ACTA SCIENTIARUM POLONORUM

Acta Sci. Pol. Hortorum Cultus, 16(2) 2017, 35–45

www.acta.media.pl ISSN 1644-0692

ORIGINAL PAPER

Accepted: 11.10.2016

BIOLOGICAL CHARACTERISTICS OF SOME PLUM CULTIVARS GROWN IN MONTENEGRO

Djina Božović[1], Borut Bosančić[2], Ana Velimirović[1], Sezai Ercisli[3]✉, Vučeta Jaćimović[1], Hakan Keles[4]

[1] Biotechnical Faculty, Centre for Growing Continental Fruits, Medicinal and Aromatic Herbs, University Montenegro, 84000 Bijelo Polje, Montenegro

[2] Faculty of Agriculture, Genetic Resources Institute, University of Banja Luka, Banja Luka, Republic of Srpska, Bosnia & Herzegovina

[3] Agricultural Faculty, Department of Horticulture, Ataturk University, 25240 Erzurum, Turkey

[4] Agricultural and Natural Science Faculty, Department of Horticulture, Bozok University, 66900 Yozgat, Turkey

ABSTRACT

Some biological characteristics of 10 local and internationally well-known plum cultivars grown in Gornje Polimlje, Montenegro were studied between 2009–2011. Čačanska Rodna, Čačanska Lepotica, Stanley, Čačanska Rana, Valjevka and Valerija cultivars showed high productivity. The highest fruit mass was obtained from California Blue cultivar while the smallest fruit mass was measured for Požegača cultivar in all measured years. Soluble Solid Content (SSC), total acidity, total sugars, reducing sugars, sucrose, cellulose, vitamin C, total anthocyanin and ash content of plum cultivars were between 12.60–20.40%, 0.66–1.15%, 10.65–15.24%, 7.17–11.94%, 1.16–6.07%, 0.30–12.49%, 10.69–15.50 mg·100 g^{-1}, 0.6–7.7 mg·100 g^{-1} and 0.55–0.78%, respectively. The amount of potassium, which predominates in percentage of minerals in the ash, ranged from 1893 to 2199 mg·kg^{-1}. Local cultivar Požegača had the highest content of potassium, magnesium, calcium, iron, soluble solid content and vitamin C, and second highest content of iron, sugar, reducing sugars and cellulose. Anna Spath had the highest content of iron and sucrose. Highest content of sugar and anthocyanin was observed in Stanley cultivar. Total acids and reducing sugars were highest in cultivar Čačanska Lepotica.

Key words: physical characteristics, biochemical content, diversity

INTRODUCTION

The most widely grown fruit in Montenegro is plum and it's cultivation date back to ancient times. The environmental conditions in Montenegro, especially in the Gornje Polimlje region has moderate climate that suitable for plums [Krgović 2000]. In the assortments, indigenous cultivar Požegača and a number of brandy cultivars are widely grown [Jaćimović et al. 2011 a]. More recently there was a gradual modification of assortment and introduction of new plum cultivars in the region reveal a significant step to improve plum production [Jaćimović and Božović 2011]. Choosing suitable cultivar is the basic precondition of profitable plum production in plum growing regions [Milatović et al. 2011, Božović and Jaćimović 2012]. Genetic deficiency of non-suitable cultivars cannot be eliminated by optimum

✉sercisli@gmail.com

natural conditions, even with the application of modern cultivation technology. In order to fully express genetic potential of high-quality cultivars, it is necessary to cultivate them in appropriate agro-ecological conditions and the cultivar choice is the fundamental question for each producer of plum plantations [Miletić et al. 2001, Vitanova et al. 2004, Dinkova et al. 2007, Nenadović-Mratinić et al. 2007, Sestras et al. 2007, Walkowiak-Tomczak 2008, Erturk et al. 2009, Rop et al. 2009, Usenik et al. 2009, Ganji Moghaddam et al. 2011, Glišić et al. 2011, Ionica et al. 2013].

The fruits of plums are used as fresh, dried or processed into jam, marmalade, juice, brandy etc. [Nergiz and Yildiz 1997, Ertekin et al. 2006, Sestras et al. 2007, Družić et al. 2007, Voća et al. 2009, Milošević et al. 2013]. Calorie value of plum fruits is low, and highly nutritive [Mišić 2006, Voća et al. 2009]. Carbohydrates, organic acids, pectin, tannins and enzymes are substances that are significantly present in the fruits of plums and determine its nutritional value and taste. In addition to the nutritional value of fruits, plums have a significant role in the prevention and treatment of certain disorders such as cardio-vascular, renal, stomach and other illnesses [Kayano et al. 2003, Walkowiak-Tomczak et al. 2008, Usenik et al. 2008]. The plum fruits are rich for many vitamins and minerals that are essential for the proper functioning of the organism [Ertekin et al. 2006, Jaćimović et al. 2011 b, Milošević and Milošević 2012, Ionica et al. 2013] as well as phenolic compounds which show high antioxidant activity [Kayano et al. 2002, Chun et al. 2003, Walkowiak-Tomczak et al. 2008, Gadže et al. 2011, Nisar et al. 2015].

The aim of the study is to present the most important biological properties of the European plum cultivars (*Prunus domestica* L.) in agro ecological conditions of Montenegro in order to recommend them for further spreading.

MATERIALS AND METHODS

Site description

The paper presents three-year data (2009–2011) of biological characteristics of 10 plum cultivars grown in agro-ecological conditions of the Gornje Polimlje, Montenegro. Municipalities Andrijevica, Berane, Plav, Gusinje and Bijelo Polje are one territorial, climatic and orographic unit known as the Gornje Polimlje. It extends from 42°10' to 43°50' north latitude and 19°40' and 20°30' east geographical length, and includes the basin of the upper course of the river Lim with an altitude of 528 to 2500 m. The relief has a big influence on the climate in the Gornje Polimlje influenced by a humid, moderate continental and mountain climate [Jaćimović and Božović 2014]. In this area mostly represented is brown acid soil [Fuštić and Đuretić 2000]. Tests were carried out in the plantation located in the village of Kostenica at 860 m, near Bijelo Polje city.

Plant material and analytical methods

Valerija, Anna Spath, Čačanska Rodna, Valjevka, Čačanska Rana, Čačanska Najbolja, Stanley, Čačanska Lepotica, California Blue and Požegača European plum cultivars (*Prunus domestica* L.) are used as material. All varieties are grafted on seedlings of cherry plum (*Prunus cerasifera* Ehrh.), except Požegača, which is non-grafted but it has its own roots. Examined orchard was planted in autumn 2001. Every cultivar is presented with 5 trees. Crown shape is enhanced pyramids and the distance between the trees is 6 × 5 m. Pruning, fertilizing, mulching of soil around fruit trees with green grass and protection from pest and diseases are applied within agricultural management practices in the orchard. In year 2010 there was observed influence of El Nino followed by La Nina effects being one of the strongest recorded in 20th century [Bissolli 2010]. There was twice as much precipitation in year 2010 in comparison to years 2009 and 2011 [Bizek and Shekhovtsov 2012].

