Changes in vitamin content and sensory characteristics of frozen wild berries during storage

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Abstract

Introduction. The aim of the study was to evaluate changes in the content of ascorbic acid, bioflavonoids, and β-carotene, as well as the organoleptic properties of frozen wild berries under the influence of cryoprotectants after long-term storage.

Materials and methods. Wild edible berries (fresh, frozen, and defrosted) of chokeberry, blackberry, raspberry, blueberry, and guelder rose were used in the study. The berries were frozen under the protection of a cryoprotectant (a 10% aqueous solution of sucrose together with a 1% solution of citric acid). Defrosting of frozen berries after 9 months of storage was performed by four different methods to determine the most effective one.

Results and discussion. The berries contain ascorbic acid ranging from 49.7 (guelder rose) to 139.5 (chokeberry) mg/100 g of fresh weight (FW), and β-carotene ranging from 1.94 (blueberry) to 3.76 (chokeberry) mg/100 g FW. Wild berries had high content of bioflavonoids, ranging from 785 mg/100 g FW (guelder rose) to 1654 mg/100 g FW (blueberry). Even after 9 months of storage, frozen berries under the protection of cryoprotectants lost no more than 11.6% of ascorbic acid that is the most labile bio-component; sensory characteristics of the berries showed almost no significant difference with fresh raw material by all indicators.

The methods of defrosting frozen berries affect sensory characteristics and the indicator of cell juice loss of the resulting product; the most effective method was found to be defrosting berries in a refrigerator at a temperature of 0 °C for 30–33 minutes. This method preserved the tissue strength of the berry surface completely, resulting in null loss of cell juice. The best indicators were obtained after thawing the berries in air at a temperature of 18–22 °C for 130-135 minutes: the loss of cell juice was 19.8%, and the surface of the berries had cracks, so the sensory characteristics were 4.1 points, and 3.7 points for the color. Frozen berries proved to be a reliable source of vitamins for dietary needs: 50 g of berries provide the human body with 24.9–65.7% of the Recommended Dietary Allowances for ascorbic acid, 19.0–36.6% for β-carotene, and 156.4–332.2% for bioflavonoids (priority was given to blueberries).

Conclusions. Berries, processed with a water solution of cryoprotectant before freezing, after 9 months of storage, showed almost no significant difference with fresh raw materials in terms of vitamin content and sensory characteristics. The optimal conditions for defrosting of berries was temperature 0 °C for 30–33 minutes.

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Introduction

To overcome the vitamin deficiency in the population diets, great importance is given to berries that accumulate essential concentrations of biologically valuable active substances, primarily antioxidants and vitamins (Becker et al., 2004; Stabnikova et al., 2024; Vahapoglu et al., 2021). However, the berries do not have a protective peel, are not able to retain water for a long time and are highly perishable, so it is necessary to develop special conditions for their storage. Optimum storage conditions for strawberries (7–10 days), blueberries (2–4 weeks), raspberries, and blackberries (2–5 days) are 0 °C and 90–95% of relative humidity (Błaszczyk et al., 2022; Horvitz, 2017).

Since berries are a seasonal product, they must be preserved to be used effectively throughout the year. The most effective method for this is freezing (Arteaga et al., 2021). Frozen berries retain their biological value and attract consumers due to their high sensory characteristics and the preservation of fresh material properties even during long-term storage (Goyal et al., 2000; Rickman et al., 2007). Therefore, there is a growing demand for frozen fruits worldwide, with their turnover increasing annually by 4–6% (Frozen fruit, 2018).

Cultivated and wild berries occupy a special place among plant raw materials, increasingly gaining importance in therapeutic, preventive, and dietary nutrition (Paredes-López et al., 2010), particularly in extreme living conditions (Simakhina et al., 2021). Berries serve as suppliers of bioactive secondary metabolites (polyphenols, aromatic compounds, volatile acids) that contribute to their aroma, fragrance, and taste (Gu et al., 2022). The antioxidant substances of various chemical natures (bioflavonoids, ascorbic acid, carotenoids) contained in fruits and vegetables foodstuffs in different concentrations are believed to resist the expansion of free-radical processes (Ishiguro et al., 2007; Pap et al., 2021; Toor et al., 2006). Unlike the synthetic pharmacological remedies, antioxidants of biological origin are easily and organically involved in metabolic processes in the organism and, in turn, do not cause undesirable side effects (Gundesli et al., 2019). Polyphenolic compounds are secondary metabolites of plants and constitute the largest group of phytochemicals that promote health. These compounds are known to be important antioxidants, exhibiting antiglycemic, antiviral, anticancer, and anti-inflammatory activities, as well as antiallergic and antimicrobial properties (Manach et al., 2004).

