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Review Article

Plant-based probiotics – Viability, Stability and Products properties: Review

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ABSTRACT

Consumers' health awareness is increasing, so food demands must be healthy or even be able to prevent disease. Therefore, health experts are increasingly focused on researching and proving the effectiveness of nutritious foods like probiotics. The types of probiotics, often developed based on dairy products, have been established to have beneficial effects. However, there are still problems when consuming dairy products, such as dairy allergies, lactose intolerance, and high cholesterol. Since then, using natural plant materials instead of milk has increased. Probiotic products are developed based on plants, such as cereals, legumes, fruits, and vegetables, to be suitable as plant bases for developing probiotic food lines. The goal of this review is to summarize and evaluate close investigations on plant probiotics linked to their ability to exist, stability, functional qualities, and influence on the physicochemical and organoleptic properties of these products, which will help guide future study. More than a hundred study studies published in Pubmed, NCBI, BMC Med, and other journals during the last two decades on the favorable benefits of phytochemicals were examined. Numerous result has shown that plant-based substrates are suitable for the culture of probiotic bacteria, opening up a new path for the development of creative and sustainable probiotic foods.

Keywords: Probiotic, Plant-based, Non-dairy probiotic, Viability

Introduction

The term "probiotic" (derived from Latin pro and Greek bios, "for life") was coined in 1953 by German scientist Werner Kollath to describe "the lively ingredients important for the healthy growth of existence.". Lilly and Stillwell used the word in another context in 1965, indicating that "materials secreted through one organism will stimulate the growth of another." More precisely, in 1992, Fuller described probiotics as "a live microbial feed complement that benefits the host by enhancing the balance of its gut microbiota.".[1] However, in 2002, the World Health Organization ("WHO") released a credible definition of probiotics and launched further research: living bacteria, when used in sufficient amounts, provide a fitness benefit to the host. This resulted in a microbiological discovery in the international market for probiotics. Several species of lactic acid bacteria (LAB) are being employed in the manufacture of probiotic meals, including lactic acid bacteria (*Lactobacillus, Bifidobacterium*), yeasts (*Saccharomyces cerevisiae*), and others (*Escherichia coli, Bacillus, Lactococcus*, and etc.).[2–4] Although there is no definitive confirmation on the number of probiotics required to have a beneficial effect on the host, many studies suggest that at least 10^6 to 10^7 Colony-forming unit per milliliter (CFU/mL) or g of probiotic cells must be present in the product at the time of consumption is necessary for host health, though there are few definitive assertions.[5]

These helpful bacteria must survive passage through the gastrointestinal tract in sufficient concentrations before attaching to and persisting in the intestinal epithelium.[6] The frequent use of probiotics is connected with numerous health benefits that have been extensively studied.[7] Humans' probiotic supply has been connected to traditional dairy meals such as fermented milk, yogurt, and cheese, with the majority of them being of animal origin. Milk has unique nutritional qualities, particularly its high lactose content, which helps bacteria to survive and grow. Furthermore, some dairy products, such as fermented milk and cheese, benefit from preservation because of properties such as pH and buffering capacity, dense network structure, and high-fat content. Microorganisms are protected while they transit through the digestive system, particularly from the acidic environment of the stomach. Despite being a great microbe carrier, plant-based probiotic meals are becoming increasingly popular for a variety of reasons, including protein allergy, lactose intolerance, food-related lifestyle changes, vegetarianism, ethical concerns, and negative environmental effects.[6] These alternatives are high in dietary fiber, important minerals, and protein, all of which contribute to a balanced diet and may reduce the risk of chronic diseases.[8,9] Dairy consumption is limited in several emerging countries, such as Japan, China, and portions of Africa, due to cultural and economic reasons. This has prompted research into other delivery mechanisms for probiotic bacteria, such as lowering their reliance on milk components or perhaps replacing milk entirely with plant-based substrates such as cereals, fruits, and veggies. As a result, much research has been conducted to investigate the potential of plant-based probiotics (Table 1). Plants have emerged as promising candidates to replace dairy as a substrate for probiotic delivery. Beyond their fundamental role as a food source, plants have long been recognized for their medicinal properties, leading to extensive research on herbal remedies. The substantial health benefits associated with plant-based diets, attributed to the presence of phytochemicals, have fueled interest in exploring plant-based matrices for probiotics. These plant-based foods, rich in fiber, minerals, proteins, starch, vitamins, phytochemicals, antioxidants, and other bioactive compounds, have been linked to the prevention of various diseases.[8,9] Juices, desserts, and cereal-based products enriched with probiotics offer potential as

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alternative carriers. Advances in food technology have enabled the modification of plant-based matrices by manipulating their composition, such as adjusting pH and enhancing growth media.[10] These modifications can render plant matrices ideal for probiotic cultivation, as they inherently contain beneficial nutrients like minerals, vitamins, fiber, and antioxidants while being free from dairy allergens that may limit consumption in certain populations.[11]

