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USE OF BLACK ELDERBERRY AND WHEY IN BEVERAGE TECHNOLOGY

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Abstract. *Research on the use of secondary dairy raw materials and processed products of wild berries is a promising direction of innovative approaches in the technology of functional beverages. This contributes to expanding their assortment, increasing their biological value, introducing resource-saving technologies, and improving environmental sustainability in production.*

The article is devoted to studying the quality indicators of cheese whey and juice obtained from black elderberry berries, as well as their use in the technology of health-promoting beverages in order to expand the product range and increase the biological value of the final product. Scientific achievements related to the use of whey and black elderberry processing products in food production technologies were analyzed.

Experimental studies of organoleptic and physicochemical quality indicators of the raw materials (whey and black elderberry juice) confirmed the presence of a significant amount of nutrients. In particular, whey contains proteins, while elderberry juice contains biologically active substances, among which phenolic and coloring compounds are of special importance. It was confirmed that the predominant share of polyphenolic substances in fruit raw materials is anthocyanins, which possess antioxidant properties and positively affect the organoleptic characteristics of beverages. Microbiological studies of whey, black elderberry juice, and beverages produced on their basis were also conducted.

The results of experimental studies confirm the feasibility of using wild plant raw materials in beverage formulations based on whey. It was determined that the best organoleptic and physicochemical indicators are achieved when 15% black elderberry juice is added to the beverage formulation. This not only enriches the composition of the final product and increases its nutritional and biological value, but also provides an attractive color and improves taste properties.

Keywords: *whey, black elderberry, chemical composition, juice, beverages, quality indicators, microbiological indicators.*

Problem Statement in General. The modern development of the food industry is characterized by increasing attention to resource conservation, rational use of raw materials, and the introduction of waste-free production technologies. This issue is particularly relevant for the dairy industry, where significant amounts of secondary raw materials, especially whey, are formed during milk processing.

Despite the high content of biologically active substances, complete proteins, lactose, minerals, and vitamins, a significant portion of whey is still used inefficiently. This leads to the loss of valuable nutrients and creates environmental problems. One of the promising directions for the rational use of milk whey is its involvement in the technology of functional beverages. Due to its high nutritional and biological value and the ability to combine with various plant raw materials, whey can serve as a basis for creating new types of health-promoting beverages.

Wild plant raw materials, particularly black elderberry (Sambucus nigra L.), also have significant potential for the development of waste-free technologies. The use of wild berries in food production technologies contributes not only to expanding the range of products but also to more rational use of natural resources and promotion of local plant raw materials.

The combination of whey with processed black elderberry products in beverage technology represents a promising direction for the development of new products with increased biological value. This approach corresponds to modern trends in food production aimed at the comprehensive use of raw material resources, waste minimization, and obtaining products with improved functional properties.

Analysis of major studies and publications. Over the past decades, Ukraine has seen a trend towards a reduction in livestock numbers and a decrease in milk production, although the situation improved somewhat in 2025 [14]. The problem of insufficient raw materials to meet the population's needs for dairy products can be solved by attracting secondary dairy resources, in particular whey, the volume of which, according to

statistics, in Ukraine is about 2 million tons. However, the share of its further processing at dairy enterprises, despite its high nutritional and biological value and moderate price, is only 25...33% [26].

The issue of complete and rational processing of whey exists in all countries with a developed dairy industry [28]. This is due to the significant volumes of whey obtained using traditional technology during the production of protein-fat products. According to the generalized data of recent years, the main directions of its processing are the production of dry whey, milk sugar [30, 31], sour whey as a precipitating agent for the production of casein [30], fresh and fermented drinks [2, 16, 33].

Whey contains more than two hundred vital nutritional biologically active substances. Of these, about 25% of the protein substances are represented by whey proteins (α-lactalbumin, β-lactoglobulin, serum albumin, immunoglobulin and proteose-peptones), which are rich in essential amino acids [12, 26]. The main whey proteins are β-lactoglobulin and α-lactalbumin. They are rich in deficient essential amino acids (lysine, tryptophan, methionine, threonine) and cysteine, which allows us to attribute them to the most biologically valuable part of milk proteins [26]. The biological value of whey proteins compared to ideal protein is given in Table 1.

