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Synthesis and functionality of proteinacious nutraceuticals from casein whey—A clean and safe route of valorization of dairy waste

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ABSTRACT

Due to stricter environmental legislation, coagulation and precipitation technologies have been practiced for whey protein sedimentation from a long prior. Nowadays, in pharmaceutical and dairy industries, individual whey proteins have been isolated by size-exclusion membrane separation technology, ion-exchange membrane chromatography, gel-permeation chromatography, affinity-peptide ligand chromatography and electro-chromatography. Furthermore, whey protein-derived peptides have been synthesized by conventional batch or catalyst-immobilized packed-bed bioreactors or membrane-assigned bioreactor with high throughput and purity, considering raw whey or isolated individual protein as feedstock. Different types of enzymes, such as trypsin, chymotrypsin, alcalase, pepsin and chymosin, have been popularly used for enzymatic hydrolysis of whey proteins. Whey proteins, such as β-lactoglobulin, α-lactalbumin, bovine serum albumin, lactoperoxidase, lactoferrin and immunoglobulins, and enzymatic hydrolysis of whey proteins have their unique physiological, medicinal, functional and nutritional values. It could be expected that without going for mere treatment of whey (coagulation or sedimentation of whole protein), synthesis of proteinacious bioactives (separation of individual whey proteins and synthesis of their derivatives) will lead to zero effluent discharge within a domain of whey upgradation. The present review pretends to highlight the different process-related technological aspects for the synthesis of different proteinacious bioactives from whey, as well as their functionality.

1. Introduction

The emergence of bioprocess engineering is a boon to the industrial biological research and academics, which possess a revolutionary challenge for the production of valuable biomolecules (Doran, 2012). Intellectual uprising of new visions and hopes by dispensation of any method of bioprocess, dealing with the design and development of equipment for the manufacturing of various products, such as food beverages, pharmaceuticals, semi-synthetic organs, etc., from biological sources are drawing a great attention (Shuler and Kargi, 2002). The development in the field of bioprocess also opens up the opportunity to use nutrient-rich waste streams, such as dairy, agricultural and cattle waste, for the production of useful biochemicals (Illanes, 2011; Prazeres et al., 2012).

Dairy industry, a major economical resource of tropical and subtropical countries, is generating a large volume of waste liquid effluent, namely whey (Siso, 1996). Fig. 1 shows

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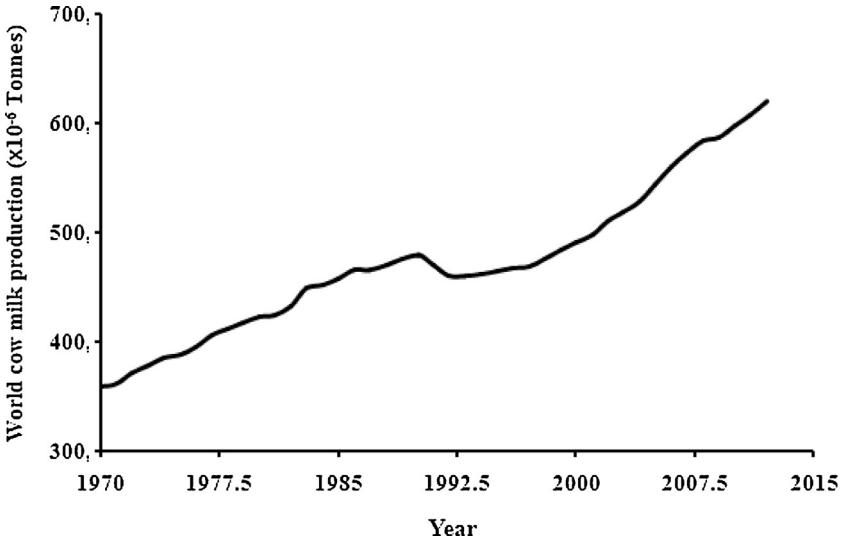

