Quality of prunes obtained from new plum cultivars created in Čačak

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Abstract

The paper presents the most significant fresh fruit characteristics in new plum cultivars created at the Fruit Research Institute in Čačak, Serbia, intended for the production of prunes ('Nada', 'Krina', and 'Mildora', and 'Čačanska Rodna' as the standard cultivar). Drying was performed using fruits of optimum ripeness level using the experimental dryer at 90°C air temperature. The tested parameters of prune quality included the sugar content, acid content, and the sugar-acid ratio, as well as the organoleptic characteristics (appearance, flavour, aroma, and consistency). Contents of phenolic components in fruits were also determined, including rutin, neochlorogenic acid, chlorogenic acid, caffeic acid, protocatechuic acid, gallic acid, and cyanidin. All of the examined cultivars are conducive to prune production, despite the differences in chemical composition, organoleptic evaluation and contents of phenolic compounds. The colour of the prunes ranged from amber ('Mildora' cultivar) to black ('Nada' cultivar), which is interesting from the aspect of different consumers' tastes. The organoleptic evaluation of the prunes ranged from 17.02 ('Krina' cultivar) to 18.88 ('Čačanska Rodna' cultivar), which is primarily determined by the different values of the sugar-acid ratio and different phenolics contents.

Keywords: *Prunus domestica*, chemical composition, sugar-acid ratio, phenolic content

INTRODUCTION

European plum (*Prunus domestica* L.) is widely considered as Serbia's national fruit and dominates the fruit production in Serbia both in the number of trees and in annual volume of production, largely contributing to the country's high rank among the world's leaders in plum production. Autochthonous plum cultivars are mostly cultivated in extensive cultivation conditions (Milošević et al., 2010, 2014), constituting a suitable base for plum brandy production (Popović et al., 2015). Occupying a significant share in the overall production, table plum cultivars (Milatović et al., 2011; Miletić et al., 2011) are grown exclusively in intensive plantations in order to achieve the quality requirements for fresh consumption and a better price in the market. Considering, however, the relatively low consumption of plum in Serbia, Nenadović-Mratinić et al. (2007) pointed out that the production of typical table plum cultivars entails considerable risks. To overcome the problem of low demand on the fresh plums market, they recommended that growers consider cultivating cultivars of combined traits instead, enabling the use of the fruits for both fresh consumption and processing.

In recent years, several plum cultivars with combined-features have been created at the Fruit Research Institute in Čačak, which can be used for different types of processing. From the aspect of nutrition value, the most important plum product is the prune. It represents a highly nutritious food that gives a considerable source of energy and is as a source of important phenolic components acting as anti-oxidants (Donovan et al., 1998; Del Caro et al., 2004; Jabeen and Aslam, 2011). Prunes have to fulfil organoleptic criteria to meet the customers' expectations: they should have a harmonious taste and pleasantly pronounced aroma, balanced skin overcolour, and fruits should be even in size (Barbanti et al., 1994; Mitrović et al., 2016). For these aims to be reached, prunes are typically obtained from late-ripening plum cultivars with dark blue or violet-blue oval fruits and a favourable sugar/acid

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ratio (Crisosto et al., 2007).

The aim of this study is to present the quality of prunes obtained from new plum cultivars, which can be recommended for drying based on the characteristics of their fresh fruits.

MATERIALS AND METHODS

Plum fruits of optimum ripeness were used for the study purposes, collected from intensive plum plantations subjected to regular agro- and pomo-technical measures typically used for this type of fruit. The cultivars used in the study were 'Čačanska Rodna', 'Mildora', and 'Krina', grown at Zdravljak (near Čačak), as well as the 'Nada' cultivar collected at Stapari (near Valjevo). The fruits of the 'Čačanska Rodna' and 'Nada' cultivars are characterised by blue and dark blue skin colour, typical for many European plum cultivars, whereas the fruits belonging to the 'Krina' and 'Mildora' plum cultivars have a violet-blue and red skin colour.

The drying was conducted in a laboratory convective air dryer (Kandić et al., 2006). Fresh fruits with stones of uniform size and maturity were placed on a tray. The air dryer could accommodate six trays, with pre-heated air of defined characteristics streaming through the trays. Fruits of the above-mentioned plum cultivars were placed on two symmetrically laid trays, ensuring uniform drying conditions, as the direction of the vertical airflow was alternated in 60 min intervals. The predetermined air-drying temperature in our trials was 90°C and it was maintained throughout the drying process along with air velocity of 1 m s^{-1}. During the drying process, moisture losses from plum fruits were recorded at 60 min intervals by a digital balance. Drying was terminated when the dry matter content of the samples was about 75%. The initial dry matter of fresh plum fruits and final dry matter of prunes were determined by the standard method (drying at 105°C until the constant mass was reached). The prunes were not used immediately upon drying but had to be conditioned at room temperature in order to level the moisture content of the fruit (Zlatković, 2003). For this, dried fruits were packed in a plastic bag and maintained at room temperature for two months until the analyses.