The absolute content of the main ash elements in whey (in mg%): potassium 90–100; magnesium 9–20; calcium 40–110; sodium 3.5; phosphorus 4–10; chlorine 8–11. The trace element composition of whey (in μg/kg) is represented by: iron – 67.4; zinc – 3.1; copper – 7.6; cobalt – 6.1, etc. [12]. Vitamins pass from milk into whey, and water-soluble vitamins are more abundant than fat-soluble vitamins, which is associated with the degree of fat utilization [26]. The specific color of whey (yellowish-green color) is explained by the presence of riboflavin in it, which is especially noticeable after protein purification. Organic acids in whey are represented by lactic, citric, acetic, formic, propionic, butyric and other acids. The main share of all acids is lactic. Partly in whey it is found in the form of lactates [32].

Table 1

Biological value of whey proteins

Amino acids	Ideal protein, g/100 g	Amino acid content in 100 g of whey protein	Amino acid score (AAS), %
Valine	5,0	6,5	130,0
Isoleucine	4,0	5,5	137,5
Leucine	7,0	8,8	125,7
Lysine	5,5	8,0	145,4
Methionine + Cystine	3,5	4,6	131,4
Threonine	4,0	6,1	152,5
Tryptophan	1,0	1,3	130,0
Phenylalanine + Tyrosine	6,0	6,0	100,0

Source [27].

The biological value of whey also lies in the presence of finely dispersed fat and milk sugar in the whey, which is very well absorbed by the body (99.7%) [1, 3, 16]. Along with energy functions, lactose performs the functions of a structural carbohydrate. In addition, being slowly absorbed, it helps maintain the vital activity of lactic acid bacteria. Lactic acid produced from lactose inhibits the development of putrefactive microflora in the human intestinal tract [8, 16, 27]. The complex of mineral salts in whey, from a biological point of view, both in terms of spectrum and composition of compounds, is the most optimal. Enzymes, vitamins, phospholipids and other biologically active substances in whey also play an important role in the metabolism and breakdown of protein substances. The energy value of whey is significantly lower than that of milk, which is due to the lower fat and protein content, but the biological value is approximately the same, which makes it advisable to use it in dietary nutrition [5, 17, 19].

Thus, the nutritional value and dietary properties of whey allow it to be used for food purposes, and the use of such recipe ingredients as the juice of wild raw materials in the technology of functional beverages based on whey will make it possible not only to diversify the assortment of beverages and enrich their biological value, but also to carry out ecologization of production [5, 13, 26].

Black elderberry fruits contain a number of useful substances: ascorbic and malic acids, rutin, carotene, sambucin, sugars (glucose, fructose), tannins, pectins, anthocyanin dyes, polyphenols. The use of elderberry fruits is quite wide: in winemaking and the alcohol industry for the preparation of port wine, liqueur, champagne; preparation of natural purple and red dyes used in the food and textile industries [15].

Scientific studies confirm that phytochemical compounds with high antioxidant capacity include polyphenolic substances, in particular, flavonoids, which include flavonols, flavones, flavones, isoflavones, anthocyanidins, proanthocyanidins. Black elderberry contains a whole complex of these substances [21, 22].

Black elderberry fruits and berries contain antioxidants that can neutralize the effects of free radicals. Dietary supplements, medicinal preparations and food products containing berries have a tonic effect and increase performance. Thanks to ascorbic acid and anthocyanins, black elderberry increases immunity and activates the body's protective properties against viral infections [4, 20]. Modern studies show that elderberry preparations help in the treatment of hyperlipidemia, reduce the risk of cardiovascular diseases, and solve many other health problems [15, 22].

