

Review Article

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Non-Dairy Probiotics – An Emerging Trend in Health Care Products

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ABSTRACT

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The beneficial effects of consuming probiotics wouldn't have been possible without the extensive research for the past two decades. However, due to enhanced awareness and health consciousness among today's population, there is an emerging trend of counterparts and substitutes for dairy probiotics. Globally, the commercial market of dairy probiotics is on boom, however, the allergic reactions associated with the dairy ingredients and lactose intolerance in people has resulted in the extensive research and development of non-dairy probiotics, which prove to be beneficial for health conscious and allergy vulnerable population. Non-dairy probiotics have geared up in the market due to their wide acceptability regarding taste, consumption benefits and cost effectiveness, besides the satisfactory nature of the non-dairy probiotic strains has been an important factor for their sustainability and growth. Even though dairy probiotics have world over market, the emerging trend of the non-dairy probiotics has lead to enhanced acceptability regarding the beneficial health implications.

Introduction

Probiotics have been in use for the benefit of humans since the time the consumption of fermented milk and milk products has started. Probiotics are 'live microorganisms which when administered in adequate amounts confer a health benefit on the host (FAO/WHO, 2002). The history of probiotics dates back to the times when Elie Metchnikoff a Russian scientist postulated that lactic acid bacteria (LAB) offer health benefits that promote longevity. He suggested that "intestinal autointoxication" could be suppressed by modifying the gastrointestinal microflora by replacing toxic producing

proteolytic microbes such as *Clostridium* with useful microbes. Lilly and Stillwell coined the term "probiotics" in 1965 and defined probiotics as microbially derived factors that accentuate the growth of other organisms. In 1989, Roy Fuller introduced the idea that probiotics have a beneficial effect on the host. Probiotics are able to be formulated into different types of products, including foods, drugs, and dietary supplements. In addition to some species of *Bifidobacterium*, and *Lactobacillus*, some yeasts like *Saccharomyces cerevisiae* and *Bacillus* species are also classified as probiotics. Lactic acid bacteria which are in use for food preservation by fermentation process for a

number of years, serve enormous number of functions by acting as agents for food fermentation besides potentially having multiple health benefits.

Health claims

Probiotics are used to assist the natural gut microflora of humans. Some probiotic preparations are used to prevent diarrhoea caused by antibiotics, or as part of the treatment for antibiotic-related dysbiosis. Several studies have confirmed probiotic effects on a variety of gastrointestinal disorders, including inflammatory bowel disease (IBD), irritable bowel syndrome (IBS), and immune enhancement. Probiotics have also been thoroughly studied in relation to allergies like atopic eczema and liver cirrhosis. Many investigations have also been done regarding the suppression of *Helicobacter pylori* infection by addition of selected strains to food products (Gotcheva *et al.*, 2002; Nomoto, 2005; Imasse *et al.*, 2007; Shah 2007; Vijayendra and Gupta, 2012). In modern health care regime, probiotics are added to curd, yoghurt and other fermented dairy products (Laroia and Martin 1991; Penna *et al.*, 2007; Vijayendra and Gupta 2013) and make those to be used as functional foods (Table 1).

Role of probiotics in human health

Susceptibility of humans to many diseases due to environmental effect, food patterns and infections lead to the studies about the use of probiotics as remedial agents. Probiotics play an important role in averting or at least subsiding various diseases. For example, Acute diarrhoea in children that is mainly caused by rotaviruses infections. The probiotic strains of *Bifidobacterium lactis*, *Lactobacillus delbrueckii*, *Lactobacillus reuteri*, subsp. *Bulgaricus*, *Streptococcus thermophilus* and, *Lactobacillus rhamnosus*

GG, besides having therapeutic effect also have preventive effect on the apparition of acute diarrhoea in children.

