High Protein Milk Ingredients - A Tool for Value-Addition to Dairy and Food Products

Abstract

Milk protein ingredients provide not only nutrition, but also specific technological functionality when applied in food formulations. Milk protein ingredients are natural, trusted food ingredients and are ideal for unique nutritional and functional applications. Value addition to dairy and food products are being strived by the dairy and food industry to woo more consumers for their innovative products. Use of high protein milk solids can be one mode of such value-addition to food products. Some of the important functional properties of dairy protein ingredients include solubility, viscosity building, emulsification, heat stability, aeration, etc. The high protein dairy based ingredients highlighted in the review include caseinates, co-precipitates, whey protein concentrates and isolates, milk protein concentrates, micellar casein, UF retentate powder, etc. Cheese analogues are glaring product example in which high protein ingredients are indispensable. Whey less cheese can be made utilizing UF retentate powders. Some of the drawbacks of conventional product such as reduced cheese yield, wheying off from yoghurt, break down of body during storage can be taken care of utilizing high protein dairy ingredients in the product formulation. The applications of such high protein tailor-made ingredients in dairy and food products have been discussed in the review paper.

Review Article

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Introduction

Dairy ingredients are used in food systems because they provide desirable sensory properties, physical properties, and/or nutritional traits in a convenient, wholesome and economical way. These key attributes, which are made available in a wide array of dairy ingredients, make them desirable to food formulators. Milk protein ingredients provide not only nutrition, but also specific technological functionality when applied in food formulations. Milk protein ingredients are natural, trusted food ingredients, and are ideal for unique nutritional and functional applications [1]. Proteins are vital ingredients since they provide all the essential amino acids needed for human health combined with a wide range of dynamic functional properties, such as the capacity to form network structures and stabilize emulsions and foams. The proteins of milk have excellent functional properties and nutritional value, and some have distinctive physiological properties, which are widely exploited in the food industry.

Advances in the dairy industry such as ultrafiltration (UF), microfiltration (MF), nanofiltration (NF) and ion exchange (IE) have brought about radical changes in the commercial processing of dairy ingredients, especially protein ingredients. Powders in which both casein and whey proteins are present in high concentrations would be particularly valuable as ingredients in dairy and non-dairy foods since the unique characteristics of both the proteins would be harnessed [2].

Functional Properties of Protein

Food manufacturers have been utilizing milk powder as a functional ingredient in a wide variety of foods, e.g., chocolate, bakery products, beverages, confectionery items, and yogurt. Some of the important functional properties include solubility, viscosity building, emulsification, heat stability, aeration, etc. The benefits of using milk-based powders in food applications are shown in Table 1.

Table 1: Functionality of milk based powders for food applications.

Function	Benefits	Applications
Solubility	Prevents sedimentation in beverages, soups, and sauces.	Bakery, beverages, confections, frozen desserts, infant formula, soups and sauces, yogurt.
Emulsification	Prevent fat globule from forming lumps. Improved product appearance.	Baked goods, confections, recombined milk, nutritional beverages, sauces, soups, salad dressings, meats.
Flavour enhancement	Provides baked flavour during baking and heating. Provide creamy dairy notes.	-do-

Browning/ Colour	Accentuates colour development during cooking and baking. Enhances the colour of viscous products such as sauces, soups. Improves opacity in low-fat foods.	Baked goods, confections, recombined milk, nutritional beverages, sauces, soups, salad dressings.
Gelling and heat setting	Improves mouthfeel, helps provide the creamy, smooth texture of fat in low-fat products.	Confections, recombined milk, meat, prepared foods.
Water binding and viscosity building	Provides fat like attributes in products. Allows fat reduction. Improves product texture.	Baked goods, confections, recombined milk, nutritional beverages, prepared foods, sauces, soups.
Whipping, foaming and aeration	Maintains foam properties which enhance visual appeal as well as taste and texture.	Baked products, confections, recombined milk, nutritional beverages.

Source: Sharma et al. [4].

In order to improve the nutritional value of food, use of high protein milk powders have become the tool of today, which exhibits functionality far superior than the normal milk powders which was being used till now.

Types of High Protein Milk Solids

Some of the important high protein dairy ingredients include (i) Acid/rennet casein, (ii) Caseinates, (iii) Co-precipitates, (iv) Milk protein concentrate (v) Whey protein concentrates and isolates (vi) Micellar casein, and (vii) UF retentate powder.

