

# Lactiplantibacillus (Lpb.) plantarum

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Lactic acid fermentation of fresh fruit juices is a low-cost and sustainable process, that aims to preserve and even enhance the organoleptic and nutritional features of the raw matrices and extend their shelf life. Selected Lactic Acid Bacteria (LAB) were evaluated in the fermentation of various fruit juices, leading in some cases to fruit beverages, with enhanced nutritional and sensorial characteristics. Among LAB, *Lactiplantibacillus (Lpb.) plantarum* subsp. *plantarum* strains are quite interesting, regarding their application in the fermentation of a broad range of plant-derived substrates, such as vegetables and fruit juices, since they have genome plasticity and high versatility and flexibility. *L. plantarum* exhibits a remarkable portfolio of enzymes that make it very important and multi-functional in fruit juice fermentations. Therefore, *L. plantarum* has the potential for the production of various bioactive compounds, which enhance the nutritional value and the shelf life of the final product. In addition, *L. plantarum* can positively modify the flavor of fruit juices, leading to higher content of desirable volatile compounds.

[L. plantarum](#)

[probiotics](#)

[fruit juices](#)

[health benefits](#)

[enzymes](#)

[phenolics](#)

## 1. Introduction

The focus of innovations in the food industry has turned to new functions of food, which are prevention from various lifestyle diseases, mainly through the development of dietary supplements, that can affect the intestinal microbial composition. In addition, the preference of many consumers to foods free of additives has also boosted the facilitation and promotion of various novel products by the food industry called functional foods. Functional foods are foods that can positively affect specific human body functions beyond adequate nutritional effects, leading to the delivery of various health benefits to humans <sup>[1]</sup>. Functional foods mainly include probiotics, prebiotics, and more recently symbiotics <sup>[2][3]</sup>. Dairy products such as cheese, sour milk, yogurt and others are considered as the main representatives of probiotic foods. However, other alternative food products are being developed as probiotic substrates in the last few years <sup>[4][5]</sup>. The main reason for this shift is that dairy products display some drawbacks, affecting consumers' attitudes, such as milk cholesterol content, lactose intolerance and dairy allergies <sup>[6][7]</sup>. Thus, alternative food substrates were proposed as ideal carriers or mediums for probiotics, in order to tackle these disadvantages, such as cereals, vegetables and fruits in fermented and unfermented forms <sup>[7]</sup>. Particularly, fruit juices are presumed as attractive good substrates for probiotic delivery. The advantages of fruit juices, as probiotic "vehicles" include: (i) high nutritional value, (ii) positive health effects, and (iii) wide acceptance and consumption by consumers worldwide <sup>[8][9][10]</sup>. Many fruit juices were inspected, explored and evaluated, regarding their suitability, as viable and shelf-stable probiotic carriers, through lactic acid fermentation. Nevertheless, fermentation is a complex process, which needs control and selection of appropriate conditions in order to achieve desirable food characteristics and preserve probiotic cell functionality and viability. Likewise, the

proper selection of the starter culture for the fermentation of fruit juices and possible modifications of fruit juices (before fermentation) are considered critical parameters. Lactic acid bacteria (LAB) are the most common microorganisms applied for the fermentation of fruit juice. Particularly, *Lactobacillus plantarum* or, as it has lately been denoted, *Lactiplantibacillus (Lpb.) plantarum* subsp. *plantarum* [11] is an interesting and well-studied strain in the fermentation of fruit juices.

## 2. Lactic Acid Fermentation of Fruit Juices

The preference of consumers to fruit juices, nectars and ready-to-drink juice drinks was boosted in the last decade worldwide [12]. This is mainly, due to the shift of consumers' preference to more natural foods containing less or no chemical preservatives and the better awareness of consumers, regarding the nutritional values of foods [13]. In particular, fruit juices contain appreciable amounts of dietary fibers, antioxidants, polyphenols, minerals and vitamins and meet the consumer's claims for healthy, tasty, and practical foods.

On the other hand, fresh fruit juices are susceptible to spoilage by different microorganisms [14]. The shelf life of fresh fruit juices is very short and varies between 5 to 7 days at 4 °C [15]. Therefore, the preservation of fruit juices should be controlled by the addition of various synthetic preservatives, such as potassium sorbate and sodium benzoate [16]. Nevertheless, fresh juices extracted from fruits are commercialized as refrigerated products, without preservatives and with a very short shelf-life [17]. However, currently, consumers prefer fruit juices free of chemical additives and safe for consumption. Lactic acid fermentation of fruit juices seems a good alternative and could satisfy consumers' demands and preferences. Several studies were reported in the literature, verifying a clear positive impact in the extension of self-life of fruit juices, through fermentation by LAB. This impact depends on the kind of fruit juice and its chemical composition, the strain applied and the conditions of fermentation and storage (time, temperature, etc.). Lactic acid fermentation of fruit juices can keep or ameliorate: (i) the self-life [18], (ii) the nutritional, and (iii) the sensorial properties of the final product [19][20]. It is also considered as a mild processing method for preservation, which meets the standards regarding the consumption of fresh-like minimal processed beverages [21]. The most common microbiocidal group applied for lactic acid fermentation of fruit juices is LAB. Several studies were conducted and published in the literature and some examples are presented in **Table 1**, with the respective advantages.

**Table 1.** Examples of fermented fruit juices with various LAB strains (including *L. plantarum*) in single or mixed cultures with the respective effects.