Most often, antibiotic therapy results in diarrhoea due to disturbance of natural balance of intestinal microflora which leads to quick growth of *Clostridium difficile*. Probiotic strains like *Saccharomyces boulardii* GG, *Lactobacillus acidophilus*, *Lactobacillus rhamnosus* and *Lactobacillus delbrueckii* subsp. *Bulgaricus* during antibiotic therapy, decreases the prevalence of diarrhoea by 52 %. Besides, Non-degraded lactose induces convulsions, flatulence, diarrhea and nausea. In fermented dairy products, the concentration of lactose is significantly lower besides, probiotic variety of fermented dairy products also contains microbial β -galactosidase (Fooks *et al.*, 1999), upon consumption of which lactose intolerance lowers down considerably. Casein, calcium-phosphate and lactate of fermented dairy products neutralize gastric acid, microbial β -galactosidase in the active form comes to a small intestine and the symptoms of the illness are made oblivious (Pochart *et al.*, 1989). β -galactosidase contained in yoghurt is enough to digest 50-100 % of 20g of consumed lactose (Miller *et al.*, 2007).

Many investigations have resulted in conclusions that confirm the effects of probiotic cultures on the immune system. It has been documented that probiotic bacteria are able to enhance both natural and acquired immunity by increasing phagocytosis, and also increasing levels of immunoglobulins. Two probiotic strains have been developed with a particular focus on their enhancing effects on immune responses vis-à-vis *Bifidobacterium lactis* and *Lactobacillus rhamnosus* and their ability to enhance natural immune function in healthy people has been demonstrated in several studies (Fuller *et al.*, 2008). In 1980's, the hygiene hypothesis was proposed by

Strachan that clearly emphasized the role of microorganisms in atopy prevention. Pelto *et al.*, established that *Lactobacillus rhamnosus* GG results in immunostimulatory effect in healthy adults. Probiotics have also been used successfully in the management of atopic eczema in infants. When pregnant ladies and the postnatal mothers, or the infants who are given *Lactobacillus rhamnosus* GG fortified products for 6 months, reduced the frequency of atopic to half (Delcenserie *et al.*, 2010).

Most of the fermented milk products have been promoted as cancer preventing foods. Studies suggest that colon cancer is associated with a high-fat diet. The high fat diet potentially amplify bile acid turnover and can lead to an increased quantity of bile acids in the colon which affects the metabolism of the gut microflora. Brady *et al.*, did animal studies over a period of 10 years that threw light directly at the promising relationship between consumption of probiotics and development of colon cancer. They found that evidently probiotics have an inhibitory effect on the development of carcinogenic lesions and tumors in animal models. In Japan, a study was conducted that exhibited the significant effect of continuous intake of lactic acid bacteria on lowering the risk of bladder cancer (Rafter, 2004). Investigations regarding effect of lactic acid bacteria on constipation have exhibited eloquent results in healthy but constipated adults. Addition of strains of *Bifidobacterium longum* BB536 to the diet of constipated females resulted in a remarkable improvement in bowel movements and mitigating the constipation issues, besides this, the same strain has a positive effect on defecation frequency for elderly people (Ouweland *et al.*, 2002).

Above all, there are several results of the investigations exhibiting for the cholesterol lowering effects of probiotics. Nevertheless numerous studies have demonstrated

impressive effects of probiotics in reducing cholesterol levels in both animals and humans, controversial results have surfaced. Hatakka *et al.*, (2008) reported that the regulation of *L. rhamnosus* LC705 for 4 weeks did not influence blood lipid profiles in 38 men with average cholesterol levels of 6.2 mmol/L (240 mg/dL). There is a need for large-scale clinical trials, determination of ability, and other critical indices to provide the important scientific evidence required to ascertain effectuality of the progressively increasing use of probiotics.

Why non-dairy probiotics?

