurt cultures may be linked to the proteins. Bioactive peptides, produced during fermentation, are effective in decreasing cell proliferation in a cell culture model system. When the proteins were separated and fermented, α -lactalbumin inhibited cell division, but β -casein did not. The effect is a hypothesized explanation for the association between the reduced incidence of colon cancer and yogurt consumption.

Other studies link whey proteins to nutraceutical benefits in nonfermented systems. Bioactive whey protein compounds, protected from heat denaturation, provided a significant percentage of the protein in a diet fed to HIV-seropositive individuals. On this diet, the individuals regained body weight and the glutathione content of blood mononuclear cells increased three fold. A laboratory study revealed that WPC80 increases growth and multiplication of osteoblasts, the bone forming cells. The stimulatory effect of whey proteins on osteoblasts was not affected by heat treatment, or exposure to digestive enzymes. Another study compared the effect of diets with soybean protein, casein and whey proteins on blood cholesterol levels of rats. The reported results were a three times increase over the pretreatment level in the group fed the casein diet, a two fold increase in the group fed the soy protein diet and a 30% reduction in the group fed the whey protein diet. Substantially elevated rate of cholesterol excretion was observed when rats on high fat diets were fed whey proteins. Suppressed cholesterol synthesis was observed when rats on fat-free diets were fed whey proteins.

Lactoferrin, a milk protein that is now being commercially isolated from whey, has been identified as one of the most interesting nutraceutical food ingredients. It is reported to stimulate intestinal cell growth and the growth of bifidobacteria. Lactoferrin is also a selective antimicrobial agent. Through its ability to chelate free iron, it controls the organisms that need iron for growth. It can be converted by digestive proteases to lactoferricin, a peptide that is active against Gram negative bacteria and yeast. The iron binding ability and the ability to transport iron are other recognized benefits of lactoferrin.



Lactoperoxidase is another nutraceutical component of milk and whey products. The lactoperoxidase/thiocyanate/hydrogen peroxide (LP) system in raw milk has been recognized for its antibacterial properties. Basaga and Dik reported that mixed yogurt starter culture is very sensitive to the LP system with very limited growth of the culture and no acid production during five-hour incubation. Hirano et.al. studied the lactoperoxidase system as a means of controlling acidity development and pH shift during refrigerated storage of yogurt. The researchers did not report the effect of the lactoperoxidase on the number of culture cells, but did report that it produced yogurt that was smoother in texture. A potential effect of the lactoperoxidase system on the oxidation of the SH groups of the β -lactoglobulin was suggested.

High mineral content will inhibit yogurt culture activity. However, the milk mineral concentrates that are being processed from whey are another potential ingredient for yogurts. These products, that typically contain 20 -25% calcium, can be used to enhance the calcium content of foods, and the viscosity of yogurt lends itself to minimizing any sedimentation of the mineral salts. However, the concentration of the monovalent salts (sodium, potassium and chlorides), protein and non-protein nitrogenous compounds can vary depending upon the process used for manufacture. Levels of addition need to be controlled to avoid flavor impact, and viscosity of the yogurt must be adequate to suspend any insoluble salts.



In the production of fat-free yogurts, a fat "mimic" made from whey proteins can be substituted for the milk fat. Tamine et.al. studied the differences in the microstructure of yogurts prepared with anhydrous milk fat or with microparticulated whey protein. Following homogenization, pasteurization and fermentation, both the milk fat and the fat substitute become part of the protein matrix of the yogurt. The yogurts produced with the fat mimetic can be softer and more susceptible to syneresis.

For those concerned about calorie consumption, Vandewater and Vickers reported that panelists initially preferred yogurt fortified to a higher protein content with whey protein concentrates. However, after consuming equal calorie servings of low protein and high protein yogurt, panelists' hunger was significantly less (indicated by significantly lower liking rating) after consuming the high protein product.

CONCLUSIONS

Yogurt is one of the dairy products which should continue to increase in sales. The key to that growth is a continuous evaluation and modification of the product to match consumer expectations. Currently there are many apparent benefits that result from incorporating selected whey products into yogurt formulas. Whereas whey products have traditionally been perceived as a means of reducing ingredient costs, the real benefit of adding whey products are the enhanced value resulting from flavor, texture and nutritional improvements as well as nutraceutical or health-enhancing benefits.



Q: How can whey products help yogurt processors meet consumer expectations?

A: Many of the nutrients and bioactive compounds in milk are separated with the whey during cheesemaking. New processing technologies enable whey processors to modify, fractionate and concentrate these into highly nutritious and/or functional ingredients.

Q: Which whey products are used as ingredients in yogurt?

A: Whey protein concentrates are very successfully used in yogurt production. New commercially available whey products with potential application in yogurt include lactoferrin and milk protein concentrates.

Q: How are whey protein concentrates used?

A: They fortify the protein content in the yogurt milk and/or practically replace skim milk protein in the milk. Replacing 15-35% of the skim milk protein with 0.75-2% whey protein is common. The high protein whey products, such as WPC, are also added to replace stabilizers.

Q: Which process changes are required when producing yogurt with whey protein concentrates?

A: The functional benefits of whey proteins result from protein-protein interactions. These interactions are initiated during the preheating and pasteurizing of the yogurt, before fermentation. Pasteurization temperatures of 85-90°C, with hold times of 5-30 minutes are common in yogurt production. These are generally appropriate for formulas with added whey protein concentrates. If textural problems occur, try adjusting the temperature and minimize the free calcium ions in the mix.

Q: Are there other benefits of adding whey protein concentrates to yogurt?

A: Laboratory studies suggest improved buffer capacity for probiotic cultures and Beta-galactosidase activity in the intestine. Peptides produced from whey proteins may help control proliferation of tumor cells in the colon and whey proteins may help reduce blood cholesterol levels.

Q: How are milk calcium concentrate or milk minerals used?

A: Several whey products can be used as a source of natural, highly bioavailable calcium. Because high calcium and salt concentrations can affect protein-protein interactions and activity of cultures, it is recommended to mix these products in the yogurt after fermentation.

Q: Can lactoferrin be used in yogurt?

A: Lactoferrin is a milk protein that is present at comparatively high concentrations in early human milk and at lower levels in cow's milk. It is identified with improved iron transport, stimulation of bifidobacteria, stimulated growth of intestinal cells and antimicrobial activities against pathogenic bacteria. It should be added after pasteurization and fermentation of yogurt.



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