Substrate carries beneficial bacteria

Aside from dairy probiotic goods, customers are particularly interested in probiotic foods manufactured from fruits due to their diverse flavors, which appeal to people of all ages. Furthermore, they are regarded as nutritious and meet the sensory needs of consumers when compared to dairy foods.[12,13] However, cell viability is an important property of cell function and is primarily regulated by the makeup of the food matrix.[14]

Viability of probiotics

To ensure a sufficient number of live probiotic cells at the time of consumption, probiotics must be able to endure extreme environmental conditions during food processing and storage, such as pH during fermentation, cold or freeze temperature, etc.[15] Analyzing the relationship between dietary substrates and probiotics could help to increase microbial viability and broaden the creation of probiotic food products.[16]

When researching and developing new probiotic food products, the selection of microorganisms is also one of the most challenging that food manufacturers need to face.[17] The main factors for selecting probiotic organisms include pathogenicity, infectiousness, toxicity, metabolic activity, and intrinsic characteristics such as antibiotic resistance.[17,18] Therefore, probiotic strains should be thoroughly tested by taking all the above parameters before being put into food products. Furthermore, probiotic strains used alone or in combination should also be carefully considered as the quantity and compounds produced after fermentation may differ thereby affecting the quality of the final product.[19] At the same time, potential probiotic strains must also be selected with great care as it can be more difficult to maintain the viability of probiotics in the plant matrix than in milk.[20] The reliance on dairy-derived probiotics necessitates the development of alternative strains better suited for plant-based products. The limitations of dairy probiotics in these environments include a lack of necessary nutrients, unfavorable pH levels, and insufficient buffering capacity, all of which can impede their growth and survival. When traditional probiotics stem from dairy, recent research suggests that fruits and vegetables hold promise as ideal carriers due to their wealth of minerals, vitamins, antioxidants, and fiber.[21] This abundance of nutrients may contribute to a more resilient cell wall in the LAB used as probiotics. This stronger cell wall, in turn, allows the bacteria to better adapt to the challenging environment within plant-based products, including low humidity and the presence of antimicrobial compounds. Fruits, such as apples, guavas, bananas, and melons, are to be carriers of probiotics and their strong adhesion ability to fruit tissue.[22] Plant tissues provide favorable conditions for microbial colonization. Fruits, vegetables, and legumes contain indigestible fibers such as cellulose which are good sources of nutrients, and the presence of ridges may have a protective effect on beneficial bacteria as they move through the intestinal tract.[14] Therefore, plant-based substrates including juices, pickles, etc., can be considered as potential carriers to deliver probiotics to humans.

Processing, packing, handling, and shipping are all crucial procedures that influence probiotic viability and survival. Finally, to have a therapeutic effect on the body, probiotics must first survive stomach acid and intestinal bile salts. However, preserving the viability and stability of probiotic bacteria under adverse environmental conditions during food production, storage, and marketing continues to be a significant challenge in probiotic product research and development. Optimizing production circumstances, such as manufacture, packing, and preservation till the products reach consumers, is critical to their survival. In addition, artificial flavors and colorants, food additives, preservatives, enzymes, nitrite percentage, inoculation ratio, strain type, pH, water activity, salt concentration, sugars, and microorganism-killing chemicals such as hydrogen peroxide can all have an impact on the viability of beneficial bacteria.[18] Several research in food applications have revealed that *Lactobacillus* and *Bifidobacterium* are acceptable strains of bacteria for cultural media due to their high vitality. Probiotics' stability should be considered during manufacture, processing, transit, and storage.[23] Several probiotic carrier technologies, including bacterial immobilization or, more specifically, microencapsulation[24] and spray drying,[25] have been identified as a potential way to boost beneficial bacteria survival rates, particularly in goods with severe environments. One of the difficulties of utilizing probiotics is guaranteeing their survival in the harsh acidic environment of the stomach. Modern technologies, such as probiotic cell microencapsulation, overcome this issue. This method involves encasing probiotic cells in safe and common materials, which successfully increases their vitality. Furthermore, some research suggests that fixation, another approach, might offer some protection from stomach acid, albeit they may come at the cost of diminished viability.[26,27]

On the other hand, there is research that shows that adding prebiotics (the type of fiber found in vegetables, fruits, and legumes that humans cannot digest, but gut bacteria can) has a positive effect on maintaining the number of beneficial bacteria.[28] The effect of prebiotics on probiotic survival appears to depend on the strain. To improve product stability and quality, stabilizers can also be used such as gum and carrageenan, etc. Before processing raw materials, there are stages such as soaking, rubbing or bleaching, etc., or heat treatment, which are involved during processing that may affect the solubility and extraction ability of the original vitamins, minerals as well as intrinsic compounds (e.g. heat-sensitive compounds may be degraded, proteins may be denatured and some water-soluble vitamins, etc.).[29] Therefore, several new techniques have been researched and used such as ultrasound, pulsed electric field, high-intensity ultrasonic irradiation, resistance heating, and high-pressure assimilation to produce probiotic foods on plant bases to increase the stability, keeping the good properties of the raw materials, inactivating microorganisms and enzymes, increasing the viability of these beneficial bacteria.[7] The above issues need further attention and research to improve the survival and properties of probiotic products.