Although probiotics are proven to be boon for mankind, a recent trend of non-dairy probiotics has surfaced extraordinarily. Non-dairy probiotic products have gathered a global importance due to the ongoing swing of vegetarianism and also due to an exorbitant prevalence of lactose intolerance in large population all over the globe. In current sales of probiotics in the world, 78% sales are delivered through yogurt. Fruit juices, desserts, and cereal-based products featuring probiotics may be other suitable media for delivering probiotics (Cargill, 2009).

With the help of advanced technologies, alteration in some structural characteristics of fruits and vegetables matrices by manipulating their constituents in a regulated way such as modification of pH, culture media fortification, besides others (Betoret *et al.*, 2003). These modifications, convert these conventional food products deal substrates for probiotics culture, as they already contain beneficial nutrients, but lacking the dairy allergens that might prevent consumption by the population suffering from dairy allergies (Sheehan *et al.*, 2007). Lactose intolerance, high cholesterol levels, and some milk proteins which may prove to be allergens are the major limitations related to the intake of

dairy products, which makes it necessary to pave way for the development of new non-dairy probiotic food products.

Currently most probiotic foods available are dairy based, but considering the consumer preference that is inclined towards the plant based dietary supplements, in which cholesterol is either absent or present negligibly. The market for functional foods is in its baby stage in most of the countries; however, product innovation in different areas, such as beverages, bakery and probiotics, is apparent, with trends generally following those of the U.S. and U.K. (Luckow *et al.*, 2004) Asian diets are relatively low in non-vegetarian and dairy based foods, while botanical foods contribute the maximum of their daily food intake. Besides dietary habits, lactose intolerance in Asian population discourages them from consuming milk and allied products. Taking the above mentioned facts into consideration cereals, fruits and vegetables turnout to be promising products, where the viable probiotic flora can pave their way, in the developing as well as the developed countries.

Health risks associated with fermented dairy foods

In spite of numerous health benefits, there are certain health risks associated with dairy based probiotic foods. These risks mainly include lactose intolerance, milk protein allergies, high fat and high cholesterol content. These risks are elaborated below.

Lactose intolerance

Lactose intolerance (LI) also known as lactose mal absorption is a condition characterized by the inability to digest lactose due to low levels of lactase enzyme activity. Activity of lactase enzyme is dependent on a large number of factors such as race, age, soundness of the

small intestinal membrane and small intestinal transit time (Table 2).

Milk protein allergy

Atopic dermatitis (AD) is a disease that is frequently associated with food allergy in children (Ricci *et al.*, 2006; Johnke *et al.*, 2007). Various investigations have determined that the consumption of probiotics lowers the occurrence of atopic dermatitis (Reid and Kirjaivanen, 2005). With selective strains of probiotics, various studies have reported a lowering of signs and symptoms in these patients. Some studies have also shown that the probiotic supplementation has no remarkable effect on the symptoms related to infantile allergies (Brouwer *et al.*, 2006).

High fat and cholesterol

Fat content in milk depends upon the source from which it is obtained. Cow milk has approximately 4–5 % fat, whereas, buffalo milk contains approximately 7–8 %. Large amount of milk consumption risk a consumer to increased level of total cholesterol and LDL-cholesterol contents in the blood that proved to be a major risk factor for coronary heart disease fat (Levy and Feinleib, 1980). This risk can be decreased by lowering the quantity of low-density lipoproteins (LDL) cholesterol by lowering the quantity of saturated fats in the diet. According to a study decrease in the serum cholesterol level at the end of 30 days in rats fed with probiotic *dahi* and probiotic yoghurt, containing *Lb. acidophilus* and *Bifidobacterium bifidum* demonstrate the hypocholesterolaemic effect of the probiotic cultures (Vijayendra and Gupta 2012).

Development of non-dairy probiotics

Innovation is today's business mantra. Experts proclaim that the only hope for survival of any

business is the ability to continue innovating. Considering this fact, the development of new non-dairy probiotic food products turns out to be enormously challenging, as it has to achieve the expectations of consumer for products that are healthy as well as tasty (Shah 2007). Developing a new Milk-free probiotic food is a cost intensive process. Food companies have largely funded research for new food product formulations, however, the stakes are higher for products where lactose is absent, (Walzem 2004). The high reported failure rates for new international functional foods suggest a failure to manage the customer knowledge effectively, as well as a lack of knowledge management between the functional disciplines involved in the new product development process (Jousse, 2008).

