Paper 13: Food Additives

Module 20: Nutrients as food additives - 2: Proteins

Introduction

Dairy ingredients can boost the protein content of foods, while delivering on the promise of superior flavor with minimum guilt. Diets higher in protein have been associated with increased satiety, so foods fortified with dairy proteins show great promise in foods intended for weight management market. Protein products high in casein independently or in combination with whey proteins are not new. Traditional procedures for manufacture of such products include acid precipitation or rennet induced coagulation. To achieve proper solubility and functionality, the precipitated casein is frequently sold in the form of sodium or calcium caseinates. If whey proteins are to be included with casein, co-precipitation techniques are required (i.e. calcium co-precipitates). Vegetable proteins are also good sources of plant proteins. The most successful one being the soy protein products.

Protein sources and their digestibility

Some of the protein ingredients obtained from various sources are tabulated in Table 1.

Table 1. Commercial protein ingredients used for food manufacture

Source	Protein ingredients
Soy, wheat, maize and other vegetable sources	Grits, flour, concentrates or isolates, fractionated proteins
Milk	NFDM, acid casein, rennet casein, caseinate, Co-precipitate, WPC, MPC, Lactalbumin
Egg	Liquid egg white, dried egg, egg yolk
Meat	Meat hydrolysates, comminuted meat, mechanically recovered protein, gelatin
Fish	Fish protein hydrolysates, collagen, muscle

NFDM – Nonfat dried milk, WPC – Whey protein concentrate, MPC – Milk protein concentrate

In order to confer the benefits derived out of protein, it has to be digested easily. The protein quality can be determined by finding the content of the first limiting essential amino acid of the test protein as a percentage of the content of the same amino acid content in a reference pattern of essential amino acids. This in turn can be corrected to have true fecal digestibility of the test protein. The value obtained was referred to as the protein digestibility corrected amino acid score (PDCAAS) which is the preferred method for measurement of the protein value in human nutrition. The protein digestibility corrected amino acid score of various proteins is shown in Table 2.

Table 2. Comparison of selected protein products for human nutrition

Type of protein	Protein digestibility corrected amino acid score (PDCAAS)
Casein	1.0
Egg white	1.0
Soy protein concentrate	0.99
Soy protein isolate	0.92
Pea flour	0.69
Peanut meal	0.52
Rice	0.47
Whole wheat	0.42
Wheat gluten	0.25

Dairy proteins

The two dairy proteins are caseins (80% of total protein) and whey proteins (20% of total protein). Whey proteins remains soluble over a wide range of pH levels and have superior gelling and water binding capability, unless they are heated and become denatured. Dairy proteins with their hydrophilic and hydrophobic polar nature function as emulsifiers and can be used to replace fat, improve texture and shelf life of a variety of breads, meats and frozen desserts.

Whey proteins can be used to boost the protein content of a wide variety of beverages. They can be used in meal replacers, smoothies, isotonics, protein waters and sports drinks.

Traditionally used milk derived high protein powders

The examples of traditional high protein powders of dairy origin are acid casein, rennet casein, calcium co-precipitate, and derivatives of casein viz., sodium or calcium caseinates.

I. Rennet and acid caseins: These are precipitation of a casein curd from skim milk (acid and rennet enzyme for acid and rennet casein respectively) followed by washing and drying. The whey proteins are lost in preparing such products. They are approximately 90% protein on dry basis.

II. Caseinates: These are made by treating the rennet or acid casein with alkali (sodium or calcium salt) and then drying. The products are Na-caseinate and Ca-caseinate. The products contain approximately 90% protein. This improves the solubility of the caseins for use as an ingredient in foods.

III. Co-precipitates: These are prepared by adding calcium chloride or dilute acid to skim milk followed by a heating step to cause a curd formation that captures both the caseins and whey proteins. The products are approximately 90% protein.

IV. Milk protein blends: Combinations of dry milk derived products from whey, casein, co-precipitates, caseins, nonfat dry milk, etc. technically can be blended together to produce a milk protein concentrate. They can be blended to produce products with a wide range of compositions for use as custom ingredients in food product manufacture. However, the functionality (i.e., solubility, flavor, etc.) may be very different than Milk Protein Concentrate (MPC) prepared by ultrafiltration of milk.

