

Recent Trends in Developing Whey Products by Advanced Technologies

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Abstract

Original Research Article

Whey as a by-product of cheese has been considered a waste product and looked upon seriously by environmentalists and technologists. However, nowadays, it has been unlocked by modern processing technology, enabling them to recover economically in their natural state to produce new whey products with diverse functional properties which can be substituted with expensive ingredients such as egg white and milk proteins. Whey products have many nutritional, biological, and functional properties that make them excellent ingredients in a wide variety of food applications such as bakery products, beverages, dry mixes, infant formula, frozen desserts and ice cream, nutrition bars, dairy goods, nutritional supplements, and lactose-free products that reduce carbohydrate, fat, and calorie content, all of which are extensively covered in detail in this study.

Keywords: Whey, membrane filtration, cutting-edge technology, useful qualities, and dietary supplements.

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1. INTRODUCTION

Whey is the milk serum produced during the manufacture of cheese after separating casein and fat during milk coagulation. Due to its potent strength to pollute, whey has always been viewed as a waste product and taken seriously by technologists and environmentalists. It is no longer regarded as a waste product. Modern processing technology has uncovered a treasure trove of nutritionally dense whey protein, allowing them to recover profitably in its natural form. The advent of this method has greatly facilitated the recovery of these priceless solids such as whey protein concentrate (WPC). Whey proteins can replace expensive components like egg white and milk proteins and are potentially nutritional and functional food ingredients for various kinds of food. It also contributes to the development of new food products. This review focuses on functional aspects of WPC concerning their application in food product formulation. The production of modified whey, such as WPC, has expanded gradually. The United States is the world's largest producer of whey products. In 1998 the U.S.A manufactured over 700,000 tons of whey, including 535,000 tons of whey powder, 130,000 tons of WPC, and 48,000 tons of other modified whey products.

2. Whey components

Protein, lactose, fat, and minerals make up the complex component of whey. The most well-known whey component is protein, composed of numerous smaller protein components such as beta-lactoglobulin, alpha-lactalbumin, immunoglobulins (IgGs), glycomacropptides, bovine serum albumin (BSA), and minor peptides like lactoperoxidase, lysozyme, and lactoferrin. Each of the subfractions found in whey has its unique biological properties. Up until quite recently, separating these subfractions on a large scale was either impossible or prohibitively expensive. Modern filtering technology has improved dramatically in the past decade, allowing companies to separate some highly bioactive peptides, such as lactoferrin and lactoperoxidase, from whey. Over the past few decades, whey protein powders have evolved numerous generations, moving from low-protein concentrates to extremely high-protein isolates.

3. Reduction of BOD/COD:

Whey is the liquid removed from the curd during the cheese-making process. It is a by-product of the cheese industry. According to the variety of cheese, 100 kilograms of milk will typically provide 10–20 kg of

cheese and 80–90 kg of liquid whey. Due to its composition and other factors, disposal is a significant issue for the dairy industry. It is challenging to use since it has low solids content and a very unfavorable lactose-protein ratio. It has a serious disposal issue due to its biological oxygen demand (BOD), ranging from 32,000 to 60,000 ppm. The use of whey to boost product production and replace fat is made possible by the microparticulate process, which creates particles that are identical to milk fat particles. Numerous dairy products contain whey that has been micro-particulate. To reduce wastewater, reverse osmosis polishers can concentrate BOD/COD (*chemical oxygen demand*) from evaporator condensate, and RO (*reverse osmosis*) permeate streams. Polished water can also be reused in plants for boiler water make-up and CIF (*communications and information foundation*) systems. The "polishing" of these process water streams in dairy industry applications aids in producing Class I water for reuse from dairy products, as defined and governed by *Food and Drug Administration regulations*. Water produced with this technique is also very soft, resulting in lower cleaning chemical consumption.

4. Health Benefits of Whey

Whey proteins are an ideal ingredient in various food applications because they have numerous beneficial nutritional, biological, and functional characteristics. Whey proteins have the highest nutritional value of all food proteins. They include all the amino-acids that the human body requires in the proper ratios. They are rich in branched-chain amino acids and easily digestible and completely bio-available. In their pure form, these functional whey protein groups can substitute for much higher amounts of caseinates, soy protein, WPC, egg whites, or gelling agents. Therefore, whey can significantly enhance the nutrition and flavor of any food or beverage in formulae where nutrition, high gel strength, viscosity, aeration, water binding, or solubility is crucial.

