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EVALUATION OF PHYSICO-CHEMICAL PROPERTIES AND BIOACTIVITY OF DERIVATIVES OF BLACK CHOKEBERRY PRODUCTS OBTAINED DURING OSMOTIC DEHYDRATION

The object of the study was black chokeberry derivatives, namely syrup and powder obtained by osmotic dehydration. The problem solved in the study is the lack of a comprehensive definition of the physicochemical properties and bioactivity of Aronia melanocarpa derivatives obtained by osmotic dehydration. The described problem limits the effective use of black chokeberry syrup and powder in the production of food products with increased biological value. During the study, an assessment of the complex of physicochemical characteristics (acidity, moisture, dry matter content) of black chokeberry derivatives obtained by osmotic dehydration was carried out. The content of bioactive compounds, such as anthocyanins, flavonoids, polyphenolic and hydroxycinnamic acids, was studied. As a result of the studies, it was found that they contain a high level of anthocyanins, flavonoids, polyphenolic compounds and tannins. The moisture content of the raw material was 7.6 ± 0.5%, and soluble solids – 58.9 ± 0.2%. In addition, a significant concentration of coloring substances (10.07 ± 0.05 g/dm^3 *in syrup and 82.7 ± 0.05 g/kg in powder) and bioactive components was found, which determines the high antioxidant activity of the product. The results obtained are explained by the high natural bioactivity of black chokeberry in combination with the use of the osmotic dehydration process for its processing. The results obtained during the study allowed us to assess the potential of using osmotic dehydration for black chokeberry processing. In practice, the results of the study can be used to develop new technologies for processing and storing black chokeberry-based products, in particular for the production of natural dyes and additives to functional foods or beverages. Such additives can be used in the food industry to create products with increased antioxidant properties, as well as to improve taste and preserve the beneficial properties of the product during storage.*

Keywords: *black chokeberry, osmotic dehydration, syrup, powder, derivatives, biologically active substances, antioxidant properties.*

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1. Introduction

Among the promising ingredients for the creation of such products, a special place is occupied by black chokeberry (*Aronia melanocarpa*).

Black chokeberry is a wild plant raw material native to North America. It has been proven that the chemical composition of black chokeberry varies depending on the place of cultivation and processing methods. Previous studies have shown that black chokeberry fruits contain a significant amount of phenolic compounds, which provide significant antioxidant activity [1].

Black chokeberry fruits of all varieties are a valuable raw material for the food and pharmaceutical industries due to the high concentration of biologically active compounds, in particular anthocyanins, flavonoids, polyphenols and organic acids. Studies confirm its antioxidant, anti-inflammatory, immunomodulatory, antimicrobial and antidiabetic properties [2]. In addition, they contain tannins (0.3%) and organic acids (1.9–3.9%), including malic, tartaric, citric, succinic, oxalic and sorbic [3].

Studies have shown that benzaldehyde present in black chokeberry fruits can have a positive effect on cardiovascular diseases, eye inflammation, urinary tract infections, diabetes and various viral diseases [4]. In addition, black chokeberry extracts demonstrate strong geroprotective properties. They extend lifespan, have antiproliferative activity, and improve glucose and lipid metabolism due to their high content of polyphenols and anthocyanins [5]. It has also been proven that the leaves and berries have a more powerful antioxidant activity compared to the stems [6]. Phenolic acids, flavonoids and proanthocyanidins have been found in rowan berries, the content of which varies depending on the type of rowan [7]. However, during processing, the biological value changes under the influence of various technological factors.

Analysis of the sensory properties and phenolic composition of black chokeberry juice showed that its unique taste, caused by volatile esters, and astringent taste are due to the presence of flavanols [8].

It was found that the addition of sucrose and freezing for 3 months leads to a decrease in the content of polyphenols [9]. At the same time, the level of anthocyanins increases, while the antioxidant activity changes unevenly.

Thus, the choice of the method of processing rowan berries plays an important role in the further use of the resulting derivatives.

A study of black chokeberry (*Aronia melanocarpa*) juice showed that fermentation with a novel strain of Lactiplantibacillus plantarum

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resulted in a decrease in pH, an increase in lactic acid content, and an increase in antioxidant activity [10]. Meanwhile, enrichment of apple juice with black chokeberry not only increased anthocyanin content but also improved antioxidant activity and color characteristics of the beverage [11]. In addition, the use of black chokeberry pomace powders as natural colorants in food products provides high stability of anthocyanins over 28 days of storage, making them an attractive choice for products with a long shelf life [12]. At the same time, replacing more than 10% of traditional flour with black chokeberry pomace flour leads to a decrease in product quality, especially for gluten-containing products. However, up to 10% flour replacement was acceptable to consumers, which opens up opportunities for the use of plant-based products in the context of sustainable development [13].

