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PRESERVING BELL PEPPER QUALITY THROUGH FREEZING BY ASSESSMENT OF PRE-TREATMENT CONDITIONS AND FREEZE- DRYING EFFECT

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Abstract

Bell peppers (Capsicum annuum) are a widely consumed vegetable; however, their highly perishable nature necessitates the implementation of preservation techniques to prolong their storage potential. This study sought to analyze and characterize the biochemical properties and freezing suitability of several bell pepper varieties, including Cantemir, Buzău 10, Arum, and Galben superior, which the Buzău Research and Development Station has approved for Vegetable Growing. This research endeavored to identify the bell pepper variety most suitable for long-term frozen preservation based on an evaluation of their physicochemical attributes. In order to determine the effect of the freezing process on the products, four sample variants were studied: fresh vegetables, immediately after harvesting; blanched vegetables; fresh vegetables, preserved by freezing and thawed at certain periods of time; blanched vegetables, preserved by freezing and thawed for certain periods of time. In this study, a series of analyzes and observations were conducted on the pepper fruits to assess various characteristics, such as humidity content, ascorbic acid content, total polyphenol content, acidity, and antioxidant activity at different maturity stages.

Key words*: bell pepper, varieties, freezing suitability, physicochemical properties.*

INTRODUCTION

To determine the effect of the freezing process on the products, four sample variants were studied: 1. Fresh vegetables, immediately after harvest; 2. Blanched vegetables; 3. Fresh vegetables, preserved by freezing and thawed at certain periods of time; 4. Blanched vegetables, preserved by freezing and thawed at certain periods of time. A series of analyses, biometric measurements and observations were carried out on pepper fruits, determining the following characteristics: humidity, total polyphenol content, acidity of the studied samples, determination of antioxidant activity at different degrees of maturity. In addition, observations were made in the crop regarding plant height, plant diameter, number of leaves/plant, leaf length, leaf width, number of buds, number of fruits, fruit length, fruit width, number of main branches, number of flowers and stem diameter. The results obtained revealed significant differences between varieties and treatments applied, with implications for the quality and durability of frozen peppers.

Bell pepper (*Capsicum annuum*) is an important vegetable, appreciated for its sweet taste and nutritional benefits. Freezing of vegetables is a widespread practice, but this process can influence the organoleptic characteristics and nutritional value of the final product. Thus, the aim of this study was to evaluate the effect of the freezing process on the quality of bell pepper varieties Cantemir, Buzău 10, Arum and Galben Superior, varieties approved by the Buzău Vegetable Research and Development Station (SCDL Buzău).

MATERIALS AND METHODS

The study was conducted during 2024-2025, within the Buzău Vegetable Research and Development Station and the Faculty of Biotechnology within the USAMV of Bucharest. To analyze the freezing suitability of peppers, four varieties of bell pepper (*Capsicum annuum* L.) were selected: Cantemir, Buzău 10, Arum and Galben Superior, all four varieties are approved by SCDL Buzău.

The varieties were cultivated in open fields, under agrotechnical conditions specific to the southeastern area of Romania. The cultivation technology included basic fertilization, drip irrigation, maintenance work and phytosanitary protection, according to current technological guides.

The fruits were harvested manually, when they reached commercial maturity, according to the standards specific to each variety. The samples were immediately transported to the laboratory, where they were sorted and prepared for the experiment.

VERDANT RED TWO-COLOURED

Figure 1. Appearance of Cantemir bell pepper variety

YELLOW TWO-COLOURED

Figure 2. Appearance of bell pepper variety Buzău 10

YELLOW

Figure 3. Appearance of the Yellow Superior bell pepper variety

RED

Figure 4. Appearance of Arum bell pepper variety

Freeze-drying preserved over 93% of the original polyphenol content in all varieties compared to the fresh sample. Also, antioxidant activity was significantly higher compared to frozen samples, indicating minimal degradation of phenolic compounds by this preservation method.

Freeze-drying, although a more expensive process than freezing, has shown significant advantages in preserving the nutritional and antioxidant value of bell peppers. Especially for varieties with high water content, such as Galben Superior, this method allowed for almost complete preservation of the initial biochemical profile. At the same time, the porous structure of the freeze-dried product favors rapid rehydration and maintenance of natural color, which makes it suitable for industrial applications or functional foods.

Experimental plan

To study the influence of freezing on the quality of bell peppers, four experimental variants were established for each variety:

1. **V1** – Fresh vegetables, analyzed immediately after harvest;
2. **V2** – Blanched vegetables (for 2 minutes in hot water at 95°C), then analyzed;
3. **V3** – Fresh vegetables, quickly frozen at -18°C, kept for 3 months, then slowly thawed under refrigeration conditions (+4°C);
4. **V4** – Blanched vegetables, frozen and stored at -18°C for 3 months, then thawed under the same conditions as in V3.

Freezing was performed by the quick-freezing method, using a forced-air freezer, to minimize the formation of large ice crystals that can affect the texture of the vegetable products. Thawing was performed slowly, in the refrigerator, to mimic home consumption conditions.

In addition to the freezing treatment variants, a fifth experimental variant was introduced for each variety studied:

V5 – Blanched vegetables, then freeze-dried

The freeze-drying process was carried out in a Labconco Freeze Dryer Freezone 2.5 laboratory freeze-drier

Labconco Freeze Dryer Freezone 2.5 at a pressure of 0.04 mbar and a shelf temperature of -50°C in the initial phase. The process took a total of 36 hours, until a constant mass was

reached. The fruits were cut into 1.5 cm cubes, after blanching (2 min, 95°C), to uniformize the drying.

