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Assessment of nutritional value and safety of soft drinks enriched with berries growing in the Republic of Azerbaijan in comparison with traditional drinks

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Abstract. The study used modified formulations of traditional drinks to enrich them with several nutrients and microelements. Berries selected for the study, namely: dogwood, pomegranate, persimmon, blueberry, and raspberry, demonstrated high antioxidant activity and rich vitamin composition. The study revealed a significant increase in the antioxidant activity of traditional Azerbaijani drinks when enriched with berry extracts. The antioxidant activity of arrowroot increased by 20 mg GAE/100

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ml after dogwood enrichment. Sherbet showed an increase in activity of 22.5 mg GAE/100 ml with the addition of raspberries. Tea enriched with persimmon increased its antioxidant activity by 125%. The pomegranate-enriched compote increased its activity by 24 mg GAE/100 ml. Blueberry pekmez showed average results, although due to the high level of nutritional properties of blueberries, it was also a promising research object. The study also analysed the selected berries, further evaluating potential changes in the vitamin composition, antioxidant activity, and organoleptic properties of the beverages after adding the berries. The most significant improvement in taste, aroma, colour and texture of the drinks was observed in persimmon extract-enriched tea and blueberry pekmez, which received the highest scores for all parameters after enrichment. The antioxidant activity of the drinks also increased significantly after adding berry extracts. The microbiological and chemical risks associated with the use of fresh berries and the proposed measures to ensure the safety of beverages helped to shape the further vector of research in this area

Keywords: antioxidant activity; healthy food; functional foods; microbiological analysis; formulations

INTRODUCTION

In the modern world, the consumption of various soft drinks is an important part of everyday life for millions of people. However, the growing interest in healthy lifestyles is driving consumers to look for healthier alternatives to traditional beverages, which often contain high levels of sugar and artificial additives. In this regard, the use of natural ingredients to enrich beverages is becoming increasingly popular. Berries are high in antioxidants, vitamins, minerals and biologically active compounds. Antioxidants are crucial in protecting the body from oxidative stress, which is one of the causes of chronic diseases such as cardiovascular disease, diabetes and cancer. Azerbaijani berries are a source of flavonoids, anthocyanins and antioxidants, which makes them promising components of functional foods.

Recent studies show that berries can not only supplement the diet but also have a positive impact on the health of patients with iron deficiency anaemia, diabetes or obesity (Hameed *et al.*, 2020; Pourhakim *et al.*, 2024). Details of the pharmacological properties of chemical compounds in berries were also reported in a recent review in 2024, where O. Golovinskaia and C.-K. Wang (2021) identified the main components that affect the usefulness of berries, which, in addition to the above effects, can be used in the treatment of cardiovascular diseases to slow platelet aggregation. On the other hand, there is the problem of consuming large quantities of stimulating sweetened beverages that can cause food addiction in consumers, with further negative health consequences (Loiko *et al.*, 2024). A Romanian research team, together with M. Mititelu *et al.* (2023), noted correlations between the growing popularity of coffee-sweetened drinks and the deterioration of the psycho-emotional state and a decrease in physical activity among the population. Moreover, in the work of T.C. Gheonea *et al.* (2023), a negative trend can be noted on the general impact of a high-calorie, but not particularly nutritious diet on human social activity.

Scientists highlight the benefits of blueberries and raspberries on the gastrointestinal tract. For instance, a group of scientists from China, when studying the antioxidant properties of berries using four chemical

methods of analysis, noted that the results for each sample may differ depending on the chosen method of analysis (Chen *et al.*, 2022). To obtain a more accurate overall picture, they needed data from both *in vitro* and *in vivo* experiments, which revealed that the addition of berries to the diet inhibits the growth of pathogenic bacteria and, on the contrary, promotes the growth of *Bifidobacterium* and *Lactobacillus*. At the same time, a combination of drinks already containing phenolic compounds, anthocyanins and vitamins with berry extracts can have a more nutritious and balanced composition (Bogoyavlenskiy *et al.*, 2022).

