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Evaluation of morphological, chemical, and sensory characteristics of raspberry cultivars grown in Bosnia and Herzegovina

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Abstract: Due to the growth in production of raspberry (*Rubus* sp.) in the Una-Sana Canton, there is a considerable need to research the fruit quality, as well as to guide the production in order to satisfy the requirements of the market. Raspberry fruit is very interesting for consumers because of its pleasant aroma and color, low calories, and high nutrient value, with health benefits that manifest in the high amount of antioxidants. In this paper, we have examined the morphological, chemical, and sensory properties of four cultivars of raspberry (Meeker, Willamette, Fertödi, Polka) grown in the area of the municipality of Bosanska Krupa. The Polka cultivar had the best morphological properties with average fruit width of 1.91 cm, height of 2.31 cm, and weight of 4.80 g. This cultivar also received the best sensory scores. In all the cultivars, there was a high percentage of dry matter (14.05%–16.67%), ash (0.33%–0.59%), reducing sugar (2.3%–4.99%), acid (0.78%–1.95%), and cellulose (0.93%–2.66%), as well as phenols (164.54–416.24 mg GAE/100 g), anthocyanins (53.38–58.83 mg/100 g), and vitamin C (35.77–54.92 mg/100 g). Among the cultivars, Fertödi had the highest share of antioxidant compounds and those differences were significant ($P \geq 0.05$). By using principal coordinate analysis the Polka cultivar was characterized by width, height, and mass of fruit; Willamette by anthocyanin and phenols; and Meeker by vitamin C content.

Key words: Antioxidants, fruit characteristics, principal coordinate analysis, raspberry fruits, sensory evaluation

1. Introduction

According to the Agency for Statistics of Bosnia and Herzegovina (www.bhas.ba), raspberry production in Bosnia and Herzegovina (B&H) increased from 9433 t to 13,631 t by 2015, followed by an increase in yield that increased from 5 t/ha to 8.1 t/ha. During this period, a decline in production was recorded in 2012 due to the heavy floods that hit B&H. Production of raspberries and other berries is very important from an economic point of view, i.e. from the aspect of agricultural development (Ercisli, 2004; Tosun et al., 2009; Ercisli et al., 2010; Zorenc et al., 2016). At the same time, the production of new cultivars has been introduced and agronomic practices have been changed, which ultimately affected the properties of the fruit together with other factors, such as climate, season, soil quality, and degree of ripeness (Skrovankova et al., 2015). To differentiate the quality of raspberry fruits on the market, sensory characteristics and the content of nutritive components are important (Pelayo et al., 2003). However, consumers give ever-increasing importance to nonnutritive components of the berry fruits that have positive effects on human health (Hancock et al., 2007; Nile and Park, 2014). This effect in raspberries is reflected in a significant concentration of antioxidants

when the raspberries are fresh; by processing them in jam or freezing them, raspberry fruits lose their antioxidant capacity (Pichler, 2011). It is believed that raspberry has a higher antioxidant capacity than most other fruits and vegetables (Beekwilder et al., 2005). Antioxidants are associated with a reduced risk of heart disease, cancer, and other degenerative diseases, as well as slowing the aging process (Skupien and Oszmainski, 2004). When it comes to antioxidant components, raspberries contain anthocyanins the most; in addition, these compounds give them an attractive intense red color (da Silva et al., 2007). These are contained in raspberries in different proportions ranging from 45 to 791 mg/100 g of fresh fruit (Rimpapa et al., 2007; Borges et al., 2010). Raspberry is also an excellent source of vitamin C, a very powerful antioxidant with anticancer and immunomodulatory properties and known to prevent colds (Kumar and Rizvi, 2012). However, the antioxidant capacity of fruit results from the content of total phenolics, mostly of the subgroup of flavonoids, to which antiinflammatory, antiallergenic, antiviral, antiaging, and anticarcinogenic activities are attributed (da Silva et al., 2007). Therefore, the goal of all production is to grow a cultivar with good productivity, large fruit, and excellent quality. Considering that there are

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not enough scientific data on qualitative characteristics of raspberry fruits grown in the northwestern area of B&H, and particularly not on the content of antioxidants, this study aimed to explore the four most common cultivars of raspberry (Willamette, Meeker, Fertödi, and Polka), which are grown in the area of Bosanska Krupa. The study aimed to compare the morphological, chemical, and sensorial characteristics as well as the content of antioxidants (anthocyanins, vitamin C, and total phenolics) in different cultivars. For the classification of cultivars considering the researched parameters, independent methods of multivariate statistics were used.

