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Review

Zero- and Low-Alcohol Fermented Beverages: A Perspective for Non-Conventional Healthy and Sustainable Production from Red Fruits

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Abstract: The growing health consciousness among consumers is leading to an increased presence of functional foods and beverages on the market. Red fruits are rich in bioactive compounds such as anthocyanins with high antioxidant activity. In addition, red fruits contain sugars and are rich in phenolic compounds, vitamin C, dietary fibers, and manganese. Due to these characteristics, they are also suitable substrates for fermentation. Indeed, nowadays, microbial transformation of red fruits is based on alcoholic or lactic fermentation, producing alcoholic and non-alcoholic products, respectively. Although products fermented by acetic acid bacteria (AAB) have been thoroughly studied as a model of health benefits for human beings, little evidence is available on the acetic and gluconic fermentation of red fruits for obtaining functional products. Accordingly, this review aims to explore the potential of different red fruits, namely blackberry, raspberry, and blackcurrant, as raw materials for fermentation processes aimed at producing low- and no-alcohol beverages containing bioactive compounds and no added sugars. AAB are treated with a focus on their ability to produce acetic acid, gluconic acid, and bacterial cellulose, which are compounds of interest for developing fruit-based fermented beverages.

Keywords: red fruits; acetic acid bacteria; vinegar; non-alcoholic beverages; gluconic acid; acetic acid

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1. Introduction

Nowadays, the consumption of functional fermented foods and beverages is a well-established habit as consumers are strongly interested in products with health claims. As a matter of fact, since ancient times, fermented products have been a part of human nutrition. Originally, their production was performed to improve the shelf life of perishable raw materials from agriculture and animal husbandry. Subsequently, many different microorganisms have been selected in order to obtain disparate fermented products with favorite quality characteristics, mostly regarding shelf life, taste, texture, mouthfeel, flavor, and color [1–6]. More recently, in addition to researching certain sensory and technological characteristics, the challenge goes so far to obtain products with the added quality of beneficial influencing human health. In this frame, zero- and low-ethanol beverages production is an expanding globally promoted market, although availability, acceptability, and affordability are still issues and current gaps that need to be filled [7].

Thus, a diversity of fermented products is obtained starting from disparate raw materials, depending on their availability and diffusion in the territories of origin. Therefore, milk, meat, cereals, vegetables, and fruits are widely used in both traditional and modern food manufacturing processes.

In general, fruits are suitable raw materials due to their fermentative aptitudes, such as high content of sugars, in particular glucose and fructose. It has been reported that fermentation enhances the nutritive value of the final products, which are generally characterized by lower amounts of glucose and great antioxidant content [8]. Among the different kinds of fruits, red fruits are extremely beneficial for human health and, with their intense flavor, are appreciated by consumers. Several studies have stated their phytochemical composition, which includes minerals, fibers, and antioxidant compounds able to exert a protective effect against many chronic diseases [9–12] (Figure 1).

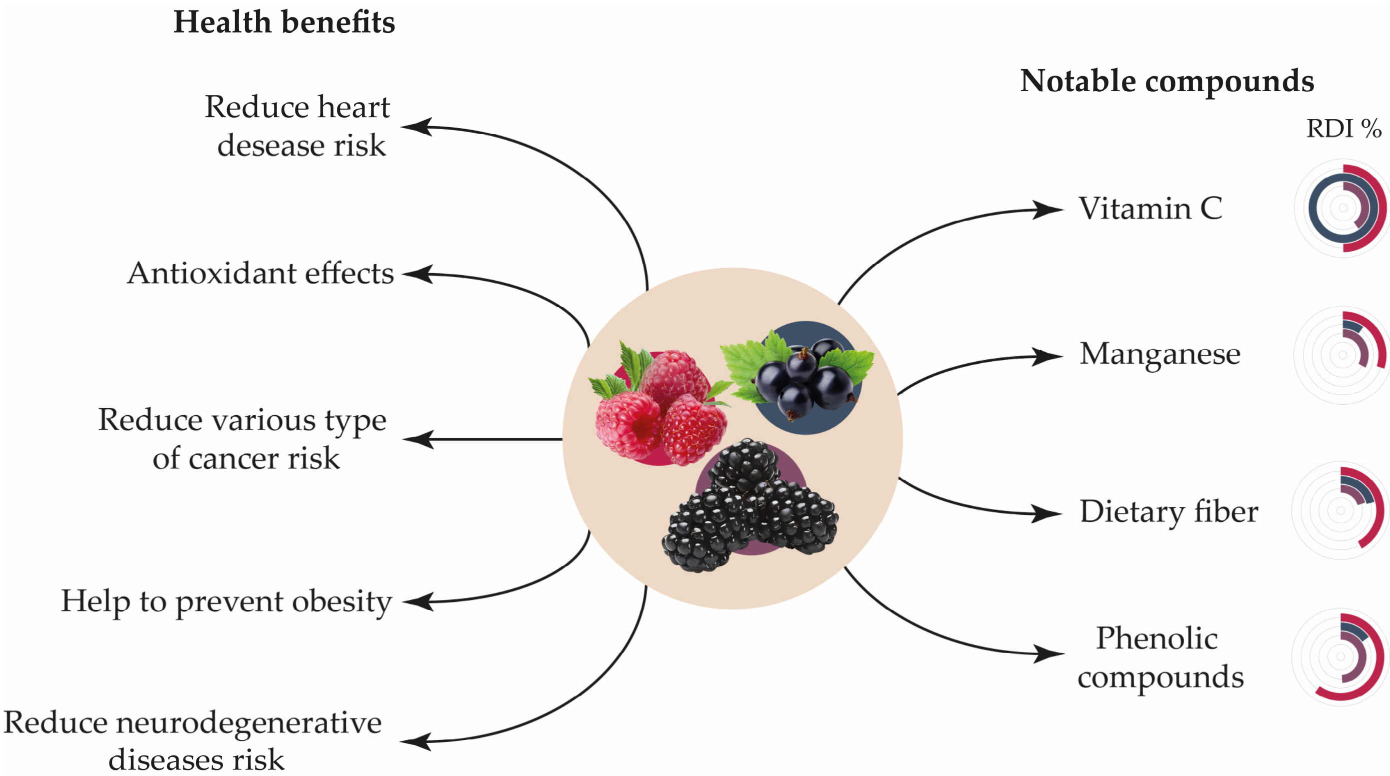

Figure 1. Raspberry, blackcurrant, and blackberry are the main health benefits reported in the literature. Notable compounds are listed, and the recommended daily intake (RDI) is reported as a percentage covered by a 100 g portion of raspberry (dark red), blackcurrant (blue), and blackberry (violet).

Polyphenols, carotenoids, and anthocyanins are the main kinds of antioxidant phytochemicals found in red fruits.

Anthocyanins are responsible for the red/dark color of fruits and are the major flavonoid family molecules present in raspberry, blackberry, and blackcurrant. The most common naturally occurring anthocyanins are the 3-O-glycosides or 3,5-di-O-glycosides of cyanidin, delphinidin, peonidin, petunidin, pelargonidin, and malvidin. Numerous studies have shown that they can have various biological activities, including antimicrobial and anti-inflammatory activities, protective action against various degenerative diseases, and an important role in decreasing the invasiveness of tumor cells [13–17]. Nevertheless, the profile and concentration of anthocyanins are different depending on the fruit. Some red fruits, for example, strawberries, have lower concentrations of anthocyanins, and others, such as black currants, have higher concentrations [18].

Other than anthocyanins, red fruits also contain vitamin C, ellagitannins, and several minerals such as manganese, giving berries and derivative products outstanding health benefits for human beings [19]. Amongst health benefits, the antioxidant effect is a major characteristic of red fruits [20].

However, health-based recommendations include reducing alcohol consumption and calories, thus promoting zero/low-ethanol and no added sugars beverages [21].

For these reasons, owing to outstanding functional properties, red fruits represent valid non-conventional raw materials for producing low- and no-alcohol fermented beverages with health benefits. This is in line with the recent increasing trend to exploit non-conventional raw materials containing fermentable sugars for producing new functional beverages. Date palm fruits, for instance, were proven to be a valid starting substrate for the formulation of functional foods and beverages, as they show a high amount of sugars, which makes them highly fermentable and dietary fibers, minerals, vitamins, and phenolic compounds, which confer functional features to end-products [22].

Moreover, legumes, single-cell protein, bee pollen, and tropical fruits assume a greater role in the food market as non-conventional matrices suitable to produce dairy-free functional products [23]. The recognition of the beneficial effects of consuming functional products on a daily basis led to the scientific interest in developing new products; in this perspective, quince, kiwifruit, prickly pear, and pomegranate juices have been explored as fermentable substrates to developing new non-dairy fermented beverages [24].