Substrate properties from plants

Food carrier substrates not only affect the viability of beneficial bacteria during food processing and preservation but also affect the survival of the gastrointestinal (GI) tract. Fruits and vegetables are considered healthy food groups, which provide various energy and nutrients. At the same time, they contain a lot of fiber, vitamins, and minerals, which are a source of chemical substances that function as antioxidants, plant estrogens, anti-inflammatory agents, and many other compounds. Therefore, fruits and vegetables are considered an ideal carrier for some functional components.[30] They are high in nutrients and sugars, which are important for the growth of probiotics, and combined with rapid movement through the harsh acidic conditions of the stomach lead to an increased viability of probiotic cells.[31] Unlike dairy products, these plant-based products do not contain cholesterol, are low in saturated fat and high in unsaturated fat, and do not cause symptoms of lactose allergy, which affects negatively consumers. The fruit is healthy, has an attractive taste, and adapts to all consumer groups.[32] Several plant-based probiotic products are researched, developed, and commercialized such as fruit juice, puree, dried fruits and vegetables, fermentation, etc. from pineapple, cranberry, strawberry, lemon, mangoes, grapes, apples, olives, carrots, beets, and oranges. Thus, it shows the growth potential of these plant substrates, as well as their ability to satisfy the market for vegetarians. Although fruits and vegetables are a potential substrate when applied to probiotic products, which are also important to consider the microbial strains suitable for each type of substrate, which influences the properties of the product, stability, and final microbial count upon consumption.[13] The essential, large proportion and beneficial bacteria commonly used in the development of many probiotic products from fruits and vegetables are usually *Lactobacillus* and *Bifidobacteria* (e.g. *Lactobacillus casein, Lactobacillus plantarum, Bifidobacterium lactis, Bifidobacterium breve, Bifidobacterium animalism*, etc.). The research of Fenech et al.[33], which reported the association of several micronutrients with genomic stability, and five micronutrients retinol, vitamin E, folate, nicotinic acid, and calcium showed effects to protect against damage and repair genomes; these micronutrients can be found in fruit juices. Besides the fact that fruits contain essential nutrients, there are still factors that affect beneficial bacteria including food parameters, processing parameters, and microbiology.

Grains, a commonly consumed food around the world, are the main source of energy, protein, B vitamins, and minerals for consumers. The most widely used grains are rice, wheat and corn, barley, sorghum, millet, oats, wheat, and rye. Grains are also a good source of various phytochemicals such as phenolic acids, flavonoids, phytosterols, and ferulic acids; and contain vitamins such as B1, B2, B3, E, minerals, and dietary fiber. Based on these properties make cereals a potential raw material to produce probiotic foods.[34] The method of grain processing that has existed for a long time and is still maintained today is fermentation, which is often common in countries such as Asia and Africa to produce beverages and porridge.[35] The effects of this fermentation process reduce phytosterols, glycosylated soya-saponin, tocopherols and significantly reduce isoflavones due to the hydrolysis of glucosides to aglycones. On the other hand, this process releases phytochemicals and increases the content of available minerals.[34] The strength of cereal substrates is that they contain fiber and indigestible carbohydrates such as oligosaccharides, which have the potential as prebiotics as the source of nutrients for the growth of beneficial bacteria.[35] Therefore, grain fermentation could be an efficient and inexpensive way to obtain a potential substrate that maintains a favorable environment for beneficial bacteria.[36] Fermented cereal products have existed and been used for a long time, but their potential to participate in the fermentation process has only been focused on in recent years.

Soybeans contain many biologically functional components that can be grouped into isoflavones, saponins, lignans, cinnamic acid derivatives, terpenes, and sterols; they also contain anti-nutritional factors such as phytates, lectins, etc. However, fermentation leads to chemical changes and reduction of soybean components such as phytate and trypsin inhibitors, copper by hydrolyzing tannic acid through tannase activities, lectins are destroyed, and this process can also reduce the sugars stachyose and raffinose which can cause bloating, cramps, and flatulence.[19] For example, in the probiotic *Lactobacillus acidophilus* LA-2 used in soy protein bars, the cells were microencapsulated and lyophilized so that L. *acidophilus* LA-2 remained in high quantity during 14 weeks of storage at 4ºC and showed a high level of *α*-galactosidase activity at 5.0 U/mg.[37] Soy proteins and peptides have shown potential applications as good carriers to protect beneficial bacteria from the acidic environment in the intestines and bile.