Studies show that ripe elderberries contain 83–85% moisture, 6–8% monosaccharides (mainly glucose and fructose in approximately equal amounts), 1.5–2.0% sucrose, 1.3–1.4% organic acids, 1.0–1.2%

pectic substances, as well as a small amount of amino acids and carboxylic acids. The composition of minerals includes Mn, Ca, K, Ba [22].

Black elderberry is cultivated throughout Ukraine, primarily in the steppe and forest-steppe zones, so it is advisable to expand the scope of its use in food formulations.

The antioxidant activity of black elderberries is determined by the presence of phenolic substances, mainly coloring ones. Anthocyanins, represented by cyanidin glycosides, dominate the composition of phenolic substances in berries [20–22].

The relevance of the conducted research lies in the use of wild raw materials as a component of the recipe composition of beverages prepared on the basis of whey, which allows solving simultaneously the problem of using secondary raw materials in food technology and enriching finished products with a biologically active complex of plant ingredients.

Formulation of the research objectives. The aim of the study is to use processed products of black elderberry in the technology of beverages based on whey.

Materials and Methods. During the research, black elderberry berries and their processed products (juice), as well as whey, were used in the formulation of functional beverages.

To conduct the experimental studies, standard analytical methods were used to determine the quality indicators of black elderberry berries and juice, whey, and finished beverages according to organoleptic and physicochemical parameters.

The content of phenolic compounds was determined using the high-performance liquid chromatography (HPLC) method on an Agilent Technologies chromatograph (model 1100). For the analysis, a chromatographic column measuring 2.1 × 150 mm packed with octadecylsilyl sorbent (particle size 3.5 μm), "ZORBAX" SB-C18, was used.

Microbiological indicators were determined according to the following standard methods: the number of mesophilic aerobic and facultative anaerobic microorganisms was determined in accordance with DSTU 7357:2013, DSTU IDF 100B:2003, and DSTU IDF 122C:2003; coliform bacteria were determined on Kessler medium according to DSTU 7357:2013; the number of yeasts and molds was determined according to DSTU ISO 7954:2006; the detection of Salmonella bacteria was carried out in accordance with DSTU IDF 93A:2003 [7–10].

To process the results of the experimental studies, statistical analysis methods were applied using standard software packages of Microsoft Office.

Presentation of the main research material with a full justification of the obtained scientific results. Whey is a promising component for the development of functional beverages with health-promoting properties due to its high nutritional and biological value. It is rich in whey proteins, which have a complete amino acid composition, are easily digestible, and support important metabolic processes in the human body, including muscle tissue synthesis and the functioning of the immune system. In addition, whey contains water-soluble vitamins, mineral elements, and trace elements, particularly calcium, magnesium, phosphorus, and B-group vitamins, which contribute to the normalization of nervous system activity, maintenance of mineral metabolism, and homeostasis [1, 16].

At the first stage of the research, the quality indicators of the raw materials were determined: whey and elderberry berries. The characteristics of the organoleptic indicators are presented in Table 2, while the physicochemical indicators are shown in Tables 3 and 4.

For the study, cheese whey was used, which had the following indicators: mass fraction of dry substances – 5.6±0.15%, including lactose – 3.5±0.3%; mass fraction of fat – 0.2±0.03%; density – 1020 kg/m^3; acidity – 53 °T; active acidity (pH) – 4.5 pH units (Table 3).

Scientists have proven that the high biological value of whey is determined by proteins, vitamins,

Table 2

Organoleptic indicators of source raw materials

Raw material name	Appearance	Colour	Taste	Odor
Whey	homogeneous, transparent, liquid with a slight sediment	white with a greyish tint	slight sour taste	characteristic of this product
Black elderberry	berries of oval shape, quite small, d – 4 mm	purple-black	sweet, specific	light, specific

Table 3

Chemical composition of whey (n=3, p≤0,05)