In addition to health reasons, sometimes using alternatives to traditional raw materials can also have an economic return since the resources existing in a territory can be exploited in the best possible way. This is the case, for example, of non-conventional edible plants that are spontaneous, wild, or cultivated vegetable species, e.g., wax mallow, used in certain regions and cultures as therapeutic herbs and can be opportunely used to produce fermented beverages showing beneficial bioactivity [25,26]. In this frame, fermented beverages, such as vinegar with different content of acetic acid, gluconic beverages, and kombucha tea, fit as functional products with health benefits for human beings. These beverages are the result of the fermentative activity of different microbial groups, including yeasts, acetic acid bacteria (AAB), and lactic acid bacteria (LAB).

Vinegars and vinegar-based beverages are produced via a double fermentation: an alcoholic fermentation performed by yeasts and then an acetic acid fermentation by AAB. Yeast hydrolyzes sucrose into glucose and fructose, which are used to produce ethanol. AAB oxidizes ethanol into acetic acid, which is the main organic acid that characterizes vinegar-based beverages, even though the concentration is significantly lower compared to vinegar [27].

Gluconic beverages are produced by a single-step fermentation in which glucose is oxidized into gluconic acid. The latter is a weak organic acid exploited to improve the sensorial complexity of foods and beverages. Gluconic acid can be further oxidized into 2,5-diketo-D-gluconate acid and 5-keto-D-gluconic acid [28].

Kombucha tea is produced by the activity of a consortium of microorganisms growing on sugared tea. AAB and yeasts are the most present, whereas LAB occurs less frequently [29]. Kombucha fermentation starts with the hydrolyzation of sucrose into glucose and fructose by yeasts, then bacteria start oxidative and fermentative processes of glucose, fructose, and ethanol [30]. The result is a beverage containing a mix of organic acids, mainly acetic and gluconic acids, ethanol in small amounts, CO_2, and a floating layer of bacterial cellulose produced by AAB [31]. In addition, kombucha is reported to have beneficial effects on human health, such as anticancer, antimicrobial, antioxidant properties, and anti-aging activity [32].

In this review, raspberry, blackcurrant, and blackberry are focused on their composition and aptitude to develop fermentations. Alcoholic and lactic fermentations are described as the more applied microbial transformations. Acetic acid fermentation for producing low- and non-alcoholic products, namely vinegar and acetic and gluconic beverages (Figure 2), are discussed, highlighting their potential as well as the limited availability of existing marketed products.

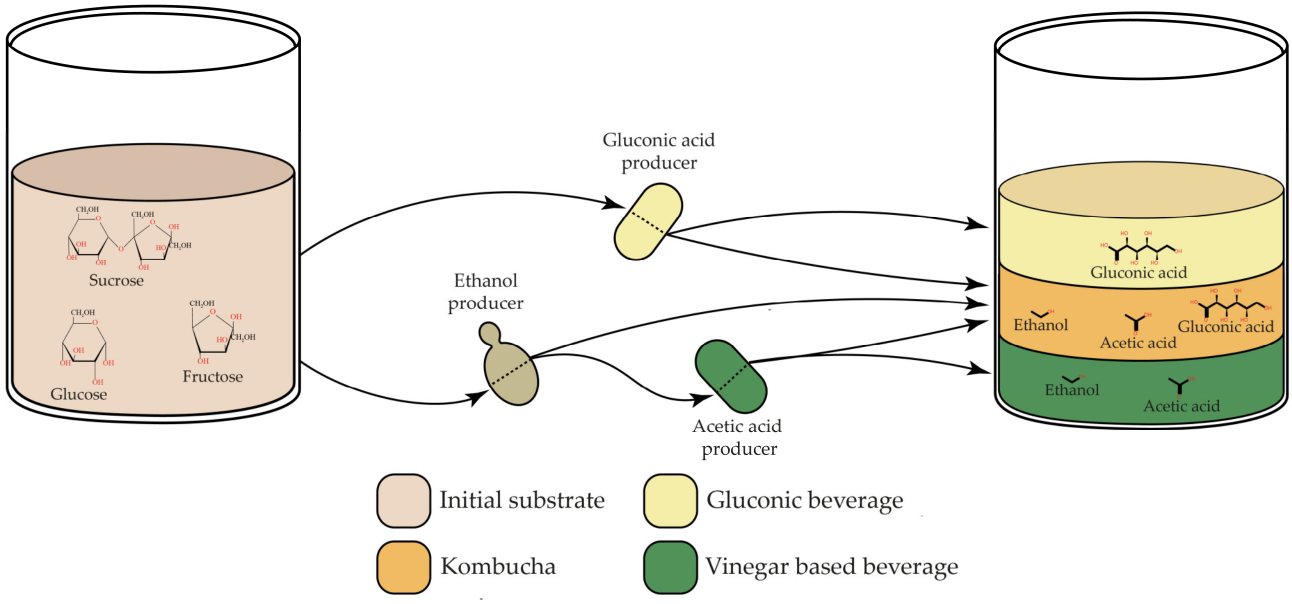

Figure 2. Microbial transformations and interactions in the production of gluconic beverages, kombucha, and vinegar-based beverages starting from a sugared substrate.

2. Red Fruits Features

2.1. Blackberry Fruit (Rubus Subg. Rubus)

Blackberry is a worldwide consumed fruit, mostly produced in North America, Europe, and Asia [33]. The major producers are North America and Europe, producing 65,000 and 45,000 tons/year, respectively [34]. Amongst European countries, Serbia and Hungary lead the production, representing almost all European annual production.

At the industrial level, blackberries are used for different productions, such as dietary supplements or jams. However, they are mostly consumed as fresh fruits or sold as individually quick-frozen packs. Although blackberries' chemical composition is strictly dependent on several factors, such as the cultivar or the stage of ripeness [35], generally, they are rich in sugars, minerals, and phenolic compounds [33,36]. Total sugars, soluble solids, and total anthocyanin increase as the fruit ripens. On the other hand, protein content and total phenolic compounds significantly decrease along the maturation steps [37]. Glucose and fructose are the main sugars, with sucrose present in traces. Potassium and magnesium are the main minerals detected in blackberries, followed by calcium and manganese [37] (Table 1).

Table 1. Chemical composition of fresh blackberries per 100 g at ripe stage (adapted from [33,38–43]).

Blackberry Composition	Lowest Reported	Highest Reported
	Content [g/100 g]	
Water	85.8	90.3
Protein	1.00	1.49
Total lipids	0.42	0.53
Ash	0.21	1.20
Total fiber	0.80	6.6
Total sugars	4.88	10.22
Sucrose	0.07	1.08
Glucose	2.31	2.61
Fructose	2.40	3.38
Maltose	-	0.07
Galactose	-	0.03

Table 1. *Cont.*

Minerals	Content [mg/100 g]	
Calcium	7.25	29.0
Iron	0.62	4.70
Magnesium	10.7	21.4
Phosphorus	7.25	22.0
Potassium	79.7	185.5
Sodium	0.30	1.00
Zinc	0.18	0.31
Copper	0.05	0.17
Manganese	0.42	1.47
Vitamins	**Content [mg/100 g]**	
Total ascorbic acid	1.50	44.0
Thiamin	-	0.02
Riboflavin	-	0.03
Niacin	-	0.65
Pantothenic acid	-	0.28
Vitamin B6	-	0.03
A-tocopherol	-	1.17
B-tocopherol	-	0.04
Γ-tocopherol	-	1.34

Blackberry contains a high amount of citric and malic acid. In addition, various studies reported the presence of shikimic, fumaric, and succinic acids [44,45]. Organic acid content is of fundamental importance for evaluating fruits' quality levels since they act as a stabilizer for anthocyanins. The health benefits of blackberries are associated with anthocyanins and other phenolic compounds such as ellagitannins, flavonols, and procyanidins [33,46]. Anthocyanins are responsible for the characteristic color of blackberry and are strong antioxidant compounds with potential antidiabetic, anticancer, anti-inflammatory, antimicrobial, and anti-obesity effects, as well as prevention of cardiovascular diseases [47,48].

2.2. Raspberries (Rubus idaeus)

Raspberries hold a special position due to their culinary versatility, the ideal nutritional profile of low calories, high fiber, mineral, potassium, sodium, and vitamins, the presence of several essential micronutrients, and phytochemical composition (Table 2).

Table 2. Composition of fresh red raspberries per 100 g (adapted from [9,42,49–52]).

Raspberry Composition	Lowest Reported	Highest Reported
	Content [g/100 g]	
Water	85.7	88.6
Protein	1.00	1.80
Total lipids	0.10	0.65
Carbohydrate	10.1	11.90
Dietary fiber	6.50	11.94
Total sugars	3.60	6.50
Sucrose	0.20	4.20
Glucose	1.86	2.50
Fructose	2.35	3.65

Table 2. *Cont.*

Minerals	Content [mg/100 g]	
Calcium	24.0	35.6
Iron	0.55	0.80
Magnesium	9.00	23.0
Phosphorus	30.0	35.0
Potassium	133	184
Sodium	0.02	4.00
Zinc	0.30	0.42
Copper	-	0.09
Manganese	0.11	0.67
Vitamins	**Content [mg/100 g]**	
Total ascorbic acid	13.4	43.9
Thiamin	0.03	0.10
Riboflavin	0.04	0.10
Niacin	0.03	0.70
Pantothenic acid	0.01	0.50
Vitamin B6	0.06	0.30
Total folate (μg)	21.0	36.0
Choline	-	12.3
Vitamin A, RAE (μg)	-	2.00
Lutein—zeaxanthin (μg)	136	360
Vitamin E	0.30	1.60
A-tocopherol	0.30	1.60
Vitamin K (μg)	-	7.38

Raspberries are consumed as fresh or frozen fruits or as processed products such as juices, jams, or jellies [49,53].