In the study standard methods were used. Abundance of flowering is assessed according to a scale from 0 (no flowers) to 5 (abundant flowering). Productivity is shown by coefficient of productivity (CEC), which represents the ratio between the yield in kg and trunk cross-sectional in cm^2, on average for period of 2009–2011. Analysis of the fruit is done in the phase of full maturity, on an average sample of 50 fruits per cultivar (ten fruits per tree and each tree

accepted as one replicate). Fruit and stone mass was determined by measuring on the analytical balance, "Mettler" 1200. The result is expressed in grams with 0.01 g accuracy.

Chemical analysis of mesocarp included the following tests: Total Dry Matter (TDM), Soluble Solid Content (SSC), Total Acids (TA), total and reducing sugars, sucrose, cellulose, vitamin C, total anthocyanin, ash, contents of macro and micro elements – potassium (K), calcium (Ca), sodium (Na), magnesium (Mg), zinc (Zn) and iron (Fe). Analyses were performed by conventional methodology [AOAC 2002]. Morphological and biochemical characteristics were analyzed by standard analysis of variance for all studied plum cultivars, with consequent calculation of LSD value in all cases where significant difference was observed. Morphological characteristics were analyzed separately from biochemical characteristics. Principal Components Analysis was used in order to compare studied plum cultivars by several measured characteristics in different years and environmental conditions in order to find grouping and dispersion patterns [Sneathp and Sokal 1973, Williams 1976, Iezzoni and Pritts 1991, Peres et al. 2003]. Statistical analyses were performed in the software package SPSS 22 (IBM 2013).

RESULTS AND DISCUSSION

Physical characteristics

Morphological characteristics of the selected plum cultivars were measured in three consequent years (tab. 1). From the factorial analysis of variance, it can be observed that there is statistically significant interaction for all studied cultivars in different years of study. Best results for the fruit mass were exhibited by the California Blue cultivar in first year of study (93.16 ±3.79 g), which statistically highly significantly differed from all other cultivars in all the other years of study. The smallest fruit mass was measured for Požegača cultivar in third year (18.62 ±0.58 g) which was comparable with fruits of this cultivar in all measured years and consistently statistically significantly smaller than the other cultivars. The longest fruits were measured in Čačanska Rana cultivar in the second year (57.20 ±0.85 mm), which was in the same statistical group as Čačanska Najbolja in the same year. The shortest fruit was measured for Požegača cultivar (37.49 ±0.46 mm). Fruit width was largest for California Blue cultivar in the first year of the study (51.49 ±0.97 mm) and the smallest for the Požegača cultivar in the third year (28.39 ±0.72 mm). California Blue cultivar had the largest fruit thickness in the first year of the study (52.98 ±0.44 mm) and the smallest was obtained in Požegača in the third year (27.90 ±0.67 mm). The largest pit mass was measured for Čačanska Rana cultivar in the second year (3.04 ±0.08 g) and the smallest observed for Požegača in the third year (0.74 ±0.02 g).

Results on fruit mass and dimensions are in agreement of the plums reported in Bulgaria [Vitanova et al. 2004] and in Poland [Hodun et al. 1998]. The obtained data on the mass of the fruit have higher values in relation to the information that are obtained in Serbia [Miletić et al. 2001, Nenadović-Mratinić et al. 2007, Glišić et al. 2011]. Milatović et al. [2011] showed similar data for fruit size for cultivar Čačanska Rana, smaller fruit size for Čačanska Lepotica and Cacanska Najbolja, and higher fruit size for Anna Spath cultivar. These differences can be explained by different environmental conditions and the applied cultivation techniques. The fruit mass is important for consumer preference for fresh consumption [Ogašanović 1990, Hodun et al. 1998, Miletic et al. 2001, 2011, Nenadović-Mratnić et al. 2007, Milatović et al. 2011] and also of crucial importance for the obtain quality products such as dry fruit, freezing, jam and brandy [Veličković et al. 2004, Popović et al. 2006]. Stone or pit mass of Čačanska Lepotica, Čačanka Rana and Čačanska Najbolja presented by Ogašanović et al. [1996] is similar to the data presented here, but Miletić and Petrović [1996] reported lower value for this parameter in the same cultivars that can be correlated with smaller fruits.

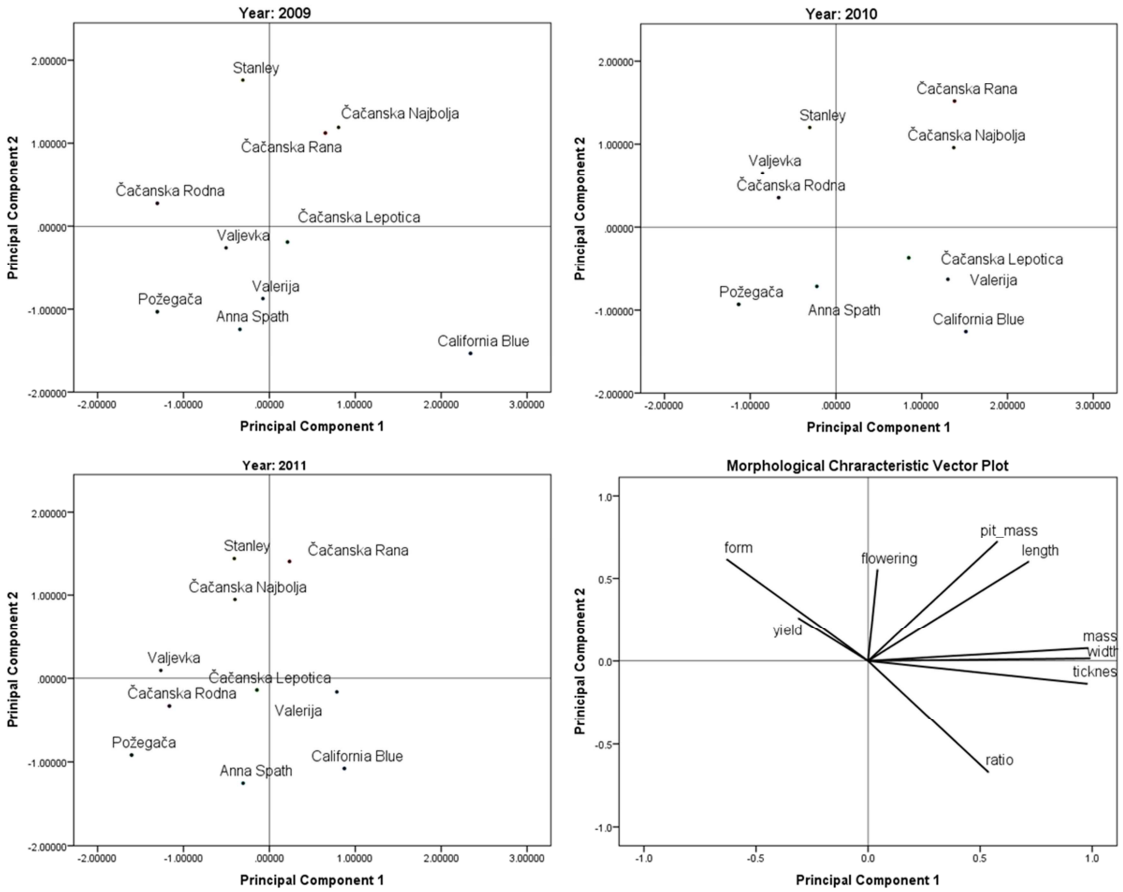
Abundance of flowering of varieties tested was in the range from 2.33 (Anna Spath) to 4.67 (Čačanska Najbolja and Stanley), (tab. 1). Except for Anna Spath that has moderately abundant flowering, other varieties showed abundant flowering and high yield

