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A Study on Suitable Non Dairy Food Matrix for Probiotic Bacteria - A Systematic Review

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Abstract

Fermentation by probiotic lactic acid bacteria makes food beneficial to the gut and has the potential to be therapeutic. Most probiotic products in the market are dairy based even as there is a growing demand for vegan probiotic foods. Though many studies on plant foods as a medium for probiotics have been carried out, only a few have been successful. Hence a systematic review of plant based probiotic products was conducted to identify the most suitable and acceptable plant foods medium for probiotic bacteria. For this, studies published and indexed in Google scholar between 2002-2017 were manually searched and analyzed. The study includes substrates from different food groups and combinations: cereals (22%), pulses (3%), cereal-pulse mix (5%), vegetables (19%), fruits (32%), combination (16%) and unconventional foods (3%). Soymilk was found to be the most promising among pulse-based substrates. The shelf life and viability of probiotics varied from 7 days to 4 weeks based on the initial count, temperature, time, strain of bacteria and substrate. Though a majority of the studies were carried out with fruit substrates, good probiotic count, improvements in nutritional properties, better acceptability and quicker fermentation time was found incereal based products. Hence, it is concluded that cereal based products is more suitable for the production of non-dairy probiotic products.

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Keywords

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Prebiotics;
Probiotic Products.

Introduction

Consumer interest in attaining wellness through diet has increased the demand for functional foods that deliver nutrition and modulate physiological functions in an advantageous way. Recent focus has been on foods that impact overall well-being

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and offer health benefits beyond just providing nutrients. The Food and Drug Administration (FDA) (2004) termed these as functional foods and are defined as foods or nutrients whose ingestion leads to important physiological changes in the body in addition to delivering nutrients. Food products, with such biologically active ingredients have the potential to be used as non-pharmaceutical alternatives and possess immense market potential. Of the various categories of functional foods, probiotics have received maximum attention both as a therapeutic in supplements and as health foods in beverages and yoghurts. Probiotics ferment sugars in food to produce lactic acid. The enzymatic action of probiotics modifies the nature of food in a way that favors the gastrointestinal tract. They are defined as "live microorganisms which when administered in adequate amounts confer a health benefit on the host".[2] This indicates that the organisms should be live and in sufficiently high numbers inorder to provide the intended health benefit.

Prebiotics, a group of complex carbohydrates can offer a synergistic effect and enhance probiotic growth when ingested together. Many of the prebiotics are plant components, naturally present in some foods like wheat, onion, garlic etc and are known to nourish the gut flora.[3] Therefore, the possibility that plant foods be used as substrates for probiotics in the preparation of healthy functional foods is promising. Furthermore, these plant foods are a source of indigestible polysaccharides that selectively stimulate healthy bacteria in the large intestine. Food formulations using plant foods as substrates for probiotic bacteria are a novel way for probiotic delivery. Fermentation of plant foods by probiotics makes the food easily digestible and imparts characteristic taste to the product. It degrades anti-nutritional factors, increases mineral bio-availability, improves protein digestibility in tannin-rich cereals and degrades flatulence-causing oligosaccharides.[1]

Among the multitude of probiotic products available in the market currently, most of them are dairy based in the form of yoghurts and fermented milk. Intolerance to lactose and the cholesterol content in milk are two major concerns related to fermented dairy products.[4] These are compelling reasons to explore the potential of plant foods in supporting probiotics. Such explorations can be crucial for commercial production of plant probiotic product. Hence a systematic review on plant foods that support the growth of probiotic bacteria and its suitability in developing probiotic products was conducted.

