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Probiotic foods for human health: A review

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Abstract

Probiotic foods are the leading components of functional food sector. Probiotic organisms are known for their several health beneficial abilities. Fermented dairy products are the most preferred traditional matrix for probiotic, but increasingly, other products are being used as the probiotics delivery vehicle. Composite foods are the relatively uncommon matrix for probiotic. Combination of milk and cereal can provide better nutrition to mankind with higher growth of the probiotic organism. Composite probiotic products may lead to product diversification with improved nutrition at a lower cost. However, the sensory acceptability of these types of food products remains to be a major problem. Further, Probiotic composite dairy products are not systematically evaluated for their health beneficial properties in animal and human model. Systematic and in-depth study is required in this field.

Keywords: Probiotic, functional foods, health benefits, probiotic substrate

Introduction

'Let food be thy medicine and medicine be thy food', is the word of Hippocrates and the prime philosophy for health conscious consumers. The phrase probiotic was originated from Greek word, meaning 'for life'. In the late 19th century, microbiologists observed that the gut flora of healthy subjects differed from those of diseased persons. Nobel Laureate Elie Metchnikoff, reported the advantageous role of selective microbiota on gut health. Probiotic organism improves body's natural defense system (Getahun *et al.*, 2017) [20]. The first definition was provided by Fuller, (1989) that, "probiotics are live microbial feed supplements that beneficially affect the host by improving its microbial balance". The Food and Agriculture Organization provides official definition of 'probiotic' as living organisms that upon ingestion in certain numbers, exert benefits to the consumer's health (FAO/WHO, 2002) [13]. The food products termed as 'probiotic' must contain $\geq 6 \log$ CFU per millilitre or gram viable microbial count throughout their life span to provide their claimed health benefits (Garcia *et al.*, 2012). According to recent suggestion the concentration of probiotic bacteria should be 10^8 CFU/g of a product to provide health beneficial effect to host (ICMR-DBT, 2011) [16]. The idea of probiotic usage for disease management as well as restoration and maintenance of health is not new. However, recently, the interest of usage of probiotics as bio-therapeutic agents has been renewed mainly due to consumers awareness. Further research into this area, had revealed that regular consumption of these bacteria could provide several health benefits. Their inclusion into different food products popularized a new segment of functional foods termed as 'probiotic foods'. Bacteria from Lactobacillus and Bifidobacterium genera are commonly considered as probiotic (Doron *et al.*, 2006) [11] and they regarded as safe and don't have any harmful effects on gut health (Kimoto-Nira *et al.*, 2007) [27]. The most commonly used lactobacilli are *L. acidophilus*, *L. casei*, *L. rhamnosus*, *L. reuteri*, *L. plantarum*, etc. (Meurman and Stamatova, 2007) [43]. The bifidobacteria species used are *Bifidobacterium breve*, *B. Animalis subsp lactis* formerly known as *B. Lactis* (Masco *et al.*, 2004) [38] and *B. Longum* biotypes *infantis* and *longum* (Masco *et al.*, 2005) [37]. Other lactic acid bacteria (LAB) include in probiotic family are *Streptococcus*, *Lactococcus*, *Enterococcus*, *Leuconostoc*, *Propionibacterium*, and *Pediococcus*. Some non-related microbes identified as probiotic are non-pathogenic *E. coli* Nissle 1917 and *Clostridium butyricum* (Harish and Varghese, 2006) [21], yeast spp (*Saccharomyces boulardii*), filamentous fungi (*Aspergillus oryzae*), and some spore forming bacilli (Fuller, 2003) [15]. For providing the health benefits to the host, probiotic organism must survive during gastric transit, able to tolerate bile, acid and gastric enzymes followed by adherence and colonization in the intestinal epithelium (Huang and Adams, 2004) [22]