Fruit Juices	Strains	Main Positive Effects	References
Mulberry juice ( <i>Morus nigra</i> )	<i>L. plantarum</i> , <i>L. acidophilus</i> , <i>L. paracasei</i>	Increase in total anthocyanin, phenolic, antioxidant activity.	[22]
Pomegranate juice ( <i>Punica granatum</i> L.)	<i>L. plantarum</i>	Increase in antimicrobial activity. Volatile free fatty acids content increased. Better	[23]

Fruit Juices	Strains	Main Positive Effects	References
Pomegranate juice ( <i>Punica granatum</i> L.)	<i>L. plantarum</i>	organoleptic properties and composition of volatile compounds.	
Pomegranate juice ( <i>Punica granatum</i> L.)	<i>L. paracasei</i>	Improved sensorial characteristics. improved TPC and antioxidant activity.	[24]
Cornelian cherry ( <i>Cornus mas</i> L.)	<i>L. paracasei</i>	Improved TPC and antioxidant activity.	[26]
Cashew apple juice ( <i>Anacardium occidentale</i> L.)	<i>B. bifidum</i> , <i>B. longum</i> subsp. <i>infantis</i> , <i>L. plantarum</i> , <i>L. acidophilus</i> , <i>L. mesenteroides</i> , <i>L. johnsonii</i>	Improved antioxidant activity. Modification of the type and content of phenolic. Possible prebiotic action of phenolics to lactic acid bacteria. Contained prebiotic oligosaccharides <i>mesenteroides</i> ) enhanced the growth of <i>L. johnsonii</i> .	[27]
Cantaloupe melon ( <i>Cucumis melo</i> L.) and cashew apple juice ( <i>Anacardium occidentale</i> L.)	<i>L. casei</i>	Emergence of new volatile compounds.	[28]
Apple juice	<i>L. acidophilus</i> , <i>L. rhamnosus</i> , <i>L. casei</i> , <i>L. plantarum</i>	Generation of new aromatic compounds.	[29]
Apple juice	<i>L. plantarum</i>	Enhanced antioxidant capacity and bioavailability of polyphenols.	[30]
Elderberry juice ( <i>Sambucus nigra</i> L.)	<i>L. plantarum</i>	Improved composition of volatile compounds.	[20]
Jujube juice ( <i>Ziziphus jujuba</i> Mill.)	<i>L. plantarum</i>	Enhanced sensorial features.	[31]
Noni juice ( <i>Morinda citrifolia</i> )	<i>L. casei</i> , <i>L. plantarum</i> , <i>B. longum</i> , <i>L. acidophilus</i>	Slight increase in total antioxidant activity. ACE inhibitory potential decreased during fermentation. The content of ascorbic acid and antioxidant activity remained stable.	[32]
Cranberry juice ( <i>Vaccinium macrocarpon</i> )	<i>L. paracasei</i>	Synergistic and additive antibacterial effects of the combination of fermented cranberry juice and antibiotics.	[33]

Fruit Juices	Strains	Main Positive Effects	References
Phyllanthus emblica fruit juice	<i>L. paracasei</i>	Increased Total polyphenol content and antioxidant activity.	[34]
Jujube juice ( <i>Ziziphus jujuba</i> Mill.)	<i>L. rhamnosus</i> , <i>L. plantarum</i> , <i>L. paracasei</i> , <i>L. mesenteroides</i> , <i>L. plantarum</i>	[37] Increased flavonoid content.	[35]
[25] Cactus pear juice ( <i>Opuntia fucus-indica</i> )	<i>L. plantarum</i>	Ameliorated insulin resistance.	[36]

fermented juices, can be affected by exposure to certain types of stress, such as acid and cold. Specifically, some fruit juices are very acidic, such as cranberry (pH 2.7), pomegranate (pH 3.0-3.5), lemon and lime juices (pH 2.8) [39], exhibiting severe impact on the viability of LAB, [40] during the production process and storage [41]. Especially, in the case of probiotic LAB strains, survival in harsh conditions is an essential prerequisite for probiotic delivery [42]. These obstacles could be tackled, with mainly 5 ways: (i) pre-adaptation or adaptive evolution, (ii) encapsulation, (iii) physical treatments (iv) mixing with a second juice and (v) proper selection of a probiotic LAB.

The most commonly way for stress adaptation is the modification of the growth medium and/or incubation conditions. Pre-adaptation or adaptive evolution [43] involves the treatment of a microorganism to a sublethal stress (pH, cold, osmotic press etc,) for a limited time; this treatment would act on strain resistance, when exposed to a higher level of stress or to another stress. This method has been applied in lactic acid fermentation of fruit juices by probiotics, with very promising results [44][45].

Microencapsulation is considered as a promising method for the improvement of probiotics' viability in functional beverages. Microencapsulation of probiotics leads to high preservation of the probiotic load and strengthen cells, versus various physicochemical changes, such as pH, temperature, bile salts, etc. [46][47][48]. Another target of probiotic microencapsulation, is the improvement of the resistance of the probiotic cells in the gastro-intestinal tract, besides enhancing the viability of the bacterial strains in the food products. Various methods have been proposed for probiotic cell microencapsulation, such as emulsification, spray freeze drying and extrusion, with numerous encapsulating agents [49]. The most commonly employed encapsulating agents are natural biopolymer, such as alginate and  $\kappa$ -carrageenan, as well as prebiotics, such as resistant starch, inulin, fructooligosaccharide and fiber [50]. Application of prebiotics as encapsulating agents seems more attractive, because it is a cost-effective technology for the industrial scale and offers encouraging results [47][49]. The functionality of LAB could be significantly ameliorated employing physical treatments. The most common applied technology is ultrasound (US). Probiotic *L. casei* NRRL B442 manage to survive for at least 21 days at 4 °C in a sonicated pineapple juice [51]. In another report, *L. reuteri*, *L. plantarum*, *L. casei*, bifidobacteria, and propionibacteria were treated with US, before the inoculation in an organic rice beverage and maintained the pH and sensory scores for at least 7 days [52][53]. Addition of a second juice (fresh or fermented) to the main one is a quite interesting perspective. The main reason for this treatment, is the slight increase of the low pH value of the main juice, in order the survival of the probiotic

strain to be ameliorated. Likewise, carrot juice has been proposed for this purpose, since it has approximately a pH value of 6 [24]. Furthermore, addition of 5% acerola juice to orange juice, prevented the production of carbon dioxide gas for three weeks and has no impact on the probiotic content during four weeks of storage at 8 °C [54].