Whey gives a successful new product the competitive edge it needs in terms of nutrition, usability, and flavor. Whey protein consumption has been linked to numerous other health advantages besides adding protein to the diet. In addition to being used in the newborn formula, whey protein has improved immunity, weight control, and athletic performance.

5. Whey in Food Industry

The food industry frequently uses whey protein concentrates (WPCs) because they view them as extremely nutritious and functional ingredients. Their protein make-up and content affect how they function. Proteins and polysaccharides coexist in many foods, and their interactions impact the quality of the final product. Due to the stability and texture modification offered in the end goods, analyzing these mixes is of great interest. Studies by *Stephen Danielle* in 2006 suggested that modifying whey protein concentrates to contain large

amounts of phospholipids could transform common emulsifiers into useful components that promote health. Various food products, including ice creams, beverages, salad dressings, and sports supplements, use whey proteins from cow's milk as emulsifiers. The new study compared nutritionally *modified whey protein concentrates* (MWPC) with regular whey protein concentrates (WPC) to generate and stabilize oil-in-water emulsions. It was published online in the journal *Food Research International*. It is also used in producing groceries concentrating ice cream, yogurt, drink nutrients, and functional foods.

5.1 Advanced Technologies:

Today's food business uses various cutting-edge technology to create new whey products with various useful qualities. The use of cross-flow membrane filtration technology in numerous production process lines in the food, dairy, pharmaceutical/biotechnology, starch, and sweetener industries is swiftly gaining recognition on a global scale. Compared to more traditional techniques like rotary vacuum filtration or filter presses, membrane filtration can sometimes be a far more cost-effective alternative since it can generate apparent separations at low or ambient temperatures without phase change. According to current estimates, the dairy industry has membrane installations covering more than 300,000 square meters worldwide. *Reverse osmosis* (RO) and *ultrafiltration* (UF) dominate usage now, but *microfiltration* (MF) and *nanofiltration* (NF) are predicted to rise significantly over the next ten years. The processing of cheese whey is a good illustration of the effective use of membrane technology and ultrafiltration. Despite ongoing efforts to identify uses for whey or its main ingredients—high-quality protein and lactose—in either their raw or dried form, it is estimated that up to 40–50% of the whey produced is disposed of as sewage, with the remainder being mostly used for animal or human food. The world produces between 80 and 130 million tons annually, with the United States producing roughly 30 million tons. We can anticipate that the whey disposal issue is getting worse because cheese consumption is rising globally [6]. This explains why cheese and whey producers are interested in membrane technology: The right membrane can simultaneously concentrate, cleanse, and fractionate the components of whey, improving their use and lowering pollution issues. Membrane filtration is a pressure-driven technology with pores sizes ranging from 100 molecular weight to microns. The technologies included in membrane filtration are:

Reverse Osmosis

The closest of these molecular-level separations is *reverse osmosis* (RO), sometimes known as hyperfiltration. The ability of RO membranes to reject sodium chloride (NaCl) under specific pressure, temperature, and concentration circumstances serves as its defining characteristic. In reverse osmosis, the driving

force for water molecules to diffuse into and across the membrane is provided by hydraulic force, which is delivered more than a solution's natural osmotic pressure. The usual operating pressure might range from a few hundred to as much as a thousand pounds per square inch (25 to 68 bars). Rejection percentages typically range from 98 to 99.5%.

Nanofiltration

The next, more open cross-flow membrane filtration type is called *nanofiltration* (NF). NF membranes are generally characterized by their ability to retain a divalent ionic species, often magnesium sulfate (MgSO₄) or calcium chloride (CaCl₂). Monovalent ions will typically permeate (pass through) the membrane in solutions of mixed ionic species, whereas divalent or multivalent species would typically be strongly rejected at the membrane interface.

