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Probiotic Fruit and Vegetable Juices: Approach Towards a Healthy Gut

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ABSTRACT

The useful effects of foods with added live microbes on human health are being increasingly promoted by health professionals. The major probiotic beverage available in the markets today, are milk-based products; usually in the form of fermented milk. However, with an increase in the consumer vegetarianism and demand for cholesterol free probiotics, there is also a demand for the non-dairy based probiotic beverage. Considering the above mentioned facts, fruits and vegetable juices may be the potential substrates, where the probiotic bacteria will make their mark, both in the developing and the developed countries. Fruits and vegetables are easily perishable commodities due to their high water activity and nutritive values. Lactic acid fermentation increases the shelf life of fruits and vegetables and also enhances various beneficial properties, including nutritive value and flavours, and reduces toxicity. As a whole, fermented fruit and vegetable juices with probiotics not only serve as food supplements but also attribute towards health benefits. This review aims at describing various factors affecting the viability of probiotic bacteria throughout the storage period in diverse fruit and vegetable juices and perspective technologies to improve the survivability of probiotics.

Introduction

Today, all consumers have a considerable amount of their nutritional needs met through fermented foods and beverages (Steinkraus, 1997). Fermented/ functional foods are those containing bioactive compounds viz. dietary fibers, oligosaccharides, minerals, vitamins and probiotics (active friendly bacteria), having pleasant aroma, flavour and texture, that maintain the equilibrium of intestinal microflora (Steinkraus, 1997; Jankovic *et al.*, 2010; Shah and Prajapati, 2007). Fermented foods and beverages have diversity in cultural preferences and traditions found in the different geographical areas, where they are produced. Fermentation has helped the ancestors in colder regions to survive during the winter season and those in the tropics to survive drought periods (Swain *et al.*, 2014). According to FAO (1998), fermentation is a slow decomposition process of organic substances where carbohydrates are converted to alcohols or organic acids with the help of microorganisms or their enzymes. Fermentation processes have been developed for preserving the fruits and vegetables by preserving them by organic acids or alcohols, impart the desired flavour and texture to the food, decrease the cooking time and also reduce the toxicity (Rolle, 2002). Lactic acid fermentation of fruits and vegetables is a usual practice for maintaining and improving the nutritional and sensory attribute of the food products (Rolle and Satin, 2002; Endrizzi *et al.,* 2009; Demir *et al.,* 2006). Certain nutrients such as minerals and vitamins and acidic nature of fruits and vegetables provide a favourable medium for fermentation by Lactic acid bacteria. Probiotics are defined as live microbial feed, which is supplemented by food that maintains the intestinal health of the host in a beneficial manner (Tamang, 2009). Various studies suggest that supplementation of probiotic via food has several health benefits such as enhanced immune system (McNaught and MacFie, 2001), improved gastrointestinal function (Saarela *et al.*, 2002), reduction of serum cholesterol (Anandharaj *et al.*, 2014) and lower the risk of colon cancer (Rafter, 2003).

World Health Organization (WHO) and Food and Agriculture Organization (FAO) approved a specific daily intake dose of fruits and vegetables to prevent chronic pathologies such as coronary heart disease, hypertension, and risk of strokes (Swain *et al.,* 2014). Nowadays, the consumer prefers to intake the food and beverages, which is fresh, highly nutritional, ready to eat or drink and health-promoting (Endrizzi *et al.,* 2009). According to many literatures, the functional food market constitutes one of the main captivating areas of investigation and innovation in the food sector. As suggested by one survey, probiotics will be incorporated in various food products viz. dietary supplements, functional foods, animal feed, and in therapeutic and preventive healthcare applications and the probiotic market will rise to worth $46.55 Billion by 2020 (Anon, 2016). Plant based foods in Asian diets is the main food of the daily intake as they consume a relatively low amount of meat and dairy foods. Excluding dietary habits, lactose intolerance prevents many Asian people from consuming milk. In last decade, the average per capita dairy consumption in milk equivalent for the major dairy markets was 97.6 Kg in Japan, 80 Kg in South Korea, 71.8 Kg in India, 67.8 Kg in Malaysia, 28.7 Kg in Thailand, 24 Kg in Philippines, 10.2 Kg in China, 8.6 Kg in Vietnam and 7.8 Kg in Indonesia. This creates disparity with per capita consumption of 330 Kg in EU-15, 310 Kg per capita in Australia, and 251 Kg per capita in the United States (Dong, 2006). Therefore, in view of the above facts, fruits and vegetables can be utilized as the potential substrates, where healthy probiotic bacteria will make their impression, both in the developing and the developed countries.