### 3. Main Advantages of *L. plantarum* Application in Food Fermentations

*L. plantarum* is a safe microorganism (Generally Regard as Safe — GRAS) and has been widely used in food-fermentation technologies [55][56]. It has also been employed in probiotic food production, such as *L. plantarum* 299v strain, which is widely marketed [57]. It is a facultative heterofermentative LAB, that can tolerate the combination of high acidity and ethanol concentration and survive under conditions, that are usually fatal to LAB [58]. The adaptability of *L. plantarum* to a fermentation process and its metabolic flexibility and versatility are some of the critical attributes, that makes it unique among the other LAB [59]. *L. plantarum* has been isolated through numerous food sources, such as cereals, meats, dairy products, vegetables, fruits and drinks [60][61][62][63][64], as well as human and mammals niches [65]. *L. plantarum* can adapt to various niches, probably due to its genome size (average 3.3 Mb), which is one of the largest detected within *Lactobacillus* genus [66].

In addition, *L. plantarum* can be involved in several biochemical reactions, usually ended in desirable metabolites, due to its specific enzymatic composition. *L. plantarum* contains a variety of extracellular enzymes, that contribute to the secretion and modification of proteins and to the modification and degradation of extracellular compounds, allowing for the use of such molecules as a source of nutrients [67][68]. Specifically, *L. plantarum* possesses enzymes, such as tannase,  $\beta$ -glucosidase,  $\alpha$ -glucosidase and  $\beta$ -galactosidase *p*-coumaric acid decarboxylase and general decarboxylase, that catalyze the production of high added-value compounds, such as phenolic compounds leading to the production of compounds, that influence positively food aroma and increase the antioxidant activity [69]. The production of aryl  $\beta$ -glucosidases, by *L. plantarum* initiates an increase in the functionally (antioxidant activity and bioavailability) of glycosylated phenolic compounds. Besides, employment of *L. plantarum* to various plant-based products, such as fruit juices, with high content of tannins, attenuated the phenolic astringency, which is responsible of the unpalatability of many fruit juices [70].

Recently, probiotic strains of *L. plantarum* has been successfully applied in medical fields, with encouraging outcome. Specifically, the efficacy of *L. plantarum* strains in the cure or treatment of gastrointestinal disorders, cholesterol lowering and reduction in the irritable bowel syndrome (IBS) symptoms has been highlighted in human trials [71].

Several strains of *L. plantarum* have been exhibited antimicrobial and antagonistic activity, against some adverse microorganisms, antifungal activities and antiviral effects [72]. In addition, it should be highlighted the wide range of bacteriocins and exopolysaccharides (EPS), that *L. plantarum* is able to produce [73]. Bacteriocins show a broad antimicrobial activity spectrum against Gram-positive and Gram-negative bacteria, while EPS provide potential health-promoting properties in the advances of functional foods [74].

## Application of *L. plantarum* Strains in Various Fruit Juices Fermentations

A great variety of fruit juices has been successfully fermented by *L. plantarum* strains leading to final products with potentially functional properties. Most of these reported positive effects are presented in **Table 1** and are recapitulated to: (i) enhanced antioxidant activity, (ii) increased total phenolic and total anthocyanin content, (iii) extension of the shelf-life of fruit juices and (iv) better sensorial features. It has been reported, that *L. plantarum* ATCC14917 modified the phenolic composition of apple juice after fermentation and enhanced its overall antioxidant capacity, as well as the bioavailability of polyphenols of apples [30]. The absorption of food phenolics in humans, is necessary for the exhibition of their beneficial effects. It is mainly evaluated by their chemical structure, which depends on factors such as the degree of glycosylation and conjugation with other phenolics [75].

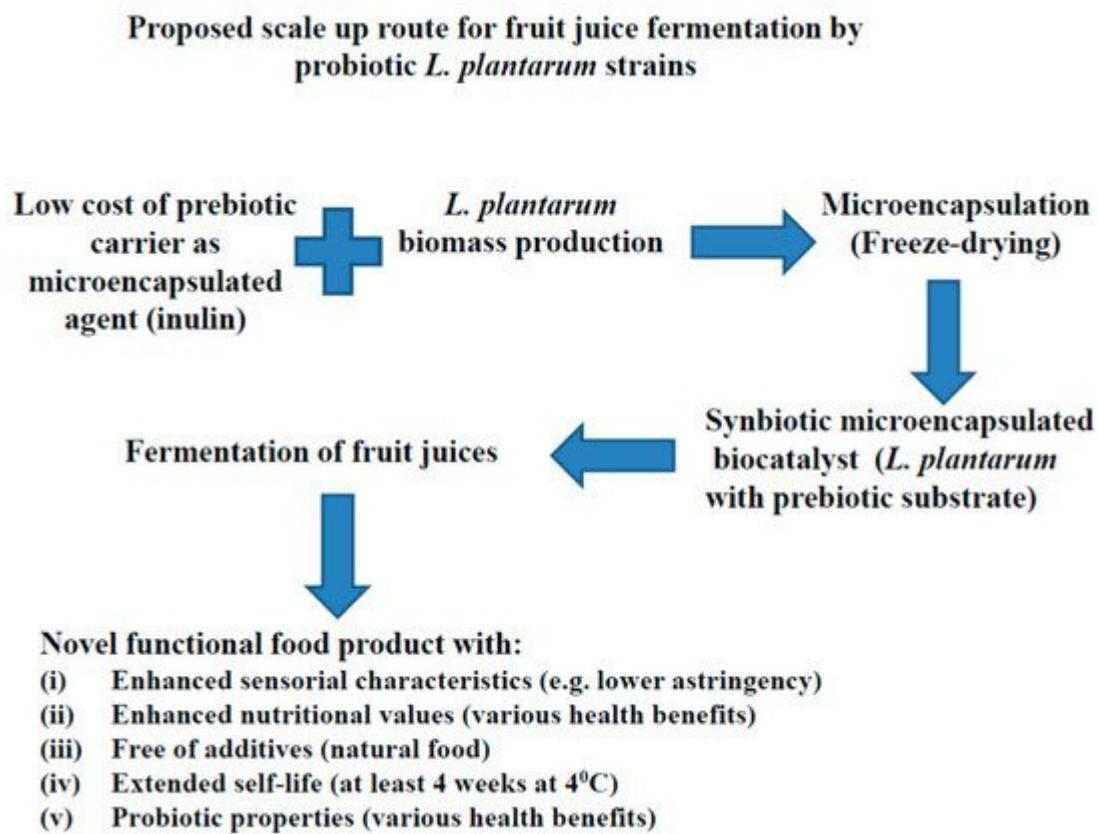
On the other hand, food industry is seeking ways to produce novel products with increased nutritional value. Moreover, there are many reports, that application of a probiotic bacteria in the fermentation of fruit juices may lead to a final product, with functional properties and specific health benefits [76][77][78].

