**Current development in non-dairy probiotic beverage: Associated health benefits**

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**Abstract:**

Probiotics are live bacteria that, when administered in sufficient quantities, provide health benefits to the host. Today's probiotic commodities are typically fermented milks and yoghurts; but, with an increase in consumer vegetarianism throughout developed countries, there is also a need for vegetarian probiotic products. Cereals, legumes, fruits, and vegetables may be potential substrates where the beneficial probiotic bacteria will establish themselves, both in emerging and established nations, in light of the aforementioned facts. The non-dairy probiotic beverages' ingredients may present particular difficulties for the survival of the health-promoting microorganisms. Therefore, strain selection and product protection strategies are crucial in creating a stable product to address these issues. Additionally, it looks at the most recent advancements in probiotic beverage with an emphasis on the good viability cell count in the finished product. This review covers non-dairy probiotic drinks, ideal beverage qualities, and popular probiotic strains. The goal of this review is to draw attention to the studies on probiotic beverages derived from non-dairy sources. These non-dairy probiotic beverages can be consumed by people who are lactose intolerant as well as a healthy substitute for dairy probiotics.

*Keywords*: Probiotic; Non-dairy beverage; Microorganisms

**1. Introduction:**

Probiotic is a relatively new phrase that means “for life,” and refer to microorganisms that have positive effects on both people and animals (Hotel and Cordoba, 2001). An Expert Committee’s scientific definition of the term “probiotic” is “live microorganisms that, when consumed in specific amounts, have health benefits beyond those basic nutrition” and it can be consumed either in the form of food components or as non-food preparation (Guarner and Schaafsma, 1998). This requires that the microorganisms be active and abundant, often more than 109 cells per daily dose and each product should provide the daily dosage needed to bestow any desired health benefit(s). Although not solely, the probiotic bacteria primarily comprise of strains from the genera *Lactobacillus* and *Bifidobacterium* species (Table 1) and have been used since recorded history in the manufacture of fermented dairy products (FAO/WHO, 2002; Gorbach, 2002). However, because of their positive impact on health, species from the genera *Lactococcus*, *Enterococcus*, *Saccharomyces*, and *Propionibacterium* are also taken into account (Balandino et al., 2003; Sanders and Huis in’t Veld, 1999; Vinderola and Reinheimer, 2003). The adult gastrointestinal tract is home to more than 500 distinct bacterial species (Alvarez-Olmos and Oberhelman, 2001; Pham et al., 2008; Bengmark, 1998). While certain bacteria are considered to be advantageous to the human host and others are pathogenic. The gut flora is typically kept in balance, but antibiotics, immunosuppressive drugs, surgery, and radiation therapy can increase the amount of harmful bacteria and upset this equilibrium. The microbial equilibrium in the gastrointestinal system may be restored with probiotics, which contain beneficial bacteria and yeast (Williams, 2010). Probiotics need to have specific characteristics and must able to withstand passage through the digestive system: acid and bile resistance; adhesion to human epithelial cells; colonization in the human gastrointestinal tract; manufacture of antibacterial chemicals (bacteriocins); non-pathogenic and GRAS (Generally Regarded As Safe); favorable growth qualities and benefits to human health (Figure 1) and possesses some desirable characteristics that is low cost, maintain of viable cell count during processing and storage, application capability in the products, physicochemical processing of the food resistance (Prado et al., 2008). Therefore, in this book chapter reviews the recent various non-dairy probiotics based product available on worldwide based on fruits and vegetables, cereal and legumes, soy and other non-dairy based products.

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| Table 1: Microorganisms used as probiotics in products (Prado et al., 2008; Williams, 2010; Holzapfel et al., 2001) |
| *Lactobacillus* species | ***Bifidobacterium* species** | **Other species** |
| *Lactobacillus rhamnosus* | *Bifidobacterium animalis* | *Bacillus cereus* |
| *Lactobacillus casei* | *Bifidobacterium lactis* | *Enterococcus faecalis* |
| *Lactobacillus paracasei* | *Bifidobacterium bifidium* | *Enterococcus faecium* |
| *Lactobacillus plantarum* | *Bifidobacterium adolescentis* | *Escherichia nissle* |
| *Lactobacillus acidophilus* | *Bifidobacterium breve* | *Streptococcus thermophilus* |
| *Lactobacillus delbrueckii* | *Bifidobacterium infantis* | *Saccharomyces boulardii* |
| *Lactobacillus fermentum* | *Bifidobactrium longum* | *Clostridium botyricum* |
| *Lactobacillus reuteri* |  | *Escherichia coli* |
| *Lactobacillus bulgaricus* |  | *Lactococcus lactis* sp. *cremoriss* |
| *Lactobacillus crispatus* |  | *Lactococcus lactis* sp*. lactis* |
| *Lactobacillus gasseri* |  | *Leuconostoc mesenteroides* sp*. dextranicum* |
| *Lactobacillus johnsonii* |  | *Pediococcus acidilactici* |
| *Lactobacillus amylovorus* |  | *Propionibacterium freudenreichii* |
| *Lactobacillus crispatus* |  | *Saccharomyces boulardii* |
| *Lactobacillus helveticus* |  | *Streptococcus salivarius* sp*. thermophilus* |
| *Lactobacillus lactis* |  | *Bacillus coagulans* |
| *Lactobacillus gallinarum* |  | *Weissella kimchii* |
|  |  | *Sporolactobacillus inulinus* |
|  |  | *Saccharomyces cerevisiae* |

