Fruit quality of red raspberry cultivars and selections grown in Western Serbia

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Abstract

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Biological and chemical properties of cv. Willamette were contrasted with those of cvs Tulameen, Latham, Meeker and K81-6 grown under agro-environmental conditions of Western Serbia. The following parameters were examined: yield per unit land area, total dry matter content, soluble solids content, total reducing sugars, total acids content, pH value, total pectines and total anthocyanins. The obtained results showed that cvs Willamette and Meeker had exceptional yield potential and highest quality fruits, which renders them suitable for both fresh use and various forms of processing, whereas cv. Tulameen can be recommended for fresh consumption only. K81-6 is recommended for processing and fast freezing after harvesting.

Keywords: yield; varieties; chemical composition; anthocyanins

Red raspberry (*Rubus idaeus* L.) is a major small fruit and the most profitable fruit species in Serbia. Geographically, Western Serbia (municipalities of Arilje, Ivanjica, Bajina Bašta, Brus, Valjevo, Guča, Kosjerić, Krupanj, Mionica and Čačak) is the major raspberry growing region. Raspberry is also grown across Serbia, although on smaller scale (Petrović, Milosević 2005).

Globally, the Republic of Serbia ranks first in raspberry production, exceeding 93,000 tons in 2003 (Petrović, Leposavić 2011).

Red raspberry contains numerous organic and non-organic compounds (sugars, acids, pectines, anthocyanins, phenol compounds, mineral matter, etc.). Their content varies among cultivars (Janda, Gavrilović 1983), and depends on various issues viz. environmental factors (temperature, rainfall, soil type), irrigation, yield efficiency, ripeness of harvested fruits (Tešović 1988), agrotechniques, control of pests and diseases, etc.

In their studies on seven raspberry cultivars, Marinković et al. (2008) report on the decline in yield and fruit quality (a significant decline in soluble solids and poor fruit consistency) induced by unsuitable climate conditions (inappropriate temperature sum and the distribution, small differences

between day and night temperatures). According to Riaz and Bushway (1996), significant differences in chemical composition are governed by cultivar specificities, and can be more or less affected by different weather conditions (particularly small differences between day and night temperatures) during growing period. In his studies on chemical composition of fresh and frozen raspberries, Stančev (1991) reports on a possible major influence of meteorological factors and locality which also influences a great majority of fruit characters. The author adds that organoleptic assessment of fresh fruits point to the markedly higher quality of fruits in primocane cultivars. Eyduran and Ağaoğlu (2006) obtained similar results by investigating technological properties (fruit weight, soluble solids and dry matter content, and total acids) of fruits in both primocane and floricane raspberries.

In recent years antioxidant and antiproliferating activities of phenolic components in raspberry fruits received considerable attention worldwide (Juranić et al. 2005). In his investigations into pomological and antioxidant properties of soft fruits, Milivojević (2008) reported on a considerably higher total anthocyanins content in cv. Willamette compared to wild raspberry (*Rubus idaeus* L.) or cv. Meeker. As for the antioxidants (phenols, anthocyanins and ascorbic acid) in fruits of raspberry, blackberry, red currant, gooseberry and cornelian berry, Pantelidis et al. (2007) recorded a pronounced antioxidants content in floricane raspberries, such as cvs Heritage, Autumn Bliss and Fallgold.

The present paper was undertaken to investigate major chemical properties of fruits of cvs Tulameen, Latham, Meeker and K81-6, and to establish their suitability for growing in Western Serbia as contrasted with standard cv. Willamette.

MATERIAL AND METHODS

The trial planting was established in spring 2002 at Zdravljak site (Fruit Research Institute, Čačak; 43°50'N, 20°18'E; altitude of 649 m a.s.l.), at a gentle slope of north-west orientation. The studies were conducted over 2003–2006.

For yield examination, 100 shoots per cultivar (25 shoots × 4 replications) were monitored all through the harvest. The total number of shoots per hectare in cvs Willamette, Meeker, Latham Tulameen and K81-6 were 22,026, 21,910, 21,833, 21,712 and 21,711, respectively. Yield per unit land area was obtained by multiplying yield per shoots by total number of shoots per unit land area.