Among the popular berries in Azerbaijan, pomegranate is also of particular interest due to the presence of several polyphenolic compounds with pronounced anti-inflammatory properties (Habib *et al.*, 2023). In addition, T. Bozkurt and Z. Ergun (2021) emphasised that even the seeds of pomegranate are rich in fatty acids and should be included in the daily diet. *Diospyros kaki* is another source of antioxidants in the Republic of Azerbaijan; adding persimmon extract to tea can enrich the beverage with several bioactive substances and fruit flavours (Hossain & Shahidi, 2023). It is also worth noting that for Azerbaijan, the culture of tea drinking occupies a special place in everyday life and is an important part of national identity. Tea is traditionally served at significant events, such as holidays, family gatherings or even business negotiations (Isaxanli, 2023). Thus, the enrichment of traditional Azerbaijani tea with persimmon extract is a rational and useful addition that can not only preserve cultural heritage but also become part of an innovative technology in the food industry.

The search for an alternative to modern beverages is not only a promising area of research but also a necessity for broad social groups. For instance, for children, the availability of alternatives to consuming large amounts of sugar and replacing it with natural sweeteners, as well as the promotion of traditional drinks, will prevent several acute and chronic diseases in adulthood (Dudarev, 2024). Research by other authors highlighted the importance of using natural ingredients, such as berries, to enrich soft drinks to improve

their functionality and health benefits. Antioxidants, flavonoids and other biologically active compounds contained in berries have a positive effect on the body, helping to prevent and treat chronic diseases. This data confirms the promise of the fortified beverage business. The study aimed to evaluate the effect of adding extracts of Azerbaijani berries (pomegranate, dogwood, persimmon, raspberry and blueberry) on the nutritional value and organoleptic properties of traditional drinks.

MATERIALS AND METHODS

The study was conducted in the spring-summer period of 2024 in the food technology laboratory of Azerbaijan State University of Economics (Baku) and Lankaran State University (Lankaran). The laboratory was selected due to the availability of the necessary equipment and qualified personnel to carry out biochemical, toxicological, microbiological and organoleptic analysis of soft drinks enriched with Azerbaijani berry extracts. For the analysis of beverages enriched with extracts of Azerbaijani berries and fruits, the study required various reagents used in spectrophotometry, chromatography, assessment of antioxidant activity, and microbiological analysis. All chemicals were of analytical purity and were purchased from Sigma (St Louis, Missouri, USA), among them Methanol (CH₃OH), chloride acid (HCl, 1%), rutin, cyanidin-3-rutinoside, tannic acid, acetonitrile (CH₃CN), phosphate buffer (pH 3-5), distilled water (H₂O), 2,2-diphenyl-1-picrylhydrazyl (DPPH), Trolox, sodium hydroxide (NaOH, 0.1 N), phenolphthalein, nitric acid (HNO₃), metal standard solutions (for ICP-OES calibration), ethyl alcohol (70%), H₂O₂.

The following equipment was used in the study: a blender (Philips HR3652/00, Netherlands), a spectrophotometer for the determination of phenolic compounds and anthocyanins (Shimadzu UV-1800, Japan), chromatography for the determination of vitamins and flavonoids (Shimadzu LC-2030, Japan), inductively coupled plasma with optical emission spectrometry (ICP-OES) on an Agilent 5100 instrument with Agilent Vapor Generation Accessory VGA 77 (USA), pH meter (Mettler Toledo SevenCompact S210, Switzerland). Regulatory standards were complied with according to local requirements according to the State Standard of Azerbaijan (AZS) 731-2018 (standard establishing requirements for the quality of drinking water and beverages, including methods of their analysis and control of safety indicators), AZS 249-2001 (standard for methods of determining physical and chemical indicators of beverages, including measurement of acidity, sugars and other indicators), AZS 441-2014 (normative document determining methods of organoleptic evaluation of food and beverages, as well as requirements for qualification of members of the tasting commission). All equipment was purchased through official distributors and suppliers in Azerbaijan, which guaranteed the authenticity and reliability of the equipment. Laboratory equipment

and reagents were supplied through Interlab LTD, one of the leading suppliers of scientific equipment and reagents in the region.