Even though, *L. plantarum* can grow generally at temperatures between 15–30 °C and at pH values near to 4 [79], there are specific probiotic strains of *L. plantarum* with respectable tolerance at low pH values (approximately 3.2) and at low temperatures in the matrix of fruit juices (4–8 °C) [80]. For instance, viability of probiotic *L. plantarum* NCIMB 8826 decreased during cold storage (4 °C) of cranberry, pomegranate and lemon & lime juices with initial pH values approximately 3. However, only in the case of lemon & lime juice cells were viable until the 35<sup>th</sup> day [39]. This could be explained by: (i) the high levels of phenolic compounds in cranberry juice [39] and pomegranate juice [81], which are known to have strong antimicrobial properties [82] and (ii) the fact that cells were pre-adapted to citric acid, which is the main antimicrobial compound in the lemon & lime juice, leading to higher viabilities to this juice compared to the others [39]. In another recent study, cell viability of probiotic *L. plantarum* ATCC14917 was remained at high levels throughout the 21 days of cold storage (4 °C) of fermented pomegranate juice (initially 11.43 log cfu/mL) and decreased to 8.83 log cfu/mL at the 4<sup>th</sup> week of storage, above the limit for the exhibition of probiotic properties. The same observations were made, during cold storage (4 °C) of fermented Cornelian cherry [83] and pomegranate juice [24], with *L. plantarum* ATCC 14917 and fermented sweet lemon juice (*Citrus limetta*) with *L. plantarum* LS5 [84].

Furthermore, *L. plantarum* has a positive effect on the flavor of fruit juices, leading to higher content of desirable volatile compounds during fermentation. Lactic acid fermentation of jujube juice by *L. plantarum* significantly enhanced the composition and production of desirable volatile compounds, leading to aroma complexity and better sensorial characteristics [31]. *L. plantarum* 285 exhibited interesting features, in terms of total aromatic potential, as well as in the type of volatiles compounds produced through lactic acid fermentation of elderberry juice [20]. Fermentation of blueberry juices with *L. plantarum* enhanced the acceptability of the final product [85].

Besides, Food Industry has selected probiotic *L. plantarum* strains in single or mixed culture, in order to produce a variety of probiotic fruit beverages, through fermentation (**Table 2**). The commercialization of the whole fermentation system, which includes *L. plantarum* verifies the eligibility of this important LAB. A proposed route for

the scale up of the whole procedure could be feasible and it is presented in **Figure 1**. However, research is continuing and it is possible, that through in vivo tests and human trials, more interesting outcomes may be recorded. The main reason for this assumption is the biological activities, that this microorganism has exhibited so far.



**Figure 1.** Proposed scale-up route for fruit juice fermentation by probiotic *L. plantarum* strains.

**Table 2.** Global commercial probiotic products based on fruit matrices fermented by probiotic *L. plantarum*. Source: [\[86\]](#).

Food Matrix	Commercial Name	Origin	Active Probiotic Culture
Fruit drink	Probi-Bravo Friscus	Sweden	<i>L. plantarum</i> , <i>L. paracasei</i>
Fruit drink	Danone-ProViva	Sweden, Finland	<i>L. plantarum</i>
Raw organic fruits and vegetable blend	Garden of Life RAW Organic Kids Probiotic	Florida, USA	<i>L. gasseri</i> , <i>L. plantarum</i> , <i>L. casei</i> , <i>L. acidophilus</i>
Fruit juice drink	GoodBelly	Colorado, USA	<i>Lb. plantarum</i> 299v
Fruit- and vegetable-based	KeVita active probiotic drink	Oxnard, USA	<i>B. coagulans</i> , <i>L. rhamnosus</i> , <i>L. plantarum</i>

Food Matrix	Commercial Name	Origin	Active Probiotic Culture
Fruit juice	Healthy Life Probiotic juice	Australia	<i>L. plantarum</i> , <i>L. casei</i>

## References

1. Oliveira, A.; Amaro, A.L.; Pintado, M. Impact of Food Matrix Components on Nutritional and Functional Properties of Fruit-Based Products. *Curr. Opin. Food Sci.* 2018, 22, 153–159.
2. Mantzourani, I.; Plessas, S.; Odatzidou, M.; Alexopoulos, A.; Galanis, A.; Bezirtzoglou, E.; Bekatorou, A. Effect of a Novel *Lactobacillus Paracasei* Starter on Sourdough Bread Quality. *Food Chem.* 2019, 271, 259–265.
3. Wong, W.-Y.; Chan, B.D.; Leung, T.-W.; Chen, M.; Tai, W.C.-S. Beneficial and Anti-Inflammatory Effects of Formulated Prebiotics, Probiotics, and Synbiotics in Normal and Acute Colitis Mice. *J. Funct. Foods* 2022, 88, 104871.
4. James, A.; Wang, Y. Characterization, Health Benefits and Applications of Fruits and Vegetable Probiotics. *CyTA-J. Food* 2019, 17, 770–780.
5. Vitali, B.; Minervini, G.; Rizzello, C.G.; Spisni, E.; Maccaferri, S.; Brigidi, P.; Gobbetti, M.; Di Cagno, R. Novel Probiotic Candidates for Humans Isolated from Raw Fruits and Vegetables. *Food Microbiol.* 2012, 31, 116–125.
6. Kandylis, P.; Pissaridi, K.; Bekatorou, A.; Kanellaki, M.; Koutinas, A.A. Dairy and Non-Dairy Probiotic Beverages. *Curr. Opin. Food Sci.* 2016, 7, 58–63.
7. Ranadheera, C.S.; Vidanarachchi, J.K.; Rocha, R.S.; Cruz, A.G.; Ajlouni, S. Probiotic Delivery through Fermentation: Dairy vs. Non-Dairy Beverages. *Fermentation* 2017, 3, 67.
8. 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.
9. Horáčková, Š.; Rokytová, K.; Bialasová, K.; Kloj dová, I.; Sluková, M. Fruit Juices with Probiotics—New Type of Functional Foods. *Czech J. Food Sci.* 2018, 36, 284–288.
10. Perricone, M.; Bevilacqua, A.; Altieri, C.; Sinigaglia, M.; Corbo, M.R. Challenges for the Production of Probiotic Fruit Juices. *Beverages* 2015, 1, 95–103.
11. Zheng, J.; Wittouck, S.; Salvetti, E.; Franz, C.M.; Harris, H.M.; Mattarelli, P.; O'Toole, P.W.; Pot, B.; Vandamme, P.; Walter, J.A.; et al. Taxonomic Note on the Genus *Lactobacillus*: Description of 23 Novel Genera, Emended Description of the Genus *Lactobacillus* Beijerinck 1901, and Union of *Lactobacillaceae* and *Leuconostocaceae*. *Int. J. Syst. Evol. Microbiol.* 2020, 70, 2782–2858.
12. Pontonio, E.; Montemurro, M.; Pinto, D.; Marzani, B.; Trani, A.; Ferrara, G.; Mazzeo, A.; Gobbetti, M.; Rizzello, C.G. Lactic Acid Fermentation of Pomegranate Juice as a Tool to Improve