The food industry takes into consideration many variables to develop or rebuilt milk free probiotic products, such as sensory attributes, stability, cost, and functional properties. Consumption of beverages and food products that contain probiotic microflora is a globally growing trend (Verbeke, 2005). Mayonnaise, soymilk, meats, baby foods, ice creams, fruit drinks, vegetable drinks, and many others have already been proposed (Champagne *et al.*, 2005; Homayouni *et al.*, 2008). There is a wide variety of traditional non-dairy foods developed around the world. Many of them are non-alcoholic beverages manufactured

with cereals as main raw materials. There are different non-dairy based probiotic foods developed, some of which are briefly taken account of (Table 3).

Cereal and pulses based probiotic products

A multitude of non-dairy fermented cereal products has been created throughout history for human nutrition, but only recently probiotic characteristics of microorganisms involved in traditional fermented cereal foods have been reported (Table 4).

Boza

A traditional fermented beverage made from cereals is a cold beverage consumed in Bulgaria, Albania, Turkey, and Romania. Microbial identification of Bulgarian boza determines that it consists of yeasts and lactic acid bacteria (Gotcheva *et al.*, 2000).

Bushera

A traditional cereal-based beverage made in the Western highlands of Uganda.

Mahewu (amahewu)

It is a sour beverage prepared from corn meal, mostly available in Africa and some Persian Gulf countries.

Table.1 Definitions used by the international scientific associations for probiotics, prebiotics and synbiotics

Probiotics: Live microorganisms that confer a health benefit on the host when administered in adequate amounts

Prebiotics: Selectively fermented ingredients that result in specific changes in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefit(s) upon host health

Synbiotics: Products that contain both probiotics and prebiotics

Table.2 Population of different countries affected by lactose intolerance

	Country	% Population afflicted by lactose – intolerance
1	France	30 to 40
2	Germany	15 to 20
3	Russia	20 to 30
4	Finland	15 to 20
5	Sweden	< 5
6	Greece	70 to 80
7	Ethiopia	80 to 90
8	Nigeria	80 to 90
9	China	90 to 100
10	Japan	95 to 100
11	India	60 to 65
12	Israel	70 to 80
13	USA (white)	10 to 15
14	USA (black)	65 to 70
15	Mexico	50 to 60
16	Uruguay	60 to 65

Source: Alm (2002).

Table.3 List of some non-dairy probiotic products developed recently

Category	Product	Refrence
Fruit and Vegetable based	Vegetable-based drinks	Lambo <i>et al.</i> , (2005)
	Fermented banana pulp	Tsen <i>et al.</i> , (2004)
	Fermented banana	Tsen <i>et al.</i> , (2009)
	Beets-based drink	Yoon <i>et al.</i> , (2005)
	Tomato-based drink	Yoon <i>et al.</i> , (2004)
	Many dried fruits	Betoret <i>et al.</i> , (2003)
	Green coconut water	Prado <i>et al.</i> , (2008)
	Peanut milk	Mustafa <i>et al.</i> , (2009)
	Cranberry, pineapple, and orange juices	Sheehan <i>et al.</i> , (2007)
	Ginger juice	Chen <i>et al.</i> , (2008)
	Grape and passion fruit juices	Saarela <i>et al.</i> , (2006)
	Cabbage juice	Yoon <i>et al.</i> , (2006)
	Carrot juice	Nazzaro <i>et al.</i> , (2008)
	Noni juice	Wang <i>et al.</i> , (2009)
	Onion	Roberts and Kidd (2005)
	Probiotic banana puree	Tsen <i>et al.</i> , (2009)
Non fermented fruit juice beverages	Renuka <i>et al.</i> , (2009)	