**2. Necessity of non-dairy probiotics:**

The majority of probiotic meals now on the market are milk-based, but customers now prefer botanical nutritional supplements that are either cholesterol-free or contain very little cholesterol. The U.S. functional food market is evolving in a different way from that seen in Europe, with its functional food sector more broadly defined as neutraceuticals and consumer interest tending to lie more with botanical dietary supplements than with the fortification of foodstuffs. This trend draws attention to the aforementioned fact. However, as awareness of immunity, cancer, and heart health increases, this pattern is shifting. Additionally, the market for functional foods is still developing in many nations, although product innovation is visible across a variety of industries, including drinks, baking, and probiotics, with trends typically mirroring those in the United States and the United Kingdom (Vasudha and Mishra, 2013).

The majority of the daily intake in Asian diets comes from plant-based meals, which are relatively low in meat and dairy products. In addition to eating patterns, lactose sensitivity prevents many Asians from drinking milk. The major dairy markets had average per capita dairy consumption in the last ten years of 10.2 kg in China, 71.8 kg in India, 7.8 kg in Indonesia, 97.6 kg in Japan, 67.8 kg in Malaysia, 24 kg in the Philippines, 80 kg in South Korea, 28.7 kg in Thailand, and 8.6 kg in Vietnam (including fluid milk, butter, cheese, non fat dry milk and whole milk powder). This contrasts with per capita consumption of 251 kg in the United States, 330 kg in the EU-15, and 310 kg in Australia (Dong, 2006). Considering above, cereals, fruits, and vegetables may be suitable substrates for beneficial probiotic bacteria to establish themselves, both in developing and industrialised countries.

**3. Effects of probiotics on health**: Some of the health benefits associated with probiotic drinks were discussed below:



Figure 1: Beneficial effects of probiotic on health (Adapted from Prado et al., 2008)

**3.1 Prevention of diarrhoea**

Diarrhoea is frequently accompanied by a disruption in the microbial balance of the gastrointestinal tract. Probiotics have received clinical interest for their potential therapeutic use in the treatment of diarrhoea since they are beneficial microbes for host health. *Lactobacillus*, *Bifidobacterium* and *Saccharomyces* are the probiotics for diarrhoea that have been the most well investigated. Efficacy for treatment for mild to moderate infectious diarrhoea may be specific. For instance, *Saccharomyces boulardii* and *Lactobacillus* GG may help rotavirus-related diarrhoea, whereas *Lactobacillus paracasei* has no such effect (Yan and Polk, 2006).

**3.2** **Stimulation of the immune system**

Many human studies on the effects of probiotic cultures on the immune system have revealed that probiotic bacteria can improve both innate and acquired immunity by increasing natural killer cell activity and phagocytosis, changing cytokine profiles, and increasing immunoglobulin levels. *Bifidobacterium lactis* and *Lactobacillus rhamnosus* are two probiotic strains that have been produced with a specific focus on their boosting effects on immune responses. Numerous studies have shown that both strains improve healthy people's natural immune response (Fuller et al., 2008)

**3.3 Inflammatory bowel disease**

Crohn's disease and ulcerative colitis are two overlapping phenotypes of inflammatory bowel disease (IBD) that mostly affect the colon and/or the distal small intestine. The disease's aetiology is unknown, but genetic predisposition and normal gut microbiota are likely to play essential roles. Changing the composition and activity of the normal microflora may help to alleviate the condition (Ouwehand et al., 2002). Some selective probiotics have been shown to lower the incidence of relapses and lengthen the period of remission. Not only lactic acid bacteria, *Lactobacillus salivarius* UCC118 and *Lactobacillus rhamnosus* GG, but also *Saccharomyces cerevisiae* (*boulardii*) and an *Escherichia coli* strain (Nissle), have been shown to be useful in reducing IBD symptoms.