Antioxidant Activity. *Front. Microbiol.* 2019, 10.

13. Plessas, S.; Nouska, C.; Karapetsas, A.; Kazakos, S.; Alexopoulos, A.; Mantzourani, I.; Chondrou, P.; Fournomiti, M.; Galanis, A.; Bezirtzoglou, E. Isolation, Characterization and Evaluation of the Probiotic Potential of a Novel *Lactobacillus* Strain Isolated from Feta-Type Cheese. *Food Chem.* 2017, 226, 102–108.

14. Snyder, A.B.; Worobo, R.W. The Incidence and Impact of Microbial Spoilage in the Production of Fruit and Vegetable Juices as Reported by Juice Manufacturers. *Food Control* 2018, 85, 144–150.

15. Rojo, M.C.; López, F.A.; Lerena, M.C.; Mercado, L.; Torres, A.; Combina, M. Evaluation of Different Chemical Preservatives to Control *Zygosaccharomyces rouxii* Growth in High Sugar Culture Media. *Food Control* 2015, 50, 349–355.

16. Panitsa, A.; Petsi, T.; Kandylis, P.; Kanellaki, M.; Koutinas, A.A. Tubular Cellulose from Orange Juice By-Products as Carrier of Chemical Preservatives; Delivery Kinetics and Microbial Stability of Orange Juice. *Foods* 2021, 10, 1882.

17. Silveira, A.C.; Aguayo, E.; Artés, F. Shelf-Life and Quality Attributes in Fresh-Cut Galia Melon Combined with Fruit Juices. *LWT-Food Sci. Technol.* 2013, 50, 343–348.

18. Ma, L.; Zhang, M.; Bhandari, B.; Gao, Z. Recent Developments in Novel Shelf Life Extension Technologies of Fresh-Cut Fruits and Vegetables. *Trends Food Sci. Technol.* 2017, 64, 23–38.

19. Filannino, P.; Tlais, A.Z.; Morozova, K.; Cavoski, I.; Scampicchio, M.; Gobbetti, M.; Di Cagno, R. Lactic Acid Fermentation Enriches the Profile of Biogenic Fatty Acid Derivatives of Avocado Fruit (*Persea Americana* Mill.). *Food Chem.* 2020, 317, 126384.

20. Ricci, A.; Cirlini, M.; Levante, A.; Dall'Asta, C.; Galaverna, G.; Lazzi, C. Volatile Profile of Elderberry Juice: Effect of Lactic Acid Fermentation Using *L. plantarum*, *L. rhamnosus* and *L. casei* Strains. *Food Res. Int.* 2018, 105, 412–422.

21. Di Cagno, R.; Filannino, P.; Gobbetti, M. Lactic Acid Fermentation Drives the Optimal Volatile Flavor-Aroma Profile of Pomegranate Juice. *Int. J. Food Microbiol.* 2017, 248, 56–62.

22. Kwaw, E.; Ma, Y.; Tchabo, W.; Apaliya, M.T.; Wu, M.; Sackey, A.S.; Xiao, L.; Tahir, H.E. Effect of *Lactobacillus* Strains on Phenolic Profile, Color Attributes and Antioxidant Activities of Lactic-Acid-Fermented Mulberry Juice. *Food Chem.* 2018, 250, 148–154.

23. Valero-Cases, E.; Nuncio-Jáuregui, N.; Frutos, M.J. Influence of Fermentation with Different Lactic Acid Bacteria and in Vitro Digestion on the Biotransformation of Phenolic Compounds in Fermented Pomegranate Juices. *J. Agric. Food Chem.* 2017, 65, 6488–6496.

24. Mantzourani, I.; Kazakos, S.; Terpou, A.; Alexopoulos, A.; Bezirtzoglou, E.; Bekatorou, A.; Plessas, S. Potential of the Probiotic *Lactobacillus plantarum* ATCC 14917 Strain to Produce

Functional Fermented Pomegranate Juice. *Foods* 2019, 8, 4.

25. Mantzourani, I.; Terpou, A.; Bekatorou, A.; Mallouchos, A.; Alexopoulos, A.; Kimbaris, A.; Bezirtzoglou, E.; Koutinas, A.A.; Plessas, S. Functional Pomegranate Beverage Production by Fermentation with a Novel Synbiotic *L. Paracasei* Biocatalyst. *Food Chem.* 2020, 308, 125658.

26. Mantzourani, I.; Terpou, A.; Alexopoulos, A.; Bezirtzoglou, E.; Bekatorou, A.; Plessas, S. Production of a Potentially Synbiotic Fermented Cornelian Cherry (*Cornus Mas* L.) Beverage Using *Lactobacillus Paracasei* K5 Immobilized on Wheat Bran. *Biocatal. Agric. Biotechnol.* 2019, 17, 347–351.

