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PROSPECTIVE UTILIZATION OF VALUABLE DAIRY BY- PRODUCT: WHEY

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Abstract
There has been a great interest in creating newer channels of utilization for the by-products of dairy and food industry throughout the world. For profitable dairying, economic disposal of by-products is essentially prerequisite and recent trend in utilization of whey is justifying the need up to certain extent. Whey, a watery part of milk is one the most interesting nutritional by- product obtained during the production of milk based products like cheese, paneer, chhanna and casein. It is rich in minerals, lactose and whey proteins that can get easily absorb in the body. Few years back, majority of the liquid whey was converted into powder forms. Fascinatingly, the nutritional and health benefits associated with whey have led development of many whey based products. Researchers from different corners of the world have developed many fermented and non-fermented drinks, alcoholic and non-alcoholic beverages, sports/energy drinks, as well as dairy and bakery products. However, none of these products are produced commercially at mass consumption level except whey protein powders and its supplemented products especially in sports nutrition. One of the probable reasons could be cost associated with sophisticated technologies and less awareness among consumers. Hence, global dairy and food industries should come forward to develop systematic economically viable approaches to make available these novel healthy food products in the market for the consumers.

Key words: whey proteins; by-product; fermented beverages; peptides; probiotics

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1. INTRODUCTION

Whey is the major by-product of dairy industry generated during manufacturing of paneer, cheese, chhanna, chakka (product formed by removal of water from fermented milk), and casein like dairy products. It is the watery part of milk that remains after separation of curd or coagulated milk products resulting from acid or proteolytic enzyme mediated coagulation. While manufacturing of these products, from milk about 10- 20% portion is coagulated as desired end product and 80-90% of liquid portion is remained as the whey. Whey contains a number of high quality and biological active proteins, minerals and carbohydrates. The annual production of whey is more than 160 million tones, with an estimated growth rate of 1–2% yearly (Das et al., 2016).

It has been observed that whey has very high (35,000-45,000 mg/L and 60.000 – 80,000 mg/L) biological oxygen demand (BOD) and chemical oxygen demand (COD) respectively due to the presence of organic matter content with lactose being the major constituent (4.5-5% w/v). Thus, previously, draining off whey was related with great loss of valuable nutrients and furthermore this organic matter can create problem of environmental pollution. Alternatively, it was employed as animal feed but there it was associated with increased urination if fed to animal. Whey is also having other issues like as it can lead to corrosiveness and had short shelf life which creates serious difficulty for its disposal. There are two types of whey, acid whey which is produced during manufacturing of paneer, chhanna, chakka and acid casein manufacture; and sweet or rennet whey that is generated during manufacturing of cheese. The average composition of whey (both acid and rennet whey) is shown in Table 1.

Processing of whey for conversion into whey powder or whey protein isolates is one of the means to tackle these difficulties, but it is very expensive alternative. Therefore, best utilization of whey demands for systematic approaches which must be cost effective. For

profitable dairying, economic disposal of by products is essentially prerequisite and recent trend in utilization of whey is justifying the need up to certain extent (Figure 1). Nowadays processed whey is used for manufacturing of various types of drinks and beverages, such as fermented or non fermented beverages with or without addition of flavours, fruit juices or pulp; vegetable soups, carbonation and probiotification. Many of these products have been successfully developed at small scale and have limited market (Shah et al., 2019). Whey have been also utilized for the production of alcoholic beverages (wine, ethanol, and beer), organic acids, butter milk, yoghurt, ice cream, coffee drink, cream yoghurt, caramel, and lactose. With modern developments and technologies, nowadays whey is a part of the human diet.

Table 1: Average composition of whey (Source: Darade and Ghodake, 2012; Gupta, 2000)

Parameters	Acid whey*	Rennet whey[#]
Total solids(%)	6.06	6.87
pH	5.60	6.40
Lactose (%)	4.40	4.60
Protein (%)	0.30	0.98
Fat(%)	0.13	0.34
Ash(%)	0.60	0.54
Lactic acid (%)	0.21	0.14
Calcium (ppm)	710.65	501.50
Phosphorus (ppm)	560.50	441.50

*obtained during manufacturing of fresh acid cheeses (ricotta or cottage cheese), paneer & chhanna; [#] obtained during manufacturing of cheese

