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ANALYTICAL INDICATORS OF PLUM FRUIT SENSORY CHARACTERISTIC CHANGES AFTER SEVEN-DAY STORAGE AT ROOM TEMPERATURE

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ABSTRACT

Consumer acceptance of plum is based, primarily, on the corresponding sensory characteristics of the fruits: appearance, colour, firmness, taste and aroma. If not consumed immediately after harvesting, the aforementioned characteristics of plum will change. Still, those changes are less expressed when fruits are kept in cold storage, at low temperatures. However, during the transport and storage of plum at room temperature, which is often the case in local market plum sale, intense changes of certain characteristics of the fruit happens as well as a significant shortening of shelf life. The most expressive is firmness change where fruits become completely soft after seven days. Appearance and colour of the fruit are less susceptible to change. Since plum taste and odour depend on sugar and acid content, i.e., sugar-acid ratio and the content of certain volatile aromatic components, changes of their contents have been examined in some important plum cultivars in Serbia after seven-day storage at the temperature 20±1 °C. Sugar-acid ratio that determines sweetness, i.e., fruit acidity, has not significantly changed during the storage period. Among 10 examined aromatic components, the most significant changes have been observed in 2-E-hexenal, which gives a distinctive green note aroma and nonanal, characteristic plum-like scent. During the seven-day storage of picked plums, the content of 2-E-hexenal decreased while the content of nonanal increased.

Keywords: *Plum, shelf life, sugar/acid ratio, volatile aromatic components, odour activity values.*

INTRODUCTION

The quality of fresh fruits is prescribed by different official standards. It lays down the commercial value of fruits (which is usually based on a subjective evaluation of its external characteristics - colour, size, firmness, freshness) and guarantees uniformity of appearance. Such approach ignores sensory, nutritional, health and

other aspects that in a more comprehensive way define fruit quality. Increasing interest in the sensory quality of fruits reflects in the fact that 38% of consumers in the EU consider taste as a crucial criterion for purchasing fruits (Huyskens-Keil and Schreiner, 2004). When it comes to plums, even 75% of consumers consider taste and 71% of them, flavour, as very important characteristics of fruit, while the size and skin colour are considered to be very important characteristics only by 6% and 8% of consumers, and firmness of 14% of them (Hoehn *et al.*, 2005).

Like other fruits, the quality of plums for fresh consumption is, apart from the cultivar, crucially influenced by ripening stage at harvesting (Crisosto, 1994; Kader, 1999; Hoehn *et al.,* 2005; Kader, 2008; Usenik *et al.,* 2008), as well as by temperature and storage period if not consumed immediately after the harvest (Paunović and Grković, 1956; Guerra and Casquero, 2008; Casquero and Guerra, 2009; Guerra *et al.,* 2009). For plum sale on distant markets, the fruits have to be picked far before full ripe stage (regardless of not having a distinctive varietal flavour and aroma) and usually transported and stored at temperatures between 0 and 5 °C. It is considered much more important for the fruits to be in the wholesale market before they reach full ripe stage, in order to maintain attractive appearance and reach adequate ripening stage in retail, without major decrease in fruit firmness (Childers, 1949). For fresh consumption on local markets, plums are usually picked shortly before full ripe, that is, at their ripening stage when the fruits are still firm enough and have an established varietal flavour and aroma. In this ripening stage plums also have a very short shelf life considering that post-harvest handling, including transport and storage, is usually carried out at about room temperatures. It is often the case that, for local markets as well, plums are picked far before their full ripe stage in order to, on one hand, achieve higher price at the beginning of season when supply is low and provide sufficient fruit firmness and higher storage potential at about room temperature (Kader, 2008).

Although during storage period, numerous changes of physiological and physicochemical, as well as some sensory (colour and firmness) plum fruit characteristics have been established, there are almost no studies dealing with changes of taste and odour and their association with changes in content of the corresponding components of the fruit. Guerra *et al.* (2009) have attempted, for the sake of objective assessment of changes in taste, odour and aroma (determined by sensory analysis) during plum storage, to establish a correlation between their variations with changes in fruit characteristics (colour, firmness, total soluble solids/acid ratio) that can be determined by quick and simple instrumental analytical methods. This resulted in a partial success, since taste, odour and aroma of the fruit does not directly depend on its characteristics, but on the content of sugars, acids and volatile aromatic components, for which determination both time consuming methods and expensive analytical instruments need to be used. Sugar/acid ratio determines the sweetness i.e. acidity of the fruits, and concentration of the certain volatile aromatic components and odour threshold ratios (so called Odour activity values – OAV) determine the impact of each component on the overall volatile aroma, that is on aroma profile of the fruit.

The aim of this study was to determine the changes in the content of individual constituents of the fruit that decisively influence the taste and odour of the plum fruits Čačanska Rodna and Stanley, cultivars widely cultivated in Serbia and used, among other things, for fresh consumption.