However, it is only in recent decades, after clinical studies confirmed the beneficial properties of black chokeberry, that it began to gain popularity. Now this crop is actively used in the production of nectars, syrups, jams, fruit desserts, jellies, wines and liqueurs [14, 15]. In addition, black chokeberry is actively used as a natural colorant in the production of sugar confectionery, replacing synthetic dyes that can cause allergic reactions [16].

Considerable attention has been paid to the use of black chokeberry in the meat industry. The addition of an extract of this berry effectively inhibited the formation of malondialdehyde (MDA), which reduces the level of lipid peroxidation, without adversely affecting the pH, color and texture of the products [17].

Black chokeberry has also shown potential in improving the quality of fermented beverages. A study of the effect of its addition on the physicochemical and organoleptic properties of makkoli (traditional Korean rice wine) showed a decrease in pH, an increase in acidity, alcohol content and amino acids [18]. Enrichment of fermented milk beverages, such as yogurt, with black chokeberry had a positive effect on the content of phenolic compounds, changed the physicochemical and textural characteristics, making yogurt more attractive to consumers [19]. In addition, fermented black chokeberry juice added to yogurt increased antioxidant activity and preserved probiotic properties [20]. Studies have also shown that the bioavailability of black chokeberry polyphenols depends on the food matrix. For example, anthocyanins were better preserved in dairy yogurts than in plant-based yogurts, where their degradation occurred faster, which affected antioxidant activity [21].

It has been established that the processing methods of rowan berries have a significant impact on the physicochemical properties of the derived products. An important aspect is the thermodynamic and kinetic parameters of the copigmentation between the anthocyanins of rowan berries and chlorogenic acid. It has been found that at high temperatures the copigmentation complex is destroyed, and at low temperatures it is restored [22].

Other methods, such as ultrasonic maceration and extrusion, have demonstrated a positive effect. Ultrasonic maceration improves the extraction of polyphenols and antioxidant activity [23], and extrusion improves the texture and functionality of the powders, while maintaining their antioxidant properties [24]. Also, the application of treatments for rowan berries juice ensures microbiological safety and preserves its physicochemical properties during long-term storage, which is important for ensuring high product quality [25].

Despite the significant potential of black chokeberry as a raw material for the production of food products, it is practically not used to improve their functional properties. This is due to the fact that during processing changes in the chemical composition occur [8, 26].

Osmotic dehydration is increasingly attracting attention as a processing method that allows preserving the biological value of the processed products [27]. The content of phenolic compounds in osmotic solutions obtained during osmotic dehydration of black chokeberry fruits was studied. It was shown that the addition of a rowan osmotic solution to beer in an amount of 6–10% leads to an increase in its antioxidant activity by 9–16 mmol Trolox/100 g [28].

A review of the scientific literature indicates a significant number of studies devoted to the chemical composition of black chokeberry and its biological activity. However, there are still no studies on the chemical composition of derived products formed during osmotic dehydration. Important characteristics such as active acidity (pH), content of organic acids, soluble solids, mass concentration of coloring substances, etc. have not been sufficiently studied. In particular, data on the content of anthocyanins are not sufficiently systematized. The lack of a comprehensive approach to assessing these indicators complicates the justification of technological processes for processing raw materials and ensuring stable quality of final products.

The aim of research is to determine the physicochemical properties of processed products formed as a result of osmotic dehydration of black chokeberry fruits. This will allow the development of new technologies for the production of natural food products and expand the range of food products, increase their biological value and improve consumer properties.

To achieve the aim, the following objectives were solved:

– to determine the pH of the syrup and the content of organic acids in rowan berries by-products to assess the impact of the osmotic dehydration process on the acid-base balance and taste characteristics of the product;

– to determine the content of biologically active substances in rowan berries by-products in order to assess their functional value;

– to establish the content of dry matter and moisture in rowan berries by-products to predict stability and possibilities of their further use in the production of food products.