Worldwide, 822,493 tonnes of raspberry are produced per year. Mexico, Serbia, and the Russian Federation altogether produce more than 50% of the world's total raspberry. The major raspberry producer in the world is the Russian Federation, with 174,000 tonnes of production per year; Mexico comes second with 128,848 tonnes of yearly production, and the third largest producer of raspberry with 120,058 tonnes of production per year is Serbia [9].

Raspberries are a good source of phenolic compounds and many nutrients, such as vitamins, minerals, and fatty acids [54]. Raspberries are also rich in fructose and contain small amounts of glucose and sucrose. Among vitamins, vitamin C is the most abundant, followed by riboflavin, folic acid, and niacin. It is worth noting that a 100 g portion of raspberries provides 50% of the recommended intake of vitamin C [49]. Raspberries are also a good source of manganese, potassium, copper, and iron. The nutrient profile of raspberry potentially helps regulate blood sugar levels by slowing digestion and contributes to a satiety effect (given by the high fiber content) [12].

Likewise, other red fruits, such as raspberries, contain high levels of anthocyanins and ellagitannins. Ellagic acid and ellagitannins exhibit a wide range of beneficial effects on human health, such as antioxidant, antimutagenic, anticarcinogenic, and antiviral. Besides anthocyanins and ellagitannins, raspberries contain other phenolic compounds, including quercetin, kaempferol, and gallic acid, reaching a total phenolic content between 160–645 mg/100 g of fresh fruit [55–57].

2.3. Blackcurrants (Ribes nigrum)

Black currants represent an important cultivation among small fruits, with an annual production of 185,000 tonnes. Most of the world's production is concentrated in Europe, which represents the largest world producer with 160,000 tonnes per year [34]. Globally, Germany, Poland, and the United Kingdom contribute to about 80% of the total production of blackcurrant.

Blackcurrant is widely recognized for containing high concentrations of phenolic compounds (125–151 mg/100 g fresh weight), especially of proanthocyanins and anthocyanins, which together constitute 80% of total phenolics [55,58]. Furthermore, blackcurrants contain high levels of vitamin C, about five times more than oranges [47,54], high minerals (potassium, calcium, magnesium, and sodium), and monosaccharides [33] (Table 3).

Table 3. Nutrient composition of fresh blackcurrant per 100 g (adapted from [20,59–64]).

Blackcurrant Composition	Lowest Reported	Highest Reported
	Content [g/100 g]	
Water	77.0	83.0
Dietary fiber	5.30	6.20
Total sugars	7.10	14.0
Sucrose	0.10	1.30
Glucose	1.71	3.42
Fructose	0.85	1.52
Minerals	**Content [mg/100 g]**	
Calcium	31.3	64.2
Iron	1.13	6.36
Magnesium	17.0	65.9
Phosphorus	35.0	40.0
Potassium	251	320
Sodium	0.98	2.50
Zinc	0.16	0.36
Copper	0.15	0.20
Manganese	0.002	0.52
Vitamins	**Content [mg/100 g]**	
Total ascorbic acid	98.0	284
Thiamin	0.08	0.11
Riboflavin	0.08	0.11
Niacin	37.6	41.1
Vitamin B6	0.10	0.50
Vitamin A	17.8	20.0
A-tocopherol	0.50	0.90

Vitamin C levels range from 98 to 284 mg/100 g of fresh fruit, covering 100% of recommended daily intake with a portion of just 25 g. High levels of vitamin C, anthocyanins, and phenolic compounds suggest that blackcurrant can be used as a potential nutraceutical ingredient. Therefore, the phytochemicals present in blackcurrant have been extensively studied for their antioxidant activity [65], anti-inflammation activity [66], neuroprotective actions [67], anti-obesity properties [66,68], and anti-cancer properties [69].

Blackcurrants could be consumed as fresh fruit or as juices obtained from frozen processed berries. However, when berries are frozen, chemical changes can occur, including the concentration of solutes and chemicals, oxidative reactions, and enzyme activity. Contrarily, total phenolic and anthocyanin contents decrease during the processing of berry fruits into juices. Djordjević and co-workers [63] reported a strong reduction in anthocyanins, varying from 12% to 80%, and a slight decrease in total phenolics during the processing of berry fruits into juice. However, the content of total phenolics increased by 46.09–171.76% when berries were frozen and stored for 1 year, while in juices, total phenolics increased by 107.58%. Contrarily, the content of total anthocyanins in berries and juices after 1 year of storage decreased by 5.63–52.76% and 13.04–36.82%, respectively.

3. Red Fruits' Conventional Fermentation through Lactic Acid Bacteria and Yeasts

LAB are among the most used microorganisms to transform vegetables and fruits into more stable products. During fermentation, microbial enzymes produce newly derived compounds impacting aroma and functionality, reduce sugar content, improve nutritional value, and extend the shelf life of products.

Frozen fruits, juices, or smoothies can be fermented by LAB, obtaining healthy and functional products rich in bioactive compounds. To produce low-alcohol or non-alcoholic berry beverages, various LAB species (*Lactiplantibacillus plantarum*, *Levilactobacillus brevis*, *Lactocaseibacillus rhamnosus*, *Lactobacillus acidophilus*, *Lactocaseibacillus casei*) strains have been used in berry fermentation [59,70,71].

During fermentation, microbial enzymes produce new derived compounds impacting aroma and functionality (e.g., vitamins, phenolic compounds, or bioactive peptides), reduce sugar content, improve nutritional value, and extend the shelf life of fruit-based beverages [72,73]. Hence, depending on the juice and starter culture mix, fermented beverages with outstanding beneficial effects related to phenolic content, bioactive compounds presence, vitamin content, and probiotic activity could be obtained.

L. casei showed good adaptation when inoculated in blackberry juice, providing a beverage with functional characteristics [74].

Wu and co-workers [69] fermented blueberry and blackberry juices using three potential probiotic strains, reaching the recommended level for probiotic effects in both juices with each strain. In addition, fermentation improved the overall acceptability of both juices. Authors observed an increasing trend in syringic acid, ferulic acid, gallic acid, and lactic acid during fermentation. On the other hand, *p*-coumaric acid, protocatechuic acid, chlorogenic acid, and anthocyanins decreased during fermentation, with cyanindin-3-glucoside and peonidin-3-glucoside being the most affected, with a reduction of over 30%.

Low-ethanol blackcurrant beverage was obtained via sequential fermentation with *Metschnikowia* yeasts, showing promising future prospects for the development of low-ethanol content beverages [75]. The feasibility of efficient alcoholic fermentation using red fruits as raw material to produce fruit wine is well documented and is a common practice worldwide. Raspberry wines are characterized by high anthocyanins content and aromatic descriptors associated with volatile compounds such as ethyl pyruvate and ethyl butyrate [76,77]. In addition, raspberry wine is a rich source of phenolic compounds and represents a traditional product in Asian countries, especially Korea [78]. Comparing the proanthocyanidin content of grape wine with raspberry wine, the latter's results are three times richer, which explains the characteristic bitterness and astringency of raspberry wine [79]. Blackberry, raspberry, and blackcurrant wines are established products in the USA, mainly due to the peculiar flavor which distinguishes them from grape wine. In addition, blackberry wine showed higher total phenolic and total anthocyanin contents compared to grape wine and other fruit wines, as reported by Johnson and de Mejia [80].

4. Acetic Acid Bacteria-Based Beverages

4.1. Vinegar and Vinegar-Based Beverages

Vinegar is widespread in the world, and it is mainly known as a condiment and a preservative of foods. However, more recently, vinegars with healthy attributes were rising in the market. Some benefits to consuming vinegar include enhanced immunity, reduced risk factors for cardiovascular diseases, improved digestion, appetite suppression, and reduced fasting blood glucose, blood pressure, and serum cholesterol [81].

Conventionally, vinegar is produced from several raw materials, such as grapes, apples, rice, and diluted ethanol, according to established practices [82,83]. Moreover, several works highlight the feasibility of vinegar production from other fermentable raw materials, mainly fruits such as dates, oranges, strawberries, pineapples, and prickly pears [18,84–87].