Table 1. Fruit morphological characteristics (per year) and index of flowering and productivity of studied plum cultivars (average of 2008–2011)

Variety	Year	Mass (g)	Length (mm)	Width (mm)	Thickness (mm)	Pit mass (g)	Flowering (index)	CEC ($kg \cdot cm^{-2}$)
				$\bar{x} \pm S_{\bar{x}}$				
California Blue	2009	93.16 ±3.79	53.48 ±0.98	51.49 ±0.97	52.98 ±0.44	1.44 ±0.07	4.00 ±0.58	0.15 ±0.03
	2010	69.45 ±3.18	48.44 ±1.04	47.02 ±0.76	48.84 ±0.71	1.50 ±0.06		
	2011	58.52 ±2.37	44.77 ±0.65	41.81 ±0.64	44.46 ±0.98	1.42 ±0.08		
Čačanska Lepotica	2009	43.94 ±2.04	47.04 ±0.58	39.56 ±1.00	37.87 ±1.13	1.58 ±0.04	4.33 ±0.66	0.47 ±0.06
	2010	59.27 ±1.01	51.77 ±0.54	43.97 ±0.25	42.10 ±0.33	1.80 ±0.07		
	2011	45.59 ±2.32	44.08 ±0.78	38.57 ±0.82	34.35 ±0.64	1.53 ±0.05		
Čačanska Najbolja	2009	57.11 ±2.05	54.44 ±2.04	42.96 ±0.58	41.20 ±0.59	2.37 ±0.09	4.67 ±0.33	0.21 ±0.06
	2010	69.90 ±4.28	57.10 ±1.09	45.32 ±1.30	44.51 ±0.97	2.60 ±0.13		
	2011	41.68 ±1.73	44.92 ±0.71	35.33 ±0.52	34.69 ±0.61	2.14 ±0.08		
Čačanska Rodna	2009	27.90 ±1.08	43.14 ±0.53	30.53 ±0.99	30.57 ±0.98	1.25 ±0.05	4.00 ±0.00	1.09 ±0.17
	2010	36.07 ±2.27	47.90 ±0.72	36.85 ±0.80	33.11 ±0.94	1.30 ±0.05		
	2011	27.28 ±1.78	42.51 ±1.20	32.15 ±0.81	31.89 ±0.67	0.95 ±0.05		
Stanley	2009	44.96 ±1.92	52.68 ±0.67	35.17 ±0.70	35.61 ±0.80	2.13 ±0.06	4.67 ±0.33	0.48 ±0.04
	2010	40.06 ±2.15	49.58 ±0.96	36.75 ±0.78	36.39 ±0.73	2.16 ±0.13		
	2011	42.20 ±1.93	49.34 ±0.89	36.27 ±0.61	34.09 ±1.40	2.07 ±0.09		
Čačanska Rana	2009	57.38 ±2.85	52.58 ±1.41	41.39 ±1.02	40.88 ±0.75	2.63 ±0.10	4.00 ±0.00	0.45 ±0.11
	2010	70.62 ±2.06	57.20 ±0.85	46.45 ±0.86	43.90 ±0.51	3.04 ±0.08		
	2011	55.05 ±3.22	50.61 ±1.43	40.18 ±1.30	36.88 ±0.86	2.68 ±0.08		
Anna Spath	2009	37.04 ±1.49	41.01 ±0.48	35.77 ±0.50	37.24 ±0.82	1.53 ±0.06	2.33 ±0.33	0.25 ±0.05
	2010	36.38 ±1.02	42.47 ±0.43	37.93 ±0.48	37.35 ±0.43	1.62 ±0.03		
	2011	35.91 ±0.78	42.10 ±0.40	36.58 ±0.54	36.78 ±0.27	1.46 ±0.03		
Valjevka	2009	35.80 ±1.03	49.68 ±0.90	34.44 ±0.38	34.66 ±0.44	1.23 ±0.04	3.67 ±0.67	0.61 ±0.18
	2010	30.06 ±1.56	46.28 ±0.86	34.38 ±0.71	33.96 ±0.56	1.32 ±0.06		
	2011	29.64 ±1.07	44.39 ±0.68	30.40 ±0.65	30.06 ±0.37	1.31 ±0.05		
Valerija	2009	40.35 ±4.15	42.68 ±2.20	37.79 ±1.34	39.32 ±1.64	1.58 ±0.06	3.67 ±0.33	0.65 ±0.14
	2010	67.45 ±4.00	49.12 ±0.96	45.59 ±0.92	47.72 ±1.01	1.81 ±0.05		
	2011	63.97 ±1.14	46.51 ±0.46	42.48 ±0.41	43.31 ±0.42	2.09 ±0.06		
Požegača	2009	21.32 ±0.99	38.13 ±1.04	29.80 ±0.39	30.13 ±0.54	0.84 ±0.03	3.67 ±0.33	0.18 ±0.04
	2010	24.44 ±0.70	41.57 ±0.41	31.37 ±0.53	31.02 ±0.36	0.94 ±0.01		
	2011	18.62 ±0.58	37.49 ±0.46	28.39 ±0.72	27.90 ±0.67	0.74 ±0.02		
ANOVA				F < p			F p	F < p
variety		153.69 < 0.00	62.96 < 0.00	133.10 < 0.00	160.79 < 0.00	218.1 < 0.00		
year		35.09 < 0.00	53.27 < 0.00	76.62 < 0.00	81.16 < 0.00	18.29 < 0.00	2.51 0.04	7.79 < 0.00
interaction		15.90 < 0.00	8.19 < 0.00	10.21 < 0.00	9.03 < 0.00	3.82 < 0.00		
$LSD_{0.05}$ (int.)		8.30	3.57	2.89	2.86	0.25	1.24	0.31

