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Professional paper

SOME QUALITY AND NUTRITIONAL PROPERTIES OF FRESH AND FROZEN PLUMS

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Abstract

To prolong the shelf life of fresh plums, the process of freezing as an efficient preserving method can be applied. The fresh plums as a raw material intended for processing must met some certain quality requirements, which are important for the quality of the final product.
In this study were used two plums varieties, *stanley* and *chachanska rodna*, to determine some of their quality and nutritional properties. Then were applied different pretreatments with technological process of freezing, to assess how these methods have impact of the analyzed parameters. The main aim of this research is to assess which of plum variety have better quality and nutritional properties as a raw material for process of freezing. After analysis of fresh and frozen plums, for both varieties were estimated how the quality and nutritional parameters were changed after some storage time. According to the results of mechanical properties, the variety *chachanska rodna* had higher production yields (96.3 %). The variety *stanley* had higher content of total dry matters. The highest average values for the content of total polyphenols (131.08 mg/100 g), total flavonoids (76.02 mg/100 g) and total anthocyanins (8.36 mg/100 g) were determined in the *chachanska* rodna variety.
In terms of the obtained results, it was confirmed that the both varieties *chachanska rodna* and *stanley* have good quality and nutritional characteristics, they are suitable for preservation by freezing. For that purpose, it is important to provide that the technological process, as well as the method of storage, has been properly conducted.

Keywords: plums varieties, freezing, quality, nutritional properties

Introduction

The plum (*Prunus domestica* L.) is a highly productive fruit species that is of great importance for fruit production in the Republic of North Macedonia. In terms of number of trees and production, plum is our most widespread and important fruit crop, ranking second, right after the apple. In our country, plum production ranges from 10 to 15 thousand tons per year. The quality plum fruits are used as an extra class for fresh consumption and achieve a high price, both in our and in the foreign market. Other classes of plum fruits are used for industrial processing: marmalade, jam, frozen, dried, strong alcoholic beverages, etc. Most of the plum fruits are used for the production of plum rakija (about 65 %), for fresh consumption about 8 %, for the production of dried plums about 4 %, for the production of jam under 2 %, and for other plum products 21 % is used (Vlahović, 2003).
Since fresh plums are easily perishable, applying a preservation method as freezing, extends their useful value and allows them to be present on the market throughout the year. The fruits of plum intended for processing, must be met certain requirements regarding its quality as a raw material, because the quality of the final product depends on the quality of the fresh raw material (Niketić-Aleksić,1994).
The physical properties of plums are important for design of equipment for processing, transportation, sorting, separating and also packing. If the used system had been designed without taking these criteria into consideration, the results in a reduction in work efficiency, an

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increase in product loss. Also, for processing are important the pomological and nutritional properties of fruits of plums (Ertekin et al., 2006).
Plum fruits have a low caloric value, but relatively high nutritional value. They are a rich source of carbohydrates, organic acids, pectin, nitrogen, vitamins and minerals and other biochemical compounds. The quantitative and qualitative composition of soluble dry matter is considered an indicator of fruit quality and degree of maturity. The sensory properties of plum fruits are determined based on the content of sugar, organic acids, tannins, aromatic substances, anthocyanins and other compounds. Ripe fruits are a good energy source in the diet, and they also possess dietary and therapeutic properties (Veličković 2002; Walkowiak-Tomczak et al., 2008, Karakashova i sar., 2020).
During the freezing process, the temperature of the product being decrease, causing the water in the cells to turn into a solid aggregate state (ice). This causes a cessation of chemical and biochemical reactions in plant tissue, i.e. enzymatic activity, and creating unfavorable conditions for growth, development and reproduction for microorganisms (Vračar, 2012). To avoid negative effects of freezing, the process is carried out in such a way that the product is quickly frozen at a temperature of - 30 °C or lower, and stored, transported or marketed at a temperature of - 18 °C (Lembaša–Belak i sar., 2006).
The quality and time of storage of a final product, frozen plums, depends on the nature and quality of the raw material used for freezing, the preparation and manner in which the freezing process is performed, the manner and type of packaging used for the final frozen product (PPP factors – product, process, packaging), the temperature of storage on the frozen product, as well as the duration of the storage itself (TTT factors – time, temperature, tolerance) (Hui et al., 2004).
In this research were determine the technological and nutritional properties of the two plum varieties (*chachanska rodna* and *stanley*) to gained knowledge which of the selected variety has better suitable properties for freezing in order to obtain a quality final product. Also, in the purpose was to determine the influence of the way of treatment with citric and ascorbic acid, as well the storage period in a refrigerator at a temperature of - 18 °C, on the nutritional properties of frozen plum fruits of both varieties.