27. Vergara, C.M.d.A.C.; Honorato, T.L.; Maia, G.A.; Rodrigues, S. Prebiotic Effect of Fermented Cashew Apple (*Anacardium Occidentale* L) Juice. *LWT-Food Sci. Technol.* 2010, 43, 141–145.

28. de Godoy Alves Filho, E.; Rodrigues, T.H.S.; Fernandes, F.A.N.; Pereira, A.L.F.; Narain, N.; de Brito, E.S.; Rodrigues, S. Chemometric Evaluation of the Volatile Profile of Probiotic Melon and Probiotic Cashew Juice. *Food Res. Int.* 2017, 99, 461–468.

29. Chen, C.; Lu, Y.; Yu, H.; Chen, Z.; Tian, H. Influence of 4 Lactic Acid Bacteria on the Flavor Profile of Fermented Apple Juice. *Food Biosci.* 2019, 27, 30–36.

30. Li, Z.; Teng, J.; Lyu, Y.; Hu, X.; Zhao, Y.; Wang, M. Enhanced Antioxidant Activity for Apple Juice Fermented with *Lactobacillus Plantarum* ATCC14917. *Molecules* 2019, 24, 51.

31. Li, T.; Jiang, T.; Liu, N.; Wu, C.; Xu, H.; Lei, H. Biotransformation of Phenolic Profiles and Improvement of Antioxidant Capacities in Jujube Juice by Select Lactic Acid Bacteria. *Food Chem.* 2021, 339, 127859.

32. Nayak, B.S.; Marshall, J.R.; Isitor, G.; Adogwa, A. Hypoglycemic and Hepatoprotective Activity of Fermented Fruit Juice of *Morinda Citrifolia* (Noni) in Diabetic Rats. *Evid. -Based Complementary Altern. Med.* 2010, 2011.

33. Mantzourani, I.; Bontsidis, C.A.; Plessas, S.; Alexopoulos, A.; Theodoridou, E.; Tsigalou, C.; Voidarou, C.; Douganiotis, G.; Kazakos, S.L.; Stavropoulou, E. Comparative Susceptibility Study against Pathogens Using Fermented Cranberry Juice and Antibiotics. *Front. Microbiol.* 2019, 10, 1294.

34. Peerajan, S.; Chaiyasut, C.; Sirilun, S.; Chaiyasut, K.; Kesika, P.; Sivamaruthi, B.S. Enrichment of Nutritional Value of *Phyllanthus Emblica* Fruit Juice Using the Probiotic Bacterium, *Lactobacillus Paracasei* HII01 Mediated Fermentation. *Food Sci. Technol.* 2016, 36, 116–123.

35. Zhao, M.-N.; Zhang, F.; Zhang, L.; Liu, B.-J.; Meng, X.-H. Mixed Fermentation of Jujube Juice (*Ziziphus Jujuba* Mill.) with *L. Rhamnosus* GG and *L. Plantarum*-1: Effects on the Quality and Stability. *Int. J. Food Sci. Technol.* 2019, 54, 2624–2631.

36. Verón, H.E.; Cano, P.G.; Fabersani, E.; Sanz, Y.; Isla, M.I.; Espinar, M.T.F.; Ponce, J.V.G.; Torres, S. Cactus Pear (*Opuntia Ficus-Indica*) Juice Fermented with Autochthonous *Lactobacillus Plantarum* S-811. *Food Funct.* 2019, 10, 1085–1097.

37. Shubhada, N.; Rudresh, D.L.; Jagadeesh, S.L.; Prakash, D.P.; Raghavendra, S. Fermentation of Pomegranate Juice by Lactic Acid Bacteria. *Int J Curr Microbiol Appl Sci* 2018, 7, 4160–4173.

38. Muhialdin, B.J.; Kadum, H.; Hussin, A.S.M. Metabolomics Profiling of Fermented Cantaloupe Juice and the Potential Application to Extend the Shelf Life of Fresh Cantaloupe Juice for Six Months at 8 C. *Food Control* 2021, 120, 107555.

39. Srisukchayakul, P.; Charalampopoulos, D.; Karatzas, K.A. Study on the Effect of Citric Acid Adaptation toward the Subsequent Survival of *Lactobacillus Plantarum* NCIMB 8826 in Low PH Fruit Juices during Refrigerated Storage. *Food Res. Int.* 2018, 111, 198–204.

40. Sheehan, V.M.; Ross, P.; Fitzgerald, G.F. Assessing the Acid Tolerance and the Technological Robustness of Probiotic Cultures for Fortification in Fruit Juices. *Innov. Food Sci. Emerg. Technol.* 2007, 8, 279–284.

41. Vinderola, C.G.; Bailo, N.; Reinheimer, J.A. Survival of Probiotic Microflora in Argentinian Yoghurts during Refrigerated Storage. *Food Res. Int.* 2000, 33, 97–102.

42. Hill, C.; Guarner, F.; Reid, G.; Gibson, G.R.; Merenstein, D.J.; Pot, B.; Morelli, L.; Canani, R.B.; Flint, H.J.; Salminen, S.; et al. The International Scientific Association for Probiotics and Prebiotics Consensus Statement on the Scope and Appropriate Use of the Term Probiotic. *Nat. Rev. Gastroenterol. Hepatol.* 2014, 11, 506–514.

43. Papadimitriou, K.; Alegría, Á.; Bron, P.A.; De Angelis, M.; Gobbetti, M.; Kleerebezem, M.; Lemos, J.A.; Linares, D.M.; Ross, P.; Stanton, C. Stress Physiology of Lactic Acid Bacteria. *Microbiol. Mol. Biol. Rev.* 2016, 80, 837–890.

44. Bucka-Kolendo, J.; Sokołowska, B. Lactic Acid Bacteria Stress Response to Preservation Processes in the Beverage and Juice Industry. *Acta Biochim. Pol.* 2017, 64, 459–464.