Indicator name	Unit of measurement	Indicator
Mass fraction of dry substances, including:	%	5,60
– mass fraction of protein	%	0,82
– mass fraction of fat	%	0,20
titrated acidity	°T	53,00
active acidity	unit pH	4,50
density	kg/m^3	1020,00

hormones, organic acids, and trace elements. Lactose dominates among the carbohydrate composition of whey. The acids contained in whey are represented by lactic, propionic, formic, acetic, citric, and other acids. Almost all organic acids found in whey are products of the vital activity of microorganisms that develop in whey, with the exception of citric acid [27–30]. However, according to organoleptic indicators, whey has an inexpressive color and a sour taste, and given its high biological value, it is advisable to combine it with a component that will give the drink a more pronounced color, increase its biological value, and taste properties.

Black elderberry juice was chosen as such a component. To obtain the juice, the berries were subjected to preliminary processing: washed, sorted, crushed and the juice was extracted by pressing. The quality indicators given in Table 4 were determined in the finished juice.

According to the organoleptic assessment, black elderberry juice had a dark purple color, a sweet, specific taste and a light aroma corresponding to elderberries.

Elderberry juice contains about 7.8% sugar, citric acid dominates among organic acids, but there are also malic and succinic acids.

The main indicator that characterizes the antioxidant activity of elderberry is the presence in their composition of L-ascorbic acid, phenolic substances, among which coloring substances predominate (Table 5).

The resulting juice contained L-ascorbic acid (30.50 mg/100 g) and a significant content of phenolic substances (580 mg/100 g), which affect the biological activity index. The presence of antioxidants such as L-ascorbic acid and flavonoids, and their interaction with each other, determine the value of the biological activity index.

The fractional composition of phenolic compounds in black elderberry berries and juice was studied (Table 6).

The phenolic composition of black elderberry revealed the presence of representatives from the groups of flavones and their derivatives and anthocyanins. Anthocyanins account for 92.0% (berries) ... 97.0% (juice) of the total flavonoid content.

Among anthocyanins, the dominant representative is cyanidin-3-O-sambubioside, which accounts for 44% of the total anthocyanin content. The following were found in the anthocyanin group: cyanidin-3-O-sambubioside-5-O-glycoside (20.0% of the total content), cyanidin-3,5-di-O-glycoside (3.0%), cyanidin-3-O-glycoside (33.0%). Chromatograms of anthocyanins in black elderberry berries and juices are shown in Fig. 1.

Studies have shown that about 50.0% of anthocyanins pass from the berry to the juice, and the same proportion goes into production waste.

According to the results of the analysis of the physicochemical parameters of the starting raw materials, it can be stated that the selected raw materials are suitable for compositional combination and can be used to produce functional beverages.

To develop the recipe composition of whey-based beverages, different ratios of whey and black elderberry juice were experimentally studied. According to organoleptic, physicochemical and microbiological parameters, the best ratio of components was 85:15 (whey: black elderberry juice).

For the study, a whey-based beverage was prepared in the following way: the whey was filtered, heated to a temperature of 93±2 °C, kept for 30 minutes and cooled to a temperature of 35 °C for 5–6 hours for clarification, filtered again and mixed with juice and sugar, cooled to a temperature of 4±2 °C.

Table 4

Physical and chemical parameters of black elderberry juice

Mass fraction, %			pH, units pH
soluble dry substances	titrated acids	pectic substances	
13,20	0,65	0,60	4,50

Table 5

The content of biologically active substances in black elderberry juice

Content, mg/100 g			Biological activity, conditional units act.
L-ascorbic acid	coloring substances*	phenolic substances	
30,50	370,00	580,00	4000,00

*– calculated as cinidyn

Table 6

Content of phenolic compounds in blackcurrant berries and juice, mg/100 g

Name of samples	Oxycinnamic acids and their derivatives	Flavones and their derivatives	Anthocyanins	Flavan-3-ols	Total
Berries	–	65,97	742,26	–	808,23
Juice	–	8,90	360,25	–	369,15