Basically, in order to obtain vinegar both in submerged and static fermentation regimes, mixed AAB starter cultures are used [88,89]. In vinegar, AAB drives the production of acetic acid, thereby preventing the growth of microbial competitors. Some AAB also produce a cellulosic layer when growing in media containing sugars. Bacterial cellulose is a biopolymer of interest in the biotechnological industry, as well as a compound occurring in some fermented beverages [90,91]. Cunha and co-workers [92] produced blackberry vinegars through successive acetification cycles and evaluated bioactive compound variation from raw material to the final product. Vinegars were characterized by an average acetic acid content of 51.6 g/L and considerable quantities of phenolic compounds. Interestingly, phenolic compounds, antioxidant potential, and anthocyanins content were observed to be stable along several acetic fermentation cycles. On the other hand, a slight decrease in phenolic compounds, antioxidant potential, and anthocyanins content was observed when comparing blackberry wine and vinegar after acetic fermentation. However, the anthocyanins content in blackberry vinegar was appreciable (32.78 mg cyanidin 3-glucoside/L).

Su and Chien [93] obtained a blueberry vinegar with an anthocyanins content of 3.22 mg/100 mL via fermenting fruits and barks. In addition, Dogaru and co-workers [94] reported a higher antioxidant capacity of raspberry and blackberry vinegars compared to bilberry and apple vinegars, reaching a total antioxidant capacity of 16.0 and 15.2 mM Fe^{2+}/L, respectively.

The high phenolic compounds content and high antioxidant capacity of red fruit vinegars, along with the presence of organic acids and amino acids, could have health-promoting effects on human beings. Indeed, bioactive compounds of red fruit vinegars have been correlated with positive effects, such as an increase in digestion absorption and decreases in cardiovascular disease, serum cholesterol level, arterial stiffening, and blood pressure, by various studies [18,95–99]. In addition, the bioactive compounds in vinegars can be produced and/or increased through the overall vinegar fermentation process, where phenolic compounds are transformed into new antioxidative molecules.

Next to the production of vinegar, a range of non-dairy products consists of low-alcoholic and non-alcoholic fermented beverages. These products, although they could be an alternative to dairy-based beverages in terms of texture, flavor, as well as nutritional value, have received little attention from consumers and industry, especially in Western society [100]. Instead, the production and consumption of vinegar-based beverages obtained from fruits are more developed in Asian countries such as China or Korea [101].

Kim and co-workers [102] extensively investigated the physicochemical properties of various commercially available vinegar-based beverages at low- or non-alcohol content consumed in the Korean market, including their pH, acidity, sugar, total soluble sugar, total acid, and total amino acid content. Acetic acid content ranged between 0.84 to 1.91 g/L, representing more than 50% of total acid content. Oxalic, citric, malic, succinic, and lactic acids were also present. The authors also evaluated total phenolic compounds, anthocyanins, flavonoid content, and antioxidant activity. Specifically, blackberry vinegar-based beverages had high total anthocyanin content (13.21 mg/100 mL), antioxidants activity (10.98 %), total polyphenol content (87.25 mg/100 mL), and flavonoid value (51.12 mg/100 mL).

4.2. Kombucha and Gluconic Beverages

Kombucha is a slightly sweet and sparkling beverage obtained from fermented green or black tea with sugar via a microbial consortium composed of several AAB, yeasts, and LAB [103]. This microbial consortium forms a powerful symbiosis capable of inhibiting the growth of potentially contaminating microorganisms. The fermentation process also leads to the formation of a cellulose pellicle due to the activity of AAB, mainly belonging to the *Komagataeibacter* genus [104]. Actual food trends toward minimally processed products, without additives, with high nutritional value and health benefits, have increased with consumer awareness. In this context, traditional Kombucha tea has recently captured the attention of researchers and consumers. In addition, Kombucha consumption has been associated with a wide range of health functions, such as anti-inflammatory and hypoglycemic effects, and antioxidant, antimicrobial, and antiproliferative properties, and mainly related to the presence of organic acids, vitamins, minerals, and phenolic compounds [105].

Although studies [106] confirmed that the fermentation process breaks down larger compounds already present in the liquid into small molecules with greater bioavailability, initial substrate composition in terms of bioactive compounds is fundamental. Indeed, recently, different substrates have been tested in the fermentation of kombucha tea, resulting in new kombucha beverages with different sensorial properties and functional properties [107].

Salak, commonly known as snake fruit in Indonesia, was used to produce Salak kombucha, fermenting salak juice over 14 days. The obtained functional fermented beverage, rich in antioxidants, such as tannins and polyphenols, and organic acids, such as acetic, citric, and lactic, was demonstrated to have anti-hyperglycemia activity [108].

Moreover, kombucha prepared using black tea, sugar, and different berry fruits (blackberry, raspberry, and red goji berry) resulted in much richer in mineral and phenolic contents compared to standard kombucha [109]. Blackberry kombucha was the most appreciated and was characterized by the highest catechins content (92.38 mg/100 g) and good contents in potassium (1487.52 mg/kg), calcium (271.45 mg/kg), and magnesium (236.41 mg/kg). On the other hand, raspberry kombucha had higher potassium (1486.323 mg/kg) content but was lower in calcium (236.47 mg/kg) and phosphorus (197.52 mg/kg).

Likewise, in red fruit vinegar production, the total phenol content of kombucha increases due to the release of small molecules with higher antioxidant activities caused by enzyme activity or acidity increase during the fermentation process. On the other hand, as observed by Ulusoy and co-workers [110], extended storage time could affect total phenol content in black carrot kombucha, blackthorn kombucha, and raspberry kombucha. However, even though the reduction in total phenol content, raspberry kombucha showed high antioxidant capacity primarily constituted by anthocyanins and ellagitannins.

Other than antimicrobial and anti-proliferative properties, kombucha produced from red fruits could have a potential gastroprotective effect given by the high phenolic content, as reported by Barbosa and co-workers [111]. Indeed, phenolic compounds have been reported to stimulate e Prostaglandin E2 and to improve the status of different oxidative stress biomarkers [111,112]. By choosing initial substrates rich in phenolic compounds, the beneficial effects of kombucha could be further improved.

An innovative trend of the last years is acidic beverages containing mainly gluconic acid as an acidifier. These beverages are based on the fermentation by *Gluconobacter* sp., which transforms the glucose present in the fruit juice into gluconic acid. However, few examples of beverages from fruits containing no ethanol obtained by AAB exist on the market.

The study of Hornedo-Ortega and co-workers [113] demonstrated that alcoholic fermentation of strawberry purees decreased the anthocyanin content, while gluconic fermentation preserved these compounds, which is an advantage of this last process. Following these results, the authors reported that the chemical composition and antioxidant activity of strawberry gluconic beverage are stable for 60 days of storage at 4 °C [113].

However, the use of kombucha microbial consortium to ferment alternative raw matrices is becoming even more popular in trying to achieve the aim of producing novel pro-healthy and eco-friendly products. Moreover, in the agricultural and food field, there are numerous by-products coming from other food productions that still have an exploitable potential use. As a matter of fact, many times, the waste products of food processes still contain nutritional valuable compounds, such as proteins, sugars and polysaccharides, minerals, and secondary metabolites. Thus, matrices such as soybean whey and banana peel extract have been shown to be suitable for microbial fermentation, leading to beverages containing bioactive compounds with antioxidant and antimicrobial features [114,115].

5. Opportunities and Challenges

Currently, zero- and low-ethanol fermented beverages available on the market are produced mainly from fermentation processes by LAB. Most of these products are milk-based beverages [100]. Nowadays, there is an expanding market of zero- and low-alcohol beverages due to major awareness about the long-term effects of ethanol intake, and societal and individual vulnerability factors on alcohol consumption, in conjunction with a greater propensity of consumers to purchase healthier foods [116–118]. However, the habit of consuming alcoholic beverages is still very widespread despite the health and religious aspects, being linked to deeply rooted cultural factors and food styles. The consumption of zero- and low-alcohol beverages could be enlarged and supported by the introduction of new fermentation processes.

In this light, exploring AAB for producing non-conventional beverages from red fruits meets different needs which cross the consumer health and acceptance, as well as sustainable principles, reducing food wastes and recovering seasoning surplus. Moreover, considering fruits or leaves (as in the case of kombucha-based beverages), it is possible to set up bioprocesses for obtaining beverages at zero- and low-ethanol content and with no added sugars.

Numerous raw materials could be suitable as a substrate for fermentation by AAB, but few examples of marketed beverages, except for vinegar and, more recently, kombucha tea, are available. In particular, to obtain functional beverages, red fruits could represent suitable substrates bringing a positive impact on human health [119]. Eventually, even red fruit waste or by-products, such as leaves or seeds, could be used as raw materials rich in bioactive compounds. Ziemlewska and co-workers [120] utilized the kombucha microbial community as a starter culture to ferment red fruit leaves, obtaining an extract rich in bioactive compounds. Fermented and raw extracts were compared in terms of antioxidant potential and anti-aging properties. Results showed higher effects in fermented extracts, highlighting the positive impact of AAB on bioactive compounds.

In this frame, the know-how acquired in vinegar production can be the starting point for vinegar-based, zero- and low-ethanol, and gluconic beverages. Indeed, established techniques, such as static and submerged methods, could be suitable for developing new healthy products [121–123]. Future challenges that need to be considered include the optimization of vinegar fermentation methods for non-conventional raw materials and the increase in consumer awareness for new healthy products.