Probiotics in human health

Probiotic organism improves natural defense mechanisms of body (Saarela *et al.* 2000) ^[51]. Now a days, probiotic have been found useful in various human health problems like food allergy, lactose intolerance, atopic dermatitis, acute gastroenteritis, colon cancer, arthritis etc. (Lee *et al.* 2003; Lenoir-Wijnkoop *et al.*, 2007) ^[28, 29]. Some of the reported health benefits are been discussed below:

Synthesis and bioavailability of Nutrients

Probiotic organisms have been found to enhance nutrients availability and digestibility during fermentation and absorption of fermented foods. Fermented dairy products are reported to be a good source of folic acid, niacin and riboflavin, etc. (Deeth and Tamime, 1981; Alm, 1982) ^[7, 2]. Bacterial enzymatic hydrolysis aid in protein and fat digestion, leading to enhanced bioavailability of nutrients (Fernandes *et al.*, 1987) ^[14] and an increased production of functional components. Lactobacilli may produce and release bacterial lactase to the intestine where lactose is degraded and can prevent lactose intolerance problem (Martini *et al.*, 1991) ^[36].

Management of diarrhoea

Probiotic are well known for preventive and management action against acute viral and bacterial diarrhoea as well as they can control antibiotic associated diarrhoea. A number of specific strains have been reported to have significant benefit for diarrhoea, includes *Lactobacillus GG*, *Lactobacillus reuteri*, etc. (Benchimol and Mack, 2004) ^[3]. Probiotic ingestion is a valuable and potential strategy for treatment of antibiotic associated diarrhea and *Clostridium difficile* infections (McFarland, 2006) ^[39]. The possible mechanism behind this are: increased production of secretory IgA, decreased viral shedding and competitive exclusion of pathogens and increased intestinal mucin production, leading to prevention of the attachment of entero-pathogenic organisms. (del Miraglia and De Luca, 2004) ^[8].

Alleviation of lactose intolerance

Probiotic have been found to alleviate the symptoms of lactose intolerance in lactase-deficit persons, which may be due to as a result of the increased lactase activity in the small intestine (Marteau *et al.*, 1990) ^[34], leading to improved lactose digestion and reduced intolerance symptoms (Sanders, 1993) ^[52]. In lactose intolerant patients, administration of probiotic leads to hydrolysis of milk lactose by probiotic strains leading to proper lactose assimilation and calcium absorption.

Inflammation/arthritis

Probiotic had been found useful in inflammation, through regulation of inflammatory mediators such as cytokines. Inflammatory responses may be modulated through regulating the immune markers in the GI tract. It has been observed that probiotic therapy may be useful in rheumatoid arthritis (Marteau *et al.*, 2001) ^[35].

2.1.2.6 Allergies/eczema

Probiotic may improve endogenous barrier mechanisms of the gut alleviating intestinal inflammation, providing a useful tool for food allergy treatment (MacFarlane and Cummings., 2002; Miraglia and De Luca, 2004) ^[30, 8]. The beneficial effect of probiotic on allergic reaction, may be due to improved mucosal barrier function and stimulation of immune system

(MacFarlane and Cummings, 2002) ^[31]. Probiotic bacteria may control inflammation linked with hypersensitivity reactions in patients with atopic eczema and food allergy (Isolauri, 2004; Pohjavuori *et al.*, 2004) ^[24, 48]. Administration of *Lactobacillus rhamnosus GG* was observed to decrease the occurrence of eczema in infants (Isolauri *et al.*, 2000) ^[23].

HIV and immune function

Application of probiotic can be a useful strategy for immune-compromised hosts for providing a positive effect on immune response. The immune response may further be improved by consumption of combinations of probiotics together, that work synergistically (Cunningham-Rundles *et al.*, 2000) ^[6]. The most of evidence from *in vitro*, animal and humans studies suggest that probiotic may enhance both specific and nonspecific immune responses (MacFarlane and Cummings, 2002; McNaught *et al.* 2005) ^[31, 41]. These effects are to be mediated through following mechanisms: activation of macrophages, increased levels of cytokines, enhancing natural killer cell activity and/or increased levels of immunoglobulin secretion (Perdigon and Alvarez, 1992; Ouwehand *et al.*, 2002) ^[56, 46].