Functional properties of proteins

Functional properties of proteins could be classified according to the mechanism of action on three main groups: (i) properties related to hydration (absorption of water/oil, solubility, thickening, wettability) (ii) properties related to protein structure and rheological characteristics (viscosity, elasticity, adhesiveness, aggregation and gelification), and (iii) properties related to protein surface (emulsifying and foaming activities, formation of protein-lipid films, whippability). Some of the functionalities of protein ingredient in food product is tabulated in Table 3.

Table 3. Multiple protein functionality in selected processed foods*

Type of food	**Multiple functionality**
Beverage	Solubility, colour, grittiness
Baked goods	Emulsification, foaming, gelation,
Dairy substitutes	Gelation, foaming, emulsification
Egg substitutes	Foaming, gelation
Meat emulsions	Emulsification, foaming, gelation, adhesion-cohesion
Soups and gravies	Viscosity, emulsification, water adsorption
Topping	Foaming, emulsification
Whipped dessert	Foaming, gelation, emulsification

Kinsella (1982), Kilara (1994)

Now, with the adoption of newer technologies such as ultrafiltration, microfiltration and nanofiltration, purified protein products having a wide range of functionality can be tailor made. Protein powders based on such novel technologies include Whey Protein concentrates (WPC), Milk Protein Concentrates (MPC), Micellar casein powder, etc.

A. Milk Protein concentrates

MPC production begins with ultra filtration of skim milk to make a lactose-reduced, skim milk concentrate, which is further concentrated in an evaporator by using two-stage drying process and, finally, spray dried into powder form. Milk protein concentrate contains high levels of protein and low lactose. Milk protein concentrate preserves the unique casein to whey ratio in milk. Milk protein concentrates (MPCs) are complete dairy proteins (containing both caseins and whey proteins) that are available in protein content ranging from 40.0 to 89.0 percent. As the protein content of MPCs increases, the lactose levels decreases (Table 4).

Table 4. Proximate composition of some high protein dairy based food ingredients

Constituents	MPC-42	MPC-80	WPC-34	WPC-80	Acid casein*	Rennet casein*
Moisture	5.0	5.0	4.0	5.0	10.0	10.0
Fat	2.0	3.0	5.0	5.0	2.0	2.0
Protein	42.0	80.0	34.0	80.0	90.0	84.0
Lactose	46.0	6.5	50.0	6.5	1.0	1.0
Ash	5.0	5.5	7.0	3.5	2.3	7.6

* on dry matter basis, except for moisture

Typical MPCs offered are MPC42, MPC70, MPC75, MPC80, MPC85 and milk protein isolate (MPI with 90% protein). MPCs are produced by ultrafiltration (UF) or by blending different dairy ingredients. Although UF is the preferred method for producing MPCs, they also can be produced by precipitating the proteins out of milk or by dry-blending the milk proteins with other milk components. The functionality of MPCs may differ depending on how they were produced. For comparison, skim milk powder (SMP) contains about 35.0% protein and 52.0% lactose.

Functional characteristics of MPCs

Some of the common functional characteristics that MPCs offer in various food and beverage applications include:

Solubility: Ultrafiltration (UF) preserves the original protein structure of MPCs, which results in a greater solubility. Since they are readily soluble, MPCs are beneficial in dry dairy-based mixes. MPCs that are stored at ambient to cool temperatures (40 to 70^{o}F) and low humidity retain good solubility for 6-8 months. Dissolvability of MPCs can be improved by increasing the sodium or potassium content, which makes MPCs more suitable for use in specific food and beverage applications such as meal replacement beverages and process cheese.

Emulsification/Foaming/Whipping*:* The proteins in MPC act at the oil/water interface to form and stabilize fat emulsions in sausages and other processed meats, dairy drinks, soups, vinaigrettes, sauces and bakery products. The proteins in MPC act at the air/water interface to form a stable film of air bubbles. Hence during its application, it stabilizes meringues, mousses, cake, ice creams, whipped cream. The whey protein denaturation levels, different types of casein-whey protein complexes, various levels of casein-bound calcium and soluble casein, and manipulating casein micelle size can help in improveing MPC functionality. This would enhance the emulsions (oil/water interface) and whipping (air/water interface) of MPCs for application in sausages, processed meats, dairy drinks, soups, vinaigrettes, sauces and bakery products. MPC can form a consistent film of air bubbles to stabilize meringues, mousses, cakes, ice creams, whipped cream and soufflés.

