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Research Article

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Vitamin C Content in Fruits of Common Raspberry (*Rubus idaeus* L.) Cultivar Polka Depending on Storage Methods

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Common raspberry (*Rubus idaeus* L.) are highly perishable fruits rich in bioactive compounds, including vitamin C, which is highly sensitive to post-harvest processing and storage conditions. Preservation of their nutritional quality remains an important challenge for both producers and consumers. This study investigated the effect of different processing and storage methods on the vitamin C (ascorbic acid) content in fruits of *Rubus idaeus* cultivar Polka collected in the Chernihiv region. The aim was to identify the most effective method for preserving the nutritional value of the fruits during post-harvest handling. Vitamin C content was determined using the Tillmans titration method. The studied preservation techniques included drying at 40 °C and 60 °C, freezing at -17 °C, boiling, and treatment with 0.4% chitosan solution. The results showed that drying at 40 °C was the most effective traditional method for vitamin C retention, followed by freezing, while boiling caused the greatest losses of ascorbic acid. Chitosan treatment demonstrated the highest efficiency in preserving vitamin C during storage and significantly reduced nutrient degradation compared to untreated fruits. Thus, chitosan coating represents a promising natural and environmentally friendly alternative to conventional preservation methods, effectively maintaining the nutritional quality of raspberry fruits by reducing vitamin C degradation and microbial spoilage, while also extending shelf life during storage.

Keywords: *Rubus idaeus*, vitamin C, chitosan, storage methods

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Introduction

The fruit and berry production and processing industry currently faces the challenge of ensuring high-quality products that retain their beneficial properties over time. A key issue is the significant reduction in vitamin C content in raspberry (*Rubus idaeus* L.) fruits during transportation, which complicates efforts to provide consumers with nutritious and health-promoting products. Raspberries are among the most popular fruits due to their pleasant taste and are used not only in the food industry but also in medicine for their biologically active compounds (Gašperlin et al., 2011; Ali, 2012; Fotschki et al., 2015; Polischuk et al., 2018; Cervantes et al., 2020; Gales et al., 2021). These fruits contain a wide range of health-related components, including vitamins, minerals, antioxidants, polyphenols, and organic acids (Ali, 2012; Niculae et al., 2014). The preservation of raspberry fruits under different cultivation, processing, and storage conditions was studied by Nunes et al. (2002), González et al. (2002), Haffner et al. (2002), Chiabrando et al. (2015), Giongo et al. (2019) etc. All these authors point out that raspberry fruits can only be preserved for short periods of time and that loss of biologically active substances in fruits varies depending on the conditions of fruit processing and storage. The shelf life of fruits is mainly limited due to rapid darkening, loss of firmness, and rotting occurring soon after the yield. To prevent fruit spoilage, they are mostly stored in modified atmosphere packaging (MAP) at low temperatures (approx. 0 °C) (Nunes et al., 2002; Forney et al., 2015), but this approach cannot be used to preserve raspberry fruits for long periods of time, especially if transporting to stores is required. Stavang et al. (2015) studied how the lightning mode affects fruit preservation and determined that fruits preserved their color properties after 8 days of preservation at 2–3 °C, but the loss of other important consumer properties was observed. Kruger et al. (2003) concluded that raspberry fruits gathered at the semi-ripe stage are better preserved during transportation at the cost of their taste quality. In other work, Krüger et al. (2011) determined that the content of biologically active substances (e.g., anthocyanins, phenols, ascorbic acid) and the antioxidant activities of fruits depend on the ripeness stage of raspberry fruits during harvest. Giuggioli et al. (2015) found that storing fruits in MAP prolongs their shelf life, but temperature fluctuations can lead to changes in the quality and flavor of the fruits. Despite this, shelf life is not significantly extended under MAP storage. The fruits processing with low-molecular-weight chitosan is a promising method to prolong the shelf life of fruits. Particularly, the application of chitosan polymer films to preserved consumer qualities of plant products was studied by Blahopoluchna and Liakhovska (2020, 2021), Blahopoluchna et al. (2023), Ciçek et al. (2018), Luksiene et al. (2020), Orzali et al. (2017), Tian and Liu (2020), and Ali et al. (2022).