However, AAB fermentation could play a key role in the emerging market of zero-and low-alcohol beverages, contributing to more sustainable productions of beverages and positively impacting public health.

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References

1. De Roos, J.; De Vuyst, L. Acetic acid bacteria in fermented foods and beverages. *Curr. Opin. Biotechnol.* **2018**, *49*, 115–119. [CrossRef]
2. Gullo, M.; Giudici, P. Acetic acid bacteria in traditional balsamic vinegar: Phenotypic traits relevant for starter cultures selection. *Int. J. Food Microbiol.* **2008**, *125*, 46–53. [CrossRef]
3. Bassi, D.; Puglisi, E.; Cocconcelli, P.S. Comparing natural and selected starter cultures in meat and cheese fermentations. *Curr. Opin. Food Sci.* **2015**, *2*, 118–122. [CrossRef]
4. Pereira, G.V.M.; De Carvalho Neto, D.P.; Junqueira, A.C.D.O.; Karp, S.G.; Letti, L.A.; Magalhães Júnior, A.I.; Soccol, C.R. A Review of Selection Criteria for Starter Culture Development in the Food Fermentation Industry. *Food Rev. Int.* **2019**, *36*, 135–167. [CrossRef]
5. Calvert, M.D.; Madden, A.A.; Nichols, L.M.; Haddad, N.M.; Lahne, J.; Dunn, R.R.; McKenney, E.A. A review of sourdough starters: Ecology, practices, and sensory quality with applications for baking and recommendations for future research. *PeerJ* **2021**, *9*, e11389. [CrossRef] [PubMed]

6. Yousseef, M.; Lafarge, C.; Valentin, D.; Lubbers, S.; Husson, F. Fermentation of cow milk and/or pea milk mixtures by different starter cultures: Physico-chemical and sensorial properties. *LWT* **2016**, *69*, 430–437. [CrossRef]
7. World Health Organization. *A Public Health Perspective on Zero-and Low-Alcohol Beverages*; WHO: Geneva, Switzerland, 2023.
8. Anagnostopoulos, D.A.; Tsaltas, D. *Chapter 10–Fermented Foods and Beverages*; Woodhead Publishing: Cambridge, UK, 2019.
9. Zhang, X.; Ahuja, J.K.; Burton-Freeman, B.M. Characterization of the nutrient profile of processed red raspberries for use in nutrition labeling and promoting healthy food choices. *Nutr. Health Aging* **2019**, *5*, 225–236. [CrossRef]
10. Xue, B.; Hui, X.; Chen, X.; Luo, S.; Dilrukshi, H.; Wu, G.; Chen, C. Application, emerging health benefits, and dosage effects of blackcurrant food formats. *J. Funct. Foods* **2022**, *95*, 105147. [CrossRef]
11. Derosa, G.; Maffioli, P.; Sahebkar, A. Ellagic Acid and Its Role in Chronic Diseases. *Adv. Exp. Med. Biol.* **2016**, *928*, 473–479. [CrossRef] [PubMed]
12. Burton-Freeman, B.M.; Sandhu, A.K.; Edirisinghe, I. Red Raspberries and Their Bioactive Polyphenols: Cardiometabolic and Neuronal Health Links. *Adv. Nutr. Int. Rev. J.* **2016**, *7*, 44–65. [CrossRef]
13. Jakobek, L.; Seruga, M.; Medvidovic-Kosanovic, M.; Novak, I. Anthocyanin content and antioxidant activity of various red fruit juices. *Dtsch. Lebensm.* **2007**, *103*, 58.
14. Ma, Y.; Ding, S.; Fei, Y.; Liu, G.; Jang, H.; Fang, J. Antimicrobial activity of anthocyanins and catechins against foodborne pathogens Escherichia coli and Salmonella. *Food Control.* **2019**, *106*, 106712. [CrossRef]
15. Ma, Z.; Du, B.; Li, J.; Yang, Y.; Zhu, F. An Insight into Anti-Inflammatory Activities and Inflammation Related Diseases of Anthocyanins: A Review of Both In Vivo and In Vitro Investigations. *Int. J. Mol. Sci.* **2021**, *22*, 11076. [CrossRef]
16. Zhong, H.; Xu, J.; Yang, M.; Hussain, M.; Liu, X.; Feng, F.; Guan, R. Protective Effect of Anthocyanins against Neurodegenerative Diseases through the Microbial-Intestinal-Brain Axis: A Critical Review. *Nutrients* **2023**, *15*, 496. [CrossRef]
17. Rabelo, A.C.S.; Guerreiro, C.d.A.; Shinzato, V.I.; Ong, T.P.; Noratto, G. Anthocyanins Reduce Cell Invasion and Migration through Akt/mTOR Downregulation and Apoptosis Activation in Triple-Negative Breast Cancer Cells: A Systematic Review and Meta-Analysis. *Cancers* **2023**, *15*, 2300. [CrossRef]
18. Vilela, A.; Cosme, F. Drink Red: Phenolic Composition of Red Fruit Juices and Their Sensorial Acceptance. *Beverages* **2016**, *2*, 29. [CrossRef]
19. Skrovankova, S.; Sumczynski, D.; Mlcek, J.; Jurikova, T.; Sochor, J. Bioactive Compounds and Antioxidant Activity in Different Types of Berries. *Int. J. Mol. Sci.* **2015**, *16*, 24673–24706. [CrossRef] [PubMed]
20. Nour, V.; Trandafir, I.; Ionica, M.E. Ascorbic acid, anthocyanins, organic acids and mineral content of some black and red currant cultivars. *Fruits* **2011**, *66*, 353–362. [CrossRef]
21. Who, J.; Consultation, F.E. Diet, nutrition and the prevention of chronic diseases. *World Health Organ. Technol. Rep. Ser.* **2003**, *916*, 1–149.
22. Cantadori, E.; Brugnoli, M.; Centola, M.; Uffredi, E.; Colonello, A.; Gullo, M. Date Fruits as Raw Material for Vinegar and Non-Alcoholic Fermented Beverages. *Foods* **2022**, *11*, 1972. [CrossRef] [PubMed]
23. Pontonio, E.; Rizzello, C.G. Editorial: Ad-Hoc Selection of Lactic Acid Bacteria for Non-conventional Food Matrices Fermentations: Agri-Food Perspectives. *Front. Microbiol.* **2021**, *12*, 681830. [CrossRef] [PubMed]
24. Randazzo, W.; Corona, O.; Guarcello, R.; Francesca, N.; Germanà, M.A.; Erten, H.; Moschetti, G.; Settanni, L. Development of new non-dairy beverages from Mediterranean fruit juices fermented with water kefir microorganisms. *Food Microbiol.* **2016**, *54*, 40–51. [CrossRef]
25. Silva, K.A.; Uekane, T.M.; de Miranda, J.F.; Ruiz, L.F.; da Motta, J.C.B.; Silva, C.B.; Pitangui, N.D.S.; Gonzalez, A.G.M.; Fernandes, F.F.; Lima, A.R. Kombucha beverage from non-conventional edible plant infusion and green tea: Characterization, toxicity, antioxidant activities and antimicrobial properties. *Biocatal. Agric. Biotechnol.* **2021**, *34*, 102032. [CrossRef]
26. Gadhoumi, H.; Gullo, M.; De Vero, L.; Martinez-Rojas, E.; Tounsi, M.S.; Hayouni, E.A. Design of a New Fermented Beverage from Medicinal Plants and Organic Sugarcane Molasses via Lactic Fermentation. *Appl. Sci.* **2021**, *11*, 6089. [CrossRef]
27. Ou, A.S.; Chang, R.C. Taiwan fruit vinegar. In *Vinegars of the World*; Solieri, L., Giudici, P., Eds.; Springer: Milano, Italy, 2009; pp. 223–242.
28. Cañete-Rodríguez, A.; Santos-Dueñas, I.; Jiménez-Hornero, J.; Ehrenreich, A.; Liebl, W.; García-García, I. Gluconic acid: Prop-erties, production methods and applications—An excellent opportunity for agro-industrial by-products and waste bio-valorization. *Process Biochem.* **2016**, *51*, 1891–1903. [CrossRef]
29. Landis, E.A.; Fogarty, E.; Edwards, J.C.; Popa, O.; Eren, A.M.; Wolfe, B.E. Microbial Diversity and Interaction Specificity in Kombucha Tea Fermentations. *Msystems* **2022**, *7*, e00157-22. [CrossRef]
30. May, A.; Narayanan, S.; Alcock, J.; Varsani, A.; Maley, C.; Aktipis, A. Kombucha: A novel model system for cooperation and conflict in a complex multi-species microbial ecosystem. *PeerJ* **2019**, *7*, e7565. [CrossRef]
31. Bishop, P.; Pitts, E.R.; Budner, D.; Thompson-Witrick, K.A. Kombucha: Biochemical and microbiological impacts on the chemical and flavor profile. *Food Chem. Adv.* **2022**, *1*, 100025. [CrossRef]
32. Chakravorty, S.; Bhattacharya, S.; Chatzinotas, A.; Chakraborty, W.; Bhattacharya, D.; Gachhui, R.; Paul, S.K. Kombucha Drink: Production, quality, and safety aspects. *Sci. Beverages* **2019**, *220*, 259–288. [CrossRef]
33. Strik, B.; Finn, C.; Clark, J.; Bañados, M.P. Worldwide Production of Blackberries. *Acta Hortic.* **2008**, *777*, 209–218. [CrossRef]
34. FAOSTAT, F. Forestry Database. Available online: https://www.fao.org/forestry/statistics/84922/en/ (accessed on 15 April 2023).