2. Materials and Methods

2.1. The object and hypothesis of research

The object of research was derived products of black chokeberry, namely syrup and powder, obtained by osmotic dehydration. The main working hypothesis of research is that due to the process of osmotic dehydration, derived products with high biological value are formed from rowan fruits. They retain active components and have increased stability during storage. The obtained derived products can be used as functional ingredients in the production of food products, in particular natural supplements, jelly and confectionery products, various soft and alcoholic beverages.

2.2. Materials

The processing of black chokeberry fruits was carried out by osmotic dehydration according to previous experimental studies using the specified parameters for the processing of fruits and berries [27, 28]. Osmotic dehydration was carried out in an osmotic dehydrator [29]. The prepared black chokeberry berries were placed in the working chamber of the unit together with a concentrated (70%) sugar solution in a ratio of 1:1. The osmotic dehydration process was carried out for one hour at a temperature of 50°C.

As a result, syrup and partially dehydrated black chokeberry fruits were obtained. Partially dehydrated fruits after osmotic dehydration were separated from the syrup and dried in an IR dryer WetAir WFD-K700BSS (China). Drying was carried out at a temperature of 50°C for 6 hours. The dryer power was 1.8 kW.

After drying, the fruits were ground to a given dispersion using a laboratory disk mill LZM-1 operating at a shaft rotation speed of 1047 rad/s. Grinding was carried out until the material completely passed through a brass sieve with a mesh size of 0.2 mm.

2.3. Determination of acidity of black chokeberry derivatives

The determination of active acidity (pH) of the syrup was carried out using a pH meter "pH-150MI" (Ukraine), previously calibrated with buffer solutions with pH 4.00 and 7.00 at a temperature of (20 ± 2)°C. Active acidity was determined according to DSTU 6045:2008 "Fruits, vegetables and processed products, canned meat and meat-vegetables. Method for determining pH". All determinations were carried out in triplicate.

The determination of titrated acidity was carried out by titration method according to DSTU 4957:2008 "Products of processed fruits and vegetables. Methods for determining titrated acidity". Samples of syrup and powder (having previously made an extract from it) were titrated with a 0.1-normal solution of sodium hydroxide (NaOH) in the presence of phenolphthalein as an indicator. The results obtained were converted into the mass fraction of the corresponding organic acids (malic, citric, tartaric, acetic, oxalic, and lactic) that are naturally contained in black chokeberry fruits.

2.4. Determination of the content of biologically active substances

The mass concentration of coloring substances was determined according to DSTU 3845-99 "Natural food dyes. Technical conditions" using a photocolorimeter KFK-2 (Ukraine) at a wavelength of 520 nm. During sample preparation, the syrup was diluted with distilled water in a ratio of 1:10, for powder – 1 g of the powder sample was extracted in 25 ml of 70% ethanol at 40°C for 30 min with periodic shaking. The content was calculated using a calibration curve based on cyanidin-3-O-glucoside, with a graduated range of 0–100 mg/dm^3. The calibration curves had high linearity ($R^2 \geq 0.999$). The curve was constructed by measuring the optical density of samples of different concentrations. The results were expressed in g/kg (for powder) or g/dm^3 (for syrup).

To determine anthocyanins, the syrup was diluted with distilled water in a ratio of 1:10 with subsequent filtration, for powder, 1 g of the sample was extracted in 25 ml of 0.1 M HCl (pH 1) at room temperature, and allowed to stand for 30 min.

The anthocyanin content was determined using V1000(721N) spectrophotometer (China) with a wavelength range of 340–1020 nm. The method is specified in the monograph of the State Federal University of Agriculture "Blueberries, Fresh Fruits" 2014. For quantitative determination, a calibration curve based on a standard solution of cyanidin-3-O-glucoside was used. The anthocyanin content was determined taking into account the molar absorption coefficient. The determination was performed at $\lambda = 540$ nm. The ratio of absorption in the medium pH 1 and pH 4.5 allowed to adjust the influence of other flavonoids.

Hydroxycinnamic acids were determined by a modified method by spectrophotometric analysis on a V1000(721N) spectrophotometer (China) based on chlorogenic acid. The method is specified in the TFS (42U-6/37-232-96) "Canadian ginseng herb". Sample preparation was carried out similarly to the determination of anthocyanins. The calibration curve was constructed using chlorogenic acid as a standard in the range of 5–50 μg/ml. The absorption was measured at $\lambda = 324$ nm.