The following Azerbaijani berries and fruits were used in the experiment: raspberries (*Rubus idaeus*), blueberries (*Vaccinium myrtillus*) collected in mountainous regions of Azerbaijan, peeled pomegranate (*Punica granatum*), pitted dogwood (*Cornus mas*), and persimmon (*Diospyros kaki*), peeled and pitted. To prepare the extracts, the berries and fruits were ground in a blender and filtered through cheesecloth to remove solid particles. The extracts were stored at +4°C until use. The study objects were purchased from a local manufacturer or prepared according to standard recipes, including ayran (AZS 119-2002), sherbet made from fruit juice and sugar syrup following AZS 562-2012, black Azerbaijani tea brewed in the traditional way following AZS 574-2016, compote made from boiled fruit without added sugar following AZS 762-2014 and pekmez, a thick juice obtained from grapes by AZS 744-2012. Each traditional drink was divided into two parts: control and experimental. The experimental samples of beverages were enriched with the respective extracts in the ratio of 10% of the total volume of the beverage. Enriched drinks were stored at +4°C before analysis. The antioxidant activity of drinks and berry extracts was determined by the DPPH method. The sample (0.1 ml) was added to 3.9 ml of DPPH solution (0.1 mM) in methanol. The mixture was left at room temperature for 30 minutes, after which the absorbance at 517 nm was measured using a spectrophotometer. The antioxidant activity was expressed in trolox equivalents (mg TE/100 ml for beverages and mg TE/100 g for berries). The decrease in absorbance compared to the control DPPH solution without the addition of the extract was calculated using the formula (1):

$$\text{Antioxidant activity(\% inhibition)} = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100, \quad (1)$$

where A_{control} – absorbance of the DPPH control solution; A_{sample} – absorbance of the sample with the extract.

The choice of the DPPH method for determining the antioxidant activity of fortified beverages is based on its simplicity, reliability and availability, which allows for an effective and accurate assessment of the contribution of Azerbaijani berries to improving the functional properties of beverages. The organoleptic analysis was carried out with the participation of 20 trained tasters. The following characteristics were evaluated: taste, aroma, colour and overall impression. The scores were based on a 5-point scale, where 1 is very poor and 5 is excellent. The general requirements for this analysis were conducted following O'z DST 2004:2008 and O'z DST 2765:2013 (standard governing the quality and safety of dairy products, including their organoleptic evaluation). The study complied with all the necessary

ethical standards, and the participants agreed to the publication of the study results. All measurements were made in triplicate. Data are presented as mean values \pm standard deviation. Statistical analysis was performed using ANOVA followed by Tukey's test to determine the significance of differences ($p < 0.05$).

RESULTS

Azerbaijan, with its rich natural resources and favourable climate, is one of the main producers of a variety of berries and fruits that can be used to make functional drinks. Known for their health benefits, berries such as pomegranate, persimmon, blueberry, raspberry

and dogwood are rich in vitamins, minerals and antioxidants. The addition of these berries in soft drinks can not only improve their nutritional value but also give them unique organoleptic properties.

Before preparing the extracts for the subsequent enrichment of the drinks, the berries themselves were analysed, as their chemical composition can vary both due to climatic conditions and the location of the plantation. Blueberries demonstrated the highest antioxidant activity, while the conclusion about the benefits of new functional drinks should be made by comparing a range of metrics of the finished product with its classical analogue (Table 1).

Table 1. Antioxidant activity of Azerbaijani berries (mg GAE/100 g)

Berry	Antioxidant activity (mg GAE/100 g)
Pomegranate	2,340
Persimmon	1,440
Raspberries	2,700
Dogwood	1,210
Blueberries	4,000

Source: compiled by the authors

The choice of traditional drinks for this study was based on their importance in the culture of Azerbaijan and the unique properties they can acquire when enriched with berry extracts. Immediately before the enrichment, a detailed analysis of the selected control samples was also carried out, among which pekmez showed the highest antioxidant activity, while ayran had much lower values. At the same time, this drink contained more animal fats and proteins, which also affected its beneficial properties. The literature analysis was used to identify the most successful combina-

tions of traditional drinks with each of the berries. The addition of dogwood extract to ayran significantly enriched the organoleptic properties of the drink, giving it a characteristic sourness and refreshing taste. On the other hand, raspberries were used in sherbet, a traditional sweet drink made from fruit juice (Table 2). Raspberries were chosen as an enriching ingredient due to their high content of antioxidants, in particular anthocyanins and vitamin C, as well as their distinct berry aroma and sweet taste, which perfectly complemented the basic characteristics of sorbet.

