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DETERMINATION OF QUALITY INDICATORS OF SUGAR FORTIFIED WITH A BY-PRODUCT OF ELDERBERRY PROCESSING

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Granulated and pressed beet sugar consists of 99.61–99.7 % sucrose, which is a source of energy for the body. However, this product does not contain other vital nutrients. The object of the study is the method of non-waste processing of elderberry fruits. Wild-growing fruits of black elder Sambucus nigra L were used as the subject of the study. Pre-cleaned elder fruits were frozen at a temperature of −18±2 °C, and after defrosting they were subjected to osmotic dehydration. For this, a 70 % sugar solution with a temperature of 50±5 °C was used (hydromodule 1). The duration of osmosis was 1 hour. The derivative product formed as a result of osmotic dehydration of elderberries (elderberry syrup) was used to enrich granulated sugar in an amount of 10 % by weight of sugar. After thorough mixing with the solution, the sugar was dried in a laboratory vacuum dryer. Anthocyanin dyes contained in the elderberries gave the sugar a bright pink color. The resulting product had a characteristic smell and taste of elderberry. The composition of sugar was studied by high-performance liquid chromatography. It was found that sugar enriched with an elderberry derivative contains 0.03±0.02 mg/100 g of vitamin C and 0.28±0.02 % flavonoids. This gives it certain antioxidant properties. In addition to sucrose, glucose (0.20±0.02) and fructose (0.27±0.02) were found in the product by the polarimetric method. Analysis of the amino acid spectrum of enriched sugar showed the presence of 18 amino acids (total amount of 5.547 mg/100 g), including all essential ones. The most found in enriched sugar, mg/100g: tyrosine (0.93), alanine (0.79), phenylalanine (0.752) and leucine (0.749). The results obtained indicate an increase in the biological value and additional functional properties of fortified sugar

***Keywords:** enriched sugar, elderberry syrup, antioxidant properties, amino acid composition, simple carbohydrates*

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1. Introduction

One of the most dangerous interventions in the human body is the restriction of sugar in the diet. The normal activity of the brain and nervous system is almost entirely dependent on the content of glucose in the blood. The brain is not able to independently process fats in its absence. Sugar is a precursor of glycogen in the human body, which is a source of the carbohydrate skeleton of amino acids, takes part in the construction of coenzymes, nucleic acids, glycoproducts, immunoglobulins, adenosine triphosphate (ATP) and other biologically important compounds.

In the absence of sugar in a person's diet, ketone bodies appear in the blood, the function of the central nervous system and muscles is disrupted, mental and physical activity is weakened, and life expectancy is reduced. In addition, sugar has a positive effect on a person's emotions and mood. This is due to the ratio of sucrose and serotonin. Serotonin is a biologically active substance involved in a number of important metabolic processes. With an increase in the content of serotonin in the blood, a person's mood worsens, a feeling of anxiety appears. Glucose can lower the level of serotonin in the blood.

Sugar is one of the most consumed staple foods in the world. At the same time, there is constant "anti-sugar" propaganda. The reason for this is the fierce competition of food products in the world market from the manufacturers of sweeteners. The physiological norm of sugar consumption is 70–80 g/day. Sugar has a large number of positive functional properties and in the minds of consumers is the only natural harmless product. To increase the biological value, it is advisable to introduce substances into the composition of sugar that can give it additional functional properties. The enrichment of sugar with biologically active components of plant raw materials is an extremely topical issue. This will not only increase its biological value, but also expand the range of this type of product.

2. Literature review and problem statement

Sugar-containing products are produced based on crystalline sugar and various plant powders (lemon, mint, ginger, raspberry, strawberry, etc.). However, the powder additives contained in these products are not water-soluble. Due to this, the product is more like a sugar confection.

Synthetic vitamin supplements are also used, but such fortified sugar has not found favor with consumers. Among the assortment of sugar with additives, gelling sugar enriched with vegetable pectin should be distinguished. It is used to make jelly products and jams.