The content of flavonoid glycosides was determined on V1000(721N) spectrophotometer (China) with the maximum absorption recorded at 415 nm. The samples were prepared in the same way as for anthocyanins, but 0.5 ml of 2% $AlCl_3$ in 96% ethanol was added to the extract. Calibration was performed on the basis of rutin according to the monograph of the State Federal University "Blueberries, fresh fruits" 2014.

The determination of the total content of polyphenolic compounds was performed using the Folin-Chocalteau method. The extracts were reacted with the Folin-Chocalteau reagent and sodium carbonate solution, kept for 60 min at room temperature. The optical density was recorded on V1000(721N) spectrophotometer (China) at $\lambda = 765$ nm. The construction of the calibration curve was performed using gallic acid standards.

2.5. Determination of tannins

The content of tannins in samples of syrup and powder from black chokeberry was determined using V1000(721N) spectrophotometer (China) according to the GOST 24027.2-80 method. To conduct the study, 5 ml of syrup was diluted with distilled water to a volume of 25 ml; 0.5 g of powder was extracted in 50 ml of hot distilled water, cooled and filtered using laboratory filter paper of the "White Ribbon" type, with a density of 80–100 g/m^2, a pore size of 8–10 μm. The difference in optical density between the total content of phenolic compounds and non-tannin phenolic compounds was converted to the content of tannins according to a calibration graph constructed on the basis of a standard tannin solution. The results were expressed as a percentage of the mass (for powder) or volume (for syrup) of the sample. To determine non-tannins, the sample was treated with a gelatin solution, filtered, and after 30 minutes the optical density was measured at a wavelength of 760 nm using a spectrophotometer.

2.6. Determination of the content of soluble solids in syrup and moisture content in powder from black chokeberry fruits

The content of soluble solids (SSD) in syrup was determined by the refractometric method. The syrup samples were pre-filtered using laboratory filter paper of the "White Ribbon" type, with a density of 80–100 g/m^2, a pore size of 8–10 μm. The filter paper was used to remove undissolved impurities and was thoroughly mixed until homogeneous. The measurements were performed using a digital refractometer Hanna HI 96801 (0–85% Brix) (Italy), calibrated at a temperature of 20 ± 2°C. Several drops of the test sample were applied to the measuring prism of the refractometer. After stabilization of the indicator, the result was read, which was expressed in percent of the mass concentration of soluble substances (Brix). If the sample temperature differed from the standard, temperature correction was performed according to the appropriate correction scale given in the standard. Three parallel measurements were performed for each sample.

To determine the moisture content of black chokeberry powder, the standard method of drying in a drying oven at a temperature of 105°C was used.

Determination of dry matter content and moisture content was carried out in accordance with DSTU 7804:2015 "Products of fruit and vegetable processing. Methods for determining dry matter or moisture".

2.7. Statistical analysis

The processing of the obtained experimental data was carried out using generally accepted methods of mathematical statistics, using the Microsoft Excel 2016 program. To determine the reliability of the difference between the mean values, the Student's t-test was used, taking into account three levels of statistical significance: $p < 0.05$, $p < 0.01$ and $p < 0.001$.

The results are presented in tables as the mean ± standard deviation.

3. Results and Discussion

3.1. Study of active and titrated acidity of black chokeberry derivatives

The results of the study showed that the syrup after dehydration of black chokeberry has a weakly acidic environment, since the average pH value was 5.2 ± 0.1. This indicator is characteristic of most natural fruit syrups that do not contain a significant amount of added acids. The acidity at the level of 5.2 contributes to the preservation of a mild, balanced taste of the syrup without excessive acidity. Compared with similar studies [30, 31], the pH value for black chokeberry syrups usually varies within 4.8–5.4, which indicates that the results obtained correspond to typical values for this type of product.

Despite this, anthocyanins, which are the main colorants in black chokeberry, are most stable in an acidic environment. A pH value close to neutral can lead to their gradual degradation during storage. In turn, the pH value can also vary depending on the degree of fruit ripening, processing conditions and the content of organic acids, in particular malic and citric, inherent in black chokeberry [32].

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The results of the study of the content of organic acids in black chokeberry derivatives (syrup and powder) are given in Table 1.