Water Binding/Viscosity: Efforts are underway to enhance the functionality of MPCs to improve water binding and viscosity similar to rennet casein utilizing enzymatic process before spray-drying. The functionalized MPCs will enhance the viscosity of the food product and will be applicable in products such as cheeses, firm yogurts, sauces, milk-based drinks and creams for desserts and bakery products.

Application of MPCs

MPCs are used for their nutritional and functional properties. MPC averages approximately 365 kcal/100g. Higher-protein MPCs provide protein enhancement and a clean dairy flavor without adding significant levels of lactose to food and beverage formulations. MPCs also contribute valuable minerals such as calcium, magnesium and phosphorus to formulations, which may reduce the need for additional sources of these minerals. MPCs are multifunctional ingredients and provide benefits such as water binding, gelling, foaming, emulsification and heat stability.

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 higher-protein MPCs are used in beverage and bar applications. They are used as an ingredient in applications that rely on nonfat dry milk (NFDM) but require a higher level of protein where casein and caseinate are used traditionally. Use of MPCs as an ingredient is growing at the expense of casein and caseinate, due to their improved flavor profile. Common applications include infant formulas, desserts, baked goods, toppings, low-fat spreads, dairy-based dry mixes, dairy-based beverages, sports and nutrition beverages/foods, geriatric nutritional products, weight loss beverages/foods and some process cheese products. MPCs are now widely used in a variety of protein-enhanced foods, but primarily in meal replacements, nutritional beverages and bars.

MPCs can be used to boost the protein content and reduce the sugar levels of a wide variety of puddings, nutritional beverages, process cheeses and frozen desserts.

Yoghurt: Skim milk powder (SMP) is used commonly to enrich yogurt at a rate of 3.0-4.0% to increase the TS. Addition of milk protein helps form a firmer body and reduces whey expulsion in the final product. The dry matter content of typical commercial yogurts ranges from 13.0-17.0% because of enrichment of the base milk. There is a limit to the quantity of SMP that can be used to get firmer body because large amount can produce powdery mouth feel, and excess lactose from SMP can lead to extreme acidity during storage of the final product. MPC possesses unique casein to whey protein ratio. Such qualities make MPC an alternative to NFDM in yogurt.

Pizza cheese: The addition of MPC (to standardize cheese milk to protein/fat of 1.40) improved the yield from 10.34% in control pizza cheese to 14.50% and 16.65%, respectively, for pizza cheese made by starter culture (SC) and direct acidification (DA) methods. The TS recoveries were in the order, SC > DA > control. DA pizza cheese had the best meltability.

B. Micellar casein concentrates

Manufacture of Micellar Casein Concentrates (MCC) from milk by microfiltration (MF) produces a range of compositions depending on the amount of milk derived whey (MDW) protein removed. Further concentration and diafiltration (DF) can increase the total protein and decrease the amount of lactose in the final ingredient. MCC ingredient provides notable nutritional benefits and is an excellent source of all essential amino acids and calcium. Apart from nutritional benefit, it offers a unique functional benefit for application in retort beverages and cheese production. An MCC with 95.0% of the MDW protein removed has approximately 84.0% protein, of which 80.5% was casein and 3.7% was whey protein (Table 5).

Table 5. Composition of Micellar casein concentrate as against caseinate powder

Constituents	Micellar casein concentrate (MCC84)*	Caseinate
Moisture	5.20	8.0
Fat	2.20	2.0
Protein	84.10	88.0
Lactose	0.70	1.0
Ash	7.80	-
pH	-	8.0

* values are on dry matter basis

The composition of MDW protein ingredients are unique compared with those derived from cheese whey. The protein composition of cheese whey differs from MDW because it contains glycomacropeptide (GMP), which is cleaved from κ-casein through the action of chymosin in cheese making. The microfiltration process retains milk fat in the retentate, which yields an MDW that is essentially free of fat (< 0.3%), even after further concentration to 80.0% protein. Alternatively, cheese-whey-derived WPCs (CD-WPC) with 80.0% protein typically contain 6.0-7.0% fat. This difference in fat content also is a major factor in explaining their differences in functionality, flavor and appearance.