Of particular interest is the high vitamin C content of raspberries, known for its strong antioxidant, anti-inflammatory, and immune-boosting effects (Polishchuk et al., 2018; Lopez-Corona et al., 2022). However, raspberries are highly perishable, susceptible to mechanical damage, and prone to nutrient degradation during transport and storage (Nunes et al., 2002; González et al., 2002; Kruger et al. 2003, 2011; Ali, 2012; Giongo et al., 2019; Blahopoluchna et al., 2023). The loss of vitamin C under these conditions is a problem that must be addressed to preserve the fruit's nutritional value (Polishchuk, 2020).

As such, research aimed at analyse the ascorbic acid content in raspberries and to identify optimal vitamin C preservation methods, which is of practical significance to both producers and consumers (Ponder et al., 2020). The *Rubus idaeus* cultivar Polka is widely cultivated for its high yield and favorable organoleptic properties, making it suitable for assessing nutrient retention during post-harvest handling (Blahopoluchna et al., 2023). Degradation of ascorbic acid can occur due to various physical and chemical processes during processing and storage (De Ancos et al., 2020). External factors such as temperature fluctuations and changes in humidity further contribute to nutrient loss (Turmanidze et al., 2017). Vitamin C content is crucial not only for its nutritional but also for its pharmacological value, including potential cytoprotective and therapeutic effects (Lopez-Corona et al., 2022; Yan et al., 2021).

Therefore, the aim of the study was to determine the vitamin C content in fruits of *Rubus idaeus* cultivar Polka and to evaluate the effect of different processing and storage methods on its preservation in order to identify the most effective approach for maintaining the nutritional quality of the fruits.

Material and Methodology

Materials and storage

Fruits of *Rubus idaeus* cultivar Polka collected in the village of Smoliazh (Chernihiv region, Ukraine) were used in this study. Commercial chitosan was purchased from Sigma-Aldrich (St. Louis, Missouri, USA; https://www.sigmaaldrich.com/UA/

en/product/aldrich/448869) and dissolved in distilled water (dH_2O).

The following preservation methods were applied: drying at different temperatures, freezing, boiling, and treatment with chitosan, which was used to maintain fruit freshness. Fresh fruits were dehydrated for 48 hours at 40 and 60 °C in a TSO-80 dry-air thermostat with forced air circulation (MICROmed, Ukraine). Freezing was carried out at -17 °C in a Bosch freezer (Spain). Boiling was performed in dH_2O at 100 °C.

For chitosan treatment, fresh fruits were immersed in a 0.4% chitosan solution, placed in plastic containers, and stored in a refrigerator at 0 ±1 °C (Blahopoluchna et al., 2023). Untreated fresh fruits served as the control.

Determination of the vitamin C content

The vitamin C content was determined using the Tillmans method, which is based on the titration of ascorbic acid with 2,6-dichlorophenolindophenol as an indicator (Kujawińska et al., 2022). The calculations were performed using the following formula:

$$A_k = \frac{0.088 \cdot a \cdot 10}{3}$$

where: A_k – vitamin C content in 1 g of sample (mg); a – volume of 0.0005 mol·L^{-1} 2,6-dichlorophenolindophenol solution used in titration; 0.088 – coefficient representing the amount of vitamin C equivalent to 1 mL of indicator; 10 – mass of extract; 3 – volume of filtrate used for titration

The retention of vitamin C was calculated using the formula:

$$P = \left(C_1/C_0\right) \times 100\%$$

where: P – percentage of vitamin C retention; C_0 – vitamin C content in untreated sample (mg·100^{-1} g of product); C_1 – vitamin C content after processing or storage (mg·100^{-1} g of product)

All experiments were performed in triplicate to ensure reliability of the results.