Control of blood cholesterol and hyperlipidaemia

Cholesterol has essential role in human body, a precursor to several hormones, vitamins, an important constituent of cell membranes and nerve cells, however, increased levels of total blood cholesterol is associated with increased risk of coronary heart disease development. Probiotic bacteria are observed to have beneficial effect on blood lipid profile. Application of low dose of *L. reuteri* for 7 days reduced total cholesterol and triglyceride levels by 38% and 40%, respectively in hypercholesterolemic murine model (Taranto *et al.*, 1998) ^[56].

Irritable bowel syndrome

Probiotic therapy has been found beneficial in management of inflammatory bowel disorders. In a clinical trial, *L.plantarum* 299 v and DSM 9843 strains were observed to reduce abdominal pain, bloating, flatulence, and constipation, in irritable bowel syndrome (MacFarlane and Cummings, 2002) ^[31]. A number of probiotics have been reported for their effectiveness in IBS (Niedzielin *et al.*, 2001) ^[45] however, *Bifidobacteriainfantis* have established for its efficacy (Brenner, *et al.*, 2009). *Saccharomyces boulardii* was found to decrease diarrhoea in irritable bowel syndrome, but was not effective in controlling other symptoms (Marteau *et al.*, 2001) ^[35].

Colon cancer

Colorectal Cancer (CRC) is the third most common form of cancer in men and second in women in worldwide (Jemal *et al.*, 2011) ^[25]. The risk of colon cancer is strongly associated with diet and environment. Current treatment options for CRC include surgery, chemotherapy and radiation therapy etc., causing significant reduction in quality of life. Probiotic therapy has been found highly useful in colorectal cancer. The mechanisms for prevention of CRC involves, i) Alteration of intestinal micro-ecology, ii) reduced production of carcinogenic faecal enzyme, iii) Lower level of Toxigenic/Mutagenic reaction in gut, and iv) Protection against DNA damage by production of short chain fatty acids etc. (Verma and Shukla, 2013) ^[58].

Probiotic Substrate

Matrices are the substrate of probiotic organisms that provides the basic growth nutrients and act as delivery medium of probiotic. Food matrices confer very vital role in growth, viability as well as providing the health beneficial effects of probiotic (Espirito Santo *et al.* 2011) [12]. Fermented dairy foods are commonly used as probiotic carriers. This is due to milk products are stored at cold (4 °C-8 °C), they have short shelf life (15-25 days), contain all necessary nutrients for growth of probiotic, together with readily available guidelines for application of probiotic in milk and milk products. Fermented beverages play an important role to the human diet in many countries and are mostly used as matrices for probiotics. Several probiotic dairy products have been represented in Table 1.

Probiotic food markets worldwide are dominated by mostly milk-based probiotic food products, and very few probiotic foods are available containing other fermentable substrates. Traditionally probiotics have been added to fermented dairy products, but recent times they have also been incorporated into unfermented dairy products, drinks, supplements, tablets, capsules etc. (Shah 2001) [55]. Whole grain is becoming as one of favoured choices for probiotics delivery vehicle, mainly because the formulation of probiotics with whole grain may offers consumers with dual benefits of probiotics, and other bioactive components (Marquart and Cohen 2005) [33]. The cereal components can be utilized in probiotic food formulations as substrates for fermentation or encapsulating material. Several cereal or cereal component-based probiotic foods are available in the global market like cereal bars CornyActiv® (Germany), probiotic flakes Muesli®

(Portugal), whole wheat breakfast cereals Weetaflakes® (France), wholegrain porridge (UK), snack bar Goodness® (UK), etc. (Dornblaser 2007) [10].