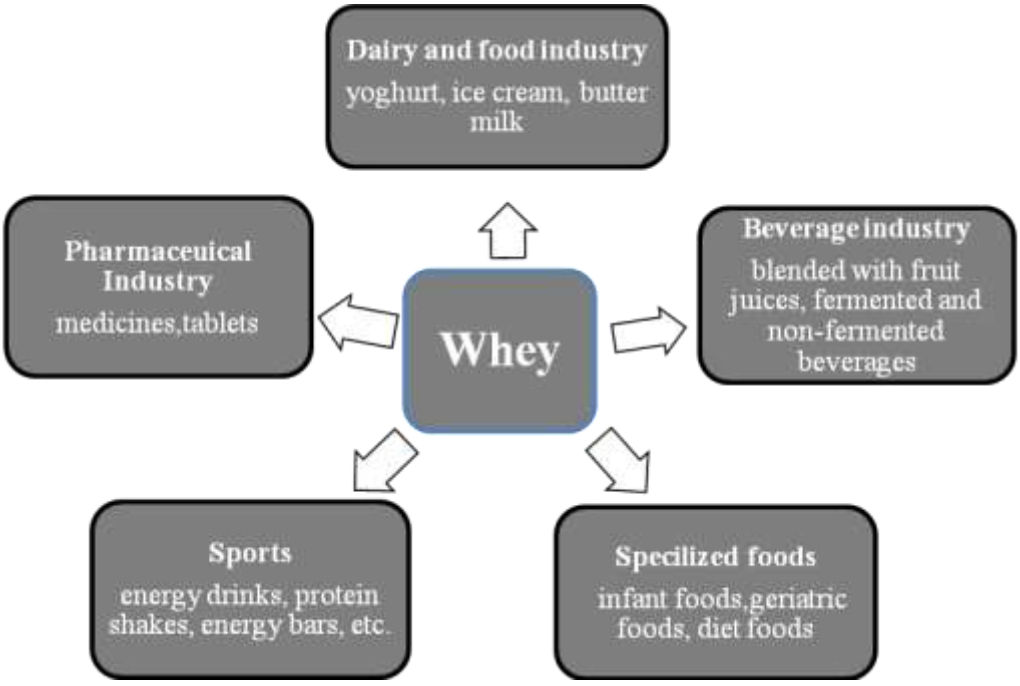

Fig. 1. Current and future prospective applications of whey

2. WHEY-FUNCTIONAL AND NUTRITIONAL SIGNIFICANCE

The demand for whey ingredients has been growing much faster, on average at approximately 4-5% across all whey and lactose ingredients, while the most dynamic ingredients have grown by approximately 10% annually. For India whey protein market is projected to grow at a compound annual growth rate (CAGR) of about 20% during 2017-2022 (Anon, 2018). Along with growing awareness about the health benefits associated with whey protein products, rising living standard, increasing disposable income, growing demand for whey protein from Fast-moving consumer goods (FMCG) companies and consistent growth in organized retail and e-commerce platforms are some of the other major factors expected to augment whey protein demand during the forecast period. Both nutritional markets including infant nutrition, sports nutrition and clinical nutrition as well as commodity markets like food and animal feed are driving this development.

Whey proteins are highly versatile, get easily absorbed in the body and also possess sulphur containing amino acids and other essential amino acids like leucine, isoleucine and valine which are important in growth and repair of tissue, improved muscle strength and body composition (Khare et al., 2007). Therefore, functional ingredients present in whey enhance the therapeutic as well as nutritional values of food or beverage manufactured along with satisfying consumers demand for novel tasty products. Researchers have also prepared whey protein isolate (WPI) tablets to treat or supplement specific benefits associated with these valuable whey proteins (Zhang et al., 2018). Several value added products have been prepared incorporating whey proteins, whey powders or concentrated whey.

In recent times, whey proteins derived bioactive peptides have open up a wide range of possibilities within the market for functional foods (Poltronieri et al., 2012). Whey proteins including β-lactoglobulin, α-lactalbumin, lactoferrin and lactoperoxidase are mainly involved with health-promoting properties (Table 2). Bioactive peptides derived from these whey proteins can be obtained at industrial scale via enzyme-mediated hydrolysis (digestive enzymes like pepsin, trypsin and chymotrypsin). Alternatively, bioactive peptides can be also obtained through microbial fermentation.

A. Whey based solid products: In addition to nutritional and functional significance of whey ingredients, they may also serve as substitutes. Addition of whey ingredients like whey powders, whey protein concentrate, or whey protein isolates in several foods can reduce and substitute fat and sugar. It is observed that incorporation of whey products enhances viscosity, emulsification, gelation as well as taste & flavor of dairy product like yoghurt, ice cream and khoa (heat desiccated milk product). They can be used to replace lipid from fat rich products while it can also reduce soy protein and meat protein partially (Królczyk et al., 2016).