2. Materials and methods

As material in this research, four cultivars of red raspberry (Meeker, Willamette, Fertödi, and Polka) planted in 2014 were used. The varieties were acquired from the producer, located in the municipality of Bosanska Krupa. Geographically, this is the northwestern part of B&H, which administratively belongs to the Una-Sana Canton. In 2014, the sum of rainfall in this area was 1934.3 mm, which was considered to be an extremely rainy season, and the average annual air temperature was 11 °C. Since raspberry matures successively and its harvest takes days, fruit samples of all cultivars were taken in the middle of the maturing season to make the samples representative. Randomly selected fruits were harvested at physiological maturity in the morning and transported to the laboratory of the Faculty of Biotechnical Sciences, University of Bihać. The morphological characteristics (fruit width, length, and weight) were obtained according to the method described by Milivojević et al. (2009). For each cultivar, 30 repetitions were performed. Contents of water (drying at 105 °C), dry matter (refractometrically), ash (525 ± 25 °C), acidity (titration with 0.1 N NaOH solution), and reducing sugar (volumetrically according to the Luff–Schoorl method) were analyzed according to the method described by Vračar (2001) and cellulose (Weender analysis) as described by Prosky et al. (1988). For chemical parameters, three repetitions were performed. For the determination of anthocyanins, the pH differential method was used (Wrolstad et al., 2001); for vitamin C, iodine titration as described by Ciancaglinia et al. (2001) was used; and the total phenol content was analyzed by the Folin–Ciocalteu method adapted according to Waterhouse (2006), each measured on 30 samples. All measured parameters were compared with those in the literature, especially with the cultivars planted in B&H and neighboring countries. The sensory analysis involved five testers tested previously according to the guide published by the ISO on sensory analysis (ISO, 1993). This guide contains instructions for testing candidates for sensory analysis. Candidates are chosen on the basis of their senses for color and shade recognition, basic and different taste identification, sensitivity levels, and smell differentiation. The analysis

was done using scoring systems for appearance (5–15), flavor (10–20), taste (1–3), and color (1–10), where each number of a score indicates a certain property (for example, flavor is evaluated as 1–3, where 1 represents sweet-sour, 2 sour, and 3 sweet). For others, sensory property scores were based on scale from 1 to 20, where 1 represented the property that they liked the least and 20 the best. This procedure was described by Vračar (2001). Finally, statistical analysis of all results was conducted. The data were reported as mean \pm standard deviation ($x \pm SD$), range, and coefficient of variation (CV). Analysis of variance (ANOVA) and Duncan's test revealed significant differences between varieties at the $P \leq 0.05$ significance level. The classification of samples based on morphological properties and content of antioxidants was performed using multivariate analysis by the method of principal component analysis (PCA) and grouping of data using cluster analysis (CA). For data processing we used the computer programs XLSTAT 2011 and STATISTICA 10.0.