MATERIAL AND METHODS

For a two-year study (2008 and 2009), fruits of the plum cultivars Čačanska Rodna and Stanley from a commercial orchard, planted in 1999 near Čačak (Site Premeća), at an altitude of 440 meter were used. Myrobalan was used as a rootstock and the spacing was 5 × 4 m, with standard agro-technical measures applied in the orchard.

Harvesting was performed on the basis of visual assessment, i.e. at the moment when characteristic fruit colour of the cultivar is developed and with maximum up to 10% of the skin area with green colour observed, which is 3 weeks (in case of the cultivar Čačanska Rodna), that is, 4 weeks (the cultivar Stanley) before reaching full ripe stage. At this ripeness stage fruits are firm, which makes them very suitable for transport and post-harvest handling; it is common that the fruits of such characteristics are picked for transport to distant markets, and sometimes for local markets, for fresh consumption. Picked fruits are stored for 7 days at a temperature of 20 ± 1 °C, a period during which the plums are usually sold in local market groceries, which is approximately their shelf life, at this temperature. After that, in addition to the change of certain sensory characteristics, the fruits soften a lot and there is an intensive development of mould and fruit rot (results not shown).

For the analysis of sugar and acid content in freshly-picked fruits and fruits after 7 days of storage, 20 fruits were used each. Standard methods of analysis were used (Trajković *et al.*, 1983): total sugars content (Luff-Schoorl method), total acids content (by neutralisation with 0.1 M NaOH, phenolphthalein added). Based on the results obtained, sugar/acid ratio was calculated. In order to isolate the volatile aromatic components from 250 g of plum fruits with stones, the Lickens-Nickerson method of simultaneous distillation/extraction was used. The GC/MS (Gas Chromatography/Mass Spectrometry) analysis was performed using the gas chromatograph Agilent 6890 (Agilent Technologies, Inc., USA), column Agilent 19091S-433 HP-5MS (30 m x 0.25 mm x 0.25μm) connected with the detector Agilent 5973 MSD. The identification of components was performed by comparing the GC/MS analysis results with the spectres of NIST (National Institute of Standards and Technology) and Wiley and Adams libraries. The quantitative (GC/FID) analysis was performed using the gas chromatograph HP 5890 II with FID (Flame Ionization Detector) and column HP-5 MS (30 m x 0.25 mm x 0.25μm), with the internal standard (menthol solution in dichloromethane). Contribution of certain volatile components to the overall fruit aroma was given on the basis of Odour activity values (OAV) representing the quotient of the concentration of certain volatile components in a fruit and its odour threshold in water (Leffingwell and Associates, 2016).

RESULTS AND DISCUSSION

Compared to freshly picked plums, after 7 days of fruit storage at room temperature, in most cases, there are no significant changes in the content of total sugars and total acids, so there are no significant changes in the value of sugar/acid ratio (Table 1). Similar results were found by other authors (Paunović and Grković, 1956; Guerra and Casquero, 2008; Casquero and Guerra, 2009) during the storage of different cultivars of European plum (*Prunus domestica* L.), at about room temperature.

Table 1. Contents of total sugars and acids (%) and sugar-acid ratio in plum fruits immediately after harvesting and after 7 day storage at a temperature of 20±1 °C

Characteristics	Year	Čačanska Rodna		Stanley	
		At harvest	After a 7-day storage	At harvest	After a 7-day storage
Total sugars	2008	8.20	7.95	8.70	8.95
	2009	9.70	9.95	9.70	11.95
Total acids	2008	0.98	0.94	0.78	0.78
	2009	1.20	1.12	0.75	0.69
Sugar/acid ratio	2008	8.37	8.45	11.15	11.47
	2009	8.08	8.88	12.93	17.32

Since the fruits of both tested cultivars are picked at very early stage, at the beginning of ripening on tree, they belong, due to the very low value of sugar/acid ratio (<16), according to Mitrović *et al.,* (2016), to a group of plums with sour taste. Since there is no change in value of ratio of sugar/acid, they remain acidic even after 7-day storage. The only exception were fruits of the cultivar Stanley in 2009, because their somewhat more remarkable change of sugar and acid content led to the value sugar/acid ratio to be greater than 16 (17.32), so these fruits could be classified into a group of fruits with sour-sweet taste (with the range of this ratio from 16 to 20) (Mitrović *et al.,* 2016). According to these authors, fruits of the cultivars Čačanska Rodna and Stanley, picked up for drying at full ripe stage have the value of sugar/acid ratio 18.67 (fruits of sour-sweet taste) and 20.34 (fruits of sweet-sour, harmonized taste, as the ratio sugar/acid is within the limits of 20-25). If we take into account that fruits for drying are picked at full ripe stage, it can be seen that early picked fruits (3-4 weeks before full ripe) cannot, even after 7-day ripening after harvest, in terms of room temperature, get the taste of the fruits at full ripe stage, with fully developed varietal sensory characteristics.