Probiotics in fruit and vegetable juices

Hippocrates once wrote: ‘Let food be thy medicine, and let medicine be thy food.’ Nowadays, food having medicinal value has been renewed as ‘functional foods.’ A probiotic may also be a functional food (Scheinbach, 1998). Functional foods are defined as ‘foods that contain traditional nutrition along with some health-promoting component(s).’ Functional foods are also known as designer foods, nutraceuticals, therapeutic foods, medicinal foods, foodiceuticals, medifoods, and superfoods (Soccol *et al.,* 2010). In general, the term functional foods mentions to a food that has been improved in some way to become ‘functional.’ One way in which foods can be improved to become functional is by the incorporation of probiotics (FAO/WHO). Food products have been formulated with the addition of probiotic cultures. Different food matrices have been used such as various types of cheeses, powdered milk, ice-creams, milk-based desserts, butter, mayonnaise, and fermented food of vegetable origin (Tamime *et al.,* 2005). Presence of allergens, lactose intolerance, fat content, and requirement of cold storage are some limitations of probiotic dairy products (Heenan *et al.,* 2004; Yoon *et al.,* 2006). This aspect has led to the initiation of novel probiotic products based on non-dairy matrices (Table 1). In recent times, various raw materials have been investigated extensively for determining the appropriate matrix to produce new non-dairy functional foods (Vasudha and Mishra, 2013). Matrices used in the development of non-dairy probiotic products are fruits, vegetables, cereals, and legumes. Fruits and vegetables are considered good matrices as they contain nutrients such as minerals, dietary fibers, vitamins, and antioxidants (Patel, 2017) while lacking the dairy allergens that might prevent consumption by a particular section of the population (Luckow and Delahunty, 2004). The development of various fruit juices has been studied (Yoon *et al.,* 2004; Soccol *et al,* 2007).

Besides potential sensory challenges, there is a sincere attentiveness towards the development of fruit and vegetable-based functional juice/ beverage, fortified with probiotic and prebiotic ingredients. The fruit and vegetable-based juices inherently contain beneficial nutrients, they have taste profiles that are appealing to all age groups, they are recognized as being refreshing and healthy, and therefore, they have been recommended as a suitable medium for the functional health ingredients (Tuorila and Cardello, 2002).

Hardaliye is a lactic acid fermented beverage, prepared by the natural fermentation of red grape juice supplemented with crushed mustard seeds and benzoic acid. This drink is originated in the Thrace region of Turkey. Eteric oils of mustard seeds affect the yeast and give a characteristic flavour to the final product. Benzoic acid also affects the yeast by inhibiting or decreasing the production of alcohol. Hardaliye is stored at 4ºC after fermentation. It can be consumed fresh or aged. The lactic acid bacteria found in this beverage are *Lactobacillus acetotolerans*, *Lactobacillus brevis*, *Lactobacillus casei* subsp. *pseudoplantarum*, *Lactobacillus paracasei* subsp. *paracasei and Lactobacillus vaccinostercus* (Arici and Coskun, 2001). Globally, there are so many commercially available probiotic fruit or vegetable juices, mentioned in Table 2.