However, berries pose the most challenging object for freezing due to their high water content (up to 90%), extremely delicate surface tissue, and low storage stability. This necessitates the search for innovative solutions in developing freezing technologies for berry crops. One of the most promising methods is the combination of artificial cold with the use of cryoprotectant compounds (Neri et al., 2020). Only recently has this direction become the subject of research in the field of food technologies. Scientific developments in cryobiology can be adapted to the processes of freezing berry raw materials (Simakhina et al., 2019) and minimize losses of the most labile component (ascorbic acid) to 5–7%. This is achieved because the development of extra- and intracellular crystallization, which is the main destructive factor for the cells and tissues of frozen objects, is significantly inhibited in berries treated with aqueous solutions of cryoprotectants (Neri et al., 2020).

The subject of research for most authors is the freezing of cultivated berries: cherry (Kutlu et al., 2022), strawberry (Da Silva et al., 2022), blueberry and raspberry (Neri et al., 2020). Therefore, the study of the biological value of wild berries remains relevant, considering their ability to produce vitamins more effectively during vegetation, as well as the fact that no other plant sources have such a balanced quantitative content of essential nutrients. Methods of wild berries freezing and conditions for their storage should be oriented towards ensuring that the final products, after prolonged storage, practically do not differ in quality and sensory characteristics from fresh raw materials and serve as a rich source of vitamins in the population's diet during the inter-seasonal period for berry gathering. One realistic approach to solving such tasks is the pretreatment of berries with aqueous cryoprotectant solutions before freezing. There are only a few articles in the periodicals on this subject (Neri et al., 2020), hence the research on the impact of cryoprotection on the preservation of vitamins, sensory characteristics of berries at the stages of freezing, storage, and thawing remains relevant.

The aim of the present study was to determine the content of ascorbic acid, bioflavonoids, and β-carotene in fresh and cryoprotectant-covered frozen wild berries after prolonged storage and to provide a comparative assessment of their sensory characteristics.

Materials and methods

Materials

Selection of berries for research

The criteria for selecting berries for research are based on their vitamin value (content of ascorbic acid, bioflavonoids, and β-carotene), correlation between the content of ascorbic acid and bioflavonoids, presence of natural cryoprotectants (mono- and disaccharides) that enhance the stabilization of intracellular berry structures during freezing, ability of berry components to participate in cold adaptation, structural strength of berry surface tissues, and minimal difference in sensory indicators between fresh and frozen berries.

Fresh and frozen wild berries golden rose (*Viburnum opulus* L.), blackberries (*Rubus caesius* L.), raspberries (*Rubus ideaus* L.), blueberries (*Vaccinium myrtillus* L.), and chokeberries (*Aronia melanocarpa* L.) were used in the study. The berries were collected at their individual optimal maturity stage, in the mixed forests of the central part of Zhytomyr Oblast (province), Ukraine, in July-September, 2023.

Pre-treatment of berries with cryoprotectants

For the pretreatment of berries prior to freezing, a water solution of a mixture of sucrose and citric acid was applied (Simakhina et al., 2019. Solution of cryoprotectant containing sucrose, 10%, and citric acid, 1%, was prepared using distilled water, crystalline sucrose and crystalline citric acid at a temperature of 18–22 °C, and thoroughly mixed until complete dissolution of the components.

A single layer of berries was placed into a broad-bottomed container, completely covered with the cryoprotectant solution, held for 60 minutes at a temperature of 18–22 °C with periodical stirring to ensure even treatment of their surface. Each subsequent batch of berries was treated with a freshly prepared cryoprotectant.

Obtaining frozen berries

After treatment with cryoprotectants, the berries were dried to remove excess moisture and then frozen in a blast freezer spread out at a temperature of –34 °C for 25 minutes, corresponding to the parameters of rapid freezing (Zlabur et al., 2021). The process continues until the temperature in the center of the berries reaches –18 ± 1 °C.

The frozen berries were packed into 500-gram packets made of thermoplastic polymer materials suitable for low-temperature storage (–18 °C), ensuring the integrity and hermetic sealing of the packaging. The containers with the frozen berries were packed into boxes made of triple-layer corrugated cardboard weighing 6 kg and stored in a refrigerated chamber for 12 months (maximum term) at a temperature of –18 °C and relative humidity not exceeding 95%. Prior to research, the berries were thawed.