Table 2. Content of volatile compounds (μg/kg) in fruits of the plums picked immediately after harvesting and after 7-day storage at a temperature of 20±1 °C (ND - not detected)

Compounds	Year	Čačanska Rodna		Stanley	
		At harvest	After a 7-day storage	At harvest	After a 7-day storage
2-E-Hexenal	2008 2009	7318.81 6419.99	5408.16 4368.57	5348.65 6665.57	5843.67 2221.71
2-E-Hexenol	2008 2009	ND ND	ND 69.11	ND 179.67	ND 74.05
Hexanol	2008 2009	204.98 195.69	280.38 406.82	319.69 457.56	365.19 521.81
Heptanal	2008 2009	43.30 43.48	67.49 82.84	ND 97.75	63.33 134.28
Octanal	2008 2009	ND 62.10	57.28 45.10	57.57 49.74	84.08 57.03
Nonanal	2008 2009	352.74 356.69	733.96 715.95	277.49 454.19	597.54 1005.97
Benzaldehyde	2008 2009	ND 31.41	ND ND	ND ND	33.37 136.63
Benzeneacetaldehyde	2008 2009	33.58 85.85	ND ND	ND ND	399.05 ND
Linalool	2008 2009	ND 140.50	ND 48.89	ND ND	ND 57.66
α-Terpineol	2008 2009	56.02 61.58	275.41 179.10	49.75 70.61	26.27 277.21
Sum of C6 compounds	2008 2009	7682.90 6755.18	5842.58 4966.71	5795.00 7478.18	6360.91 2867.73
Sum of volatile compounds	2008 2009	8168.54 7536.79	6976.71 6038.58	6179.81 8150.46	7564.54 4536.78

Among 10 identified and quantified volatiles in freshly picked plums and the plums after 7-day storage (Table 2), the most were C6 aldehydes and alcohols, and nonanal, which is in accordance with the results of other authors (Herrmann, 1991; Chai *et al.*, 2012). The contribution of each individual volatile compound to the fruit odour, based on their OAV (Odour activity values) was shown in Table 3. Since they have OAV>1, the fruit aroma is significantly affected by nonanal, 2-E-hexenal, octanal, heptanal, linalool and benzeneacetaldehyde. On the other hand, because of OAV<1, α-terpineol, hexanol, 2-E-hexenol and benzaldehyde, do not have significant influence on the fruit odour. Having in mind the odour quality and changes of OAV in individual components, after 7 day storage of both studied cultivar fruits, at room temperature, a decrease in green note (due to a decrease of

OAV for 2-E-hexenal) and an increase of fruit aroma (due to an increase of OAV for nonanal, heptanal and octanal) could be observed. OAVs for 2-E-hexenal accounted for a total OAV of freshly picked plums from 41.2% (Stanley, 2009) to 53.4% (Č. Rodna 2008), whereas in 7 day stored plums, from 10.3% (Stanley 2009) to 29.1% (Stanley 2008). On the other hand, involvement of OAVs for nonanal in a total OAV of freshly picked plums was from 40.4% (Č. Rodna 2009) to 47.8% (Stanley 2009), and in 7 day stored plums at room temperature, from 50.5% (Stanley 2008) to 78.9% (Stanley 2009).

Table 3. Odour threshold (OT) and Odour activity values (OAVs) of aroma compounds in plum fruits

Compounds	Odour quality	OT (µg/kg)	Year	OAV			
				Čačanska Rodna		Stanley	
				At harvest	After a 7-day storage	At harvest	After a 7-day storage
Nonanal	fruity, woody, canned plum	1	2008	352.7	734.0	277.5	597.5
			2009	356.7	716.0	454.2	1006.0
2-E-Hexenal	green	17	2008	430.5	318.1	314.6	343.7
			2009	377.6	257.0	392.0	130.7
Octanal	citrus-like, fruity	0.7	2008	-	81.8	82.2	120.1
			2009	88.7	64.4	71.1	81.9
Heptanal	citrus-like, fresh	3	2008	14.4	22.5	-	21.1
			2009	14.5	27.6	32.6	44.8
Linalool	flowery, citrus, fruity	6	2008	-	-	-	-
			2009	23.4	8.2	-	9.6
Benzeneacetaldehyde	pungent, green	4	2008	8.4	-	-	99.8
			2009	21.5	-	-	-
α-Terpineol	peach-like, lilac-like	330	2008	0.2	0.8	0.2	0.1
			2009	0.2	0.5	0.2	0.8
Hexanol	green, fresh, fruity	2500	2008	0.1	0.1	0.1	0.1
			2009	0.1	0.2	0.2	0.2
2-E-Hexenol	leafy, green, fruity, fresh	400	2008	-	-	-	-
			2009	-	0.2	0.4	0.2
Benzaldehyde	bitter almond-like	350	2008	-	-	-	0.1
			2009	0.1	-	-	0.4

CONCLUSION

After 7 day storage of the cultivars Čačanska Rodna and Stanley at room temperature there are no significant changes in sugar/acid ratio and, consequently no change in the fruit flavour. On the other hand, due to changes in concentration of certain volatile components (2-E-hexenal, nonanal, octanal and heptanal) odour of fruit loses its green note and receives a fruity character.

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