35. Siriwoharn, T.; Wrolstad, R.E.; Finn, C.E.; Pereira, C.B. Influence of Cultivar, Maturity, and Sampling on Blackberry (*Rubus* L. Hybrids) Anthocyanins, Polyphenolics, and Antioxidant Properties. *J. Agric. Food Chem.* **2004**, *52*, 8021–8030. [CrossRef]
36. Schulz, M.; Seraglio, S.K.T.; Della Betta, F.; Nehring, P.; Valese, A.C.; Daguer, H.; Gonzaga, L.V.; Costa, A.C.O.; Fett, R. Blackberry (*Rubus ulmifolius* Schott): Chemical composition, phenolic compounds and antioxidant capacity in two edible stages. *Food Res. Int.* **2019**, *122*, 627–634. [CrossRef] [PubMed]
37. Tosun, I.; Ustun, N.S.; Tekguler, B. Physical and chemical changes during ripening of blackberry fruits. *Sci. Agric.* **2008**, *65*, 87–90. [CrossRef]
38. Guedes, M.N.S.; De Abreu, C.M.P.; Maro, L.A.C.; Pio, R.; De Abreu, J.R.; De Oliveira, J.O. Chemical characterization and mineral levels in the fruits of blackberry cultivars grown in a tropical climate at an elevation. *Acta Sci. Agron.* **2013**, *35*, 191–196. [CrossRef]
39. Kafkas, E.; Koşar, M.; Türemiş, N.; Başer, K. Analysis of sugars, organic acids and vitamin C contents of blackberry genotypes from Turkey. *Food Chem.* **2005**, *97*, 732–736. [CrossRef]
40. Izadyar, A.B.; Wang, S.Y. Changes of lipid components during dormancy in 'Hull Thornless' and 'Triple Crown Thornless' blackberry cultivars. *Sci. Hortic.* **1999**, *82*, 243–254. [CrossRef]
41. Zia-Ul-Haq, M.; Riaz, M.; De Feo, V.; Jaafar, H.Z.; Moga, M. *Rubus Fruticosus* L.: Constituents, Biological Activities and Health Related Uses. *Molecules* **2014**, *19*, 10998–11029. [CrossRef] [PubMed]
42. de Souza, V.R.; Pereira, P.A.P.; da Silva, T.L.T.; De Oliveira Lima, L.C.; Pio, R.; Queiroz, F. Determination of the bioactive compounds, antioxidant activity and chemical composition of Brazilian blackberry, red raspberry, strawberry, blueberry and sweet cherry fruits. *Food Chem.* **2014**, *156*, 362–368. [CrossRef]
43. Moraes, D.P.; Lozano-Sánchez, J.; Machado, M.L.; Vizzotto, M.; Lazzaretti, M.; Leyva-Jimenez, F.J.J.; da Silveira, T.L.; Ries, E.F.; Barcia, M.T. Characterization of a new blackberry cultivar BRS Xingu: Chemical composition, phenolic compounds, and antioxidant capacity in vitro and in vivo. *Food Chem.* **2020**, *322*, 126783. [CrossRef]
44. Fan-Chiang, H.-J.; Wrolstad, R.E. Sugar and Nonvolatile Acid Composition of Blackberries. *J. AOAC Int.* **2010**, *93*, 956–965. [CrossRef]
45. Mikulic-Petkovsek, M.; Schmitzer, V.; Slatnar, A.; Stampar, F.; Veberic, R. Composition of Sugars, Organic Acids, and Total Phenolics in 25 Wild or Cultivated Berry Species. *J. Food Sci.* **2012**, *77*, C1064–C1070. [CrossRef]
46. Wang, S.Y.; Lin, H.S. Antioxidant activity in fruits and leaves of blackberry, raspberry. *J. Agric. Food Chem.* **2000**, *48*, 140–146. [CrossRef]
47. Khoo, G.M.; Clausen, M.R.; Pedersen, H.L.; Larsen, E. Bioactivity and chemical composition of blackcurrant (*Ribes nigrum*) cultivars with and without pesticide treatment. *Food Chem.* **2012**, *132*, 1214–1220. [CrossRef]
48. He, K.; Li, X.; Chen, X.; Ye, X.; Huang, J.; Jin, Y.; Li, P.; Deng, Y.; Jin, Q.; Shi, Q.; et al. Evaluation of antidiabetic potential of selected traditional Chinese medicines in STZ-induced diabetic mice. *J. Ethnopharmacol.* **2011**, *137*, 1135–1142. [CrossRef]
49. Rao, A.V.; Snyder, D.M. Raspberries and Human Health: A Review. *J. Agric. Food Chem.* **2010**, *58*, 3871–3883. [CrossRef]
50. Alibabić, V.; Skender, A.; Bajramović, M.; Šertović, E.; Bajrić, E. Evaluation of morphological, chemical, and sensory characteristicsof raspberry cultivars grown in Bosnia and Herzegovina. *Turk. J. Agric. For.* **2018**, *42*, 67–74. [CrossRef]
51. Rambaran, T.F.; Bowen-Forbes, C.S. Chemical and sensory characterisation of two *Rubus rosifolius* (red raspberry) varieties. *Int. J. Food Sci.* **2020**, *2020*, 8. [CrossRef]
52. Wang, S.Y.; Zheng, W. Preharvest application of methyl jasmonate increases fruit quality and antioxidant capacity in raspberries. *Int. J. Food Sci. Technol.* **2005**, *40*, 187–195. [CrossRef]
53. Bowen-Forbes, C.S.; Zhang, Y.; Nair, M.G. Anthocyanin content, antioxidant, anti-inflammatory and anticancer properties of blackberry and raspberry fruits. *J. Food Compos. Anal.* **2009**, *23*, 554–560. [CrossRef]
54. Bobinaite, R.; Viškelis, P.; Venskutonis, P.R. Chemical Composition of Raspberry (*Rubus* spp.) Cultivars. In *Nutritional Composition of Fruit Cultivars*; Simmonds, M.S.J., Preedy, V.R., Eds.; Academic Press: Cambridge, MA, USA, 2016; pp. 713–731. ISBN 9780124081178.
55. Lugasi, A.; Hóvári, J.; Kádár, G.; Denes, F. Phenolics in raspberry, blackberry and currant cultivars grown in Hungary. *Acta Aliment.* **2011**, *40*, 52–64. [CrossRef]
56. Krivokapić, S.; Vlaović, M.; Vratnica, B.D.; Perović, A.; Perović, S. Biowaste as a Potential Source of Bioactive Compounds—A Case Study of Raspberry Fruit Pomace. *Foods* **2021**, *10*, 706. [CrossRef]
57. Biesalski, H.-K.; Dragsted, L.O.; Elmadfa, I.; Grossklaus, R.; Müller, M.; Schrenk, D.; Walter, P.; Weber, P. Bioactive compounds: Definition and assessment of activity. *Nutrition* **2009**, *25*, 1202–1205. [CrossRef]
58. Cortez, R.E.; de Mejia, E.G. Blackcurrants (*Ribes nigrum*): A Review on Chemistry, Processing, and Health Benefits. *J. Food Sci.* **2019**, *84*, 2387–2401. [CrossRef]
59. Pinto, T.; Vilela, A.; Cosme, F. Chemical and Sensory Characteristics of Fruit Juice and Fruit Fermented Beverages and Their Consumer Acceptance. *Beverages* **2022**, *8*, 33. [CrossRef]
60. Raudsepp, P.; Kaldmäe, H.; Kikas, A.; Libek, A.-V.; Püssa, T. Nutritional quality of berries and bioactive compounds in the leaves of black currant (*Ribes nigrum* L.) cultivars evaluated in Estonia. *J. Berry Res.* **2010**, *1*, 53–59. [CrossRef]
61. Haeknel, H.; Wegner, R. Some B vitamins in different varieties of black currants. *Ernahrungsforschung* **1957**, *2*, 801–802.
62. Paunović, S.M.; Nikolić, M.; Miletić, R.; Mašković, P. Vitamin and mineral content in black currant (*Ribes nigrum* L.) fruits as affected by soil management system. *Acta Sci. Pol. Hortorum Cultus* **2017**, *16*, 135–144. [CrossRef]