Materials and methods

In this paper as a material for the research were used two varieties fruits of plums *stenlay* and *chachanska rodna*, which were in appropriate health condition and harvested at their technological maturity. The variety *stenlay* originates from the USA. It ripens in the second half of August and the beginning of September. The fruit of plum is large, with about 28 - 36 g. The color of the skin is dark blue and almost black. The mesocarp is green-yellow, juicy and firm, with sweet taste. The stone is partially separated from the mesocarp. A varietal defect is the appearance of double fruits-twins. It tolerates well transportation, unless it is overripe. It is suitable for different ways of processing (Mišić, 1979; Niketić-Aleksić, 1994; Veličković, 2002).
The fruit of plum variety *chachanska rodna* ripens in the third decade of August, almost at the same time as the *stanley* variety. The fruit is medium to large (28 to 42 g), ovoid, dark blue and with attractive appearance. The mesocarp is yellowish, firm, medium juicy, aromatic and sweet. The stone is easily separated from the mesocarp. The plum fruit has a wide range of uses (Mišić, 1979; Veličković, 2002).
The fruits of plums, varieties *chachanska rodna* and *stanley* were manually harvested at a technological maturity of 70 to 75 %. A selective harvest was performed in order the fruits to be of approximately the same size and shape. For both varieties of fresh plums, the mechanical and chemical properties were analyzed to determine their quality and nutritional properties.

Before the freezing process, by random 30 fresh fruits of plums were selected from each variety and the following parameters were analyzed: the dimensions of the fruits (length, width and thickness) by a manual caliper with a precision of 0.01 mm; the mass of the fruit and the mass of the stone by using an analytical balance, with a precision of 0.01 g; the yield (%) was determined as the portion of the mass of the mesocarp in the mass of the plum fruit.
After the harvest, the fresh plum fruits were transported at the production plant, where were performed the following processing phases: inspection, washing, calibration, pitting (manually with a knife), treatment, freezing, packing and storage. In the phase of treatment, one part of the plum fruits was treated with a 0.2 % solution of citric and ascorbic acid (100 g citric acid and 100 g ascorbic acid/100 L water) to prevent oxidative processes (darkening of the mesocarp and loss of plant pigments). The other part of the plum fruits was used in the research as a control, without treatment. The process of freezing of the plum fruits was performed at a temperature of -38 °C, in a conveyor belt tunnel (fluidizer) for 15 minutes. The frozen plum fruits were packed in polyethylene bags, then in 10 kg cardboard boxes, which were appropriately closed, labeled and stored at temperature -18 °C.
Chemical analyses were performed in order to analyze certain parameters, based on which the quality and nutritional properties of both fresh and frozen fruits of the two plum varieties were determined. The frozen plums were analyzed immediately after freezing (1) and three months after freezing (2) with two variants: untreated (NT) and treated (T). The following samples marks were used for analysis: (VNT1) untreated variant (control) immediately after freezing; (VT1) treated variant immediately after freezing; (VNT2) untreated variant (control) three months after freezing and (VT2) treated variant three months after freezing.
Various standard laboratory methods were applied to determine the following parameters:

- total dry matter, in a drying oven at a temperature of 105 °C;
- total sugars by Luff-School method;
- total acids, by using the titrimetric method;
- total mineral matter (ash) by burning at a temperature of 550 °C, (Vračar, 2001);
- vitamin C was determined by 0.1 N solution of I_2 and 1 % starch solution (Famakopeja, 1984);
- total plant pigments, the measurements were performed after extraction with a mixture of methanol/water/HCl in the ratio 80:20:1 (*V*:*V*:*V*), using routine spectrophotometric methods for the determination of:

a) total polyphenols (with Folin-Ciocalteu reagent) expressed as gallic acid, the quantitative determination of the content of total polyphenolic compounds in plums was performed according to the method of Gadzovska et al. (2012);
b) total flavonoids (with $AlCl_3$) expressed as catechin, the quantitative determination of the content of flavonoids in plums is described in the paper of Macris et al., (2007);
c) total anthocyanins expressed by cyanidin glucoside, the quantitative determination of the content of total anthocyanins in plums was made by measuring the absorbance of a diluted extract (300 μL with 700 μL of methanol containing 1% HCl) at a wavelength of 530 nm (Macris et al., 2007);
The obtained results were statistically processed by using analysis of variance (ANOVA), and the statistic significant differences were tested with the LSD test at a probability level of P = 0.05 and P = 0.01 using the R Core Team 3.3.1 statistical package.

Results and discussion

Morphometric characteristics of fresh plum fruits – according to the morphometric measurements of fresh plum fruits of the varieties *stenlay* and *chachanska rodna*, the obtained results for mass (g) and dimensions of fresh plums (mm) are present in Table 1 and Table 2.

From the Table 1, the both varieties were characterized by large fruits, from 40.10 g for *chachanska rodna* and 43.30 g for *stanley*. The masses of stone were from 1.50 g for *chachanska rodna* and 2.00 g for *stanley*, what indicate that the variety *stanley* had larger stone mass. Therefore, the yield of plum fruits was higher (96.30 %) for variety *chachanska rodna* then the yield (95.40 %) the for variety *stanley*.
In the Table 2 are presented the results obtained from the dimension measurements of the fresh plum fruits for both varieties.

Table 1. Mass of fresh plum fruits, mass of stone (g) and yield (%) for both varieties

Variety	**Plum mass (g)**	**Stone mass (g)**	**Yield (%)**
Chachanska rodna	40.10	1.50	**96.30**
Stenlay	**43.30**	**2.00**	95.40
Mean ($\bar{X}$)	41.7	1.75	95.9
Standard deviation (SD)	2.3	0.4	0.6
Coefficient of variation (CV)	5.4	20.2	0.7
Error of the mean ($S\bar{X}$)	1.6	0.3	0.5

The results presented in the Table 2 shows that the variety *chachanska rodna* had the higher average values for width (41.50 mm) and for thickness (39.70 mm) of the plum fruits. On the other hand, the variety *stenlay* had the higher average value for length (52.30 mm) of the plum fruits.

Table 2. Dimensions (length, width and thickness) of the fresh plum fruits for both varieties (mm)

Variety	***Chachanska rodna***			***Stenlay***		
Sample (n = 30)	**length**	**width**	**thickness**	**length**	**width**	**thickness**
Mean ($\bar{X}$)	51.00	**41.50**	**39.70**	**52.30**	39.10	37.70
Error of the mean ($S\bar{X}$)	0.83	0.60	0.33	1.01	0.55	0.56
Coefficient of variation (CV)	5.15	4.58	2.67	6.12	4.42	4.69
Standard deviation (SD)	2.62	1.90	1.06	3.20	1.73	1.77
Minimum (mm)	48.01	40.02	38.03	46.00	36.03	35.04
Maximum (mm)	56.02	45.00	42.01	56.04	41.00	40.01

Quality and nutritional properties of fresh plum fruits – the results of analysis for the parameters in fresh plum fruits for both varieties are given in Table 3 and Table 4, where was determined that the content of total dry matter ranges from 17.00 % in the variety *chachanska rodna* up to 20.10 % in the variety *stenlay*. Accordingly, the content of total sugars ranges from 14.20 % in the variety *chachanska rodna* up to 15.10 % in the variety *stenlay*.