In addition, substrate selection such as prebiotics, and parameters such as temperature, environment, and packaging should also be considered, and they have an impact on the quality of the probiotic product. Wang, Yu, and Chou (2004) compared different drying methods to produce fermented soybeans with probiotics, and the results showed that the microorganism was less susceptible, packed in multi-layer bags and stored at 4ºC, the viability of beneficial bacteria with the freeze-drying method is better than spray drying.[38] Soy yogurt formulation was also studied based on the response surface method to study the interaction effects of factors such as FOS soluble fiber concentration, *Streptococcus salivarius* subsp. *thermophilus* NCDC11 - L. *acidophilus* NCDC11 inoculant size, temperature fermentation to fermentation time, structure, whey separation, overall acceptability of the product.[39] Research has shown that the optimized product has a good structure, low whey separation, and good nutritional and organoleptic properties. A survey by Yeo and Liong (2010) studied probiotic soy drinks with prebiotics added. Viability of six probiotics (*L. Acidophilus* feet DC 2113, *L. Acidophilus* toes DC 8033, *L. Acidophilus* ATCC 4356, *L. Casei* ATCC 393, *B. Longum* feet DC 8943 and B. *Longum* feet DC 8643) when combined with FOS, inulin, mannitol, maltodextrin or pectin have been reported. All strains showed high bacterial counts and viability in soymilk products after 24 hours of storage.[40] In another study, a higher yield of peptides and amino acids by proteolysis was found in fermented soy milk produced by L. *acidophilus* compared with other strains. L. *acidophilus* FTCC 0291 can utilize the available reducing sugars in soybeans and hydrolyze oligosaccharides into simple sugars for growth. This may account for the high *α*-galactosidase specific activity and viability that can maintain 10^7 CFU/g in soy cream cheese during storage at 4°C and 25°C for 20 days.[41]

Safety, physicochemical and organoleptic properties

Overall, with careful preparation and screening, bacterial strains are safe to use and have beneficial effects on the host. However, in starting materials, there may be opportunistic pathogens that can withstand temperature, which can compete/negatively affect the survival of beneficial bacteria and affect product quality. For example, *Enterobacteriaceae* has been shown to occur in soft drinks from quinoa that have been heat treated but not fermented. After fermentation of quinoa beverage with Lb. *Plantarum* DSM 9843, pH dropped below 4, the number of *Enterobacteriaceae* was lower than the limit of detection, and the number of *lactobacilli* was reduced after 28 days.[42] In another study, L. *plantarum* Tennozu-SU2 and L. *lactis* BF1 were tested for antagonistic activity against the pathogens *Salmonella typhimurium* and *Listeria monocytogenes* during and after soybean milk fermentation, the results showed that they may be desirable starter strains to produce safe soymilk products.[43] One research addressed the possibility of using hemp seed extract (*Cannabis sativa L.*) to inhibit the growth of select pathogenic gut bacteria and biofilm formation of risk-causing bacteria serious of food diseases - *Staphylococcus aureus*, the selective antibacterial activity of hemp extracts against pathogenic strains and no inhibitory effect on the growth of probiotic strains of the genus *Bifidobacterium* and *Lactobacillus.*[44] Probiotics can be stimulated to produce antimicrobial compounds by certain oligosaccharides. For example, *β*-glucooligosaccharides (*β*-GOS) derived from barley *β*-glucan showed no significant growth of some pathogens on it compared with the prebiotic fructooligosaccharide (FOS), and the substrate inulin, *β*-GOS can selectively regulate the growth of probiotics (e.g., *Lactococcus lactis* subsp. *lactis*, *Lactobacillus reuteri*, and *Pediococcus acidilactici*) and the antibacterial activity due to nisin - Z production is increased by approximately 25% compared with glucose by *Lactococcus lactis.*[45] Nissen and coworkers, in 2020, showed that some bioactive compounds produced during fermentation (e.g., acetate, propionate, and butyrate) promote the selective growth of beneficial bacteria, while others such as terpenes inhibit the growth of harmful bacteria.[46] Microbial fermentation has been shown to improve microbial safety.

In addition to technical and technological challenges, some limitations still exist when it comes to the production of plant-based probiotic foods in terms of organoleptic properties and overall acceptability. Therefore, sensory evaluation in probiotic products of plant origin is important in determining their commerciality. One of the important things needed to be able to optimize the processes and in the right direction for the manufacture of this product should be to consider the sensory acceptance of consumers in terms of appearance, aroma, texture, or taste during the development of non-dairy probiotic products.[23] Interactions between food substrates and different microbial strains can affect the sensitization properties of plant probiotic products. Due to the production of different metabolites, such as lactic acid, by different strains during fermentation and storage, the properties of texture, odor, taste, and color can be better or worse. Therefore, the organoleptic properties and acceptability of plant-based probiotics during production and storage are important to the appropriate strains of probiotics and their survival rates in food products.