63. Djordjević, B.; Šavikin, K.; Zdunić, G.; Janković, T.; Vulić, T.; Pljevljakušić, D.; Oparnica, C. Biochemical Properties of the Fresh and Frozen Black Currants and Juices. *J. Med. Food* **2013**, *16*, 73–81. [CrossRef]
64. Ersoy, N.; Kupe, M.; Gundogdu, M.; Ilhan, G.; Ercisli, S. Phytochemical and Antioxidant Diversity in Fruits of Currant (*Ribes* spp.). *Not. Bot. Horti Agrobot. Cluj-Napoca* **2018**, *46*, 381–387. [CrossRef]
65. Michalska, A.; Wojdyło, A.; Łysiak, G.P.; Figiel, A. Chemical Composition and Antioxidant Properties of Powders Obtained from Different Plum Juice Formulations. *Int. J. Mol. Sci.* **2017**, *18*, 176. [CrossRef] [PubMed]
66. Cao, L.; Park, Y.; Lee, S.; Kim, D.-O. Extraction, Identification, and Health Benefits of Anthocyanins in Blackcurrants (*Ribes nigrum* L.). *Appl. Sci.* **2021**, *11*, 1863. [CrossRef]
67. Subash, S.; Essa, M.M.; Al-Asmi, A.; Al-Adawi, S.; Vaishnav, R.; Guillemin, G.J. Effect of dietary supplementation of dates in Alzheimer's disease APPsw/2576 transgenic mice on oxidative stress and antioxidant status. *Nutr. Neurosci.* **2014**, *18*, 281–288. [CrossRef]
68. Tsuda, T. Recent Progress in Anti-Obesity and Anti-Diabetes Effect of Berries. *Antioxidants* **2016**, *5*, 13. [CrossRef]
69. 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. [CrossRef]
70. Samtiya, M.; Aluko, R.E.; Dhewa, T.; Moreno-Rojas, J. Potential Health Benefits of Plant Food-Derived Bioactive Components: An Overview. *Foods* **2021**, *10*, 839. [CrossRef]
71. Castellone, V.; Bancalari, E.; Rubert, J.; Gatti, M.; Neviani, E.; Bottari, B. Eating Fermented: Health Benefits of LAB-Fermented Foods. *Foods* **2021**, *10*, 2639. [CrossRef]
72. Rodríguez, L.G.R.; Gasga, V.M.Z.; Pescuma, M.; Van Nieuwenhove, C.; Mozzi, F.; Burgos, J.A.S. Fruits and fruit by-products as sources of bioactive compounds. Benefits and trends of lactic acid fermentation in the development of novel fruit-based functional beverages. *Food Res. Int.* **2020**, *140*, 109854. [CrossRef] [PubMed]
73. Paramithiotis, S.; Das, G.; Shin, H.-S.; Patra, J.K. Fate of Bioactive Compounds during Lactic Acid Fermentation of Fruits and Vegetables. *Foods* **2022**, *11*, 733. [CrossRef]
74. Bernal-Castro, C.A.; Díaz-Moreno, C.; Gutiérrez-Cortés, C. Inclusion of prebiotics on the viability of a commercial *Lactobacillus casei* subsp. rhamnosus culture in a tropical fruit beverage. *J. Food Sci. Technol.* **2019**, *56*, 987–994. [CrossRef]
75. Kelanne, N.M.; Siegmund, B.; Metz, T.; Yang, B.; Laaksonen, O. Comparison of volatile compounds and sensory profiles of alcoholic black currant (*Ribes nigrum*) beverages produced with Saccharomyces, Torulaspora, and Metschnikowia yeasts. *Food Chem.* **2021**, *370*, 131049. [CrossRef]
76. Aguirre, M.J.; Chen, Y.Y.; Isaacs, M.; Matsuhiro, B.; Mendoza, L.; Torres, S. Electrochemical behaviour and antioxidant capacity of anthocyanins from Chilean red wine, grape and raspberry. *Food Chem.* **2010**, *121*, 44–48. [CrossRef]
77. Duarte, W.F.; Dias, D.R.; Oliveira, J.M.; Vilanova, M.; Teixeira, J.A.; e Silva, J.B.A.; Schwan, R.F. Raspberry (*Rubus idaeus* L.) wine: Yeast selection, sensory evaluation and instrumental analysis of volatile and other compounds. *Food Res. Int.* **2010**, *43*, 2303–2314. [CrossRef]
78. Jagtap, U.B.; Bapat, V.A. Wines from fruits other than grapes: Current status and future prospectus. *Food Biosci.* **2015**, *9*, 80–96. [CrossRef]
79. Lim, J.W.; Jeong, J.T.; Shin, C.S. Component analysis and sensory evaluation of Korean black raspberry (Rubus coreanus Mique) wines. *Int. J. Food Sci. Technol.* **2012**, *47*, 918–926. [CrossRef]
80. Johnson, M.; DE Mejia, E. Comparison of Chemical Composition and Antioxidant Capacity of Commercially Available Blueberry and Blackberry Wines in Illinois. *J. Food Sci.* **2011**, *77*, C141–C148. [CrossRef]
81. Xia, T.; Zhang, B.; Duan, W.; Zhang, J.; Wang, M. Nutrients and bioactive components from vinegar: A fermented and functional food. *J. Funct. Foods* **2019**, *64*, 103681. [CrossRef]
82. Giudici, P.; De Vero, L.; Gullo, M. Vinegars. In *Acetic Acid Bacteria: Fundamentals and Food Applications*, 1st ed.; Sengun, I.Y., Ed.; CRC Press, Taylor & Francis Group: Boca Raton, FL, USA, 2017; pp. 261–287.
83. Pothimon, R.; Gullo, M.; La China, S.; Thompson, A.K.; Krusong, W. Conducting High acetic acid and temperature acetification processes by Acetobacter pasteurianus UMCC 2951. *Process Biochem.* **2020**, *98*, 41–50. [CrossRef]
84. Di Donna, L.; Bartella, L.; De Vero, L.; Gullo, M.; Giuffrè, A.M.; Zappia, C.; Capocasale, M.; Poiana, M.; D'urso, S.; Caridi, A. Vinegar production from Citrus bergamia by-products and preservation of bioactive compounds. *Eur. Food Res. Technol.* **2020**, *246*, 1981–1990. [CrossRef]
85. Hidalgo, C.; Torija, M.; Mas, A.; Mateo, E. Effect of inoculation on strawberry fermentation and acetification processes using native strains of yeast and acetic acid bacteria. *Food Microbiol.* **2013**, *34*, 88–94. [CrossRef]
86. Roda, A.; Lucini, L.; Torchio, F.; Dordoni, R.; De Faveri, D.M.; Lambri, M. Metabolite profiling and volatiles of pineapple wine and vinegar obtained from pineapple waste. *Food Chem.* **2017**, *229*, 734–742. [CrossRef]
87. Ben Hammouda, M.; Castro, R.; Durán-Guerrero, E.; Attia, H.; Azabou, S. Vinegar production via spontaneous fermentation of different prickly pear fruit matrices: Changes in chemical composition and biological activities. *J. Sci. Food Agric.* **2023**. *ahead of print*. [CrossRef]
88. Gullo, M.; Zanichelli, G.; Verzelloni, E.; Lemmetti, F.; Giudici, P. Feasible acetic acid fermentations of alcoholic and sugary substrates in combined operation mode. *Process Biochem.* **2016**, *51*, 1129–1139. [CrossRef]