Casein and caseinates

Casein products include rennet casein, acid casein, and caseinate. Production starts with skim milk, and then casein is separated from milk serum by adding rennet, acid, or using membrane filtration. Chymosin hydrolyzes the bond between methionine and phenylalanine in κ-casein and it coagulates into three-dimensional networks. The gel is cut, stirred, drained, and washed before being dried into a powder. Casein can be precipitated at its isoelectric point (pH of 4.6). The acidification can be achieved using mineral acids, e.g., hydrochloric acid or sulphuric acid, or lactic acid produced by microbiological fermentation. Caseins are nearly 90% protein on dry matter basis. Caseinates (Na, K or Ca-caseinate) can be obtained by adding alkalis (sodium hydroxide, potassium hydroxide, or calcium hydroxide) to acid casein [3-4]. Caseinates contain about 90% protein. The treatment improves the solubility of the casein for use as an ingredient in foods.

Co-precipitates

The term co-precipitates is used to describe a product produced by the acidification and heating of a combination of casein and whey proteins, with or without addition of calcium salts. The use of coprecipitates in meat products, desserts, confectionery foods and baked products was found to be of value as a functional and nutritional supplement [5]. Co-precipitates are of three types viz., high-calcium, medium-calcium and low-calcium co-precipitates.

Milk protein concentrate

A delactosed, High Milk Protein Powder (HMPP), also referred to as Milk Protein Concentrate (MPC) or Total Milk Proteins (TMP) is a complete dairy protein (containing both caseins and whey proteins). The protein content of MPC ranges from 35 to 85%. Most high-quality MPCs are prepared using UF of skim milk. They can also be produced by precipitating the proteins out of milk or by dry-blending the milk proteins with other milk components [6]. MPC is grayish-white as compared to the yellowish-white color of skimmed milk powder (SMP). The MPC has lower loose (0.31 g/ml) and packed densities compared to SMP [2]. One great advantage of MPC over other milk protein ingredients is that it contains the caseins and whey proteins in their natural ratio and in native state.

Whey protein concentrates and isolates

Whey protein concentrates (WPCs) refers to soluble form of whey protein products containing 25-95% protein on dry matter basis, obtained by UF of sweet whey or acid whey. These products provide proteins which are highly soluble, also under acidic conditions, have good emulsifying properties and excellent water binding, gelling and thickening properties [7,8. These products are widely employed as value added ingredients for protein fortification. Typical applications include infant formula, clinical nutrition, nutritional bars, beverages and mixes. In addition, these WPCs are used in processed cheese, yoghurts, desserts, as well as processed meat and fish products.

Whey protein isolates (WPI) has highest amount of whey protein (i.e. 90-92% protein). It typically contains a maximum of 1% fat plus lactose, 2–3% ash and 4–5% moisture. Preparation of WPI involves subjecting whey to Microfiltration (MF) to reduce its fat content. Subsequently, the MF permeate is subjected to UF and diafiltration (DF), to achieve the desired proportion of protein on dry matter in the product [9]. Another means to increase the whey protein content is through the use of Ion-exchange (IE) chromatography. Using the latter process, the whey proteins are selectively absorbed on the IE resin, while the fat, lactose and minerals are eluted. Subsequently, by increasing ionic strength, the whey proteins are eluted from the IE resin [10].

UF milk retentate and retentate powder

Ultrafiltration of milk can be used to produce popular new dairy ingredients and dairy based foods and beverages that are higher in protein and lower in carbohydrates than traditional milk based ingredients. Spray-dried and freeze-dried ultrafiltered skim milk retentate powders were obtained from mechanically separated whole milk. Retentate spray dried skim milk of high protein concentrations made industrially with agglomeration can meet all the criteria required for skim milk powders. Such standards were also met by freeze dried retentate powders [11].

Functional properties of UF retentate powders include water absorption, whippability/ foaming and gelation. Spray dried retentate skim milk powders displayed low density and flowability, but freeze dried retentate (FDR) powders were comparable with the commercial SMP. Solubility indices of FDR powders were higher than those of spray dried retentate powders. Specific viscosity is lower for FDR powders than in spray-dried powders; there is a rise in viscosity with an increase in the retentate volume concentration. Foaming capacity of spray dried retentate powder reconstituted to 5.0% total solid (TS) was comparable with that of 5.0% Na-caseinate solution [11-14]. The composition of various high protein dairy based powders is collated in Table 2.