Table 7

Organoleptic indicators of the beverage

Name of Indicator	Indicator value
Appearance and consistency	Homogeneous liquid
Taste and odor	Clean, without foreign flavors and odors, slightly sour taste due to the acidity of the whey and juice
Colour	Purple, due to the addition of black elderberry juice, uniform throughout the mass

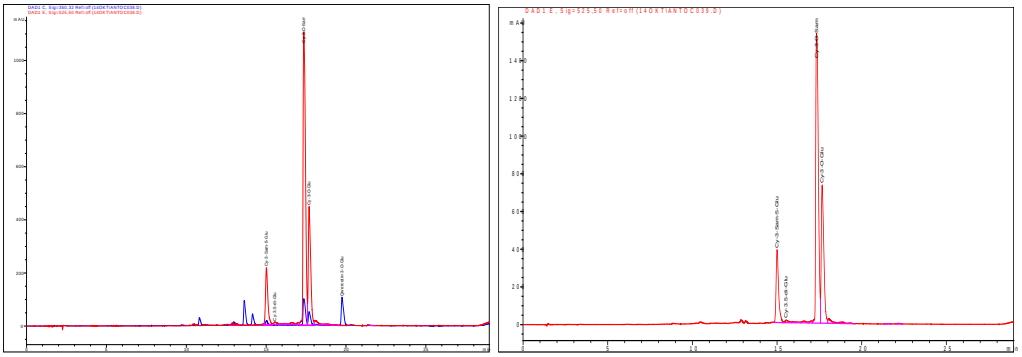
Table 8

Physical and chemical indicators of the drink

Name of Indicator	Beverage with black elderberry juice
Titrated acidity, °T	81,00
Density, g/cm³	1,027
Mass fraction of fat,%	0,25
Dry substances content,%	7,40
Protein content,%	0,76
Lactose content,%	4,85
Temperature of the cooled product, °C	4±2

The organoleptic and physicochemical indicators characterizing the whey and elderberry juice beverage are given in Tables 7, 8, and a comparative photofixation of whey samples and a whey-based beverage with the addition of elderberry juice is shown in Fig. 2.

The elderberry juice beverage is characterized by moderate titrated acidity (81 °T), which indicates a balanced acid-base reaction, and a density of 1.027 g/cm³, which corresponds to typical indicators of whey-based beverages. The low fat content (0.25%) makes the product dietary, and the protein content (0.76%) and lactose (4.85%) provide the body with easily digestible proteins and carbohydrates, contributing to the normalization of digestion and maintenance of intestinal microflora. The total mass fraction of dry substances (7.4%) determines the consistency and taste characteristics of the drink.



а) berries б) juice

Fig. 1. Chromatograms of anthocyanins in berries (a) and juices (b) of black elderberry



а) whey б) elderberry beverage

Fig. 2. Comparative photofixation of whey samples (a) and whey-based beverage with the addition of black elderberry juice (b)

Table 9

Microbiological indicators of starting raw materials (whey and juice)

Name of Indicator	Indicator value			
	standard according to DSTU 7515:2014	whey	standard according to DSTU 8074:2015	elderberry juice
Total mesophilic aerobic and facultative anaerobic microorganisms (MAFAnM), CFU/g, not more than	2×10^5	$1{,}8x10^3$	$1\cdot10^3$	$3{,}7x10^2$
Escherichia coli (coliforms) per 1 g	not allowed	-	not allowed	-
Pathogenic microorganisms, including Salmonella spp., in 25 g	not allowed	-	not allowed	-
Molds, CFU in 1 g, not more than	not normalized	-	10	-
Yeasts, CFU in 1 g, not more than	not normalized	-	10	-

Table 10

Microbiological indicators of the resulting beverage

Name of Indicator	Indicator value	
	standard according to DSTU 8549:2015 (beverages)	beverage
Total mesophilic aerobic and facultative anaerobic microorganisms (MAFAnM), CFU/g, not more than	1×10^5	$3{,}4x10^3$
Escherichia coli (coliforms) per 1 g	not allowed	-
Pathogenic microorganisms, including Salmonella spp., in 25 g	not allowed	-
Molds, CFU in 1 g, not more than	50	-
Yeasts, CFU in 1 g, not more than	50	-

According to microbiological indicators, the starting raw materials and the beverage based on them correspond to the indicators specified in Tables 9 and 10 and do not exceed the regulatory values stipulated by the standard.