To enrich sugar, it is advisable to use natural additives produced on the basis of vegetable raw materials. A number of functional brown sugar products have been developed with the addition of various herbs, such as *Phyllanthus emblica*, *Polygonatum spp.*, *Dendrobium spp.*, *Pueraria montana var. Lobata*, *Lepidium meyenii*, *Panax notoginseng*, *Citrus x limon*, *Vitis vinifera*, *Zingiber officinale*, *Wolfiporia* and *Angelica sinensis*. It has been found that these products with added value and improved nutritional value are a rich source of biologically active compounds [1]. However, the issue of choosing universal methods for extracting biologically valuable components from raw materials remains unresolved.

Black elderberries (*Sambucus niga L.*) are widely used in the food and pharmaceutical industries [2]. The fruits are rich in carbohydrates, flavonoids, anthocyanins, amino acids, vitamin C and have analgesic, antifungal, antiviral effects on the human body. The inclusion of elderberry derivatives in the formulation of food products increases their shelf life [2]. It is known that elderberries have antioxidant properties and are used as a functional natural food supplement [3]. Due to the high content of anthocyanins. They are used for the production of food dyes with high stability [4, 5]. Elderberry fruits have therapeutic and prophylactic properties. Their positive influence on the functioning of many organs has been proven [6, 7]. Elderberry has antiviral and immunomodulatory properties [8]. Elderberry has been shown to have various health-improving functions in vitro, including antioxidant, anti-inflammatory, anticancer, anti-influenza, antimicrobial, antidiabetic, cardiovascular, and neuroprotective activities [9]. Elderberry (*Sambucus nigra L.*) is a source of some valuable compounds for the body, namely: monosaccharides (18 %) [10], fiber (7 %), proteins (3 %), lipids (0.35 %) [11]. Elderberry fruits also contain ascorbic acid (6–25 mg/100 g), and elderberry seed flour is a source of vitamin E and gamma-tocopherol [11]. According to other data, the concentration of vitamin C was found in the amount of 32.75–44.42 mg/100g [12]. The main sugars identified in elderberries are glucose (33.33–50.23 g/kg) and fructose (33.99–52.25 g/kg). Elderberry fruits also contain a small amount of sucrose from 0.47 to 1.68 g/kg [13]. Elderberry lipids have a high content of polyunsaturated fatty acids (about 80 %) and a low content of saturated fatty acids [14]. Elderberry fruits also contain trace elements, mostly magnesium and calcium [11, 15]. They contain B vitamins (B2, B3, B5, B6, B9) [16]. The antioxidant properties of elderberry fruits are explained by the high content of polyphenols in their composition [17]. Among the polyphenols in elderberry, anthocyanins, flavonols, and phenolic acids are the most found [18, 19]. The results of these studies indicate the need to use elderberry for sugar fortification. All this suggests that it is advisable to conduct a study on the influence of elderberry processing products on sugar quality indicators.

Considering that the regulatory documentation for enriched sugar [20] does not contain parameters indicating the quality of sugar with food additives based on elderberry processing derivatives, it became necessary to conduct an appropriate study.

A method for processing *Sambucus nigra L.* fruits with osmotic dehydration is proposed. Osmotic dehydration is considered one of the best pretreatment methods to reduce energy consumption, limit thermal damage to products, and increase drying efficiency [21]. Along with the many advantages of using this process, the issue of recycling or reusing waste osmotic solutions remains unresolved. During osmotic dehydration, part of the cell sap from plant materials passes into the osmotic solution, as a result of which the concentration of dissolved substances in it decreases and it is not advisable to use it again, without regeneration. To make the process more economically attractive, the osmotic solution must be reused. To do this, it should be concentrated by evaporation or by adding a fresh osmotic reagent [22, 23]. Solubles can be added continuously, but this can lead to an undesirable buildup of the solution. An alternative is to concentrate the dilute solution by membrane treatment or evaporation. However, these operations can be very expensive [24]. It is advisable to use the resulting osmotic solution without additional processing for the production of various food products.

The use of osmotic solutions in food technologies will solve two problems at once: reduce the amount of industrial waste and increase the biological value of products.

3. The aim and objectives of the study

The aim of this work is to determine the effect of a by-product of elderberry processing (osmotic solution) on sugar quality indicators. This will prove that sugar is enriched with certain biologically active substances.