**3.4 Lactose intolerance**

The main carbohydrate in milk is lactose. In people with low levels of the intestinal enzyme beta-galactosidase (lactase), the disaccharide lactose can result in significant intestinal distress marked by bloating, gas, and abdominal pain. The usage of dairy products is highly restricted due to this illness. It restricts the consumption of calcium-rich foods when they are vitally needed due to bone loss in the elderly people because the disease tends to get worse with age. *Lactobacilli* generate lactase during fermentation, which hydrolyzes lactose in dairy products into glucose and galactose. Lactase is continually produced throughout yoghurt fermentation (Goldin, 1998). Lactose-intolerant subjects who were given fermented milk had much lower hydrogen levels in their breath than those who were given unfermented milk. A sign of lactose digestion by bacteria in the larger intestine is hydrogen in the breath. Lower hydrogen levels mean that lactose has already been metabolised before reaching the large intestine (Kim and Gilliland, 1983). The improvement of lactose metabolism is a claimed health benefit of probiotics, and it appears to involve some strains more than others and in particular concentrations, although conventional yoghurt preparations using *S. thermophilus* and *L. delbrueckii* ssp*. bulgaricus* are even more effective in this direction, partly due to higher beta-galactosidase activity (Kechagia et al., 2013).

**3.5 Allergies**

Recent research suggests that early bacterial exposure may have a protective role against allergy, and probiotics may offer a safe alternative to the microbial stimulation that young children's growing immune systems require and improve the mucosal barrier function, which is responsible for alleviating allergic response. Children and newborns with allergies and those without them show quantitative and qualitative differences in their intestinal microbiota, with the former showing colonisation by a more adult-like type of microflora. This supports the function of intestinal microbiota in allergy (Marteau et al., 2002; Salminen et al., 1998; Kalliomäki et al., 2001; Ouwehand et al., 2001). However, a small number of strains have been evaluated for their efficacy in the treatment and prevention of newborn allergies. In a recent research of breast-fed infants with atopic eczema, *B. lactis* and *L. rhamnosus* GG were found to be useful in reducing the severity of the eczema (Isolauri et al., 2000). However, probiotics have not proved very effective in relieving asthma symptoms (Wheeler et al., 1997).

**3.6 Cancer**

It has been noted that diets, particularly those high in meat and fat or low in fibre, alter the composition of the intestinal microflora, resulting in higher levels of *Bacteroides* and *Clostridium* and lower levels of *Bifidobacterium* (Benno, 1991). An increase in faecal enzyme activity, including beta-glucuronidase, azoreductase, urease, nitroreductase, and glycocholic acid reductase, is linked to this change in microflora composition. These enzymes turn procarcinogens into carcinogens, raising the risk of colorectal cancer as a result. This faecal enzyme activity has been seen to decrease when certain lactobacilli are consumed. However, the majority of epidemiological studies—but not all of them—indicate that consuming fermented dairy products on a regular basis may reduce the chance of developing some types of cancer (Hirayama and Rafter, 2000).

**3.7 Respiratory tract infections**

In animal models, probiotics have been shown to have effects on the respiratory system that include reducing allergic airway reactions and defending against respiratory infections. While regulatory T cells are emerging as potentially key effectors of probiotic-mediated responses, particularly in the reduction of allergic inflammation, dendritic cells appear to be crucial in directing the beneficial immune response to probiotic bacteria and in translating microbial signals from the innate to the adaptive immune system. Despite advancements in basic research, probiotics' performance in clinical studies for allergy/asthma and respiratory infections has been at best highly unpredictable, which has undermined trust in this prospective therapeutic approach (Vasudha and Mishra, 2013).

**3.8 Constipation**

One of the most common digestive issues among the elderly people, especially those who are institutionalised, is constipation. Adults and hospitalised patients who are generally healthy may also experience constipation. Probiotics have been proposed as a treatment for constipation (Lee et al., 1999; Goldin, 1998). Constipated people have a changed faecal microflora, with lower amounts of bifidobacteria, *Bacteroides*, and, in particular, clostridia (Shimoyama et al., 1984). Correcting the microflora composition may not assist because the altered microfiora composition is more likely to be a symptom than the root cause of constipation.

**3.9 High cholesterol**

Many human research have yielded mixed results when it comes to the impact of cultured dairy products or probiotic bacteria on cholesterol levels. Pereira and Gibson (2002) had reported that a fermented milk containing *Enterococcus faecium* and *Streptococcus thermophilus* was found to reduce total and LDL cholesterol in patients with primary hypercholesterolemia.