Fermentation of fruit and vegetable juice by probiotic bacteria

The consumption of LA fermented vegetable juices (lacto-juices) has increased in many countries. Lacto-juices are produced mainly from cabbage, carrot, celery, red beet, and tomato (Demir *et al.,* 2006). They can be produced by either of the following ways:

(i) Fermentation of vegetable mash or juice;
(ii) Usual way of vegetable fermentation and then processed by pressing the juice.

There are three ways of lactic fermentation of fruit and vegetable juices:

(i) Spontaneous fermentation by natural microflora;
(ii) Fermentation by starter cultures (added to the raw materials);
(iii) Fermentation by heat-treated materials by starter cultures.

During the production of lacto-juices, the pressed juice can be sterilized at first and consecutively it is inoculated by a starter culture mainly a LAB at a concentration varying from 2 x 10^5 to 5 x 10^6 CFU/ml (Demir *et al.,* 2006; Panda and Ray, 2007). The difference between the production of fermented and non-fermented juice is explained in Figure 1. For fermentation of juices of high quality, it is necessary to use commercially supplied starter cultures viz. *L. plantarum*, *L. bifidus*, *L. brevis*, *L. xylosus*, and *L. bavaricus*. The criteria used for determining the suitability of a strain are mentioning below (McFeeters, 2004):

(i) Ability of a substrate to acquire a starter culture;
(ii) The rate and total production of lactic acid, change in pH, loss of nutritionally important substances;
(iii) Decrease in nitrate concentration and production of biogenic amines;
(iv) Type of metabolism and ability of culture to produce desirable sensory properties of fermented products.

Major factors affecting the survivability of probiotic bacteria in juices

The health benefits of probiotic juices mainly depend on the concentration of probiotics in the juices, along with their ability to survive the unfavourable conditions of the gastrointestinal tract. Two important criteria to be fulfilled by fruit juices are to maintain the viability (atleast 10^6 – 10^7 cells/ml) and activity of probiotics in the final product at the end of the shelf life (Nualkaekul and Charalampopoulos, 2011).

However, probiotic viability is strain dependent (Corbo *et al.*, 2012; Tripathi and Giri, 2014; Do Espírito Santo, 2011), i.e., some strains of *L .plantarum*, *L. acidophilus* and *L. casei* can grow in fruit matrices as they survive in acidic environments (Peres *et al.*, 2012). Although, fruit and vegetable juices have presented limitations to the addition of probiotic cultures such as (1) Intrinsic food parameters – pH, titratable acidity, molecular oxygen, water activity, presence of sugar, salt, artificial flavouring and colouring agent and chemical and microbial preservatives like bacteriocins and hydrogen peroxide; (2) processing parameters – incubation temperature, extent of heat treatment, cooling rate; (3) microbiological factors – kind of probiotic strains, rate and proportion of inoculum, inter-compatibility of different strains.

Probiotic cultures are neutrophils, with a pH optimum between 5 and 9. When the cells are present in low pH environments, there is an increased requirement of energy for the maintenance of intracellular pH and ATP is lacking for other crucial functions, resulting in cell death (Nualkaekul *et al.*, 2011). Also, they are usually microaerophilic or anaerobic and therefore, they lack electron carrier chain and the catalase enzyme, and the presence of oxygen may cause formation and accumulation of toxic metabolites in the cell and cause cell death from oxidative damage. Furthermore, the presence of preservatives, flavourings, and colourings may decrease the survivability of probiotic cultures. The probiotic cultures can change the sensory attributes (development of unpleasant aroma and flavour).

The metabolism of probiotic lactic acid bacteria may result in the production of metabolites and can affect the flavour and aroma of the food product. Among various probiotics, lactobacilli were found to survive in fruit juices with pH ranging 4.3 to 3.7; whereas bifidobacteria are less acid-tolerant (Tripathi and Giri, 2014).

Therefore, the type of microorganism and juice, storage conditions, and the addition of other compounds may influence the sensory traits of the finished product. Fermented juices with sugars had a more accepted taste and flavour than the sugar-free juices (Sivudu *et al.*, 2014).