To achieve the aim, the following objectives were set:

– to develop a method for non-waste processing of elderberry fruits, providing for the enrichment of sugar with a by-product;

– to determine the content of vitamin C and flavonoids in fortified sugar;

– to determine the mass fraction of carbohydrates (sucrose, glucose, fructose) in fortified sugar;

– to study the amino acid composition of fortified sugar.

4. Materials and methods

4. 1. Object and hypothesis of the study

The object of the study is a method of sugar enrichment, which provides for the waste-free processing of black elderberry and the use of all its derivatives.

The subject of the study is the quality indicators of sugar (content of vitamin C, flavonoids, carbohydrates, amino acids) enriched with a derivative of black elderberry processing (osmotic solution).

The hypothesis of the study: when black elderberry fruits are processed by osmotic dehydration, part of the cell sap passes into a sugar solution due to osmosis. The cell sap of elderberries contains a number of biologically active components, such as vitamins, antioxidants, monosaccharides, dyes, amino acids and others. By adding an osmotic solution to granulated sugar, its chemical composition can be changed. In addition to sucrose, other nutrients will appear in its composition.

It is assumed that the introduction of additional useful nutrients into the composition of sugar, even in small amounts, will increase its biological value and expand its range.

4. 2. Materials

Fruits of *Sambucus nigra L.* were collected in October 2022 in the Sumy region. Thoroughly washed and dried black elderberries were frozen (18±2 °C). Before processing, they were defrosted and mixed with a 70 % sucrose solution (hydraulic module 1), preheated to 65±5 °C. Osmotic dehydration of the fruits was carried out for 1 hour in a laboratory unit for osmotic dehydration (Fig. 1).

Fig. 1. Laboratory unit for osmotic dehydration

The dehydration temperature was 50±5 °C. At the same time, the cell sap from the fruits passed into the osmotic solution due to one-way diffusion. Separation of the mixture was carried out using a braided brass sieve No. 015 (0.15 mm). The separated solution in an amount of 10 % by weight was mixed with granulated sugar. The sugar enriched with the by-product of elderberry processing was dried in a vacuum dryer at a temperature of 65±5 °C to a mass fraction of moisture of 0.10–0.14 %. Partially dehydrated fruits were dried in an infrared laboratory dryer (t=50±5 °C) and powdered. Experimental studies were carried out on the basis of the Sumy National Agrarian University.

4. 3. Study of the flavonoid content in fortified sugar

A weighed portion of 1 g of sugar pre-ground in a mortar was transferred to a flask, 50 ml of 50 % ethanol (ethanol-water 1:1) was added. The mixture was thoroughly mixed with a magnetic stirrer for 60 min at a temperature of 70 °C. The resulting syrup was filtered. The volume of the filtrate in the volumetric flask was added to 50 ml with 50 % ethanol. Three test tubes were filled with 0.5 ml of sugar solution. Then, 0.25 ml and 0.5 ml of a standard quartzetin solution with a content of $1.5 \cdot 10^{-5}$ g/ml were added to two of them. After that, 0.5 ml of yttrium solution with a content of $1 \cdot 10^{-3}$ mol/l and 0.2 ml of 0.4 % urotropine were added to all three test tubes. The solutions were brought to a volume of 3 ml with ethanol and mixed. The luminescence intensity was recorded. The quartzetin content was calculated by the method of additions. This method is based on measuring the signal for an experimental sample and a sample with a known addition of a buffer component. To do this, the spectra were taken under standard conditions, and a graph was plotted. The concentration of the component in the sample was estimated graphically. Based on the obtained data, a graph of the measurement results versus the concentration of additives was constructed. The resulting graph was extrapolated to the intersection with the concentration axis (corresponding to zero concentration). The segment on the axis between the intersection point and the abscissa of the signal at concentration was taken as the value of the desired concentration.

4. 4. Study of the vitamin C content in fortified sugar

The content of vitamin C in the experimental samples was studied by high-performance liquid chromatography (Agilent Technologies 1200, UV-Vis Abs detector, detection at λ=240 and 300 nm, C18 column (Zorbax SB-C18 4.6×150 mm, 5 μm)). The following mobile phase was used: methanol and 0.02 M KH_2PO_4 solution (20:80). Isocratic processing with an elution rate of 1 ml/min and an analytical column temperature of 40 °C was used. The injection volume is 20 μl. The samples were extracted by adding the mobile phase (20 ml) to 1 g powder. The obtained samples were centrifuged three times (OPN-12 centrifuge) at 10,000 rpm for 10 min. The extracts were filtered using an Agilent 0.45 μm PTFE filter.