Statistical analysis

Statistical significance of differences in mean vitamin C content was determined using one-way analysis of variance (ANOVA). Differences were considered statistically significant at $p < 0.05$. Statistical analysis was performed using Microsoft Excel. Data are presented as mean ± standard deviation (SD). Standard deviation is shown in the text after the ± sign and in error bars on graphs.

Results and Discussion

Post-harvest processing and storage methods are known to significantly influence vitamin C stability in berry fruits. According to the obtained results, different methods of processing and storage had different effects on the content of vitamin C in *Rubus idaeus* fruits (Table 1).

It was determined that drying fruits at +40 °C is the most effective method for preserving vitamin C, as the loss of ascorbic acid was only 18.6% (Table 1). Under freezing at -17 °C 61.6 ±6.0 mg·100 g^{-1} of vitamin C content was preserved, which is better compared to drying at +60 °C, where the content decreased to 76.2 ±3.0 mg·100 g^{-1}. The greatest losses of vitamin C were recorded when boiling fruits with added sugar, where the ascorbic acid level decreased to 52.8 ±4.0 mg·100 g^{-1}. Thus, drying at +40 °C is the best method for preserving vitamin C among the traditional methods of fruit processing.

The study of the effect of chitosan edible coating on the preservation of vitamin C in raspberry fruits of the cultivar Polka significantly expanded understanding of the potential of natural biopolymers for preserving fresh products (Blahopoluchna and Liakhovska, 2021; Blahopoluchna et al., 2023). Chitosan, a natural polysaccharide obtained from chitin (a component of crustacean shells), shows great promise as a safe material for the manufacture of food packaging systems

Table 1 Indicators of the content of ascorbic acid (vitamin C) in fruits of the *Rubus idaeus* L. cultivar Polka depending on the storage methods

Method of storage and processing of drupelets	Vitamin C, mg·1 g^{-1}	Vitamin C, mg·100 g^{-1}
Drying at +40 °C	0.821 ±0.05	82.1 ±5.0
Drying at +60 °C	0.762 ±0.03	76.2 ±3.0
Freezing at -17 °C	0.616 ±0.06	61.6 ±6.0
Boiling with added sugar	0.528 ±0.04	52.8 ±4.0

Figure 1 Changes in the appearance of untreated (a, b) and chitosan-treated (c, d) fruits of *Rubus idaeus* L. on the first (a, c) and eighth (b, d) day

that should ensure long-term storage without loss of beneficial properties (Elieh-Ali-Komi and Hamblin, 2016).

Based on the results of experiments the high efficiency of using chitosan was confirmed in the preservation of freshness and nutritional value of raspberry fruits (Table 2).

In particular, raspberries coated with chitosan exhibited a significant reduction in fruit weight loss (by 1.2–2.5 times). The chitosan coating created an effective barrier that slowed moisture evaporation from the fruits, thus preserving them for a longer time. In addition, a significantly higher vitamin C content was recorded in fruits treated with chitosan compared to control samples. For example, on the third day of storage, the ascorbic acid content in the treated fruits was 1.2 times higher (1.418 ±0.02 mg·1 g^{-1}) than in the control (1.173 ±0.05 mg·1 g^{-1}). On the fifth day, the difference increased almost three times, and on the eighth day – up to 2.6 times (0.307 ±0.04 mg·1 g^{-1} in the treated ones versus 0.118 ±0.04 mg·1 g^{-1} in the untreated ones).

In addition, due to its antimicrobial properties, chitosan significantly reduced the development of microorganisms, in particular mold (Blahopoluchna and Liakhovska, 2021) (Figure 1), thereby providing additional protection for fruits and significantly extending their shelf life. This confirms that chitosan is not only an effective means for preserving nutritional value, but can also potentially be used to create safe, effective packaging for food products requiring long-term storage (Blahopoluchna and Liakhovska, 2021).

