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Nutritional components of fresh and frozen fruits of highbush blueberries (*Vaccinium corymbosum* L.)

Abstract. The relevance of the study is conditioned by the significant popularity of highbush blueberries among consumers, which they have gained due to their balanced taste and the content of nutrients and bioactive substances that are useful for the human body. Therefore, the purpose of the study was to establish the suitability of fruits of the varieties 'Duke', 'Patriot', 'Chanticleer' for freezing and storage in a frozen state. Biometric, laboratory, analytical, and statistical research methods were used to achieve this goal. As a result of the conducted studies, it was established that the frozen fruits of highbush blueberries of the studied varieties 'Duke', 'Patriot', 'Chanticleer' met the requirements of the highest commercial grade according to DSTU 4837:2007. Defrosted berries of the 'Duke' variety had a better appearance than the other two varieties under study, were unfrozen with a wax coating inherent in this type of fruit, their weight loss during freezing was 0.20%, and juice loss after defrosting – 0.71%. Highbush blueberries of the varieties 'Duke', 'Patriot', 'Chanticleer' in the forest-steppe of Ukraine accumulated from 17.6 to 19.0 mg/100 g of vitamin C, 378-545 mg/100 g of polyphenolic substances, 127.2-176.8 mg/100 g of flavonoids, 59.4-162.9 mg/100 g of anthocyanins, and 15.6-32.5 mg/100 g of chalcones. Defrosted 'Duke' berries contained the largest amount of nutrients, while losses during freezing and defrosting were: vitamin C – 2.7 mg/100 g, total polyphenols – 102 mg/100 g,

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anthocyanins – 41.8 mg/100 g. The data obtained are of practical value for gardeners when choosing a variety for creating plantings of highbush blueberries, the fruits of which can be used both for fresh consumption and freezing

Keywords: polyphenols, vitamin C, anthocyanins, chalcones, flavonoids

INTRODUCTION

Fruit and berry crops are excellent sources of nutrients. They contain a significant amount of biologically active compounds, in particular, ascorbic acid, anthocyanins, flavanols, flavonoids, phenols, and tannins (Prokhorchuk, 2019; Galat, 2021). Fruit consumption improves the overall condition of the body, in particular, it helps strengthen the immune system, the functioning of the cardiovascular and digestive systems (Skrovankova *et al.,* 2015). Considering the data of the State Statistics Service of Ukraine, which indicates that the amount of fruit products consumed by one person per year from 2005 to 2021 increased by 29.4 kg and amounts to 58.7 kg, it can be assumed that functional food products have become a trend and are actively in demand in recent years (Balances and consumption..., 2019). The main reason for the increase in demand for fruit products is a healthy lifestyle, rational nutrition, and vegetarianism (Dhalaria *et al.,* 2020).

The prospects of highbush blueberries *(Vaccinium corymbosum* L.*)* are evidenced by the ever-growing volume of production of its fruits (Manganaris *et al.,* 2014; Dhalaria *et al.,* 2020). Their global production increased from 262 tonnes in 2006 to 556 tonnes in 2016 (Aliman *et al.*, 2020). According to FAOSTAT, the leaders in the production of highbush blueberry fruits are the United States (269 tonnes) and Canada (179 tonnes). In Ukraine, over the past 10 years, highbush blueberries have moved from a little-known niche crop to the status of one of the widely cultivated ones. As of 2017, Ukraine became one of the 5 largest European producers of highbush blueberries. The area under highbush blueberries for the period from 2007 to 2017 increased almost 12 times, from 130 to more than 1,500 hectares, and at the end of 2018, it was expected to expand to 2,000 hectares (Shevchuk *et al.,*2021). Berries of *Vaccinium corymbosum* L. contain a large amount of valuable nutrients that have a positive effect on the human body and are part of a balanced diet (Szajdek & Borowska, 2008). A significant antioxidant capacity of its fruits is provided by the high content of vitamin C, anthocyanins, and phenolic compounds (Szajdek & Borowska, 2008; Skrovankova *et al.,* 2015; Coronel *et al.,* 2019). The fruits of highbush blueberries are consumed both fresh and processed, in particular, in the form of defrosted after freezing, dried or freeze-dried, as well as in the form of jams, jellies, juices, canned fruit and purees (Michalska & Łysiak, 2015; Balances and consumption..., 2019).

However, the short shelf life of highbush blueberries is the main problem in providing the population with products of this type. Therefore, producers are faced with the problem of choosing a processing method that would ensure maximum preservation of the nutritional components of this type of fruit. One of such methods is freezing.

The main task of the research was to establish the influence of the freezing process, the duration of storage of berries in the frozen state and defrosting on the content of bioactive substances, as well as changes in physical and sensory indicators of their quality.

A number of researchers claim that processing highbush blueberries by freezing causes a significant decrease in its nutritional components (Brownmiller *et al.*, 2008). On the other hand, some researchers argue that certain freezing processes have a positive effect on the functional properties of raw materials, since they can promote the release of bound compounds, in particular, phenols and anthocyanins (Mullen *et al.,* 2002; Leong *et al.*, 2012; Neri *et al.*, 2020). R. Veberic (2014) noted an increase in the content of bioactive substances in berries after their long-term storage in a frozen state. Such ambiguous conclusions of the researchers gave rise to the study of the effect of freezing on the preservation of the nutritional values of highbush blueberry fruits. Therefore, the purpose of the study was to identify varieties of highbush blueberries, the fruits of which, according to the complex of preserved quality indicators, are an excellent raw material for freezing. The scientific originality of the study lies in the fact that for the first time, the physical, sensory, and bioactive quality indicators of fruits of the 'Duke', 'Patriot', 'Chanticleer' varieties grown in the forest-steppe of Ukraine were investigated and their suitability for freezing was established.

LITERATURE REVIEW

Highbush blueberry berries, according to researchers from Ukraine (Shevchuk *et al.,*2021), France (Brat *et al.,* 2006) and other countries of the world (Smrke *et al.*, 2021), are a source of nutritional biologically active substances that are useful for the human body. They contain a significant number of compounds that have an antioxidant effect, in particular: vitamin C, polyphenols, flavonoids, anthocyanins, and chalcones. Anthocyanin substances, which are more than 500 in highbush blueberries, provide its fruits with a characteristic black colour. Anthocyanins have become the subject of many scientific studies, mainly for two reasons: their beneficial effects on human health and their use as potential sources of natural food colouring.