4. 5. Study of the mass fraction of carbohydrates in fortified sugar

The mass fraction of sucrose was determined by the polarimetric method. To do this, a sample of 26 % sugar solution was prepared. With an allowable error of ±0.0002 g. The sample was dissolved in hot distilled water in small portions, then the contents of the flask were cooled to 20 °C and made up to volume with water. The solution was filtered, the first portions of the filtrate were discarded. 100 cm^3 of the solution is sufficient for determination. The filtered solution was poured into a 200 mm long polarimetric tube, and readings were taken using a polarimeter reading device corresponding to the mass fraction of sucrose in sugar, expressed as a percentage. The mass fraction of sucrose was calculated by the formula (%):

$$x = \frac{P \times 100}{100 - W}, \quad (1)$$

where x – mass fraction of sucrose in terms of dry matter, %; P – saccharimeter reading obtained as the arithmetic mean of the results of five determinations, %; W – mass fraction of moisture in sugar, %.

To determine the mass fraction of glucose, 1 g of crushed sugar was weighed and quantitatively transferred to a 100 ml volumetric flask. Made up to volume with water and mixed. The sample was filtered through a paper filter. 10 ml of the filtrate was taken into a conical flask and 25 ml of iodine was added. Stirred for 3 min. While stirring the contents of the flask, 35 ml of sodium hydroxide solution was added. The flask was closed with a rubber stopper and left in a dark place for 20 min. Then 5 ml of sulphate solution was added. Titrated with sodium thiosulfate solution until a light yellow color appeared. 4 drops of indicator starch were added and the titration continued until the blue color disappeared. The glucose content was determined by the formula (%):

$$\Gamma = \frac{(A - B) \times 0.009 \times V1}{(n \times V2) \times 100\%}, \quad (2)$$

where A and B – the amount of sodium thiosulfate used for titration of the control and experimental samples, ml, respectively; 0.009 – amount of glucose equivalent to 1 ml of 0.1 N iodine solution, g/ml; n – sample weight, g; $V1$ – volume of sample dissolution, ml; $V2$ – volume taken for titration, ml; 100 – percentage conversion factor.

The mass fraction of fructose was determined by the polarimetric method. To do this, a sample of enriched sugar weighing 5 g was transferred with water into a 100 ml flask. The prepared solution was kept in a water bath at a temperature of 100 °C for 10 min to complete the mutarotation process. Then the mixture was cooled to 30 °C, made up to volume with water, stirred, filtered with a paper filter. The first drops of the filtrate were poured off and polarized in a 200 mm tube. The results of the analysis were recorded, then the solution was cooled to 20 °C and polarized in the 200 mm tube. The fructose content was determined by the formula (%):

$$\tilde{N}f = \frac{P_2 - P_1}{0.0344 \times (t_2 - t_1)}, \quad (3)$$

where P_2 and P_1 – polarization at a temperature 30 °C and 20 °C; 0.0344 – polarization change factor; t_1 and t_2 – temperatures of 30 °C and 20 °C.

4. 6. Study of the amino acid composition of fortified sugar

The amino acid spectrum was identified by high-performance liquid chromatography on an Agilent 1200 liquid chromatograph (Agilent technologies, USA). Zorbax AAA column with a length of 150 mm and an internal diameter of 4.6 mm, the diameter of the sorbent grain is 3 µm. Mobile phase A – 40 mM Na_2HPO_4, pH 7.8; B – ACN:MeOH: water (45:45:10, v/v/v). Gradient separation mode with a constant flow rate of 1.5 ml/min. The column oven temperature is 40 °C. Pre-column derivatization was performed in an automated programmed mode using FMOC reagent (Agilent 5061-3337) and OPA reagent (Agilent 5061-3335). The detection of derivatized amino acids was carried out using a fluorescent sensor. The final results were expressed as the mean±standard deviation (SD) of the measurements from three separate extracts, and the measurements were made in three different studies. Comparison of group means and significance of the difference between groups were tested by Student's t-test. Statistical significance was set to $p \leq 0.05$.