Improving probiotic survival in juices

Fortification with prebiotics

The simplest way to improve the viability of probiotics in fruit juices could be the fortification with some prebiotics (dietary fibers, cellulose) or with some elements able to exert a protective effect within the juice. Apple juice incorporated with *L. rhamnosus* was fortified with oat flour, and 20% of β-glucan, and this could protect the probiotic bacteria during refrigerated storage (Saarela *et al.,* 2006). Orange juice fortified with pearl millet exhibited high viability of *L. plantarum* and a good source of fibers that contribute to maintaining the intestinal balance and had the potential to exhibit prebiotic effects such as the effects on the sensory traits and post acidification (Gupta and Sharma, 2016). Beetroot and carrot juices were enriched with brewer's yeast autolysate before lactic acid fermentation with *L. acidophilus*. The supplementation with autolysate convincingly increased the number of lactic acid bacteria during fermentation (Aeschlimann and Von Stocar, 1990), decreased the fermentation time (Chae *et al.,* 2001). Use of brewer's yeast helped in the economic optimization of the fermentation. A mixture of beetroot and carrot juice had an optimum quantity of antioxidants, minerals, pigments, amino acids, and vitamins after the addition of brewer's yeast (Rakin *et al.,* 2007). Fig juice incorporated with *L. delbrueckii* and fortified with inulin had a high viable count than the control (probiotic fig juice) and exhibited high antioxidants, polyphenols, medicinal properties, and organoleptic attributes (Khezri *et al.,* 2018)

Induction and adaptation of resistance

Exposure of probiotics to sub-lethal stress could instigate a resistance and an adaptive stress response (Gobetti *et al.,* 2010). Many researchers examined this approach. Viability of *L. reuteri* DSM 20016 was examined in pineapple, orange, green apple, and red fruit juices and found that the viability of the probiotic strain lost due to the combined effect of pH and phenols. Two different strategies were executed to overcome this survivability loss. Strain cultivation in different concentrations of red fruit juices (upto 50%) and provide phenol stress in the form of addition of vanillic acid and acid stress by acidification to pH 5.0. These approaches resulted in the prolongation of the viability of *L. reuteri* by 5 days (phenol stress) and 11 days (acid stress) (Perricone *et al.,* 2014). Survivability of *B. breve* in a blended juice of orange-grape and passion fruit was improved by creating an acid tolerance variant of the bacteria by UV mutagenesis along with cultivation at sub-lethal pHs (Saarela *et al.,* 2011).

Storage under refrigeration and microencapsulation

Lactic acid bacteria are highly sensitive to variation in storage temperature. The probiotic strain viability in fruit or vegetable juice is found to be affected, as refrigeration could promise a more prolonged survival, whereas thermal abuse could exhibit a detrimental effect (Patel, 2017). Many authors proposed various approaches to resolve the issue of thermal abuse. Microencapsulation techniques have been successfully applied using different matrices to protect the probiotic bacterial cell from the damage caused by the external environmental components (Patel, 2017). A novel microencapsulation method helped in reducing the acidification and improving the viability of probiotic strains *L. acidophilus* and *L. rhamnosus* at 25ºC for 9 days in orange juice (Sohail *et al.,* 2012). The cells of *B. animalis* subsp. *lactis* Bb12 were microencapsulated in a milk protein matrix.