**3.10 Improve skin health**

Probiotic bacteria can promote skin health through oral consumption (in vivo) or topical application (in vitro). Many studies on oral consumption have been conducted in recent years. Probiotics may have skin-protective or skin-healing properties (Roudsari et al., 2015). It has been discovered that taking probiotic bacteria orally can benefit both damaged and healthy skin (Holma et al., 2011). According to research on the skin health advantages of probiotics, oral ingestion may reduce skin irritation and improve the skin's immune function. In one clinical trial, taking a *Lactobacillus johnsonii* supplement orally for six weeks appeared to speed up the recovery of the skin's immune system when compared to a placebo (Gueniche et al., 2009), while another study found that combining *Lactobacillus paracasei* and *Bifidobacterium lactis* reduced neuro sensitivity in women with reactive skin (Gueniche et al., 2007). Oral ingestion of probiotic bacteria has been discovered to be a novel strategy to protecting the skin immune system against UV radiation. Some effects have been recorded in hairless mice, and dietary supplementation with *L. johnsonii* has been shown to protect the cutaneous immune system from the immunosuppressive effects of ultraviolet B radiation ((Guéniche et al., 2006). Hou et al. (2000) had also reported that during a 48-hour fermentation in soymilk, two bifidobacteria strains (*Bifidobacterium infantis* CCRC 14633 and *Bifidobacterium longum* B6) were found to boost riboflavin levels. Probiotic bacteria applied to the skin may operate as a protective shield, similar to a physical barrier. This bacterial interference is assumed to hinder colonisation by other, potentially pathogenic, bacterial strains by competing inhibition of binding sites (Roudsari et al., 2015).