Ultrafiltration

With ultrafiltration (UF), the membrane comprises a discrete porous network. Smaller molecules pass through the membrane's pores, while larger molecules are trapped as a mixed solute solution is pumped. The open membrane construction further decreases operating pressure, which makes mass transfer more flow dependent than pressure dependent.

Microfiltration

Finally, microfiltration (MF) describes the coarsest filtration in the cross-flow membrane filtration range. Membrane porosity is conventionally depicted as a distance measure generally from a fraction of a micron up to a micron (10⁻⁶ m) or so. The separation of exceedingly massive or complex molecular structures into large and small molecules is thus possible.

Optimization Subtraction Ratios

Isolating certain bioactive sub-fraction proteins from whey proteins on a big scale, such as lactoferrin or Glycomacro peptide, using some of the processing methods mentioned above. This was not possible on a large scale just a few years ago but can be done today with modern filtering techniques employed by a few companies.

As a result, it is possible to add back in specific sub-fractions in amounts that aren't present in nature, creating a truly tailored customized protein supplement. The best whey products will have a lactoferrin content of 0.5% to 1%, a rare but crucial micro-fraction. Some companies can add a specific subfraction to get a truly "designer" protein. A company is also working on making higher levels of the beneficial subfraction alpha-lactalbumin and lower concentrations of the less nutritious and more allergic subfraction beta-lactoglobulin. Large-scale manufacture of "high alpha-lac" whey isolates could be superior to what is currently available.

5.2 Different Whey Types

Various varieties of whey products will have multiple functional qualities and applications depending on the techniques employed in their manufacturing.

Whey protein concentrates (WPC)

First-generation whey protein powders contain as low as 30–40% protein and large levels of lactose, fat, and undenatured proteins. They are categorized as a "whey concentrate" and mainly used by the food industry for baking and as a partial nonfat milk replacer for sports nutrition, meal replacement products, infant food, processed foods, processed cheese, meat or fish products, and other uses. WPC34% enhances yogurt's nutritional value and texture while enhancing the texture of low-fat recipes. Concentrates today have a higher percentage of protein—70–80%—and less lactose. This is accomplished using ultra-filtration processing, eliminating lactose and increasing the end product's protein and fat concentrations. When WPC 80% is utilized as an ingredient, nutritious drinks, meal bars, supplements, infant foods, processed cheese, meat or fish products, and feed rations are nutritionally improved.

Instantized WPC80%

May be quickly dissolved in liquids with hand stirring or shanking, unlike high protein powders that require an electric blender to dissolve. Application ideas include infant foods, food bars, supplements, and nutritional drinks. While normal WPC80% are both appropriate in many applications, modern technology enables this protein to have increased functional capabilities that offer certain performance qualities. To select the ideal ingredient for the application, look at the entire variety of functional proteins. Whey protein concentrate is used in the bakery industry, such as in bread, which improves the overall flavor profile and aids in the bread's ability to reach standard loaf volume when heated.

Whey Protein Isolates (WPIs)

WPIs typically have a protein content of 90–96%. WPIs have a protein concentration of over 90%, little to no lactose, and almost no fat. Only whey proteins in their undamaged natural condition, or native conformational state, have been discovered to have biological action. The company takes extra care while processing whey protein to eliminate lactose, lipids, etc., without losing its biological activity. The protein needs to remain in its naturally undenatured state for it to continue to have its immune-suppressing and anti-cancer effects. To prevent "denaturant," the protein must be treated at low temperatures and/or with little acid.

Bioactive whey fraction protein (BAWF)

A new generation of whey products known as bioactive whey Fraction protein soon hit the marketplace and has the potential to be a worthwhile addition to an athlete's diet. This novel product comprises a wide range

of intriguing substances that are not present in appreciable proportions in either whey isolates or concentrates. These new BAWF proteins offer the advantages of a high protein level (>70%) and significantly higher quantities of bioactive chemicals promoting health. BAWF protein has significantly greater total growth factors, including IGF-1, TGF- β 1, and TGF- β 2 molecules. It also has a much higher level of various phospholipids and bioactive lipids such as *conjugated linoleic acid* (CLA), phosphatidyl-serine, phosphatidyl-choline, sphingomyelin and a higher level of immunoglobulins and lactoferrin.

