

Review

Strategies to Improve the Potential Functionality of Fruit-Based Fermented Beverages

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Citation: Keșa, A.-L.; Pop, C.R.; Mudura, E.; Salanță, L.C.; Pasqualone, A.; Dărab, C.; Burja-Udrea, C.; Zhao, H.; Coldea, T.E. Strategies to Improve the Potential Functionality of Fruit-Based Fermented Beverages. *Plants* **2021**, *10*, 2263. <https://doi.org/10.3390/plants10112263>

Academic Editors: Fernando Lidon and Marta Laranjo

Received: 25 August 2021

Accepted: 17 October 2021

Published: 22 October 2021

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Abstract: It is only recently that fermentation has been facing a dynamic revival in the food industry. Fermented fruit-based beverages are among the most ancient products consumed worldwide, while in recent years special research attention has been granted to assess their functionality. This review highlights the functional potential of alcoholic and non-alcoholic fermented fruit beverages in terms of chemical and nutritional profiles that impact on human health, considering the natural occurrence and enrichment of fermented fruit-based beverages in phenolic compounds, vitamins and minerals, and pro/prebiotics. The health benefits of fruit-based beverages that resulted from lactic, acetic, alcoholic, or symbiotic fermentation and specific daily recommended doses of each claimed bioactive compound were also highlighted. The latest trends on pre-fermentative methods used to optimize the extraction of bioactive compounds (maceration, decoction, and extraction assisted by supercritical fluids, microwave, ultrasound, pulsed electric fields, high pressure homogenization, or enzymes) are critically assessed. As such, optimized fermentation processes and post-fermentative operations, reviewed in an industrial scale-up, can prolong the shelf life and the quality of fermented fruit beverages.

Keywords: fermentation; functional; fermented beverages; bioactive compounds

1. Introduction

Fruit-based beverages are among the oldest and most traditional fermented products. Fruits are characterized by high sugar content and thus are a raw material particularly suitable for alcoholic fermentation and other fermentations, such as acetic or lactic fermentation. Numerous examples can be mentioned for both alcoholic and non-alcoholic fermented fruit-based beverages, such as vinegar, fruit beer, water kefir [1], cider, wine (both conventional wine and wines from fruits other than grape), and several less common traditional products such as the Turkish *hardaliye*, the Namibian *ombike* and *omalunga*, the

Mexican *tepache*, the Rwandese *urwagwa*, the *setopoti* and the *khadi* from Botswana, all described in detail in Section 1.1.

Interest in the consumption of fermented beverages has been steadily increasing due to consumer awareness of their positive effect on human health, mostly related to the content of bioactive compounds and their purported probiotic effect. Several methods have been therefore proposed to improve the extraction of bioactive compounds from the raw materials, both at the pre-fermentative stage (by simple maceration, decoction, and by extraction assisted by supercritical fluids, microwave, ultrasound, or enzymes) and during fermentation or post-fermentation, using optimized processes and technologies that are able to prolong the shelf life and quality of fermented fruit beverages [2–19].

Recent work in the field has highlighted the microbial community as well as the health benefits of yeast and/or lactic acid bacteria in fermented fruit beverages and other food products [20–25], the technical limitations for their industrial upscaling [20], the quality of the ingredients and safety aspects related to traditional fermented foods and beverages [26,27], the new ways to analyze their fermentation processes [28], and the recent trends related to the consumption of fermented fruit-based beverages [29–31].

Nevertheless, many of the most widespread fruit-based fermented beverages are alcoholic, i.e., have an alcohol content higher than 1.2% (the lower limit according to EU rules), which must be indicated on their label. Moreover, it has to be considered that alcoholic beverages containing more than 1.2% alcohol by volume (ABV) cannot bear health claims on the label. As such, in order to take advantage of the potentially functional properties of fruit-based beverages, dealcoholization processes are therefore of paramount importance and have been extensively reviewed by Mangindaan et al. [32].

Assuming alcohol content reduction below 1.2% is technically feasible and has already been reviewed, the aim of this work is to highlight the functional potential of fermented fruit beverages in terms of chemical and nutritional profiles and to give an overview on the possible strategies to improve the potential functionality of these beverages. The latest trends on pre-fermentative methods used to optimize the extraction of bioactive compounds are critically assessed, as well as the optimized fermentation and post-fermentation operations, in view of an industrial scale-up.

1.1. Major and Minor Fruit-Based Fermented Beverages

With more than 3.2 million liters consumed every day in China due to its nutritional benefits [33], vinegar is available worldwide in several different assortments. Vinegar's traditional use dates back to ancient times [34], even if there is no clear information about its origin [35]. Vinegar was defined by the joint commission of the FAO/WHO as "a liquid fit for human consumption, produced from a suitable raw material of agricultural origin, containing starch, sugars or starch and sugars, by the process of double fermentation, alcoholic and acetous, that can contain a specified amount of acetic acid" [36]. At present, wine vinegar is the most widely marketed, although vinegar can be produced from various raw materials [34]. If solely fruits are considered, it can be prepared from pineapple, including pineapple by-products [37,38], persimmon, apple, jujube [39], pomegranate [40], plum, cranberry [41], sour cherry [42], soursop [43], mango, orange, banana [44], and papaya [45]. Initially, juices are typically inoculated with *Saccharomyces cerevisiae* to allow alcoholic fermentation, converting sugars into ethanol under anaerobic conditions. The addition of *Acetobacter* species is the second stage of fermentation, enabling ethanol oxidation under aerobic conditions and its conversion into acetic acid [33]. The earliest methods used to produce vinegar include the Orléans method, generator method, and submerged culture method [45]. Vinegar is used primarily as an ingredient in food processing due to its taste and aroma [46,47], as a seasoning and preservative [41], as a marinating liquid for meat [48], or in sauces, ketchup, and mayonnaise [33], and recently as an ingredient for beverage formulations [44].

Similarly, beer, which is the most consumed alcoholic beverage worldwide [49], is produced by the saccharification of starch and fermentation of the resulting glucose, mal-