Table 1: Traditional Cereal based probiotic beverages

Name	Plant sources	Strains isolated	Country of origin	Reference
Boza	Wheat Rye Millet Maize	*L. plantarum* *L. acidophilus* *L. fermentum* *L. coprophilus*	Turkey	(8)
Bushera	Sorghum, millet flour	*Lactobacillus* *Lactococcus* *Leuconostoc* *Enterococcus* and. *Streptococcus L. brevis*	Uganda	(9)
Mahewu	Maize, sorghum, millet malt, wheat flour	*Lactococcuslactis* *subsp. lactis*	South Africa	(8)
Togwa	Maize flour finger millet malt	*Lactobacillus* *Streptococcus* *L. plantarumA6*	East Africa	(10)
Pozol	Maize	Molds, yeasts, bacteria	Mexico	(8)

Materials and Methods

Articles published and indexed in Google scholar during the period from 2002-2017 were located using Google scholar search engine. Those studies that used non-plant based medium for fermentation of probiotics were excluded from the study.

Keywords such as 'Non-dairy probiotic products', 'fermentation of cereals/millets', 'fruit/vegetable based probiotic products', 'acceptability of probiotic products' were used for the search.

Results

Thirty seven articles which studied the possibility of various plant sources as media for probiotic bacteria were located using Google scholar.

Plant foods are the oldest and most commonly fermented foodstuffs. Most of the traditional fermented foods are cereal based and non-alcoholic beverages (Table 1) like Boza (wheat, rye, millet, maize), Bushera (germinated sorghum and millet), mahewu (maize, sorghum, millet malt or wheat flour), pozol (maize) and togwa (maize and finger millet).[5] Wide array of fermented foods where cereals are often combined with legumes/pulses are dominant across different Indian states. A few cereal/cereal-pulse fermented food preparations like idli, appam, chole baturae and rice porridge are very popular and regularly consumed by Indians. Although these Indian food preparations warrant high heat treatment during cooking, many potential lactic acid bacteria have been isolated from these naturally fermented foods.[6,7]

Lactic acid bacteria have especially displayed good adaptability in cereals and other plant foods like vegetables and fruits that may be potentially prebiotic. Among the traditional cereal based fermented foods listed in this study, Lactobacillus sp.

Table 2: Traditional vegetable based fermented foods of India

Name	Plant source	Strain isolated	References
Inziangsang	Mustard leaf (*Brassica juncea*)	*L.plantarum* *L.brevis* *Pediococcusacidilactici*	(11)
Soidon	Bamboo Shoot (*Bambusa vulgaris*)	*L.brevis* *L.fallax* *L.lactis*	(12)
Gundruk	Rayosag (*Brassica rapa subsp. campestris var. cuneifolia*) mustard leaves (*Brassica juncea*) cauliflowerleaves (*Brassica oleracea*) cabbages (*Brassica oleracea var. capitata*) *Pediococcuspentosaceus*	*L. fermentum* *L. plantarum* *L.caseii* *L.caseiL.caseisubsp.* *pseudoplantarum*	(13)
Sinki	radish tap root (*Raphanusraphanistrum subsp. Sativus*)	*L. plantarum* *L.brevis* *L.caseii* *Leuconostocfallax*	(14)
Khalpi	Cucumber (*Cucumissativus*)	*L. plantarum* *L.brevis* *Leuconostocfallax*	(15)
Goyang	Maganesaag (*Cardaminemacrophylla Wild.*)	*L. plantarum* *L. brevis* *Lactococcuslactis* *Enterococcus faecium* *Pediococcuspentosaceus* *Yeasts Candidaspp.*	(16)

has been isolated from about 50% of the traditional cereal based probiotic beverages and about 60% of these beverages have maize either alone or as major ingredient along with other substrates.

