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The importance and benefits of whey

Diana Raveca (Balțatu) Fluerașu*, Ersilia Alexa

Faculty of Food Engineering, University of Life Sciences "King Mihai I" from Timisoara, Calea Aradului No. 119, 300645 Timisoara, Romania

**Corresponding author: dianabaltatu93@gmail.com*

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Abstract

The food industry is constantly in search of innovative new products to meet consumer needs and expectations. For many years, there has been a tendency in the food processing industry to use substitutes of ingredients in recipes of many products. There is an increasing trend towards the functional foods, as a result of consumer awareness and interest in nutritious and healthy foods, as example whey protein.

This review aims to analyze the possibilities of capitalizing the whey resulting as a by-product in the dairy industry, in different constituent forms (protein isolate, protein concentrate and hydrolyzed), as functional supplements.

Keywords: *whey, whey powder, bakery, concentrate, isolate, hydrolisate*

1. Whey composition & methods employed for its utilization

Global whey production is estimated at around 200 million tonnes per year, with Europe accounting for around 40 million tonnes. More specifically, 400 thousand tons of the most valuable milk protein and 1.6 million tons of milk sugar are lost per year. Thus, approximately 80–90 litres of whey are obtained from 100 litres of milk used in cheese production. Depending on the type of cheese produced, the average yield is 1 kg from 10 litres of milk, with the remaining 9 litres being whey [1, 2, 3].

Whey is the yellow-green, watery part of milk (the serum) that remains after the curd has been separated during the production of cheese. It accounts for 85–90% of milk's volume and contains 55% of its nutrients. The average composition of whey residue is 70% lactose (depending on the whey's acidity), 14% protein, 9% minerals, 4% fat and 3% lactic acid. Based on the method of milk protein coagulation, whey is classified into two categories: *sour* and *sweet* [4].

Sour whey, with a pH < 5, is a by-product of fermentation or of processes involving the addition of organic or mineral acids to coagulate casein, e.g. in the production of fresh cheese or industrial casein.

Sweet whey, with a pH of 6–7, is derived from the production of cheese or certain casein products where processing is based on coagulating casein with rennet, an industrial coagulant containing chymosin or other proteolytic enzymes [5].

Whey is highly nutritious and easily digestible and assimilable. It is also considered an excellent source of functional proteins, as well as being rich in vitamins B and minerals such as calcium (Ca), phosphorus (P), sodium (Na), potassium (K), chloride (Cl), iron (Fe), copper (Cu), zinc (Zn) and magnesium (Mg), and lactose [6,7].

Due to the excellent nutritional and functional properties of whey solids, a large proportion of whey is processed into powders, while the rest is used to produce sweet whey powder, demineralised whey, delactosed whey, whey protein concentrate (WPC) and whey protein isolate (WPI), or lactose [8].

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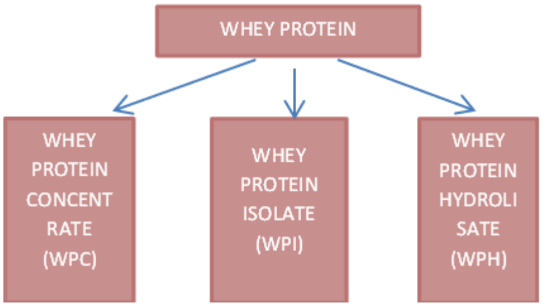

Figure 1. Classification of whey proteins [9]

Like we see in figure 1, whey proteins can be classified into different types according to the amount of protein such as whey protein concentrate (WPC), whey protein isolate (WPI) and whey protein hydrolysate (WPH).
WPC is the first level of refined whey proteins and classified into higher end concentrate (70-90%) and lower end concentrate (20 - 30%) whey protein. WPI contains 90% of protein with low fat and lactose. WPH is the purest form of whey protein [10].
Whey is a fairly dilute product with a total solids of about 6,5%, the solids are basically consisted by lactose, whey protein, ash, lactic acid and fat (Table 1).