potential. Similar data for cultivars Čačanska Rana, Čačanska Lepotica and Čačanska Rodna is presented by Glišić et al. [2011] and Ogašanović et al. [1996]. Milatović et al. [2011] reported the abundance of flowering of Čačanska Najbolja rated 3.2, and the cultivar Anna Spath 3.5 points, while Čačanska Rodna and Čačanska Lepotica had approximately the same scores (4.0 and 4.9).

Productivity is trait, which is directly affecting economy of plums. The lowest level of productivity obtained from California Blue (0.15), and the highest in Čačanska Rodna (1.09) (tab. 1). Except Čačanska Rodna, high productivity was found in Čačanska Lepotica, Stanley, Čačanska Rana, Valjevka and Valerija. The presented data on productivity are generally consistent with the data presented by Nenadović-Mratinić et al. [2007]. Milatović et al. [2011] classified Čačanska Lepotica in the group with high productivity, Čačanska Najbolja and Anna Spath in the middle, which is the same as in this study, but in the middle rank Čačanska Rana that in our research proved to be productive. High yielding reported for Čačanska Rana in Czech Republic [Blažek et al. 2004] and in Bulgaria [Dragoyski et al. 2005]. In studies of Milošević et al. [2013], Čačanska Lepotica, Čačanska Rodna and Stanley, grafted on the native variety 'Belošljiva' (*P. domestica* L.) had high productivity coefficients 0.687, 0.566 and 0.548, and



Figs 1, 2, 3 and 4. Principal Components analysis of studied plum cultivars in years 2009 (up left), 2010 (up right), 2011 (down left) and vectors of measured morphological characteristics (down right)

considerably less productivity observed for Čačanska Rana and Čačanska Najbolja as 0.274 and 0.287. Cultivars, rootstocks, environmental conditions and applied cultivation techniques as well significantly affect productivity of fruit trees.

Grouping and dispersion patterns regarding morphological characteristics were analyzed by Principal Components Analysis. It was observed that (figs 1, 2, 3 and 4) in the different years grouping of plum cultivars showed similar trend and thus indicate stability and influence of climate disturbance exhibited in year 2010.

Valjevka, Anna Spath, Čačanska Lepotica and indigenous variety Požegaca exhibited stability over the observed period. In year 2010 observation indicate reaction of studied cultivars to the climate disturbance in form of massive amount of precipitation.

Biochemical characteristics

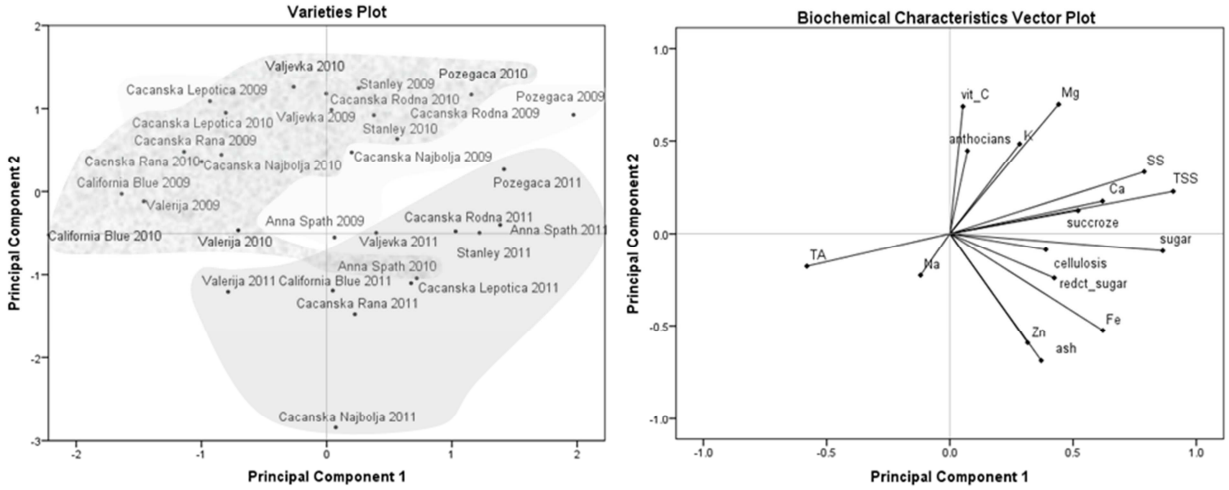
Biochemical characteristics of plum cultivars are shown in Table 2. The minimum soluble solid content (SSC) and total dry matter found in the fruit of California Blue cultivar as 12.60 and 13.68%, and highest in Pozegaca cultivar as 20.40 and 21.68%, respectively. Earlier matured cultivars such as California Blue, Čačanska Rana and Valerija have lower dry matter content in the fruit compared to the late ripening cultivars. Minev and Stojanova [2012] reported SSC content in the fruit Čačanska Lepotica, Čačanska Najbolja, Čačanska Rodna and Stanley in the range of 16.75 to 20.00%, which is similar to our results. However Oparnica and Jovanović [2000] and Nenadović-Mratinić et al. [2007] reported lower values. Popović et al. [2012] found same value of SSC in Stanley, lower values for Čačanska Lepotica and Čačanska Najbolja and higher values for Čačanka Rodna and Valjevka. SSC content in the plum fruits depend on the cultivar, location, age of plants, growing systems, the harvest time and degree of maturity [Glišić et al. 2011, Popović et al. 2012]. Total and reducing sugars ranged from 10.65 (Valerija) to 15.24% (Stanley), and 7.17 (California Blue) to 11.94% (Čačanska Lepotica). Sucrose content ranged from 1.16% (Čačanska Rana) to 6.07% (Anna Spath). The highest and lowest cellulose content was in Čačanska Rana 0.49% and Čačanska Lepotica as 0.30%.