Thawing

Thawing was conducted using several methods: (a) air thawing at temperatures of 18–22 °C and 37–42 °C; (b) volumetric thawing in a microwave oven, and (c) in a refrigerated chamber at 0 °C. Thawing continued until the recommended consumption temperature of the thawed berries reached –5 °C. The duration of thawing depended on the size of the berries, the structure of their tissues, and the density of the pulp. On average, the time spent on thawing berries through air thawing at temperatures of 18–20 °C was 130–135 minutes, at temperatures of 37–42 °C it was 45–50 minutes; for thawing in a microwave oven, it was 3–5 minutes, and in a refrigerated chamber, it was 30-33 minutes.

Cellular juice loss

Cellular juice loss during thawing was determined as a percentage based on the relative change in mass of the frozen berry sample before and after thawing.

Determination of ascorbic acid content

Ascorbic acid content was determined by titrometric method based on extraction of ascorbic acid from the test sample with a solution of acid (hydrochloric, metaphosphoric or a mixture of acetic and metaphosphoric), followed by titration visually or potentiometrically with a solution of 2,6–dichlorophenoline sodium phenolate (Majidi et al., 2016).

Determination of bioflavonoid content

The content of bioflavonoids was determined using a method involving the Folin-Ciocalteu reagent by spectrophotometric analysis (Viña et al., 2006).

Determination of β-carotene content

The content of carotenoids was determined using a commonly employed method based on the extraction of carotene using organic solvents (hexane) and measuring the optical density of the solution using a spectrophotometer at a wavelength of 450 nm (Juntachote et al., 2005).

Sensory evaluation

A panel of 7 members (staff from the Department of Technology of Healthy Foods in National University of Food Technologies) was selected on their ability to perceive the indicators of appearance, surface state, color, aroma and taste of fresh and frozen berries and to verbalize those perceptions. Panelists were semi-trained.

Table 1 presents a 5-point evaluation system for the sensory indicators of fresh berries, while Table 2 shows the evaluation of frozen berries under cryoprotectants after 9 months of storage.

Statistical analysis

The data represents the mean of a minimum three replicates ± standard deviation (S.D.). Graphical presentation of experimental data was performed using the program Microsoft Excel 2010.

Table 1

Assessment of sensory characteristics of fresh berries

Index	Score points	Estimation of fresh berries quality by score points
Appearance	5	Fresh, whole, without defects and microbial damages, homogenous.
	4	Fresh, whole, practically without defects.
	3	Whole, partly withered, slightly damaged.
	2	The significant share of withered and damaged berries.
	1	Inhomogeneous, with defects and microbial damages.
Taste and smell	5	Typical for fresh berries, without strange taste and smell.
	4	Slight strange taste and smell.
	3	Stable and obvious strange taste and / or smell.
	2	Stable and expressed, atypical strange taste and / or smell.
	1	Strong rotting stench and atypical taste.
Color	5	Typical for a certain type of ripen berries, saturated, homogenous.
	4	Meets the requirements of the special type, slightly lighter.
	3	Low-intensive due to anthocyanin decomposition.
	2	Transforms from natural to brown.
	1	Dull and unpleasant.
Maturity grade	5	Berries are homogenous in maturity grade, well shaped.
	4	Berries are sometimes inhomogeneous in maturity grade, well shaped.
	3	Berries are slightly inhomogeneous in maturity grade, mostly well shaped.
	2	Berries are practically inhomogeneous in maturity grade, different in shape.
	1	Berries are different in maturity grade, non-calibrated.

Note: berries with quality estimated as 1 or 2 points were not recommended for further procession.

Table 2

Assessment of sensory characteristics of frozen berries

Index	Score points	Estimation of frozen berries quality by score points
Appearance	5	Frozen, with bluish coating, well-shaped
	4	Frozen, about 5 percent of berries with slightly damaged skin
	3	About 8 percent deformed, slight losses of juice
	2	Frozen, over 15 percent damaged, losses of juice, unsuitable for storage
	1	Frozen, wrinkled turgor, over 25 percent deformed, significant losses of juice
Taste and smell	5	Typical for special sort of berries, without strange taste and smell; sour, sweet, spicy, astringent tastes or their combinations; smell may get stronger due to cold stress
	4	Typical for special sort of berries, slightly strange taste and smell due to cold stress
	3	Expressed strange taste with stable bitter aftertaste and smell atypical for special sort of berries
	2	Stable expressed strange taste atypical for special sort of berries; strange smell due to destructive biochemical processes
	1	Unpleasant strange taste and smell due to destructive biochemical processes
Color	5	Typical for special sort of berries, may get stronger due to cold stress
	4	Typical for special sort of berries, slightly less intensive and saturated
	3	Berries almost discolored, upper layer attained the brown hue
	2	Berries attain the brown hue due to the anthocyanin decomposition
	1	Dull, dark-brown, unpleasant due to microbiological damages
Surface state	5	Clean, slightly moisturized, with natural turgor, without skin damages; berries are suitable for long-term (under 12 months) storage
	4	Clean, without skin damages and losses of juice; berries are suitable for long-term (under 12 months) storage
	3	Slightly deformed and crushed (about 5 percent) berries, slight cracks with signs of juice losses
	2	Significantly deformed, crushed (about 15 percent) berries, with cracks and juice losses
	1	Serious surface defects in significant amount of berries (about 25 percent), skin damages with significant juice losses