Table 3. Quality and nutritional properties of fresh plum fruits for both varieties (1)

Plum fruits	Total dry matters (%)	Total sugars (%)	Total acids (%)	Total ash (%)	Vitamin C (mg/100 g)
Chachanska rodna	17.00	14.20	**0.72**	0.80	**7.10**
Stenlay	**20.10**	**15.10**	0.54	**0.90**	6.60
Mean ($\bar{X}$)	18.55	14.65	0.63	0.85	6.85
Standard deviation (SD)	2.19	0.64	0.13	0.07	0.35
Coefficient of variation (CV)	11.81	4.34	20.16	8.35	5.17
Error of the mean ($S\bar{X}$)	1.55	0.45	0.09	0.05	0.25

The average value of the total acids for the variety *chachanska rodna* was 0.72 % and for the variety *stenlay* was 0.54 %. The average value for total ash was lower in the variety *chachanska rodna* (0.80 %) than in the variety *stenlay* (0.90 %). The content of vitamin C was determined in the range from 6.60 mg/100 g in the variety *stenlay* up to 7.10 mg/100 g the variety *chachanska rodna.*

In the Table 4 are presented the obtained average results for total polyphenols, total flavonoids and total anthocyanins, as nutritionally important bioactive components. The variety *chachanska rodna* had higher average values for total polyphenols (98.8 mg/100 g), total flavonoids (68.60 mg/100 g) and total anthocyanins (14.90 mg/100 g). For the variety *stenlay* these average values were lower: total polyphenols 80.90 mg/100 g, total flavonoids 49.20 mg/100 g and total anthocyanins 9.90 mg/100 g. Statistical analysis of the obtained results for the content of total polyphenols, total flavonoids and total anthocyanins in fresh plum fruits of the both analyzed varieties showed that there were statistically significant differences between their average values ($p > 0.05$).

Table 4. Quality and nutritional properties of fresh plum fruits for both varieties (2)

Variety	Total polyphenols (mg/100 g)	total flavonoids (mg/100 g)	total anthocyanins (mg/100 g)
Chachanska rodna	**98.80 a***	**68.60 a****	**14.90 a*****
Stenlay	80.90 b	49.20 b	9.90 b
Mean ($\bar{X}$)	89.85	58.90	12.40

*values marked with different letters are statistically significantly different when compared with $LSD_{0.05}$ for total phenolics,

** values marked with different letters are statistically significantly different when compared with $LSD_{0.05}$ for total flavonoids,

*** values marked with different letters are statistically significantly different when compared with $LSD_{0.05}$ for total anthocyanins

Comparing with other researches, there are differences in morphometric measurements and chemical analysis made by other authors, which occur as a result of different climatic and soil conditions for growing plums, the application of agrotechnical measures, irrigation, and etc.

Quality and nutritional properties of frozen plum fruits – after process of freezing and three months later, the analysis were made on the both variants of frozen plum, treated and untreated. In the table 5 are presented the obtained results, to be compared the exanimated parameters of quality and nutritional properties of fresh and frozen plum varieties, treated and untreated.

For the variety *chachanska rodna*, comparing the obtained results for the dry total matter content in fresh plum fruits with the total dry matters for frozen variants, the lowest value was determined in the untreated variant (control) immediately after freezing (VNT1 = 14.5 %), what is decreasing in the value by 15 %. The highest value for total dry matters was in the treated variant three months after freezing (VT2 = 18.60 %), what is increasing in the value by 9 %. Comparing the obtained results for the variety *stanlay* in terms of total dry matters in fresh plum fruits, the lowest value was found in treated variant three months after freezing (VT2 = 18.90), what is decreasing of 6 % and the highest value was found in the untreated variant (control) immediately after freezing (VNT1 = 21.90 %), what is increasing of 9 %.
In terms of total sugars for the variety *chachanska rodna*, comparing the data results for fresh and all frozen plum frits variants was noted decreasing of 13 % in the untreated variant (control) immediately after freezing (VNT1 = 12.40 %) and increasing of 22 % in the untreated variant (control) immediately after freezing (VNT1 = 17,40 %). For the variety *stenlay*, comparing the data results for fresh and all frozen plum frits variants was noted decreasing of 9 % in the untreated variant (control) immediately after freezing (VNT1 = 13.7 %) and increasing of 11 % in the untreated variant (control) three months after freezing (VNT2 = 16.8 %).
Comparing the obtained results for total acids in fresh and all frozen plum frits variants for the variety *chachanska rodna*, was found decreasing of 7 % in the untreated variant (control) three months after freezing (VNT2 = 0.67 %) and increasing of 14 % in treated variant three months after freezing (VT2 = 0.82 %). For the variety *stenlay*, comparing the data results for fresh and all frozen plum frits variants was found lowest increasing of 15 % in the untreated variant (control) immediately after freezing (VNT1 = 0.62 %) and highest increasing of 39 % in treated variant three months after freezing (VT2 = 0.75 %).

