Industrial applications of whey

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Abstract
Almost 85% of the entire milk utilized for manufacturing cheese/paneer is dismissing as whey. Most of the milk plants do not have a decent pretreatment practice for the jettisoning of whey and the discarding of whey. Whey deemed as the most significant pollutant of the dairy enterprise, not solely due to its high organic content but also owing to its lofty volume.

Whey protein-enriched method can develop for end groups such as infants, cardiac-risk group, and diabetics. Whey is assuredly an attractive growth medium for several kinds of microorganisms. The notable decline of BOD with the subsequent generation of valuable bio-products such as ethanol, bacteriocin and biogas has accomplished. Therefore, now whey is not a pollutant but a possible raw material for innovative products and processes.

Keywords: whey protein, lactalbumin, lactoglobulin, lactoferrin, antioxidant, antihypertensive, antidiabetic, antiviral, ethanol, bacteriocin, biogas

Introduction
Milk is a copious reservoir of protein with a crucial role in neonates and adults. Milk protein and bioactive peptides have health-enhancing traits. Almost 85% of the entire milk utilized for manufacturing cheese/paneer is dismissing as whey. Most of the milk plants do not have a decent pretreatment practice for the jettisoning of whey and the discarding of whey. It represents 85-90% of milk volume and comprise a vital loss of potential food and energy source as whey retains approximately 55% of the whole milk nutrients including, lactose, soluble proteins, lipids, and mineral salts, and so on (Siso, 1996; Smithers, 2008) [29, 30] which contributed to high biochemical oxygen demand. Whey deemed as the most significant pollutant of the dairy enterprise, not solely due to its high organic content but also owing to its lofty volume (Walzen et al., 2002) [36]. Nevertheless, the discernment of whey as a pollutant has transformed with the development of its utilitarian and bioactive attributes, being viewed as a supplementary commodity of cheese manufacture (Smithers, 2008) [30].

Antioxidant activity
Oxidation of food components is a pivotal phase in food decomposition. It is quite understood that lipid peroxidation of food commodities can generate decay in food quality, reduce the shelf life and minimize the acceptability of processed foods. Lipid peroxidation can produce free radicals that can begin the fatty acid disintegration, which may diminish the nutritional aspect and food safety by producing unpleasant flavors and toxic elements (Niki et al., 2005) [38]. Synthetic antioxidants render potent antioxidant activity against several oxidation systems. However, their use is restricted in some countries because of their marked toxic impact on individual physiology and metabolism (Okada and Okada, 1998) [22]. On the other hand, bioactive peptides are recognized as natural antioxidants and possess a vast interest because of their safety and distribution properties. Zhidong et al. (2013) [34] studied the antioxidant activity of whey protein isolate (WPI) hydrolysate and found that DPPH radical scavenging activity of hydrolysate was 31.48% and reducing power was 0.612 at 700 nm for enzyme to substrate ratio (E/S, w/w) of 2.22%, hydrolysis time 3.60 h at 45.70 °C temperature. Mann et al. (2015) [35] hydrolyzed the whey protein concentrate (WPC) with three different protease flavourzyme, alcalase and corolase and evaluated the antioxidant activity by using 2, 2-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) method. The Trolox equivalent antioxidant activity of all the hydrolysates i.e. flavourzyme (0.81±0.04), alcalase (1.16±0.05) and corolase (1.42±0.12) were higher than the WPC (0.19±0.01). Among these, whey protein hydrolysates prepared using corolase showed maximum antioxidant activity.
DPPH radical scavenging activity of fermented whey from cow and buffalo was 32.73% and 25.65% respectively (Vankudre et al., 2015) [35].