Table 1. *The whey composition* [11]

Constituent	Unit	Acid whey	Sour whey
Water	%	93-94	94-95
Dry matter	%	6-6,5	5-6
Lactose	%	4,5-5	3,8-4,3
Lactic acid	%	traces	Up to 0,8
Total protein	%	0,8-1	0,8-1
Whey protein	%	0,6-0,65	0,6-0,65
Citric acid	%	0,1	0,1
Minerals	%	0,5-0,7	0,5-0,7
pH		6,4-6,2	5,0-4,6
SH Value		About 4	20-25

Production of Whey powders

Whey drying is the simplest operation used in whey utilization. Whey powder is a dry milk product produced by thickening and then drying whey. The efficiency of the drying process increases significantly with a minimum content of lactic acid and amorphous lactose in the serum [12,13,14].
Baromembrane technologies, including ultra-filtration, electrodialysis, nanofiltration and reverse osmosis, are currently widely used to solve many practical whey processing problems [15,16].
It has been concluded that processing whey at high temperatures negatively affects protein quality compared to filtration, after which the products can be used in infant formula. Interestingly, ultrasound treatment can alter the functional characteristics of whey proteins [17,18,19].
Whey proteins are not only used for basic products, but also to produce highly nutritious and functional products, thereby improving the taste, color, and texture of the final product and contributing to an increase in its shelf life [20,21].
Serum-based proteins exhibit emulsifying, foaming, and gelling properties. Nevertheless, their functional properties strongly depend on acidity. However, there are studies in which serum-based protein performance was improved through the interaction of polyphenols through covalent and non-covalent bonds [22, 23].
There are also studies in which whey proteins have been used as a substitute for wheat flour containing gluten. For instance, Ammar et al. (2021) used a whey protein concentrate from two-layer rice and corn flour to produce gluten-free sponge cakes. The results of the experiment proved that the selected ingredients for making cakes could replace wheat flour. Moreover, using whey proteins, it is possible to enrich bakery products. An increase in nutritional value may occur by including high-protein ingredients such as whet proteins. However, if the protein content reaches 5% after further addition, a bitter taste is observed because of the presence of small peptides, ferulic acid, and tannins. In addition, the use of the constituent elements of whey in the production of functional foods has significantly positive effects on the quality of products and human health. For instance, emulsification of squalene into chitosan-whey protein and its further encapsulation showed better results in terms of oxidative stability when added to a bakery product (cake) [24, 25, 26].

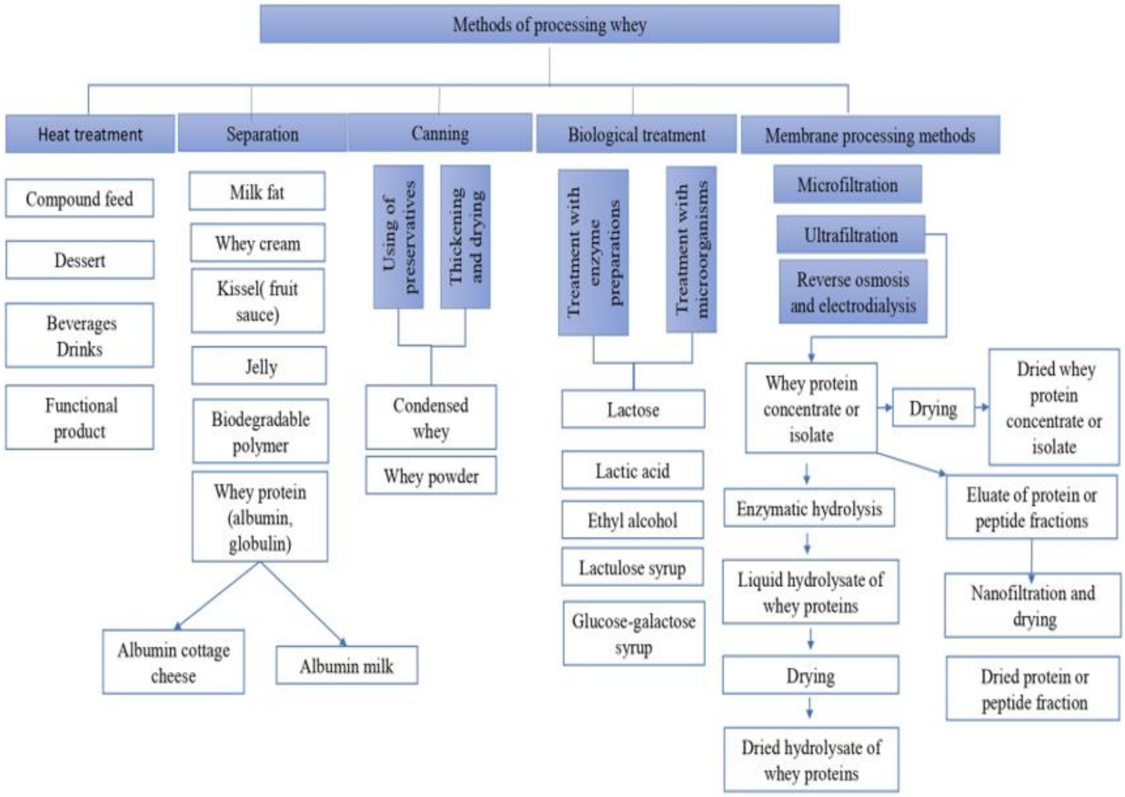

Figure 2. Methods of whey processing and their final products [9].