Whey proteins apart from being highly nutritious have very good functional attributes such as water binding, emulsifying, gelling, viscosity, solubility, and foaming that can be used while making bakery items like biscuits, cookies and cakes (Jyotsna et al., 2007). Baked goods are products rich in carbohydrates, but poor in proteins. Incorporation of whey processing products in combination with sugar alcohols or artificial sweeteners contribute to a reduction in carbohydrate content of the baked products like biscuits, cakes, muffins, etc. For example, WPC34 is suitable for products such as spice cookies or chocolate chip cookies as a partial replacement for both egg and fat. On the other hand, WPC80 is a good substitute for eggs in products such as bread, biscuits, cakes and muffins. WPCs, which are classified as fat mimetics can lower fat content by up to 50%, and thereby increase the moisture content of the finished product, such as cakes, cookies, and muffins (Stoliar, 2009). In Table 3, several dairy and bakery based products incorporated with whey proteins by various researchers have been summarized.

Table-2 Bioactive spectrum of whey proteins and peptides

Proteins and Peptides	Bioactivity spectrum	Reference(s)
β-lactoglobulin β-lactorfin	influences the smooth muscles	Pihlanto-Leppälä (2000)
β-lactotensin	exhibits hypocholesterolemic and anti-stress activities	Pihlanto-Leppälä (2000)
α-lactalbumin α-lactorfin	displays effects similar to that of morphine, namely blood pressure reduction	Pihlanto-Leppäla (2000)
Caseinomacropeptide	prebiotic effects on Bifidobacteria and Lactobacilli	Martinez et al. (2009)
	antimicrobial effect against oral pathogens	Malkoski et al.,(2001) Aimutis (2004)
	anti-inflammatory activity	Requena et al., (2009)
Lactoferrin	antibacterial properties	Lopez Exposito and Recio (2006)
Serum albumin Serophorin (399-404, YGFQDA)	opioid-like activity	Poltronieri et al., (2012)
ALKAWSVAR	ACE-inhibitory peptide	Poltronieri et al., (2012)
Proline rich polypeptide (PRP)	immunotropic functions	Camfield et al., (2011)
Proteoso-peptone fraction (PP3)	antimicrobial activity	Campagna et al., (2004)
Immunoglobulins	immunological effects	
Lysozyme	antimicrobial activity	
Folate-binding protein	Bind with folic acid	

Table 3: Utilization of whey in novel product development

Kind of Product	Form of Whey	Major Outcomes	Reference
Fermented Kefir drink	liquid whey protein concentrates	The fermented drinks showed acceptable physicochemical and sensorial properties, and contained above 7 log CFU/mL of lactococci and lactobacilli and 6 log CFU/mL of yeasts after 14 days of refrigerated storage	Pereira et al., (2015)
Ice candy	Lactose hydrolyzed whey	The overall acceptability score was significantly higher for candy sample with orange flavour (8.70). However, the sample with jaljira (8.40) flavour was statistically at par with the score obtained for orange flavour.	Raval (2014)
Whey based iced tea	Liquid paneer whey	The sensory parameters including flavor, body & texture, color & appearance, overall acceptability got significantly ($p<0.05$) higher score for both the samples contained 80% whey and 100% whey compared to 50% whey concentration. The optimized product showed 25% antioxidant activity as per DPPH assay	Shah et al. (2019)
Lassi	Concentrated Paneer/cheese whey	Addition of concentrated whey resulted in thinning effect as reflected by consistency, viscosity and index of viscosity values	Patel (2013)
Yoghurt	Liquid whey	Yoghurt manufactured from 70% milk plus 20% milk whey, followed by enzymatic treatment, presented similar characteristics to traditionally manufactured yoghurt, with no alteration in the syneresis of the samples ($p > 0.05$) and presented texture parameters similar to the control yoghurt	Gauche et al., (2009)
Yoghurt	Concentrated liquid whey	Yoghurt supplemented with whey retentant had shown less apparent viscosity and greater tixotrophya; less firmness and adhesiveness and greater cohesiveness; and higher syneresis index in comparison with the yogurt made only with milk retentant	Magenis et al., (2006)
Biscuits	3%,5%, 10% whey protein concentrate (WPC)	The whey protein enriched biscuits containing 10% WPC were highly acceptable as comparable to control and other treatments in sensory characteristics	Munaza et al., (2012)