Natural extracts of these pigments are used in the food industry as a natural dye, which is an environmentally friendly alternative to synthetic ones (Mullen *et al.,* 2002). In addition to anthocyanins, blueberries contain flavonoids, which are a subgroup of polyphenols. It is the latter that are of particular interest to human health researchers because of their antioxidant activity (Brat *et al.,* 2006). The largest and most diverse group of polyphenols are flavonoids, which are found in the form of free molecules or bound to sugars. Flavonoids are characterised by a wide range of health benefits and are used in the pharmaceutical, medical, and cosmetics industries. This is conditioned by their antioxidant, antiinflammatory, antimutagenic, and anticarcinogenic properties, combined with their ability to modulate key functions of cellular enzymes. They are used to fight diseases such as cancer, Alzheimer's disease, and atherosclerosis (Panche *et al.,* 2016).

Chalcone substances are another subclass of flavonoids. They are also known as open-chain flavonoids. Chalcones, like flavonoids, have anticancer, antioxidant, antibacterial, antiinflammatory, antitumor, cytotoxic, and immunosuppressive properties. But due to their biological and morphological characteristics, the fruits of highbush blueberries are not endowed with good shelf life. The maximum period during which they can maintain their quality indicators is 1-3 months, so producers of highbush blueberries are faced with the task of extending the shelf life of this type of product while maximally preserving sensory and bioactive indicators of its quality.

One of the most effective ways to store fruits for a long time, which minimally affects their quality, is freezing (Neri *et al.,* 2020). With this method of processing, a significant amount of biologically valuable substances containing fruits is preserved, which allows the population to consume natural and useful products throughout the year (Michalska & Łysiak, 2015). Freezing inhibits many metabolic processes in fruits, slows down the growth kinetics of microorganisms, and ultimately prevents degradation reactions of important biological substances, which mainly affect the deformation of the texture and structure of the product and worsens the characteristic colour of berries (Neri *et al.,* 2020).

Processing and storage conditions cause a gradual decrease in the content of nutritionally valuable components, including vitamin C in berries (Skupień, 2006) . The vitamin C content of berries is influenced by numerous factors: genetic variation, ripeness, climate, methods of cultivation, harvesting, and storage (Davey *et al.*, 2000), therefore, the content of this vitamin in berries is highly variable (Skupień, 2006).

Based on the considerable amount of scientific literature, it is established that the issue of changes in the content of biologically active substances in the fruits of highbush blueberries during freezing and defrosting is rather underinvestigated, so the studies performed are relevant and necessary. They will be useful both for scientific breeders to further conduct the breeding process for creating new varieties of highbush blueberries, and for producers when choosing raw materials for freezing.

MATERIALS AND METHODS

The study was conducted during 2020-2021. The objects of the study were the fruits of highbush blueberries – varieties of American selection 'Duke', 'Patriot', 'Chanticleer'. Fruits for laboratory tests were selected at the experimental sites of the laboratory of selection and technology of berry crops cultivation of the Institute of Horticulture of the National Academy of Agrarian Sciences (IH NAAS) of Ukraine. The weight of one sample was one kilogramme. Its geographical location is in the forest-steppe zone of Ukraine, altitude above sea level – 187 m (50° 27`16`N, 30° 131`25`W), distance to Kyiv – 4.0 km. Year of creation of plantings – 2016, planting scheme 1×3 m, the soil of the site is grey forest medium loamy. The system of soil retention in a row is mulching with sawdust, in the row spacing – sodification. The experiment was laid without irrigation, the care of plantings is recommended for the forest-steppe zone of Ukraine (Balabak *et. al.,* 2017).

The zone's climate is temperate continental. According to long-term data, the average air temperature was +9.7°C and the amount of precipitation for the year was 466.3 mm. The minimum average long-term temperature – negative 28.4°C (February), the maximum – 37.7°C (August).

Analytical research

Analytical research was conducted in the laboratory of post-harvest quality of fruit and berry products of the Institute of Horticulture of the National Academy of Sciences of Ukraine. On the day of fruit collection, the content of vitamin C, total polyphenols, anthocyanins, flavonoids, and chalcones was determined. Laboratory tests were conducted on blueberries in a state of consumer ripeness with a characteristic shape and colour for each of the studied varieties according to the 'Methods of assessing the quality of fruit and berry products' (Kondratenko *et.al.,* 2008). Crushed analytical samples of fruits to determine the content of biologically active substances in them were prepared using a laboratory homogeniser. The berries were weighed on an analytical scale with an accuracy of up to the second sign. Biochemical studies were performed in threefold repetition.

Highbush blueberries were frozen in a Samsung RZ32M7110SA/UA freezer, at a temperature of -24°C, in plastic containers. They were stored at a temperature of negative 18-20°C for six months. At the end of storage, weight loss in frozen fruits was determined. After that, the fruit was thawed at room temperature (+20°C) for 6 hours. Juice losses were determined in defrosted berries. Weight and juice losses were measured by weighing on analytical scales with accuracy up to the second sign, expressed in% of the weight of the fresh sample.

Determination of the content of nutrients was carried out in fresh and defrosted berries.

Vitamin C content (ascorbic acid) was determined according to the method based on its extraction from berry samples with a mixture of 2% aqueous oxalic solution and 1% aqueous hydrochloric acid solution (80:20). 5 g of crushed fruit was ground using broken glass and transferred to a measuring flask with a capacity of 100 ml. The contents of the flask were brought to the mark with a mixture of 2% oxalic and 1% acetic acids (80:20) and left for extraction for 10 minutes. The resulting extract was filtered through a cotton wool filter into a 100 ml flat-bottomed flask. In a glass with a capacity of 50 ml, 10 ml of the extract was added and titrated from the microburette with a solution of 2.6 – dichlorophenol-indophenol with sodium salt (Tilmans paint) until a slightly pink colour appeared, which did not disappear for 1 min. According to the amount of paint that was used for oxidation, the content of vitamin C is determined, and a mixture of oxalic and acetic acids is used for control (Kondratenko *et.al.* 2008).