The amount of vitamin C (ascorbic acid) depends on many factors: growing conditions, ripeness of drupelets, temperature (Boissonneault, 2007), method, and storage time of fruits after harvest (Nejat and Mantri, 2017; Polishchuk et al., 2018).

As demonstrated in Figure 2, the amount of vitamin C (ascorbic acid) in this study varied from 82.1 ±5.0 to 52.8 ±4.0 m·100 g^{-1}. It was determined that the amount of vitamin C decreased by 2.8 times in dried fruits at a temperature of +40 °C, by 3.05 times in dried fruits at +60 °C, by 3.7 times in frozen fruits at -17 °C, and by 4.4 times in boiled fruits. According to the results of analysis, the best method of processing *Rubus idaeus* fruits is the method of drying common raspberry fruits at +40 °C, as at this temperature the amount of ascorbic acid suffers less loss resulting in 82.1 ±5.0 mg·100 g^{-1} of product. These data also indicate that the boiling method is an unreliable processing method, as the result is the lowest among all the methods – 52.8 ±4.0 mg·100 g^{-1} of product. Previous studies contain quantitative

Table 2 The effect of chitosan on the vitamin C content in *Rubus idaeus* L. fruits

Research day	Vitamin C content in control (mg)	Vitamin C content under chitosan treatment (mg)
Day 1	2.326 ±0.04	
Day 3	1.173 ±0.05	1.418 ±0.02
Day 5	0.287 ±0.03	0.619 ±0.05
Day 8	0.118 ±0.04	0.307 ±0.04

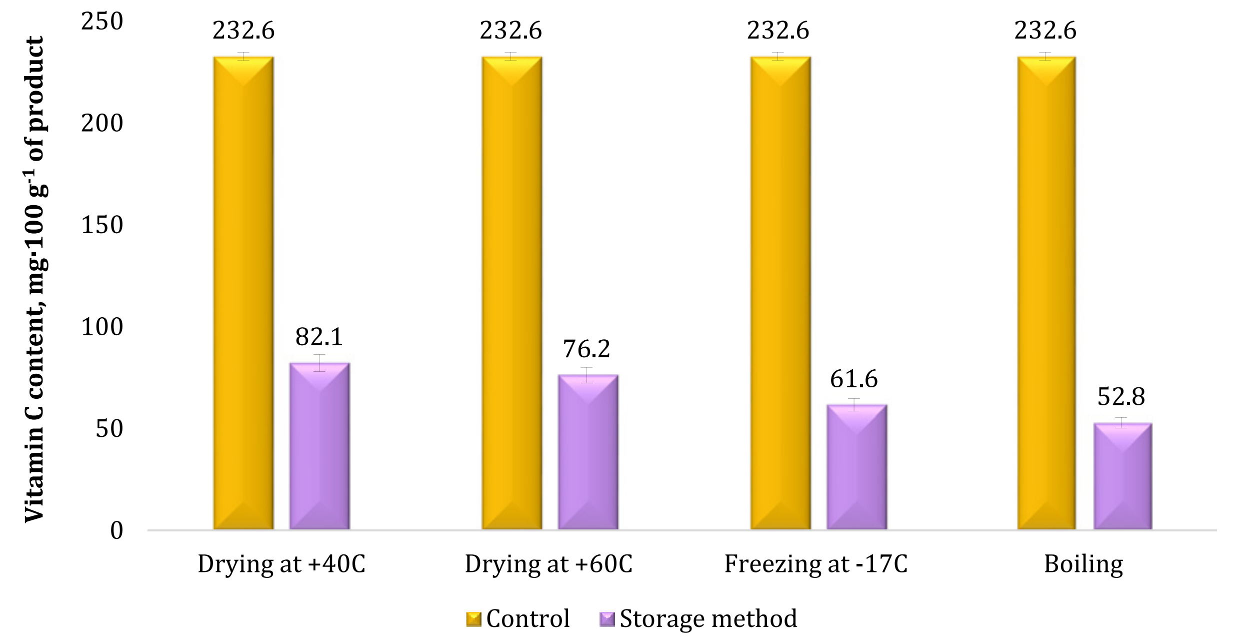

Figure 2 Comparison of the vitamin C content in fruits of *Rubus idaeus* L. cultivar Polka under different storage methods after 3 days of storage; in control – vitamin C content in fresh fruits