45. Gaucher, F.; Bonnassie, S.; Rabah, H.; Marchand, P.; Blanc, P.; Jeantet, R.; Jan, G. Adaptation of Beneficial Propionibacteria, Lactobacilli, and Bifidobacteria Improves Tolerance toward Technological and Digestive Stresses. *Front. Microbiol.* 2019, 10, 841.

46. Mitropoulou, G.; Nedovic, V.; Goyal, A.; Kourkoutas, Y. Immobilization Technologies in Probiotic Food Production. *J. Nutr. Metab.* 2013, 2013.

47. Colín-Cruz, M.A.; Pimentel-González, D.J.; Carrillo-Navas, H.; Alvarez-Ramírez, J.; Guadarrama-Lezama, A.Y. Co-Encapsulation of Bioactive Compounds from Blackberry Juice and Probiotic Bacteria in Biopolymeric Matrices. *LWT* 2019, 110, 94–101.

48. Dimitrellou, D.; Kandylis, P.; Lević, S.; Petrović, T.; Ivanović, S.; Nedović, V.; Kourkoutas, Y. Encapsulation of *Lactobacillus Casei* ATCC 393 in Alginate Capsules for Probiotic Fermented Milk Production. *LWT* 2019, 116, 108501.

49. Sarao, L.K.; Arora, M. Probiotics, Prebiotics, and Microencapsulation: A Review. *Crit. Rev. Food Sci. Nutr.* 2017, 57, 344–371.

50. Cook, M.T.; Tzortzis, G.; Charalampopoulos, D.; Khutoryanskiy, V.V. Microencapsulation of Probiotics for Gastrointestinal Delivery. *J. Control. Release* 2012, 162, 56–67.

51. Costa, M.G.M.; Fonteles, T.V.; de Jesus, A.L.T.; Rodrigues, S. Sonicated Pineapple Juice as Substrate for *L. Casei* Cultivation for Probiotic Beverage Development: Process Optimisation and Product Stability. *Food Chem.* 2013, 139, 261–266.

52. Racioppo, A.; Corbo, M.R.; Piccoli, C.; Sinigaglia, M.; Speranza, B.; Bevilacqua, A. Ultrasound Attenuation of Lactobacilli and Bifidobacteria: Effect on Some Technological and Probiotic Properties. *Int. J. Food Microbiol.* 2017, 243, 78–83.

53. Bevilacqua, A.; Casanova, F.P.; Petrucci, L.; Sinigaglia, M.; Corbo, M.R. Using Physical Approaches for the Attenuation of Lactic Acid Bacteria in an Organic Rice Beverage. *Food Microbiol.* 2016, 53, 1–8.

54. Gawkowski, D.; Chikindas, M.L. Non-Dairy Probiotic Beverages: The next Step into Human Health. *Benef. Microbes* 2013, 4, 127–142.

55. Arellano, K.; Vazquez, J.; Park, H.; Lim, J.; Ji, Y.; Kang, H.-J.; Cho, D.; Jeong, H.W.; Holzapfel, W.H. Safety Evaluation and Whole-Genome Annotation of *Lactobacillus Plantarum* Strains from Different Sources with Special Focus on Isolates from Green Tea. *Probiotics Antimicrob. Proteins* 2020, 12, 1057–1070.

56. Szutowska, J. Functional Properties of Lactic Acid Bacteria in Fermented Fruit and Vegetable Juices: A Systematic Literature Review. *Eur. Food Res. Technol.* 2020, 246, 357–372.

57. Wang, Q.; Sun, Q.; Wang, J.; Qiu, X.; Qi, R.; Huang, J. *Lactobacillus Plantarum* 299v Changes MiRNA Expression in the Intestines of Piglets and Leads to Downregulation of LITAF by Regulating Ssc-MiR-450a. *Probiotics Antimicrob. Proteins* 2021, 1–13.

58. Oh, Y.J.; Kim, T.S.; Moon, H.W.; Lee, S.Y.; Lee, S.Y.; Ji, G.E.; Hwang, K.T. *Lactobacillus Plantarum* PMO 08 as a Probiotic Starter Culture for Plant-Based Fermented Beverages. *Molecules* 2020, 25, 5056.

59. Behera, S.S.; Ray, R.C.; Zdolec, N. *Lactobacillus Plantarum* with Functional Properties: An Approach to Increase Safety and Shelf-Life of Fermented Foods. *BioMed Res. Int.* 2018, 2018.

60. De Vries, M.C.; Vaughan, E.E.; Kleerebezem, M.; de Vos, W.M. *Lactobacillus Plantarum*—Survival, Functional and Potential Probiotic Properties in the Human Intestinal Tract. *Int. Dairy J.*

2006, 16, 1018–1028.

61. Wang, S.-Y.; Zhu, H.-Z.; Lan, Y.-B.; Liu, R.-J.; Liu, Y.-R.; Zhang, B.-L.; Zhu, B.-Q. Modifications of Phenolic Compounds, Biogenic Amines, and Volatile Compounds in Cabernet Gernishct Wine through Malolactic Fermentation by *Lactobacillus Plantarum* and *Oenococcus Oeni*. *Fermentation* 2020, 6, 15.

62. Lanza, B.; Zago, M.; Di Marco, S.; Di Loreto, G.; Cellini, M.; Tidona, F.; Bonvini, B.; Baccelli, M.; Simone, N. Single and Multiple Inoculum of *Lactiplantibacillus Plantarum* Strains in Table Olive Lab-Scale Fermentations. *Fermentation* 2020, 6, 126.

63. Campaniello, D.; Speranza, B.; Bevilacqua, A.; Altieri, C.; Rosaria Corbo, M.; Sinigaglia, M. Industrial Validation of a Promising Functional Strain of *Lactobacillus Plantarum* to Improve the Quality of Italian Sausages. *Microorganisms* 2020, 8, 116.

64. Alemneh, S.T.; Emire, S.A.; Hitzmann, B. Teff-Based Probiotic Functional Beverage Fermented with *Lactobacillus Rhamnosus* and *Lactobacillus Plantarum*. *Foods* 2021, 10, 2333.