Bread	0-30% Whey protein (WP)	Incorporation of WP changed rheological properties of dough; it decreased dough stability time (MST), minimum torque (MMT), G' and G″, but increased dough peak torque (MPT), stickiness, G' and G″ in temperature sweep	Zhou et al., (2018)
Cookies	WPC (0, 2, 4, and 6%)	Cookie supplemented with 4% WPC showed maximum overall acceptability (4.76) as compared control sample	Wani et al., (2015)
Eggless cake	10, 20, 30%-WPC	Replacement of wheat flour with 20% WPC produced highest cake volume with best crumb structure among all other levels.	Jyotsna et al., (2007)

B. Whey based liquid products: Whey based beverages are highly refreshing, thirst quenching, easily digestible and appetizing. Nutritionally, whey beverages are far superior to various synthetic and aerated drinks available in the market. Whey beverages can be made from natural whey, whey permeates refined whey, ultra filtered whey, or whey concentrate. These may be further classified as described below:

(a) Non- fermented beverages: Many researchers have utilized simple technologies to incorporate fruit juices or flavor in liquid whey. In a previous attempt, Singh (1991) prepared whey based chocolate drink using deprotenized whey and milk in equal proportion, sugar (6%), CMC (0.05%) and cocoa powder (1.5%). Researchers have tried to use different fruit juice or pulp such as banana (Shekeilengo et al., 1997), mango (Sikder et al., 2001; Sahu et al., 2005), Pineapple (Suresha and Jayaprakasha, 2003), Papaya (Gupta et al., 2017) and pomegranate (Babar et al., 2008) to make refreshing whey drinks and beverages.

People have also tried to develop carbonated whey beverages. Earlier in 1981, Kudryavtseva and co-workers developed the technology to manufactured carbonated whey beverage. Then after many researchers have utilize similar technology; for instance, probiotics carbonated whey beverage (Silva e Alves et al., 2018), carbonated lemon whey beverage (Patel, 2017); and carbonated whey beverage with orange juice (Pareek et al. 2013). Further, instead of cheese or paneer whey Dilipkumar and Yashi (2014) prepared carbonated whey fruit juice utilizing acidic whey obtained from *Shrikhand*, a popular fermented milk dessert popular in India.

(b) Fermented beverages: Recently, Thakkar et al. (2018) prepared whey-based functional beverage containing orange juice and probiotic bacteria. Authors stated that the product remained good in terms of overall acceptability and maintained the viability of probiotic bacteria viz. 6.10 and 7.25 log CFU/ml for control (A) and B2 (60F:40W), ($p<0.05$) during storage at refrigeration temperature for 28 days. On the other hand, Sasi Kumar (2015) carried out quality evaluation and shelf life studies of probiotic beverages containing whey with aloe vera juice. Many other researchers have also performed similar studies (Castro et al., 2013; Kamble et al., 2017).

Whey have been utilize to develop alcoholic beverages including whey beer, wine, and sparkling wine called 'whey champagne' using yeast strains like *Kluyveromyces fragilis and Saccharomyces lactis.* These products are characterized by a low alcohol content (>1.5%). Lactose and minerals present in whey are suitable ingredients while fat is considered as unfavorable part as it has a destructive effect on beer foam (Jeličić *et al*., 2008).

(***c) Other uses of liquid whey****:* Previously, Nupur and Gandhi (2009) prepared electrolyte whey drink making use of paneer and cheese whey. Several authors have used liquid whey to prepare soups such as vegetable soup (David and Kumar, 2014; Rai et al., 2014), corn flour soup (Verma et al., 2010) and Mushroom- whey soup powder (Singh et al., 2003). Direct liquid whey has been successfully used to prepare ice candy (Raval, 2014) and butter milk (Mehta et al., 2015).

As compared to traditional sports beverages, inclusion of small amounts of whey protein (typically 20% of total calories) in a beverage may produce benefits and may increase

performance time to fatigue, reduce post exercise muscle damage, and enhance muscle glycogen repletion. So, researchers have also incorporated whey ingredients in sports drinks and other specialized foods like infant foods, diet foods and geriatric food to enhance bioavailability of proteins and provide balance nutrition.

3. CONCLUSION

Whey is one of the major by-products of the dairy industry. Whey contains almost about 40% of the valuable milk solids with high biological oxygen demand. Hence, whey needs to be treated appropriately for its disposal to avoid environmental pollution. A number of novel food products have been developed using direct liquid whey or whey ingredients globally but still date none of them are of mass consumption type except whey protein based powders and products supplemented with it. Thus, huge quantities of whey produced globally are not absorbed currently in a systematically and economically feasible viable approach. It is prerequisite to develop appropriate processes for the manufacturing of mass consumption products by utilizing both whey and its ingredients. It may be of great interest of the dairy and food industry in context to satisfy need of consumers for value added functional food products.

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