High ranges of the Himalayan corridor in Northeast India and Nepal have a rich variety of fermented foods (Table 2) made from locally grown indigenous plant sources. Several strains of lactic acid bacteria

Table 3: Different plant based substrates used in various studies

S. No.	Plant food	Reference	S. No.	Plant food	Reference
	Cereals			**Fruits**	
1	Barley extract	(20)	19	Banana	(36)
2	Malt and Barley extract	(21)	20	Black currant	(37)
3	Oat bran	(22)	21	Cashew apple	(38)
4	Oat flakes	(23)	22	Cornelian cherry juice	(39)
5	Oat flour	(24)	23	Orange and Grape	(40)
6	Rice bran	(25)	24	Orange juice	(41)
7	Rice, germinated	(26)	25	Papaya	(42)
8	Sprouted wheat flour, sprouted wheat bran, oat & guar gum	(27)	26	Pomegranate	(43)
			27	Pineapple	(44)
			28	Sweet Lime, Sugar cane	(45)
	Pulses				
9	Soyabean	(28)	29.	Tomato juice	(46)
			30.	Watermelon:Tomato	(47)
	Cereal:Pulse				
10.	Ragi:soyabean (7:3)	(29)		**Combination of food groups**	
11.	Sorghum:Green gram	(30)			
			31.	Apple fibres carrot, apple, pear	(48)
	Vegetable				
12.	Ash gourd, Bottle gourd, Bitter gourd Snake gourd Pumpkin	(31)	32.	Barley flour, whey, sprouted green gram paste and tomato pulp	(49)
			33.	Italian millet flour, wheat flour, soya flour, skimmed milk powder, roasted bengal gram dal powder Oat bran,	(50)
13.	Bitter gourd, Bottle gourd, Carrot	(32)			
14.	Cabbage Cucumber, Cabbage, Red	(33)	34.	Unripe banana flour	(51)
15.	Cabbage	(4)	35.	Rice, whey, green gram and tomato	(52)
16.	Celery	(34)			
17.	Onion Shallot Garlic Sweet potato Radish, White Yam Yam bean Taro	(26)	36.	Soyprotein:passion fruit	(53)
				Others	
			37.	Coffee beans and spent coffee	(54)
18.	Red beets	(35)			

have been reportedly isolated from these foods. This offers validation about the suitability of plant foods in the preparation of probiotic products.

Lactic acid bacteria was the major species found to be isolated from fermented vegetable products. *L.plantarum* and *L.brevis* were found in about 83%of traditional vegetable-based fermented products considered in this study and in about 60% of them they were found to thrive together. *L.fallax* was isolated from about 50% of the products. *Enterococcus*, *Pediococcus* and yeasts were the other sp. isolated from these traditional products.

The ability of a probiotic to utilize plant food is very strain specific. Hence choosing the right plant source for the right probiotic as starter is essential, as right starter culture inhibits the growth of spoilage organisms and pathogens.[17] Fermentation improves the nutritional[18] as well as organoleptic properties[19] of foods. Therefore, fermentation of plant foods by potentially probiotic bacteria helps identify ideal plant substrates as a prebiotic source. It also helps identify an ideal substrate to organism combination in the development of non-dairy probiotic products.

Table 3 depicts various plant foods used in the chosen studies. Substrates from different food groups and combination that includes cereals (22%), pulses (3%), cereal pulse mix (5%), vegetables (19%), fruits (32%), combination (16%) and unconventional foods (3%) have been considered for the study.

Cereal, pulses and legumes form a major part of the diet and provide essential macronutrients apart from vitamins, minerals and fiber. As a non-digestible carbohydrate source, it can selectively stimulate the growth of *Lactobacilli* and *Bifidobacteria* present in the colon, thereby acting as prebiotics. Cereals contain water-soluble fiber (such as β-glucan and arabinoxylan), oligosaccharides (such as galacto- and fructo-oligosaccharides) and resistant starch, and thus have been suggested to validate the prebiotic concept.[55] Some strains of Lactobacillus require fermentable carbohydrates, amino acids, B vitamins, nucleic acids and minerals to grow. Hence, fermentation of cereals may be a cheap way to obtain a rich substrate that sustains the growth of beneficial microorganisms.