The stability of free and encapsulated probiotic cells was studied in pineapple juice and strawberry-apple juice during 28-day storage. Pineapple juice was proved to be a suitable carrier for encapsulated probiotic cell viability whereas microcapsules and free cells were not stable in strawberry-apple juice and died after 14 days of storage at 22ºC (Horáčková *et al.,* 2018). *L. acidophilus* immobilized in Ca-alginate exhibited a higher cell survival rate in tomato juice and overall acceptance by the sensory evaluation when compared with the free cells during the cold storage at 4ºC (King *et al.*, 2007). A novel probiotic food product had been prepared with *L. acidophilus* when immobilized with Ca-alginate and found to carry out the normal banana puree fermentation (Tsen *et al.*, 2004). Thai herbal extracts such as cashew flower, pennywort, and yanang were alginate encapsulated and studied for the viability of probiotic bacterial isolates *L. casei* 01b, *L.acidophilus* LA5 and *B. lactis Bb-12* in mulberry, maoberry, longan, and melon juices. After 30 days of cold storage, higher viability of *L.casei* 01b entrapped with 0.05% (w/v) cashew flower extract was determined as compared with those encapsulated with pennywort and yanang extracts (Chaikham, 2015). Microencapsulated probiotic cells in fruit juices were found to be more stable in comparison with free probiotic cells. The encapsulated probiotic cell of *L. acidophilus, L. paracasei, L. plantarum, L. rhamnosus, L. salivarius, B. longum, B. lactis* Bi-04, and Bi-07 managed to survive in the acidic environment of the orange juice, did not exhibit a survivability loss, and 5 log CFU/ml cell count was determined (Ding and Shah, 2008). Viable count of encapsulated *L. plantarum* in grapes, orange, sapodilla, and watermelon juices was evaluated as 7 log CFU/ml or more (Gaanappriya *et al.*, 2013). It was reported that microencapsulation provides a favourable anaerobic environment for sensitive probiotic bacteria and provide a physical hindrance from the harsh acidic conditions of the fruit or vegetable juices (Ding and Shah, 2008). The probiotic cultures of *L. casei*, *L. plantarum*, *L. fermentum*, *Lysinibacillus sphaericus*, and *Saccharomyces boulardii* were microencapsulated using alginate coated chitosan beads and incorporated in tomato and carrot juices. The juices were pasteurized for 20 min at 63ºC and incubated at 37ºC for 72 h. Viable cell count of *Lysinibacillus sphaericus* and *Saccharomyces boulardii* were increased from 6.5 to 8.9 log CFU/ml and 5.2 to 7.6 log CFU/ml, respectively during 24-42 h and found to be decreased afterward (Naga *et al.*, 2016).

Use of antioxidants

During the storage of packaged foods, the level of oxygen should be maintained low in order to avoid oxidative damage to the probiotics, however, the degree of sensitivity is highly strain variable. Oxidative damage by oxygen is due to the generation of ROS (Reactive Oxygen Species) such as hydrogen peroxide or superoxide ion. Bifidobacteria are more sensitive than lactic acid bacteria (Nag and Das, 2013). Modification of the product atmosphere was suggested by many authors by raising the CO_2 content in the headspace (Corbo *et al.*, 2014). Incorporation of antioxidants could help to control the harmful effects of oxygen. The probiotic bacteria HOWARU *L. rhamnosus* HN001, HOWARU *B. lactis* HN001 and *L. paracasei* LPC 37 were incorporated into model juice along with vitamins viz. vitamin B2, vitamin B3, vitamin B6, vitamin C and vitamin E and antioxidants such as grape seed and green tea extract. The model juice containing grape seed extract, green tea extract, and vitamin C showed better survival of probiotic bacteria, exhibited viability of 4.29 log CFU/ml, 7.41 log CFU/ml, and 6.44 log CFU/ml after 6 weeks of storage (Shah *et al.*, 2010).

Effects of different amounts of (+)-catechin, green tea extracts, and green tea epigallocatechin gallate were studied on the viability of *B. longum* ATCC 15708, *B. longum* subsp. *infantis* ATCC 15697 and *L. helveticus* R0052 having different oxygen sensitivities and found that the growth of *L. helveticus* was greatly enhanced (Gaudreau *et al.*, 2013).