During the manufacturing process, carbohydrates in fruits, vegetables, grains, and legumes are fermented by probiotic bacteria, releasing CO_2 and producing alcohol. There is research showing that fermented fruit juices contain aroma ("perfume", "dairy") and taste ("sour", "savory") characteristic of functional ingredients. In addition, they are described to contain some characteristic flavors that regular juices do not have such as "dairy", "medicinal" and "dirty".[47] Depending on the type of fruit, the probiotic organism, the storage temperature, and the addition of prebiotics and protective agents, they can affect the organoleptic properties of probiotic juices.

Table 1: Some plant-based probiotic fermented foods have been studied around the world.

Type	Name	Main ingredient	Isolated probiotic strains	Reference
Cereals and legumes	Boza	Wheat, rye, millet mix with sacarine	LAB: *Lactobacillus acidophilus, Lb. fermentum, Lb. coprophilus, Lb. brevis, Leuconostoc reffinolactis, Leuconostoc mesenteroides* Yeast: *Saccharomyces cerevisiae, Candida tropicalis, Candida glabata, Geotrichum penicilliatum, Geotrichum candidum*	Blandino *et al.*[49]
	Kefir	Soybean	*Lb. brevis, Lb. kefir, Lb. mesenteroides, Lb. helveticus, Kluyveromyces maxianus and Kluyveromyces lactis*	Simova *et al.*[50]
	Tempeh	Soy milk	*Lb. rhamnosus, Bifidobacterium* spp.	Yudianti *et al.*[51]
	Bushera	Sorghum or millet flour	*Lactobacillus, Lactococcus, Leuconostoc, Enterococcus, Streptococcus*	Muyanja *et al.*[52]
Fruits and vegetables	Pickled cabbabe	cabbabe	*Pediococcus pentosaceus, Tetragenococcus halophilus*	
	Shalgam	Black carrot, bulgur wheat flour, sourdough, salt, radish, and water	*Lb. plantarum, Lb. paracasei subsp. paracasei, Lb. brevis, Lb. fermentum*	Tanguler *et al.*[53]
	Kimchi	Napa cabbage and Korean radish	*Leuconostoc mesenteriodes, Leu. carnosum, Lactobacillus curvatus, Lb. pentosus, Weissela kimchi, W. cibaria and Pediococcus pentosaceus*	Chang *et al.*[54]
	Paocai	Cabbage, celery, cucumber and radish	L. *pentosus, L. plantarum, Leuconostoc mesenteroides, L. brevis, L. lactis, and L. fermentum*	Dallal *et al.*[55]
	Ca muoi	Tomato	*Lb. fermentum, Lb. pentosus, Lb. plantarum*	Wouters *et al.*[56]
Fruit	Olive	Olive	*L. plantarum, L. brevis, L. pentosus, P. cerevisiae, L. mesenteroides*	Randazzo *et al.*[57]
	Tempoyak	Durian	*Lb. mali, Lb. brevis, Lb. mesenteroides, Lb. fermentum*	Abegaz[58]
	Yan-tao zih	Peach	*L. mesenteroides, W. cibaria, L. lactis subsp. lactis, W. paramesenteroides, E. faecalis, W. minor, L. brevis*	Chen[59]

Some studies have shown that the overall acceptability of fruit juices is not affected by probiotics, for example, pineapple juice containing *Lactobacillus reuteri* does not have negative flavors. The other researchers have looked at a technique (flavor-masking techniques) that can increase consumer preference as well as sensory acceptance, which is to use flavors and volatile compounds in fruit juices to mask the taste due to the existence of beneficial bacteria. Even though, several tropical fruits contain special flavors that can positively contribute to the sensory quality of the final product. In the research in 2006, Luckow et al. stated that pineapple, mango, or passion fruit juice, with 10% (v/v) spiked, had a positive effect on the aroma and taste of the plant-based probiotics.[48]

Conclusion

In conclusion, this analysis has demonstrated the enormous potential of plant-based matrices as carriers for probiotic microorganisms. While dairy-based products have long dominated the probiotic industry, rising demand for plant-based alternatives due to dietary constraints, allergies, and ethical concerns has prompted studies in this field. Plant-based matrices provide various advantages, including the existence of natural prebiotics, different nutritional profiles, and the potential to produce allergen-free products. However, problems such as the complicated composition of plant-based matrices, the harsh gastrointestinal environment, and the requirement for effective encapsulation and delivery systems persist.