A number of studies has been carried out to test the ability of cereals in supporting probiotic growth. Majority (75%) of the cereal based fermented foods have included β-glucan rich oats and/or barley as medium for probiotic bacteria. Many scientists have studied the role of oat flours as a substrate in the formulation of nondairy probiotic products.[24,22,23] A probiotic beverage with 25% oat flakes, enzyme and *L. plantarum* LP09 has been reported[23] to have increased polyphenol availability and antioxidant activity by 25% and 70% respectively. Another symbiotic functional beverage providing 7.5 x 1010 CFU/mL of *L.plantarum* A28 was optimized and formulated from oat mash known for the β-glucan component.[24] The content of β-glucan remained constant throughout fermentation and storage indicating that the starter culture did not ferment β-glucan.

Barley β-glucan exhibited an increase in *Bifidobacteria*l counts in a double blind placebo controlled trial conducted on 52 adults in the age group of 39-70 years when ingested at 0.75g/d for 30 days.[20] This variability could be due to differences in the ability of the bacterial strain in utilizing β-glucan. Sharma, Mridula and Gupta (2014) developed a sprouted wheat based probiotic beverage providing a high count of about 10.43 log10cfu/ml of *Lactobacillus acidophilus* NCDC-14 using 7.86g sprouted wheat flour, 5.42g oat, 1.42g sprouted wheat bran and 0.6 g guar gum.[27]

Improved resistance to gut conditions as well as a change in the gut flora has also been reported in cereal based probiotic fermentations. Kedia *et al.*, (2009) reported utilization of oat bran by gut flora in an anaerobic fermentation model carried out with human fecal flora.[22] Further, a decrease in a few anaerobes and Clostridia and high butyrate production was also observed. A study reported significant improvement in viability of *L.plantarum* in the presence of malt and barley extracts in simulated Gastro intestinal condition.[21] Relief in symptoms of constipation after consumption of a cereal pulse health mix made from dietary prebiotic sources like wheat, oats, and soya bean has been reported earlier.[56] Along with probiotics, the reported health drink brought about a beneficial change in the fecal micro flora of elderly people.[57]

Among pulses, soymilk has received a lot of attention due to its protein quality. The suitability of soymilk for lactic acid fermentation has been reported earlier as well.[58] The possibility of formulating highly acceptable soymilk beverages through lactic fermentation with addition of suitable flavorings has been demonstrated.[28] They produced sweetened soymilk fermented with a mixture of *Streptococcus thermophilus, Bifidobacterium lactis* and *Lactobacillus acidophilus* and found products with pineapple and guava flavors highly acceptable. Fermentation of sorghum and green gram multimix was shown to markedly increase the crude proteins, free amino acids, soluble proteins and in vitro protein digestibility of the sorghum meal.[30]

Apart from cereals and pulses, several fruits and vegetables too have been used as a culture medium for probiotics. Two studies have explored fermentation of cabbage using probiotic bacteria on the lines of sauerkraut, a popular vegetable based fermented product.[4,33] However sauerkraut involves natural sequential fermentation whereas, in these studies probiotic bacteria has been deliberately added to bring about fermentation with desirable properties.

Tomato juice[46] and red beets[35] have been evaluated for its use as substrates by four lactic acid bacteria sp. namely *L.acidophilus* LA39, *L.plantarum* C3, *L.casei* A4 and *L.delbrueckii* 07. Both were found to ably support the growth of the four bacteria although the fermentation took a long time. Tomato beverage maintained viable counts better than red beets that showed a decline in counts of most lactic acid bacteria during 4 weeks storage at refrigerated temperature yet, maintained counts in the range of 10^6-10^8cfu/ml.

The suitability of celery for probiotics has been reported.[34] The authors found sugars in celery to be rapidly consumed by probiotics with higher acidity than beetroot. However, a profound sourness in the celery product hindered its commercial value.