65. Ibrahim, F.; Ouwehand, A.C. The Genus *Lactobacillus*. *Lact. Acid Bact. Microbiol. Funct. Asp.* 2019, 47.

66. Prete, R.; Long, S.L.; Joyce, S.A.; Corsetti, A. Genotypic and Phenotypic Characterization of Food-Associated *Lactobacillus Plantarum* Isolates for Potential Probiotic Activities. *FEMS Microbiol. Lett.* 2020, 367, fnaa076.

67. Shahidi, F.; Peng, H. Bioaccessibility and Bioavailability of Phenolic Compounds. *J. Food Bioact.* 2018, 4, 11–68.

68. Boekhorst, J.; Wels, M.; Kleerebezem, M.; Siezen, R.J. The Predicted Secretome of *Lactobacillus Plantarum* WCFS1 Sheds Light on Interactions with Its Environment. *Microbiology* 2006, 152, 3175–3183.

69. Park, J.-B.; Lim, S.-H.; Sim, H.-S.; Park, J.-H.; Kwon, H.-J.; Nam, H.S.; Kim, M.-D.; Baek, H.-H.; Ha, S.-J. Changes in Antioxidant Activities and Volatile Compounds of Mixed Berry Juice through Fermentation by Lactic Acid Bacteria. *Food Sci. Biotechnol.* 2017, 26, 441–446.

70. Huang, R.; Xu, C. An Overview of the Perception and Mitigation of Astringency Associated with Phenolic Compounds. *Compr. Rev. Food Sci. Food Saf.* 2021, 20, 1036–1074.

71. Seddik, H.A.; Bendali, F.; Gancel, F.; Fliss, I.; Spano, G.; Drider, D. *Lactobacillus Plantarum* and Its Probiotic and Food Potentialities. *Probiotics Antimicrob. Proteins* 2017, 9, 111–122.

72. Al-Tawaha, R.; Meng, C. Potential Benefits of *Lactobacillus Plantarum* as Probiotic and Its Advantages in Human Health and Industrial Applications: A Review. *Adv. Environ. Biol* 2018, 12, 16–27.

73. Li, P.; Li, X.; Gu, Q.; Lou, X.; Zhang, X.; Song, D.; Zhang, C. Comparative Genomic Analysis of *Lactobacillus Plantarum* ZJ316 Reveals Its Genetic Adaptation and Potential Probiotic Profiles. *J. Zhejiang Univ. -Sci. B* 2016, 17, 569–579.

74. Moradi, M.; Molaei, R.; Guimarães, J.T. A Review on Preparation and Chemical Analysis of Postbiotics from Lactic Acid Bacteria. *Enzym. Microb. Technol.* 2021, 143, 109722.

75. Kumar, N.; Goel, N. Phenolic Acids: Natural Versatile Molecules with Promising Therapeutic Applications. *Biotechnol. Rep.* 2019, 24, e00370.

76. Putnik, P.; Pavlić, B.; Šojić, B.; Zavadlav, S.; Žuntar, I.; Kao, L.; Kitonić, D.; Kovačević, D.B. Innovative Hurdle Technologies for the Preservation of Functional Fruit Juices. *Foods* 2020, 9, 699.

77. Tanganurat, P. Probiotics Encapsulated Fruit Juice Bubbles as Functional Food Product. *Cell* 2020, 4, 5.

78. Zhu, W.; Lyu, F.; Naumovski, N.; Ajlouni, S.; Ranadheera, C.S. Functional Efficacy of Probiotic *Lactobacillus Sanfranciscensis* in Apple, Orange and Tomato Juices with Special Reference to Storage Stability and In Vitro Gastrointestinal Survival. *Beverages* 2020, 6, 13.

79. Todorov, S.D.; Franco, B.D.G.D.M. *Lactobacillus Plantarum*: Characterization of the Species and Application in Food Production. *Food Rev. Int.* 2010, 26, 205–229.

80. Filannino, P.; Cardinali, G.; Rizzello, C.G.; Buchin, S.; De Angelis, M.; Gobbetti, M.; Di Cagno, R. Metabolic Responses of *Lactobacillus Plantarum* Strains during Fermentation and Storage of Vegetable and Fruit Juices. *Appl. Environ. Microbiol.* 2014, 80, 2206–2215.

81. Gil, M.I.; Tomás-Barberán, F.A.; Hess-Pierce, B.; Holcroft, D.M.; Kader, A.A. Antioxidant Activity of Pomegranate Juice and Its Relationship with Phenolic Composition and Processing. *J. Agric. Food Chem.* 2000, 48, 4581–4589.

82. Landete, J.M.; Rodriguez, H.; De Las Rivas, B.; Munoz, R. High-Added-Value Antioxidants Obtained from the Degradation of Wine Phenolics by *Lactobacillus Plantarum*. *J. Food Prot.* 2007, 70, 2670–2675.

83. Mantzourani, I.; Nouska, C.; Terpou, A.; Alexopoulos, A.; Bezirtzoglou, E.; Panayiotidis, M.I.; Galanis, A.; Plessas, S. Production of a Novel Functional Fruit Beverage Consisting of Cornelian Cherry Juice and Probiotic Bacteria. *Antioxidants* 2018, 7, 163.

84. Hashemi, S.M.B.; Khaneghah, A.M.; Barba, F.J.; Nemati, Z.; Shokofti, S.S.; Alizadeh, F. Fermented Sweet Lemon Juice (Citrus Limetta) Using *Lactobacillus Plantarum* LS5: Chemical Composition, Antioxidant and Antibacterial Activities. *J. Funct. Foods* 2017, 38, 409–414.

85. Wu, Y.; Li, S.; Tao, Y.; Li, D.; Han, Y.; Show, P.L.; Wen, G.; Zhou, J. Fermentation of Blueberry and Blackberry Juices Using *Lactobacillus Plantarum*, *Streptococcus Thermophilus* and

Bifidobacterium Bifidum: Growth of Probiotics, Metabolism of Phenolics, Antioxidant Capacity in Vitro and Sensory Evaluation. *Food Chem.* 2021, 348, 129083.

86. Dey, G. Non-Dairy Probiotic Foods: Innovations and Market Trends. In *Innovations in Technologies for Fermented Food and Beverage Industries*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 159–173.

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