Total polyphenol content was determined according to a method based on the extraction of phenolic substances from berry samples with ethyl alcohol. To do this, 5 g of crushed berry samples were added to a porcelain mortar, a small amount of ethyl alcohol was added and filtered under vacuum on a Buchner funnel through a blue ribbon paper filter into a Bunsen flask. The residue on the filter was washed with a small amount of ethyl alcohol until the sample was completely discoloured. The number of washes depended on the intensity of staining of the sample and was 3-5 times. Record the volume of alcohol used in ml. 7.9 ml of distilled water, 0.1 ml of Extract, 1 ml of Folin-Denis reagent were added to the test tube, mixed and after 3 minutes 1 ml of saturated sodium carbonate solution was added and mixed again. For an hour, the optical density of the contents of test tubes was recorded on an ULAB 102UV spectrophotometer at a wavelength of 640 Nm. For control, a mixture prepared from 8 ml of distilled water, 1 ml of Folin-Denis reagent and after 3 minutes, 1 ml of saturated sodium carbonate solution was added.

Total polyphenol content in the sample was calculated by equation (1):

$$X = \frac{A \cdot V \cdot 100}{V_1 \cdot M}, \quad (1)$$

where: X – total polyphenol content in the sample, mg/100 g; A – amount of chlorogenic acid in the volume taken for spectrophotometric determination, found on the calibration graph, mcg; V – total volume of the final extract of the sample, ml; V_1 – volume of aliquot of the final extract of the sample taken for analysis, ml; M – sample weight, g (Kondratenko *et. al.,* 2008).

Anthocyanin and chalcone content was determined by spectrophotometric method (ULAB 102UV spectrophotometer). The absorption of extracts was determined at wavelengths of 530 and 364 Nm, respectively, using an alcohol extract from plant homogenate acidified with 3.5% hydrochloric acid (Kryventsov, 1982).

Flavonoid content was determined by absorption spectrophotometry by measuring the absorption of a flavonoid complex with a 3% aluminium chloride solution. An ULAB 102UV spectrophotometer with a wavelength of 410 Nm was used for the measurement (Vronska, 2018).

Statistical analysis

Statistical data processing was performed using STATISTICA 13/1 (StatSoft, Inc., USA). The results are presented as averages with their standard errors as the mean ± standard error (x±SE). Differences between repetitions and relative to the average intersort value were determined using ANOVA statistical model. The results of the research are presented at the level of reliability in $P<0.05$. Two-factor variance analysis of the materiality of the influence of the genotype of the variety and weather and climatic factors on the content of biologically active substances in the fruits of highbush blueberries and correlation analysis were performed in Excel software suite, Data Analysis tab.

RESULTS AND DISCUSSION

1.Sensory and physical indicators of the quality of frozen and defrosted highbush blueberry fruits

Weight loss of fruits during frozen storage and juice after their defrosting is a physical indicator that depends on the freezing temperature, defrosting rate, and varietal characteristics (Odarchuk *et. al.*, 2020). It is from these physical characteristics of fruits that their appearance depends, which is normalised by the requirements of DSTU 4837:2007 (2008). According to the specified standard, 95% of frozen blueberries should be not cracked, and after defrosting without excessive juicing, the number of frozen blueberries should not exceed 10% of the total volume of the sample, and the colour should be uniform and characteristic of the berries of this variety, taste without extraneous flavour. According to the results of organoleptic analysis, the fruits of all the varieties under study were of the highest grade, they were whole, not deformed, and without foreign taste and smell.

In the process of freezing and storing in a frozen state, the weight loss of blueberry fruits ranged from 0.20 (‘Duke’) to 0.37% (‘Patriot’), an intermediate value (0.21%) was found in the ‘Chanticleer’ variety (Fig. 1). These figures are significantly lower than those of red currants, where, according to research conducted by Y. Tereshchenko (2018), they were 1.5-1.8%.

Highbush blueberries of the ‘Duke’ variety after their defrosting had not only the smallest weight loss, but also the smallest juice loss (0.71%), they were more significant in the ‘Chanticleer’ variety (1.3 %), slightly smaller – in ‘Patriot’ (0.87%) (Fig. 1).

Considering the data obtained and comparing them with the results on juice losses of fruits of various crops, in particular, currants (2.7-4.9%) (Tageshchepko, 2018), cherries (4.8-7.1%) (Voitok, 2018), strawberries – 10.7% (Simakhina, 2019) and 16.9% (Odarchuk *et. al.*, 2020), as well as sweet cherries of different maturation periods (13.6-22.9%) (Ivanova *et. al.,* 2019), blueberries from among all the above fruits have the least juice loss after their defrosting.

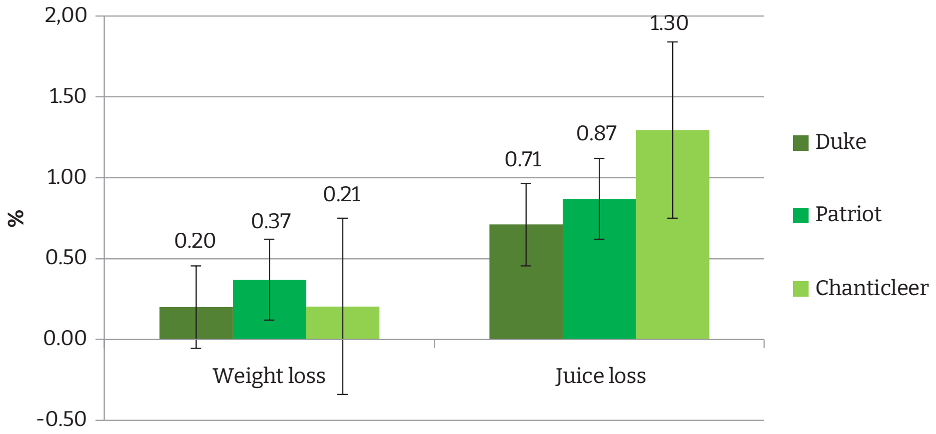

Figure 1. Weight and juice loss of highbush blueberries, % to fresh fruits (average for 2020–2021)

2.Vitamin C content of defrosted blueberries

According to Rafał Nadulski *et al.* (2019), highbush blueberries are not considered a source rich in vitamin C. They found a low content of this vitamin in fruits – 6.75±1.06 mg/100 g of weight. Similar data were obtained by Latvian researchers. The fruits of highbush blueberry varieties studied by them contained from 7.43 to 9.98 mg/100 g by weight of ascorbic acid (Ozola &Duma, 2019). Blueberries grown in Romania accumulated this vitamin from 18.40 mg/100 g ('Blueray') to 13.79 mg/100 g 'Duke', average value – 16.28 mg/100 g (Ciucu-Paraschiv & Hoza., 2021). While blueberry fruits of the 'Bluecrop' variety grown in Turkey had a vitamin C content of 39.10 mg per 100 g of raw weight, which is significantly higher than fruits from Poland and Romania, as well as berries of wild forms of this crop, which accumulated this vitamin from 4 to 8 mg/100 g of raw weight (Celik *et al.*, 2018). According to B. Silenko and S. Marchenko (2013), fruits of highbush blueberries under growing conditions in the Right-Bank part of the western forest-steppe of Ukraine can accumulate from 15.19 ('Patriot') to 34.72 ('Dzhonni') mg/100 g of ascorbic acid.

