

Functional Properties and Nutritional Quality of Whey Proteins

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Abstract: Whey proteins are one of the main groups of the milk proteins obtained mainly from the cheese manufacture and used for various applications in food industry due to high nutritional value and valuable functional properties. β -lactoglobulin and α -lactalbumin are globular proteins and formed the great part of proteins present in the whey. Considering whey proteins in food industry can reduce environmental pollution and lead to processing functional foods with high nutritional value. In addition to using as the common protein source for supplementation in food industry, whey proteins are used in sports and medical formulations. They are used for manufacturing of new products for physically active people and sportsmen based on their nutritional and functional properties. In this context, protein digestibility, amino acid composition, bioavailability of essential amino acids and physiological utilization of specific amino acids after digestion and absorption are the parameters that influence the nutritional quality of whey protein supplements. Whey proteins can be recovered from the milk in various forms consisting of whey protein concentrate, whey protein isolate and whey protein hydrolysate for different commercial proposes using the methods such as thermal evaporation or filtration. Whey protein concentrate is mainly used in food industry or as a health or sport supplement, while whey protein hydrolysate used for pediatric formulas. In this review, various functions of different forms of whey proteins in food industry and health section have been considered.

Keywords: *Whey, whey proteins, functional properties, nutritional quality, cheese manufacture*

Introduction

The whey proteins are obtained from whey, a yellow/green liquid protein remaining after coagulation and separation of caseins from the milk by enzyme (chymosin) or acid (mineral/organic) during the cheese-making process (Smithers, 2008). Lactose along with soluble proteins and minerals are the main fractions of solids in whey. The total amount of whey production in the worldwide is estimated about 190 million tons/year. Environmental and health issues related to high amount of BOD and COD are the major problem of whey removed from cheese factories as wastewater. It was reported that whey removed to the farmlands affected the physicochemical properties of soil and led to decreasing in crop yields (Ghaly *et al.*, 2007; Yadav *et al.*, 2015).

Caseins and whey proteins are two major families of milk proteins that classified based on their solubility in pH 4.6 and exist in milk system in insoluble and soluble form, respectively. While the main fractions of caseins are α ₁-CN, α ₂-CN, β -CN and κ -CN, the most important whey proteins are β -lactoglobulin, α -lactalbumin, immunoglobulins, bovine serum albumin, bovine lactoferrin, lactoperoxidase, proteose-peptone and glycomacropeptide. The protein profile of whey is presented in Table 1. The glycomacropeptide is produced during the addition of chymosin to milk for cheese manufacture. Other whey proteins are naturally present in whey (Farrell *et al.*, 2004; Madureira *et al.*, 2007; Livney, 2010). β -lactoglobulin is a small globular protein and contains two disulfide bridges and a free thiole. α -lactalbumin is also a small globular metloprotein and contains four disulfide bridges and needs calcium for its functional fold. Bovine serum albumin is a large globular protein with a alpha-helical structure. This protein contains 17 disulfide bridges and a free thiol and found both in

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blood serum and in milk. Lactoferrin with antimicrobial activity is a globular glycoprotein and belongs to transferrin family (Livney, 2010).

Table 1. The protein profile of whey (Madureira *et al.*, 2007)

Protein	Concentration (g/L)	Molecular weight (kDa)	Number of amino acids residues
β-lactoglobulin	1.3	18277	162
α-lactalbumin	1.2	14175	123
Glycomacropeptide	1.2	6700	64
Immunoglobulins	0.7	Light chain: 25000 Heavy chain: 50000-70000	-
Bovine serum albumin	0.4	66267	582
Lactoferrin	0.1	80000	700
Lactoperoxidase	0.03	70000	612

Table 2 presents the composition of whey. The composition and quality characteristics of the whey and whey proteins are affected by some parameters such as the source of the milk, the type of feed provided for dairy animal, the stage of lactation and the processing method. However, the enzymes used for manufacturing of cheese and the type of cheese can be influenced the properties of the whey and categorized it into sweet and acidic whey. Sweet whey has 6.0 to 10 g/L and acidic whey has 6.0 to 8.0 g/L of whey proteins (Bozanic *et al.*, 2014; Yadav *et al.*, 2015; Ganju & Gogate, 2017).

Table 2. The composition of whey (Ganju & Gogate, 2017)

Constituent	Sweet whey	Acidic whey
Water	93-94 %	94-95 %
Dry matter	5-6 %	5-6 %
Lactose	4.5-5.0 %	3.8-4.3 %
Lactic acid	Traces	Up to 0.8 %
Total protein	0.8-1.0 %	0.8-1.0 %
Whey protein	0.60-0.65 %	0.60-0.65 %
Citric acid	0.1 %	0.1 %
Minerals	0.5-0.7	0.5-0.7
pH	6.2-6.4	4.6-5.0

In following, common methods used for processing of whey into whey proteins and functional and nutritional properties of various forms of whey proteins are considered.

Processing of whey into whey proteins

High functional, nutritional and pharmaceutical values are caused to processing of whey in various forms (i.e. whey proteins) in order to respond to increasing demands of related industries (Korhonen, 2009). Valuable products are produced from application of different biotechnological and physicochemical processes in order to utilization of whey solids to industrial products (Prazeres *et al.*, 2002). Anaerobic and aerobic fermentation and aerobic digestion are common biotechnological processes applied to whey for biotransformation. On the other hand, coagulative precipitation, thermal precipitation and membrane separation are physicochemical methods used for manufacture of whey powders or whey concentrates. Among these methods, thermal treatment is commonly used for transfer of whey into various forms of whey powders such as whey protein concentrate, whey protein isolate and whey protein hydrolysate (Yadav *et al.*, 2015; Ganju & Gogate, 2017). Membrane filtration including ultrafiltration, microfiltration and nanofiltration can also be used for recovery of proteins from whey. It has been reported that high yield and purity can be obtained by using ultrafiltration for recovery of proteins from whey. Ultrafiltration with membranes containing different molecular weight cut-off can be applied for separating different proteins with different molecular weight from whey. Microfiltration is used for removing suspended fat and casein particles in order to prevention of fouling of the ultrafiltration membrane. Nanofiltration is also used for removing of ions and production of concentrate valuable products (Das *et al.*, 2016).