tose, and maltotriose [50]. Fruit beers, primarily popular in craft breweries, are made with the addition of fruit. Their production depends on the seasonality of fruit harvest and is influenced by the risk of microbial contamination due to microorganisms present on the fruit skin [51]. For centuries, fruits were used as beer ingredients, especially in Belgian lambic styles [52]. In Belgium, it is a tradition to add the whole fruit into the beer (lambic fermentation occurs in casks) for the production of cherry lambic ('Kriek') or raspberry lambic ('Framboise') [53]. In cherry lambic, 150–400 g/L intact sour cherries are added into wooden casks filled with a blend of old and young lambic beer, where the sugar from the fruits passes a secondary fermentation. Fruit addition during the fermentation process might enhance the content of bioactive compounds of beer, in particular polyphenols and carotenoids [54]. The fermentation process of lambics can be divided into four distinct stages: the *Enterobacteriaceae* phase, the primary fermentation phase, the acidification phase, and the maturation phase. Microorganisms are mainly responsible for the flavor and aroma within each stage [55]. *Hanseniaspora uvarum*, a wild yeast also known as *Kloeckera apiculata*, dominates the first stage of fermentation, while the second stage of the fermentation process is dominated by *Saccharomyces* spp. and in the third stage lactic acid bacteria (LAB). A wild yeast often associated with the spoilage of red wines and ciders, *Brettanomyces*, has positive effects upon flavor characteristics and dominates the final fermentation stage in lambic beer. The fermentation process starts after the wort has been cooled. *H. uvarum* rapidly reaches its maximum content of 10^5 cells/mL within the first week of fermentation, but it is quickly overcome by *Saccharomyces*. *H. uvarum* can ferment glucose but not maltose or more complex carbohydrates. Consequently, pH drops from 5.1 to 4.6 due to the fast growth of *Enterobacteriaceae* and *H. uvarum* and the production of acetic and lactic acids. The following stages of fermentation overlap one another [56]. The third phase of traditional lambic beer production processes is characterized by the growth of lactic acid bacteria that are responsible for the acidification process, which is essential as lambic beer is recognized for its acidity [57]. Many of the lactic acid bacteria present in lambic beer are from the *Pediococcus* genus. Some strains have beneficial effects, and others can produce a "ropy" surface, creating permanent cloudiness [56–58]. The final stage of the process is marked by an increase in the number of yeast cells, *Brettanomyces* playing an essential role in developing the aromatic and flavor profile of lambic beer [56] by fermenting higher malto-oligosaccharides not fermented by *Saccharomyces*.

Cider is a fermented beverage with an alcohol level typically in the range 4–10% ABV [59] that recognizes 'territoriality' as essential for its appreciation [24]. Alcohol-free cider containing less than 0.5% ABV and low-alcohol cider, with an alcohol content between 0.5 and 1.2% ABV, are also marketed [60]. Traditionally, cider is made from apple, but it can also be made from other types of fruit such as wax apple (or Java apple, *Syzygium samarangense*), a tropical fruit having many nutritional bioactive compounds and high economic value [61]. Over time, Europe became known as the heart of cider production. In some countries (England, Spain, France, Ireland, and Germany), cider production is particularly abundant and dates back for centuries [60]. Smaller productions are found in countries such as Switzerland, Poland, and Austria [24]. According to the European Cider and Fruit Wine Association, in 2020, Romania was the first small market cider producer with 148.8 hL, followed by Portugal and Bulgaria with about 143 hL [62]. Cider production has also become an important and promising segment of the fruit industry in China, because of the large production of apples in this country [63]. The processing of apple cider involves the following steps: apple conditioning (washing and sorting); apple crushing (small pieces of 4–5 mm thickness); pressing and separating the apple juice; clarification and depectinization; yeast inoculation and alcoholic fermentation; addition of nutrients for the lactic acid bacteria (LAB) and malolactic fermentation; stabilization and maturation (i.e., wood aging, optional) [60]. During the process of fermentation and aging, sugars, acids, and pectic and phenolic substances present in the apples [64] are transformed into alcohols (propan-1-ol, iso-pentan-1-ol), organic acids (malic, lactic), and esters (ethyl and butyl lactate, ethyl-2 and ethyl-3-methylbutyrate, ethyl decanoate) [65]. Commercially, a selected

strain of *Saccharomyces* spp. (*Saccharomyces cerevisiae*) [65] is used for the production of cider, but also other yeast strains were studied, such as *Hanseniaspora osmophila* and *Torulospira quercuum* in co- and sequential fermentation, where the production of organic acids varied depending on the yeast species employed and inoculation method. The simultaneous fermentation resulted in the highest ethanol content because of a more efficient sugar consumption [66]. *Saccharomyces cerevisiae* × *Saccharomyces eubayanus* hybrids [67] were able to ferment the juice completely to about 5% ABV.

According to the International Organisation of Vine and Wine, wine is obtained through the alcoholic fermentation of grape juice by yeast, followed by the aging process. The term can be commonly used for all fermented beverages obtained from sweet fruits and vegetables, such as fruit wines, and undistilled alcoholic beverages [68] that are nutritive, flavorful, mild stimulants, and have an alcohol content ranging between 5–13% ABV [69]. These types of wines are made from blackberry (representing a traditional Croatian alcoholic beverage, a source of minerals and polyphenolics) [70], mulberry [71], pineapple and passion fruit [72], mango [73], and mixtures of banana, pawpaw, and watermelon [74]. The techniques used to obtain fruit wines are similar to those for the production of conventional wines. Some differences in the content of sugar and acids can be adjusted by diluting the juice or adding sugar, as well as by testing different yeast strains to select the most effective in different environments [68,72,75].

Kombucha is a refreshing low alcoholic beverage obtained from the fermentation of sweetened black or green tea, inoculated with acetic acid bacteria and osmophilic yeast (“tea fungus”). Given the ascending trends in kombucha consumption, its production was scaled up in recent years [76]. Its fermentation lasts between 7–21 days, and it is recognized for its beneficial nutritional and health effects [77]. Alternative raw materials for kombucha production are spices, fruits such as snake fruit [78] and papaya [79], fruit juices [80], leaves [81,82], coffee [83–85], vegetables [86], milk [87], and other food industry by-products and wastes [88].

Other fermented fruit beverages have a more limited diffusion, rendering them “minor” compared to globally known beverages such as vinegar, wine, beer, etc. However, based on raw materials typical of the area of origin, these minor beverages are essential expressions of local traditions. *Hardaliye* is an indigenous beverage of the Thrace region of Turkey and is produced from red grape juice fermented with crushed black mustard seeds [89]. *Ombike* is the generic name for a fermented beverage made from wild fruits, including bird plum, buffalo thorn, and makalani palm, prepared in Namibia, where *omalunga*, a palm wine [90], is also produced. *Tepache* is a popular beverage in Mexico, prepared by fermenting pineapple peel and sometimes adding other fruits such as orange, apple, and guava [91]. *Urwagwa* is an alcoholic beverage common in Rwanda, produced from the fermentation of bananas. In Botswana, *setopoti* and *khadi* are traditional alcoholic beverages made from the fermentation of watermelons and *Grewia flava* fruits, respectively [92].

Ultimately, fruit juice fortification with probiotics and/or prebiotics is a challenge and a frontier goal, as juices could combine their specific nutritional effects in addition to providing specific health benefits through probiotic bacteria or prebiotic ingredients [93].

2. Composition and Functional Potential of Fruit-Based Fermented Beverages

Alongside their nutritional properties, fruit-based fermented beverages may show a functional potential related to the content of bioactive compounds, in particular phenolics. The phenolic compounds of fruits can fortify or enhance food or beverage functionality [94], impacting their sensorial, nutritional, and antimicrobial properties [20]. Beverages such as fruit juice, beer, and wine are rich in hydroxycinnamic acids [95]. Table 1 shows the content of phenolic acids and flavonoids in some fruit-based fermented beverages. Quercetin, from the flavonol class, is found in fruits such as blueberries, strawberries, apple, goji, apricot, and grape and is recognized to have antioxidant, antidiabetic, and anti-inflammatory properties [96]. The flavonols and their derivatives significantly influence taste characteristics, particularly bitterness and astringency [97].