Chemical analysis of fruits included following: total dry matter (DM) content – obtained by drying in a laboratory dryer Sperimatik SP 11 (Instrumentaria, Zagreb, Croatia) at 105°C and 101.3 kPa; soluble solids (SS) measured by manual refractometer Carl Zeiss 3828 (Carl Zeiss, München, Germany); total reducing sugars (by Luff-Schoorl method; Tanner, Brunner 1987); total acids – by 0.1M NaOH titration method, with addition of phenolphthalein; actual acidity (pH value) – by potentiometer (pH Meter MA 5707; Iskra, Ljubljana, Slovenia); total pectines–carbazole method, spectrophotometer UV/VIS (PU 8740; Pyu Unicam, Cambridge, UK) – Rouse and Atkins (1955); and total anthocyanins – Niketić-Hrazdina method (Niketić, Hrazdina 1972).

Optimally ripe, cultivar-typical fruits collected thrice over growing period (beginning, mid-season, end) from each cultivar were used for analyses. Out of 100 shoots tested per cultivar, 3 kg fruits (taken from 25 shoots), randomly selected and classified as three separate 1 kg samples, were included in the analysis. Crushed fruits were frozen at –18°C. The presented data represent means over growing period.

Organoleptic assessment involved sensory analysis done by the panel of experts using credits system assessing appearance (0–5), flavour (0–8), aroma (0–2) and consistency (0–5), with 20 credits at maximum.

Data processing. The obtained results were subjected to analysis of variance (ANOVA) of two-factorial trial (Hadživuković 1991), A and B denoting cultivar and year respectively. Significance testing of mean values of the studied cultivars and control cultivar was done by the Dunnet's method (Dunnet 1955), whereas significance testing of mean values by years and interaction means (cultivar + year) involved the Dunnet's multiple range test (Dunnet 1955). Significance of difference was done at $P < 0.05$ and $P < 0.01$.

RESULTS AND DISCUSSION

The comparison among the raspberry cultivars studied inferred that cv. Willamette gave higher yield per unit land area ($P < 0.01$), which is in agreement with the results of Eyduran et al. (2008). However, the obtained results are not in agreement with those obtained by Marinković et al. (2008),

Table 1. Yield and chemical properties of fruits

Treatment	Cultivar		Yield (kg/ha)	Dry matter (%)	Soluble solids (%)	Sugars (%)
Cultivar (A)		Meeker	9,050.78**	15.86**	12.12**	8.84**
		Latham	5,692.08**	12.70**	9.35**	6.83**
		K81-6	9,092.05**	13.87ns	10.51**	7.04**
		Tulameen	8,143.17**	14.53**	11.85**	7.47**
		Willamette	9,900.49	13.90	10.11	6.33
Year (B)		2003	7,770.21^{c}	13.83^{b}	10.53^{bc}	7.14^{b}
		2004	8,826.42^{b}	14.02^{b}	10.30^{c}	7.25^{b}
		2005	7,636.43^{d}	14.61^{a}	11.60^{a}	7.57^{a}
		2006	9,269.79^{a}	14.14^{b}	10.71^{b}	7.04^{b}
A × B	Meeker	2003	8,536.40^{gh}	15.15^{c}	11.57^{c}	8.44^{b}
		2004	9,387.02^{c}	16.86^{a}	12.50^{b}	9.68^{a}
		2005	8,365.28^{h}	15.92^{bc}	12.50^{b}	8.60^{b}
		2006	9,914.43^{b}	15.52^{c}	11.90^{bc}	8.65^{b}
	Latham	2003	4,687.98^{l}	12.54^{hi}	9.30^{hi}	6.81^{ef}
		2004	6,504.76^{k}	12.89^{ghi}	9.00^{i}	7.05^{de}
		2005	4,793.14^{l}	12.38^{i}	9.60^{ghi}	6.67^{ef}
		2006	6,782.43^{j}	13.01$^{f–i}$	9.50^{ghi}	6.77^{ef}
	K81-6	2003	8,651.08^{fg}	13.70$^{d–g}$	10.40^{def}	6.98^{de}
		2004	9,071.53^{d}	13.25$^{e–h}$	9.80$^{e–h}$	6.29^{f}
		2005	8,632.18^{fg}	14.25^{d}	11.30^{c}	7.83^{c}
		2006	10,013.42^{b}	13.80^{def}	10.53^{d}	7.04^{de}
	Tulameen	2003	7,664.66^{i}	13.90^{def}	11.30^{c}	7.15^{de}
		2004	8,425.43^{h}	13.56$^{d–g}$	10.50^{de}	6.95^{de}
		2005	7,652.93^{i}	16.36^{ab}	14.00^{a}	8.45^{b}
		2006	8,829.67^{e}	14.31^{d}	11.60^{c}	7.36^{cd}
	Willamette	2003	9,310.94^{c}	13.86^{def}	10.10$^{d–g}$	6.30^{f}
		2004	10,743.36^{a}	13.54$^{d–g}$	9.70$^{f–i}$	6.28^{f}
		2005	8,738.62^{ef}	14.15^{de}	10.60^{d}	6.31^{f}
		2006	10,809.04^{a}	14.05^{de}	10.03$^{d–g}$	6.41^{f}
ANOVA						
Cultivar (A)			**	**	**	**
Year (B)			**	**	**	**
A × B			**	**	**	**