Despite the absence of information, studies will probably be finished to show how BAWF protein affects athletes' muscle mass or performance. Recent research indicates that these substances may enhance gut health and immunity, among other benefits that athletes and less active people may find useful. The amounts of these components in this BAWF protein differ significantly from those in typical concentrates and isolates. A BAWF protein, for instance, has 350% more lactoferrin, 400% more CLA, 200% more PS and PC, and 150% more IGF than is present in a conventional concentrate (such as WPC80).

Microparticulate whey proteins

Can be utilized as a fat substitute in dairy products such as cheese, desserts, yogurt, and ice cream since they behave like fats and have a similar texture. Microparticulate proteins, for instance, significantly enhance the texture and flavor of low-fat cheese. The use of microparticulate proteins is predicted to significantly extend the low-fat dairy product market and lower the price of conventional cheeses.

5.3 Functional Properties of Whey

All of the whey protein is completely soluble in its natural form. The environment around the whey protein changes throughout processing. These processing factors, such as heat, pH, ionic strength, etc.,

can alter the protein's conformations or shape, denaturing or altering the whey protein to varying degrees. Whey proteins in their original condition behave differently from those that have been denatured. The ability of the substances to gel, bind water, thicken, foam, emulsify, form films, etc., is one way the differences can be seen. Depending on the application, it may be feasible to use these functional qualities by carefully regulating the whey proteins' alteration, a process known as "controlled denaturation." Whey protein's characteristics, particularly those related to rheology and flavor, can be improved through controlled denaturation in various applications.

Solubility

Whey proteins are entirely soluble in their natural state. Over a pH range of 2.0 to 9.0, whey is completely soluble. Protein solubility is essential for the creation of beverage applications.

Gelation

Gelation happens when heat-induced denaturant (unfolding) of native, globular whey proteins causes gelation. The aggregated, three-dimensional matrices created by the denatured protein capture and contain water. Protein composition, degree of denaturation, pH temperature of heat treatment, protein concentration, heating rate, ionic strength, and the presence of certain ions are only a few variables that affect heat-induced gelation. The main component of whey protein that gels, and a significant amount of its composition, is beta-lacto globulin.

Foaming

Whey protein has two functions in forming foams, one of which is the production of foams. Whey has superior foaming properties (foam overrun and foam stability). It functions as a surfactant to ease pressure at the air/liquid interface, and it creates a continuous cohesive layer at the contact that keeps foam bubbles stable.

Table 1: Functional properties of whey in the food industry

Functional property	Mode of action	Food system
Whipping/foaming	Forms stable film	Eggless cakes, desserts, whipped topping
Emulsification	Formation & stabilization of fat emulsion	Vegetable sausages, salad dressings, coffee whiteners soups, cakes, biscuits, infant food formulas
Gelation	Pr. Matrix formation & setting	Meats, baked goods, cheeses
Viscosity	Thickening/ water binding	Soups, gravies, salad dressings
water binding	Hydrogen binding of water entrapment of water	Meats, sausages, cakes, bread
Solubility	Protein, solubility	Beverages
browning	Undergoes Millard reaction	Bread, biscuits, confectionary, sauces
Flavor/aroma	Lactose reacts with milk proteins	Baked goods, biscuits, confectionery, sauces, Soups, dairy products

5.4 Application

Since many years ago, proteins have been utilized in various food products because of their useful

qualities and high nutritional worth. Worldwide food producers now have new options thanks to the discovery of microparticulate. There are multiple uses for whey

products. Whey is used in pet food, feed for livestock, pigs, and poultry, and milk substitutes for calf calves. Additionally, whey and its derivatives are utilized in several other foods, such as dairy products, baked goods, candies, snack foods, dry mixes, processed meats, newborn formulae, nutritional drinks, and a wide range of other dried, frozen, and prepared foods. Food producers respect the varied functional and nutritional qualities that whey products offer. Whey, for instance, can be used to replace the fat in low-fat dairy products. It enhances the characteristics of malting, spreading, and slicing in processed cheeses. Whey improves the flavor and color of the crust in baked items. It increases moisture retention in processed meats. High-quality protein, calcium, and vitamins are provided by whey, which can be used to boost the nutritional value of many dishes. Whey encourages the formation of good bacteria in the digestive tract and makes the newborn formula resemble human milk.