According to the conducted studies, the fruits of highbush blueberries in the conditions of the forest-steppe of Ukraine accumulate 18.24 mg/100 g of raw weight of vitamin C (average for varieties), which is at the level of data obtained by Romanian researchers (Bunea *et al.*, 2011) and more than the indicators obtained by Polish researchers (Szajdek & Borowska, 2008). The highest amount of it was observed in fresh fruits of the 'Duke 'variety – 19.0 mg/100 g of raw weight, the lowest – in 'Chanticleer' berries (17.6 mg/100 g of raw weight) (Fig. 2). Somewhat similar data were obtained in the laboratory of the horticultural Institute, but for other varieties, in particular, the amount of vitamin C in fresh blueberries ranged from 20.0 mg/100 g of raw weight ('Reca') to 27.0 mg/100 g of raw weight ('Elisabeth') with an intermediate value of 22.5 mg/100 g of raw weight ('Bluegold') (Shevchuk *et al.*, 2021).

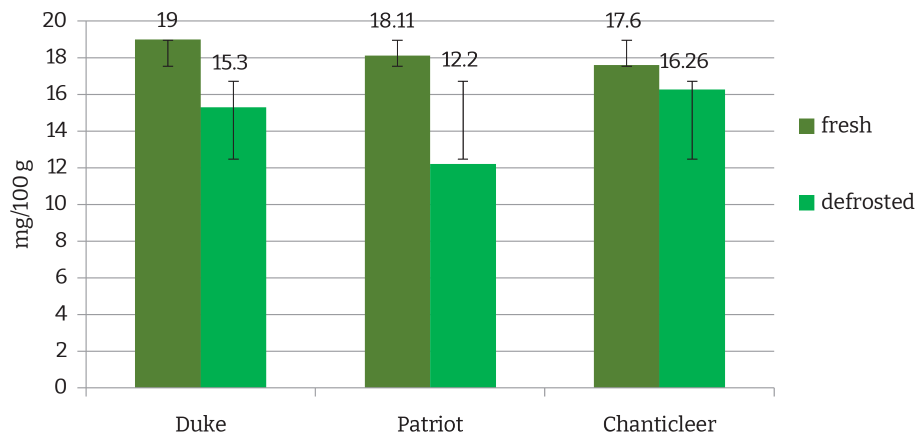

Figure 2. Vitamin C content in fresh and defrosted blueberry fruits, mg/100 g of raw weight (average for 2020-2021)

The fact of a decrease in the amount of vitamin C during fruit storage and defrosting has been established by many researchers (Skupień, 2006; Simakhina&Khalapsina, 2015). In particular, K. Scupien *et al* (2006), argue that as the shelf life of frozen berries increases, the loss of this vitamin increases. As a result of the conducted studies, confirmation of previously obtained data was found, namely, the content of ascorbic acid in the studied deforstated blueberry fruits remained at the level of 62-76%, depending on the variety (Poiana *et. al.,* 2010b). The fruits of the studied varieties of highbush blueberries, after storage in a frozen state and defrosting, quite significantly lost their vitamin C content. The lowest losses of this vitamin were in the variety 'Chanticleer' (8%), twice as high in 'Duke' (19%), and the largest in 'Patriot' (34%). The significance of the difference in the obtained data is explained by the different strength of fruit cells of different varieties, which during freezing causes cryogenic damage to them, and in the future, the process is accompanied by oxidation of ascorbic acid. The data obtained largely do not agree with the results of studies by Polish researchers, who note that blueberries lost from 57% ('Bluecrop') to 72% ('Jersey') of vitamin C during 6 months of storage (Skupień, 2006). Similar data were provided by G. Simakhina *et al.* (2019), which noted that the loss of vitamin C in highbush blueberries, blackberries, and mountain ash is 55.6-71.0%.

3.Content of total polyphenols and flavonoids in fresh and defrosted highbush blueberry fruits

Findings of L. Shevchuk (2021) showed that the content of total polyphenols in highbush blueberries ranges from 280.4 to 494.4 mg/100 g of fresh fruit weight, similar indicators of the content of these substances were obtained by W. Zheng and S.Y. Wang (2003) for blueberries of the 'Sierra' variety – 410 mg/100 g. According to research held in Romania, their number in the fruits of the 'Bluecrop 'and 'Duke' varieties was 424.84-952.27 mg/100 g (Bunea *et. al.,* 2011). According to K. Skupień (2006), similar to the amount of vitamin C, the highest total polyphenol content was found in 'Bluecrop' berries, and the lowest – in 'Blueray' and 'Jersey'. According to the data obtained, the fruits of highbush blueberries contained a higher amount of total polyphenols than indicated in the studies by a number of researchers, in particular, R. Moyer (2002)**,** W. Zheng and S. Wang (2003). The content of polyphenolic substances in fresh fruits of the studied varieties was 482±83 mg/100 g, significantly less than these substances accumulated in the 'Chanticleer' variety (378±9.5 mg/100 g). Varietal difference of the polyphenolic component was at the average level, the variation coefficient was 17% (Table 1).