*, **in columns stand for significant differences among mean values at $P < 0.05$ and $P < 0.01$, respectively, based on the Dunnett's test and ANOVA results (F-test); ns – not significant; mean values for year (B) and interaction mean values (A × B) within columns with letters in index show that there are no significant differences for $P < 0.01$ shown by the Duncan's multiple range test (Duncan 1955)

which is probably due to the unfavourable climate conditions for raspberry in their trial.

Besides cultivar differences, major difference in yield per unit land area was observed by years (Table 1). Raspberry yields were highest in the fourth and lowest in the third year. Yield was lowest in the first year of study, which was expected as this was the initial cropping year, whereas in the other years yields were primarily correlated with rainfall rate and the distribution over growing period.

The comparative analysis of total dry matter in the studied cultivars and cv. Willamette (control) suggests considerably higher values in cvs Meeker and Tulameen ($P < 0.01$), and markedly lower ones in cv. Latham ($P < 0.01$). The results of our study confirmed the findings of Tešović (1988) and Veličković et al. (2004). However, a four-year study of Eyduran and Ağaoğlu (2006) inferred significantly higher dry matter content in cv. Willamette than in cv. Tulameen and the other studied cultivars. Distinctly different agro-environmental conditions of growing raspberry in the above investigations (vicinity of Ancara, Turkey), different precipitation rate and air temperature during growing period in particular may account for the different results of the Turkish authors.

Regardless of the studied raspberry cultivars, total dry matter content was significantly higher in the third year of study. Extremely high temperatures accompanied by low air humidity and water deficiencies in soil during fruit ripening period (3rd year) can account for high dry matter in fruits, which is confirmed by Riaz and Bushway (1996).

Given the values of total dry matter over the trial period, it can be easily observed that raspberry cultivars perform differently, which confirms the significance of the cultivar × year interaction. Cvs Willamette and K81-6 exhibited relatively low variation compared with the other cultivars. Total dry matter in cvs Willamette and K81-6 is greatly governed by yield, i.e. the lower the yield the higher total dry matter content. The latter was high in cv. Tulameen in third trial year, which may be due to the long fruit ripening period and a substantial influence of high temperatures and humidity and water deficiencies on fruits of cv. Tulameen. Dry matter content in cv. Latham was low and not different among years. Additionally, cv. Latham had markedly lower yields and shorter fruit ripening period compared with the other cultivars studied.

Analysis of variance showed that soluble solids content greatly varied among the cultivars and years. It also showed that cultivars responded differently to fluctuating growing conditions (cultivar × year interaction, Table 1). Cvs Meeker, Tulameen and K81-6 exhibited significantly higher soluble solids in comparison with control ($P < 0.01$). Values of soluble solids in cvs Willamette and K81-6 are in agreement with the values of dry matter content. Cv. Latham performed similarly, however its values are conversely correlated with total dry matter content. Exceptionally high variability of cv. Tulameen, i.e. very high yield in the third year of study and lower than its average production in the second year can be partly due to duration of harvesting.

Analysis of variance of total reducing sugars suggested variations in performance among cultivars by years as well as in their response in some years (cultivar × year correlation, Table 1).

The results of our study revealed considerably lower total reducing sugars in the control cultivar ($P < 0.01$), which is in accordance with the results of Janda and Gavrilović (1983). Total reducing sugars were considerably higher in the third year of study than in the other years when no significant differences were recorded.