5. Results of the study on the use of derivatives of *Sambucus niga L* processing products for sugar fortification

5. 1. Method for non-waste processing of elder fruits

A method was developed for the waste-free processing of elderberry fruits (Fig. 2), which includes the following processes: washing, sorting, freezing, defrosting, osmotic dehydration of fruits, separation of partially dehydrated fruits and osmotic solution, drying of fruits, and grinding.

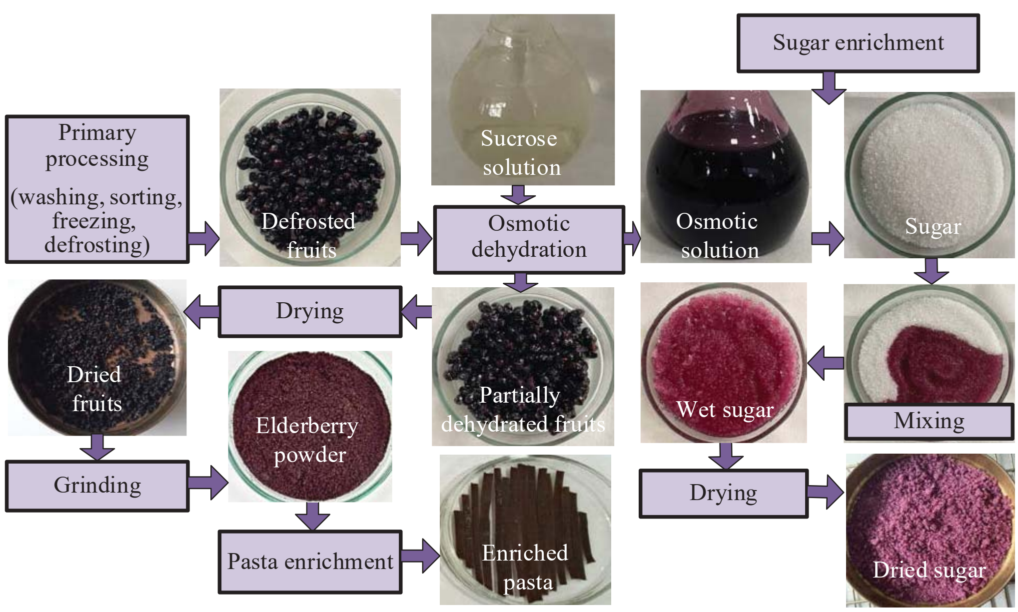

Fig. 2. Method of processing *Sambucus nigra* fruits

These processes are carried out using standard equipment used for processing berries. The design of the apparatus for osmotic dehydration was developed independently, taking into account rational parameters and modes of dehydration of raw materials [25].

According to the proposed method, thoroughly washed berries are frozen (–18±2 °C) to improve the taste properties. Before processing, the fruits are defrosted. After defrosting, part of the cell sap (10–12 %) is removed from them. Separated elderberry juice is recommended to be added to the osmotic dehydration apparatus after 30 minutes of fruit dehydration. Defrosted fruits are mixed in a ratio of 1:1 with a 70 % sucrose solution heated to 65±5 °C. The mixture is thoroughly stirred for 1 hour at a constant temperature of 50±5 °C. As a result, partial dehydration of elderberries occurs. The removal of water occurs due to diffusion and capillary flow. An osmotic solution separated from partially dehydrated fruits is added to granulated sugar in an amount of 10 % by weight. At the same time, its moisture content increases, so enriched sugar must be dried to a mass fraction of moisture of 0.10–0.14 %. To do this, any industrial dryer can be used.

Partially dehydrated berries are separated from the osmotic solution and sent for drying in an infrared dryer at a temperature of 50±5 °C. After drying, the berries are crushed to a finely dispersed state.