3. Results and discussion

The results of fruit dimensions (fruit width and length) as well as fruit weight are shown in Table 1. The values found in the literature are also presented. Major differences can be observed between cultivar Polka and the other three examined cultivars. The measured width ranged from 1.7 cm to 2.2 cm and length from 1.9 cm to 2.6 cm, both parameters being higher than the dimensions of the Meeker, Willamette, and Fertödi cultivars, but also higher than the dimension of fruits grown in other areas, as presented in the literature. Contrary to results of cultivar Polka, Meeker and Willamette had lower dimensions than those presented in the literature. The same results were obtained for fruit weight: Polka had the highest average weight (4.80 g) in comparison with other cultivars and compared with literature data. Statistical significance ($P \leq 0.05$) in fruit width, length, and weight was observed between Polka and the other three cultivars and also between Willamette and two other cultivars (Fertödi and Meeker) in fruit width and length, as well as between Fertödi and two other cultivars (Meeker and Willamette) in fruit weight. There are examples where fruit weight for the Polka cultivar reaches 6.2 g, but the conditions of growth in that case were higher temperatures and extended daylight (Sønsteby and Heide, 2012). The morphological characteristics of the fruit, including chemical and sensory characteristics, vary among cultivars and depend on many factors, such as environmental factors (temperature, rainfall, soil type), irrigation, yield efficiency, ripeness of harvested fruits, and agrotechniques (Kader et al., 1985; Skrovankova et al., 2015; Canan et al., 2016) and especially on the cultivar itself (Leposavić et al., 2013). The chemical composition of the four investigated cultivars, as shown in Table 2, indicated variability between cultivars and also in comparison to the literature data. All fruits had high dry

Table 1. Fruit width, length, and weight.

Parameters		Meeker	Willamette	Fertödi	Polka
Fruit width (cm)	x ± SD	1.58 ± 0.13 ^c	1.80 ± 0.15 ^b	1.53 ± 0.14 ^c	1.91 ± 0.14 ^a
	Range	1.3 - 1.8	1.3 - 1.8	1.5 - 2.0	1.7 - 2.2
	CV	0.024	0.026	0.029	0.027
	Literature	1.85 - 2.14	1.80 - 2.16	1.26	1.72 - 2.05
Fruit length (cm)	x ± SD	1.45 ± 0.13 ^c	1.62 ± 0.14 ^b	1.40 ± 0.14 ^c	2.31 ± 0.17 ^a
	Range	1.2 - 1.8	1.2 - 1.7	1.4 - 1.9	1.9 - 2.6
	CV	0.024	0.01	0.027	0.035
	Literature	2.02 - 2.24	1.60 - 2.40	1.26	1.73 - 2.28
Fruit weight (g)	x ± SD	2.55 ± 0.31 ^b	2.60 ± 0.37 ^b	2.21 ± 0.46 ^c	4.80 ± 0.73 ^a
	Range	1.9 - 3.2	1.5 - 3.4	2.0 - 3.4	3.6 - 6.4
	CV	0.057	0.11	0.08	0.13
	Literature	3.56 - 4.23	1.53 - 3.30	1.70	1.67 - 4.60

Mean value ± standard deviation (x ± SD); coefficient of variation (CV), n = 30.

The same letter in the same row indicates no significant difference ($P \leq 0.05$).

Literature data for Meeker: Stanisavljević et al. (2003), Nikolić et al. (2009), Kulina et al. (2012).

Literature data for Willamette: Stanisavljević et al. (2003), Veličković et al. (2004), Nikolić et al. (2009), Kulina et al. (2012).

Literature data for Fertödi: Skender et al. (2011).

Literature data for Polka: Nikolić et al. (2008), Lepaja et al. (2016).

matter contents ranging from 14.05% to 16.67%, acidity from 0.78 to 1.95%, and ash from 0.33 to 0.59%, higher than values in the literature, except in the case of Fertödi (acidity and ash were higher than those in literature). Reducing sugar (2.3%–4.99%) and cellulose content (0.93%–2.66%) were slightly lower compared to data from the literature. Fertödi was the cultivar with the highest dry matter content, acidity, and cellulose, while the cultivar Polka had the highest ash content and cultivar Meeker had the highest reducing sugar content. The acidity value established in Fertödi was significantly different ($P \leq 0.05$) from those of all the other cultivars. Statistical significance ($P \leq 0.05$) in concentrations of reducing sugar was observed between all cultivars. According to the literature, the concentration of chemical components can have even a twofold difference between different years of production or depending on cultivation- and cultivar-related factors (Lewandowski et al., 2015); also, conditions after harvesting, such as storage conditions, have great influence (Talcott, 2007). In our experiment, the fruits were frozen at $-18\text{ }^{\circ}\text{C}$ until analysis. The contents of the compounds with antioxidant capacity are presented in Table 3 as x ± SD and range in comparison with the literature ranges. The results of our study revealed noticeably higher contents of total phenols in the cultivar Polka (372.58 mg GAE/100 g) than in most literature cited in Table 3, even though the range of literature data is slightly wider. This is not the case for Willamette, in which fruit content was twice lower (164.54