The prebiotic composition and prebiotic activity of a variety of plant foods indigenous to Thailand was analyzed and found highest inulin content in garlic (41.72) followed by shallots (33.22%) and onion (27.17 %). *Lactobacillus acidophilus* grown on these extracts had the highest prebiotic activity scores comparable to that of commercial inulin.[26]

The current review also included a few (28%) studies on usage of gourd vegetables as substrates for probiotics. In one such study the authors demonstrated production of beneficial short chain fatty acids (SCFA) due to lactic acid fermentation of gourd vegetables. *L.fermentum* on ash gourd fibres had the maximum production of acetic and propionic acid that increased between 24-48hours fermentation. All other gourd vegetable fibres of bottle, bitter, snake gourds and pumpkin supported the production of acetic acid alone.[31]

While most studies on lactic acid fermentation of vegetables reported a probiotic count in the range of 10^8-10^{10}cfu/ml, one study alone reported very high counts of *L.acidophilus* LA-5 on cabbage (19.25x10^{14} CFU/ml), red cabbage(11.9x10^{14} CFU/ml), cucumber (18.6x10^{14} CFU/ml) and cucumber with onion juice (10.25x10^{14} CFU/ml). An increase from 10^5 to 10^{14} was reported within 8hrs fermentation.[33] This is much higher than that reported by other authors.

The technological challenges in producing non-dairy probiotic products are many. Yet, several researches have been conducted in the production of fruit based probiotic products. Fruits contain beneficial nutrients like minerals, vitamins, fibre and antioxidants and please the taste profile of all age groups making it ideal for development of a functional product.[37] About 63% of the studies on fruits have used citrus fruits like orange, sweet lime and cherries as substrates.

Nithyapriya and Vasudevan (2016) experimented in formulating probiotic papaya juice and found both *L. plantarum* and L. acidophilus to be capable of utilizing papaya juice. Good viability was obtained at 48hours with a 3% inoculum concentration.[42] An attempt was made to produce pomegranate based probiotic drink using four probiotic strains namely Lactobacillus acidophilus DSMZ 20079, *L. plantarum* DSMZ 20174, *L. delbrueckii* DSMZ 20006 and *L. paracasei* DSMZ 1599643. All strains had reached 108cfu/ml after a long fermentation period of 48 hours.

Fermentation in the shortest possible time is essential in the development of a probiotic product as rapid decrease in pH causes the lactic acid produced to act as a preservative. Hence the viability, acceptability and commercial feasibility of products with long fermentation as demonstrated in previous studies[43,46,35] is questionable. This is seconded by another study[47] which showed that extension of fermentation time over 24 hours in probiotication of watermelon-tomato, significantly decreased the viable counts of *L.fermentum* and *L.casei*. Both species were reported to survive during cold storage. Addition of sucrose was found to affect the survival of the lactic acid bacteria due to high acidity.

Few non-dairy probiotic products have been produced using a combination of ingredients from different food groups. Combining makes the product more balanced and wholesome. About 50% of the probiotic products studied here, have used a