**4. Non-dairy probiotic beverage:**

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| Category | Product | Probiotic strain | Results | Reference |
| Fruit and vegetable based | Apricot based drink | *Lactobacillus rhamnosus* | Probiotic count of treatment (T2) shows highest with 6.56 log colony form unit (CFU)/mL on 28th day at 40C | Bashir et al. (2023) |
| Kombucha drink with butterfly pea flower | *Lactiplantibacillus plantarum subsp. plantarum* | It ha a count of 6.26 log CFU/mL for 28 days at 40C | Majid et al. (2023) |
| Snake fruit juice  | *Lactiplantibacillus plantarum subsp. Plantarum* Dad-13 | Viable cell count was 2.7 × 108, pH 3.77 and total acid 0.33% with 24 h fermentation | Alwi et al. (2023) |
| Sorrel and pineapple juice | *Lacticaseibacillus paracasei* 62L | After 30 days of storage at 30 °C and 27 days at 4 °C, the viability of L. paracasei 62L was better than 50%. | Marius et al. (2023) |
| Cupuassu juice | *Lactiplantibacillus plantarum* Lp62 | Probiotic strain remain viable at refrigeration condition, acidic environment and survive gastrointestinal transit *in vitro* and exhibited 30% adhesion to HT-29 intestinal cells | da Silva et al. (2023) |
| White finger millet based beverage | *Lactobacillus rhamnosus* GG (LGG) | Phenolic content increases and viable count was 8.31 log CFU/mL greater than control (7.76 log CFU/mL) | Meena et al. (2023); Navyashree et al. (2022); Byresh et al. (2022) |
| Pomegranate drink | *Lactobacillus plantarum* | Juice with probiotic strain shows more effective since rich in phenolic content and fermentation of juice | Naeem et al. (2023) |
| Peach based beverage | *Lactobacillus casei* | The probiotic count and total plate count ranged from 29 to 12.68 CFU/mL and 5.27 to 9.83 CFU/mL, respectively. | Parveen and tul Ain (2023). |
| Whole grape juice drink | *Lactic acid bacteria* | Viability of strain at 14 days storage had 7.5 log CFU/mL | Santos et al. (2023) |
| Crystal guava juice probiotic drink | *Lactobacillus casei* | Fermentation for 28 h shows best result with viable cell count of 9.09 log CFU/mL | Rosida and Yusuf (2022) |
| Dry coconut pulp synbiotic drink | *Lactobacillus casei* | Observed increase in phenolic and antioxidant and after 28 days storage the viability at gastric phase and intestinal phase were 5.90 log CFU/mL and 4.75 log CFU/mL, respectively | Cunha Júnior et al. (2022) |
| Fermented beverage enriched with pea and rice protein | Lactic acid bacteria | After 143 days of storage the viability was 8.4 log CFU/mL | Allahdad et al. (2022) |
| Passion fruit drink | *Lacticaseibacillus rhamnosus* GG (LGG) | Viability was above 107 CFU/mL throughout 28 days storage | Miranda et al. (2022) |
| Gac fruit juice | *Lactobacillus paracasei* CASEI 431 | Fermentation increases beta-carotene, organic acid and antioxidant activity. Fermented Gac juice (FGJ10) showed highest viability (8.38 log/CFU/mL)  | Marnpae et al. (2022) |
| Fermented mango juice | *Strptococcus thermophilus; Bifidobacterium acidophillus; Lactobacillus acidophilus; Lactobacillus delbruikki ssp bulgaricus; Strptococcus thermophilus;Lactobacillus rhamnosus* GR-1 | *Lactobacillus rhamnosus* GR-1 showed highest cell count of log10 9.14 CFU/mL for 48 h | Mwanzia et al. (2022) |
| Mangosteen juice | *Lactobacillus casei* TISTR 390*; Lactobacillus fermentum* TISTR 391*; Lactobacillus pantarum* TISTR 1463 | Probiotic mangosteen juice had stronger antioxidant activity than control mangosteen juice (72 h), which had lower IC50 values. | Mongkontanawat et al. (2022) |
| Mango juice drink | *Lactobacillus acidophilus* La-5 | Probiotic viability increased with addition of 10% mango juice; improve probiotic tolerance in vitro gastrointestinal digestion | Ryan et al. (2020) |
| Orange juice drink | *Pediococcus acidilactici* CE51 | Probiotic cell count found to be 7.2 and 8.5 log CFU/mL after 35 days at 40C and 300C | de Oliveira Vieira et al. (2020) |
| Passion fruit drink | *Lactobacillus reuteri* | Optimal condition was found to be 300C at pH 3.18 (5.59 × 1011 CFU/mL) | Santos Monteiro et al. (2020) |
| Whey and pineapple juice  | *Lactobacillus acidophilus* LA-5 | After 42 and 56 days, the viable probiotic cell counts in the beverage were 4.92 log10 CFU/ mL and 4.20 log10 CFU/mL, respectively. | Islam et al. (2021) |
| Pumpkin juice | *Lactobacillus casei* 431 | The culture remained above 106 CFU/mL after 13 days of refrigerated storage, according to the survivability test. | Dimitrovski et al. (2021) |
| Mango juice | *Lactobacillus acidophilus* | Probiotic viability in probiotic mango juice generated at the pilot plant size was more than 8 log CFU ml for up to 28 days. | Dhillon et al. (2021) |