The total soluble solids content (TSS) of the fruit was determined by a manual refractometer (3828, Carl Zeiss, Oberkochen, Germany). Titratable acidity (TA) was determined by neutralization with 0.1 N NaOH to pH 8.2, using phenolphthalein as indicator and expressed as malic acid, whereas the pH value was determined using a potentiometer (pH metre Mettler Toledo EL 20-Basic, Schwerzenbach, Switzerland). Sucrose, inverted sugars, and total sugar content were determined by the Luff-Schoorl method (Tanner and Brunner, 1979).

Phenolic compounds extraction was performed. The extracts of fruit samples were prepared according to the methodology described by Hertog et al. (1992). They were analysed using an Agilent 1260 series HPLC (Agilent Technologies, CA, USA) linked to a ChemStation software, using a ZORBAX Eclipse Plus C18 column (4.6×150 mm, 3.5 μm particles). Injection volume was 5 μL and the temperature was set at 30°C. Solvent A was 1% formic acid and solvent B was acetonitrile. The gradient used was as follows: 0-10 min, 15% of B in A; 10-25 min, 15-50% of B in A; 25-30 min, 50-80% of B in A; 30-32 min, 10% of B in A. By using this gradient (flow rate 0.5 mL min^{-1}), separation was achieved in fruit extracts. The HPLC equipment was used with a diode array detector (DAD). Phenolic compounds were detected at 260 nm (protocatechuic acid), 280 nm (gallic acid), 329 nm (neochlorogenic acid, chlorogenic acid, and caffeic acid), 360 nm (rutin), and 520 nm (cyanidin). Phenolic compounds were identified according to peak retention time and UV/Vis spectra, by comparison to the standards. The quantities of the different phenolic compounds were based on peak areas and expressed as mg per 100 g of prune (mg 100 g^{-1}).

Additionally, organoleptic properties of prunes were also assessed. A four-member expert commission did a point-based sensory analysis of the fruit samples. Four properties of prune were assessed, i.e., appearance (maximum 6 points), taste (maximum 8 points), aroma (maximum 2 points), and consistency (maximum 4 points), maximum total points being 20.

RESULTS AND DISCUSSION

Fruits of even mass (size) and ripeness were used for drying. Table 1 shows the composition values of fresh fruits of the tested plum cultivars. The fruit mass is in the range between 26.90 g ('Mildora') and 35.93 g ('Čačanska Rodna'). According to Sottile et al. (2010), the most desirable characteristics of fruits intended for processing by drying are fruit mass in a range from 30-40 g, as well as the stone mass in a range from 1.2-2.0 g. This was taken into consideration in our study of the cultivars 'Čačanska Rodna', 'Krina', and 'Nada'. On the other hand, the 'Midora' cultivar with its fruit mass of 26.90 g belongs to the group of plums with smaller to medium-sized fruits. However, owing to its very small stone mass (Mitrović et al., 2013; Miletić et al., 2014a), it is suitable for processing by drying.

Table 1. Mechanical properties of fresh plum fruits.

Cultivar	Fruit mass (g)	Stone mass (g)	Stone ratio (%)
Čačanska Rodna	35.93	1.35	3.76
Mildora	26.90	1.19	4.42
Krina	30.30	1.42	4.68
Nada	34.20	1.49	4.35

The chemical analysis included the basic parameters responsible for the taste and quality of fruits (Table 2). Regarding the content of total dry matter (DM), TSS, fruits of all plum cultivars were cropped at the phase of full technological maturity for drying, whereas the ensuing differences in the determined values occurred as a result of cultivar-specific features. Namely, the 'Mildora' cultivar was characterised by a markedly high content of DM and TSS (Mitrović et al., 2013), whereas the 'Nada' cultivar contained lower levels of these parameters (17.35 and 15.48%, respectively), which corresponds well to the results obtained by Glišić et al. (2015).

Table 2. Chemical composition of fresh plum fruits.