Total acid in fruits of investigated cultivars was in the range of 0.66 (Stanley) to 1.15% (Čačanska Lepotica). Table varieties that ripen earlier have richer in organic acids and when used in fresh have sour, refreshing taste. Dinkova et al. [2007] showed that Čačanska Rodna had a higher content of soluble solids and had smaller amount of total sugar and total acids compared to our study and Stanley had similar dry matter content and total acidity, and lower total sugar content compared to present study.

Vitamins are essential nutrients that the human body that cannot synthesize, but are consumed through food. Vitamin C strengthens the immune system and has antioxidant effect. Studied cultivars had 10.69 (California Blue) to 15.50 mg·100 g^{-1} vitamin C (Požegača). The amount of vitamin C in the fruits of three cultivars of plums examined by Voća et al. [2009] was from 9.04 to 12.05 mg·100 g^{-1}, and eleven plum cultivars in Turkey were 5.82 to 28.42 mg·100 g^{-1} [Nergiz and Yildiz 1997].

Anthocyanins are nutritional bioactive components impact characteristics of food products. It is also important for human health. Because it is one of the most important bioactive compounds prevent cardiovascular disease and cancer [Wrolstad 2004, De Pascual and Sanchez 2008]. Total anthocyanins in the fruits of plum cultivars tested were ranged from 0.6 (Valerija and Anna Spath) to mg·100 g^{-1} (Valjevka). Ćujić et al. [2013] reported that the total amount of anthocyanins in the fruit of plum cultivars were between 2–25 mg·100 g^{-1}.

Foods of plant origin are biologically more valuable and represent the most important source of minerals. Life protective value of mineral substances and other ingredients of fruit are gaining more and more importance. The tested varieties don´t have significant ash content in it's fruits, which varied from 0.55% in Čačanska Rana to 0.78% in Stanley cultivar. Šoškić [2008] points out that the fruit of plum has 0.60% of mineral matter and Nergiz and Yildiz [1997] showed wider variation (0.37–0.90%). Nergiz



Figs 5 and 6. Principal Components Analysis of studied cultivars (left) with shading marking years and vectors of measured biochemical characteristics (right)

and Yildiz [1997] pointed out that the most abundant mineral is potassium in the plum fruits and confirmed by Zlatković [2000] and Mišić [2006]. In our study, the amount of potassium in fruits of investigated cultivars ranged from 1893 (Čačanska Najbolja) to 2199 (Požegača) mg·kg^{-1}. Stanley had 2003 mg·kg^{-1} potassium and previously this cultivar was reported to have 2177 mg·kg^{-1} potassium [Nergiz and Yildiz 1997]. However, Vukojević et al. [2012] reported 1160 mg·kg^{-1} potassium. Potassium regulates the alkalinity in the human cell. The increase of potassium lowers blood pressure, so the plums are recommended for people with hypertension [Zlatković 2003]. The other macroelements in fruits of investigated cultivars of plums were represented in the following quantities Na 4.31 (Čačanska Lepotica) to 9.89 mg·kg^{-1} (Anna Spath), Mg 74.88 (California Blue) to 123.66 mg·kg^{-1} (Požegača) and Ca from 77.07 (California Blue) to 196.84 mg·kg^{-1} (Požegača). Cultivars had important microelements as well. Fe was in the range from 1.20 (California Blue) to 1.95 mg·kg^{-1} (Anna Spath) and Zn 0.41 (Čačanska Lepotica) to 0.70 mg·kg^{-1} (Anna Spath). Janković and Mašković [2000] reported 150 mg of Ca which is in line with this research. Slightly higher Mg content (170 mg·kg^{-1}) in plum fruits is presented by Zlatković [2003], and similar to our research Janković and Mašković [2000] reported 90 mg·kg^{-1} Mg. Comparing data of Nergiz and Yildiz [1997], examined cultivars have a much lower content of Na and Fe, and a significantly greater amount of Ca in the fruit, which can be explained by cultivars, environmental and geographical factors, rootstocks used etc.

As shown in Tab. 2, there were statistically significant difference among cultivars for content of K, Na, Mg, Ca, SSC, TDM, reducing sugars, sucrose, total acids, vitamin C and anthocyanin. Local variety Požegača had the highest content, but not significant highest, of potassium, magnesium, calcium, iron, SSC, TDM and vitamin C, and second highest content of iron, sugar, reducing sugars and cellulose. Anna Spath had the highest content of iron and succrose. Stanley had the highest content of total sugar, and Valjevka had highest content anthocyanin and high content of vitamin C. Total acids and reducing sugars were highest in cultivar Čačanska Lepotica.

Based on the Principal Components Analysis (figs 5 and 6), it is indicated that in year 2011 all varieties exhibited separate biochemical characteristics in comparison to years 2009 and 2010.

Table 2. Biochemical characteristics of studied plum cultivars (means of 2008–2011) with results of the ANOVA and subsequent grouping in accordance with post-hoc tests