Table.1 The diversity of probiotic food products and the viability of each probiotic in different products at the end of appropriate storage conditions

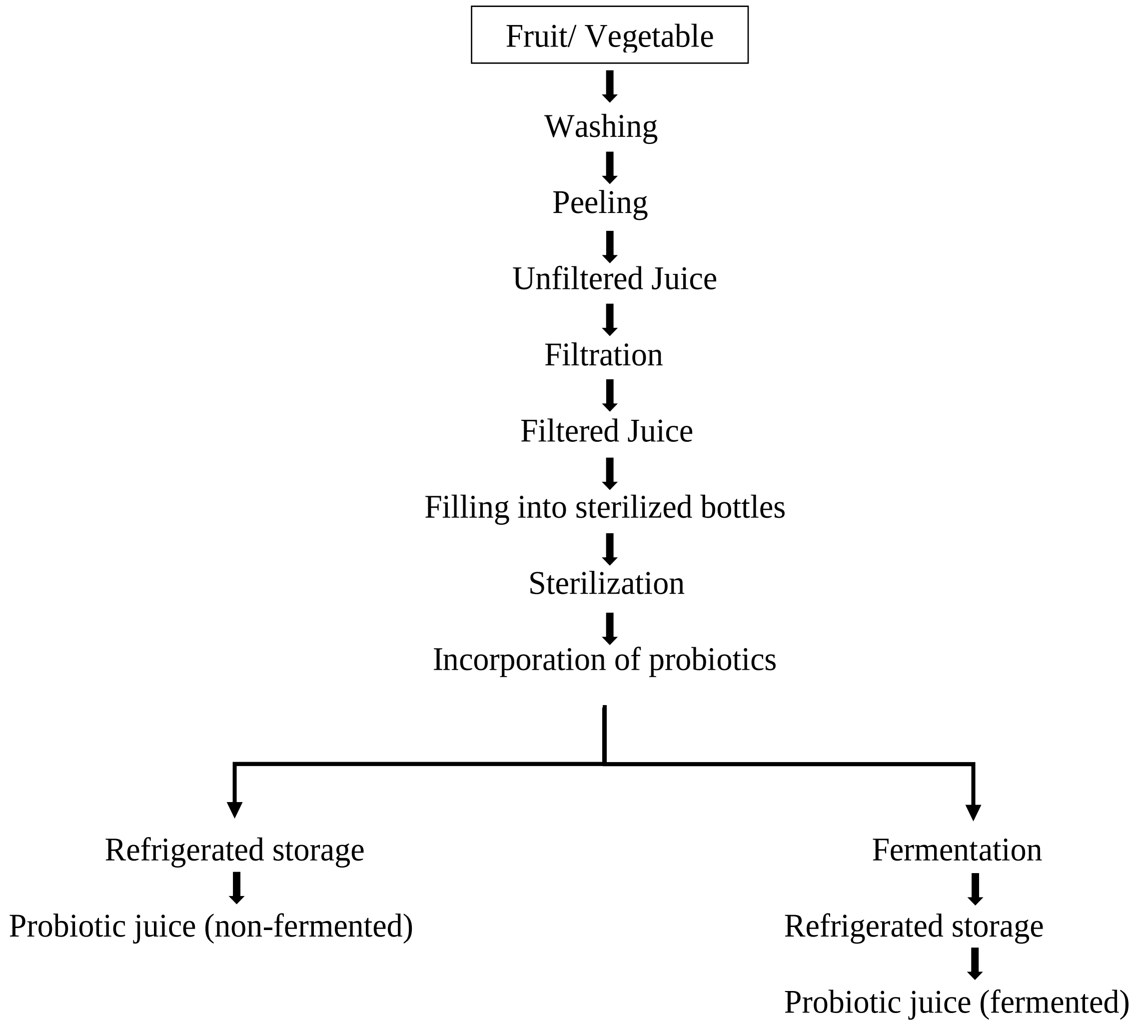
Product type (Fruit and vegetable based)	Probiotic strain	Viability at the end of storage	Total storage time	References
Apple juice	*L.acidophilus* *L.rhamnosus* *L.plantarum* *L.salivarius* *L.paracasei* *B.longum* *B.lactis* type Bi-04 *B.lactis* type Bi-07	10^6 CFU/mL	6 weeks	Ding and Shah, 2008
Amla (*Phyllanthusemblica*)	*L.paracasei* HII01			Peeranjan *et al.*, 2016
Beet root juice	*L.plantarum*C3, *L.casei*A4, *L.acidophilus*LA39, *L.delbrueckii*D7	10^6– 10^8 CFU/mL	4 weeks	Yoon *et al.*, 2005
Cabbage juice	*L.plantarum*C3, *L.casei* A4 *L.delbrueckii*D7	4.1 X10^7 CFU/mL (*L.plantarum*), 4.5 X 10^5 CFU/mL (*L.delbrueckii*), *L.casei* lost complete cell viability after 2 weeks of	4 weeks	Yoon *et al.*, 2006
Carrot juice	*B.lactis* Bb-12, *B.bifidum* B7.1 & B3.2	15-17 mg/ml lactic acid production	4 weeks	Kun *et al.*, 2008
Carrot juice	*L.rhamnosus*, *L.bulgaricus* with inulin or fructooligosaccharides		4 weeks	Nazzaro *et al.*, 2008
Carrot, beet and apple juice	*L.casei*	1.5 x 10^6 CFU/ml	4 weeks	Zandi*et al.*, 2016
Carrot blended with	*L.plantarum* CECT	10^8 – 10^9	30 days	Valero-Cases and