mg GAE/100 g) than in the other three cultivars and in the literature. The contents of total phenols in Meeker (350.38 mg GAE/100 g) were comparable with the literature. The highest average content of total phenols in this study was found in Fertödi (416.24 mg GAE/100 g), but we could not find appropriate literature data for comparison. However, according to the polyphenol classification proposed by Vasco et al. (2008), all four cultivars are good sources of polyphenols because they belong to the category of medium polyphenol contents (100–500 mg GAE/100 g). Two other groups were established by Vasco et al. (2008) as low (<100 mg GAE/100 g) and high (>500 mg GAE/100 g). The comparative analysis of anthocyanin contents in the studied cultivars (53.38–58.83 mg/100 g) is in agreement with data from the literature (25.1–137.7 mg/100 g) and the same can be stated for the content of vitamin C. The range of average contents (35.77–54.92 mg/100 g) was within the previously established range (19.4–73.80 mg/100 g). According to the classification of Vasco et al. (2008), cultivars Meeker, Willamette, and Polka are classified as sources with medium (30–50 mg/100 g) and Fertödi with high (>50 mg/100 g) contents of vitamin C. These differences in contents of total phenols, anthocyanins, and vitamin C among cultivars are statistically significant ($P \leq 0.05$). These differences are also possible because their contents in fruits are affected by many factors, especially climate conditions. Battino et al. (2009) reported that fruits grown in the conditions of a cold northern climate,

Table 2. Chemical composition (%) of fruit.

Parameters		Meeker	Willamette	Fertödi	Polka
DM	x ± SD	14.32 ± 0.02 ^a	14.93 ± 0.48 ^a	16.67 ± 2.76 ^a	14.05 ± 0.87 ^a
	Literature	11.60 - 15.86	7.10 - 13.90	13.59	12.10 - 14.49
Ac	x ± SD	1.85 ± 0.07 ^a	0.78 ± 0.07 ^a	1.95 ± 0.07 ^b	1.65 ± 0.25 ^a
	Literature	0.98 - 1.29	1.35 - 2.40	0.13	0.80-1.87
Ash	x ± SD	0.58 ± 0.02 ^a	0.33 ± 0.24 ^a	0.51 ± 0.03 ^a	0.59 ± 0.05 ^a
	Literature	0.18 - 0.54	0.44	*	*
RS	x ± SD	4.99 ± 0.55 ^a	3.76 ± 0.11 ^c	2.30 ± 0.01 ^d	4.86 ± 0.02 ^b
	Literature	4.20 - 9.81	2.55 - 7.19	4.30	6.82
C	x ± SD	1.53 ± 0.04 ^a	1.55 ± 1.06 ^a	2.66 ± 0.11 ^a	0.93 ± 0.03 ^a
	Literature	1.64	1.50	*	6.14 - 7.50

Dry matter (DM); acidity (Ac); reducing sugar (RS); cellulose (C); mean value ± standard deviation (x ± SD), n = 3.

The same letter in the same row indicates no significant difference ($P \leq 0.05$).

Literature data for Meeker: Veličković et al. (2004), Nikolić et al. (2009), Viskelis et al. (2012), Karakashova et al. (2012), Stajčić et al. (2012), Kulina et al. (2012), Leposavić et al. (2013).

Literature data for Willamette: Veličković et al. (2004), Nikolić et al. (2009), Stajčić et al. (2012), Kulina et al. (2012), Leposavić et al. (2013), Orzeł et al. (2016).

Literature data for Fertödi: Skender et al. (2011).

Literature data for Polka: Nikolić et al. (2008, 2009), Milivojević et al. (2011a, 2011b), Skupien et al. (2011), Orzeł et al. (2016).