Parameter	Cultivar			
	Čačanska Rodna	Mildora	Krina	Nada
Total dry matter (DM; %)	22.48	23.47	18.32	17.35
Total soluble solids (TSS; %)	21.00	21.80	17.20	15.48
pH value	3.69	4.26	3.78	4.14
Titratable acidity (TA; %)	0.53	0.36	0.59	0.31
Total sugar (%)	13.95	15.70	12.20	10.95
Inverted sugar (%)	8.23	10.03	8.48	6.60
Sucrose (%)	5.43	5.39	3.53	4.13
Total soluble solids/acid ratio (TSS/TA)	39.62	60.55	29.15	49.93
Sugar/acid ratio	26.32	43.61	20.68	35.32

In the fruits of 'Čačanska Rodna', DM and TSS amount to 22.48 and 21.00%, compared to 18.32 and 17.20% in 'Krina', which was in accordance with the values stated for these cultivars by other authors (Mitrović et al., 2013; Miletić et al., 2014a). The contents of total and invert sugars were in accordance with the content of total dry matter and soluble solids, so that the highest contents of these parameters were present in the fruits of 'Mildora' (15.70 and 10.03%), compared to 'Krina' (12.20 and 8.48%).

The mass of the dried plum fruits is determined by the mass of fresh fruits on one side, and the content of total dry matter on the other side. Table 3 shows that the largest dry fruits were those of 'Čačanska Rodna' (11.41 g) from the cultivar with the largest fresh fruits in our study. 'Mildora' also provided a large prune (9.27 g), even though these fruits were within the small to medium-large size category (26.90 g). This was due to the fact that fresh fruits of this

cultivar possess a larger content of total dry matter (Mitrović et al., 2013), requiring a smaller quantity of water to evaporate during the drying process. Prunes obtained from 'Krina' and 'Nada' cultivars were smaller in size (8.42 and 8.79 g) compared to those of the 'Mildora' cultivar, as these two cultivars possessed a considerably smaller DM content in the initial form, the fresh fruits. This is clearly noticeable in the plum/prune ratio as well, which is lowest in the 'Mildora' (2.90), and highest in the 'Nada' cultivar (3.89). It takes 3.89 kg of fresh fruits of the 'Nada' cultivar in order to obtain 1 kg of dried plums, which is a highly relevant parameter from the aspect of the cost-effective industrial production of prunes. Regardless of the facts stated above, all of the studied cultivars yielded prunes of outstanding quality in accordance with the Serbian regulative (Sl. List RS, 2013), considering that the number of prunes in 0.5 kg is under 60.

Table 3. Mechanical properties of prunes (75% dry matter content).

Cultivar	Fruit mass (g)	Stone ratio (%)	Plum/prune ratio	No. prunes in 0.5 kg
Čačanska Rodna	11.41	11.83	3.15	43
Mildora	9.27	12.84	2.90	53
Krina	8.42	16.86	3.60	59
Nada	8.79	16.95	3.89	56

The TSS/TA ratio provided a more precise definition of the fruit quality than the two parameters applied separately because it determines the taste of the fruits and their attractiveness for consumers (Crisosto et al., 2004; Jayasena and Cameron, 2008). However, for the prune consumers, the sugar/acid ratio bears a higher significance, because it is directly correlated to their perception of sweetness, taste, and aroma (Slatnar et al., 2011). Table 2 shows the values of these parameters in fresh plums, while Table 4 shows the value of the sugar/acid ratio in prunes with 75% DM.

Table 4. Chemical composition of prunes (75% dry matter content).

Parameter	Cultivar			
	Čačanska Rodna	Mildora	Krina	Nada
Titratable acidity (%)	2.03	1.18	2.23	1.43
Total sugar (%)	42.86	42.21	43.20	44.47
Inv. sugar (%)	38.14	37.37	38.39	40.40
Sucrose (%)	4.48	4.59	4.99	3.86
Sugar/acid ratio	21.11	35.77	26.32	31.10

Mitrović et al. (2016) pointed out that a harmonious taste of prune is achieved when the sugar/acid ratio is in the range of 20-25. According to the results of our study, the 'Čačanska Rodna' and 'Krina' cultivars possessed optimum values of this parameter. As opposed to this, the 'Mildora' and 'Nada' cultivars produced sweet-tasting prunes with the sugar/acid ratio of 35.77 and 31.10, respectively. Their prunes had a lower content of total acids (1.18 and 1.43%, respectively) accompanied by similar total sugars contents on the other side (Table 4), despite the fact that their fresh fruits differed considerably in the content of total sugars (15.70 and 10.95%, respectively, Table 2).

The results of the sensory analysis of the prunes are shown in Table 5. Based on their sensory grades, prunes obtained from 'Krina' and 'Nada' cultivars were considered to be of a good quality; whereas those obtained from the 'Mildora' and 'Čačanska Rodna' cultivars were considered high-quality prunes. All of the prunes were of adequate consistency and aroma typical of prune.