Variety	SSC (%)	TDM (%)	Total Sugar (%)	Reducing sugar (%)	Sucrose (%)	Cellulose (%)	TA (%)	Vitamin C ($mg \cdot 100g^{-1}$)
	$\bar{x} \pm S_{\bar{x}}$							
California Blue	$12.60^{a} \pm 1.23$	$13.68^{a} \pm 1.40$	10.86 ± 1.87	$7.17^{a} \pm 0.83$	$3.53^{abc} \pm 1.45$	0.34 ± 0.01	$1.09^{c} \pm 0.05$	10.69 ± 0.77
Čačanska Lepotica	$17.00^{ab} \pm 0.58$	$17.85^{abc} \pm 0.66$	13.50 ± 1.33	$11.94^{b} \pm 1.88$	$1.48^{ab} \pm 0.91$	0.30 ± 0.03	$1.15^{c} \pm 0.02$	12.81 ± 0.89
Čačanska Najbolja	$16.37^{ab} \pm 1.14$	$17.32^{abc} \pm 1.17$	13.00 ± 1.76	$10.37^{ab} \pm 0.61$	$2.50^{abc} \pm 1.09$	0.37 ± 0.03	$0.95^{bc} \pm 0.06$	12.58 ± 1.97
Čačanska Rodna	$18.10^{ab} \pm 0.70$	$18.90^{abc} \pm 0.90$	14.27 ± 1.05	$9.58^{ab} \pm 0.84$	$4.46^{abc} \pm 0.90$	0.39 ± 0.03	$0.72^{ab} \pm 0.12$	13.94 ± 2.79
Stanley	$17.97^{ab} \pm 2.06$	$20.82^{c} \pm 0.62$	15.24 ± 0.62	$9.25^{ab} \pm 0.46$	$5.68^{cb} \pm 0.29$	0.41 ± 0.05	$0.66^{a} \pm 0.05$	12.10 ± 0.08
Čačanska Rana	$13.97^{ab} \pm 0.32$	$14.94^{ab} \pm 0.57$	12.14 ± 0.93	$10.92^{ab} \pm 1.33$	$1.16^{a} \pm 0.65$	0.49 ± 0.09	$1.12^{c} \pm 0.05$	12.80 ± 2.16
Anna Spath	$18.43^{ab} \pm 2.04$	$19.22^{bc} \pm 1.73$	14.21 ± 1.41	$7.75^{a} \pm 0.87$	$6.07^{c} \pm 0.51$	0.40 ± 0.09	$0.67^{ab} \pm 0.05$	11.98 ± 1.28
Valjevka	$16.70^{ab} \pm 0.87$	$17.60^{abc} \pm 0.77$	12.11 ± 0.36	$8.17^{ab} \pm 0.74$	$3.74^{abc} \pm 1.05$	0.39 ± 0.05	$0.75^{ab} \pm 0.02$	13.59 ± 2.17
Valerija	$12.83^{a} \pm 0.33$	$13.98^{ab} \pm 0.44$	10.65 ± 1.08	$8.69^{ab} \pm 1.24$	$2.29^{abc} \pm 0.41$	0.33 ± 0.04	$0.90^{abc} \pm 0.07$	10.83 ± 1.17
Požegača	$20.40^{b} \pm 1.95$	$21.68^{c} \pm 1.67$	15.19 ± 0.68	$10.94^{ab} \pm 0.14$	$4.04^{abc} \pm 0.53$	0.48 ± 0.05	$0.75^{ab} \pm 0.05$	15.50 ± 1.06
ANOVA: F, p	3.91^{*} 0.01	$6.31^{**} < 0.00$	1.89^{ns} 0.11	2.39 0.05	3.79^{*} 0.01	1.19^{ns} 0.31	$10.75^{**} < 0.00$	0.78^{ns} 0.64
Variety	Anthocyanin ($mg \cdot 100\ g^{-1}$)	Ash (%)	K ($mg \cdot kg^{-1}$)	Na ($mg \cdot kg^{-1}$)	Mg ($mg \cdot kg^{-1}$)	Ca ($mg \cdot kg^{-1}$)	Fe ($mg \cdot kg^{-1}$)	Zn ($mg \cdot kg^{-1}$)
	$\bar{x} \pm S_{\bar{x}}$							
California Blue	$2.8^{b} \pm 0.02$	0.72 ± 0.17	$2054.00^{abc} \pm 10.21$	$6.48^{ab} \pm 1.65$	$74.88^{a} \pm 9.98$	$77.07^{a} \pm 12.82$	1.20 ± 0.32	0.63 ± 0.07
Čačanska Lepotica	$5.6^{de} \pm 0.03$	0.70 ± 0.22	$2124.67^{bc} \pm 23.57$	$4.31^{a} \pm 0.36$	$87.03^{ab} \pm 7.53$	$92.40^{a} \pm 15.68$	1.61 ± 0.23	0.41 ± 0.10
Čačanska Najbolja	$2.0^{ab} \pm 0.00$	0.77 ± 0.33	$1893.67^{a} \pm 76.76$	$7.30^{ab} \pm 1.80$	$98.59^{ab} \pm 15.09$	$96.92^{a} \pm 12.19$	1.63 ± 0.24	0.62 ± 0.06
Čačanska Rodna	$3.1^{b} \pm 0.06$	0.68 ± 0.20	$2008.00^{abc} \pm 10.02$	$4.45^{a} \pm 1.11$	$103.98^{ab} \pm 6.26$	$154.10^{ab} \pm 28.16$	1.51 ± 0.25	0.52 ± 0.05
Stanley	$6.8^{ef} \pm 0.02$	0.78 ± 0.27	$2003.33^{ab} \pm 56.23$	$4.67^{a} \pm 0.85$	$107.58^{ab} \pm 7.23$	$98.75^{a} \pm 17.88$	1.43 ± 0.10	0.55 ± 0.08
ČačanskaRana	$4.7^{cd} \pm 0.01$	0.55 ± 0.06	$1974.00^{ab} \pm 39.88$	$6.25^{ab} \pm 0.86$	$97.03^{ab} \pm 2.82$	$106.50^{a} \pm 4.53$	1.65 ± 0.34	0.56 ± 0.06
Anna Spath	$0.6^{a} \pm 0.01$	0.63 ± 0.09	$1964.67^{ab} \pm 3.38$	$9.89^{b} \pm 0.25$	$92.11^{ab} \pm 2.18$	$157.15^{ab} \pm 7.20$	1.95 ± 0.05	0.70 ± 0.02
Valjevka	$7.7^{f} \pm 0.02$	0.70 ± 0.16	$2050.33^{abc} \pm 13.64$	$4.74^{a} \pm 0.61$	$111.24^{ab} \pm 2.83$	$96.71^{a} \pm 2.89$	1.84 ± 0.36	0.54 ± 0.02
Valerija	$0.6^{a} \pm 0.01$	0.69 ± 0.12	$1920.67^{a} \pm 52.59$	$4.56^{a} \pm 0.69$	$91.94^{ab} \pm 13.02$	$108.25^{ab} \pm 35.27$	1.47 ± 0.20	0.57 ± 0.04
Požegača	$3.4^{bc} \pm 0.05$	0.73 ± 0.16	$2199.00^{c} \pm 21.36$	$5.69^{ab} \pm 0.31$	$123.66^{b} \pm 6.95$	$196.84^{b} \pm 12.75$	1.92 ± 0.17	0.60 ± 0.05
ANOVA: F, p	$72.71^{**} < 0.00$	0.12^{ns} 0.99	$5.73^{**} < 0.00$	3.13^{*} 0.02	2.62^{*} 0.03	$4.53^{**} < 0.00$	0.91^{ns} 0.53	1.72^{ns} 0.15

* indicates statistically significant difference, ** indicates statistically highly significant difference, ^{ns} indicates statistically non-significant difference (ANOVA)

$^{a,b,c\cdots}$ letters in superscript indicate significant differences and grouping of the cultivars according to HSD post-hoc test with 95% significance

In years 2009 and 2010 no obvious differences can be observed. Characteristics that most influenced such separation are SSC, TDM, reducing sugar, iron, calcium, zinc, cellulose and sugar content in increasing intensity and total acids (TA) in decreasing intensity. As climatic influences in years 2009 and 2011 were similar, it is possible that such difference in biochemical composition was an effect of previous year 2010, during which El Nino effect was observed.

CONCLUSION

1. Best results for the fruit mass were exhibited by the California Blue variety and the smallest fruit mass was measured for Požegača cultivar.