The functional properties of MDW protein concentrates (MD-WPC) are typically better than CD-WPC. MD-WPC has greater foaming, gel strength, solubility and emulsification capacity than CD-WPC. Owing to the higher denaturation levels in the commercial CD-WPC, it has greater water-holding capacity (WHC) and lower solubility.

Sensory properties and appearance: The sensory properties of MD-WPC are notably different from commercial CD-WPC. Similar aroma compounds have been identified both protein products, many of which are lipid and protein oxidation products. Commercial CD-WPCs have higher concentrations of volatile compounds such as hexanal, heptanal and pentanal compared with MD-WPC. Besides a cleaner flavor, MD-WPC has a very different appearance in solution compared with a CD-WPC, which is related to the fat content. The low fat content in MD-WPC gives it a clear appearance in solution, while a CD-WPC appears very milky and cloudy. This clear appearance allows MD-WPC at any protein level to be used in clear beverage applications.

Specific applications of Micellar casein powder

Beverages: MCC would be a good choice for neutral pH UHT or retort-processed nutritional drinks because of their heat stability. The use of MD-WPC produces a clear, high-acid beverage (pH 3.4) that has similar heat stability and clarity to a whey protein isolate (WPI). No significant change in pH, viscosity or solubility occurred during the shelf life (39 weeks at 20^{o}C) of either beverage. The WPI beverage developed some off-flavors typically associated with high-protein beverages, while the MD-WPC-80 beverage had a clean flavor and aroma when compared with WPI beverages.

Cheese: The practice of cheese milk standardization is common and is typically done to improve yield and produce cheese with a consistent composition. Cheese makers in the United States are allowed to use ingredients such as condensed skim milk and NFDM for this purpose in standard of identity cheeses, such as Cheddar and Mozzarella. The ideal ingredient for standardization of cheese milk would contain predominantly casein protein, as that is the primary protein in cheese. Use of microfiltration retentates (liquid MCC) in the manufacture of cheese revealed that MCC is a useful ingredient for increasing production capacity while maintaining cheese quality. Fractionation of milk by microfiltration (MF) creates more value-added, milk-derived ingredient opportunities that have diverse applications for use by the dairy and food industries. These ingredients can provide unique functionalities along with clean flavor and excellent nutrition.

C. Whey protein concentrates and isolates

About half of whey proteins are β-lactoglobulins with (Isoelectric pH (IEP) of ~5.4); about 20.0% are α-lactalbumin (IEP of 4.4) and a little more than 10.0% are glycomacropeptides (IEP of < 3.8). Whey protein concentrates (WPC) is prepared by passing whey (cheese) through ultrafiltration membrane to recovery whey proteins in the retentate. Ultrafiltration retains (retentate) any insoluble material or solutes > 20,000 Da molecular weight. The rest of the whey stream passes through the membrane, driven by the applied pressure and is called permeate. The permeate contains most of the lactose, minerals and water from the whey. The retentate, the volume of which is about 1-4% that of the feed whey, is spray dried to a powder containing 35-85% protein as desired. Usually two types of WPCs are available commercially viz., WPC-35 and WPC-70; the number indicating the protein content of powders.

Functionality of whey protein powders

Clarity/Opacity: If clarity is the goal, then the ingredient of choice is WPI, which has over 90% protein and very low fat. Isolates also work well in opaque beverages, but in these applications, an MPC70 or WPC80 maybe more cost-effective and provide good opacity.

Solubility: In protein waters and isotonics, whey proteins are easily soluble at a pH of 3.4, where soy and casein would precipitate out. Whey proteins also work well at neutral pH (i.e. 7.0).

Processing: Other factors that affect the appearance and stability of whey protein beverages include ionic strength, hydration time, sugar and water. Adequate hydration can reduce turbidity by as much as 50%.

Structure and browning: If goal is to improve grain structure, retain moisture, enhance crust browning and improve flavor then high heat NFDM, WPC34 or specialty dairy blend might be a good choice.

Applications of whey protein concentrates

WPC and Whey protein isolates (WPI), for example, are added to foods and beverages for both nutritional and functional purposes.