While vinegar has a complex composition of carbohydrates, organic acids, small traces of ethanol, acetoin, 2,3-butanediol, amino acids, and peptides, the most abundant organic acids are acetic, lactic, pyruvic, malic, and citric acid [98]. The acetification process has an impact on aroma volatiles, mainly due to oxidative reactions. Furthermore, monoterpenic alcohols are found in orange vinegar, esters in banana vinegar, C13-norisoprenoids in cherry vinegar, and lactones in mango vinegar, indicating that fruit vinegars have different aroma profiles depending on the type of fruit used for the production [44]. Moreover, hydroxymethylfurfural, synthesized by thermal decomposition of reducing sugars [99], has been detected in low amounts in wine vinegar and in concentrations up to 35 mg/L in cherry vinegar and some apple vinegars [100]. The consumption of vinegar has many health benefits, such as an attenuation of cardiac injury via anti-inflammatory and anti-adiposity actions [101], a reduction of body weight, body fat mass, and plasma triglyceride (TG) levels in obese patients [102], and anti-carcinogenic and antihypertensive effects [46]. Vinegar has been associated with diminished post-prandial glucose response following a high glycemic load meal [103] and presents high antioxidant activity, antimicrobial and antidiabetic effects, and therapeutic properties [33].

Regarding beer, many studies prove that the addition of fruit juice or fruit increases the content of phenolic acids, flavonoids, and resveratrol and, consequently, improves the antioxidant activity [54]. Still, a study on goji berries enriched amber ale beer showed an increase in bioactive compounds but did not improve the flavan-3-ol oligomers, which caused colloidal instability [50]. Cornelian cherry beer contains iridoids, which have cardiovascular, hypoglycemic, antihepatotoxic, choleric, and antispasmodic activities [104]. Similarly, Cornelian cherry beer has high antioxidant properties. The best results, in terms of the degree of fermentation, were obtained when Cornelian cherry juice was added during the primary fermentation of the beer [105].

In fruit-based fermented beverages, the fermentation process enhances the quantity of B-group vitamins [106]. For instance, *Lactobacillus reuteri*, a Gram-positive bacterium, can thrive on several substrates and produce B12 vitamin and folate [107]. Santos et al. [108] tested the capability of this bacterium to ferment melon juice and obtained a 5- to 10-fold increase in folate amount. As for vitamin B12, it significantly increased from 0.28 to 11.47 mg/100 mL during fermentation of coconut water [109]. However, a decrease of vitamin C throughout the fermentation was observed in a fermented strawberry beverage (from 75.5 mg/100 g fruit to 34 mg/100 mL in strawberry wine) [110], as well as in fermented wax apple juice (from 4.97 mg/100 g to 3.81 mg/100 mL) [61] and fermented pineapple juice (4.52 mg/100 g to 2.95 mg/100 mL) [111].

Table 1. Concentration of the main phenolic compounds found in different fruit-based fermented beverages.

Beverage	Phenolic Compounds ($\mu\text{g/mL}$)								References
	Phenolic Acids					Flavonoids			
	Gallic Acid	Caffeic Acid	Ferulic Acid	<i>p</i> -Coumaric Acid	Chlorogenic Acid	Catechin	Rutin	Quercetin	
Fermented mulberry juice	15	98.3	187.5	2.4	91.6	163.5	194.7	300.8	[112]
Wax apple cider	11.5	62.1	69.1	0.14	64.6	110.1	41.3	61.1	[61]
Cider with added apple pomace	3.9	3–3.7	2–4.2	1–1.5	8.3–22.5	24.4	1.8–3.3	2.1	[63,113,114]
Amber ale beer enriched with goji berries	0.01–5.9	1.3	4.6–13.3	1.19–3.7	0.01–7.8	0.8–6.9	23.1	320–1400	[50,115]
Blackberry wine	4.5–118	1.2–10.1	1.3	0.3–4	1.2–8.3	9–45	35.1	34.9	[70,116–118]

3. Probiotic and Prebiotic Fruit-Based Fermented Beverages

According to the WHO, probiotics are defined as “live microorganisms able to give, when administered in adequate amounts, many health benefits to the host”. It is also considered that they have a beneficial effect upon health with a minimum of 10^9 cells per daily dose [119]. Probiotic organisms must have the ability to resist gastric juices, exposure to bile, and proliferate and colonize the digestive tract. The most commonly used probiotic bacteria belong to the heterogeneous group of LAB (*Lactobacillus*, *Enterococcus*) and to the genus *Bifidobacterium* [120], while among yeasts, *Saccharomyces cerevisiae* var. *boulardii* is used [121]. Probiotics can increase the activity of enzymes, improve the intestinal barrier function, generate substances with antibacterial or bactericide effects, can modify the pH, modulate host immune function, intestinal carcinogenesis, cholesterol uptake, and competitive deprivation of pathogenic bacteria [122], alleviate lactose intolerance symptoms, atopic dermatitis symptoms in children, prevent the risk of allergy in infancy, and help with inflammable bowel disease (IBD) and irritable bowel syndrome (IBS) symptoms [123]. As a side effect, the long-term use of probiotics under antibiotic selection pressure could cause antibiotic resistance, and the resistance gene could be transferred to other bacteria [119].

Products that are traditionally considered the best carriers for probiotics are fermented milk products, but nowadays, up to 70% of the world population is affected by lactose intolerance, so a trend to obtain probiotic beverages from cereals, soybeans, and fruits and vegetables is observed. Fruit juices are generally preferred due to their natural content of essential nutrients [121]. The development of nondairy-based probiotic beverages has gained consumer attention due to the need for reducing cholesterol intake as well as frequent allergies/intolerances to dairy products [124,125]. Conversely, nondairy-based probiotic beverages improve the growth of beneficial bacteria, possess antimicrobial effects towards many foodborne pathogens [93,126], and have a pleasant aroma and taste [125]. The most commonly employed probiotics include different strains from *Lactobacillus* such as *L. acidophilus*, *L. helveticus*, *L. casei*, and *L. paracasei*, *Bifidobacterium* such as *B. bifidum*, *B. longum*, and *B. adolescentis*, and other species such as *Escherichia coli* Nissle, *Streptococcus thermophilus*, *Weissella* spp., *Propionibacterium* spp., *Pediococcus* spp., *Enterococcus faecium*, *Leuconostoc* spp., and *Saccharomyces cerevisiae* var. *boulardii* [93]. Commercially, the most preferred species for lactic acid fermented fruits are those belonging to the genus *Lactobacillus* and the genus *Bifidobacterium* [127].