Cvs Willamette and Latham displayed slight variability in total reducing sugars which is contrary to cvs Tulameen and K81-6, where the values were higher in years with lower yields and vice versa. Cv. Meeker had high total reducing sugars compared with its mean values over the study period and highly uniform values over the other study years (Table 1). Given that total reducing sugars in cv. Meeker were markedly higher than in the cultivars studied, their rather high share in total dry matter can be considered as cultivar specificity. Gavrilović-Damnjanović et al. (2004) also report on high total reducing sugar content in this cultivar. All the studied raspberry cultivars had higher total reducing sugars (in the first year) in comparison with control cultivar, whereas in the second study year K81-6 recorded results similar to those found in control. As for total reducing sugars content in the third and fourth years of study, no significant differences were observed between cv. Latham and control.

Analysis of variance of total acids inferred significant differences among cultivars and years along with the significance of their correlation (Table 2). Except for cv. K81-6, which performed similarly to the control cultivar, the studied cultivars had significantly lower total acids content ($P < 0.01$), which is in accordance with the results of Daubeny (1987) and Stanisavljević et al. (1996).

Table 2. Chemical properties of fruits

Treatment	Cultivar		Acids (%)	pH	Pectines (%)	Anthocyanins (g/l)
Cultivar (A)		Meeker	1.29**	2.88*	0.34**	0.50**
		Latham	1.51**	2.80ns	0.33**	0.43**
		K81-6	1.86ns	2.75ns	0.28**	0.70**
		Tulameen	1.59**	2.67ns	0.37**	0.40**
		Willamette	1.89	2.67	0.42	0.76
Year (B)		2003	1.59^{b}	2.68	0.35^{b}	0.55^{c}
		2004	1.63^{ab}	2.76	0.36^{ab}	0.44^{d}
		2005	1.66^{a}	2.84	0.31^{c}	0.65^{a}
		2006	1.63^{ab}	2.74	0.37^{a}	0.59^{b}
A × B	Meeker	2003	1.23^{i}	2.70	$0.34^{e–h}$	$0.47^{d–g}$
		2004	1.34^{h}	3.00	$0.36^{d–g}$	0.44^{efg}
		2005	1.34^{h}	3.00	0.28^{ij}	0.58^{cd}
		2006	1.26^{i}	2.80	$0.36^{d–g}$	$0.51^{c–f}$
	Latham	2003	1.49^{g}	2.70	0.32^{ghi}	0.38^{fg}
		2004	1.60^{ef}	2.80	0.40^{bcd}	$0.47^{d–g}$
		2005	1.41^{h}	2.80	0.26^{j}	$0.46^{d–g}$
		2006	1.54^{fg}	2.90	$0.35^{e–h}$	0.41^{efg}
	K81-6	2003	1.85^{c}	2.70	0.28^{ij}	0.63^{c}
		2004	2.00^{b}	2.60	0.31^{hi}	0.40^{fg}
		2005	1.73^{d}	2.90	0.22^{k}	1.01^{a}
		2006	1.87^{c}	2.80	0.31^{hi}	0.77^{b}
	Tulameen	2003	1.53^{fg}	2.60	0.38^{cde}	0.42^{efg}
		2004	1.67^{de}	2.60	0.37^{def}	0.35^{g}
		2005	1.60^{ef}	2.90	$0.33^{f–i}$	0.42^{efg}
		2006	1.57^{fg}	2.60	0.39^{bcd}	0.42^{efg}
	Willamette	2003	1.88^{c}	2.70	0.42^{abc}	0.83^{b}
		2004	1.54^{fg}	2.80	0.37^{def}	0.54^{cde}
		2005	2.24^{a}	2.60	0.45^{a}	0.77^{b}
		2006	1.91^{c}	2.60	0.43^{ab}	0.88^{b}
ANOVA						
Cultivar (A)			**	**	**	**
Year (B)			**	ns	**	**
A × B			**	ns	**	**

*, **in columns stand for significant differences among mean values at $P < 0.05$ and $P < 0.01$, respectively, based on the Dunnett's test and ANOVA results (F-test); ns – not significant; mean values for year (B) and interaction mean values (A × B) within columns with letters in index show that there are no significant differences for $P < 0.01$ shown by the Duncan's multiple range test