Infant formula: Cheese-derived whey proteins have been the predominant source of whey protein for infant formulas today. More recently, milk-derived WPC or WPI has been highlighted to infant formula manufacturers as a source of protein not containing glycomacropeptide, which is absent in human milk.

Whey ingredients can be used in processed meats as partial replacements for meat, as binders, as flavor enhancers and meat analogues. Whey ingredients can improve yield and prevent moisture loss in ham and surimi. In meat applications, the binding of myofibrillar meat proteins decreases during cooking, due to protein denaturation. Under appropriate heating conditions, whey proteins can form irreversible gels by restructuring into extended, 3-dimensional networks.

The water binding capability of whey proteins makes them useful in a wide variety of soups and sauces. For products, that will be exposed to high temperatures, either an MPC or heat stable whey proteins may be needed.

Cheesemaking: Incorporation of WPC led to an increase in the yield of Cheddar cheese from 9.96% (cheese prepared through traditional process) to 10.31% (WPC added after whey extracting) and 11.21% (WPC added during inoculation with starter culture).

D. Vegetable protein concentrates and isolates

Commercially, the extraction and purification of vegetable protein can be performed by processing in neutral or in acid medium to produce concentrates (48–70% protein) or in alkaline medium leading to an isolate as final product (85–90% protein). Protein concentrates result from removing non-proteic constituents, mainly soluble minerals, carbohydrates, low molecular weight nitrogen compounds and antinutritive factors from full fat or, more usually, from defatted meals.

I. Soy protein as high protein ingredient

Since 1960s, soy protein products have been used as nutritional and functional food ingredients in every food category available to the consumers. Protein supplementation of cereals is desirable in many instances because cereals have low protein content and are imbalanced in essential amino acids (EAA) composition. Soy protein products are an ideal source of some of the EAAs used to complement cereal proteins.

Forms of soybean protein

At present, the various forms of soybean protein are utilized primarily for their functional effects rather than for their nutritional properties. After oil removal from soybeans, the remaining proteinaceous material is referred to as soybean defatted flakes. Three forms of soyprotein products exist as protein supplements or as protein source and their content ranges from 50% to > 90%, namely soy flours/grits, soy protein concentrates and soy protein isolates. The protein content of various soybean protein ingredients are depicted in Table 6.

Table 6. Composition of various protein ingredients of soybean origin

Protein ingredients	**Moisture**	**Protein**	**Fat**
Flours and grits			
Full fat	6.00	41.00	20.50
Defatted	6.00	53.00	0.60
Concentrate	6.70	66.20	0.30
Isolate	4.70	92.80	< 0.10
Texturized soy protein	9.00	50.00	6.0-8.0

Source: Singh *et al.* (2008)

Soy protein concentrates: Soybean protein concentrates (SPC) contain ≥ 70.0% protein on moisture-free basis. Protein concentrates are prepared from defatted flakes or flour by removing the oligosaccharides, part of the ash, and some of the minor components. SPC preparation involves retaining the soybean globulin proteins while selectively removing the soluble sugar carbohydrates. The physical properties of SPC will differ with based on the method of preparation (i.e. heat, acid leach or alcohol leach). Concentrates have a reduced flavor level as compared to flours and grits.

SPC were developed as flavor improvers and for increasing the protein content of foods. These products provide high quality protein and are comparable to animal protein. The Food and Drug Administration (FDA) has allowed a claim that “A daily diet of 25 g of soybean protein which is low in cholesterol and unsaturated fat can reduce total LDL cholesterol moderately” (FDA, 1999). SPC has improved flavor characteristics and provides functional characteristics such as fat-micelle stabilization, water and fat absorption, viscosity control, and texture control in forming fat emulsions in food systems. The substitution of flour by 5.0% SPC increased the blend protein content by approximately 2.5%.

Since the neutralized acid leach and steam injection/jet cooking processes can result in a product that has high dispersibility, concentrates of these types will have more desirable functional properties in emulsion type applications. These dispersible functional concentrates have many of the properties exhibited by neutralized isolates. Concentrates may vary as to color, flavor, particle size, and water and fat absorption. All of the SPCs, regardless of the process used, do have fat and water holding properties (partially due to their polysaccharide content), and modify viscosity and textural characteristics of the food system. The alcohol-denatured concentrates exhibit good nutritional value and are used in many applications requiring protein fortification. They may also be texturized.