Table 4: Shelf life of fruit and vegetable based probiotic products

S.No	Sample	Organism	Output	Shelf life	Reference
1.	Bitter gourd, Bottle gourd, Carrot	*L.acidophilus* NCDC 11, *L.plantarum* NCDC414 *Pediococcus pantosacous* MTCC 2819	8 log cfu/ml after fermentation for 72hours and pH dropped to 3.2	Gradual decrease during storage	(32)
2.	Carrot, apple, pear	*L.rhamnosus* IMC 501 *L.paracasei* IMC 502	Good growth on heat treated juices	Decreased to 10^6 during 4 week storage	(48)
3.	Cabbage	*L.plantarum* C3 *L.casei*A4	10^8 cfu/ml after 48 hr fermentation	*L.plantarum* C3 - 10^7 cfu/ml *L.delbrueckii* D7 – 10^5 cfu/ml after 4 weeks *L.casei* survived only till 2nd week	(4)
4.	Sweet Lime, Sugar Cane	*L.acidophilus*	10^8 cfu/ml after 24 hrs fermentation	Viable cells not detected in sweet lime 10^8 cfu/ml seen after 3 weeks in sugarcane	(45)
5.	Pineapple (sweetened and non	*L.casei* NRRL B442	8 log cfu/ml after 24 hr fermentation, pH dropped to 3.7	6 log cfu/ml in non sweetened and sweetened juice maintained till 42 & 28 days respectively	(44)
6.	Cashew apple	*L. casei* B-442	8.8 log cfu/ml at 16hrs fermentation	Cell counts increased from 8.41cful/ml to 8.72 cfu/ml at 21st day at 4 °C Remained above 8log cfu/ml throughout 42 days storage	(38)
7.	Cornelian cherry juice	3 Industrial strains (*L. plantarum* ATCC20174, *L. casei* ATCC 393 and L. rhamnosus ATCC 7469) 2 native strains (*L. casei* T4 and TD4)	8 log cfu/ml attained after fermentation in pH adjusted juice	Viability of Native strains (6 log cfu/ml) was better maintained than Industrial strain (4 log cfu/ml) after 7 days	(39)

cereal:pulse mix apart from other ingredients. This helps in overcoming the limiting amino acids in each group. Among them, some have also used a small ratio of dairy product namely whey[49,52] and milk co-precipitate[50] along with other plant foods. Although the authors have claimed them to be non-dairy probiotic products, the reason for inclusion of the dairy products has not been justified.

Storage and shelf life are essential parameters for commercial viability of probiotic products. Viability of probiotics depends on the initial count, temperature, time, strain of bacteria and the substrate. Effect of plant-based media on the viability of probiotic bacteria during storage is presented in Table 4. All studies reported refrigerated condition as ideal for storage of probiotic products.

Yoon, Woodams and Hang (2006) produced a probiotic cabbage based product with *L.plantarum* C3, *L.casei* A4 and L.delbrueckii D74. L..caseiA4 survived upto 2 weeks in refrigerated conditions while the other two survived till 4weeks. At the end of 4 weeks, a one-log decrease was observed in *L.plantarum* C3 while 3-log decrease in L.delbrueckii was seen which is more than that observed by most authors. Nature of the strain and its suitability to the substrate may be the reason for such differences. Cornelian cherry juice was fermented with a few native and industrial strains and found that native strains survived better than industrial strains during a short storage period of 7 days.[39]

Substrate specific differences in the cell viability in non-dairy probiotic products were noted during storage.[45] In a study that compared the storage characteristics of probiotic sugarcane juice and probiotic sweet lime juice concluded better viability of *L.acidophilus* in sugarcane than sweet lime. Sugarcane juice maintained good viability after 3 weeks of storage while sweet lime did not present any viable cells at 3 weeks.[45] In yet another study, non-sweetened probiotic pineapple juice has displayed longer shelf life when compared to sweetened probiotic pineapple juice.[44] This shows that the nutrient composition of the matrix could be an important contributor for sustainability of the organism and shelf life of the probiotic product.

Table 5: Acceptability of plant based probiotic products

S.no.	Probiotic product	Acceptability	Author
1.	Soy protein passion fruit dessert	Strong liking on 7 pt scale	(40)
2.	Fermented oat flakes beverage	Developed beverage had the features of a yogurt-like beverage Intensity of odor and flavor was enhanced when compared to the non-fermented control.	(14)
3.	Probiotic orange juice	Only 11% preferred the probiotic juice when compared to non fermented orange juice	(36)
4.	Fermented soy beverage with fruit flavouring	Pineapple and guava flavours highly acceptable Strawberry, kiwi and coconut flavours obtained score close to 6.0 (liked slightly) Hazelnut flavor was rejected (acceptance less than 5.0)	(21)
5.	Orange and grape juice with probiotic beads	Orange and grape juice with probiotic beads	(37)
6.	Barley based fermented food mixture with tomato flavour	mixture with tomato flavour acceptable even after one month storage	(39)