However, challenges like as complex plant-based matrices, hostile gastrointestinal environments, and the need for appropriate encapsulation and delivery mechanisms remain. Future research should concentrate on enhancing formulation and processing procedures for plant-based probiotic products to increase probiotic bacteria viability, stability, and functionality. Furthermore, extensive research is required to assess the influence of plant-based probiotics on human health, specifically gut microbiota regulation and immune function. By solving these problems and capitalizing on the potential given by plant-based probiotics, we can create creative and sustainable food items that support gut health and general health.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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References

1. McFarland L V. From yaks to yogurt: the history, development, and current use of probiotics. Clin. Infect. Dis. 2015;60(suppl_2):S85-S90.
2. Neffe-Skocińska K, Rzepkowska A, Szydłowska A, Kołożyn-Krajewska D. Trends and possibilities of the use of probiotics in food production. In: Alternative and Replacement Foods. Elsevier; 2018:65-94.
3. Berebon, D. P., Attama, A. A., Ofokansi, K. C., Evurani, S. A., Gugu, T. H., Onyi, P. N., Eze, C. O., Onah, A. I., Onwusoba, R. C., & Nwodo, U. Molecular identification of lactic acid bacteria isolated from Nigerian traditional fermented foods and beverage with in vitro probiotic potentials. Trop J Nat Prod Res. 2022;6(2):236-243.
4. Oshoma CE, Allen OA, Oyedoh PO. Growth enhancement of lactic acid bacteria for production of bacteriocin using a local condiment supplemented with nitrogen sources. Trop J Nat Prod Res. 2020;4(8):411-416.
5. Montanari, S. R., Júnior, B. R. D. C. L., Martins, M. L., Ramos, A. M., Binoti, M. L., Campos, R. C. D. A. B., Campos, A. N. D. R., Martins, E. M. F. In vitro gastrointestinal digestion of a peanut, soybean, guava and beet beverage supplemented with *Lactobacillus rhamnosus* GG. Food Biosci. 2020;36:100623.
6. Ranadheera CS, Naumovski N, Ajlouni S. Non-bovine milk products as emerging probiotic carriers: Recent developments and innovations. Curr Opin Food Sci. 2018;22:109-114.
7. Aydar EF, Tutuncu S, Ozcelik B. Plant-based milk substitutes: Bioactive compounds, conventional and novel processes, bioavailability studies, and health effects. J Funct Foods. 2020;70:103975.
8. Deng Y, Misselwitz B, Dai N, Fox M. Lactose intolerance in adults: biological mechanism and dietary management. Nutrients. 2015;7(9):8020-8035.
9. Panda SK, Shetty PH. Innovations in Technologies for Fermented Food and Beverage Industries. FMFS. Springer; 2018.
10. Betoret, N., Puente, L., Dıaz, M. J., Pagán, M. J., Garcıa, M. J., Gras, M. L., Martínez-Monzó, J., Fito, P. Development of probiotic-enriched dried fruits by vacuum impregnation. J Food Eng. 2003;56(2-3):273-277.
11. Sheehan VM, Ross P, Fitzgerald GF. Assessing the acid tolerance and the technological robustness of probiotic cultures for fortification in fruit juices. IFSET. 2007;8(2):279-284.
12. do Espirito Santo AP, Perego P, Converti A, Oliveira MN. Influence of food matrices on probiotic viability–A review focusing on the fruity bases. Trends Food Sci Technol. 2011;22(7):377-385.
13. Rivera-Espinoza Y, Gallardo-Navarro Y. Non-dairy probiotic products. Food Microbiol. 2010;27(1):1-11.
14. Ranadheera R, Baines SK, Adams MC. Importance of food in probiotic efficacy. Int. Food Res. 2010;43(1):1-7.
15. Ranadheera, C. S., Evans, C. A., Baines, S. K., Balthazar, C. F., Cruz, A. G., Esmerino, E. A., Freitas, M. Q., Pimentel, T. C., Wittwer, A. E., Naumovski, N., Graca, J. S., Sant'Ana, A. S., Ajlouni, S., Vasiljevic, T. Probiotics in goat milk products: Delivery capacity and ability to improve sensory attributes. Compr Rev Food Sci Food Saf. 2019;18(4):867-882.
16. Shori AB. Influence of food matrix on the viability of probiotic bacteria: A review based on dairy and non-dairy beverages. Food Biosci. 2016;13:1-8.
17. Chaturvedi S, Chakraborty S. Review on potential non-dairy synbiotic beverages: A preliminary approach using legumes. Int J Food Sci Technol. 2021;56(5):2068-2077.
18. Tripathi MK, Giri SK. Probiotic functional foods: Survival of probiotics during processing and storage. J Funct Foods. 2014;9:225-241.
19. Champagne CP, Tompkins TA, Buckley ND, Green-Johnson JM. Effect of fermentation by pure and mixed cultures of *Streptococcus thermophilus* and *Lactobacillus helveticus* on isoflavone and B-vitamin content of a fermented soy beverage. Food Microbiol. 2010;27(7):968-972.
20. Valero-Cases E, Cerdá-Bernad D, Pastor JJ, Frutos MJ. Non-dairy fermented beverages as potential carriers to ensure probiotics, prebiotics, and bioactive compounds arrival to the gut and their health benefits. Nutrients. 2020;12(6):1666.
21. Soccol, C. R., Vandenberghe, L. D. S., Spier, M. R., Medeiros, A. B. P., Yamaguishi, C. T., Lindner, J. D. D., Pandey, A., Thomaz-Soccol, V. The potential of probiotics: a review. Food Technol. Biotechnol. Published online 2010.
22. Martins EMF, Ramos AM, Vanzela ESL, Stringheta PC, de Oliveira Pinto CL, Martins JM. Products of vegetable origin: A new alternative for the consumption of probiotic bacteria. Food Res. Int.. 2013;51(2):764-770.
23. Min M, Bunt CR, Mason SL, Hussain MA. Non-dairy probiotic food products: An emerging group of functional foods. Crit Rev Food Sci Nutr. 2019;59(16):2626-2641.
24. Lopes, L. A. A., Carvalho, R. D. S. F., Magalhães, N. S. S., Madruga, M. S., Athayde, A. J. A. A., Portela, I. A., Barão, C. E., Pimentel, T. C., Magnani, M., Stamford, T. C. M. Microencapsulation of *Lactobacillus acidophilus* La-05 and incorporation in vegan milks: Physicochemical characteristics and survival during storage, exposure to stress conditions, and simulated gastrointestinal digestion. Int. Food Res. 2020;135:109295.
25. Lipan, L., Rusu, B., Sendra, E., Hernández, F., Vázquez-Araújo, L., Vodnar, D. C., Carbonell-Barrachina, Á. A. Spray drying and storage of probiotic-enriched almond milk: probiotic survival and physicochemical properties. J Sci Food Agric. 2020;100(9):3697-3708.
26. Ephrem E, Najjar A, Charcosset C, Greige-Gerges H. Encapsulation of natural active compounds, enzymes, and probiotics for fruit juice fortification, preservation, and processing: An overview. J Funct Foods. 2018;48:65-84.