Soy protein isolates: The most refined form of soybean proteins are the soy protein isolates (SPI), which contain ≥ 90.0% protein. They are prepared by removing the water-insoluble polysaccharides, as well as the oligosaccharides and other low-molecular-weight components that are separated. Defatted flakes or flours, which have received a minimum of moist heat treatment, are extracted with water plus alkali at a pH of 7.0-8.5. The insoluble residue, containing the water-insoluble polysaccharides plus residual protein, is then separated. The clarified extract containing the bulk of the proteins plus the sugars is adjusted to about pH 4.5. These precipitated proteins are removed by centrifugation or filtration. These are then washed and dried to give the isoelectric protein. The protein is neutralized before drying.

Functional properties of soy proteins

SPC and SPI provide highly concentrated protein sources, high lysine content, bland flavor, and reduction of flatulence factors and reducing sugars, and they may lead to improved overall product quality.

The common functionalities of soy protein products include solubility, water absorption and binding, viscosity control, gelation, cohesion, adhesion, elasticity, emulsification, fat absorption or repulsion, flavor binding, foaming, whipping, and color control.

Commercially available soy proteins exhibit a wide range of solubilities at pH 7 ranging from 25.0 to 95.0%; solubility being dependent on pH and salt concentration. Higher pH results in high solubility. Commercial soy proteins also have a wide range of water binding ability. Insoluble protein granules bind much more water than soluble proteins. Slurries of soy proteins have relatively low apparent viscosity and do not form strong gel networks; however, heat or alkali treatments can increase viscosity and improve gelation functionality.

Several SPIs have been developed for providing different functional or physical properties to meet the requirements of various food systems. The solubility of isolates ranges from 25.0 to 95.0 NSI (nitrogen solubility index). Other than solubility, emulsifying capacity, gelling, fat and water absorption, and viscosity should also be considered. The emulsion capacity of isolates can differ by a factor of nearly 4. Emulsion capacity or the ability of a protein to emulsify fat is an important functional parameter in many food products. Isolates can emulsify from 10 to about 35 mL of oil per 100 mg of protein. The film-forming properties of SPI are useful in certain meat products.

The application of heat and shear to the protein solutions can also alter their viscosity. Water and fat absorption properties are also utilized in meat and baking applications. Isolates have water absorption values from about 150 to 400%. Neutralized isolates are usually highly dispersible and gels under appropriate aqueous conditions. They possess both emulsifying and emulsion stabilizing properties, and are excellent binders of fat and water, and are good adhesive agents too. Hence, they are used in processed meat products, both coarse and fine emulsions (as in patties, loaves, and sausages). Isolates and concentrates can also be structured to have a fibrous appearance. These products are designed mainly for poultry and meat protein replacement. The fiber-like structure, adds texture and mouth feel to poultry rolls.

Commercial soy proteins display a range of emulsion and foam properties. For commercial food applications these organoleptic problems can be avoided through careful control of food processing conditions.

Applications of soy protein products

Full-fat and defatted soy flours have been used successfully as major ingredients in low-cost replacements for milk solids in beverages for human consumption in developing countries. All SPCs have much improved flavor characteristics as compared to commercially available soy flours. In general, the greatest potential areas are where casein and NFDM are used, such as emulsion-type meat products, bakery products, nutritional powder drinks, and soup bases. Baby foods, cereals, dry food mixes, milk replacers and snacks are few more examples where powdered SPC may be used.

SPI is used in the food industry for nutritional (increasing protein content), sensorial (better mouth feel, bland flavour) and functional reasons (for applications requiring emulsification, water and fat absorption and adhesive properties). In general, the greatest potential areas for use of SPC are where casein and NFDM are used, such as emulsion-type meat products, bakery products, nutritional powder drinks, and soup bases. Baby foods, cereals, dry food mixes, milk replacers, and snacks are just a few more examples where powdered SPCs may be used.