Table 2: Proximate composition of high protein dairy powders.

Constituents	Composition of High Protein Ingredients (%)					
	Rennet Casein1	Acid Casein1	Caseinate1	MPC 80[2]	WPC 75[3]	UF Skim Milk Retentate powder[4]
Moisture	10.0-12.0	10.0-12.0	7.0-8.0	4.5	3.5	3.0-9.0
Milk fat	1.5-2.0	1.5-2.0	1.5-2.0	1.8	4.8	0.5
Milk protein	84.0*	90.0*	88.0*	80.0	75.0-77.0	64.4
Lactose	0.6-1.0	0.6-1.0	1.0-1.5	4.5-5.0	10.0-15.0	24.0
Ash	7.5-8.0	2.0-2.5	-	7.5	4.0-6.0	7.8
pH (10% soln.)	-	-	Max. 8.0	-	-	-

Source: FSSA [12][1], Kumar et al. [13][2], Morr and Ha [14][3], Flores & Kosikowski [11][4]**;** *Protein on dry matter basis.

Micellar casein

Micellar casein (MC) is a dairy protein derived from cow's milk. MC is undenatured casein that exists in its natural globular structure. A casein micelle is composed of all five of α, β, γ, λ, and κ-caseins. MC differs from other caseins/caseinates as it exists in its natural form and is more readily digested and assimilated by the body. MC is an insoluble form of casein that is revered for its slow release properties; it can be used to provide a steady supply of protein [15].

MC powder can be used for fortifying cheese milk and for replacing cheese curd in process cheese formulations. MC also constitutes an excellent raw material for preparing individual caseins (β-casein notably) or glycomacropeptide producing purified nutraceutical derivatives from milk proteins [16].

Application of high protein milk solids in food industries

Application of MPCs

High content of protein, low content of lactose, well-preserved casein micelle structures and largely undenatured whey proteins makes MPCs versatile functional ingredients for various food application js. MPCs are particularly suitable for standardization of cheese milk and the stabilization of oil-in-water emulsions due to their excellent rennet gelation and emulsion stabilizing properties [17]. MPC provides about 365kcal/100g. MPCs are currently used for manufacturing products like process cheese, cream cheese, ice cream, yogurt/fermented dairy and meal replacement beverages. Typically, lower protein MPCs are used as ingredients in cheese applications, while high-protein MPCs are used in beverage and bar applications (Table 3). Use of MPCs as an ingredient is growing at the expense of casein and caseinate, due to their improved flavor profile [18-24].

Enrichment of pizza cheese milk with MPC @ 2% enhanced the cheese yield and improved its quality. The addition of MPC (63.5% protein) improved the yield from 10.34% to 14.50%. The percentage of fat recovery increased from 78.19% to 86.29% and TS recovery increased from 44.3% to 55.68% upon MPC addition. Rehman et al. [25] reported that use of MPC in pizza cheese milk resulted in increased calcium content in the cheeses made by culture acidification but low calcium in cheeses made by direct acidification. Such additive helped in obtaining cheeses having superior melt and minimum browning when used for pizza baking. Pizza cheese made using MPC and following culture acidification technique improved the meltability of cheese during storage.

Application of WPCs

Whey proteins have high nutritive value, functional properties and possess exceptional biological value. WPC is a high quality protein with all essential amino acids and richest source of naturally occurring branched chain amino acids (viz., leucine, isoleucine, valine) [26].

The ability of whey proteins to form gels capable of holding water, lipids and other components while providing textural properties is important for the consumer acceptability of foods such as processed meat, dairy and bakery products [2]. Some important applications of WPC in food products is depicted in Table 4.

Table 3: Application of MPC in food products.