*No data available.

Table 3. Concentration of anthocyanins (mg/100 g), vitamin C (mg/100 g), and total phenols (mg GAE/100 g) in the raspberry cultivars.

Parameters		x ± SD	Range	Literature
Total phenols (mg GAE/100 g)	Meeker	350.38 ± 17.57 ^c	333.8–401.3	102.0–521.4
	Willamette	164.54 ± 6.76 ^d	154.0–185.3	222.0–389.6
	Fertödi	416.24 ± 5.53 ^a	399.4–432.3	*
	Polka	372.58 ± 13.38 ^b	364.1–401.0	211.8–309.4
Anthocyanins (mg/100 g)	Meeker	53.38 ± 0.132 ^d	52.0–54.74	25.1–52.4
	Willamette	57.47 ± 0.68 ^b	55.01–58.38	43.29–70.21
	Fertödi	58.83 ± 0.31 ^a	58.49–59.88	*
	Polka	54.47 ± 2.38 ^c	53.1–56.73	38.57–137.7
Vitamin C (mg/100 g)	Meeker	40.77 ± 3.86 ^c	30.0–45.0	19.4–44.88
	Willamette	35.77 ± 1.26 ^d	31.67–37.5	40.9
	Fertödi	54.92 ± 4.52 ^a	48.9–62.0	41.5
	Polka	43.86 ± 1.85 ^b	41.8–48.3	20.71–73.80

Mean value ± standard deviation (x ± SD), n = 30.

The same letter in the same column indicates no significant difference ($P \leq 0.05$).

Literature data for Meeker: Nikolić et al. (2009), Guerrero et al. (2010), Viskelis et al. (2012), Fotirić-Akšić et al. (2012), Karakashova et al. (2012), Stajčić et al. (2012), Bobinaité et al. (2012), Milivojević et al. (2013), Kostecka-Gugała et al. (2015), Miletić et al. (2015), Ivanović et al. (2016).

Literature data for Willamette: Levaj et al. (2010), Stajčić et al. (2012), Milivojević et al. (2013), Miletić et al. (2015), Orzeł et al. (2016), Ivanović et al. (2016).

Literature data for Fertödi: Racz et al. (1991).

Literature data for Polka: Skupien et al. (2011), Moor et al. (2014), Kazimierzczak et al. (2015), Lewandowski et al. (2015), Kostecka-Gugała et al. (2015).

*No data available.

with a short growing season and without fertilizers and pesticides, have higher polyphenol contents than the same cultivars grown in milder climates.

The results of sensory analysis identified Polka as the cultivar with the best properties (Figure 1). The fruit has a sweet taste, great appearance, strong intensity of flavor typical for raspberry, and medium red color. The best organoleptic properties for Polka were expected and this

is agreeable with the literature description (Pritts, 2000), which recommended this cultivar for fresh consumption.

PCA was used to determine interrelations between morphological characteristics and the content of antioxidant compounds for each cultivar. Coordinates of factors PC1 and PC2, according to the cultivars, are shown in Figure 2. PC1 explains 45.12% of the total variability, which is in positive correlation with the morphological

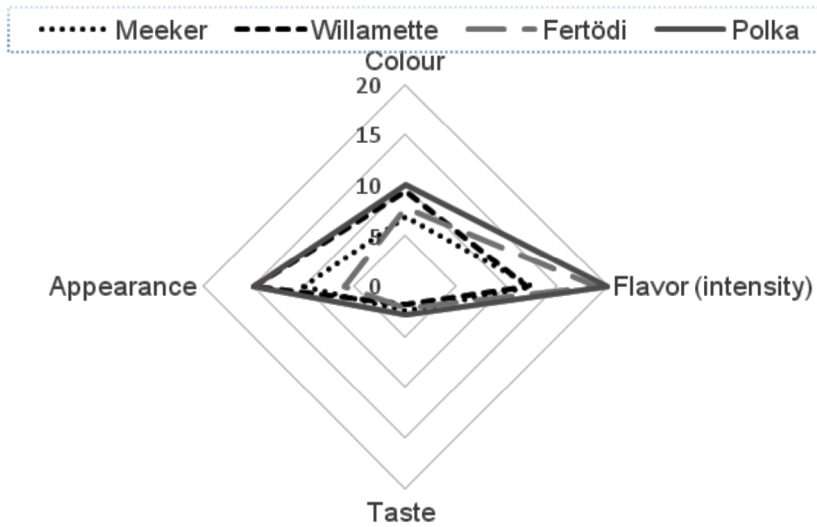


Figure 1. Sensory profile of raspberry cultivars (max. scores for appearance - 15; flavor - 20; taste - 3; color - 10).