A composite substrate is comprised of both dairy and cereal components. The combination of cereals and milk will provide better nutrition and a value-added functional foods. Milk, lacks in fibre, whereas, cereals are rich sources of fibre, milk proteins of superior quality, whereas cereal proteins are of inferior quality, milk is a rich source of minerals like calcium and phosphorus but low in iron, whereas, cereals are a poor source of calcium but good at iron. The combination of lysine-rich milk protein and lysine-deficient cereals can make up the deficit. Cereals are a cheap source of nutrition, so incorporation of cereals in milk product ultimately will result in a nutritionally superior cost-effective product. A composite substrate can also be used for the preparation of different types of novel and economic probiotic food products. However, the sensory acceptability of these types of food products remains a major concern. The composite substrate containing milk and cereal has been reported to cause a high growth of dairy isolated probiotic organism *Lactobacillus acidophilus* (NCDC-13) (Ganguly and Sabikhi 2012) [18] and improved nutritional profile by reducing phytic acid and polyphenol and improving starch and protein digestibility (Ganguly *et al.* 2013) [17]. The major limitations of these products are lack of knowledge regarding composition changes and components produced during probiotic fermentation. Further, Probiotic composite dairy products are not evaluated for their health beneficial properties in animal and human model. Systematic and in-depth study is required in this field.

Table 1: Dairy products as a substrate of probiotic

Sr. No	Product	Organism/s	References
1.	Probiotic goat milk	<i>Bifidobacterium longum, Lactobacillus acidophilus</i>	Tsend-Ayusha and Yoon 2013 [57]
2.	Ice-cream	<i>Lactobacillus casei, Lactobacillus rhamnosus</i>	Di Criscio <i>et al.</i> 2010 [9]
3.	Yoghurt like products	<i>Lactobacillus acidophilus, Lactobacillus casei, Lactobacillus rhamnosus</i>	Schillinger <i>et al.</i> 2004
4.	Milk chocolate	<i>Lactobacillus acidophilus, Lactobacillus rhamnosus, Bifidobacterium lactis</i>	Zarić <i>et al.</i> 2016 [61]
5.	Yoghurt and freeze dried yoghurt	<i>Lactobacillus acidophilus, Lactobacillus casei, Lactobacillus rhamnosus, Bifidobacterium spp.</i>	Capela <i>et al.</i> 2005
6.	Whey Cheese	<i>Bifidobacterium animalis, Lactobacillus casei</i>	Madureira <i>et al.</i> 2011 [32]
7.	Probiotic white cheese	<i>Lactobacillus acidophilus</i>	Kasimoğlu <i>et al.</i> 2004 [26]
8.	Cottage cheese	<i>Lactobacillus casei, Lactobacillus rhamnosus</i>	Abadía-García <i>et al.</i> 2013 [11]
9.	Yakult	<i>Lactobacillus spp. Streptococcus spp, Bifidobacterium spp</i>	Chuayana Jr <i>et al.</i> 2003 [5]
10.	Cheddar Cheese	<i>Lactobacillus salivarius, Lactobacillus paracasei</i>	Gardiner <i>et al.</i> 1998 [19]
11.	Cheddar Cheese	<i>Lactobacillus casei</i>	Wang <i>et al.</i> 2010 [60]

Conclusion

Probiotic foods are the most promising and dominating sector in the functional food market due to increased consumers' awareness. Probiotic organism have been found to deliver a wide range of health beneficial effect to host. Previously, fermented dairy products were the most common delivery vehicle of probiotic organisms but recently cereals and other substrates are being used as probiotic carrier. Composite probiotic food products are comparatively newer concept. Combination of milk and cereal can provide better nutrition and higher growth of organism. However, the sensory acceptability of these types of food products remains a major concern. Further, Probiotic composite dairy products are not evaluated for their health beneficial properties in animal and human model. Systematic and in-depth study is required in this field.

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