Results and discussion

Wild berries viburnum (*Viburnum opulus* L.), blackberries (*Rubus caesius L.*), raspberries (*Rubus ideaus* L.), blueberries (*Vaccinium myrtillus* L.), and chokeberries (*Aronia melanocarpa* L.) were chosen for the present research. Golden rose (also known as Viburnum) is widespread in Europe, Northern and Central Asia (Ersoy et al., 2019). Fruits are used for jam, jellies, marmalades production, could be an ingredient for different drinks, and are used in the traditional cuisine of various nations (Polka et al., 2019; Soylak et al., 2002). They are an excellent source of ascorbic acid containing from 28 to 48 mg per 100 g of fresh berries, as well as high amounts of phenolic compounds (Stabnikova et al., 2024). Raspberries are recognized by consumers as a tasty and beneficial berry, rich in bioflavonoids and carotenoids (Ponder et al., 2019), which act as antioxidants in food products. It is used in the canning industry for making jams, preserves, and jellies. Blackberries contain antioxidants, vitamins, pectin substances, mineral elements, and serve as a natural anti-inflammatory agent, used in dietary nutrition, including for diabetes prevention (Kaume et al., 2012). Blueberries are part of the functional food sector, known today as superfoods due to their high content of flavonoids, particularly anthocyanins (Kalt et al., 2020). Chokeberry is an important source of biologically active compounds (Borowska et al., 2016); this is why it is widely used in the food and pharmaceutical industries (Lyubych et al., 2022).

Vitamin content in fresh and frozen wild berries after long-term storage

The content of ascorbic acid, bioflavonoids, and β-carotene in fresh (mg/100 g fresh berries) and frozen (mg/100 g frozen berries) berries after storage for 3 and 9 months were determined. The results are shown in Figures 3-6.

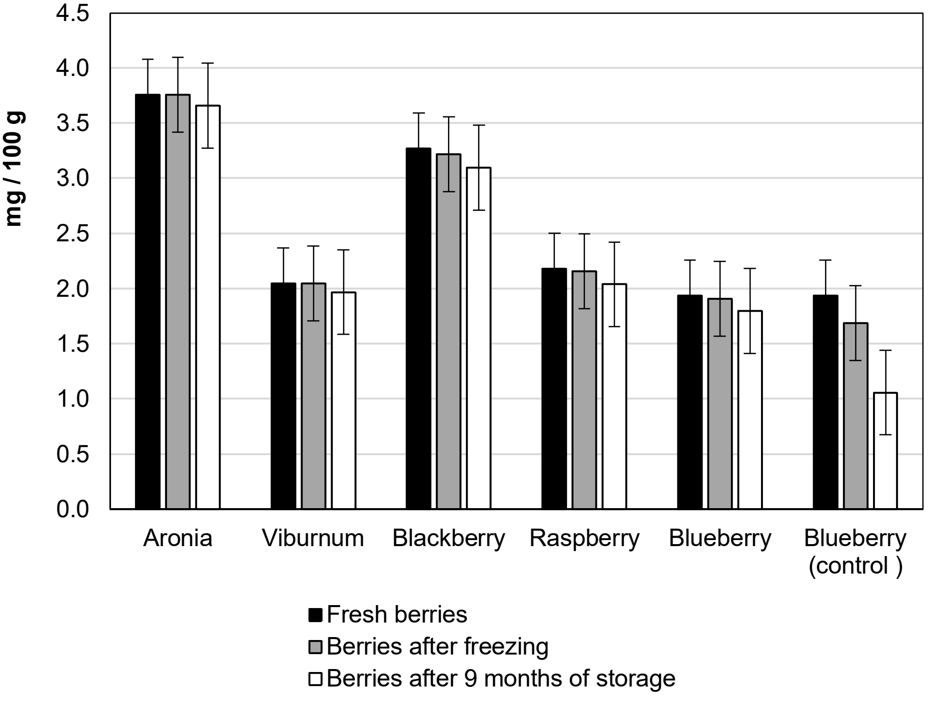

Figure 3. Content of β-carotene in fresh (mg/100g of fresh berries) and frozen (mg/100g of frozen berries) berries