During osmotic dehydration, part of the biologically active components (flavoring substances, coloring substances, etc.) passes into the osmotic solution. This is evidenced by its sensory properties. Elderberry fruits contain anthocyanin dyes, which give the fortified sugar its characteristic bright pink color. *Sambucus nigra* has a high content of bioflavonoids. Due to this, elderberry and its processing products affect the radioprotective, antioxidant, and anti-inflammatory properties. It is known that food coloring can be obtained from elderberry juice by concentration. The color of the dye can be adjusted by setting certain pH values of the medium. Sugar solutions had a light pink color and did not contain suspended impurities.

In addition to the positive impact on the organoleptic characteristics of sugar, this method is eco-centric. Since it involves the full use of by-products formed after processing elderberries. Previous studies have proven the feasibility of using powders obtained from dehydrated elderberries to enrich pasta [26].

5. 2. Results of the study of the content of vitamin C and flavonoids in fortified sugar

At the next stage of the study, the content of flavonoids and vitamin C in fortified sugar was determined. The results are presented in Table 1.

Table 1

Content of vitamin C and flavonoids in sugar enriched with elderberry derivatives (uncertainty, U (k=2, P=0.95))

Index	Units	Content in fortified sugar
Vitamin C	mg/100 g	0.03±0.02
Flavonoids	% in terms of quartzetin	0.28±0.02

The results showed that even such a small amount (10 %) of osmotic solution added to sugar contributes to its enrichment with vitamin C and flavonoids. Vitamin C is one of the most famous antioxidants, its presence in foods can slow down oxidative processes, and thereby spoilage. In addition, ascorbic acid has a bactericidal effect on some microorganisms.

5. 3. Results of the study of the content of carbohydrates in fortified sugar

Elderberries, like other berries, contain various carbohydrates. It was found that glucose and fructose monosaccharides pass into the osmotic solution during dehydration. The results of the study are presented in Table 2.

Table 2

Mass fraction of carbohydrates in fortified sugar (uncertainty, U (k=2, P=0.95))

Index	Units	Content in fortified sugar
Sucrose	% by dry matter	97.67±0.02
Glucose		0.20±0.02
Fructose		0.27±0.02

Under the action of saliva and pancreatic enzymes, sucrose is decomposed into glucose and fructose, and only in this form is absorbed by the human body. The presence of fruit sugars in enriched sugar significantly increases its biological value. Glucose is the main source of energy for cellular metabolism in the body [27]. It is the only form circulating in the blood. With a lack of glucose, glycogen (animal starch) turns into glucose and enters the blood. For the absorption of glucose by the body's cells, the hormone of the pancreas – insulin is needed. Fructose is the sweetest of all sugars [28]. It is much more slowly absorbed into the blood, but is faster converted to glycogen than glucose. It is known that 80–90 % of fructose is absorbed intact, and the rest is converted into glucose or lactate. Fructose is converted in the liver to glycogen with little or no insulin. This feature makes it a natural sugar substitute, ideal for preventive, dietary and therapeutic nutrition of people with diabetes.

5. 4. Results of the analysis of the amino acid composition of fortified sugar

An analysis of the amino acid composition of enriched sugar showed that the addition of an osmotic solution formed after partial dehydration of elderberries to sugar promotes the transfer of amino acids. The results are presented in Table 3.

Table 3

Amino acid content of fortified sugar

Amino acid	Content in fortified sugar, **mg**/100 g
Aspartic acid	0.059
Threonine	0.097
Serin	0.551
Glutamine acid	0.073
Proline	0.102
Glycine	0.011
Alanine	0.790
Cystine	0.024
Valine	0.286
Methionine	0.003
Isoleucine	0.181
Leucine	0.749
Tyrosine	0.930
Phenylalanine	0.752
Histidine	0.279
Lysine	0.053
Ammonia	0.023
Arginine	0.584

With the solution, 18 amino acids are introduced into the sugar composition (total amount of 5.547 mg/100 g), including all essential ones. Most of all, the following pass into sugar from elderberry fruits, mg/100 g: tyrosine (0.93), alanine (0.79), phenylalanine (0.752) and leucine (0.749). Tyrosine deficiency in the body leads to a lag in the physical development of children. The addition of an osmotic solution to sugar makes it possible to enrich it with amino acids.

6. Discussion of the results of the study of the effect of derivatives on sugar quality

Sugar plays many roles in food in addition to its main role as a sweetener. To be fully useful, it should be enriched with biologically active components and consumed in moderate amounts to avoid negative health effects.