Fig. 1 – Production pattern of cow milk around worldwide over 2004–2011.

the production pattern of cow milk around worldwide during 2004–2011, which represents its increasing trend (dairyco.org). Whey or milk serum is the liquid, remaining after the production of cheese or the removal of fat and casein (80% of the proteins) from milk. It is a by-product after the milk has been curdled and strained. Sweet whey is produced during the manufacturing of rennet types of hard cheese, like, cheddar or swiss cheese. Acid whey, also known as 'sour whey', is produced during the making of acidic dairy products, such as cottage cheese or strained yogurt, and considered as a liquid by-product of dairy industry. Casein and caseinates are produced by acidification of skim milk by either a culture of lactic bacteria at 298 K or by hydrochloric acid or sulfuric acid at 318 K. The casein will precipitate at around pH 4.6 and is separated from the remaining liquid by using centrifuges or decanters, followed by washing. The remaining liquid is known as acid or casein whey, which is available for further processing (Moulin and Galzy, 1984). Depending on the quality of milk, almost 10 kg of milk gives 1–2 kg of cheese and 8–9 kg of liquid whey. Therefore, it may say that the production of casein whey increases with the increase in production of dairy products.

From the knowledge of environmental stress, proper treatment of whey is extremely necessary. Whey is a potential contaminant with a BOD value between 30,000 and 50,000 ppm, representing about 0.2 kg of BOD per kg of cheese, and accordingly its direct disposal into water courses is forbidden (Prazeres et al., 2012; Siso, 1996). Chemical oxygen demand (COD) for whey lies between 60,000 and 80,000 ppm, implying that most of the oxygen demand corresponds to biodegradable organic matter, mainly proteins and lactose (Illanes, 2011). Since long preceding, coagulation and precipitation technologies have been popularly practiced for whey protein sedimentation. Meanwhile, many attempts have been taken on different approaches for consumption of whey, depicted as in Fig. 2. It is known that without going for mere treatment of whey (coagulation or sedimentation of whole protein) for lowering of BOD and COD values, production of proteinaceous nutraceuticals (individual whey proteins and their derivatives) through bioprocesses could be more ecofriendly in the context of whey upgradation (Illanes, 2011; Prazeres et al., 2012; Siso, 1996).

The present review pretends to highlight the different process related to technological aspects of different proteinaceous bioactivated nutraceuticals synthesis from whey within the policy of whey upgrading. Apart from lactose, proteins are the major bioactives in whey. In the present review, separation and purification of proteins from whey is discussed in a brief way. Subsequently, technological features of synthesis of bioactive peptide from whole or individual whey protein are described in detail. Furthermore, this review focuses on the functionality of synthesized proteinaceous bioactivated nutraceuticals (individual whey proteins and synthesized bioactive peptides). It is expected that this paper will appear a ready reference for further scientific research toward educational and industrial sector.

2. Synthesis of proteinaceous bioactive nutraceuticals from whey

Whey-derived proteinaceous bioactive nutraceuticals signify that different whey proteins which have their own physicochemical, nutritional and functional values. Moreover, enzymatic hydrolysis of whey proteins provides different bioactive peptides which have their unique property.

2.1. *Whey protein*

Whey is a heterogeneous mixture of different types of proteins such as immunoglobulins, α-lactalbumin, β-lactoglobulin, bovine serum albumin, lactoferrin and glycomacropeptides. The concentrations and characteristics of different whey proteins have been described in Table 1. Purification of different proteins from casein whey is expected to be useful both in dairy, food and pharmaceutical industries which may prove economical. Moreover, the process is also striking for the implementation of the concept of zero-effluent discharge with respect to dairy effluent (Prazeres et al., 2012; Siso, 1996). In dairy industry, concentrated protein has been obtained by two different processes (Fig. 3). First process involves the separation of lactose as a main constituent from whey, where protein is separated as a residual part. In another process, the protein is separated as a main constituent when lactose is retained as a residue.