Peptides obtained from whey proteins

The proteins present in whey and whey protein concentrates have valuable biological properties. The amino acid composition of β-Lg and α-La is very similar to that of human muscle tissue. In terms of essential amino acid (lysine, tryptophan, methionine and threonine) and branched-chain amino acid (valine, leucine and isoleucine) content, they surpass all other animal- and plant-based proteins [27,28].

Enzymatic hydrolysis, the process of splitting proteins into peptides and amino acids, is performed using proteolytic enzymes. Serum lactose can be broken down through fermentation, which helps simplify the transformation of lipids and fats during anaerobic fermentation, with the aid of a specific enzyme β-galactosidase obtained from the fungus Aspergillus oryzae [29].

In addition to its nutritional value, whey protein has been shown to possess many health-promoting functions, and both the major whey proteins (α-La, β-Lg) and the minor components (eg LF (lactoferrin), IGs (immunoglobulins)) demonstrate such functionalities . Serum albumin can bind fatty acids and immunoglobulins, such as IgA, IgM, IgG1, and IgG2, which helps develop passive immunity in consumers [30,31].

Various types of acids obtained from whey

Whey is a universal medium used for lactic acid cultivation. Numerous microbial cultures have been used for lactic acid fermentation. To reduce the cost of lactic acid production, it is necessary to choose suitable pretreatment methods for the successful hydrolysis of lactose [32].

Lactic acid production involves the preparation of mash and starter cultures, fermentation of whey with lactic acid bacteria, neutralization, decomposition of calcium lactate, purification and filtration of sludge, and decantation of whey [33].

Lactic acid, which is a permitted food additive, is used as an acidity regulator in the production of processed fruits and vegetables, beer, soft drinks, bakery products, leather, and perfume because of its high diffusion properties and strong antimicrobial action. Bacteriocins, lactic acid bacteria, are antimicrobial peptides produced by ribosomes and are used to improve the safety and quality of dairy products [34].

One of the representative acids obtained from whey is a biogenic substance called gamma-aminobutyric acid (GABA), which is effective in the treatment of neurological disorders and is useful for reducing the growth of cancer cells. The combination of whey and sodium glutamate can be used as a cost-effective feedstock to produce a valuable bioactive GABA product [35].

Fermentation is the main method used to obtain lactic acid. By applying suitable pretreatment methods, it is possible to obtain a wide range of fatty acid from whey, which have a positive effect on the human body.

Animal feed based on whey

Whey, which is a highly nutritious source, can also be used as animal feed. Nevertheless, because it contains a large amount of lactose and minerals, its use in poultry feed is limited. A small amount of whey up to 2% in the diet of broiler chicks improves their health, including the health of the gastrointestinal tract, but an increase in the proportion of serum has a detrimental effect on the state of the bone system of broiler chicks. Whey is also mainly used in the diet of pets to increase their weight and height. Experiments on rats have shown the effects of whey protein and soy protein on rat growth rates. Whey-based proteins have been found to have a better effect on insulin-like growth factor (IGF)-I in rats [36,37].

The use of whey as a substrate for the fermentation of animal feed additives is also common. interest in probiotics in animal feed is growing every day as they can replace antibiotics as well as for the prevention of certain diseases in animals, such as gastrointestinal pathology and dysbiosis [38,39,40].

Whey is a full-fledged raw material for feed products with proven positive effects on the animal body. The addition of whey-based feed to the diet of animals can improve their growth rates, reduce diseases, and increase output weight.

Biodegradable polymers from whey

Every minute, plastic garbage, with a volume of one garbage truck, is thrown into the ocean. Plastic pollution is a global health concern. The best solution to this problem is to produce biodegradable polymers from whey. Whey protein is one of the most promising biopolymers, with characteristics such as biodegradability, and is an eco-friendly alternative to synthetic polymers. A whey protein-based film is a polymer mesh with a three-dimensional gel-like structure. Compared with other protein polymers, whey protein-based films have high mechanical and barrier properties, as well as odorlessness, transparency, and elasticity, which are very important parameters in the manufacture of food packaging [41,42].