	Blackcurrant juice	Luckow and Delahunty (2004)
	Plum juice	Sheela and Suganya (2012)
	Cashew apple juice	Pereira <i>et al.</i> , (2011)
	Table olives	De Bellis <i>et al.</i> , (2010)
	Fruit juices (mango, sapota, grape)	Vijaya Kumar <i>et al.</i> , (2013)
Cereals and Pulses based	Non fermented soy-based frozen desserts	Heenan <i>et al.</i> , (2004)
	Fermented soymilk drink	Donkor <i>et al.</i> , (2007)
	Soy-based stirred yogurt-like drinks	Saris <i>et al.</i> , (2003)
	Soy based products	Bedani <i>et al.</i> , (2013)
	Soyghurt	Bedani <i>et al.</i> , (2014)
	Soy curd	Roopashri and Varadaraj (2014)
	Soy product fermented with Kefir	Baú <i>et al.</i> , (2014)
	Cereal-based puddings	Helland <i>et al.</i> , (2005)
	Rice-based yogurt	Boonyaratanakornkit and Wongkhalaung (2000)
	Oat-based drink	Angelov <i>et al.</i> , (2006)
	Oat-based products	Martensson <i>et al.</i> , (2002)
	Oat milk	Bernat <i>et al.</i> , (2014)
	Oat, barley, and malt based	Salmerón <i>et al.</i> , (2014)
	Yosa (oat-bran pudding)	Blandino <i>et al.</i> , (2003)
	Mahewu (fermented maize beverage) Maize-based beverage	McMaste <i>et al.</i> , (2005)
		Wacher <i>et al.</i> , (2000)
	Wheat, rye, millet, maize, and other cereals fermented probiotic beverages	Blandino <i>et al.</i> , (2003)
	Malt-based drink	Kedia <i>et al.</i> , (2007)
	Boza (fermented cereals)	Moncheva <i>et al.</i> , (2003)
	Maize, sorghum, and millet malt fermented probiotic beverages	Blandino <i>et al.</i> , (2003)
	Millet or sorghum flour fermented probiotic beverage	Muyanja <i>et al.</i> , (2003)
	Mixed cereal beverage	Rathore <i>et al.</i> , (2012)
	Bread and baked products	Côté <i>et al.</i> , (2013)
Sorghum based	Sorghum based ‘Sorghurt’	Sanni <i>et al.</i> , (2013)
	Pseudo cereals (amaranth, buckwheat)	Monika <i>et al.</i> , (2013)
	As an edible film on pan bread	Soukoulis <i>et al.</i> , (2014)

Source: Dr. vijaysivakumar *et al.*, March 2015

Table.4 Comparative account of dairy and non-dairy probiotic foods

Parameter	Dairy probiotic foods	Non-dairy probiotic foods
Lactose intolerance	Negative effect	No issue
Calcium availability	Positive effect	No issue
High fat	Negative effect	No issue
Cholesterol content	Negative effect	No Issue
Dietary fibre	No issue	Positive effect
Digestibility	Not easy	Easy to digest
Survival rate of probiotics	High	Low
Flavour (diacetyl/acetaldehyde)	Positive effect	No issue
Phyto-chemicals	No issue	Negative effect
Isoflavons	No issue	Positive effect

Pozol

Prepared from cocoa and cornmeal, it is a refreshing beverage, widely produced in the Southeastern Mexico (Prado and others 2008a).

Fruit and vegetable based probiotic products

Despite potential sensory challenges, there is a genuine interest in the development of fruit-juice based functional beverages, fortified with the probiotic and prebiotic ingredients. The fruit juices have been suggested as an ideal medium for the functional health ingredients because they inherently contain beneficial nutrients, they have taste profiles that are pleasing to all the age groups, and because they are perceived as being healthy and refreshing (Tuorila and Cardello, 2002). The fruits and vegetables are rich in the functional food components such as minerals, vitamins, dietary fibres, antioxidants, and do not contain any dairy allergens that might prevent usage by certain segments of the population (Luckow and Delahunty, 2004).