Table 5. Organoleptic assessment of prunes.

Cultivar	Appearance (0-6)	Taste (0-8)	Aroma (0-2)	Consistence (0-4)	Total (0-20)
Čačanska Rodna	5.77	7.68	1.68	3.75	18.88
Mildora	5.38	7.47	1.48	3.68	18.01
Krina	4.92	7.25	1.53	3.32	17.02
Nada	5.65	7.40	1.40	3.30	17.75

The highest grade for taste was awarded to the 'Čačanska Rodna' cultivar (7.68) owing to its harmonious sweet-acidic taste, which was highly appreciated by prune consumers; this grade was also consistent to the detected values of the sugar/acid ratio. The 'Mildora' cultivar was also awarded a high grade (7.47), despite the sweet taste of its prunes, which is radically different from the typical flavour of prunes. In addition to this, the prunes obtained from this cultivar were of an amber-like colour, atypical for prunes in general. All of these characteristics had provoked a positive reaction of the tasters, resulting in the high overall grade of 18.01. The 'Krina' cultivar fruits also had an atypical skin colour. Although partly resembling the fruits of the 'Mildora' cultivar, they had a darker overtone which was not favoured by the tasters, who gave these prunes the lowest grade for the appearance (4.92), contributing to the lowest overall grade of 17.02 points. On the other hand, the tasters found the dark colour of the 'Nada' cultivar prunes appealing and in accordance with the general taste of prune consumers, who were traditionally used to a dark skin colour.

Prunes are rich in phenolic components, which is primarily reflected in the high contents of chlorogenic acid, neochlorogenic acid, caffeic acid, and rutin (Donovan et al., 1998), contributing to the enhanced quality and health efficiency of the prune. The components that were identified in our study are presented in Table 6. The most abundant hydroxycinnamic acid was neochlorogenic acid, reaching values in the range from 3.75 mg 100 g^{-1} ('Mildora') to 25.95 mg 100 g^{-1} ('Čačanska Rodna' and 'Nada'), followed by caffeic acid (from 11.10 in 'Mildora' to 22.11 mg 100 g^{-1} in 'Čačanska Rodna') and chlorogenic acid (from 0.39 in 'Mildora' to 2.96 mg 100 g^{-1} in 'Čačanska Rodna'). The obtained values were in accordance with the results obtained by Donovan et al. (1998) for prunes of the 'd'Agen' cultivar. Miletić et al. (2013) points out that dried plum fruits with a dark skin colour ('Valjevka') possess radically higher contents of these components compared to the amber-like prunes of 'Mildora'. It has also been observed that cyanidin as a particular type of anthocyanidin was present only in prunes with dark skin colour, whereas it was not present in 'Mildora' prunes. Prunes of all cultivars involved in our study had high levels of gallic acid as previously obtained for prunes by Miletić et al. (2014b), with the exception of 'Čačanska Rodna' (5.28 mg 100 g^{-1}) which is a characteristic of the cultivar.

Table 6. Contents of selected phenolics (mg 100 g^{-1}) of prunes.

Parameter	Cultivar			
	Čačanska Rodna	Mildora	Krina	Nada
Rutin	4.40	0.50	2.01	3.26
Neochlorogenic acid	25.95	3.75	14.15	25.95
Chlorogenic acid	2.96	0.39	1.68	1.74
Caffeic acid	22.11	11.10	16.63	13.85
Protocatechuic acid	1.35	0.34	0.40	2.49
Gallic acid	5.28	12.60	12.49	18.59
Cyanidin	10.10	nd[a]	9.31	11.91

[a]nd, not detected.

CONCLUSIONS

The following conclusions can be drawn based on the results of our study:

- All of the studied plum cultivars ('Čačanska Rodna', 'Mildora', 'Krina', and 'Nada') are recommended for drying since they do achieve the quality which is acceptable for the prune consumers with regards to the nutritive values and organoleptic qualities.
- Prunes of the 'Čačanska Rodna' and 'Nada' cultivars possess a dark skin colour, typical of prunes in general, whereas the amber-like prunes of 'Mildora' may be interesting from the aspect of offering a wider variety of tastes for the more demanding prune consumers.
- Prunes of the tested cultivars possessed high levels of phenolic components, primarily of neochlorogenic acid, caffeic acid, and gallic acid, which was especially true of cultivars with dark skin colour ('Čačanska Rodna' and 'Nada').
- All of the examined cultivars had a favourable plum/prune ratio, with the obtained values under four, which was considered a good indicator for the cost-efficiency of industrial prune production.

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