Table 1. Content of total polyphenols and flavonoids in fresh and defrosted highbush blueberries, mg/100 g of raw weight (average for 2020-2021)

Variety	Polyphenols			Flavonoids		
	fresh	defrosted	% change	fresh	defrosted	% change
Duke	524±9.8	422±2.5	-19	176.8±4.5	182±9.1^{a}	28
Patriot	545±7.4	417±8.1	-23	171.8±4.4	160.3±5.9^{a}	-7
Chanticleer	378±9.5^{b}	344±8.5^{b}	-9	127.2±4.0^{b}	106.0±3.4^{b}	-17
Average by variety	482±83	394±43	-18	158.6±24.8	149.4±3.4	-6
min	368	336	-	123.1	91.7	-
max	564	447	-	187.0	189.9	-
Variation coefficient	17	11	-	16	23	-

Note: the upper indices (a and b) in the lines next to the indicators indicate significantly different values of polyphenols and flavonoids relative to the average indicator (x) for the study group at P<0.05

After freezing and defrosting, the greatest loss of polyphenols was observed in 'Patriot' variety (23%), while the lowest loss was observed in 'Chanticleer' (9%). Thus, the polyphenolic component of the studied defrosted fruits of highbush blueberries was the highest in the 'Duke' variety (422), slightly less contained in 'Patriot' (417), and the least – 'Chanticleer' (394 mg/100 g), which did not significantly change the picture regarding the amount of these substances that was in fresh fruits (Table 1). Significantly greater losses of the above substances in the fruits of blue honeysuckle were noted by R. Khattab *et al.* (2015). Scientists have found that storing frozen at negative 18°C for six months reduces the content of total polyphenols by 37.08%. Other researchers have also observed the process of reducing polyphenolic substances in the fruits of highbush blueberries in their studies (Skupień, 2006). K. Skupień (2006) proved that the materiality of losses can depend on both freezing conditions and varietal characteristics. M.-A. Poiana, D. Moigradean (2010b) and K. Skupień (2006) proved that after 10 months of storage, there is an accelerated degradation of anthocyanin substances, which are a component of polyphenols, in particular, in highbush blueberries by 13% compared to the amount that was in fresh berries. This is confirmed by the data of the conducted studies. Significantly greater losses of the above substances were noted by R. Khattab *et al.*(2015), but in the fruits of blue honeysuckle. He found that storing frozen at -18 °C for 6 months reduced the total phenol content of the fruit by 37.08%.

In general, the variation in the content of total polyphenols in fresh blueberries was average, the coefficient of variation was 17, and in defrosted blueberries it was insignificant, the corresponding indicator was 11 % (Table 1).

Fresh fruits of highbush blueberries of the varieties under study contained 158.6 mg/100 g of flavonoids. Significantly less than the average value for the studied varieties, their value was accumulated by berries of the 'Chanticleer' variety (127.2 mg/100 g), the amount of flavonoids in the other two varieties was higher, and was equal to: 171.8 ('Patriot') and 176.8 mg/100 g ('Duke'). In the process of freezing and defrosting, there was a significant reformatting of the biochemical component of the fruit, which resulted in a significant increase in the flavonoid component in the fruits of the 'Duke' variety (by 28%), a decrease in their number, by 17%, was in the 'Chanticleer' variety and by 7% – in 'Patriot' (Table 1).

4.Anthocyanin and chalcone content in fresh and defrosted highbush blueberry fruits

Compared to other crops, blueberries are a significant source of anthocyanins (Grace *et. al.*, 2019; Smrke *et. al.*, 2021). According to K. McGee and M.C. Walton (2007), 100 g of its fruit can provide up to several hundred mg of anthocyanins. According to the conducted studies, the 'Duke' berry (162.9 mg/100 g) was significantly higher in anthocyanin content among the studied varieties. The other two varieties contained them from 59.4 ('Chanticleer') to 86.9 mg/100 g ('Patriot''), these data indicate a significant varietal difference, the coefficient of variation is 47%. Storage for 6 months of highbush blueberries of the 'Duke' and 'Patriot' varieties in a frozen state and after defrosting caused a decrease in the anthocyanin content by 26 and 22%, respectively. The opposite trend was observed in blueberry fruits of the 'Chanticleer' variety – the anthocyanin content increased by 15% and amounted to 68.5 mg/100 g (Table 2).

Table 2. Anthocyanin and chalcone content in fresh and defrosted highbush blueberry fruits, mg/100 g of raw weight (average for 2021-2022)

Variety	Anthocyanins			Chalcones		
	fresh	defrosted	% change	fresh	defrosted	% change
Duke	162.9±2.1[a]	121.1±2.1[a]	-28	32.5±1.5[a]	34.7±2.4[a]	7
Patriot	86.9±2.1	68.1±2.0	-22	25.5±1.2	30.6±1.6	20
Chanticleer	59.4±1.3	68.5±1.8	26	15.6±1.5[b]	23.5±1.7[b]	51
Average by variety	103.1±47.0	85.9±27.9	-17	24.5±7.6	29.6±5.7	21
min	58.1	56.35	-	14.1	21.7	-
max	164.9	123.05	-	33.9	36.0	-
Variation coefficient	47	33	-	32	19	-

Note: the upper indices (a and b) in the rows next to the indicators display significantly different values of anthocyanins and chalcones relative to the average indicator (x) for the study group at P<0.05

Long-term frozen storage of blueberries did not significantly affect the total polyphenol content, anthocyanins, or antioxidant activity (Ścibisz &Mitek, 2007). However, a number of researchers who have conducted research with other cultures indicate the opposite, in particular A. Hartmann *et al.* (2008) found that the amount of vitamin C and anthocyanins in defrosted strawberries was significantly lower than in fresh ones. Significant losses of the same substances, but in frozen pomegranate juice, were reported by H. Mirsaeedghazi *et al.* (2014), in cherry fruit – by A. Chaovanalikit & R.E. Wrolstad (2004), in frozen strawberry, cherry and cherry juices – by M.A. Poiana *et al.* (2010a). The degradation effect is explained by the storage of fruits in a frozen state and the defrosting process (Celli *et al.*, 2016). These statements are also consistent with the results obtained in the study on strawberries (Poiana *et al.*, 2010a), cherries and mazzard (Poiana *et al.*, 2010a), and blue honeysuckle berries (by 46.34-59.24%) (Khattab *et al.*, 2015).