Functional and nutritional characteristics of whey proteins

Molecular structure of whey proteins contains a large number of α -helix motifs with acidic/basic or hydrophilic/hydrophobic amino acids. Whey proteins are important in formation of structures and immune system of the body. In this context, nutritional value and expanding role of whey proteins in human health are led to increased interest in using them in food and drug industries and resulted in production of novel products (Madureira, 2007; Livney, 2010).

The protein content is the main parameter which separates these forms of whey proteins so that whey protein isolate (WPI) has the highest content of protein (more than 90%) and slightly milky taste. Whey protein concentrate (WPC) is obtained with the removal of non-protein fractions from whey and commercially contains 34-80% of protein and has mild milky taste. According to US-FDA, the protein content of WPC should be not less than 25%. On the other hand, whey protein hydrolysate (WPH) has 70-80% of protein and also may contain anti-oxidative properties (Sinha *et al.*, 2007; Yadav *et al.*, 2015; Levin *et al.*, 2016).

Whey proteins are stable in milk in their native form. However, application of heat treatment above 60°C may cause to denaturation and aggregation of them through non-covalent thiol-disulfide interactions (Guyomarc'h *et al.*, 2015). Aggregated whey proteins have reverse functions during cheese and yoghurt manufacture. So that, during cheese making, the secondary phase of renneting are adversely affected by heat-treated and denatured whey proteins because of interaction between whey proteins and casein micelles. On contrast, heat-aggregated whey proteins may cause to finer, firmer and moisturized gel in the production of yogurt (Guyomarc'h, 2006; Anema *et al.*, 2007).

Several researches indicated that different forms of whey proteins have been used in various applications in food and pharmaceutical industries including modification of edible films (Galus & Kadzinska, 2016), making emulsions and nano-emulsions (Adjonu *et al.*, 2014), formulation of modern infant products (Smithers, 2015), manufacture of processed cheese (Solowiej *et al.*, 2014), restriction of diet-induced obesity and glucose intolerance and delay the beginning of diabetes mellitus (Gillespie *et al.*, 2015).

In terms of nutrition, the value of whey proteins is depended on several properties including amino acid composition, protein digestibility, bioavailability of essential amino acids and physicochemical changes of amino acids after digestion and absorption (Almeida *et al.*, 2015). Nutritional value of whey proteins is mostly due to high contents of sulfur-containing essential amino-acids. Leucine, isoleucine and valine are branched chain essential amino acids that have important roles in metabolism and hemostasis of blood glucose in the human body (Patel, 2015). Additionally, high solubility, water adsorption, gelatinization and emulsifying properties are important factors in order to considering whey proteins as a functional food composition (Baldasso *et al.*, 2011).

Whey proteins especially whey protein concentrate and whey protein hydrolysate can be considered as a health and sport supplement due to nutritionally amino acid composition and low allergenicity. In addition, the rapid digestion of these two proteins is caused to increase synthesis of skeletal muscle protein in athletes (Ha & Zemel, 2003; Dalziel *et al.*, 2016). Whey proteins are well and quickly utilized by the human body. The biological value (the percentage of given nutrients utilized by the body) of whey proteins is also higher than that of egg protein. So, Whey protein is a proper choice for body builders and those whose health is compromised (Smithers, 2008). Moreover, some new products such as carbonated beverage with whey protein and creatine and mixture of coconut water with whey protein have been recently developed as functional products for physically active people and sportsmen (Tomczynska-Melko *et al.*, 2015). On the other hand, it has been validated that various forms of whey proteins have some biological roles i.e. anti-oxidant, anti-cancer, anti-obesity, lowering blood pressure and therapy of phenylketonuria (Patel *et al.*, 2015). In this context, anti-obesity role of α -lactalbumin and lactoferrin (Shi *et al.*, 2012), anti-cancer role of whey protein hydrolysate and lactoferrin (Ataallah *et al.*, 2012; Alexander *et al.*, 2014) and lowering hypertension property of whey peptides originated from β -lactoglobulin (Korhonen, 2009; Ballard *et al.*, 2013) has been reported in previous researches.

Conclusion

Whey is the main by-product of the cheese industry that has potential biological and environmental hazards. However, significant functional and nutritional value is resulted in using whey in various aspects of food industry and health section. Obtaining of whey solids i.e. whey proteins from whey is

performed using biotechnological and physicochemical processes. Heat treatment and membrane filtration are two major physicochemical methods for separating and manufacturing of whey proteins from whey. High contents of sulfur-containing essential amino-acids, high solubility, water adsorption, gelatinization and emulsifying characteristics of whey proteins are caused to introduce them as a food supplement with high nutritional and functional properties. Additionally, health related characteristics of whey proteins such as antioxidant, anticancer, anti-obesity and lowering blood pressure have been thoroughly proven. In conclusion, it is necessary to use proper methods for recovery of whey proteins from whey and using them in order to production of cost-effective whey protein-based products.

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