| Pineapple skin drink | *Lactobacillus casei* | 24 h fermentation shows best result | Rahayu et al. (2021) |
| Passion fruit and yam flour beverage | *Lacticaseibacillus casei* | Viability cell count was greater than 106 CFU/mL and resist gastrointestinal tract environment (> 104 CFU/mL) | GUEDES et al. (2021) |
| Orange based drink fortified with nettle | *Lactobacillus rhamnosus* ATCC 53103 | Population number of *Lactobacillus rhamnosus* was in the range of 6.75-7.33 log CFU/mL during 28 days storage at 40C  | Sengun et al. (2020) |
| Pineapple juice | *Bifidobacterium lactis* Bb-12*; Lactobacillus plantarum* 299V*; Lactobacillus acidophilus* La5 | The cell count of lactobacilli and bifidobacterial was 5×109 CFU/mL and 109 CFU/mL, respectively after 24 h fermentation | Nguyen et al. (2019) |
| Sohiong juice | *Lactobacillus palntarum* MCC 2974 | Viable cell increased up to 10 log CFU/mL at 370C for 72 h and higher than 6 log CFU/mL during four week storage at 40C | Vivek et al. (2019) |
| Vegetable (Jicama, winter melon and carrot) mixture juice | *Lactobacillus plantarum* CICC2269*6; Lactobacillus acidophilus* CICC20710 | At 28 days storage (40C) the viability of *Lactobacillus plantarum* was around 8 log CFU/mL, whereas the viability of *Lactobacillus acidophilus* was only 4.57 log CFU/mL. | Do and Fan (2019)  |
| Beet juice | *Lactobacillus plantarum; Lactobacillus paracasei* | Viability count of Lactobacillus plantarum and Lactobacillus paracasei increased to 9.03 log CFU/mL and 9.69 log CFU/mL, respectively during 42 days cold storage (40C) | Jafar et al. (2019) |
| Ready to drink ice tea | *Lactobacillus acidophilus* | After reconstitution, ready-to-drink tea and spray dried premix viability count were 10.03 log CFU/mL and 9.98 log CFU/mL, respectively | Tewari et al. (2018) |
| Breadfruit flour beverage | *Lactobacillus acidophilus; Lactobacillus plantarum* DPC 206; *Lactobacillus casei* | The combination of three strain after 72 h fermentation shows highest (8.106 log10 CFU/mL)  | Gao et al. (2019) |
| Pomegranate juice | *Lactobacillus acidophilus* | No bacteria was detected after second week of storage (40C) | Ghazavi and Abedi (2018) |
| Mulberry-whey beverage | *Lactobacillus delbrueckii* subsp*. bulgaricus; Streptococcus thermophilus; Lactobacillus rhamnosus* GG | Sweet whey and black mulberry juice (SWBM3) with *Lactobacillus rhamnosus* possessed 7.88 log CFU/mL viable cell count when stored for 21 days at 40C | AbdulAlim et al. (2018) |
| Orange-whey based RTS beverage | *Lactobacillus fermentum* PH5 | Viability cell count of formulated blend (B2) and control (C) are 6.10 log CFU/mL :7.25 log CFU/mL when stored for 28 days at 70C  | Thakkar et al. (2018) |
| Ber fruit based carbonated ready to drink beverage | *Lactobacillus acidophilus* | Total viable count of Lactobacillus acidophilus (2%, T4) was 22.9 × 107 CFU/mL for 45 days storage at 40C | Shams and Wadhawan (2018) |
| Aloe vera drink | *Lactobacillus acidophilus* | Growth of strain at 250C was better than stored at 40C during 12 days | Bahrami et al. (2019) |
| Liquorice root extract | *Lactobacillus plantarum* | Capable of growing in liquorice extract under various circumstances, attaining a population of 108 CFU/ml after 48 hours. | Mousavi and Mousavi (2019) |
| Pomegranate juice | *Lactobacillus plantarum; Lactobacillus bulgaricus* | The microbiological test revealed that the produced beverage had the ideal level of cultures, or 6.5 x 109 CFU/mL, and was clear of any evidence of yeast, mould, or coli-form bacteria. | Thakur and Sharma (2017) |
| Whey and orange juice | *Lactobacillus acidophilus; Bifidobacterium bifidium* | The microbial count of Bifidobacterium bifidium and Lactobacillus acidophilus were found to be 8.29 × 108 CFU/mL and 8.25 × 108 CFU/mL, respectively (24 h) | Priyanka and Anjali (2017) |
| Carrot juice | *Lactobacillus acidophilus; Lactobacillus planetarium; Lactobacillus casei; Bifidum longum* | Under ideal circumstances (300C, pH 6 & 24 h), a mixture of *Lactobacillus acidophillus*, *Lactobacillus plantarum*, *Lactobacillus casei*, and *Bifidum longum* fermented successfully and survived in carrot juice. | Rafiq et al. (2016) |
| Mango juice | *Lactobacillus acidophilus* (MTCC10307*); Lactobacillus delbrueckii* (MTCC911); *Lactobacillus plantarum* (MTCC9511*); Lactobacillus casei*  | Reduced the pH to 3.2, acidity increased by 1.72% and viable cell count reached to 1.0 × 109 CFU/mL after fermentation of 72 h (300C). | Reddy et al. (2015) |