Food products can contain whey, powder, WPC, or other modified whey products. The manufacturer's requirements determine the kind of whey product used in these foods. Whey powder and lower protein-level WPCs, like WPC -34, are typically used in lower-priced foods like dairy and baked goods, whereas higher concentrated WPCs, like WPC -80, are typically used in higher-priced foods like meat and seafood. Whey products are being used more frequently to make medicines and nutraceuticals. According to studies, whey components may help prevent or treat various illnesses, including cancer, HIV, hypertension, and osteoporosis.

Additionally, it demonstrated the antibacterial and cavity-inhibiting properties of whey components. The more specialized whey proteins and fractions used in pharmaceuticals are extremely valuable and can occasionally sell for more than \$100/kg. Whey proteins from cow's milk are categorized as concentrates (protein concentration between 25 and 80%) or isolates. They are used as emulsifiers in a wide variety of food products, including ice cream, drinks, salad dressing, and sports supplements (more than 90 per cent protein). Recent research on whey and lactose ingredients from Danish 3A (2007) business consulting reveals that food manufacturers increasingly see whey and lactose products as the best way to add value.

Under the direction of professor Julian McClements (2006), researchers from the University of Massachusetts hypothesized that higher high molecular weight protein concentrations enhance emulsion stability. WPC is a natural emulsifier for numerous culinary items, including ice cream and frozen desserts. The increased resilience of the MWPC to higher salt concentrations and heat processing may be explained by the emulsion's better stability. The outcome may have significant effects on the food sector since it will make it possible for food formulators to create stable emulsions

with improved nutritional functionality. It increases the flavor and color of the crust in pastry goods, especially in biscuits. It is also employed as a suitable replacement for pricey food items such as SMP, eggs, etc. It provides high-quality protein, calcium, and vitamins in nutritious products. WPC is frequently utilized in the creation of food concentrates, ice cream, yogurt, drinks, and meat, as well as dry mix formulations for underweight newborns and ready-to-drink beverages. Whey proteins in processed meats boost moisture retention, extending the shelf life of meat products such as sausages, and ham. Due to its great nutritional content, whey is often utilized as a fortification and flavoring agent in nutrition bars, sports supplements, and many other nutritional products. Whey is essentially a dairy product that can be utilized in low-fat products in place of fat. Additionally, it improves processed cheese's slicing, spreading, and melting qualities. Finally, whey products are frequently used in dietetic products, including lactose-free, reduced-carbohydrate, low-fat, and low-calorie items. Recently, WPC has also been employed in manufacturing biological products in biotechnology as a suitable environment for the growth of microorganisms.

6. SUMMARY AND CONCLUSIONS

There are several interesting directions in developing and processing the next generation of whey proteins. The membrane filtration technology is used for concentration, purification, separation, clarification, and filtration. Reverse osmosis, microfiltration, ultrafiltration, nanofiltration, and other techniques enable it to produce products with unique properties and functionalities. Cross-flow membrane filtering has enabled various new and innovative dairy products. Milk protein can be hydrolyzed (i.e., fragmented) using proteolytic enzymes to enhance functional and nutritional properties. There is an increasing demand for hydrolyzed protein ingredients with specific properties for the nutrition of individuals with specialized dietary requirements, including infants, the critically ill, the immune-compromised, and athletes. Such a hydrolyzed protein can be specially created to offer unique, custom solutions to satisfy consumer needs. We could conclude that WPC and other whey product components are known as adaptable dairy proteins in cost-effective forms. They are excellent ingredients for a wide range of food applications, including bakery products, beverages, dry mixes, infant formula, frozen desserts and ice cream, nutrition bars, dairy products, nutritional supplements, lactose-free products, and products with lower carbohydrate, fat, and calorie content. However, the most practical and affordable ways to use whey are as animal feed (for calves, cattle, poultry, and pets) and in a variety of whey beverages, including fermented whey drinks and yogurt-style beverages made with lactobacillus strains, lactic beverages made with probiotic cultures, and soft drinks.

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