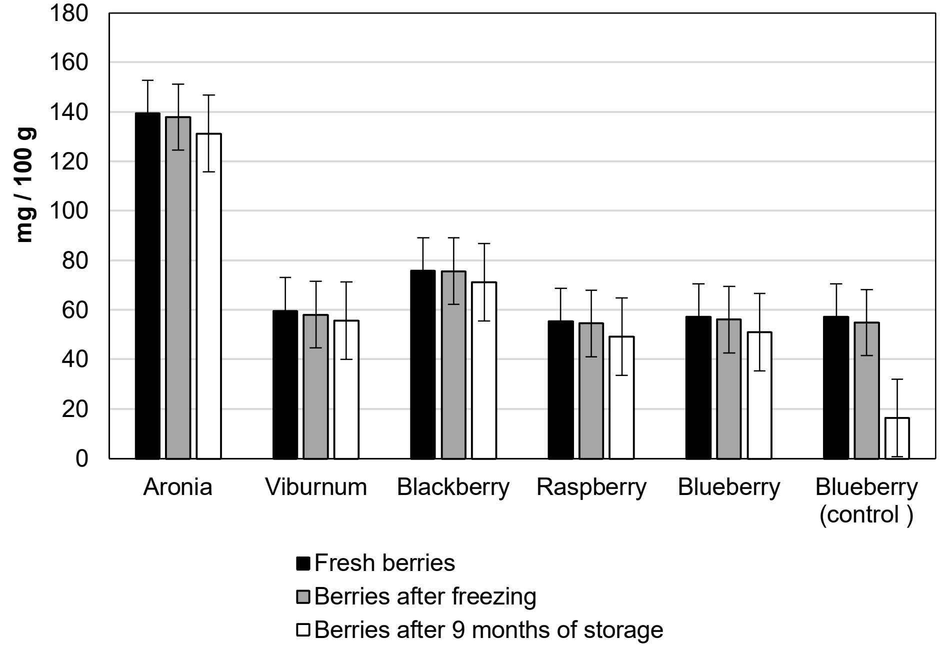

Figure 4. Content of ascorbic acid in fresh berries (mg/100g of fresh berries) and frozen berries (mg/100g of frozen berries) after prolonged storage

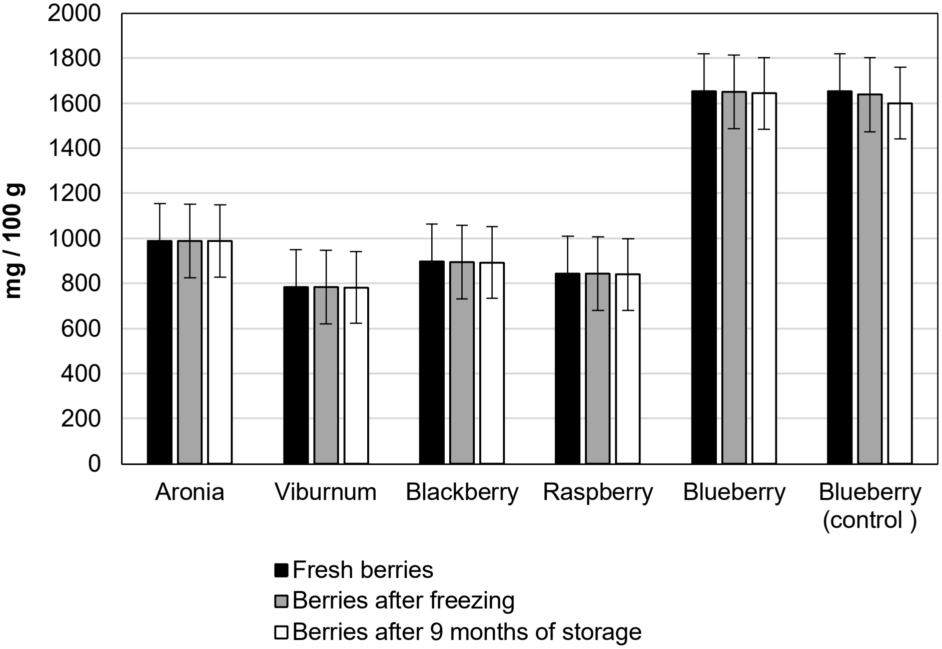

Figure 5. The content of bioflavonoids in fresh berries (mg/100g of fresh berries) and frozen berries (mg/100g of frozen berries) after prolonged storage