data on vitamin C content in raw fruits of the *Rubus idaeus* cultivar Polka, which is in agreement with our findings (Table 2). However, to our knowledge there is no data in the literature on vitamin C preservation in fruits of the *Rubus idaeus* cultivar Polka after drying, boiling, and freezing. According to the obtained results (Table 1, Figure 2), vitamin C content in raspberry fruits significantly decreases after such processing. Our results are supported by data in the literature (Bieniasz et al., 2017; Galani et al., 2017). For example, Bieniasz et al. (2017) observed a decrease in vitamin C content in *Chaenomeles japonica* fruits after boiling with sugar and freezing. Galani et al. (2017) reported losses of vitamin C in different fruits (*Malus domestica*, *Vitis vinifera*, *Citrus sinensis*, *Punica granatum*, etc) and vegetables (*Amaranthus hypochondriacus*, *Anethum graveolens*, *Trigonella foenum-graecum*, *Allium cepa*, etc) due to thermal degradation and enzymatic

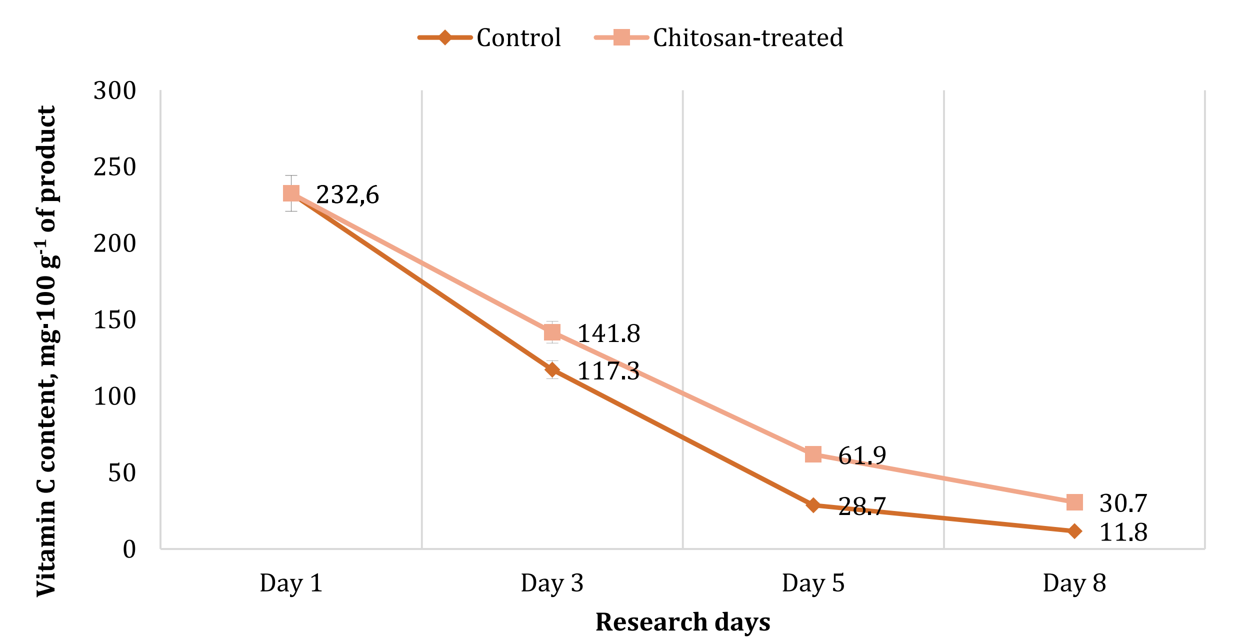

Figure 3 Losses of vitamin C (ascorbic acid) during storage in a refrigerator

oxidation. In view of these limitations of traditional processing techniques (drying, boiling, freezing), low-molecular-weight chitosan treatment is a promising alternative, especially for the preserving *Rubus idaeus* fruits, which are particularly sensitive to spoilage (Polishchuk et al., 2018). Due to its antimicrobial activity (Blahopoluchna and Liakhovska, 2021), biocompatibility, and ability to form edible films (Ali et al., 2022), chitosan has been actively investigated as a safe, environmentally friendly component for processing, storing, and extending the freshness of food products, particularly berries (Vasylyshyna, 2020; Blahopoluchna and Liakhovska, 2021; Blahopoluchna et al., 2023). Although Blahopoluchna et al. (2023) assessed the efficiency of chitosan in vitamin C preservation in *Rubus idaeus*, the effects of chitosan on vitamin C content have not been compared yet to the effects of traditional methods of storage.

As a result of experiments, it was determined that the amount of vitamin C decreased throughout the study in both control (untreated) samples and chitosan-treated fruits (Figure 3). At the end of storage, the losses of ordinary raspberries differed – the losses of control samples were 1.2–2.5 times higher than the losses of treated samples.