| Fermented mixture drink (pineapple, apple and mangifera) | *Lactobacillus casei* PTCC 1608 | The best treatment has the highest bacteria after 28 days, and it contains a concentration of 30% of juice with a density of 107 CFU/mL (containing 15% pineapple juice, 7.5% apple juice, and 7.5% mango juice). | Mashayekh et al. (2015) |
| Aloe vera drink | *Lactobacillus acidophilus; Lactobacillus casei; Lactobacillus reuteri; Lactobacillus fermentum; Lactobacillus plantarum* | *Lactobacillus acidophilus* and *Lactobacillus fermentum* are good choices for Aloe vera drinks | Sarlak et al. (2016) |
| Beetroot juice | *Lactobacillus casei* 431 | Can be stored for 6 weeks under refrigerated condition with 108-1010CFU/mL as functional drink. | Gamage et al. (2016) |
| Vegetable juice (beetroot, carrot and celery) | *Lactobacillus acidophilus* LA-5*; Lactobacillus casei* 431 | Good survival of probiotic viability was obtained higher than 1×107CFU/mL. | Profir et al. (2015) |
| Apple juice | *Lactobacillus plantarum* PCS 26 | Live bacteria of 106 CFU/ml concentration remain for about 30 days. | Dimitrovski et al. (2015) |
| Cornelian cherry juice | *Lactobacillus rhamnosus; Lactobacillus plantarum; Lactobacillus casei* | After 28 days, *Lactobacillus casei* population (log8.00 CFU/mL) had increased even higher. | Nematollahi et al. (2016) |
| Moringa (*Moringa oleifera*) leaves juice based beetroot (*Beta vulgaris*) beverage | *Lactobacillus plantarum; Enterococcus hirae* | Fermentation reduced the raffinose content by 60% and showed antibacterial activity with shelf life of 30 days at 40C. | Vanajakshi et al. (2015) |
| Vegetable juice mixture: bitter gourd (*Momordica charantia*), bottle gourd (*Lagenaria siceraria*) and carrot (*Daucus carota*) | *Lactobacillus acidophilus* NCDC 11*; Lactobacillus plantarum* NCDC 414*; Pediococcus pantosaceus* MTCC 2819 | Lactobacillus plantarum strain could be used for probiotic culture to make healthy vegetable juice mixture and can survive low pH and high acidic condition at 40C and possessed 7.2 log cfu/ml at 4 weeks of storage  | Sharma and Mishra (2013) |
| Peach (*Prunus persica*) juice | *Lactobacillus plantarum* DSMZ 20179*; Lactobacillus delbrueckii* DSMZ 15996*; Lactobacillus casei* DSMZ 20011 | *Lactobacillus delbrueckii* could be used as culture for production of probiotic beverage with cell count 106 CFU/ml | Pakbin et al. (2014) |
| Whey and pineapple juice | *Lactobacillus acidophilus* | Had shelf life of 24 days (1.8 × 107 cfu/ml) at 5±10C and 48h (9.5× 108 cfu/ml) at 30±10C with 1% *Lactobacillus acidophilus* inoculum with 65:35 blend of whey and pineapple juice | Shukla and Admassu (2013) |
| Cashew apple juice | *Lactobacillus casei* NRRL B-442 | Powder made with 20% maltodextrin held at 250C had survival rates more than 70% up to 21 days of storage  | Pereira et al. (2014) |
| Mixed watermelon and tomato juice | *Lactobacillus fermentum* (MTCC1325); *Lactobacillus casei* (MTCC1423) | *Lactobacillus fermentum* grown at a lower temperature (300C) and *Lactobacillus casei* produced at a higher temperature (370C) fared better after four weeks of cold storage at 40C | Sivudu et al. (2014) |
| Pomegranate juice | *Lactobacillus plantarum; Lactobacillus delbruekii; Lactobacillus paracasei; Lactobacillus acidophilus* | *Lactobacillus plantarum* (2.8 × 105 ± 0.05 × 105 CFU/ml) and *Lactobacillus delbruekii* (1.5 × 105 ± 0.26 × 105 CFU/ml) showed higher viability during storage (2 weeks) at 40C | Mousavi et al. (2011) |
| Cantaloupe juice | *Lactobacillus casei* NRRLB-442 | With cell viability 8.3 log CFU mL-1for 42 days storage under refrigerated condition  | Fonteles et al. (2012) |
| Cashew apple juice | *Lactobacillus casei* NRRL B-442 | Throughout the 42 days storage period, viable cell counts were greater than 8.00 log CFU/mL  | Pereira et al. (2011) |
| Vegetable juice (celery and beetroot) | *Bifidobacterium* strain (BB12) | 108 CFU/mL viable cell count was achieved at 48 hours  | Moraru et al. (2007) |
| Cabbage juice | *Lactobacillus casei* A4*; Lactobacillus debrueckii* D7*; Lactobacillus plantarum* C3 | Lactobacillus plantarum and Lactobacillus delbrueckii survived low pH and high acidic condition at 40C and reached 10×108 CFU/mL after 48 h fermentation at 300C | Yoon et al. (2006) |
| Cereal and legume based | Lupine and chickpea beverage | *Lactobacillus plantarum* 299v | Highest number of microbial count observed in fermented chickpea (7.69 log CFU/mL) and germinated fermented lupine (8.16 log CFU/mL) | Criste et al. (2023) |
| Mixture of oats, barley buckwheat and red rice beverage | *Lactobacillus plantarum* | It offered shelf stability for up to two weeks under refrigeration without any quality loss and a probiotic level of 9.70 log CFU/ml. | Kokwar et al. (2022) |