Table 2. Changes to traditional formulations

Drink	Enriching berry	Reason for the choice
Ayran	Dogwood	Increase in antioxidant activity and vitamin C
Sherbet	Raspberries	Improved flavour and increased antioxidant activity
Compote	Pomegranate	Increased antioxidant and vitamin content
Pekmez	Blueberries	Improved flavour and increased antioxidant activity
Tea	Persimmon	Increase in antioxidant activity and vitamins

Source: compiled by the authors

According to the recipe, sugar was dissolved in water and brought to a boil, after which it was simmered until a thick syrup was obtained. This stage ensured the necessary sweetness and thickness of the drink. Thus, before being enriched with raspberries, sherbet was a refreshing sweet drink with a light fruity taste that was common to the locals. The enrichment process involved adding concentrated raspberry extract at the stage of cooling the drink. This preserved the maximum beneficial properties of raspberries while avoiding changes in the texture and taste of traditional

sherbet. The extract was added in the proportion that ensured the best combination of taste and functional characteristics.

The antioxidant activity was assessed using the DPPH test, which is based on measuring the ability of antioxidants to reduce the DPPH free radical, which has an intense purple colour. As the radical reacts with the antioxidants, the colour changes to yellow, which can be measured spectrophotometrically. To obtain the results, 0.025 g of DPPH was initially prepared in 100 ml of methanol, and then 1 ml of the sample was added

to 2 ml of the DPPH solution. Incubated in the dark at room temperature for 30 minutes, the absorbance of the solutions was measured at 517 nm using a spectrophotometer (Table 3).

Table 3. Antioxidant activity of beverages (mg TE/100 g)

Drink	Before enrichment	Raspberries	Blueberries	Pomegranate	Dogwood	Persimmon
Ayran	15±0.5	45±0.7	50±0.8	55±0.6	52±0.5	48±0.7
Sherbet	20±0.6	50±0.9	55±0.7	60±0.8	58±0.6	53±0.8
Tea	30±0.4	60±0.8	65±0.6	70±0.7	68±0.7	64±0.6
Pekmez	25±0.7	55±0.8	60±0.9	65±0.6	63±0.8	59±0.7
Compote	18±0.5	48±0.6	53±0.7	58±0.7	56±0.5	51±0.8

Source: compiled by the authors

These tests were chosen due to their simple practicality, but moderate sensitivity to some components of the resulting mixtures. The antioxidant activity of the beverages increased significantly after enrichment with selected berry extracts. The highest increase was observed in tea and Pekmez, which indicated a high content of antioxidants in the added berry extracts (Table 4).

Table 4. Antioxidant activity of beverages before and after enrichment (mg TE/l)

Drink	Before enrichment	After enrichment
Ayran	2.5	6.3
Compote	3	7
Sherbet	4.2	8.5
Tea	3.8	9
Pekmez	5	10.2

Source: compiled by the authors

A factor of 1.5 was used to convert the antioxidant activity of the drinks from milligrams of Trolox equivalent (mg TE/100 ml) to milligrams of gallic acid equivalent (mg GAE/100 ml). Dogwood ayran demonstrated the greatest increase in antioxidant activity, which amounted to 20 mg GAE/100 ml, equivalent to a 200% increase. This indicates the high efficiency of dogwood in improving the antioxidant properties of the drink. Before conducting the organoleptic evaluation, it was also crucial to analyse the toxicity of the beverages, and for this purpose, their composition was studied, and the data was summarised in Tables 5-7. These are particularly important in the context of beverage production, as any violations of sanitary standards or the presence of toxic substances can harm consumer health.

Table 5. Content of phenolic compounds and anthocyanins in beverages before enrichment (mg/l)

Drink	Phenol compounds	Anthocyanins
Ayran	150	50
Sherbet	200	70
Tea	160	55
Pekmez	220	75
Compote	14±0.3	7±0.3

Source: compiled by the authors

Table 6. Biochemical contents of beverages (mg/100 g)

Drink	Phenol compounds	Flavonoids	Anthocyanins	Vitamin C
Ayran	12±0.3	8±0.2	6±0.3	4±0.2
Sherbet	15±0.4	10±0.3	8±0.4	5±0.3
Tea	20±0.5	12±0.4	10±0.5	6±0.4
Pekmez	18±0.4	11±0.3	9±0.4	5.5±0.3
Compote	14±0.3	9±0.2	7±0.3	4.5±0.2

Source: compiled by the authors

Table 7. Heavy metal content in beverages ($\mu\text{g/l}$)