**Antihypertensive activity**

ACE is a peptidyl di-peptidase enzyme, cleaves the carboxyl terminal end of the substrate that may control a rise in blood pressure by switching angiotensin I to an active peptide hormone angiotensin II. This stimulates the release of aldosterone on one hand and inactivation of vasodilator, bradykinin on other hand, as a result of which sodium concentration becomes high and blood pressure goes up. ACE inhibitory peptides have gained significant recognition due to their inherent useful results in the treatment of hypertension. α-LA and β-LG hydrolysat reported possessing ACE-inhibitory properties (Tavares et al., 2011) [32]. Whey peptides obtained through fermentation with lactic acid bacteria like L. helveticus, L. lactis are immune to the digestive tract endopeptidases, accordingly, can be easily absorbed into the bloodstream (Saito et al., 2000) [28]. Peptidase fraction (142-148) obtained from β-lactoglobulin was the most potent ACE inhibitor (Mullally et al., 1997) [18]. Digestion of α-lactalbumin and β-lactoglobulin with trypsin showed potential to produce peptides with high ACE inhibitory activity (Pihlanto-Leppala et al., 2000) [25]. Ibrahim et al. (2017) [9] studied the ACE inhibitory activity of goat milk. Pepsin-digested goat casein and whey protein showed 95% inhibition at 40 μg/ml. Ibrahim et al. (2017) [9] identified PEQSLACQCL from β-lactoglobulin (residues 113-122), QSLVYPFTGPI from β-casein (residues 56-66) and ARHPPHFLSFM from κ-casein (residues 96-106), possessing ACE inhibitory property. Several ACE inhibitory peptides of α-lactalbumin fractions (50-52), (99-108), (104-108) and β-lactoglobulin fractions (22-25), (32-40), (81-83), (94-100), (106-111), (142-146) were identified (Pihlanto-Leppala et al., 2000) [25].

**Antidiabetic activity**

Diabetes mellitus is a metabolic ailment distinguished by reduced insulin secretion by β-cells and insulin resistance in tissues, a state that is connected with the development of various convolution, including hypertension and cardiovascular disease. According to the WHO global report on diabetes, the number of people affecting by diabetes has been quadrupled since 1980 to 422 million adults. The number of individuals affected ranges from 10% to 15% of the total population. The number of people suffering from diabetes increases worldwide. According to the WHO, the number of people affected by diabetes has increased from 100 million in 1984 to 422 million in 2014. Several approaches have been applied for the fermentation of whey to ethanol. In one method, the lactose is hydrolized with β-D-galactosidase and then fermented with non-lactose yeasts such as Saccharomyces cerevisiae (Bailey et al., 1982; O’Leary et al., 1977) [2, 23]. A modern alternative is to use recombinant yeast produced directly on cheese whey, allowing a high yield of ethanol. A mixture of acetone, butanol and ethanol can be obtained by fermentation of whey. K. fragilis is the yeast of choice for most commercial plants. K. fragilis converts 95% of the lactose of non-concentrated whey into ethanol with a conversion efficiency of 80%-85% of the theoretical value (Mawson, 1994) [17]. The effects of high concentrations of whey permeate on a lactose fermenting yeast, K. marxianus designated that the immobilized cells were more tolerant to high osmolalities if the osmolality was increased slowly over time (Dale, 1994) [3].

**Antiviral activity**

Bovine lactoferrin strongly repressed HIV-1 replication and syncytium formation and decreased HIV-1 DNA in the C8166 T cell line when added before the HIV infection or during the viral adsorption step. The mechanism of action may include inhibition of HIV binding to or entry into C8166 cells although a postadsorption effect cannot be eliminated (Ng et al., 2015; Puddu et al., 1998) [19, 21]. Methylated alpha-lactalbumin and methylated beta-lactoglobulin, and their hydrolysates weakened the infectivity of cytomegalovirus in MRC-5 fibroblasts (Chobert et al., 2007) [1]. The reaction of alpha-lactalbumin, beta-lactoglobulin, and lysozyme with the chemical modification agent 3-hydroxyphthalic anhydride yielded aggregates with antiviral activity toward HSV-1 before, during, or after infection (Oevermann et al., 2003) [21]. Lactoferrin and lactoferricin prevented the entrance of HSV into host cells (Jenssen 2005) [11]. Lactoferrin exercised its antiviral activity at an initial phase of HBV infection seemingly by communicating with host cell surface molecules. Lactoferrin exhibited antiviral action toward respiratory syncytial virus in vitro but not in an in vivo mouse model (Gualdi et al. 2013) [6]. Lu et al. (2013) [14] reported inhibitory activity of 3-hydroxyphthalic anhydride-modified bovine beta-lactoglobulin, against human papilloma viruses, including HPV6, HPV16, and HPV18.