Prebiotics are non-digestible food ingredients that can impart a beneficial effect to supplemented or indigenous colonic microbiota. According to the International Scientific Association for Probiotics and Prebiotics (ISAPP), a prebiotic ingredient has to meet three criteria: resistance to degradation by stomach acid, enzymes, or hydrolysis; fermentation by intestinal microbes; selective stimulation of the growth and/or activity of beneficial microorganisms in the gut [128]. Initially, prebiotics were seen as ingredients that could not be digested and positively affected the host by selectively stimulating the growth and/or activity of one or a limited number of bacterial species in the colon [129]. Prebiotics include dietary fiber, oligosaccharides such as inulin, and fructo- (FOS) and galacto-oligosaccharides (GOS). According to Global Market Insights, INC (Delaware, USA), the global prebiotic market is increasing and is expected to surpass USD 8.5 billion by 2024. From the technological point of view, the addition of prebiotics to foods and beverages improves sensory characteristics, such as taste and texture, and enhances the stability of foams, emulsions, and mouthfeel in a vast range of food applications, such as dairy and bakery products [130]. FOS have gained special attention due to their health benefits and sweet taste, very similar to that of sucrose. FOS stimulate the growth of *Bifidobacterium* spp. in the digestive tract, decrease serum lipids and total cholesterol, relieve constipations, and improve human health [131]. At low pH and high temperature, the most stable prebiotics are GOS, while inulin and FOS are less stable [132]. Consumption of prebiotics leads to several benefits, which include increased calcium absorption and enhanced bone mineralization during pubertal growth [129], alleviating the symptoms

of IBS [132], protecting against Crohn's disease, ulcerative colitis, and inducing weight loss [119].

Several studies have aimed at formulating fruit-based fermented beverages with prebiotic and probiotic activity (Table 2). It has to be highlighted, however, that the functional beverages have to be consumed in large amounts to benefit human health, as the bioactive compounds are found in small quantities, and the daily recommended dose is much higher (Table 3). For example, fermented pomegranate juice should be consumed 2.5 L daily to gain all the benefits of this product [133,134], while sea buckthorn wine should be consumed up to 20 L daily [134–136]. Therefore, there is a need for new strategies to improve the functionality of fruit-based fermented beverages.

Table 2. Prebiotic and probiotic content in fruit-based fermented beverages.

Prebiotic Added	Recommended Dose for Fortifying	Beverage Type	Content of Prebiotic and Probiotic Compound	References
Inulin	3% <i>w/w</i> for infant formulas and 5% <i>w/w</i> for common beverages 5 g in Europe 9–10 g in Korea 1.25 g/portion in Southeast Asia	<i>L. rhamnosus</i> probiotic orange juice fortified with long chain inulin	<i>L. rhamnosus</i> 5.9×10^7 CFU/mL; long chain inulin 4 g/100 mL	[137–140]
		Pineapple juice enriched with <i>L. casei</i> or <i>L. rhamnosus</i> and inulin	<i>L. casei</i> (10^8 CFU/mL) or <i>L. rhamnosus</i> (10^8 CFU/mL); inulin 2 g/100 mL	
		Fig juice fortified with inulin and <i>L. delbrueckii</i>	<i>L. delbrueckii</i> $>10^6$ CFU/g; inulin 2 g/100 mL	
GOS	Max 5% <i>w/w</i> in beverage	PS-enriched milk-based fruit beverage with 5 g GOS/250 mL	GOS 2 g/100 mL	[141,142]
FOS	5 g in Europe 1.25 g/portion in Southeast Asia 3% <i>w/w</i> for infant formulas and 5% <i>w/w</i> for common beverages	FOS-fortified apple juice	FOS 15.5 g/100 mL	[137,143,144]
		FOS-enriched mixed fruit beverage	FOS 0.7 g/100 mL	
		Prebiotic orange juice	FOS 7 g/100 mL	

Table 3. Content of the main compounds of interest, daily recommended dose, and health effects of fermented beverages from different fruits.

Type of Beverage	Fermentation Type	Chemical Compound/Class of Compounds of Interest	Concentration of Compounds of Interest	Daily Recommended Dose of Compound of Interest	Impact on Health	References
Grape-based fermented beverage	Lactic	Polyphenols (grape must), γ -amino butyric acid <i>L. plantarum</i> DSM19463	γ -amino butyric acid 10 g/20 mL; Log 10.0 ufc/g <i>L. plantarum</i>	γ -amino butyric acid: 10 g	Anti-hypertensive activity; anti-inflammation and fibroblast cell proliferation, activities that promote the healing process of wounds	[145]
Fermented jaboticaba berry beverage (12% ABV)	Alcoholic	Phenolic compounds (rutin, quercetin, anthocyanins, coumarins, gallic acid)	Gallic acid 3 mg/mL; phenolics and coumarins 68.9 mg/mL	Quercetin: 13.4–22.8 mg—men; 11.1–17.7 mg—women	Antioxidant, vasorelaxation, and cardiovascular protection	[134,146]
Pomegranate fermented juice	Lactic	Phenolic compounds (ellagic acid) <i>L. plantarum</i>	Ellagic acid 6.4–7.1 mg/L; <i>L. plantarum</i> : 6 Log CFU/mL	Ellagic acid: 17.9 mg—men; 27.6 mg women (USA)	Antioxidant and anti-inflammatory properties, inhibits growth of tumor cells	[133,134]
Sea buckthorn wine	Alcoholic	Rutin, myricetin, quercetin, vitamin C	Ascorbic acid 176.8 mg/L; rutin 68.4 mg/L; myricetin 40.3 mg/L; quercetin 1.04 mg/L	Quercetin: 13.4–22.8 mg—men; 11.1–17.7 mg women Vitamin C: 90 mg—men, 75 mg—women	Protective effects against oxidative stress and hypercholesterolemia; anti-inflammatory, myocardial protecting, vasodilator and hepatoprotective activities	[134–136]
Symbiotic fermented Cornelian cherry beverage (0.2–0.7% ABV)	Alcoholic and lactic	Fibers, phenols, <i>L. paracasei</i> K5, lactic acid	Wheat bran-50% dietary fiber (used as a prebiotic and cell immobilization carrier for <i>Lactobacillus</i>) <i>L. paracasei</i> 9.74 Log CFU/mL, lactic acid 167.8 mg/100 mL	10^{10} – 3×10^{12} CFU <i>L. paracasei</i>	Antimicrobial activity against various pathogens; anti-inflammatory, antimalarial, antidiabetic activities	[147–149]
Symbiotic fruit based kombucha beverage	Acetic, lactic and alcoholic	Organic acids, vitamins, phenols, minerals, probiotics, carbohydrates, amino acids, bacteriocins	Acetic acid 0.016–39 g/L, gluconic acid 0.18 g/L, vitamin B1 0.74 mg/mL, vitamin B2 0.08 mg/mL, vitamin B6 0.52 mg/mL, vitamin B12 0.84 mg/mL, vitamin C 25,000 mg/mL Cu, Fe, Mn, Ni, Zn 0.1 to 0.4 μ g/mL Total phenolic content 178–264 mg GAE/L Flavonoid content 2307.14 mg QE/L	Vitamin C: 90 mg—men, 75 mg—women	Antimicrobial, antioxidant, anti-inflammatory activities, anticarcinogenic potential	[77,78,136,150]

4. Methods Used to Increase the Extraction Yield of Bioactive Compounds

4.1. Maceration and Decoction

Maceration and decoction are traditional extraction methods that require very simple equipment. Maceration is usually performed at room temperature [151,152], and it is the most employed technique for extracting compounds of interest from plant raw materials in the alcoholic beverage industry [153]. In small scale extraction, the steps used for maceration are grinding the plant material into small particles to increase the surface area, adding the solvent, and finally pressing out or filtrating. Shaking facilitates extraction by increasing diffusion and removing concentrated solution from the sample surface, for bringing new solvent and higher extraction yield [152]. Water, alcohol, or other solvents can be used, depending on the purpose. Wine, for example, is used in the preparation of vermouths, while vinegar might be enriched in bioactive compounds during or after acetic fermentation, with the maceration of herbal extracts or fruits [151]. Susana Gonzalez-Manzano et al. [154] showed that the extraction of flavan-3-ols during maceration reached the highest level at 12.5% ABV, and galocatechin was primarily extracted from the skin and catechin from the seeds of the grapes.