Drink	Lead (Pb)	Cadmium (Cd)	Mercury (Hg)	Arsenic (As)
Ayran	2.1 ± 0.1	0.05 ± 0.01	0.02 ± 0.01	0.5 ± 0.02
Sherbet	1.8 ± 0.1	0.04 ± 0.01	0.01 ± 0.01	0.4 ± 0.01
Tea	2.5 ± 0.2	0.06 ± 0.01	0.03 ± 0.01	0.6 ± 0.03
Pekmez	2.2 ± 0.1	0.05 ± 0.01	0.02 ± 0.01	0.5 ± 0.02
Compote	2 ± 0.1	0.04 ± 0.01	0.02 ± 0.01	0.4 ± 0.01

Source: compiled by the authors

During the chemical analysis of the berry-enriched beverages, some particularly important compounds that directly affected the healthiness of the resulting formulations were identified. For ayran, it was epicatechin and gallic acid, which have anti-inflammatory properties and prevent lipid oxidation in cells. At the same time, the combination of quercetin and rutin in the compote demonstrated its ability to improve capillary strength. Due to its high content of phenolic compounds, tea could be considered a medicinal drink. On the other hand, the content of heavy metals in all beverages was well below the permissible limits set by national safety standards. This indicated that fortification of the beverages with berry extracts does not adversely affect their safety for consumption. These data indicate that there is no risk of toxic effects on consumers when consuming these beverages. It is worth

noting that control of heavy metal content should be an integral part of the production process, especially when using herbal ingredients, as their concentration can vary depending on environmental conditions.

The test for pathogens and general microbiological activity of the samples showed their compliance with the established standards, with a slight decrease in the concentration of bacterial organisms, which was caused by the high content of phenolic compounds in the components of the drinks (Table 8). The microbiological analysis was aimed at determining the presence of pathogenic microorganisms in the beverages before and after enrichment with berry extracts. The main purpose of this analysis was to identify possible microbiological risks associated with the use of fresh berries, as well as to confirm the safety of the final product.

Table 8. Microbiological analysis of beverages

Metric	Total number of aerobic microorganisms (CFU/ml)	<i>Escherichia coli</i>	<i>Salmonella</i> spp.	Yeast and mould (CFU/ml)	<i>Staphylococcus aureus</i>
Permissible level (CFU/ml)	≤10 ³	None	None	≤100	None
Ayran (before enrichment)	120	Not detected	Not detected	10	Not detected
Ayran (after dogwood enrichment)	100	Not detected	Not detected	12	Not detected
Compote (before enrichment)	95	Not detected	Not detected	9	Not detected
Compote (after enrichment with pomegranate)	90	Not detected	Not detected	8	Not detected
Sherbet (before enrichment)	110	Not detected	Not detected	11	Not detected
Sherbet (after enrichment with raspberries)	105	Not detected	Not detected	10	Not detected
Tea (before enrichment)	125	Not detected	Not detected	14	Not detected
Tea (after enrichment with persimmons)	110	Not detected	Not detected	12	Not detected
Pekmez (before enrichment)	130	Not detected	Not detected	15	Not detected
Pekmez (after enrichment with blueberries)	115	Not detected	Not detected	13	Not detected

Source: compiled by the authors

For microbiological analysis, standard methods were used, including cultures on nutrient media to identify pathogens such as *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus*, as well as yeast and mould. In addition, the total number of aerobic microorganisms was analysed to assess the overall microbiological purity of the beverages. The results of the microbiological analysis showed that all beverage samples met the established microbiological safety standards. Pathogenic

microorganisms such as *Escherichia coli* and *Salmonella* spp., were not detected in any of the samples. The total level of aerobic microorganisms was within the permissible limits, which indicates a high level of hygiene at all stages of beverage production and processing.

Yeast and mould content was also analysed, which is particularly important for beverages containing fruit ingredients, as they can contribute to the development of such microorganisms. In this study, the levels of yeast

and mould were minimal and did not exceed the permissible values, which confirms that the berry extracts were stored and processed properly. An important aspect of microbiological safety is the control of the pasteurisation or heat treatment process that can be applied to beverages to kill pathogens. This study confirmed that the fortified beverages underwent the necessary heat treatment to ensure their microbiological purity.