L.M. Shevchuk (2019) found that in apple fruits, the amount of chalcones varies from 4.3 to 11.8 mg/100 g and prevails over the amount of anthocyanins, which is not typical for red-coloured fruits, in particular, their content in black currants is 40-100 mg/100 g, in strawberries – 15-28 mg/100 g, while the proportion of chalcones does not exceed 10 mg/100 g. A small number of chalcones (1.5-7.0 mg/100 g) was observed in red-coloured raspberries. The lowest content of these substances in fresh blueberry fruits was found in the 'Chanticleer' variety (15.6), and most of them were contained in the 'Duke' variety (32.5 mg/100 g). Under the influence of low freezing and storage temperatures, as well as the defrosting process, the number of chalcones in all the studied varieties increased significantly. In particular, in 'Chanticleer' – by 51% and equal to 15.6 mg/100 g, in 'Patriot' – by 20%, in 'Duke' – by 7% (Table 2).

CONCLUSIONS

According to the results of organoleptic analysis, frozen fruits of highbush blueberries of the varieties 'Chanticleer', 'Patriot', and 'Duke' met the requirements of the highest commercial grade. The lowest weight loss after long-term storage in the frozen state and juice after defrosting was in the fruits of blueberries of the 'Duke' variety – 0.20 and 0.71%, respectively. Fresh berries of this variety in the process of growth in the forest-steppe of Ukraine accumulated the greatest amount of vitamin C (19.00 mg/100 g), polyphenols (524 mg/100 g), and anthocyanins (162 mg/100 g). In the process of freezing and defrosting, the losses of the first two of these substances were 19% each, anthocyanins – 28%, and the flavonoid and chalcone components of 'Duke' berries were also the highest (176.8 and 32.5 mg/100 g) compared to other varieties.

Blueberries of the 'Chanticleer' variety, during 6 months of storage in a frozen state at a temperature of negative 18-20°C, lost 0.21% of their weight. The loss of ascorbic acid after defrosting was 8%, polyphenols – 17%, but the content of anthocyanins and chalcones increased by 51 and 26%, respectively, compared to the content in fresh berries.

The content of vitamin C, flavonoids, and anthocyanins in highbush blueberries of the 'Patriot' variety during freezing storage decreased by 34.7 and 22%, respectively, and the chalcone part increased (+20% to its original content) and amounted to 30.6 mg/100 g.

The result of the above is that the most suitable for freezing and storage in a frozen state, according to a set of quality indicators, is the 'Duke' variety. Therefore, this variety should be recommended to producers for creating plantings, the intended purpose of which is processing by freezing. 'Duke' and 'Patriot' varieties are distinguished by a significant content of common polyphenols, which is a valuable component of the nutritional quality of fruits. Therefore, both of these varieties can be involved as donors of economically valuable traits for further breeding work.

In order to clearly understand the adaptability of highbush blueberries to the conditions of Ukraine, it is necessary to continue studying the quality of fruits, including their size, shape index, crushing force, and the content of basic organic components and trace elements, which would be valuable not only for the breeding process but also for the food industry and pharmaceutical industry.

REFERENCES

[1] Aliman, J., Michalak, I., Bušatlić, E, Aliman, L., Kulina, M., Radovic, M., & Hasanbegovich, J. (2020). Study of the physicochemical properties of highbush blueberry and wild bilberry fruit in central Bosnia. *Turkish Journal of Agriculture and Forestry,* 44, 156-168. doi: 10.3906/tar-1902-36.

[2] Balabak, A.F., Pyzhyanova, A.A., & Dmitriev, V.I. (2015) *High-grown blueberry (Vaccinium corymbosum L.): biological features, introduction, varieties, breeding and production technology.* Kyiv: KT "Zabelina-Filkovska T.S. and the company Kyiv sheet music factory".

[3] Balances and consumption of basic food products by the population of Ukraine. (2020). Retrieved from http://www.ukrstat.gov.ua/druk/publicat/kat_u/2020/zb/07/Zb_bsph2019.pdf.

[4] Brat, P., George, S., Bellamy, A., Chaffaut, L.Du, Scalbert, A., Mennen, L., Arnault, N., & Amiot, M.J. (2006). Daily polyphenolintake in France from fruit and vegetables. *Journal of Nutrition*, 136(9), 2368-2373.

[5] Brownmiller, C., Howard, L.R., & Prior, R.L. (2008). Processing and storage effects on monomeric anthocyanins, percent polymeric color, and antioxidant capacity of processed blueberry products. *Journal of Food Science*, 73(5), 72-79.

[6] Bunea, A., Rugina, O.D., Pintea, A.M., Sconţa, Z., Bunea, C.I. & Socaciu, C. (2011). Comparative polyphenolic content and antioxidant activities of some wild and cultivated blueberries from Romania. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 39(2), 70-76. doi: 10.15835/nbha3926265.

[7] Celik, F., Bozhuyuk, M. R., Ercisli, S., & Gundogdu, M. (2018). Physicochemical and bioactive characteristics of wild grown bilberry (*Vaccinium Myrtillus* L.) genotypes from Northeastern Turkey. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 46(1), 128-133. doi: 10.15835/nbha46110842.

[8] Chaovanalikit, A., & Wrolstad, RE. (2004). Total anthocyanins and total phenolics of fresh and processed cherries and their antioxidant properties. *Food Science and Technology*, 69(1), 67-72. doi: 10.1111/j.1365-2621.2004.tb17858.x.

[9] Ciucu-Paraschiv, M. & Hoza, D. (2021). The effect of foliar application with organic and inorganic products on the biochemical quality indicators of highbush blueberry (*Vaccinium Corymbosum* L.). *Scientific Papers. Series B, Horticulture*. LXV(1), 48-57.

[10] Coronel, L., Pérez, J., & León, N. (2019). Influencia de diferentes agentes encapsulantes en la retención de vitamina C en el zumo de arándano (*Vaccinium corymbosum*) atomizado. *Agroindustrial Science(Artículos de investigación)*, 9(1), 47-52. doi: 10.17268/agroind.sci.2019.01.06.

[11] Davey, M.W., Van Montagu, M., Inzé, D., Sanmartin, M., Kanellis, A., Smirnoff, N., Benzie, I.J.J., Strain, J.J., Favel, L.D., & Fletcher, J. (2000). Plant L-ascorbic acid: chemistry, function, metabolism, bioavailability and effects of processing. *Journal of the Science of Food and Agriculture*, 80(7), 825-860

[12] Dhalaria, R., Verma, R., Kumar, D., Puri, S., Tapwal, A., Kumar, V., Nepovimova, E., & Kuca, K. (2020). Bioactive Compounds of Edible Fruits with Their Anti-Aging Properties: A Comprehensive Review to Prolong Human Life. *Antioxidants,* 9(11), article number 1123. doi: 10.3390/antiox9111123.