orange juice	220	CFU/Ml		Frutos, 2017
Fermented Kale juice	*L.plantarum*, *L.casei*, *L.acidophilus*, *L.brevis*	10^8 CFU/ml	4 weeks	Kim, 2017
Fermented vegetable soybean beverage	*L.acidophilus* La-5, *B.animalis* Bb-12	~10^6 CFU/Ml 10^8 CFU/Ml	28 days	Battistini *et al.*, 2017
Mango, sapota, grape and cantaloupe	*L.casei*		4 weeks	Kumar *et al.*, 2013
Noni juice	*L.casei*, *L.plantarum*, *B.longum*	10^8 CFU/Ml	4 weeks	Wang *et al.*, 2009
Orange juice after spouted bed drying	*L.casei*	~10^6 CFU/g	5 weeks	Alves, 2017
Orange, pineapple and cranberry juice	*L.casei*, *L.paracasei*, and *L.rhamnosus*	10^8 CFU/ml (Orange Juice), 10^7 CFU/ml (Pineapple juice) and very low cell viability was seen in cranberry juice	12 weeks	Sheehan *et al.*, 2007
Peach Juice	*L.casei*, *L.delbrueckii*	1.72 x 10^7 CFU/ml	4 weeks	Pakbin*et al.*, 2014
Pineapple juice	*L.casei*	10^6 CFU/ml	42 days	Costa *et al.*, 2013
Pomegranate juice	*L.plantarum* *L.paracasei* *L.acidophilus* *L.delbrueckii*		4 weeks	Mousavi*et al.*, 2011
Red grape and white grape juice	*P.pentosaceus*	3.2 – 6.5 log CFU/ml	72 h	Kumar *et al.*, 2017
Sugarcane and Sweet lime juices	*L.acidophilus*	2.0 x $10^{8\,-}$ 5.5 x 10^8 CFU/ml	3 weeks	Khatoon and Gupta, 2015
Watermelon and tomato juice	*L.fermentum*, *L.casei*		4 weeks	Sivudu *et al.*, 2014
Tomato juice	*L.plantarum* C3, *L.casei* A4, *L.acidophilus* LA39, *L.delbrueckii* D7	10^6 – 10^8 CFU/mL	4 weeks	Yoon *et al.*, 2004
Tomato, orange and grape juices	*L.plantarum*, *L.acidophilus*			Nagpal *et al.*, 2012

Table.2 Commercially available probiotic juices (Adapted from Patel, 2017; Molin, 2001; Leporanta, 2005)