The proposed waste-free method for processing elderberry fruits (Fig. 2) makes it possible to obtain two natural food additives (powder and solution) at once, which can be a good source for enriching many food products [26, 29]. Due to the osmotic pressure created by the high concentration of sucrose in the sugar solution, the cell sap diffuses through the semi-permeable membranes of the fruits. The mass fraction of solids in the solution decreases by 9±0.5 %. The active acidity of the osmotic solution decreases (pH=4.57±0.3), probably due to the transition of organic acids, which can cause partial inversion of sucrose.

The results of the study (Table 1) show that when 10 % of the derivative product obtained by osmotic dehydration of elderberry fruits is added to sugar, it acquires certain antioxidant properties. The use of osmotic dehydration for the treatment of elder fruits allows you to save vitamin C and flavonoids, which are contained in large quantities in it [2, 12]. Quercetin (a flavonoid) that enters the composition of sugar with an elderberry derivative is considered a natural pigment. In addition, it helps the cardiovascular system, reduces the risk of cancer. Taking products with quartzetin can bring significant benefits to the body, in particular, increase immune defenses, suppress allergic reactions, and support the body during physical exertion.

As a result of osmosis, simple carbohydrates pass into the solution and are preserved after sugar drying (Table 2), which are much more easily absorbed by the body. Their presence in the composition of sugar gives it certain functional properties [27]. Fructose is absorbed more slowly than glucose, but does not increase blood sugar levels, stimulates active brain activity, blocks the occurrence of caries and has a positive effect on the endocrine system [28]. The presence of glucose and fructose in the composition of enriched sugar may also indicate a partial inversion of sucrose due to the action of acids, which are diffused into the solution during osmotic dehydration.

Beet sugar, produced according to traditional technology, contains 99.75–99.9 % sucrose and a small amount of coloring matter and ash [20]. Due to its enrichment with an osmotic solution, 18 amino acids appear in the sugar composition (Table 3), 8 of which are essential. This significantly increases its biological value. Tyrosine, which in the largest amount (0.93 mg/100 g) enters sugar with an elderberry derivative, is a precursor of the hormones dopamine, adrenaline, noradrenaline and thyroxine. It improves attention, memory, concentration, supports the nervous system. Alanine, also found in large quantities (0.79 mg/100 g) in enriched sugar, strengthens the immune system and is involved in the metabolism of sugars and organic acids in the human body. Serine (contained in an amount of 0.551 mg/100 g) plays an important role in the metabolic processes of the body, provides the catalytic effect of enzymes, and is part of many proteins of plant origin.

The limitations of this study include the fact that there is no regulatory technological documentation for the production of fortified sugar. Sugar enriched by the proposed method is not advisable to use as a raw material in the manufacture of some food products. Especially in technologies involving high-temperature treatment. However, such a product is suitable for direct consumption and sweetening of beverages.

The disadvantages of this study include the fact that the primary processing of elderberries involves significant manual labor costs. However, standard berry processing equipment can be used for this. The proposed technology will not significantly improve human nutritional status. However, the proposed method of elderberry processing is waste-free and will expand the range of some food products (sugar and pasta).

Further research will be aimed at determining microbiological indicators, safety indicators and shelf life of sugar enriched with a derivative product of elderberry processing.

7. Conclusions

1. A method for the non-waste processing of elder fruits with osmotic dehydration is proposed. Due to the use of osmotic dehydration, elderberry processing products have good organoleptic properties and contain a number of biologically active substances. Their use for fortification of food products will give them additional functional properties.

2. Sugar enriched with elderberry solution contains 0.03±0.02 mg/100g of vitamin C and 0.28±0.02 % flavonoids. The presence of these substances in sugar indicates its antioxidant properties.

3. It was found that, in addition to sucrose, enriched sugar contains glucose and fructose, which perform a number of functional properties in the human body.

4. Analysis of the amino acid composition of fortified sugar showed that the product contains all the essential amino acids. The presence of 18 amino acids in sugar significantly improves its biological value.

Conflict of interest

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

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Data availability

The manuscript has no associated data.

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