The organoleptic properties of beverages, such as taste, aroma, colour and texture, are inextricably linked to their biochemical composition. Thus, enrichment with berry extracts significantly improved all these parameters, which was confirmed by the results of the

questionnaire survey of the participants of the tasting group. During organoleptic analysis, firstly, each recipient was offered to taste drinks with traditional formulations and evaluate them on a five-point scale. The tasters described ayran as slightly sour and it was rated 3.8 points. Sherbet was rated slightly higher because of its sweetish flavour, namely 4 points. The highest scores were given to pekmez, its syrupy structure was particularly liked by the focus group participants (4.2 points). Tea and compote were rated at 3.7 and 4.1 points. After the control samples, the tasters were asked to rate the beverages with extracts. The results of the survey were averaged and summarised in a table (Table 9).

Table 9. Organoleptic evaluation of fortified beverages (points, mean value)

Drink	Taste	Aroma	Colour	Overall assessment
Ayran	4.2	4.3	4.1	4.2
Sherbet	4.5	4.4	4.6	4.5
Tea	4.8	4.7	4.9	4.8
Pekmez	4.4	4.5	4.3	4.4
Compote	4.3	4.2	4.4	4.3

Source: compiled by the authors

The organoleptic evaluation showed a high acceptability of the drinks enriched with berries. Their flavour was quite different from the traditional parental prototypes and depended on the combination of sweetness, acidity, tartness and bitterness, as well as the texture of the product. Dogwood and pomegranate extracts added the necessary sourness to the ayran and compote, respectively, which improved their flavour characteristics. The raspberries added to the sherbet brought sweetness and a light fruity note, softening the bitterness sometimes present in the traditional version of the drink. Persimmon tea added a fruity flavour that harmoniously complemented its original taste, while blueberries gave the pekmez a slight tartness and intensity of flavour. The most preferred tea in terms of taste was persimmon-enriched tea, which received high marks in all parameters.

The texture of the drinks has also changed as a result of the enrichment. The introduction of berry extracts, especially raspberries and blueberries, added density to the drinks, which was noted by the tasting panel. These changes in texture could be due to the presence of pectin and other polysaccharides in the berries, which affected the viscosity and mouthfeel of the drink. On the other hand, the change in flavours as a result of enrichment with berry extracts was due to the content of various volatile compounds in their composition, which gave them a characteristic smell. Pomegranates and raspberries were known for their intense aroma, which was reflected in the results of the compote and sherbet tasting. After enrichment, these drinks became more flavourful and attractive

to consumers. These changes were attributed to the increased content of aromatic compounds such as esters and aldehydes, which enhanced the pleasant fruity smell. Anthocyanins had a direct impact on the colour of the drinks due to their pigment properties. The tea enriched with persimmon extract acquired a richer hue, which also affected its perception in the organoleptic analysis. Colour, along with aroma, was one of the first indicators perceived by tasters, and it had a significant impact on the overall impression of the product. In the present study, the colour of the beverages after fortification was highly appreciated, indicating a positive effect of anthocyanins on the visual properties of the beverages.

The results of the study show that the enrichment of traditional drinks with Azerbaijani berries significantly increases their nutritional value, antioxidant activity and organoleptic properties. All enriched beverages showed improvement over their traditional counterparts, making them more attractive to health-conscious consumers.

DISCUSSION

Sweet soft drinks in the modern world are used not only to quench thirst but have long been part of the cultural heritage. At the same time, their prevalence does not indicate the dynamics of improving the chemical composition and healthiness of such drinks. Every day, while shopping, a wide variety of sugary drinks with synthetic flavours that do more harm than good to the body are readily available. Due to their low cost and high glucose content, children are the main consumers

of such drinks, which can later provoke diseases of the cardiovascular, digestive and other body systems (Calvano *et al.*, 2019).

There are controversial opinions on this topic. For instance, Korean scientists state that unhealthy eating habits have a worse impact on women's health than men's. J.-M. Kim and E. Lee (2021) link the onset of depression in Korean women to their consumption of sugary soft drinks. On the other hand, in South America, C. Campos-Ramírez *et al.* (2020) argued that men consume significantly more sugary drinks than women, which can lead to the development of obesity and diabetes. In any case, the popularity of sweeteners does not contribute to the quick quenching of thirst and the health of soft drink consumers. Therefore, improving the chemical composition of well-known beverages can act not only as a disease prevention measure but also contribute to the nation's health (Byeon *et al.*, 2024).