27. Mantzourani I, Nouska C, Terpou A, Alexopoulos A, Bezirtzoglou E, Panayiotidis MI, Galanis A, Plessas S. Production of a novel functional fruit beverage consisting of cornelian cherry juice and probiotic bacteria. Antioxidants. 2018;7(11):163.
28. Santos, D. C., Filho, J. G. D. O., Santana, A. C. A., Freitas, B. S.M. D., Silva, F. G., Takeuchi, K. P., Egea, M. B. Optimization of soymilk fermentation with kefir and the addition of inulin: Physicochemical, sensory and technological characteristics. LWT-Food Sci Technol. 2019;104:30-37.
29. Silva ARA, Silva MMN, Ribeiro BD. Health issues and technological aspects of plant-based alternative milk. Int. Food Res. 2020;131:108972.
30. Slavin JL, Lloyd B. Health benefits of fruits and vegetables. Adv Nutr. 2012;3(4):506-516.
31. Kandylis P, Pissaridi K, Bekatorou A, Kanellaki M, Koutinas AA. Dairy and non-dairy probiotic beverages. Curr Opin Food Sci. 2016;7:58-63.
32. Panghal A, Janghu S, Virkar K, Gat Y, Kumar V, Chhikara N. Potential non-dairy probiotic products–A healthy approach. Food Biosci. 2018;21:80-89.
33. Perricone M, Bevilacqua A, Altieri C, Sinigaglia M, Corbo MR. Challenges for the production of probiotic fruit juices. Beverages. 2015;1(2):95-103.
34. Prado FC, Parada JL, Pandey A, Soccol CR. Trends in non-dairy probiotic beverages. Int. Food Res. 2008;41(2):111-123.
35. Vijaya Kumar B, Vijayendra SVN, Reddy OVS. Trends in dairy and non-dairy probiotic products-a review. J Food Sci Technol. 2015;52:6112-6124.
36. Sridharan S, Das KMS. A study on suitable non dairy food matrix for probiotic bacteria–a systematic review. CRFS. 2019;7(1):5-16.
37. Chen M, Mustapha A. Survival of freeze-dried microcapsules of α-galactosidase producing probiotics in a soy bar matrix. Food Microbiol. 2012;30(1):68-73.
38. Wang YC, Yu RC, Chou CC. Viability of lactic acid bacteria and bifidobacteria in fermented soymilk after drying, subsequent rehydration and storage. Int J Food Microbiol. 2004;93(2):209-217.
39. Pandey SM, Mishra HN. Optimization of the prebiotic & probiotic concentration and incubation temperature for the preparation of synbiotic soy yoghurt using response surface methodology. LWT-Food Sci Technol. 2015;62(1):458-467.
40. Yeo SK, Liong MT. Angiotensin I-converting enzyme inhibitory activity and bioconversion of isoflavones by probiotics in soymilk supplemented with prebiotics. Int J Food Sci Nutr. 2010;61(2):161-181.
41. Liong M, Easa AM, Lim P, Kang J. Survival, growth characteristics and bioactive potential of *Lactobacillus acidophilus* in a soy-based cream cheese. J Sci Food Agric. 2009;89(8):1382-1391.
42. Paz PC, Janny RJ, Håkansson Å. Safeguarding of quinoa beverage production by fermentation with *Lactobacillus plantarum* DSM 9843. Int J Food Microbiol. 2020;324:108630.
43. Haraguchi, Y., Goto, M., Kuda, T., Fukunaga, M., Shikano, A., Takahashi, H., & Kimura, B. Inhibitory effect of *Lactobacillus plantarum* Tennozu-SU2 and *Lactococcus lactis* subsp. *lactis* BF1 on *Salmonella typhimurium* and *Listeria monocytogenes* during and post fermentation of soymilk. LWT-Food Sci Technol. 2019;102:379-384.