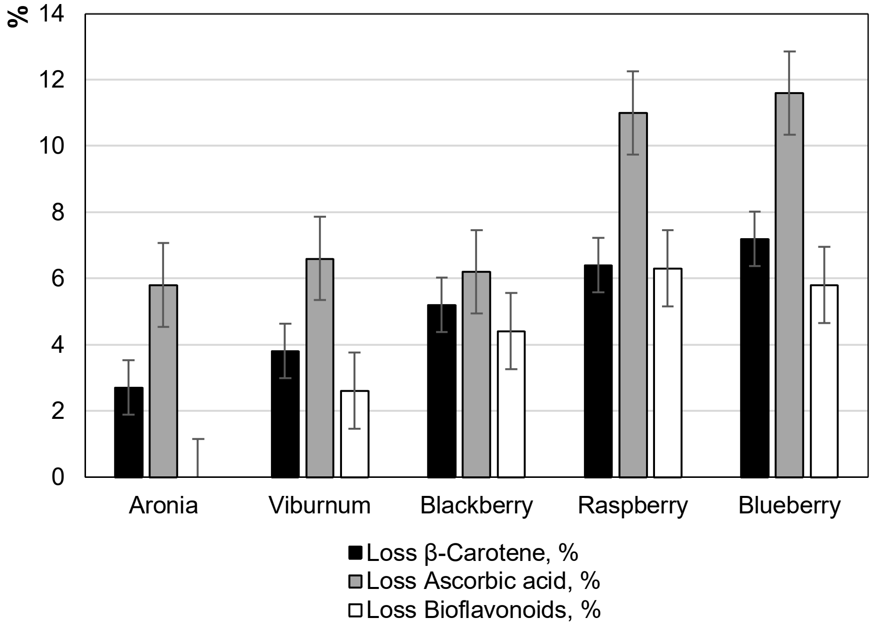

Figure 6. Vitamin losses in frozen berries after 9 months of storage, % compared to the content in fresh berries

Analysis of the data presented in the diagrams (Figures 3, 4, 5, 6) showed that freshly frozen berries, pretreated with cryoprotectants, have almost lost no vitamins, or these losses are insignificant (1–2%). Even after 9 months of storage at –18 °C, the maximum losses of β-carotene concerning fresh berries were 7.2%, and the maximum losses of bioflavonoids were 6.3% (both indicators are presented for blueberries). Along with that, blueberries and raspberries have slightly higher losses of ascorbic acid (11.6 and 11%) compared to other berries. This confirms the status of ascorbic acid as the compound most labile to any external influences, and at the same time explains that blueberries and raspberries have more delicate surface tissues than other berries, which makes them less resistant to the influence of low temperatures. In particular, some cells lose their integrity, the cytoplasmic membrane ruptures, leading to direct contact of the vitamins contained inside the cell with oxidoreductases, primarily with ascorbate oxidase, which, in process, causes the destruction of a certain amount of ascorbic acid molecules.

The results can be properly evaluated by comparing them with data obtained from freezing berries using the traditional method (without cryoprotectants). These data are presented in Figure 6 as a comparative study of vitamin losses in blueberries frozen with cryoprotectants and with traditional technology. Having compared the obtained data, we attained a convincing evidence of the effectiveness of freezing technologies with the use of cryoprotectants: losses of β-carotene with this technology amounted to 7.2% of its content in fresh blueberries, whereas for the traditional method this index counts 45.4%; respectively, losses of ascorbic acid were 11.6 and 71%; bioflavonoids – 5.8 and 31.6%. Significant losses of vitamins in berries frozen with traditional technology can be explained by the formation of large ice crystals in the cells and intercellular spaces during slow freezing, which destroy cell membranes and subcellular structures. As a result, oxidoreductases gain access to biologically active substances concentrated in the cells and initiate biochemical processes of vitamin oxidation, leading to their loss.

Sensory characteristics of fresh and frozen berries

To obtain a comparative characteristic of fresh berries and berries frozen under cryoprotectants, an evaluation of their sensory indicators was conducted, using blackberries as an example. The results are presented in Table 3.