Storage time contributed to the reduction of ascorbic acid in *Rubus idaeus* fruits. According to the graph, it can be determined that fruits treated with chitosan retain not only their external qualities, but also the amount of vitamin C content for longer. On the third day of the study, the treated fruits had 1.2 times the vitamin content of the control samples. The indicators of the treated drupelets were 141.8 ±7.09 mg·100 g^{-1}, and the control 117.3 ±5.87 mg·100 g^{-1}. On the fifth day, the indicators decreased by 2.2–4.0 times in two days of storage in the refrigerator. The fruits treated with chitosan (61.9 ±3.09 mg·100 g^{-1}) exceeded the control fruits (28.7 ±1.44 mg·100 g^{-1}) by almost 3 times in the amount of vitamin C. On the eighth day of the experiment, mold began to appear on the fruits of *Rubus idaeus*, so the last samples were taken. At the end of the study, the indicators differed by 2.6 times between the control fruits and the treated samples. The control indicator was 30.7 ±1.54 mg·100 g^{-1}, and in those treated with chitosan film – 11.8 ±0.59 mg·100 g^{-1}. To determine whether chitosan treatment is a more efficient approach of vitamin C preservation than traditional drying, freezing, and boiling vitamin C content in *Rubus idaeus* cultivar Polka fruits was compared on the third day of storage under all conditions. It was found that on the third day of storage, vitamin C content in fruits after chitosan treatment (141.8 ±7.09 mg·100 g^{-1}) was significantly higher than in fruits after drying at +40 °C (82.1 ±5.0) or +60 °C (76.2 ±3.8), freezing at -17 °C (61.6 ±3.1), and boiling (52.8 ±2.6).

Conclusions

Chitosan treatment proved to be the most effective method for preserving vitamin C in *Rubus idaeus* fruits compared to traditional processing techniques. Although drying at +40 °C and freezing also help retain ascorbic acid, they are less efficient and do not prevent microbial spoilage. Drying at +60 °C and boiling caused the greatest losses of vitamin C due to thermal degradation. In addition, chitosan provided an additional antimicrobial effect, which contributed to better preservation of fruit quality during storage. Thus, chitosan can be considered a promising natural and environmentally friendly alternative for maintaining the nutritional value and freshness of raspberry fruits.

Conflict of interest

The authors have no competing interests to declare.

Ethical statement

This article doesn't contain any studies that would require an ethical statement.

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