Product name	Manufacturer	Probiotic strain(s)	Major attributes
BiolaR	TINE BA, Norway	*L.rhamnosus* GG	Mixture of apple-pear and, orange-mango juice with 95% fruit and no added sugar
Bio-Live Gold & Dark	Bio-Live/Microbz Ltd., UK	Mixtures of 13 strains including *L.acidophilus*, *L.bulgaricus*, *L.casei*, *L.plantarum*, *L.fermentum*, *Lactococcus lactis*, *Bacillus subtilis*, *B.bifidum*, *B.longum*, *B.infantis*, *Streptococcus thermophilus*, *Comobcillus*,and *Saccharomyces cerevisiae*	Mixture of fruit juices such as acai berry, cherry, goji, noni, pomegranate, lemon, and various herbs
Bravo Friscus	Probi AB, Sweden	*L.plantarum* HEAL9 and *L.paracasei* 8700:2	Orange apple and tropical fruit juices
Gefilus Fruit drinks	Valio Ltd., Finland	*L.rhamnosus* GG and *Propionibacterium freudenreichii* ssp. *shermanii* JS	Berries
Golden Circle Healthy Life Probiotic Juice	Golden Circle, Australia	*L.paracasei* 8700:2 and *L.plantarum* HEAL9	Mixture of apple juice with mango puree or orange, apple, pineapple, passion fruit with banana puree
Goodbelly® Carrot Ginger Flavor	Goodbelly, USA	*L.plantarum* 299v (50 million cells/ portion)	Carrot juice, ginger extract, and cane sugar contains 2% or less gluten-free oat flour
KEVITA	KEVITA, USA	*L.rhamnosus*, *L.plantarum*, *L.paracasei*, *Bacillus coagulans* GBI-30 6086	Various fruit based mixtures such as strawberry and coconut, lime, mint and coconut, pineapple and coconut
Malee Probiotics	Malee Enterprise Company Ltd., Thailand	*L.paracasei*	Prune, grape and orange juice
PERKii Probiotic Water	PERKii, Australia	*L.paracasei* Lc431	Fruit juice mixtures such as raspberry and pomegranate, lime and coconut, mango and passion fruit and strawberry and watermelon
Probiotic Naked Juice	Naked® Juice, USA	*Bifidobacterium*	Mixture of apple, orange, pineapple juices and mango and banana puree with fructooligosaccharides
ProViva	EMEA Probi AB, Sweden	*L.plantarum* 299v (50 million cells/ portion)	Orange, strawberry or blackcurrant juiceand fortified with 5% oat flour
Rela Fruit Juice	Biogaia Global, Sweden	*L.reuteri* MM53	Fruit juice
Tropicana probiotics	Tropicana, USA	*B.lactis*	Fruit juice mixtures such as strawberry and banana, pineapple and mango and peach passion fruit
Vita Biosa	Biosa, Denmark	*B.lactis*, *B.longum*, *L.acidophilus*, *L.casei*, *L.rhamnosus*, *L.salivarius*, *L.lactis*, *Streptococcus thermophilus*	Ginger, blackcurrant, blueberry juice with ginger extract enriched with 19 different aromatic herbs

Fig.1 Production of fermented and non-fermented fruit/vegetable juice enriched with probiotics



In conclusion, most probiotic products available in the market are milk-based; however, the increase in the consumer vegetarianism and demand for cholesterol free probiotics has led researchers and scientists to explore newer matrices as vehicles for probiotics. Technological advances have made it possible to alter some structural characteristics of fruit and vegetable matrices by modifying food components in a controlled way. Fruits and vegetables make the ideal substrates for the culture of probiotics since they already contain beneficial nutrients such as antioxidants, minerals, vitamins, and dietary fibers while lacking the dairy allergens that might prevent the consumption by certain groups of the population. Vegetables and fruits reported containing a wide variety of antioxidant components, including phytochemicals.

There is a genuine interest in the development of fruits and vegetable functional beverage with probiotics because they serve as a healthy alternative for dairy probiotics, are cholesterol free and also favour consumption by lactose tolerant consumers. Detailed studies on the microbial composition and characteristics of fermented fruits and vegetable juices lead to further application.

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