Food Product	Benefits of Utilizing MPC in Food Formulation	Reference
Ice cream	Ice cream formulations made using MPC (as 20-50% protein replacer) had higher mix viscosity, greater extent of fat destabilization, better foaming, narrower ice melting curves and greater shape retention compared to control ice cream.	19
	Ice cream prepared with 40-60 % higher protein content (5-7% protein) than control (3.74% protein) resulted in lower lactose and ash content and higher overrun. As the MPC level increased, the ice crystal size was favourably reduced.	20
Yoghurt	Yoghurt containing MPC showed 50% higher gel strength and viscosity compared to yoghurt based on SMP.	21
	Yogurts made with mixtures containing up to 5.6% protein, 0.2% fat, 3.75% lactose and 10.5% TS after fermentation were similar in firmness to the control made from skim milk fortified with SMP to 14% TS. Sensory scores and acetaldehyde content of such yogurts were comparable to those of control.	22
Cheese	Standardization of cheese milk using MPC increased the yield of Mozzarella cheese from 13.8 to 16.7% owing to higher protein and TS recoveries.	23
High protein nutrition bar	MPC provided nutrition and water-holding capacity in such bar. Casein of MPC was digested slowly, allowing greater nitrogen retention and muscle growth.	24

Table 4: Application of WPC in food products.

Food Product	Benefits of Utilizing WPC in Food Product Formulation	Reference
Ice cream	Replacing the normal MSNF (13.0%) with WPC resulted in increased viscosity and whipping ability of mix and increased overrun, melting resistance and sensory score of ice cream.	[30]
	WPC-82 could be incorporated up to 40% level in ice cream to replace SMP. It enhanced the protein content of ice cream.	[31]
Cheese spread	Cheese spread with good melting ability and improved spreadability could be prepared using WPC-38 at level of 4.5% of cheese solids.	[32]
Mozzarella cheese analogue	Inclusion of WPC as part replacement of rennet casein (RC:WPC; 85:15) yielded cheese analogue having greater firmness and meltability, lower cohesiveness and fat leakage, and moderate chewiness.	[33]
Biscuit	The protein content of biscuit increased from 10.45 to 21.45% when using 10% WPC. Lysine, tryptophan and threonine were contributed by WPC that was lacking in wheat flour.	[34]
Salad dressing	WPC acted as an emulsifier and could replace 20% egg yolk with resultant improved viscosity.	[35]
Chocolate	Replacement of SMP with WPC @ 5% improved the nutritional profile and intensity of maillard reaction, yielding chocolate with improved taste and mouth feel.	[36]
Noodles	Increase in volume and weight while swelling ratio tended to decrease.	[37]
Coffee whitener	WPC could substitute 5-10% of Na-caseinate in the formulation. It resulted in product having higher viscosity, greater stability and sensory acceptability than control.	[35]
Meringue	Meringue prepared utilizing defatted WPC was of similar structure and appearance to that of reference egg white product.	[38]
Cakes	Whole replacement of egg by WPC resulted in high aeration value.	[38]
Soups	Improved consistency of soup.	[38]

Substitution of milk powders by WPC in bakery products can be very cost-effective and can increase the functionality (acid solubility, gel formation, whipping ability) of the system. WPC act as a functional ingredient conferring protective effect on the gluten network in the frozen dough and also in baking performance [27,28]. WPC-34, WPC-50 and WPC-80 were reported to be well suited in partially replacing the functions of whole egg in cake application. WPC-80 is better suited for egg white replacement that provide body and viscosity to cake batters to help entrap air and retain carbon dioxide produced by the leavening system [29]. Addition of WPC-80 @ 2% to a low-fat pound cake formula as a fat replacer resulted in a higher volume, softer product that was superior to both full-fat control and a low-fat control (no WPC-80) with regard to moistness, flavor and overall characteristics [29].

Whey proteins could be inducted in casein network by several techniques during cheese making. In preparation of Cheddar cheese employing WPC as an additive, an increase in the yield of product was noted. The cheese yield obtained was 9.96% in traditional process vs. 10.31 and 11.21% in cheeses prepared by incorporating WPC after whey removal and WPC added during inoculation with starter culture respectively [39].

Inclusion of WPC in ice cream mix resulted in a superior product with increased overrun, reduced freezing time besides increasing the protein content of product. It also resulted in an improved creaminess, smoothness and flavour of the resultant ice cream [30]. WPC served as an emulsifier in ice cream [30-40]. Use of WPC (0.5%) in combination with sago as a stabilizer (1.0%) helped in imparting desired body and texture, and richness to medium fat ice cream (6 %fat) which was similar in sensory quality when compared with a premium ice cream (14% fat), but significantly superior when compared to full-fat (10% fat) ice cream [40]. Non-fat yogurt containing 3.0-4.5 % WPC exhibited rheological behavior similar to that of full-fat yogurt and was effective as a milk fat replacer [41.