2. Valjevka, Anna Spath, Čačanska Lepotica and indigenous variety Požegača exhibited stability over the observed period for most of the measured characteristics.

3. Čačanska Rodna, Valerija, Valjevka, Stanley, Čačanska Lepotica and Čačanska Rana demonstrated high productivity.

4. Local variety Požegača had the highest content of potassium, magnesium, calcium, iron, SSC, TDM and vitamin C, and second highest content of iron, reducting sugars and cellulose. Anna Spath had the highest content of iron and sucrose. Stanley had the highest content of total sugar, and Valjevka had highest content anthocyanin and high content of vitamin C. Total acids and reducing sugars were highest in cultivar Čačanska Lepotica.

5. Overall, using productivity, physical and biochemical characteristics of fruits, the best results were manifested by Čačanska Rana of early cultivars, Čačačanska Lepotica from medium early and from late cultivars Valjevka, Čačanska Rodna, Požegača i Anna Spath.

ACKNOWLEDGEMENTS

Research is financially supported by the Ministry of Education and Science of Montenegro – project no. 01/3-3272/2008 “Research of biological and technological characteristics of new varieties of plums in northern Montenegro for recommendation of cultivar”.

REFERENCES

AOAC (2002). Official methods of analysis, 17th ed. Washington DC: Association of Official Analytical Chemists.

Bissolli, P. (2010). Annual Bulletinon the Climate in WMO Region VI, Europe and Middle East, 2010. DeutscherWetterdienst, Germany.

Bizek, V., Shekhovtsov, A. (2012). Review of the guidelines on the application of environmental indicators. Committee on Environmental Policy Conference of European Statisticians, United Nations.

Blažek, J., Vavra, R., Pištekova, I. (2004). Orchard performance of new plum cultivars on two rootstocks in a trial at Holovousy in 1998–2003. Hort. Sci., 31(2), 37–43.

Božović, Dj., Jaćimović, V. (2012). Phenological properties of plums under the conditions of northern Montenegro. Agric. For., 58(4), 153–159.

Chun, O.K., Kim, D.O., Moon, H.Y., Kang, H.G., Lee, C.Y. (2003). Contribution of individual polyphenolics to total antioxidant capacity of plums. J. Agric. Food Chem., 51, 7240–7245.

Ćujić, N., Kundaković, K., Šavikin, K. (2013). Anthocyanins-chemical analysis and biological activity. Lek. Sirov., 32, 19–37.

De Pascual, T.B., Sanchez, S. (2008). Anthocyanins, from plant to health. Phytochem. Rev., 7, 281–299.

Dinkova, H., Minev, I., Stoyanova, T. (2007). Vegetative and reproductive characteristics of plum cultivar Čačanska Rodna in Troyan region. J. Pom., 41, 41–44.

Dragoyski, K., Dinkova, H., Spasova, T., Minev, I. (2005). Growth and fruit bearing performance of the plum cultivars Čačanska Lepotica grown in the region of the Central Balkan mountains. J. Pom., 39, 271–277.

Družić, J., Voća, S., Čmelik, Z., Dobričević, N., Duralija, B., Skendrović ,Babojelić M. (2007). Fruit quality of plum cultivars ‘Elena’ and ‘Bistrica’. Agric. Consp. Sci., 72(4), 307–310.

Ertekin, C., Gozlekci, S., Kabas, O., Sonmez, S., Akinci, I. (2006). Some physical, pomological and nutritional prroperties of two plum (*Prunus domestica* L.) cultivars. J. Food Eng., 75, 508–514.

Erturk, Y., Ercisli, S., Tosun, M. (2009). Physico-chemical characteristics of wild plum fruits (*Prunus spinosa* L.). Int. J. Plant Prod., 3, 89–92.

Fuštić, B., Đuretić, G. (2000). Pedologija Crne Gore. Biotehnički Institut, Univerzitet Crne Gore, Podgorica.

Ganji Moghaddam, E., Hossein Ava, S., Akhavan, S., Hosseini, S. (2011). Phenological and pomological characteristics of some plum (*Prunus* spp) cultivars grown in Mashhad, Iran. Crop Breed. J., 1(2), 105–108.

Gadže, J., Čmelik, Z., Kaštelanac, D. (2011). Pomological and chemical characteristics of introduced plum varieties (*Prunus domestica* L.). Pomol. Croat., 17(3/4), 67–75.

Glišić, I., Karaklajić-Marić, Ž., Mitrović, O. (2011). Phenological and pomological characteristics and organoleptic properties of the fruit of new varieties of plums 'Zlatka' and 'Late blue' in agro-ecological conditions of Čačak. J. Pom., 45(175/176), 101–108.

Hodun, G., Hodum, M., Grzyb, Z.S. (1998). The promising plum cultivars evaluated in the field collection at Skierniewice, Poland. Acta Hort., 478, 193–197.

Iezzoni, A.F., Pritts, M.P. (1991). Applications of principal component analysis to horticultural research. HortSci., 26, 334–338.

Ionica, M.E., Nour, V., Trandafir, I., Cosmulescu, S., Botu, M. (2013). Physical and chemical properties of some Europian plum cultivars (*Prunus domestica* L.). Not. Bot. Hort. Agrobot. Cluj-Napoca, 41(2), 1–6.

Jaćimović, V., Božović, D. (2011). Pomological characteristics of important varieties of plums in the Gornje Polimlje. Proceedings of 26 Conference on Biotechnology, 323–329, Čačak.

Jaćimović, V., Božović, D., Lazović, B., Adakalić, M., Ljutica, S. (2011 a). Indigenous varieties of plums in the Gornje Polimlje. J. Pom., 45(175–176), 109–115.

Jaćimović, V., Božović, D., Nedović, M. (2011 b). Mineral substances in fruits of different varieties of plums. Agro-Knowl., 12(4), 391–396.

Jaćimović, V., Božović, Dj. (2014). Biological traits of cornelian cherry genotypes (*Cornus mas* L.) from teritory of Montenegro. Genetika, 46(2), 427–436.

Janković, M., Mašković, S. (2000). The technology of cooling and freezing of plums. Thematic collection and the International Scientific Symposium "Production, processing and marketing of plums and plum products". Koštunići, pp. 265–274.

Kayano, S., Kikuzaki, H., Fukutsaka, N., Mitani, T., Nakatani, N. (2002). Antioxidant activity of prune (*Prunus domestica* L.) constituents and a new synergist. J. Agric. Food Chem., 50, 3708–3712.