Two methods are used to produce biofilms from whey proteins, dry and wet. The wet manufacturing method is solvent casting, which is ideal for coating, as well as for producing thin films. In the initial stage, whey proteins are dissolved in water using solvents in the form of alcohols. Plasticizers, polysaccharides, lipids, and emulsifiers were added to strengthen the film. Finally, they were dried under ambient conditions at a temperature of 21–23°C and relative humidity of 50%, and the final product was obtained. However, the dry method is more often used for obtaining biofilms based on extrusion. The dry production process of biodegradable polymers based on milk protein consists of four stages. Despite the fact that whey protein-based films have high strength at low ambient humidity compared with synthetic polymers, they have lower moisture-proof properties. To solve this problem, hydrophobic substances such as lipids are added to improve the structural, optical, and tensile properties of biofilms. In a recent study, nanoparticles of sodium montmorillonite (MMT) were used, and the antioxidant activity of rosemary essential oil (EO) increased the plasticity of a film made of whey [43].

Functional beverages based on whey

Special attention has been paid to whey drinks in functional nutrition. In terms of the qualitative composition and quantity of mineral compounds, whey is more useful for traditional drinks and is similar to mineral water. Currently, various non-alcoholic and alcoholic beverages based on whey are widely used. They have a pleasant taste and useful properties, such as being a good source of energy and ease of preparation [44].

Whey-based drinks are categorized into four groups based on preparation methods and added ingredients:

1. Whey and juice mixtures (eg fruit or vegetable juices)
2. Fermented or unfermented milk drinks (eg kefir or unfermented whey)
3. Carbonated drinks (eg carbonated whey)
4. Alcoholic beverages (eg whey-based drinks with added alcohol) [45,46].

Table 1. *Overview of beverages based on whey and juices (fruit and vegetable).* [9]

Juice name	Mixing ratio (whey:juice)	Adding bacterial culture	Name of the drink	Storage period
Pineapple juice	30:70	-	Pineapple drink based on whey	20 days at cooling temperature
Orange juice	3:2	-	Functional drink	Up to 11 days at room temperature and up to 3 months in the refrigerator
Papaya pulp with water	25:75	-	Papaya RTS beverage	30 days at cooling temperature
Watermelon juice	75:25	*Lactobacillus acidophilus* NIAI L-54 (1%)	Fermented beverage	21 days in refrigerated conditions (4°C)
Costa rican guava fruit pulp (CRG)	50:50	*Lactobacillus rhamnosus* GG (LGG)	Probiotic drink based on whey containing CRG pulp	40 days at cooling temperature
Mango	60:20, 65:15	-	Mixed beverage	Up to 15 days in cooling conditions
Black mulberry juice	25:75	*L. rhamnosus* and Bifidobacterium animalis spp. lactis Bb-12	Probiotic whey beverage	In the refrigerator for 21 days
Aqueous extract of beet peel and strawberry puree	5:2, 5:5	*Staphylococcus aureus* nCtC 10788) and two gram-negative strains (*Escherichia coli* BA 12296 and *Salmonella Senftenebera* ATCC 8400)		Up to 14 days in cooling conditions (4±1°C)
Beetroot and carrot (1:1); tulsi leaf extract; sugar		-	Herbal whey beverage	up to 14 days in cooling conditions (4±1°C)

Conclusion

Due to the continuous increase in demand for cheese production, particularly cottage cheese, the volume of by-products to be processed has increased, particularly whey. However, the complex chemical and biological composition of whey, coupled with the outdated and inefficient technologies employed by many enterprises, hinders its effective processing for food purposes. As whey contains approximately 0.6% whey proteins consisting of β-Lg and α-La, it is a valuable raw material for reuse in producing food, beverages, bioplastics and so on. One of the most notable whey-based products is dry protein powder, which is now being used not only in basic products, but also in the production of highly nutritious and functional products such as production peptides, animal feed and various types of beverages. It is also used in acid production, in production bioplastics. Enzymatic hydrolysis of whey proteins using proteolytic enzymes yields peptides and amino acids superior to those found in other animal- or plant-based proteins.

Whey-based lactic acids are used as acidity regulators in the production of fruit and vegetable processing products, beer, soft drinks, bakery products, leather and perfumery because of their high diffusion properties and strong antimicrobial action.

Whey-based beverages surpass traditional drinks as their composition is very similar to mineral waters and they have a therapeutic effect on humans and animals. A wide range of beverages are being developed using whey as a feedstock, from simple fruit and vegetable drinks to carbonated, probiotic and fermented beverages. Whey-based products can also be used to feed animals, fish and birds. However, further research is needed as whey-based products contain large amounts of lactose and minerals, which can negatively affect animals. One non-food use of whey is to produce biopolymers and bioplastics, which offer a solution to environmental catastrophes that negatively impact wildlife and habitats. In terms of mechanical and barrier characteristics, bioplastics are not inferior to artificial polymer materials. They have no unpleasant odour and are transparent and elastic. In summary, processing and recycling whey to produce functional foods, beverages, animal feed and other useful products for humans and the environment is a valuable alternative to disposing of whey after dairy production.

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