[13] Galat, L.M. (2021). Export potential and problems of development of the berry growing industry of Ukraine. *Agrosvit,* 1-2, 46-55. doi: 10.32702/2306-6792.2021.1-2.46.

[14] Grace, M.H., Xiong, J.; Esposito, D.; Ehlenfeldt, M.; & Lila, M.A. (2019). Simultaneous LC-MS quantification of anthocyanins and non-anthocyanin phenolics from blueberries with widely divergent profiles and biological activities. *Food Chemistry*, 277, 336-346. doi: 10.1016/j.foodchem.2018.10.101.

[15] Hartmann, A., Patz, C.D., Andlauer, W., Dietrich, H., & Ludwig, M. (2008). Influence of processing on quality parameters of strawberries. *Journal of Agricultural and Food Chemistry*, 56, 9484-9489. doi: 10.1021/jf801555q.

[16] Ivanova, I. UE., Gerasko, T.V., & Dolgova, S.V. (2019). The analysis of the biochemical composition of fresh and fresh frozen sweet cherry fruits of the three ripening periods grown in the conditions of the Southern Steppe of Ukraine. *Taurian Scientific Bulletin,* 105, 160-165.

[17] Khattab, R., Ghanem, A., Celli, G. B., & Brooks, M.S.-L. (2015). Effect of frozen storage on polyphenol content and antioxidant activity of haskap berries (*Lonicera caerulea* L.). *Journal of Berry Research*, 5(4), 231-242.

[18] Kondratenko, P.V., Shevchuk, L.M., & Levchuk, L.M. (2008). *Methods of assessing the quality of fruit and berry products*. Kiev: SPD "Zhyteliev S.I.".

[19] Kryventsov, V.Y. (1982). *Guidelines for the analysis of fruits for biochemical composition.* Yalta: HNBS.

[20] Leong, S.Y., & Oey, I. (2012). Effects of processing on anthocyanins, carotenoids and vitamin C in summer fruits and vegetables. *Food Chemistry*, 133(4), 1577-1587.

[21] Manganaris, G.A., Goulas, V., Vicente, A.R., & Terry, L.A. (2014). Berry antioxidants: small fruits providing large benefits. *Journal of the Science of Food and Agriculture*, 94(5), 825-833. doi: 10.1002/jsfa.6432.

[22] McGhie, K., & Walton, M.C. (2007). The bioavailability and absorption of anthocyanins: towards a better understanding. *Molecular Nutrition & Food Research*, 51(6), 702-713. doi: 10.1002/mnfr.200700092.

[23] Michalska, A., & Łysiak, G. (2015). Bioactive compounds of blueberries: post-harvest factors influencing the nutritional value of products. *International Journal of Molecular Sciences*, 16(8), 18642-18663.

[24] Mirsaeedghazi, H., Emam-Djomeh, Z., & Ahmadkhaniha, R. (2014). The effect of frozen storage on the anthocyanins and polyphenolic components of pomegranate juice. *The Journal of Food Science and Technology*, 51(2), 382-386. doi: 10.1007/s13197-011-0504-z.

[25] Moyer, R.A., Hummer, K.E., Finn, C.E., Frei, B., & Wrolstad, R.E. (2002). Anthocyanins, phenolics, and antioxidant capacity in diverse small fruits: Vaccinium, Rubus, and Ribes. *Journal of Agricultural and Food Chemistry*, 50, 519-525. doi: 10.1021/jf011062r.

[26] Mullen, W., Stewart, A.J., Lean, M.E.J., Gardner, P., Duthie, G.G., & Crozier, A. (2002). Effect of freezing and storage on the phenolics, ellagitannins, flavonoids, and antioxidant capacity of red raspberries. *Journal of Agricultural and Food Chemistry*, 50, 5197-5201. doi: 10.1021/jf020141f.

[27] Nadulski, R., Masłowski, A., Mazurek, A., Sobczak, P., Szmigielski, M., Żukiewicz-Sobczak, W., Niedziółka, I., & Mazur, J. (2019). Vitamin C and lutein content of northern highbush blueberry (*Vaccinium corymbosum* L.) juice processed using freezing and thawing. *Journal of Food Measurement and Characterization*, 3, 2521-2528.

[28] Neri, L., Faieta, M., Di Mattia, C., Sacchetti, G. Mastrocola, D., & Pittia, P. (2020). Antioxidant activity in frozen plant foods: effect of cryoprotectants, freezing, process and frozen Storage. *Foods*, 9(12), article number 1886. doi: 10.3390/foods9121886.

[29] Odarchenko, D.M., Sokolova, Ye.B., & Kovalevska, N.S. (2020). Study of the chemical composition different varieties of strawberry before and after freezing. *Bulletin of Uman National University of Horticulture*, 1, 98-102. doi: 10.31395/2310-0478-2020-1-98-102.

[30] Ozola, B. & Duma, M. (2020). Antioxidant content of dark colored berries. *Agronomy Research,* 18(S3), 1844-1852. doi: 10.15159/AR.20.123.

[31] Panche, A.N., Diwan, A.D., & Chandra, S.R. (2016). Flavonoids: an overview. *Journal of Nutritional Science.*, 5, article number 47. doi: 10.1017/jns.2016.41.

[32] Poiana, M.A., Moigradean, D., & Alexa, E. (2010a). Influence of home scale freezing and storage on antioxidant properties and color quality of different garden fruits. *Bulgarian Journal of Agricultural Science*, 16(2), 163-171.

[33] Poiana, M.-A., Moigradean, D., Raba, D., Alda, L.-M., & Popa, M. (2010b). The effect of long-term frozen storage on the nutraceutical compounds, antioxidant properties and color indices of different kinds of berries. *Journal of Food, Agriculture and Environment*, 8(1), 54-58.

[34] Prokhorchuk, I. (2019).*"World berry market 2019: can it "survive" without trends?"*. Retrieved from https://www.growhow.in.ua/cvitovyy-rynok-iahid-2019-chy-mozhna-bude-vyzhyty-bez-trendiv//.

[35] Ścibisz, I. & Mitek, M. (2007). The changes of antioxidant properties in highbush blueberries (*Vaccinium Corymbosum* L.) during freezing and long-term frozen storage. *Acta Scientiarum Polonorum Technologia Alimentaria*, 6(4), 75-82.