Although scientists have been successful in identifying non-dairy medium for probiotics, reports on its sensory effects and consumer acceptance has been sparse (Table 5). Luckow and Delahunty (2004b) compared the consumer preference for probiotic orange juice with the conventional orange juice. Majority showed preference for the conventional juice while only a small segment (11%) of people reportedly liked the probiotic orange juice.[41] The same authors had previously conducted a sensory evaluation of commercially processed probiotic blackcurrant juice at a mall.[33] Consumers were informed about the presence of a special ingredient in one sample added to improve the health. The consumers voted their most preferred juice to be the healthiest sample.

Consumer acceptance of orange and grape juices supplemented with probiotic beads was evaluated in a study.[40] Overall scores of 6.7 and 6.9 respectively was obtained with more than 80% of the consumers reporting good acceptance. This was lower than the acceptability scores for probiotic bead fortified strawberry yoghurt.[59] The authors reasoned that the beads in a fruit juice were considered more as a foreign particle than as a functional ingredient.

There seemed to be better acceptability for cereal/ pulse based probiotic products with fruit flavoring than fruit/ vegetable based products. An evaluation of barley based probiotic product concluded that the product was organoleptically acceptable to the human palate.[49]

A soya bean added probiotic product fermented by *Streptococcus thermophilus, Bifidobacterium lactis*, and *Lactobacillus acidophilus* with added fruit flavours has been evaluated for consumer acceptability. Among the different fruit flavourings, pine apple and guava flavoured probiotic beverage were reported to be significantly better liked than strawberry, kiwi and coconut flavoured ones.[28] The overall acceptability of a soyprotein:passion fruit based dessert on a 7 point hedonic scale was evaluated.[53] The probiotic nondairy dessert showed great sensory potential as majority indicated a strong liking for the product.

Discussion

Many plant foods have been studied for their suitability in the preparation of probiotic products. Oat based probiotic beverages seem to be most common and promising among cereals. This has been attributed to the presence of the component β-glucan. Addition of legumes and fruit to cereal based products improved the overall nutritional quality and enhanced the taste. Fruit flavor helps mask the acidic taste to some extent thereby making it more acceptable to the consumer. Carrot, beetroot and cabbage are the most popular vegetable probiotic products. The highest viable cell growth of 14 log colonies of *L.acidophilus*5 was reported in a cucumber based probiotic product, although most fruit/vegetable based probiotic products reported only 8 log colonies of probiotic bacteria after fermentation. Most fruit based products have taken longer time than cereals to undergo lactic acid fermentation. Plant based probiotic foods is slowly gaining consumer acceptance to be on par with dairy probiotic products. Specifically, cereal probiotic products seemed to have better acceptability than fruit/vegetable based ones. Good probiotic count, improvements in nutritional properties, better acceptability and quicker fermentation time makes cereal-based products more suitable for the production of non-dairy probiotic products.

A growing interest in non-dairy probiotic products is evident from the wide array of plant foods studied. Technological challenges and consumer preferences are two main hindrances for commercial scaling up of plant based probiotic product. Technological challenges in processing and optimization need to be addressed by the scientific community through continuous research and development. Greater exposure, commercial availability of plant probiotic foods and greater awareness about the health benefits of including plant-based probiotics regularly is needed for influencing consumer preference. Focusing on indigenous/familiar food sources as a carrier medium for probiotics will help alleviate fear associated with probiotic foods. Food matrices like cereals, fruits and vegetables being rich in oligosaccharides and dietary fibers, not only provide beneficial physiological effects but can also selectively stimulate the growth of colonic micro flora and act as prebiotics. This reiterates the need for more research in the development of symbiotic products which will presumably impart beneficial effects of both probiotics and prebiotics.

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Conflicts of Interest
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