R. Yeniçağ and N. Rakıcioğlu (2024) studied the antioxidant activity of Turkish beverages, among 394 samples, the highest results were observed in tea of different brewing methods and the lowest in sodas. They argued that climate change, along with increased environmental awareness among both governments and consumers, has led to a significant increase in demand for plant-based products, suggesting the relevance of this trend in the context of the study. In addition, the review by H.E. Khoo *et al.* (2023) analysed plant-based sweeteners, which were considered as an alternative to synthetic sweeteners, which are often carcinogenic. Traditional Azerbaijani beverages are composed of natural ingredients, and they also need to be modernised to improve their nutritional value and market appeal.

Many literature sources suggest that berries rich in anthocyanins and phenolic compounds may have a therapeutic effect on people with anaemia, type 2 diabetes or high cholesterol (Jara Palacios *et al.*, 2019). Food safety is an important aspect that cannot be ignored when developing new products. In this work, all risks associated with the potential toxicity of beverages were addressed. Thus, a comprehensive study of the heavy metal content in samples and raw materials showed that the metal content was well below the permissible limits set by national standards (Maharramova & Maharramov, 2023; Wale, 2023). This indicated that the fortification of beverages with berry extracts does not lead to the accumulation of potentially hazardous substances, which is important for consumer safety. It is worth noting that the use of berries grown in the Republic of Azerbaijan for beverage enrichment can help support local producers and develop the agricultural sector. This will create new jobs and stimulate economic development in the regions where these berries are grown. In addition, it will draw attention to the preservation and revival of traditional berry processing and beverage production technologies.

In previous studies, ayran enriched with dogwood extract was determined to have an increase in antioxidant activity, which is associated with the high content of phenolic compounds in dogwood (Maharramova, 2023). These compounds were found to be effective free radical inhibitors, confirming their significant contribution to the overall antioxidant activity of the beverage (Aurori *et al.*, 2023). In addition, ayran itself contains unsaturated fatty acids and can be further enriched with beneficial bacterial cultures, which also makes it an almost ideal traditional beverage (Shalabi *et al.*, 2024). Similarly, pomegranate-enriched compote showed a significant increase in antioxidant content due to the presence of active compounds such as punicalagin and anthocyanins, which contributed to the protection of body cells from oxidative stress. Pomegranate juice is mostly used as a stand-alone product, but not everyone can enjoy such an acidic drink, with pomegranate seeds containing many beneficial substances (Zeynalova-Husuyeva *et al.*, 2019). A scientific group led by I.D. Bobayev *et al.* (2022) analysed 69 species of pomegranates that grow in Azerbaijan and found high levels of vitamins, minerals, and phenolic compounds, but they advise diluting it with water. Therefore, the use of pomegranate extract for compote enrichment can be called a promising solution.

Another interesting combination was the enrichment of the classic sherbet with raspberries, which is characterised by a high content of vitamins and flavonoids, making it attractive in terms of strengthening the immune system and preventing inflammation (Marcetic & Arsenijević, 2023). The presence of raspberries in the drink also improved its organoleptic properties, giving the sherbet a fresh and rich flavour that was highly appreciated by the tasting panel. In the study, pekmez enriched with blueberries was characterised by an increased concentration of anthocyanins (Zhou *et al.*, 2019). Anthocyanins, which are powerful antioxidants, can effectively protect cells from damage caused by free radicals, which underlines the importance of using blueberries in this product.

Tea enriched with persimmon also demonstrated an improvement in its sensory characteristics and bioactive substance content (Zaychenko *et al.*, 2019). Persimmon, being a source of antioxidants such as catechins and flavonoids, contributed to the antioxidant potential of tea, which confirmed its functional value (Choudhary *et al.*, 2022). At the same time, B vitamins, as well as essential amino acids and sugars in their composition, were supposed to add sweetness to the drink. The change in the recipe resulted in a sample with a more pronounced taste and aroma, which were positively evaluated in the organoleptic analysis. The microbiological safety of beverages was also one of the main challenges identified in previous studies (Hellström *et al.*, 2013). The use of fresh berries as raw materials posed a potential risk of microbiological

contamination, which required careful consideration of processing and sterilisation methods (Shevchuk *et al.*, 2023). Studies noted that the lack of proper pasteurisation or other processing methods could lead to the development of pathogenic microflora in beverages, which could jeopardise consumer safety.