**Ethanol production**

Whey is an exemplary material for ethanol production, because of its primary lactose content (Marwaha & Kennedy, 1984) [10]. Several approaches have been applied for the fermentation of whey to ethanol. In one method, the lactose is hydrolized with β-D-galactosidase and then fermented with non-lactose yeasts such as Saccharomyces cerevisiae (Bailey et al., 1982; O’Leary et al., 1977) [2, 23]. A modern alternative is to use recombinant yeast produced directly on cheese whey, allowing a high yield of ethanol. A mixture of acetone, butanol and ethanol can be obtained by fermentation of whey. K. fragilis is the yeast of choice for most commercial plants. K. fragilis converts 95% of the lactose of non-concentrated whey into ethanol with a conversion efficiency of 80%-85% of the theoretical value (Mawson, 1994) [17]. The effects of high concentrations of whey permeate on a lactose fermenting yeast, K. marxianus designated that the immobilized cells were more tolerant to high osmolalities if the osmolality was increased slowly over time (Dale, 1994) [3].

**Bacteriocin production**

Cladera-Olivera et al. (2004) [41] explained the process for the exploitation of whey for the generation of antibacterial substances. P. acidilactici NRRL B-5627 on whey produces...
pediocin (Guerra & Castro, 2003; Pérez Guerra et al., 2005) [7, 24]. The recombinant strains of Lc. lactis ssp. lactis, S. thermophilus and Enterococcus faecalis have been successfully used for the pediocin generation in skim milk and cheese whey (Somkuti & Steinberg, 2003) [51]. The results demonstrated the capacity of recombinant strains of LAB to produce pediocin in a variety of growth media including skim milk and inexpensive cheese whey-based media, requiring minimum nutritional supplementation. The immobilized Lc. lactis subsp. lactis ATCC 11454 has been exercised in a packed-bed bioreactor for the constant generation of nisin in laboratory media and whey permeate (Liu et al., 2005) [13].

Biogas production

Anaerobic digestion is widely used for the treatment of wastes with a high organic load can bring numerous environmental and economic gains, including the generation of energy in the form of electricity and heat (Amon et al., 2007) [1]. Methane is produced in an environment where oxygen, nitrate, and sulfate are not readily available, then CO2 is used as an electron acceptor. Anaerobic digestion happens in two steps. Firstly, the complex organic compound is converted into volatile acids by facultative and anaerobic bacteria, in the next step, the by products formed by the former, converted into methane and carbon dioxide by strictly anaerobic bacteria. Brazil uses livestock and agricultural wastes as raw materials for biogas production. Biogas can be employed in many different activities such as home heating, heating of animals, production of electricity, lighting, or sale of purified biogas as a vehicle fuel (Teghammar et al., 2014) [13]. Europe adopts anaerobic digestion of waste in biogas production and for the production of thermal energy. The principal substrates utilized are manure, grass or corn silage, and often organic industrial waste (Hjort-Gregersen et al., 2011) [9].

Conclusion

Whey is no longer an insignificant by product of the dairy plant because an escalating number of researchers are validating whey protein as an excellent source for various industrial applications. Whey protein-enriched method can develop for end groups such as infants, cardiac-risk group, and diabetics. Distinct tactics necessarily to be devised to strengthen. Whey is assuredly an attractive growth medium for several kinds of microorganisms. The notable decline of BOD with the subsequent generation of valuable bio-products such as ethanol, bacteriocin and biogas has accomplished. Therefore, now whey is not a pollutant but a possible raw material for innovative products and processes. Despite this, economic problems in the transportation of whey created a hindrance in adopting any process of utilization of whey.

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