Whey belongs to perishable food products that require special temperature conditions to maintain quality and safety, without which it undergoes irreversible changes that lead to spoilage. Elderberry juice belongs to the group of weakly acidic products and this also requires strict requirements during its storage.

According to the results of the conducted studies, it was found out that in beverages recommended for sale in catering establishments, the total microbial contamination was 3.4×10^3 CFU/g, which is lower than the established regulatory indicators. In the studied samples, no bacteria of the Escherichia coli group were detected, as well as pathogenic microorganisms, in particular representatives of the genera Salmonella and Staphylococcus.

In addition, microbiological indicators were analyzed after storage of the products for 72 hours. The obtained results of the studies of samples stored for three days at a temperature of +2…+4 °C indicate that the level of total microbial contamination also remained within the permissible values.

Conclusions. The results of the conducted experimental studies confirm the feasibility of using black elderberry juice in the formulation in the technology of whey-based beverages. The compositional combination in the formulation of whey beverage and black elderberry juice has a positive effect on the organoleptic, physicochemical parameters of the beverage, increases its biological value and allows for maximum use of the resource potential of secondary dairy raw materials.

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Анотація. *Дослідження використання вторинної молочної сировини та продуктів переробки дикорослих ягід є перспективним напрямком інноваційних підходів в технології напоїв функціонального призначення, розширюючи їх асортимент, підвищуючи їх біологічну цінність, запроваджуючи ресурсозберігаючі технології та екологізацію виробництва.*

Стаття присвячена дослідженню показників якості сирної сироватки молочної та соку з ягід бузини чорної і використанню їх в технології оздоровчих напоїв з метою розширення асортименту та підвищення біологічної цінності готового продукту. Проаналізовано здобутки науковців щодо використання молочної сироватки і продуктів переробки бузини чорної в технологіях харчових виробництв.

Проведені експериментальні дослідження органолептичних та фізико-хімічних показників якості вихідної сировини (молочної сироватки і соку з бузини чорної) підтверджують, що в їх складі міститься значна кількість поживних речовин, зокрема в складі молочної сироватки – білків, у соку з бузини чорної – біологічно активних речовин, серед яких особливе значення займають фенольні та барвні речовини. Підтверджено, що переважаючою часткою в складі поліфенольних речовин фруктової сировини є антоціани, які володіють антиоксидантними властивостями і позитивно впливають на органолептичні показники напоїв. Проведено мікробіологічні дослідження молочної сироватки і соку з бузини чорної та напоїв на їх основі.

Отримані результати експериментальних досліджень підтверджують доцільність використання дикорослої сировини в рецептурному складі напоїв на основі молочної сироватки. Визначено, що найкращі органолептичні та фізико-хімічні показники досягаються при внесенні в рецептуру напою 15 % соку з бузини чорної, що не тільки збагачує склад готового продукту, його харчову та біологічну цінність, а й надає привабливого кольору та поліпшує смакові властивості.

Ключові слова: *молочна сироватка, бузина чорна, хімічний склад, сік, напої, показники якості, мікробіологічні показники.*

Конфлікт інтересів: Тюрікова Інна Станіславівна та Хомич Галина Панасівна є членами редакційної колегії журналу. Для забезпечення незалежності редакційного процесу рукопис розглядався редактором, який не мав конфлікту інтересів з авторами. Автори не брали участі у відборі рецензентів, процесі рецензування та прийнятті рішення щодо публікації статті. Рукопис пройшов стандартну процедуру подвійного сліпого рецензування.

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