Decoction consists of boiling a plant matrix in a specific volume of water for a defined time, then cooling and straining or filtering it. Lou et al. [155] observed that the total concentration of phenolics from *Crataegus pinnatifida*, an organic Chinese hawthorn berry, was significantly higher in decoction (4044–4148 µg/g) than maceration (3398–3792 µg/g). Decoction can provide better accessibility for extracting phenolics by disrupting the plant's cell wall, releasing phenolic compounds that were conjugated or insoluble bounded.

4.2. Supercritical Fluid Extraction (SFE)

The process of extracting or separating one component from the matrix using supercritical fluids as solvents is one of the latest extraction technologies adopted in the industry, which can be used as a preparation step for further analyses or on a larger scale to eliminate unwanted material from a product (e.g., decaffeination) or collect a desired product (e.g., essential oils) [2]. Supercritical fluids (SCF) are produced by heating a gas above its critical temperature or compressing a liquid above its critical pressure and have solvent powers similar to a light hydrocarbon for most solutes. The most widely used gas in food industries is carbon dioxide. The wide range of physical conditions that can be applied make possible the preparation of very 'light' extracts, similar to essential oils, or more complex extracts, having a chemical composition comparable with that of the starting plant material, since the extraction process causes no thermal or chemical modifications [153].

Supercritical CO₂ can be used for extracting many types of compounds, such as lycopene from watermelon [3], anthocyanins and phenolics from *Syzygium cumini* fruit pulp and jamun (Indian blackberry) [156], and imperatorin and meranzin from *Citrus maxima* peel [157]. Temperature and pressure both affect the extraction yield and have to be carefully tested and adjusted [3,156]. Supercritical CO₂ can be used for removing ethanol from aqueous solutions and therefore has been proposed for developing a low-alcohol beverage from wine, maintaining the aroma and the antioxidant activity similar to that of the original wine [158]. The same technique has been also used for the stabilization of FOS-rich beverages, maintaining the prebiotic functionality [159].

4.3. Microwave-Assisted Extraction (MAE)

MAE is a combined extraction technique that uses traditional solvent extraction and the energy of microwaves. Microwave energy is used to heat solvents in contact with solid or liquid samples (or other fresh tissues), thereby partitioning the compounds of interest into the solvent. Microwaves heat the solution directly, and as a result, the temperature gradients are minimal, and the heating rate using microwave radiation is faster [4]. In the case of microwave extraction, mass ingredient and heat actions are targeted toward the exterior of the cells, enhancing the yields of extraction for high-value compounds while

reducing the time needed to extract compounds. By comparison, in a conventional process, the heat transfer occurs from the heating medium to the inside of the cells [5].

MAE can be applied to extract several types of substances. For example, anthocyanins and polyphenols have been extracted from raspberry [160], catechin from *Arbutus unedo* L. fruits [6], pectin from dragon fruit peel [8], and polysaccharides from *Camptotheca acuminata* fruits, known as wild banana [10]. A comparison of MAE with maceration and ultrasound showed that MAE and maceration were the most effective methods, able to extract 1.7 mg/g and 1.4 mg/g catechin from *Arbutus unedo*, respectively. MAE reached the maximum extraction at 137 °C in 42 min.

Furthermore, the microwave pretreatment positively affects the total anthocyanin content of hawthorn beverages (from 1.314 mg/100 mL to 2.106 mg/100 mL) [161]. Positive effects of microwave-assisted extraction (1200 W for 10 min, 40 °C) were encountered when applied to the anthocyanin content of Merlot grape wines [13]. Microwaving a peach functional beverage for 1.5 min at 850 W:50 Hz of power determined the retention and stability of bioactive compounds for up to 30 days at 4 °C. It was observed that the pH and the cloud values of the processed juice reduced with storage time, the total soluble solids remaining almost consistent while the TPC decreased rapidly during the storage period [162].

4.4. Ultrasound Assisted Extraction (UAE)

As for ultrasound, it can enhance the extraction of nutraceuticals such as phenolics, anthocyanins, and aromatic compounds. The advantages of UAE include reduced extraction time, reduced thermal gradient, small equipment size, rapid control response, increased yield, and selective extraction [152,163].

Prakash Man et al. [9] studied the effects of temperature, power of the ultrasound, time, and solid–liquid ratio in the extraction of bioactive compounds from *Nephelium lappaceum* L. fruit peel. Increasing the temperature from 30 to 50 °C made the yield of anthocyanins and polyphenols increase due to the greater cavitation, as well as increased solubility and reduced viscosity, which facilitates the solvent to penetrate deeper into the matrix. The extraction yield increased when the duration began to increase from 10 to 20 min and then decreased when the duration was extended. The optimal parameters for the extraction were 20 W for 20 min, a solid–liquid ratio of 1:18.6 g/mL, 50 °C, when were obtained 10.17 mg/100 g of the total anthocyanin content, 100.93 mg rutin equivalent (RE)/100 g total flavonoid content and 546.98 mg GAE/100 g TPC, respectively. The same fruit peel was also used to extract polysaccharides using ultrasound-assisted extraction. The highest extraction yield for polysaccharides was 8.31%, obtained at an extraction duration of 41 min, 110 W, 53 °C, and a solid–liquid ratio of 1:32 g/mL [7].

Ultrasound, alone and/or in combination with other techniques, was reported to affect *E. coli* and *Listeria monocytogenes* in apple cider. Moreover, the quality of fruit juice, such as orange, guava, and strawberry, has been affected on a smaller scale [164].

The effect of ultrasonication, pulsed light, and their combined usage on the phenolic profile and the antioxidant activities of lactic-acid-fermented mulberry juice has been assessed [112]. The mulberry juice was ultrasonicated for 15 min, 28 kHz, 60 W, at 5 °C. As for the pulse light treatment, the sample was subjected to light pulses at a pulse width of 360 μ s, a frequency of 3 Hz, and delivering radiant energy of 1.213 Jcm⁻² pulse⁻¹. An exposure time of 4 s to obtain a sub-lethal energy dose of 7.26 Jcm⁻² was employed. The TPC and total anthocyanin concentration significantly increased in the fermented mulberry juice treated with pulsed light and ultrasound.