SPI are the most acceptable products for dairy applications because of their fine particle size and dispersibility. The functional properties of emulsification, emulsion stability, color, and flavor/odor are critical factors in dairy applications. A few, such as dry and liquid coffee whiteners, liquid whipped toppings, pre-whipped toppings, and toppings of other emulsified food items to replace Na-caseinate enjoy distribution in few countries. Dairy-type foods utilizing SPIs include imitation milks, convenience beverage powders, frozen desserts, sour cream, sour cream dips, and related cheese-like products. Soy protein ingredients are now being used in emulsion-type cheeses to replace as much as 50% of Na-caseinate in some products. Soy and milk protein blends (combined to offer protein content similar to that of milk) are sold as ingredients in bakery products, sauces, meat products, and various fabricated foods, as complete or partial replacement of NFDM. Soy protein formulas are recommended for those infants, and others, who are allergic to milk protein and those who have lactose intolerance or lactase deficiency.

Water and fat absorption properties of SPI are utilized in meat and baking applications. Isolates have water absorption values from about 150.0 to 400.0%. Neutralized isolates are usually highly dispersible and gels under appropriate aqueous conditions. Some of the general-purpose isolates (nondispersible) have good nutritional properties and vary mainly in their gelling and viscosity characteristics.

Isolates and concentrates can also be structured to have a fibrous appearance. These products are designed mainly for poultry and meat protein replacement. The fiber-like structure, for example, adds texture and mouth feel to poultry rolls.

Meat products: The major application of SPI in meat and related product is based on the use of texturized SPI, in one form or another, to replace meat. The neurtralized isolates possess both emulsifying and emulsion stabilizing properties, and are excellent binders of fat and water, and are good adhesive agents. Due to such inherent properties, they are used in processed meat products, both coarse and fine emulsions (as in patties, loaves, and sausages). SPI and proteinates are used for their moisture and fat binding properties and also used as emulsion stabilizers. Typical usage levels are 1.0 to 4.0% on prehydrated basis. The use of SPI in these products permits reducing the proportion of expensive meat in the formulation, without reducing the protein content or sacrificing eating quality.

Seafood products: SPI find good application in fish sausage and *surimi* (washed, minced fish flesh) based restructured fish products in Japan.

Cereal products: SPI is sometimes used instead of, or in combination with concentrates and soy flour, in the formulation of milk replacer mixtures in bakery products. SPI has been used for protein fortification of pasta and specialty bread. In these applications, the high protein content and blandness of SPI are clear advantages.

Dairy-type products: SPI are used in non-dairy coffee whiteners, liquid whipped toppings, emulsified sour cream or cheese dressings, non dairy frozen desserts, etc. The basis for these applications is, demand for non-dairy (all-vegetarian, cholesterol-free, allergen-free) food products, as well as economy.

Imitation cheeses have been produced from isolated soy proteins, with or without milk or whey components. The types of cheeses which can be produced include soft, semi-soft, surface-cultured (imitation Camembert) and ripened hard cheeses.

Whipped toppings: Milk protein has been replaced with SPI (0.4% w/v) leading to products with a overrun of 350-400% and excellent stability. Proteinase treated SPI had superior whipping functionality compared to egg white.

Infant formulas*:* Infant formulas where milk solids have been replaced by soy products are well established commercial products. SPI is the preferred soy ingredient, because of its blandness, absence of flatus-producing sugars and negligible fibre content. The principal market for these products is lactose-intolerant babies. However, soy protein based dietetic formulas are finding increasing use in geriatric and post-operative feeding as well as in weight reduction programs.

Generalized applications of protein ingredients

It is recommended to use 2.0% of WPC34 or 0.4-0.75% of WPC80/WPI for fortification of milk solids content of yoghurt mix, along with some skim milk powder. Increasing levels beyond this may lead to graininess, lumpiness, and a short/brittle texture.

Specific applications of high protein powders

Specialty breads: The protein content of ordinary white bread is 8.0 to 9.0%. Specialty breads can be made with 13.0 to 14.0% protein by incorporating soy flour, concentrate, or isolate in the formula, along with vital wheat gluten and, if necessary, a lipid emulsifier. Without surfactants, incorporation of high levels of soy flour depresses loaf volume and gives poor crumb characteristics. In cases where 12% of soy flour was used in non-standardized bread, the Protein Efficiency Ratio (PER) increased from 0.7 to 1.95. In addition to the improvement in protein quality, the protein content also increased by > 50.0% at such level of supplementation. Soy-fortified wheat flour has been used worldwide in mass feeding and school lunch programs.