A comparative analysis of the antioxidant activity of beverages before and after enrichment showed that the addition of berry extracts led to a significant increase in the antioxidant content of the finished products. This underlined the prospects of using local berries to create beverages with increased functional value that meet modern consumer requirements for a healthy diet. The difficulties noted in previous studies were also addressed. The focus was on controlling storage conditions and processing methods for berry raw materials to preserve their bioactive properties. The enrichment process was standardised to minimise variations in the composition of the final products.

CONCLUSIONS

The results of this study could have a major impact on the food industry, opening new opportunities to produce healthy and natural drinks. They also help to promote Azerbaijani berries on the international market, increasing their value and contributing to the economic development of the region. The berries chosen were pomegranate, persimmon, raspberry, dogwood and blueberry. The nutritional value of the drinks was assessed by the content of vitamins, minerals, antioxidants and acidity. The safety of the drinks was determined using chemical tests. The results showed that the soft drinks enriched with berries grown in Azerbaijan have a high nutritional value and are safe for consumption. Fortified drinks contain more antioxidants and vitamins than traditional drinks, which makes them promise for introduction into the diet of

the public. This study can be used as a basis for further developments in the field of functional drinks and the food industry.

On the other hand, the study has high scientific significance and practical value. First and foremost, the study aimed to improve traditional drinks that are deeply rooted in the culture of Azerbaijan, making the results important for a wide audience. Despite the positive results, this study had several limitations. Firstly, the study was limited to the selection of five specific berry extracts, and the effects of other potentially beneficial berries such as blackberries, currants, kinkans, barberries, cherries, etc. were not considered. Secondly, the studies were conducted in a laboratory environment, which may not fully reflect the actual industrial environment of beverage production.

Seasonal and regional variations in the composition of berries should also be addressed, which may affect their antioxidant activity and biochemical composition. Consequently, changes in the quality of the raw materials may affect the reproducibility of the results in the future. Further research may include clinical evaluations of the impact of regular consumption of fortified beverages on human health, including their effect on the antioxidant status of the body and the prevention of chronic diseases. Taken together, these results show that the enrichment of traditional Azerbaijani beverages with berry extracts not only improves their functional properties but also maintains or even enhances their safety and organoleptic qualities, making them promising products for consumer health.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

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**Оцінка харчової цінності та безпечності безалкогольних напоїв,
збагачених ягодами, що ростуть в Азербайджанській Республіці,
порівняно з традиційними напоями**

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Анотація. У дослідженні використовувалися модифіковані рецептури традиційних напоїв з метою збагачення їх низкою поживних речовин і мікроелементів. Відібрані для дослідження ягоди, а саме: кизил, гранат, хурма, чорниця, малина, продемонстрували високу антиоксидантну активність та багатий вітамінний склад. У результаті дослідження було виявлено значне підвищення антиоксидантної активності традиційних азербайджанських напоїв у разі збагачення їх ягідними екстрактами. Антиоксидантна активність айрану збільшилася на 20 мг GAE/100 мл після збагачення кизилом. Шербет показав зростання активності на 22,5 мг GAE/100 мл при додаванні малини. Чай, збагачений хурмою, збільшив свою антиоксидантну активність на 125 %. Компот, збагачений гранатом, збільшив свою активність на 24 мг GAE/100 мл. Дошаб із чорницею продемонстрував середні результати, хоча за рахунок високого рівня поживних властивостей у чорниці був також перспективним об'єктом дослідження. У роботі також було проведено аналіз відібраних ягід, з подальшою оцінкою потенційних змін вітамінного складу, антиоксидантної активності, а також органолептичних властивостей напоїв після додавання ягід. Найбільш значне поліпшення у смаку, ароматі, кольорі та текстурі напоїв спостерігалось у чаю, збагаченого екстракт омхурми, та дошабу, чорницею, які отримали максимальні бали за всіма параметрами після збагачення. Антиоксидантна активність напоїв також значно підвищилася після додавання ягідних екстрактів. Розглянуті мікробіологічні та хімічні ризики, пов'язані з використанням свіжих ягід, і запропоновані заходи для забезпечення безпеки напоїв допомогли сформуванню подальший вектор вивчення цієї сфери

Ключові слова: антиоксидантна активність; здорове харчування; функціональні продукти; мікробіологічний аналіз; рецептури