Table 5. Comparison of quality and nutritional properties on fresh and all variants of frozen plums, treated and untreated, for both varieties

	Variety	**Fresh plum fruits**	**Frozen plum fruits variants**			
			VNT1	**VT1**	**VNT2**	**VT2**
Total dry matters (%)	***Chachanska rodna***	**17.00**	14.50	18.40	17.30	18.60
	Stenlay	**20.10**	21.90	21.60	20.50	18.90
Total sugars (%)	***Chachanska rodna***	**14.20**	12.40	15.10	16.00	17.40
	Stenlay	**15.10**	13.70	15.10	16.80	15.40
Total acids (%)	***Chachanska rodna***	**0.72**	0.70	0.80	0.67	0.82
	Stenlay	**0.54**	0.62	0.71	0.63	0.75
Total ash (%)	***Chachanska rodna***	**0.80**	0.80	0.50	0.40	0.30
	Stenlay	**0.90**	0.70	0.60	0.60	0.50
Vitamin C (mg/100 g)	***Chachanska rodna***	**7.10**	2.80	4.10	1.90	2.30
	Stenlay	**6.60**	2.70	5.00	1.60	2.50
Total polyphenols (mg/100 g)	***Chachanska rodna***	**98.80**	112.40	118.40	159.90	165.90
	Stenlay	**80.90**	82.20	89.30	91.20	97.60
Total flavonoids (mg/100 g)	***Chachanska rodna***	**68.60**	76.11	80.40	77.20	77.80
	Stenlay	**49.20**	51.80	60.30	52.80	63.00

Total anthocyanins (mg/100 g)	***Chachanska rodna***	**14.90**	5.60	9.40	2.80	11.10
	Stenlay	**9.90**	4.20	7.20	2.60	2.90

VNT1 – untreated variant (control) immediately after freezing; VT1 – treated variant immediately after freezing; VNT2 – untreated variant (control) three months after freezing; VT2 – treated variant three months after freezing.

The obtained results for total ash in the variety *chachanska rodna*, in fresh and all frozen plum frits variants, shows decreasing of 62 % in treated variant three months after freezing (VT2 = 0.30 %) and same value in the untreated variant (control) immediately after freezing (VNT1 = 0.80 %). In the variety *stenlay*, the value for total ash the most decreased of 44 % was noted in treated variant three months after freezing (VT2 = 0.5 %) and lower decreasing of 23 % in the untreated variant (control) immediately after freezing (VNT1 = 0.7 %).

The other obtained results according to the bioactive nutritional components that were analyzed in this research, as in fresh as well in variants of frozen plum fruits for both varieties also are presented in the Table 5. The variety *chachanska rodna* had have higher content of vitamin C, total polyphenols, total flavonoids and total anthocyanins in fresh and all frozen variants. The content of the vitamin C had lowest value in the untreated variant (control) three months after freezing (VNT2 = 1.90 mg/100 g), what is decreasing of 73 % compering the value in the fresh plum fruit variety *chachanska rodna*. The highest value had the treated variant immediately after freezing (VT1 = 4.1 mg/100 g) what is decreasing of 42 % compering the value in the fresh plum fruit. Compering the value of the total polyphenols in fresh plum fruit, it was noted the lowest increase of 14 % in the untreated variant (control) immediately after freezing (VNT1 = 112.40 mg/100 g) and the highest increase of 68 % in the treated variant three months after freezing (VT2 = 165.9 mg/100 g). The results obtained for total flavonoids showed the lowest increase of 11 % in the untreated variant (control) immediately after freezing (VNT1 = 76.1 mg/100 g) and highest increase of 17 % in the treated variant immediately after freezing (VT1 = 80.4 mg/100 g), comparing to the fresh plum fruit. By analysis of total anthocyanins was determined the highest decreasing of 81 % in the untreated variant (control) three months after freezing (VNT2 = 2.8 mg/100 g) and the lowest decreasing of 26 % in the treated variant three months after freezing (VT2 = 11.10 mg/100 g), comparing to the fresh plum fruit.