4.5. Enzyme Assisted Extraction (EAE)

Enzymatic extraction of bioactive compounds from plants is an alternative to conventional solvent-based extraction methods. Enzymes are ideal for assisting in extracting, synthesizing, and modifying complex bioactive compounds of natural origin. This method is based on the inherent ability of enzymes to catalyze reactions with exquisite specificity,

region selectivity, and an ability to function under mild processing conditions in aqueous solutions. In general, enzymes have been used to treat the plant material before conventional extraction methods. Various enzymes, such as cellulases, pectinases, and hemicellulases, are used to enhance the extraction yield of bioactive compounds from plants by altering the integrity of the cell wall and increasing permeability. In food processing, pectic enzymes are employed industrially for the extraction, clarification, and concentration of fruit juices and to extract several compounds from plant materials [15]. The addition of pectinase as a pre-treatment in red dragon fruit juice, followed by fermentation with *Torulasporea delbrueckii*, increased the beverage yield by 16% and enhanced the levels of esters and terpenes, improving aroma profile. Other effects included higher acetic acid production and impairment on the yeast's ability to metabolize the nitrogen compounds, with a loss of color intensity and a decrease of pigments [165].

The effects of the EAE on the stability of bilberry (*Vaccinium myrtillus* L.) anthocyanins in chilled storage at 10 °C for 9 days and extractability yield were tested by Dinkova et al. [166]. The results showed an increase of 43–60% in polyphenol content and 23–37% in anthocyanins, while the antioxidant capacity increased by 35% through enzymatic maceration. A decrease in counts of mesophilic and psychrotrophic microorganisms was also observed, as well as that of molds and yeasts at the end of storage, suggesting an inhibition of the microbial growth. The same method, by adding pectinase, was applied to extract anthocyanins from blackberry. An increase in extraction yield was observed with the increase of enzyme loading. Yield also increased by increasing the temperature up to 50 °C and then decreased due to enzyme inactivation [16]. EAE has also been used to extract polysaccharides from *Cornus officinalis* fruits, at an enzyme concentration of 2.15%, pH 4.2, 55 °C, for 97 min [17]. Moreover, pectinase has been used in the preparation of pear juice made from William Bartlett cultivar [18]. The juice yield ranged between 67.62–90.57% and the clarity from 38–91.1%. The clarity increased significantly with the enzyme concentration and the best results were obtained at 1.9% enzyme concentration, 30 °C, and 2 h incubation. Some disadvantages of EAE, however, are the high price of enzymes, and difficulties in the industrial scale-up, due to different environmental conditions for every enzyme [15].

By using commercial enzymes, Kim and Park [167] enhanced the volatile aromatic compound from Korean black raspberry wines. The wine, treated with a mix of pectinase, cellulose, hemicelluloses, and β -glucosidase, had the highest concentration of aromatic compounds: terpenes 103.1 mg/L, esters 461 mg/L, and the score of fruity and floral aroma in the sensory evaluation.

4.6. Pulsed Electric Field (PEF)

PEF is a novel non-thermal technology that causes the degradation of nutritional and sensory characteristics to a lesser extent than traditional thermal processing. It uses an electrical field in the form of short- or high-voltage pulses applied to a food item placed between two electrodes for a short time, usually in the microsecond scale [168]. The PEF can be used to control the sugar/ethanol conversion rate during fermentation, solving issues caused by some techniques used to reduce the alcohol content in beverages. This is due to the high sugar content in fruits, intensified by global warming, the fermentation of early-harvested fruits, and many such similar matters that have a low impact on the ethanol concentration of the beverage. They may influence the end result by modifying the aroma and mouthfeel of the product [169], stimulating alcoholic fermentation and *S. cerevisiae* growth while applying direct current (10 mA), alternative current (100 Ma), and electrical potential (0.75 V) to the must [170].

Siddeeg et al. [171] observed the impact of PEF application on the free amino acids, physical and chemical characteristics, and bioactive compounds of alcoholic beverages obtained from date palm fruits. The permeabilization of plant cells can be useful for more effective extraction of bioactives from fruit. The TPC increased from 3.50 mg CE/100 g to 91.90 mg CE/100 g in the highest PEF, while the total carotenoid content increased

from 3.10 to 5.15 $\mu\text{g}/\text{mL}$. A higher yield of anthocyanins was revealed in PEF treatment (0.7 kV/cm, for 200 ms and 31 Wh/kg) of Cabernet Sauvignon red grapes [172].

Moderate PEF coupled with *Hanseniaspora* sp. yeast treatment during cider production significantly increased biomass growth and decreased ethanol yield. PEF can also be used as an alternative to thermal pasteurization of beverages, as it solely modifies a small part of the sensory characteristics. Temperature increases with PEF are low and typically not more than 40 °C, but cooling systems can be attached to the standard equipment if needed. Furthermore, PEF destroys microorganisms by modifying the electric potentials between each side of the membrane [173].

4.7. High Pressure Homogenization (HPH)

HPH is a mechanical process that works to reduce particle size or to lyse cells. Rheological changes have been observed in mango juice after the use of HPH, and in kiwifruit purée HPH improved the appearance of cloudy apple juice to increase consumer acceptability. This technique improved the uniformity and cloud stability due to the reduced size of particles, increased viscosity, and yield stress. The added purée reduced enzymatic browning due to the ascorbic acid creating a saturated and bright yellow color and an improved sensory quality [174]. Morata et al. [175] proved that HPH treatment above 400 MPa applied for 10 min completely destroyed the yeasts.

Similarly, heating and high HPH treatment on litchi juice showed a good ability of HPH to preserve color, flavor acceptance, and antioxidant activity. Moreover, HPH and the heating process offered the opportunity to improve the viability of probiotic cells and extend product quality attributes after 4-week storage at 4 °C [176].

Positive results were also reported on a sulfur dioxide-free wine after using HPH treatments at 500 MPa [177]. The wine presented more significantly the scent of cooked fruit and a spicy aroma, while the untreated wine presented a more pronounced metallic and leathery aroma and a less perceived fruity and floral aroma. After 12 months of storage, the pressurized wine presented notes of an aged wine. The results demonstrated that HPH can influence long-term red wine physic-chemical and sensory characteristics.

However, despite the numerous advantages of recent technologies in obtaining added-value fermented fruit beverages, there are also some disadvantages that beverage industry stakeholders have to consider, which are synthesized in Table 4.

Table 4. Advantages and disadvantages of methods to improve the functional potential of fruit-based fermented beverages.