44. Frassinetti S, Gabriele M, Moccia E, Longo V, Di Gioia D. Antimicrobial and antibiofilm activity of *Cannabis sativa* L. seeds extract against *Staphylococcus aureus* and growth effects on probiotic *Lactobacillus* spp. LWT-Food Sci Technol. 2020;124:109149.
45. Lee JM, Jang WJ, Lee EW, Kong IS. β-glucooligosaccharides derived from barley β-glucan promote growth of lactic acid bacteria and enhance nisin Z secretion by *Lactococcus lactis*. LWT-Food Sci Technol. 2020;122:109014.
46. Nissen L, di Carlo E, Gianotti A. Prebiotic potential of hemp blended drinks fermented by probiotics. Int. Food Res. 2020;131:109029.
47. Luckow T, Delahunty C. Which juice is 'healthier'? A consumer study of probiotic non-dairy juice drinks. Food Qual Prefer. 2004;15(7-8):751-759.
48. Luckow T, Sheehan V, Fitzgerald G, Delahunty C. Exposure, health information and flavour-masking strategies for improving the sensory quality of probiotic juice. Appetite. 2006;47(3):315-323.
49. Blandino A, Al-Aseeri ME, Pandiella SS, Cantero D, Webb C. Cereal-based fermented foods and beverages. Int. Food Res. 2003;36(6):527-543.
50. Simova E, Beshkova D, Angelov A, Hristozova TS, Frengova G, Spasov Z. Lactic acid bacteria and yeasts in kefir grains and kefir made from them. J Ind Microbiol Biotechnol. 2002;28(1):1-6.
51. Yudianti NF, Yanti R, Cahyanto MN, Rahayu ES, Utami T. Isolation and characterization of lactic acid bacteria from legume soaking water of tempeh productions. Digit. Press Life Sci. 2020;2:00003.
52. Muyanja C, Narvhus JA, Treimo J, Langsrud T. Isolation, characterisation and identification of lactic acid bacteria from bushera: a Ugandan traditional fermented beverage. Int J Food Microbiol. 2003;80(3):201-210.
53. Tanguler H, Erten H. Occurrence and growth of lactic acid bacteria species during the fermentation of shalgam (salgam), a traditional Turkish fermented beverage. LWT-Food Sci Technol. 2012;46(1):36-41.
54. Chang J, Shim YY, Cha S, Chee KM. Probiotic characteristics of lactic acid bacteria isolated from kimchi. J Appl Microbiol. 2010;109(1):220-230.
55. Dallal MMS, Zamaniahari S, Davoodabadi A, Hosseini M, Rajabi Z. Identification and characterization of probiotic lactic acid bacteria isolated from traditional persian pickled vegetables. GMS HIC. 2017;12.
56. Wouters D, Grosu-Tudor S, Zamfir M, De Vuyst L. Bacterial community dynamics, lactic acid bacteria species diversity and metabolite kinetics of traditional Romanian vegetable fermentations. J Sci Food Agric. 2013;93(4):749-760.
57. Randazzo CL, Restuccia C, Romano AD, Caggia C. *Lactobacillus casei*, dominant species in naturally fermented Sicilian green olives. Int J Food Microbiol. 2004;90(1):9-14.
58. Abegaz K. Isolation, characterization and identification of lactic acid bacteria involved in traditional fermentation of borde, an Ethiopian cereal beverage. Afr J Biotechnol. 2007;6(12).
59. Chen, Y. S., Wu, H. C., Pan, S. F., Lin, B. G., Lin, Y. H., Tung, W. C., Li, Y. L., Chiang, C. M., Yanagida, F. Isolation and characterization of lactic acid bacteria from yan-taozih (pickled peaches) in Taiwan. Ann Microbiol. 2013;63:607-614.