Table 1

Organic acid content in black chokeberry derivatives

Acid name	Syrup (%)	Powder (%)
Malic	0.302 ± 0.02	0.268 ± 0.02
Citric	0.315 ± 0.02	0.280 ± 0.02
Tartaric	0.338 ± 0.02	0.304 ± 0.02
Acetic	0.272 ± 0.02	0.240 ± 0.02
Oxalic	0.203 ± 0.02	0.180 ± 0.02
Lactic	0.405 ± 0.02	0.360 ± 0.02

During the study, it was found that the content of titrated acids in both syrup and powder from black chokeberry fruits varies significantly depending on the type of acid. Previous studies indicate that black chokeberry juice contains up to 10 organic acids [7, 33].

According to the results of this study, it is possible to see that the highest values of the mass fraction of titrated acidity were recorded for lactic acid – 0.405% in syrup and 0.360% in powder. Malic and citric acids, which are natural acids of fruits, also demonstrated significant concentrations. Their content was also higher in syrup than in powder. The indicators of acetic and oxalic acids are insignificant, but in comparison they are also higher in syrup. The results obtained indicate the presence of weak fermentation processes during osmotic dehydration and the preservation of part of the acids from the primary raw materials. The difference in the amount of acids in the syrup and powder is explained by the fact that these acids actively pass from the fruits into the solution during osmotic dehydration [34].

In general, the results showed that the syrup has a more saturated acid profile compared to the powder. The obtained data open up opportunities for differentiated use of products: the osmotic solution as a food ingredient with pronounced organoleptic properties, and the powder as a functional additive with a reduced acid content.

3.2. Research on the content of biologically active substances in black chokeberry derivatives

The content of coloring substances, anthocyanins, hydroxycinnamic acids, flavonoid glycosides, polyphenolic compounds and tannins in the syrup and powder of black chokeberry was determined. The results of research on the content of biologically active substances in the derivatives of black chokeberry processing are given in Table 2.

Table 2

Results of the study of the content of biologically active substances

Name of indicators	Syrup	Powder
Mass concentration of coloring substances, g/kg, g/dm^3	10.07 ± 0.05	82.7 ± 0.05
Anthocyanin content in terms of cyanidin-3-O-glycoside, %	0.02 ± 0.002	0.13 ± 0.02
Hydroxycinnamic acid content in raw materials, %	0.05 ± 0.002	1.86 ± 0.05
Flavonoid glycoside content in raw materials in terms of rutin, %	0.7 ± 0.02	3.07 ± 0.05
Polyphenolic compounds content in raw materials in terms of gallic acid, %	0.13 ± 0.02	0.51 ± 0.02
Tannin content in raw materials in terms of tannins, %	0.11 ± 0.02	6.74 ± 0.20

The results obtained indicate that the powder from black chokeberry fruits has a significantly higher concentration of biologically active substances than the syrup. It is especially worth noting the content of flavonoid glycosides in terms of rutin, which in the powder is 3.07%, while in the syrup – only 0.7%. These compounds have antioxidant and capillary-strengthening properties, which makes black chokeberry powder a promising ingredient for use in the technology of preparing functional products or as an additive to fortified foods.

Coloring substances in the powder accumulate in an amount of 82.7 g/kg, which is 8 times more than in the syrup. A similar trend is observed for anthocyanins, flavonoids, hydroxycinnamic acids and total polyphenol content. Such high polyphenol profile indicators are confirmed by the data of many scientists [7, 19, 23], who note that black chokeberry fruits are among the leaders in terms of the content of biologically active substances among berries.

The content of tannins in the syrup was 0.11 ± 0.02%, which is an expectedly low figure, given that a significant part of phenolic compounds precipitates during the filtration process during syrup production. The content of tannins in the powder reaches 6.74 ± 0.20%, which corresponds to the high level of concentrated polyphenols, including catechins, ellagic and gallic acids, characteristic of Aronia melanocarpa.

3.3. Research on the physicochemical parameters of the products derived from the processing of black chokeberry

The content of soluble solids in the syrup and the moisture content in the powder after osmotic dehydration of black chokeberry fruits were investigated. The results obtained are given in Table 3.

Table 3

Physico-chemical parameters of derived products

Indicator	Value
Soluble solids content in syrup, %	58.9 ± 0.2
Moisture content in powder, %	7.6 ± 0.5

Fresh black chokeberry fruits usually contain about 80–85% moisture and 15–20% dry matter [35, 36]. The obtained result – 58.9 ± 0.2% soluble dry matter in the syrup after osmotic dehydration – indicates a significant removal of water from the fruits during the process and concentration of biologically active compounds.