Methods	Type	Advantages	Disadvantages	References
Pulsed electric field (PEF)	Non-thermal	Reduction of the quantity of SO ₂ used Reduced degradation of nutritional and sensorial characteristics Controlled sugar/ethanol conversion in fermentation Improved extraction of compounds of interest Alternative to pasteurization Inactivation of microorganisms	Corrosion and migration of electrode materials Metallic taste Degradation of some compounds (cyanidin-3-O-glucoside and cyanidin-3-O-sophoroside)	[168–173,178,179]
Enzyme assisted extraction (EAE)	Non-thermal	Improved yeast growth by releasing nutrients Enhanced aroma of the beverage Increased yield of fermentation Improved clarification process and biological activity	Susceptible to substrate or product inhibition The product may cause an allergic reaction High cost for isolation and purification Difficult recovery for subsequent reuse Higher temperatures (>40 °C) and pH over 7.4 lead to denaturation	[19,161,165,167,180–184]
Microwave assisted extraction (MAE)	Thermal	Increased total anthocyanin content Enzyme inactivation Inactivation of microorganisms Increased juice stability	Only certain microwave frequencies can be used because they can interfere with radio frequencies Non-uniform temperature distribution resulting in hot and cold spots Longer extraction step and poor extraction yield	[11–13,162,185–188]
Ultrasound assisted extraction (UAE)	Non-thermal	Increased content of bioactive compounds Prevention of browning Shortened aging process Inactivation of microorganisms	Degradation of ascorbic acid Decreased content of minerals Increased ultrasonic intensities may cause physical-chemical degradation	[112,164,189–194]
High pressure homogenization (HPH)	Non-thermal	Improved yield of extraction Increased shelf life Inactivation of microorganisms Changed rheological characteristics Improved overall aspect of beverages, especially color	Pressures exceeding 1200 MPa are needed to inactivate bacterial spores Most products must be stored and transported under refrigeration <i>Cladosporium</i> spores may survive in low-acid HPH products. High processing costs	[174–177,195–200]

5. Fermentation Types to Enhance the Functionality Potential

5.1. Alcoholic Fermentation

Among fermented beverages, wine results from the complex interactions between yeasts, bacteria, and other fungi that start in vineyards and continue with the fermentation process in the winery. Different yeast species are predominant on the surface of grape skins and in the winery environment, *Saccharomyces cerevisiae* being the main species responsible for this process. In recent years, non-*Saccharomyces* species with fermentative abilities were studied, emphasizing their critical role in wine fermentation under specific controlled conditions [201].

Benito et al. [202] studied the possibility of producing red wine using *Schizosaccharomyces*, which consumed less primary amino nitrogen and had less urea and more pyruvic acid than the *Saccharomyces* strains.

Interestingly, melatonin, a hormone that modulates physiological processes in humans such as circadian rhythms and the reproductive function, has been recently detected in wine, and its presence has been linked to yeast activity in the fermentation process [203], which was also confirmed by Rodriguez-Naranjo et al. [204], who showed that melatonin is absent in grapes and musts and is formed during alcoholic fermentation. As melatonin is also found in the orange fruit, Fernández-Pachón et al. [205] measured the melatonin content during the alcoholic fermentation of orange juice and revealed that melatonin content significantly increased throughout fermentation from day 0, 3.15 ng/mL, until day 15 when it reached 21.8 ng/mL. Compared to other melatonin contents in fruits, such as banana 0.47 ng/g, apple 0.05–0.16 ng/g, pineapple 0.30 ng/g, and Primoris strawberry 11.26 ng/g [206], the fermented orange juice can be a promising source of this bioactive compound. It can also provide a rich source of carotenoids and has health effects similar to those of the orange juice, with a higher content of total carotenoid and provitamin A (6.65 mg/L and 90.57 retinol activity equivalents per liter of juice (RAEs/L) than the non-fermented orange juice (5.37 mg/L and 75.32 RAEs/L) [207]. Moreover, the potential bioavailability of flavonoids increases during fermentation due to the high content of hesperetin-7-O-glucoside, which is twofold higher at the end of the fermentation process; the same ascendant trend was observed for the antioxidant activity [208].

5.2. Acetic Fermentation

Acetic acid bacteria (AAB) are Gram-negative, rod-shaped, obligate aerobes commonly known as vinegar-producing microorganisms. The AAB, in general, can oxidize ethanol to acetic acid and glucose to gluconic acid [209] and are currently found based on phylogeny, physiology, and ecology in the *Acetobacteraceae* family, class *Alphaproteobacteria* [210]. AAB are often found on flowers, plants, and fruits, as these aerobic environments are rich in carbohydrates, sugar alcohols, and/or ethanol, allowing a specific respiratory chain to rapidly and incompletely oxidize these substrates into organic acids for energy production. Acidification of the environment prevents the growth of competitive bacteria. These physiological characteristics explain the occurrence of AAB and underline their role in producing diverse fermented foods and beverages such as lambic beer, water kefir, kombucha, and cocoa [57]. The species most frequently reported in vinegar production comprise *Acetobacter* species such as *Acetobacter cerevisiae*, *A. malorum*, and *A. pasteurianus*, *Gluconacetobacter* species such as *G. entanii*, *G. liquefaciens*, and *Gluconobacter oxydans*, and *Komagataeibacter* species such as *K. hansenii*, *K. intermedius*, *K. medellinensis*, and *K. oboediens* [211].

Acetic fermentation is also an excellent method for transforming by-products into value-added products. Giuffrè et al. [212] used acetic fermentation to valorize bergamot (*Citrus bergamia*) peel and juice. Limonene, a compound exhibiting antioxidant activity, was found in high contents (0.4–2.04 mg/L) in the vinegar obtained. The TPC varied from 241 to 1953 mg/L and chlorogenic acid between 2.95–58.51 mg/L.

5.3. Lactic Fermentation

Leuconostoc spp., *Lactococcus* spp., *Lactobacillus* spp., and *Streptococcus thermophilus* are examples of LAB that can convert sugars into lactic acid. Lactic acid inhibits the growth of subsequent and potentially harmful bacteria of other species and creates favorable conditions for yeast activity, a property utilized in the production of wine and beer [213]. In winemaking, LAB are present throughout all stages, and they can either enhance or diminish the quality of wine through malolactic fermentation and affect the organoleptic properties of the final product. The concentration of LAB during malolactic fermentation reaches approximately 10^7 CFU/mL, which indicates their importance in winemaking. The density of LAB in the initial phases of winemaking ranges from about 10^3 to 10^4 CFU/mL. The most abundant are *Lactobacillus hilgardii*, *L. plantarum*, *L. casei*, *Leuconostoc mesenteroides*, and *Pediococcus damnosus*, while less common species include *Oenococcus oeni* and *Lactobacillus brevis* [214].

Lactic fermentation can be used in the beverage industry to enhance antioxidant and antimicrobial properties or produce probiotic beverages. Muhiyaldin et al. [215] tested the effect of dragon fruit juice fermentation with *L. plantarum* on consumer acceptability and biological activity of the final product. The results show that fermentation at 37 °C for 48 h enhanced the antibacterial activity of fermented dragon fruit juice threefold. As per acceptability, consumers preferred the mixed dragon fruit fermented juice with fresh juice in the 1:9 ratio, as the fermented juice was too sour, with low pH (3.49). Additionally, this beverage had an extended shelf life to 3 months with no detected odors, color, and taste modifications compared to the fresh dragon fruit juice, which developed an unpleasant aroma and taste only after 1 month of storage at 8 °C.