According to the results from the analysis of the variety *stenlay*, in fresh and all frozen variants, was noted that the content of vitamin C mostly decreased (76 %) in the untreated variant (control) three months after freezing (VNT2 = 1.60 mg/100 g) and lower decreasing (24 %) was noted in the treated variant immediately after freezing (VT1 = 5.00 mg/100 g). The obtained values for total polyphenols showed lowest increasing of 2 % in the untreated variant (control) immediately after freezing (VNT1 = 82.20 mg/100 g) and highest increasing of 21 % in the treated variant three months after freezing (VT2 = 97.6 mg/100 g), comparing to the fresh plum fruit.

For the content od total flavonoids was determined lower increasing of 5 % in the untreated variant (control) immediately after freezing (VNT1 = 51.8 mg/100 g) comparing to the fresh plum fruit and higher increasing of 28 % in the treated variant three months after freezing (VT2 = 63.00 mg/100 g). By comparing the obtained values for total anthocyanins in the fresh plum fruit, was determined the highest decreasing of 74 % in the untreated variant (control) three months after freezing (VNT2 = 2.6 mg/100 g) and the lowest decreasing of 27 % in the treated variant immediately after freezing (VT1 = 7.20 mg/100 g).

Conclusions

Based on the results obtained in this research, for the quality and nutritional properties of fresh plum fruits had shown that the both varieties *chachanska rodna* and *stenlay* were characterized by large fruits. The average values for the mass of the fruit were range from 40.1 g for the variety *chachanska rodna* up to 43.3 g for the variety *stenlay*. The both varieties had a high yield, from 95.4 % for the variety *stanley* up to 96.3 % for the variety *chachanska rodna*. The variety *stenlay* was characterized by higher values for: total dry matter 23.6 %; total sugars 15.1 % and total ash 0.9 %. The variety *chachanska rodna* was characterized by higher values for: total acids (0.72 %); vitamin C (7.1 mg/100 g); total polyphenols (98.8 mg/100g); total flavonoids (68.6 mg/100 g); total anthocyanins (14.9 mg/100 g).

According to the performed analysis on the quality and nutritional properties of all frozen variants, with or without treatment, after freezing and three months after freezing, on the both varieties *chachanska rodna* and *stenlay*, was concluded that the average values for the content of total dry matter, total acids and total mineral substances showed a significant statistical difference between the controls and the treated variants. Significant statistical differences for the content of total sugars were not found between the varieties *chachanska rodna* and *stenlay* in the treated variant immediately after freezing (VT1) and in fresh plum fruits. Also, significant statistical difference was found for the content of vitamin C and total anthocyanins between all frozen variants, where the higher average values being found in the treated variants of the analyzed varieties of *chachanska rodna* and *stenlay*. The average values for the content of total polyphenols are highest in the treated variants of the both analyzed varieties, three months after freezing. The variety *chachanska rodna* in all variants were characterized by the highest average values for the content of total flavonoids.

In accordance of these conclusions, it can be recommended that the analyzed varieties *chachanska rodna* and *stenlay* are suitable for freezing, due the both varieties had appropriate characteristics in terms of quality and nutritional properties. Also, the treatment with 0.2 % solution of citric and ascorbic acid before freezing of fresh plum fruits had a positive effect on preserving the quality and nutritional properties, therefore it is recommending this method of preparing the plum fruits for freezing to be used at the processing facilities.

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