[36] Shevchuk, L.M. (2019). The content of biologically active substances in the fruits of traditional and rare crops in the culture of fruit breeds. *Bulletin of Agricultural Science*, 11, 81-88. doi: 10.31073/agrovisnyk201911-12.

[37] Shevchuk, L.M., Grynyk, I.V., Levchuk, L.M., Yareshcenko, O.M., Tereshcenko, Ya.Yu., & Babenko, S.M. (2021). Biochemical contents of highbush blueberry fruits grown in the Western Forest-Steppe of Ukraine. *Agronomy Research*, 19(1), 232-249. doi: 10.15159/AR.21.012.

[38] Simakhina, G., Naumenko, N., Bazhaj-Zhezherun, S., & Kaminska, S. (2019). Impact of cryoprotection on minimization of ascorbic acid losses in freezing of berries. *Ukrainian Food Journal*, 8(2), 271-283. doi: 10.24263/2304-974X-2019-8-2-7.

[39] Simakhina, G.O., & Khalapsina, S.V. (2015). Features of freezing berries with a delicate texture. *Food Technologies. Scientific Works of the NUFT*, 21(4), 198-205.

[40] Simakhina, H.O. (2019). Improvement of berry freezing technology by combination of artificial cold and cryoprotection. *Food and Light Industry Technology*, 30(69), 117-121.

[41] Skrovankova, S., Sumczynski, D., Mlcek, J., Jurikova, T., & Sochor, J. (2015). Bioactive Compounds and Antioxidant Activity in Different Types of Berries. *International Journal of Molecular Sciences*, 16(10), 24673-24706. doi: 10.3390/ijms161024673.

[42] Skupień, K. (2006). Evaluation of chemical composition of fresh and frozen blueberry fruit (*Vaccinium Corymbosum* L.). *Acta Scientiarum Polonorum-Hortorum Cultus*, 5(1), 19-25.

[43] Smrke, T., Veberic, R., Hudina, M., Zitko, V., Ferlan, M., & Jakopic, J. (2021). Fruit quality and yield of three highbush blueberry (*Vaccinium Corymbosum* L.) cultivars grown in two planting systems under different protected environments. *Horticulturae*, 7(12), article number 591. doi.org/10.3390/horticulturae7120591.

[44] DSTU 4837:2007. (2008). “Fruits and berries quick-frozen”. Kyiv: Derzhspozhyvstandard.

[45] Szajdek, A. & Borowska, E.J. (2008). Bioactive compounds and health-promoting propertiesof berry fruits: A review. *Plant Foods for Human Nutrition*, 63(4), 147-156. doi: 10.1007/s11130-008-0097-5.

[46] Tereshchenko, Ya.Iu. (2018). *Selection of an industrial range of currants for the Western Forest-Steppe zone of Ukraine* (PhD dissertation, Institute of Horticulture, Kyiv, Ukraine).

[47] Veberic, R., Stampar, F., Schmitzer, V, Cunja, V., Zupan, A., Koron, D., Mikulic-Petkovsek. & Smilka, M. (2020). Changes in the contents of anthocyanins and other compounds in blackberry fruits due to freezing and long-term frozen storage. *Journal of Agricultural and Food Chemistry*, 62, 6926-6935. doi: 10.1021/jf405143w.

[48] Voitok, T.I. (2018). Preservation of consumer and organoleptic quality indicators of defrosted cherry fruits (*Cerasus Vulgaris* Mill.). In *Innovations in the production, storage and processing of plant raw materials: coll. materials of international science and practice. Conferences* (p. 39). Kyiv: Institute of Horticulture of the National Academy of Sciences of Ukraine.

[49] Vronska, L.V. (2018). Development of spectrophotomeric method of flavanoids determination in bilberry shoots. *Pharmaceutical Review*, 4, 49-56. doi: 10.11603/2312-0967.2018.4.9703.

[50] Zheng, W., & Wang S.Y. (2003). Oxygen radical absorbing capacity of phenolics in blueberries, cranberries, chokeberries, and lingonberries. *Journal of Agricultural and Food Chemistry*, 51(2), 502-509. doi: 10.1021/jf020728u.

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Нутрієнтноцінна складова свіжих та заморожених плодів чорниці високорослої (*Vaccinium corymbosum* L.)

Анотація. Актуальність досліджень обумовлена значною популярністю чорниці високорослої серед споживачів, яку вона здобула завдяки збалансованому смаку, та вмісту корисних для організму людини поживних і біоактивних речовин. Тому метою проведених досліджень було встановлення придатності плодів сортів 'Duke', 'Patriot', 'Chanticleer' до замороження та зберігання у замороженому стані. Задля досягненння мети були застосовані біометричні, лабораторні, аналітичні та статистичні методи дослідження. В результаті проведених досліджень встановлено, що заморожені плоди чорниці високорослої досліджуваних сортів 'Duke', 'Patriot', 'Chanticleer' відповідали вимогам вищого товарного сорту згідно ДСТУ 4837:2007. Дефростовані ягоди сорту 'Duke' вирізнялися кращим зовнішнім виглядом ніж два інших досліджуваних сорти, були незморщеними з притаманним даному виду плодів восковим покриттям, втрати їх маси у процесі замороження становили 0,20%, а соку після дефростації – 0,71%. Чорниця високоросла сортів 'Duke', 'Patriot', 'Chanticleer' в умовах Лісостепу України накопичувала від 17,6 до 19,0 мг/100 г вітаміну С, 378-545 мг/100 г поліфенольних речовин, 127,2–176,8 мг/100 г флавоноїдів, 59,4-162,9 мг/100 г антоціанів та 15,6-32,5 мг/100 г халконів. Найбільшу кількість нутрієнтноцінних речовин містили розморожені ягоди сорту 'Duke', при цьому втрати в процесі замороження та дефростації становили: вітаміну С – 2,7 мг/100 г, загальних поліфенолів – 102 мг/100 г, антоціанів – 41,8 мг/100 г. Дані отриманих досліджень мають практичну цінність для садівників при виборі сорту для створення насаджень чорниці високорослої, плоди яких можна використовувати як для споживання у свіжому вигляді, так і замороження

Ключові слова: поліфеноли, вітамін С, антоціани, халкони, флавоноїди