Table 3

Sensory evaluation of fresh and frozen blackberries after 9 months of storage

Indicators	Validity coefficient	Scores	Characteristics	
			Fresh berries	Frozen berries
Appearance	0.35	5	Clean, fresh, free from defects and microbiological damage, uniform, with elastic turgor	The berries are uniform, evenly frozen, with a bluish hue, elastic turgor, undamaged, with retained shape.
Taste	0.2	5	Characteristic of a particular variety, free from foreign flavors; sweet	Characteristic of a specific variety, without any foreign taste, identical to natural fresh berries, sweet
Color	0.1	5	Characteristic of this particular ripe material, intense, rich	Corresponds to the ripeness of fresh berries, no deviations from the natural color; color intensity slightly higher due to anthocyanin synthesis as a response to cold stress.
Surface state	0.2	5	Clean, free from defects and damage by pests, without cracks or spots, glossy or matte	Clean, slightly moist, with natural turgor, undamaged surface tissue, without loss of cellular juice
Aroma	0.15	5	Absence of foreign odor, delicate aroma characteristic of raspberries, rich, pronounced	Characteristic of fresh berries; more intense than the natural aroma due to the synthesis of aroma-forming compounds during cold stress, which gives the berries additional positive qualities.
Conclusion			Top grade	Top grade, suitable for long-term storage

The maximum validity coefficient, 0.35, was accepted for berry appearance since it is considered to be a comprehensive that includes shape, size, maturity grade, freshness, and color. Moreover, in case of berries' discrepancy with the established requirements for the appearance, the use of other evaluation criteria is considered inappropriate.

The results showed that blackberries frozen using cryoprotectants received the maximum score of 5 for all organoleptic indicators, which confirms the high quality of frozen berries that can be used as a source of vitamins in the off-season.

Thawing of frozen berries

Before using frozen berries, it is necessary to thaw them. Frozen berries, stored for 9 months at a temperature of –18 °C and relative humidity not exceeding 95%, were thawed using various methods. The choice of defrosting method was based on maintaining the structural integrity of the berries' surface (sensory characteristic) and, as a result, the loss of cellular juice and berry bio-components dissolved in it. A comparative characteristics of different thawing methods are presented in Table 4.

Table 4

Evaluation of frozen berry thawing methods

Thawing method	Thawing temperature, °C	Thawing duration, minutes	Loss of cellular juice, %	Sensory parameters on a 5-point scale	
				Surface state	Color
Air	18–22	130–135	19.8	4.1	3.7
Air	37–42	45–55	11.2	4.5	4.2
Microwave oven (power 400 W)	50–55	3–5	2.6	5	4.8
Refrigerator	0	30–33	0	5	5

The most effective methods of defrosting frozen berries are thawing in the refrigerator (temperature 0 °C, duration 30–33 min), and thawing in the microwave oven (temperature 50–55 °C, duration 3–5 min, power 400 W). Under these parameters, the structural integrity of the berry tissues is fully preserved (surface state rated at 5 points, and color at 4.8–5 points), preventing the loss of cellular juice and dissolved biocomponents (cellular juice loss was 0% and 2.6%, respectively). The worst indicators were observed after thawing berries in the open air (temperature 18–22 °C, duration 130–135 min), which resulted in cellular juice loss reaching 19.8%, some berries being deformed, and cracks appearing on their surface – with a rating of 4.1 for surface state and 3.7 for berry color.

Providing daily vitamin requirements through consumption of 50 g of frozen berries

Berries, especially wild ones, occupy an important place among plant-based raw materials, given their status as natural vitamin sources, characterized by various health-promoting, preventative, and therapeutic properties. The balance and quantitative content of essential vitamins are such that cannot be found in other types of plant-based raw materials. Therefore, at this stage of the research, the ability of frozen berries to meet a certain portion of the human body's daily needs for ascorbic acid, bioflavonoids, and β-carotene was calculated using a computational method, according to the Norms of physiological needs of the population of Ukraine for basic nutrients and energy (2017): the daily requirement for ascorbic acid is 100 mg, for bioflavonoids is 250 mg, for β-carotene is 5 mg. The results are presented in Figure 7.