Biochemical and physicochemical analyses

The following determinations were performed on samples taken from each variant:

- **Water content (%)**: determined by the oven drying method (105°C for 24 hours), calculating the difference between the initial mass and the mass of the dried sample.
- **Total polyphenol content (mg GAE/100 g)**: determined by the Folin- Ciocalteu method, using gallic acid as standard.
- **Total titratable acidity (g citric acid/100 g):** determined by titration with 0.1 N NaOH solution, to pH 8.1.
- **Antioxidant activity (% DPPH inhibition)**: analyzed by the DPPH method, expressed as percentage of free radical inhibition compared to a blank control.

Each analysis was performed in triplicate to ensure data accuracy.

Morphological and biometric determinations

In culture, observations and measurements were carried out on a sample of 10 plants for eachvariety, determining the following parameters:

- Plant height (cm)
- Plant diameter (cm)
- Number of leaves/plant
- Leaf length and width (cm)
- Number of buds and flowers/plant
- Number of fruits/plant
- Fruit length and width (cm)
- Stem diameter (mm)
- Number of main branches

The determinations were performed with standard laboratory instruments (millimeter ruler, electronic caliper, analytical balance, pH meter, UV-Vis spectrophotometer, etc.).

Statistical data processing

The results were statistically analyzed using Microsoft Excel, applying analysis of variance (ANOVA) to highlight significant differences etween varieties and treatments. Statistically significant differences were interpreted at a significance level of $p < 0.05$.

For each treatment variant, physicochemical and organoleptic analyses were performed. These included determination of moisture, total polyphenol content, acidity and antioxidant activity. In addition, biometric measurements of the plants and observations of the morphological characteristics of the fruits (length, width, number of fruits, stem diameter) were performed.

Parameters evaluated

For each variety studied, the following traits were analyzed:

- **Humidity**: determined by the gravimetric method to evaluate water losses during freezing and thawing.
- **Total polyphenol content**: measured by UV-Vis spectrophotometry, with the aim of evaluating the antioxidant power of peppers.
- **Acidity**: determined by titration, to evaluate pH changes during the freezing and thawing process.
- **Antioxidant activity**: evaluated using the DPPH (2,2-diphenyl-1- picrylhydrazyl) method, to understand the impact of processing on cellular protection.

In addition to these chemical analyses, biometric measurements and observations of the plants were also carried out, considering characteristics such as plant height, number of leaves, leaf size, number of buds and fruits, as well as aspects related to the main branches and flowers of the plant.

RESULTS AND DISCUSSIONS

The results showed that, regardless of the variety studied, freezing of vegetables led to a significant decrease in water content and changes in texture, especially in the case of samples that were repeatedly frozen and thawed. The Buzău 10 variety showed greater resistance to these changes, maintaining better consistency and nutritional value after freezing. In terms of antioxidant activity, blanched peppers retained a higher level of phenolic compounds than unblanched ones, suggesting that blanching is a beneficial process in preserving antioxidant properties.

Morphological analysis showed significant differences between varieties in terms of fruit size and vegetative development of plants. The Cantemir variety stood out with a higher fruit production, while Galben Superior had larger fruits but a lower number. Also, all varieties showed a significant increase in the main branches and the number of flowers in favorable growing conditions.

Interpretation of results:

-The average values obtained were compared between varieties and between treatments to highlight the influence of the freezing and blanching process on the physicochemical and nutritional characteristics of the fruits.

- Values marked with different letters in the resulting tables indicate statistically significant differences ($p < 0.05$) between treatments or varieties.

- The results obtained are consistent with the literature, supporting the hypothesis that heat treatment (blanching) followed by freezing has a beneficial role in maintaining antioxidant activity and fruit structure in some varieties.

- Freeze-drying produced visible changes in the physical structure of the fruits, but allowed for optimal preservation of bioactive compounds, especially in the Cantemir and Galben Superior varieties.

Table 1. Total polyphenol content (mg GAE/100 g dry product)

Variety	**V1 (Fresh)**	**V4 (Frozen + blanched)**	**V5 (Blanched + freeze- dried)**
Cantemir	95.2 ±2.1	82.4 ± 3.0	**90.5 ± 1.7**
Buzau 10	88.9 ±1.9	79.1 ± 2.8	**86.3 ± 2.1**
Arum	93.5 ±2.4	81.7 ± 2.5	**89.0 ± 1.5**
Yellow Superior	96.8 ±1.8	83.6 ± 3.1	**94.7 ± 1.9**

Table 2. Antioxidant activity (% DPPH inhibition)

Variety	**V1 (Fresh)**	**V4 (Frozen + blanched)**	**V5 (Lyophilized)**
Cantemir	72.1 ±2.2	60.8 ± 2.5	**70.2 ± 1.6**
Yellow Superior	74.5 ±1.9	63.3 ± 3.0	**73.1 ± 1.7**

CONCLUSIONS

Freezing vegetables is an effective method of preservation, but its effects on quality and nutritional properties vary depending on the variety and treatments applied. Following the research, the varieties Buzău 10 and Arum demonstrated the best results in terms of preserving quality and nutrient content after freezing. The study suggests that blanching before freezing and observing optimal thawing periods can significantly contribute to preserving the biochemical properties of bell peppers.

Freeze-drying has been shown to be a superior preservation method compared to freezing, preserving a higher proportion of phenolic compounds and antioxidant activity. Thus, for premium products or products destined for the specialized food industry, freeze-drying could represent a valuable alternative to freezing, especially for varieties sensitive to thawing.

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