| Oat bran fortified raspberry dairy drink | *Lactobacillus acidophilus; lactobacillus casei; Bifidobacterium lactis* | At the start of storage, oat bran considerably enhanced the vitality of the probiotic drink containing solely *Bifidobacterium lactis*. | Savas and Akan (2021) |
| Oat-based beverage (Oat, sugar and inulin) | *Lactobacillus plantarum* | Throughout storage, the *Lactobacillus plantarum* population in the beverage maintained over 107 CFU/g. | Wang et al. (2018) |
| Sprouted wheat based beverage | *Lactobacillus acidophilus* NCDC-14 | *Lactobacillus acidophilus* NCDC-14 used for development of probiotic wheat based beverage with probiotic count of 10.43 log10 cfumL-1 | Sharma et al. (2014) |
| Oats | *Lactobacillus plantarum* ATCC 8014 | Reported to be stable for 21 days with a drop in CFU/ml of less tha 1 log and β- gucan remained unchanged during fermentation and storage | Gupta et al. (2010) |
| Soy based | Fermented soy and almond milk | *Lactobacillus rhamnosus; Lactobacillus acidophilus; Lactobacillus plantarum; Lactobacillus casei* | Almond and milk (AM 100) treated with *Lactobacillus rhamnosus* showed highest viable cell count of 6.686 log CFU/mL when stored at refrigerated condition (40C) for 21 days | Zahrani and Shori (2023) |
| Fermaented soya drink | *Levilactobacillus brevis* LOCK 0944 | Soya drink and *Chlorella vulgaris* are adequate media supplies for *Levilactobacillus brevis* LOCK 0944. After 30 days of storage at 40C, the addition of algae improved the survivability of lactic acid bacteria in the soya drink. | Ścieszka et al. (2021) |
| Soy-yamgurt drink | *Lactobacillus bulgaricus; Streptococcus thermophilus; Lactobacillus acidophilus* | Viable cell count of lactic acid bacteria was 1.44 x 109 CFU/mL in probiotic drink | Rusmarilin and Andayani (2018) |
| Soymilk | *Lactobacillus acidophilus; Bifidobacterium animalis* subsp*. lactis* Bb12*.; Streptococcus thermophilus* | *Bifidobacterium animalis* subsp. *lactis* Bb12 viable cell count was above 107 CFU/ml during cold storage for 28 days | Božanić et al. (2011) |
| Other non dairy based | Fermented water soluble cashew nut extract drink | *Lactobacillus paracasei* | Probiotic concentrations in fermented water-soluble cashew nut extract can exceed 7 log CFU g-1. | Sousa et al. (2022) |
| Instant coffee | *Lactiplantibacillus plantarum subsp. Plantarum* Dad-13 | Cell viability remained over 107 log CFU/g for all treatments and during storage. | Jannah et al. (2022) |
| Saffron-based beverage | *Lactococcus lactis; Lactobacillus plantarum; Lactobacillus brevis; Lactobacillus casei* | Viability cell count of Lactobacillus casei was lactis was found highest (2.5 × 102 CFU/mL) during cold storage for 3 weeks. | Dabbagh Moghaddam et al. (2018) |
| Artichoke juice | *Lactobacillus plantarum* PCS26 | The survivability test revealed that the culture will retain more than 106 CFU/ml after 13 days in refrigerated storage. | Dimitrovski et al. (2016) |
| Honey beverage | *Lactobacillus acidophilus* | Had shelf life of 15 days (94.8 × 109 cfu/ml) at 40C and 72h (21.4× 109cfu/ml) at 300C | Nath et al. (2015) |

5**. Conclusion:**

Technological advancements have enabled the regulated modification of food components to alter several structural features of fruit and vegetable matrices. This could make them suitable substrates for probiotic culture because they already contain important nutrients including minerals, vitamins, dietary fibres, and antioxidants while lacking dairy allergies that may prohibit ingestion by certain sectors of the population. Today's probiotics products are primarily milk-based; however, the rise in consumer vegetarianism and demand for cholesterol-free probiotics has spurred scientists and researchers to investigate other matrices as probiotic vehicles, particularly vegetable and fruit juices. Vegetables have important components such as minerals, vitamins, dietary fibres, and antioxidants while lacking the dairy allergies that may preclude some segments of the population from consuming them, making them good substrates for probiotic cultures. According to reports, vegetables and fruits contain a wide range of antioxidant components, including phytochemicals. Phytochemicals, such as phenolic compounds, are thought to be helpful to human health because they reduce the risk of degenerative diseases through oxidative stress reduction and macromolecular oxidation inhibition. There is a strong interest in the development of non-dairy based functional beverages containing probiotics since they are a healthy alternative to dairy probiotics, are cholesterol free, and are also preferred by lactose sensitive consumers.

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