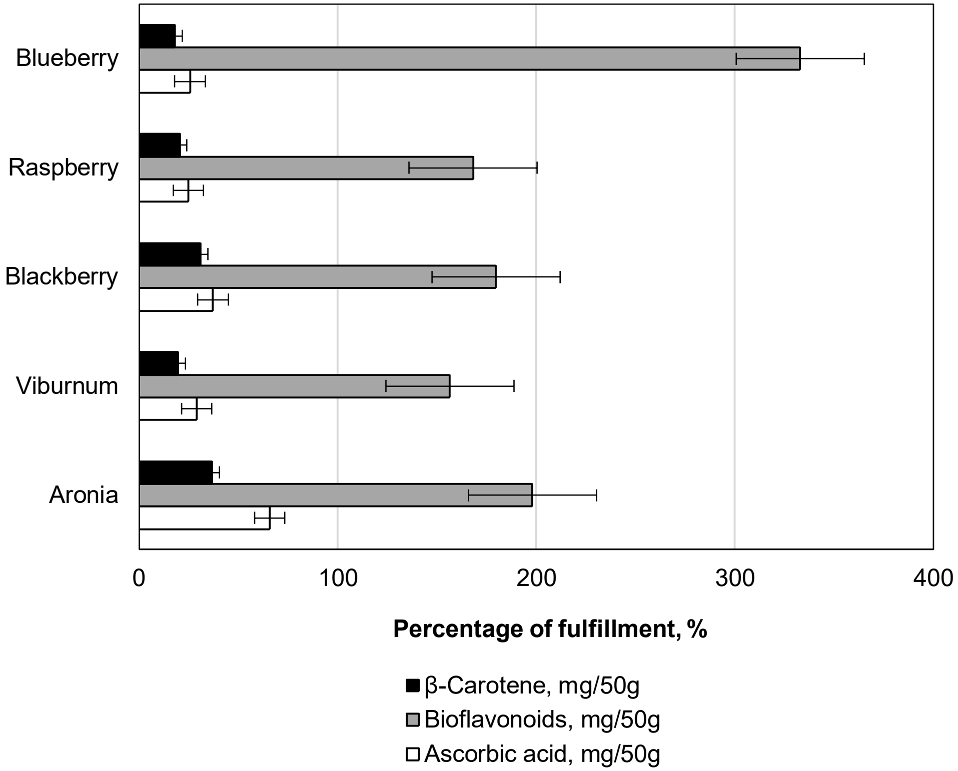

Figure 7. Meeting the average daily requirements of the human body for essential vitamins due to the consumption of 50 g of frozen berries (%)

According to the data from the diagram, 50 g of frozen berries provide a sufficiently high level of daily human vitamin requirements. For the studied berries, this portion's contribution to meeting the daily requirement for ascorbic acid ranges from 24.7% (raspberries) to 65.7% (aronia), for bioflavonoids – from 156.4% (viburnum) to 332.8% (blueberries), and for β-carotene – from 18% (blueberries) to 36.6% (aronia). For all berries, the portion providing the body's daily requirement for bioflavonoids exceeds 100%; however, this does not pose a danger or lead to overdose since bioflavonoids belong to water-soluble compounds and are excreted from the body rather quickly, meaning they do not have cumulative properties.

In European countries, the list of vitamins and their daily requirements differs slightly (The Nutrition Source, 2023). For example, women need 70 mg of ascorbic acid, and men 80 mg; β-carotene is not listed separately, but only vitamin A. The content of bioflavonoids is also not regulated, although they are recognized as potent bio-antioxidants today.

Conclusions

1. Wild berries are valuable sources of antioxidants due to significant amounts of ascorbic acid, bioflavonoids, and β-carotene.
2. The shelf life of fresh berries does not exceed 15 days, so, for long storage they are should be frozen and kept at a temperature of –18 °C. Advanced freezing technology involves combining artificial cold with the use of cryoprotectants that protect the surface and cellular structure of the berries from the damaging effects of ice crystals, thereinafter preventing losses of cellular juice during thawing and the vitamins containing in it.
3. The examined berries, frozen under the cover of a cryoprotectant, even after 9 months of storage under optimal conditions, hardly differ in quality indicators from fresh raw materials: for the content of β-carotene (losses for different types of berries ranged from 2.7 to 7.2%), ascorbic acid (losses from 5.8 to 11.6%), bioflavonoids (losses from 0 to 6.3%), and sensory indicators were rated at 5 points on a 5-point scale. Losses of vitamins in berries frozen by traditional methods without the use of cryoprotectants amounted to 45.4% for β-carotene content, 71% for ascorbic acid content, and 31.6% for bioflavonoid content, respectively, compared to these indicators in fresh raw materials.
4. 50 g of frozen berries, depending on their type, meet the daily human requirements for β-carotene by 19–36.6%, for ascorbic acid by 24.7–65.7%, and for bioflavonoids by 156.4–332.8%.
5. The search for new raw material sources of high biological value, the improvement of methods for their freezing and storage, is a relevant and promising direction for the development of the health food industry, fully meeting human nutritional needs and global market trends.

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