Increasing substitution (20.0 to 100.0%) of egg yolk with WPC in Gelato (frozen delicacy) making, led to increased overrun, number of air cells formation and texture characteristics of the product; control Gelato used 4.5-9.0% of egg yolk. Practical applications of WPC involving interaction between water and protein include yoghurt, hard pack ice cream, low-fat ice cream, non fat ice cream, soft ice cream, sour cream, and coffee whiteners. WPC80 is substantially cheaper than egg yolk. Use of WPI (95% protein) as part substitution of NFDM led to desirable properties in frozen product as against use of Na-/Ca-caseinate, rennet casein (all these with 95.0% protein) and WPC-36 (36% protein); sodium caseinate enhanced the overrun in ice cream.

Other vegetable protein powders

The fortification of human food with oilseed proteins is expanding rapidly. Much of the success has been achieved with soy protein products, but peanut protein and cottonseed protein products have also been included in human food.

Peanut protein concentrate

Use of peanut protein concentrates (PPC) at levels higher than 10.0% reduced the loaf volume of bread significantly compared to that of bread baked with other protein sources.

Cottonseed protein product was added to raise the bread protein by 30.0% as compared to bread baked with 100% wheat flour (from 10.0 to 13.0% protein by weight). Acceptable loaves were obtained with blends containing cottonseed protein concentrate, spray or freeze dried at near neutral pH. The quality of baked bread was similar to the one made using commercial soy flour.

Recent developments in high protein powders

Spray dried ultrafiltered retentate powder: Ultrafiltration is both a fractionation as well as concentration process. Subjecting milk to ultrafiltration, casein as well as whey proteins are retained in the retentate and the total protein content is increased as permeate is diffused through the membrane. Such UF concentrate when spray dried yields high protein powder ingredient whose composition is shown in Table 7.

Table 7. Comparison of physico-chemical properties of ultrafitered retentate powder with skim milk powder

Parameters	**Spray dried Skim milk powder**	**Spray dried UF retentate powder (made from 4:1 RVC)**
Moisture	3.60	3.90
Protein	35.70	64.40
Lactose	53.00	24.00
Fat	0.50	0.50
Ash	7.70	7.80
Density (packed)	0.375	0.493
Flowability (g/s)	1.25	1.22
Solubility index	0.03	1.60

* - Relative volume concentrate

Traditionally, non-fat yoghurt has poor body and frequently has excessive whey separation. To avoid this gelling and stabilizing agents are invariably used. Use of high milk protein powder, while adding protein to yoghurt, served as a stabilizer to improve the body and texture.

A high protein milk powder (HPMP) has been prepared using ultrafiltration with diafiltration of skim milk. The final protein powder had 5.33% moisture, 88.0% total protein, 2.27% fat, 0.74% lactose and 7.5% ash. Through such processing, it was possible to reduce lactose up to 99.7%. Specific application of such HPMP is in low-fat and non-fat yoghurts. Supplementing skim milk with HPMP up to 5.6% protein could produce low-fat yoghurt of good quality. The added protein helped to provide a firm body, without the use of stabilizers. Addition of 1.0% HPMP to cheese milk and fat standardization produces Gouda cheese with good sensory properties as well as increased cheese yield.

Other promising protein powders

Some of the other promising protein sources include spray dried egg yolk powder (5.5% moisture, 32.9% protein); rice bran protein, rice protein concentrate, canola protein concentrate, pea protein concentrate, barley protein concentrate, lupin protein concentrate, etc. Peanut flour contains 47.0 to 55.0% protein. Peanut protein concentrate had crude protein content of 70.2% but it had an unbalanced amino acid pattern and was deficient in lysine, threonine, methionine and tryptophan.

Conclusion

Other ingredients such as milk-derived whey protein, β-casein and individual whey proteins will soon be produced by dairy ingredient suppliers. These ingredients provide an opportunity for food and beverage companies to create new products benefiting consumers. Use of high protein ingredients can be of significance in improving the nutritive value as well as functional property of the resultant food product. Such protein powders can be used for standardizing the protein content of food to prepare 'tailor-made' product and can be favourably used for yield enhancement in protein containing products like cheeses.

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