89. Gullo, M.; Verzelloni, E.; Canonico, M. Aerobic submerged fermentation by acetic acid bacteria for vinegar production: Process and biotechnological aspects. *Process Biochem.* **2014**, *49*, 1571–1579. [CrossRef]
90. La China, S.; Bezzecchi, A.; Moya, F.; Petroni, G.; Di Gregorio, S.; Gullo, M. Genome sequencing and phylogenetic analysis of K1G4: A new Komagataeibacter strain producing bacterial cellulose from different carbon sources. *Biotechnol. Lett.* **2020**, *42*, 807–818. [CrossRef]
91. Barbi, S.; Taurino, C.; La China, S.; Anguluri, K.; Gullo, M.; Montorsi, M. Mechanical and structural properties of environmental green composites based on functionalized bacterial cellulose. *Cellulose* **2021**, *28*, 1431–1442. [CrossRef]
92. Da Cunha, M.A.A.; De Lima, K.P.; Santos, V.A.Q.; Heinz, O.L.; Schmidt, C.A.P. Blackberry Vinegar Produced By Successive Acetification Cycles: Production, Characterization And Bioactivity Parameters. *Braz. Arch. Biol. Technol.* **2016**, *59*, e16150136. [CrossRef]
93. Su, M.-S.; Chien, P.-J. Antioxidant activity, anthocyanins, and phenolics of rabbiteye blueberry (*Vaccinium ashei*) fluid products as affected by fermentation. *Food Chem.* **2007**, *104*, 182–187. [CrossRef]
94. Dogaru, D.V.; Hădărugă, N.; Trașcă, T.; Jianu, C.; Jianu, I. Researches regarding the antioxidant capacity of some fruits vinegar. *J. Agroaliment. Process. Technol.* **2009**, *15*, 506–510.
95. Bortolini, D.G.; Maciel, G.M.; Fernandes, I.D.A.A.; Rossetto, R.; Brugnari, T.; Ribeiro, V.R.; Haminiuk, C.W.I. Biological potential and technological applications of red fruits: An overview. *Food Chem. Adv.* **2022**, *1*, 100014. [CrossRef]
96. Udani, J.K.; Singh, B.B.; Singh, V.J.; Barrett, M.L. Effects of Açai (*Euterpe oleracea* Mart.) berry preparation on metabolic parameters in a healthy overweight population: A pilot study. *Nutr. J.* **2011**, *10*, 45. [CrossRef]
97. De Oliveira, P.R.B.; da Costa, C.A.; de Bem, G.; De Cavalho, L.C.R.M.; De Souza, M.A.V.; Neto, M.D.L.; Sousa, P.J.D.C.; De Moura, R.S.; Resende, A.C. Effects of an Extract Obtained from Fruits of Euterpe oleracea Mart. in the Components of Metabolic Syndrome Induced in C57BL/6J Mice Fed a High-fat Diet. *J. Cardiovasc. Pharmacol.* **2010**, *56*, 619–626. [CrossRef]
98. Lamas, C.; Lenquiste, S.; Baseggio, A.; Cuquetto-Leite, L.; Kido, L.; Aguiar, A.; Erbelin, M.; Collares-Buzato, C.; Maróstica, M.; Cagnon, V. Jaboticaba extract prevents prediabetes and liver steatosis in high-fat-fed aging mice. *J. Funct. Foods* **2018**, *47*, 434–446. [CrossRef]
99. Gale, A.M.; Kaur, R.; Baker, W.L. Hemodynamic and electrocardiographic effects of açaí berry in healthy volunteers: A randomized controlled trial. *Int. J. Cardiol.* **2014**, *174*, 421–423. [CrossRef]
100. Baschali, A.; Tsakalidou, E.; Kyriacou, A.; Karavasiloglou, N.; Matalas, A.-L. Traditional Low-Alcoholic and Non-alcoholic Fermented Beverages Consumed in European Countries: A Neglected Food Group. *Nutr. Res. Rev.* **2017**, *30*, 1–24. [CrossRef]
101. Li, X.; Cao, W.; Shen, Y.; Li, N.; Dong, X.-P.; Wang, K.-J.; Cheng, Y.-X. Antioxidant compounds from Rosalaevigata fruits. *Food Chem.* **2012**, *130*, 575–580. [CrossRef]
102. Kim, S.-H.; Cho, H.-K.; Shin, H.-S. Physicochemical properties and antioxidant activities of commercial vinegar drinks in Korea. *Food Sci. Biotechnol.* **2012**, *21*, 1729–1734. [CrossRef]
103. Villarreal-Soto, S.A.; Beaufort, S.; Bouajila, J.; Souchard, J.-P.; Taillandier, P. Understanding Kombucha Tea Fermentation: A Review. *J. Food Sci.* **2018**, *83*, 580–588. [CrossRef]
104. La China, S.; De Vero, L.; Anguluri, K.; Brugnoli, M.; Mamlouk, D.; Gullo, M. Kombucha Tea as a Reservoir of Cellulose Producing Bacteria: Assessing Diversity among *Komagataeibacter* Isolates. *Appl. Sci.* **2021**, *11*, 1595. [CrossRef]
105. Jayabalan, R.; Malbaša, R.V.; Lončar, E.S.; Vitas, J.S.; Sathishkumar, M. A Review on Kombucha Tea-Microbiology, Composition, Fermentation, Beneficial Effects, Toxicity, and Tea Fungus. *Compr. Rev. Food Sci. Food Saf.* **2014**, *13*, 538–550. [CrossRef]
106. Ziemlewska, A.; Zagórska-Dziok, M.; Nizioł-Łukaszewska, Z.; Kielar, P.; Mołoń, M.; Szczepanek, D.; Sowa, I.; Wójciak, M. In Vitro Evaluation of Antioxidant and Protective Potential of Kombucha-Fermented Black Berry Extracts against H_2O_2-Induced Oxidative Stress in Human Skin Cells and Yeast Model. *Int. J. Mol. Sci.* **2023**, *24*, 4388. [CrossRef]
107. Liu, Y.; Zheng, Y.; Yang, T.; Mac Regenstein, J.; Zhou, P. Functional properties and sensory characteristics of kombucha analogs prepared with alternative materials. *Trends Food Sci. Technol.* **2022**, *129*, 608–616. [CrossRef]
108. Zubaidah, E.; Apriyadi, T.E.; Kalsum, U.; Widyastuti, E.; Estiasih, T.; Srianta, I.; Blanc, P.J. In vivo evaluation of snake fruit Kombucha as hyperglycemia therapeutic agent. *Int. Food Res. J.* **2018**, *25*, 453–457.
109. Akarca, G. Determination of Potential Antimicrobial Activities of some Local Berries Fruits in Kombucha Tea Production. *Braz. Arch. Biol. Technol.* **2021**, *64*, e21210023. [CrossRef]
110. Ulusoy, A.; Tamer, C.E. Determination of suitability of black carrot (*Daucus carota* L. spp. sativus var. *atrorubens Alef.) juice concentrate, cherry laurel (Prunus laurocerasus), blackthorn (Prunus spinosa) and red raspberry (Rubus ideaus) for kombucha beverage production. J. Food Meas. Charact.* **2019**, *13*, 1524–1536. [CrossRef]
111. Barbosa, E.L.; Netto, M.C.; Junior, L.B.; de Moura, L.F.; Brasil, G.A.; Bertolazi, A.A.; de Lima, E.M.; Vasconcelos, C.M. Kombucha fermentation in blueberry (*Vaccinium myrtillus*) beverage and its in vivo gastroprotective effect: Preliminary study. *Futur. Foods* **2022**, *5*, 100129. [CrossRef]
112. Alanko, J.; Riutta, A.; Holm, P.; Mucha, I.; Vapaatalo, H.; Metsä-Ketelä, T. Modulation of arachidonic acid metabolism by phenols: Relation to their structure and antioxidant/prooxidant properties. *Free. Radic. Biol. Med.* **1998**, *26*, 193–201. [CrossRef]
113. Hornedo-Ortega, R.; Krisa, S.; García-Parrilla, M.C.; Richard, T. Effects of gluconic and alcoholic fermentation on anthocyanin composition and antioxidant activity of beverages made from strawberry. *LWT* **2016**, *69*, 382–389. [CrossRef]
114. Tu, C.; Tang, S.; Azi, F.; Hu, W.; Dong, M. Use of kombucha consortium to transform soy whey into a novel functional beverage. *J. Funct. Foods* **2018**, *52*, 81–89. [CrossRef]

115. Pure, A.E.; Pure, M.E. Antioxidant and Antibacterial Activity of Kombucha Beverages Prepared using Banana Peel, Common Nettles and Black Tea Infusions. *Appl. Food Biotechnol.* **2016**, *3*, 125–130. [CrossRef]
116. Liguori, L.; Russo, P.; Albanese, D.; Di Matteo, M. Production of Low-Alcohol Beverages: Current Status and Perspectives. In *Food Processing for Increased Quality and Consumption*; Academic Press: Cambridge, MA, USA, 2018; pp. 347–382.
117. Moushmoush, B.; Abi-Mansour, P. Alcohol and the heart: The long-term effects of alcohol on the cardiovascular system. *Arch. Intern. Med.* **1991**, *151*, 36–42. [CrossRef]
118. Brown, S.A.; Vik, P.W.; Patterson, T.L.; Grant, I.; Schuckit, M.A. Stress, vulnerability and adult alcohol relapse. *J. Stud. Alcohol* **1995**, *56*, 538–545. [CrossRef]
119. Costa, A.G.V.; Garcia-Diaz, D.F.; Jimenez, P.; Silva, P.I. Bioactive compounds and health benefits of exotic tropical red–black berries. *J. Funct. Foods* **2013**, *5*, 539–549. [CrossRef]
120. Ziemlewska, A.; Nizioł-Łukaszewska, Z.; Zagórska-Dziok, M.; Bujak, T.; Wójciak, M.; Sowa, I. Evaluation of Cosmetic and Dermatological Properties of Kombucha-Fermented Berry Leaf Extracts Considered to Be By-Products. *Molecules* **2022**, *27*, 2345. [CrossRef] [PubMed]
121. Mizzi, J.; Gaggìa, F.; Cionci, N.B.; Di Gioia, D.; Attard, E. Selection of Acetic Acid Bacterial Strains and Vinegar Production from Local Maltese Food Sources. *Front. Microbiol.* **2022**, *13*, 897825. [CrossRef] [PubMed]
122. Sokollek, S.J.; Hammes, W.P. Description of a Starter Culture Preparation for Vinegar Fermentation. *Syst. Appl. Microbiol.* **1997**, *20*, 481–491. [CrossRef]
123. Vegas, C.; González, Á.; Mateo, E.; Mas, A.; Poblet, M.; Torija, M.J. Evaluation of representativity of the acetic acid bacteria species identified by culture-dependent method during a traditional wine vinegar production. *Food Res. Int.* **2013**, *51*, 404–411. [CrossRef]