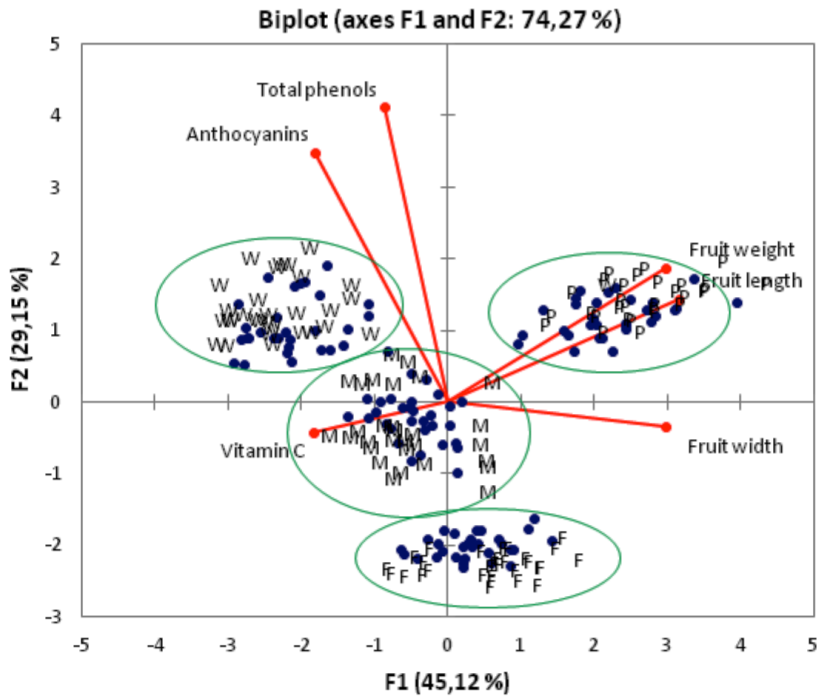


Figure 2. Two-dimensional PCA scatter plot for raspberry cultivars.

characteristics. PC2 explains additionally 29.15% of the total variability and positive correlations were found between total phenols and anthocyanins. Variables on PC1 ranged between $r = 0.83$ and 0.88 , and correlation on PC2 was the highest (0.92) for total phenols. According to the results of PCA analysis, the Polka cultivar could be characterized by morphological characteristics and Willamette and Meeker by the lowest levels of antioxidant compounds.

Judging by the results of this research, wide variability in fruit quality occurs among raspberry cultivars grown in the area of Bosanska Krupa. Polka has much better morphological characteristics, which is statistically significant ($P \leq 0.05$). Average fruit weight of Polka was almost twice heavier than that of the other fruits. Polka also has the best sensory characteristics compared to the

other studied cultivars. Polka was evaluated for color, aroma, and appearance with maximum scores during the sensory analysis. Regarding chemical composition, the highest contents of dry matter, cellulose, and acidity were noted for Fertödi, ash for Polka, and reducing sugar for Meeker, but the differences between all cultivars were statistically significant ($P \leq 0.05$) only for concentration of reducing sugar and acidity between Fertödi and the other three cultivars. Based on the concentrations of antioxidant compounds, the cultivar Fertödi stands out as the cultivar with the highest share of total phenolics, anthocyanins, and vitamin C with statistical significance ($P \leq 0.05$). Our results indicate that cultivars Polka and Fertödi have better quality characteristics than cultivars Meeker and Willamette in terms of breeding in northwestern B&H.

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