Application of UF retentate powder

Low-fat (about 31.0% fat on dry matter) Cheddar cheese were prepared from cheese milk enriched with UF retentate powder (URP) and diafiltered microfiltered (DMF) powder to elevate casein content to 5.0-6.0% level. The Cheddar cheeses prepared from URP enriched milk had similar composition to that of cheese made using DMF powder. The protein and lactose content of URP and DMF powder was 70.0% and 15.77 %, and 84.91 % and 0.47 % lactose respectively. The cheese yield (11.45 vs. 11.37%) and fat recovery (91.4 vs. 90.3%) was higher in case of cheese obtained using URP compared to DMF powder 42].

Application of casein/caseinates

Casein products are used mainly as ingredients in foods for either modifying the physical properties of food product or providing nutritional supplement (Table 5). Acid casein (90% protein on dry matter) and rennet casein (85% protein on dry matter) have been successfully used as protein source in the preparation of cheese analogues [43]. Lobato-Calleros et al. [44] made cheese analogue using Na/Ca-Caseinates in combination with soy solids. A formulation of Mozzarella cheese analogue (MCA) was standardized using rennet casein (23% by weight in the formulation) and plastic cream as protein and fat sources respectively [45]. Such MCA had superior melting, stringiness and chewiness (reduced) as compared to natural milk based Mozzarella cheese.

Table 5: Application of casein ingredient in food product.

Food Category	Casein Product	Usage Level	Function
Ice cream	Na-caseinate	1-5%	Texture, stabilizer
Cheese product	Rennet casein, acid casein, caseinates	2-25%	Fat and water binding, texture, matrix formation
Coffee whiteners	Na-caseinate	1-10%	Fat emulsification
Whipped toppings	Na-caseinate	5-10%	Film former, fat emulsifier, stabilizer, bodying agent
Baked products	Casein, caseinates	1-25%	Nutrition, water binding
Confectionery	Caseinates	1-25%	Texture
Soups and gravies	Na-caseinate	5-20%	Nutrition, thickener

Application of micellar casein

Micellar casein powder in solution or in powder has the potential to replace commercial caseinates in food industry. Use of cheese milk standardized with native micellar casein to have increased casein content is being increasingly used for making traditional and new varieties of cheese. Kashkaval cheese enriched with micellar casein has been prepared to have improved technological properties like acceleration in development of curd firmness, increased firmness and consequently higher yield [46]. Increase in casein content from 22.90 g/kg to 26.10 g/kg led to cheeses with typical texture and an increase in the recovery of fat and casein by 2.5 and 3.5% respectively; cheese yield increased by about 17%. The resultant cheese had greater firmness to [47].

Protein based fat substitutes

The protein based fat substitute that has received the most attention has been Simplesse, which consists of microparticulated milk and/or egg white proteins, sugar, pectin, and citric acid [48]. The protein is particulated during a combined pasteurization and homogenization process that produces microparticles of uniform size and spherical shape, 1 µm in diameter [49]. Simplesse contributes only 1–2 kcal/g. Such protein-based substitutes can be used to formulate a variety of products, including cheesecake, puddings, sauces, pie fillings, sour cream, ice cream, cream cheese, mayonnaise, dips, and spreads.

Simplesse acted as fat replacer in ice cream with regard to smoothness, creaminess and mouth coating. Ice creams using

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such fat mimetic had superior sensory score compared to control (10% fat) ice cream. It also gave slightly higher sweetness and stronger flavour than control ice cream made without fat mimetic. Ice cream (4% fat) with Simplesse had properties similar to those of full-fat (10% fat) ice cream [50].

Conclusion

Milk proteins have excellent nutritional as well as functional properties; these aspects are widely exploited in the food industry. Incorporation of high protein milk powders in food products results in value addition to the products. Such high protein powders can be used to produce low fat, low calorie, slimming food products targeted at specific group of people. Such protein powder also has good application in formulating 'Sports food'. Application of novel analytical approaches (genomics, nanotechnology) to milk proteins will enable the dairy industry to produce highly functional and healthy protein ingredients for specific food and dietary applications.

Conflict of Interest

None.

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