Kayano, S., Fukutsaka, N., Suzuki, T., Ikami, T., Shioaki, K., Kikuzaki, H., Mitani, T., Nakatani, N. (2003). Quantitative evaluation of antioxidant components in Prunes (*Prunus domestica* L.). J. Agric. Food Chem., 51, 1480–1485.

Krgović, L. (2000). Production, processing and marketing of products of plums and prunes in Montenegro. First international symposium of production, processing and marketing of plums and plum products. Koštunići, pp. 155–160.

Milatović, D., Đurović, D., Zec, G. (2011). Testing of table varieties of plums in the Belgrade area. J. Pom., 45(173/174), 15–22.

Miletić, R., Petrović, R. (1996). Pomological characteristics of cultivated varieties of plums in the Timok valley. J. Jug. Pom., 30(115–117), 263–269.

Miletić, R., Petrović, R., Marić, M. (2001). Pomological characteristics of important varieties of plums in eastern Serbia. Proceedings on production, processing and marketing of plums and plum products, pp. 51–58.

Miletić, R., Pešaković, M., Luković, J., Paunović, M.S., Karaklajić-Stajić, Ž. (2011). Effect of planting density on the characteristics and yield of table varieties of plums. J. Pom., 45(173–174), 23–29.

Milošević, T., Milošević, N. (2012). Agronomic properties and nutritional status of plum trees (*Prunus domestica* L.) influenced by different cultivars. Soil Sci. Plant Nutr., 13(3), 706–714.

Milošević, T., Milošević, N., Glišić, I. (2013). Agronomic properties and nutritional status of plum trees (*Prunus domestica* L.) influenced by different cultivars. Soil Sci. Plant Nutr., 13(3), 706–714.

Minev, I., Stojanova, T. (2012). Evaluation of plum cultivars in the Troyan region. J. Pom., 46(177/178), 49–54.

Mišić, P.D. (2006). Plum. Partenon, Beograd.

Nergiz, C., Yildiz, H. (1997). Research on chemical composition of some varieties of European plums (*Prunus domestica*) adapted to the Aegean district of Turkey. J. Agric. Food Chem., 45, 2820–2823.

Nenadović-Mratinić, E., Milatović, D., Đurović, D. (2007). Biological properties of plum cultivars with combined traits. J. Pom., 41(157–158), 31–35.

Nisar, H., Ahmed, M., Anjum, M.A., Hussain, S. (2015). Genetic diversity in fruit nutritional composition, anthocyanins, phenolics and antioxidant capacity of plum

(*Prunus domestica*) genotypes. Acta Sci. Pol. Hortorum Cultus, 14(1), 45–61.

Ogašanović, D. (1990). Valjevka – new plum variety for drying. J. Pom., 24(91/92), 13–16.

Ogašanović, D., Plazinić, R., Papić, V., Paunović, S. (1996). The effects of some generative rootstocks on vigor and productivity of new plum cultivars bred in Čačak. J. Jug. Pom., 30(115–116), 271–279.

Oparnica, Č., Jovanović, M. (2000). The effect of pruning intensity on pomological and technological characteristics of the major varieties of plum (*Prunus domestica* L.). Thematic collection of the first International Scientific Symposium "Production, processing and marketing of plums and plum products", Koštunići, pp. 233–242.

Peres, L., Jackson, D., Somers, K. (2003). Giving meaningful interpretation to ordination axes: Assessing loading significance in principal component analysis. Ecology, 84, 2347–2363.

Popović, B., Nikićević, N., Tešević, V., Mitrović, O., Ogašanović, D. (2006). Characteristics of brandy sljivovica produced from Čačak plum varieties. J. Pom., 40(155), 263–271.

Popović, B., Nikićević, N., Gavrilović-Damjanović, J., Mitrović, O., Kandić, M., Miletić, N. (2012). Quality of brandy sljivovica produced from plum cultivars with combined traits. J. Pom., 46(177/178), 23–31.

Rop, O., Jurikova, T., Micek, J., Kramarova, D., Sengee, Z. (2009). Antioxidant activity and selected nutritional values of plums (*Prunus domestica* L.) typical of the White Carpathian Mountains. Sci. Hort., 122(4), 545–549.

Sestras, R., Botu, M., Mitre, V., Sestras, A., Rosu-Mares, S. (2007). Comparative study on the response of several plum cultivars in Central Transilvania conditions, Romania. Not. Bot. Horti. Agrobot. Cluj., 35(2), 69–75.

Sneathp, H.A., Sokal, R.R. (1973). Numerical taxonomy. The principles and practice of numerical classification. W.H. Freeman & Co., San Francisco.

Šoškić, M.M. (2008). Modern fruit production, Partenon, Beograd.

Usenik, V., Kastelec, D., Stampar, F., Veberič, R. (2008). Quality changes during ripening of plums (*Prunus domestica* L.). Food Chem., 111(4), 830–836.

Usenik, V., Stampar, F., Veberic, R. (2009). Anthocyanins and fruit colour in plums (*Prunus domestica* L.) during ripening. Food Chem., 114(2), 529–534.

Veličković, M., Vulić, T., Oparnica, Č., Radivojević, D. (2004). Pomological and technological features of the plum varieties from various regions of Serbia. Arch. Agric. Sci., 65(231–232), 117–123.

Vitanova, I., Dimkova, S., Ivanova, D. (2004). Vegetative and reproductive parameters of introduced plum cultivars. J. Fruit Ornam. Plant Res., 12, 257–262.

Voća, S., Galić, A., Šindrak, Z., Dobričević, N., Pliestić, S., Družić, J. (2009). Chemical composition and antioxidant capacity of three plum cultivars. Agric. Consp. Sci., 74(3), 273–276.

Vukojević, D., Simić, J., Dragišić, N., Sevo, D., Misimović, M., Zavišić, N., Bolić, E., Radanović B. (2012). Evaluation of the quality of autochthonous plum cultivars in the area of Bosanski Petrovac. Proceedings Third International Scienific Simposium "Agrosym Jahorina 2012", pp. 161–166.

Walkowiak-Tomczak, D. (2008). Characteristics of plums as a raw material with valuable nutritive and dietary properties-a review. Pol. J. Food. Nutr. Sci., 58(4), 401–405.

Williams, W.T. (1976). Pattern analysis in agricultural science. Elsevier Scientific, New York.

Wrolstad, R.E. (2004). Anthocyanin pigments – bioactivity and coloring properties. J. Food Sci., 69, 419–425

Zlatković, B. (2000). The role of processing technology on the trade of plums. Thematic collection and the first International Scientific Symposium "Production, processing and marketing of plums and plum products" Koštunići, pp. 245–252.

Zlatković, B. (2003). The technology of processing and storage of fruit. Agricultural University, Beograd-Zemun.