Scientists note that the concentration of the syrup increases significantly due to the use of hypertonic solutions, which improves their biological activity [9]. It is also noted that the use of osmotic treatment as a preliminary stage before drying contributes to the preservation of bioactive substances, in particular phenolic compounds and antioxidants [34, 37]. Studies by scientists [23] indicate that during maceration using ultrasound, the content of soluble dry matter fluctuated within 60–70%.

Osmotic dehydration, in turn, allows reducing the moisture content in fruits and vegetables to approximately 6–8%, compared to 10–12% with conventional convective drying [38]. The data presented in the table indicate that the moisture content in the samples is 7.6 ± 0.5%. According to DSTU 7804:2015 "Products of fruit and vegetable processing. Methods for determining dry matter or moisture", the moisture content in food powders should not exceed 10%. The obtained value of the moisture content in black chokeberry powder does not exceed the regulatory limit (≤ 10%) according to DSTU 7804:2015, which indicates its proper stability and minimal risk of microbiological spoilage.

3.4. Limitations of research and prospects for further research

3.4.1. Research on the active and titrated acidity of black chokeberry derivatives

A limitation in this direction is that research is conducted exclusively in laboratory conditions, which may not fully reflect the behavior of the acid profile at industrial scale. The prospect is to determine the effect of long-term storage on the change in acidity and study the stability of organic acids in finished products.

3.4.2. Research on the content of biologically active substances in black chokeberry derivatives

A limitation is the use of only one variety of black chokeberry. In the future, it is advisable to study other varieties and compare the effect of osmotic dehydration on the concentration of flavonoids, anthocyanins, tannins, etc.

3.4.3. Research on the physicochemical parameters of black chokeberry derivatives

The current study did not take into account the behavior of derivatives during long-term storage or in the composition of food matrices. Further research should include studying changes in humidity, hygroscopicity, and the impact on functional properties when incorporated into food or beverage products and during long-term storage.

4. Conclusions

1. It was established that the active acidity of the syrup formed as a result of osmotic dehydration of black chokeberry fruits is pH 5.2 ± 0.1, which indicates its weakly acidic reaction of the medium. Analysis of organic acids showed the presence of a complex of acids: malic – 0.302 ± 0.02%, citric – 0.315 ± 0.02%, tartaric – 0.338 ± 0.02%, acetic – 0.272 ± 0.02%, oxalic – 0.203 ± 0.02% and lactic – 0.405 ± 0.02% in the composition of the syrup. In the powder obtained after drying the dehydrated fruits, a slight decrease in the content of organic acids was noted. In particular, the content of malic acid was 0.268 ± 0.02%, citric acid – 0.280 ± 0.02%, tartaric acid – 0.304 ± 0.02%, acetic acid – 0.240 ± 0.02%, oxalic acid – 0.180 ± 0.02%, lactic acid – 0.360 ± 0.02%. The results obtained are due to partial losses of volatile fractions during heat treatment.

2. Analysis of biologically active substances in black chokeberry processing products showed that the powder is characterized by a significantly higher content of phytochemical compounds compared to the syrup. In particular, the concentration of anthocyanins in the powder was 0.13 ± 0.02%, while in the syrup only 0.02 ± 0.002%. The content of hydroxycinnamic acids in the powder reached 1.86 ± 0.05%, which significantly exceeds the indicator in the syrup – 0.05 ± 0.002%. The powder also recorded a higher concentration of flavonoids (3.07 ± 0.05% vs. 0.70 ± 0.02%), polyphenolic compounds (0.51 ± 0.02% vs. 0.13 ± 0.02%) and tannins (6.74 ± 0.2% vs. 0.11 ± 0.02%). The content of coloring substances is also significantly higher in the powder (82.7 ± 0.05 g/kg) compared to the syrup (10.07 ± 0.05 g/dm^3). The results obtained indicate the high efficiency of the selected method of fruit processing for preserving the concentration of bioactive substances.

3. The content of soluble solids in the syrup was 58.9 ± 0.2%, which is a high indicator and meets the requirements for concentrated food products. The powder, in turn, is characterized by a low moisture content of 7.6 ± 0.5%, which ensures its stability during storage and convenience in further use.

The data obtained indicate the prospect of using syrup and powder for the production of functional food products that can have a positive effect on human health.

Conflict of interest

The authors declare that they have no conflict of interest regarding this research, including financial, personal, authorship or other nature that could affect the research and its results presented in this article.

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Data availability

The manuscript has no linked data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies in creating the presented work.

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