LAB can be used to prolong shelf life up to six months for fresh cantaloupe juice [216]. The juice was fermented with *L. plantarum* for 48 h. After fermentation, the antimicrobial activity increased due to several bioactive metabolites and demonstrated complete inhibition towards *Aspergillus flavus*. The ratio of 20:80 fermented cantaloupe juice to fresh juice showed stable shelf life and high consumer acceptability.

A significant increase in the concentration of ellagic acid, known as a potent antioxidant and anti-tumor compound [217], was noticed during the fermentation of pomegranate juice by *L. plantarum*, which can degrade tannins by a tannin acylhydrolase named tannase, inhibiting the polymerization of the aromatic compounds and juice browning. Tannase can also modify the phenolic composition of juices and improve their antiproliferative and antioxidant activities [20]. Papaya juices fermented by *L. acidophilus* and *L. plantarum* were compared in organic acids, volatile compounds, and antioxidant capacities [218]. The DDPH and ABTS radical scavenging activities of *L. plantarum* fermented juice were significantly higher than *L. acidophilus* fermented juice.

5.4. Symbiotic Fermentation

Symbiosis, or the coexistence of various microorganisms, such as LAB and AAB or yeasts and molds, contributes to traditional fermentation (brewing). Auxotrophy and optimum oxido-reduction potential of microorganisms are essential factors for their symbiotic interaction. As for LAB, they usually require different types of nutrients, such as amino acids and vitamins. In traditional fermentation environments, some nutrients are provided to LAB using yeasts and koji molds. LAB and yeasts usually favor anaerobic environments, while koji molds and AAB absolutely require oxygen for growth. Therefore, in traditional fermentation environments, koji molds and AAB are usually found on surface areas, and LAB and yeasts are typically localized in internal areas [219].

Symbiosis in the forms of mutualism or commensalism is widespread in fermented foods, for example, in yoghurt, milk kefir, or sourdough [220]. A type of symbiotic fermentation is one that uses kefir grains. Kefir grains are white or yellow irregular granules of protein and a polysaccharide matrix named kefiran. The starter culture consists of a symbiotic consortium of several yeasts and bacteria. LAB are represented by the genera of *Leuconostoc*, *Lactobacillus*, and *Streptococcus*; the yeasts include *Saccharomyces*,

Zygosaccharomyces spp., *Candida*, *Pichia*, and *Dekkera* [20]. To date, a great variety of fruits such as pomegranate [221], apple [222], and orange [223] have been used to produce functional beverages using kefir grains.

Similarly, a symbiotic culture of bacteria and yeasts (SCOBY) is used for the production of kombucha. SCOBY mainly contains acetic acid bacteria (AAB), lactic acid bacteria (LAB), and yeasts. *Komagataeibacter* (*K. xylinus*, *K. kombuchae*), *Acetobacter* (*A. aceti*, *A. pasteurianus*, *A. nitrogenifigens*), and *Gluconacetobacter* (*G. sacchari*) are major AAB strains, while strains of *Saccharomyces* (*S. cerevisiae*) and non-*Saccharomyces* (*Candida* spp., *Schizosaccharomyces* spp., *Dekkera* spp., and *Brettanomyces* spp.) are present in lower amounts. Recent research successfully tested the isolates of *Hanseniaspora valbyensis*, *Hanseniaspora vineae*, *Torulasporea delbrueckii*, *Zygosaccharomyces bailii*, and *Zygosaccharomyces kombuchaensis* [150] and *Lachancea fermentati* strains [224] from kombucha to produce alcohol-free beer and low alcohol beer, respectively.

Another example of a symbiotic product is a type of plum juice containing three different types of probiotics (*Lactobacillus kefirifaciens*, *Candida kefir*, and *Saccharomyces boulardii*) and oligosaccharides, which showed antibacterial activity against diarrhea-causing pathogens such as *Escherichia coli*, *Vibrio cholerae*, *Salmonella Paratyphi A*, *Shigella dysenteriae*, and *Staphylococcus aureus* [225]. In this range, another symbiotic beverage has been formulated using probiotics and prebiotics. As a raw material, coconut water was used, *Lactobacillus rhamnosus* as a probiotic, and inulin as a source of soluble fiber. The obtained beverage presented good sensory acceptance, an amount of 82×10^8 CFU/mL of *L. rhamnosus*, 15 g of inulin, and a shelf life of 15 days in refrigeration conditions.

6. Future Trends and Conclusive Remarks

One of the emerging trends in the food and beverage industry is reusing by-products and waste, in the perspective of a circular economy. Fruit-based fermented beverages, a convenient and rich source of bioactive compounds, can work as carriers to deliver health-benefiting components derived from fruit by-products [226]. The management of fruit waste and/or by-products is essential because they represent a valuable resource of compounds that can be reused (phenolic compounds, carotenoids, tocopherols, and dietary fibers) [227]. Waste or by-products can also be used as raw material, decreasing the volume of food waste accumulated in landfills [228]. Studies have demonstrated an improvement in TPC and/or antioxidant activity by using by-products from pomegranate, orange, banana, grape, and tamarind in beverages. For instance, a beverage made from fresh orange juice with added banana peel extract (500 mg/100 mL) reported a 21 and 150% increase for DPPH and FRAP assays, respectively, compared to the non-fortified juice [226]. Moreover, pineapple residues (100 g/kg peel) can be used to produce fermented alcoholic beverages without quality loss or negative interference with the chemical quality of the fermented products [228].

In conclusion, fermentation has shown excellent potential for the production of fruit-based beverages directly from fruits or even from their waste and by-products. Optimized fermentation processes allow for enrichment in specific bioactive compounds (typically phenolic compounds and vitamin C), serving the interest of both industry and consumers. Furthermore, current emerging technologies, based on supercritical fluids, microwaves, ultrasound, enzymes, PEF, and HPH, represent another tool to increase the extraction yield of bioactive compounds.

The perception that beverages made with natural ingredients are healthier is increasing among European consumers. It is imperative to address fermented fruit-based beverages, considering consumer trends, preferences, and needs. Moreover, there is a great interest globally in consuming functional non-dairy fermented beverages. Recent studies have proved the functionality of fruit-based beverages, based on each nutritional or functional compound (namely phenolic compounds, vitamins, prebiotics, and probiotics). Therefore, these beverages represent a convenient, easily assimilable source that can be integrated within a daily diet.

Author Contributions: Conceptualization, A.-L.K., C.R.P., and T.E.C.; writing—original draft preparation, A.-L.K., C.R.P., E.M., L.C.S., C.D., C.B.-U., and T.E.C.; writing—review and editing, E.M., T.E.C., L.C.S., C.D., A.P., and H.Z.; supervision, E.M., T.E.C., A.P., and H.Z.; funding acquisition, E.M. and T.E.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The support given by Mihaela Mihai in language editing is highly appreciated by the authors.

Conflicts of Interest: The authors declare no conflict of interest.

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