Coconut milk yogurt

Coconut milk yogurt is a delicious, dairy-free probiotic yoghurt like food product.

Kimchi spicy fermented cabbage

Kimchi is a spicy fermented cabbage, and is popular in Korea as a non-dairy side dish that is rich in probiotics.

This food also contains healthy servings of iron, folate, and vitamins A, C, K, and B6.

Sauerkraut

Sauerkraut is also a fermented cabbage that can be used to get non-dairy probiotics and digestive enzymes in diet.

Fermented pickles

Pickles are an excellent source of probiotics.

However, the pickles should be naturally fermented instead of artificially acidified ones.

Umeboshi plums

Widely available in Japan for their healing and therapeutic properties,

Umeboshi plums also called Japanese salty plums or ume plums – are a source of probiotics but are less known in the Western world.

Soy based probiotic food products

Tempeh meat substitute

Tempeh is made from cooked and fermented soybeans and has a firm texture and nutty flavor not only is it dairy-free, but it's also high in protein and calcium, and an excellent source of probiotics. It is used as a meat substitute in many types of dishes such as tacos, chili, or a vegetarian stir-fry. Some brands of tempeh are also a good source of gluten-free probiotics

Miso paste

Miso is a traditional Japanese condiment made from either fermented rye, soybeans, rice, or barley. It is a lovely source of probiotics that includes *Lactobacilli* and *Bifidobacteria*. Commonly enjoyed as miso soup, it can also be used to make a delicious salad dressing.

Natto fermented soybeans

Much like tempeh, natto is made of fermented soybeans and contains bacillus, a healthy bacteria. It's also an excellent source of protein and provides several vitamins and minerals including iron, copper, magnesium, calcium, potassium, zinc, phosphorus, selenium, and vitamins C and K. Traditionally eaten as a breakfast food, natto can be consumed by itself, or it can be added it to virtually any dish.

Non-dairy probiotic drinks

Non-dairy kefir drink

A lightly fermented drink, kefir contains up to 30 microorganism strains, which gives it a higher level of probiotics than yogurt. Although dairy Kefir exists, any milk can be used to create it, including coconut milk,

almond milk, and others. Kefir and the associated probiotics have been shown to fight against harmful bacteria and *Candida* yeast and normalize gut function.

Kombucha probiotic tea drink

Kombucha is a dairy-free probiotic drink in the form of black tea. This delicious beverage is fermented by a combination of bacteria and yeast and it contains several types of probiotics including *Gluconacetobacter*, *Lactobacillus*, *Acetobacter*, and *Enterococcus faecium* bacterial strains as well as probiotic yeasts like *Zygosaccharomyces*. Kombucha is a refreshing and healthy replacement for soda or carbonated beverages.

Future perspectives and challenges

Non-dairy product preparation is necessities in today's world, however, the technological feasibility, development of technologies that are adaptable with development are not in line with each other. The ongoing research in this field is being carrying out at remarkable rate, however, it still is unconvincing when compared with the production of their dairy counterparts. Development of new, cost effective and adaptable technological moulds is an outrageous necessity to bring the non-dairy probiotic food products in line with their demand with today's population. While developing the non-dairy probiotics, certain important factors like stability, sensory attributes related to taste, consumer attraction and price factors need to be taken into consideration because these attributes play a key role is success of the product at commercial levels. As far as the technological issues that have an impact on the survival of probiotic strains throughout the manufacturing process and storage tenure should also be taken care of while preparing new probiotic products. Exploration of non-dairy probiotic products can be enhanced by

investigating their benefits for the mankind. An idea regarding the preparation of synbiotics by combining conventional prebiotics with non-dairy probiotics can also be explored for further advancement in this area.

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