Table 3. Organoleptic assessment of fresh fruits*

Cultivar	Appearance (0–5)	Flavour (0–8)	Aroma (0–2)	Consistency (1–5)	Sum
Meeker	4.6	7.8	1.5	4.6	18.5
Latham	3.9	6.6	1.2	3.5	15.2
K 81-6	4.0	6.9	1.4	3.1	15.4
Tulameen	4.8	7.6	1.7	4.9	19
Willamette	4.6	7.6	1.8	4.7	18.7

*performed by a panel of experts consisting of pomologists and technologists

The results of the study suggest a marked influence of cultivar × year correlation on different response of cultivars over the study period. With exception of the control cultivar, in other cultivars studied high yields were correlated with high total acids content and conversely. Some variability was observed in cvs Meeker and Tulameen in this respect. In contrast, in cv. Willamette the highest total acids content was correlated with lower yield, which accounts for significant interaction. Analysis of variance of pH value of fruits showed few differences among the studied cultivars (Table 2). Comparative analysis of the mean values of the cultivars and control showed that only cv. Meeker had significantly higher pH value in fruits ($P < 0.05$).

Analysis of variance of total pectines points to considerable differences among cultivars by years and reveals the presence of strong correlation among the cultivars and years (Table 2). In the studies conducted by Gavrilović-Damnjanović et al. (2004), pectines were markedly higher in fruits of cv. Willamette compared to the other cultivars, which was confirmed in our studies. From the aspect of years of study, compared with the first year of study, pectines were markedly higher in the fourth year, and were considerably lower in the third year. The lowest pectines were recorded in cvs Latham and K81-6, depending on yield.

Significant cultivar × year interaction suggests the different reaction of the studied raspberry cultivars among years. Cvs Meeker, Latham and K81-6 had rather uniform performance, except for a slight variability in pectines content. Total pectines in the cultivars studied, except in cv. Tulameen in the first year of study, were correlated with yield. In contrast, there were minor differences in cv. Willamette pectines and yield among years.

Total anthocyanins in fruits of the raspberries studied varied among cultivars and years. The results of analysis of variance showed that besides major influence of cultivar specificities and years, environmental conditions also affected the response of the cultivars studied (Table 2).

Compared with the control cultivar, significantly lower total anthocyanins were evidenced in all the cultivars studied ($P < 0.01$). The values obtained in our paper were higher than those reported by Pantelidis et al. (2007), which can be due to the more favourable raspberry growing conditions of Western Serbia.

The results of the study infer considerable differences in total anthocyanins content among years, whereby the highest values were recorded in the third year, and the values in fourth, first and second year followed.

Cultivar × year interaction points to the different response of the cultivars over the study period. Namely, anthocyanins content varied less in cvs Meeker, Latham and Tulameen than in cvs Willamette and K81-6. Higher anthocyanins content in cv. Willamette in the fourth study year, as compared to its mean value over the study period, and pronounced variability of the content in K81-6 are the result of considerable influence of the cultivar × year interaction. Variability in anthocyanins content in fruits of K81-6 in the third year of study was considerably higher than in control, whereas the content was much lower in the cultivars studied, compared to control. In the first, second and fourth year of study all the cultivars had markedly lower anthocyanins in comparison with cv. Willamette, which confirms the report of Milivojević (2008).

The results of sensory analysis of raspberry fruits in the cultivars studied are shown in Table 3.

As regards appearance, flavour, aroma and consistency of fresh fruits, cv. Tulameen was the highest graded among the cultivars, which is in accordance with the recommendation of Pritts (2000) to use this cultivar for fresh consumption.

Control cultivar and cv. Meeker had very similar values, which speaks of their potential versatile use. In other words, the cultivars, grown in raspberry plantings of Western Serbia, display the best organoleptic properties (Stanisavljević et al. 1996). Several assessors highlighted the disadvantageous dark colour of fruits of cv. Willamette, however, new surveys suggest that it is primarily this dark colour of fruits, owing to the high anthocyanins content, that recommends this cultivar as biologically valuable food (antioxidant properties, cancer preventive and cancer suppressive activity), which is confirmed by the results of Juranić et al. (2005). Organoleptic assessment of fruits of cvs Willamette and Tulameen are in agreement with the results of Atila et al. (2006). The insufficient colour and fruit firmness in cv. K81-6 in our study can be considered as its greatest disadvantages, while cv. Latham was assessed as the poorest performing cultivar in all years of study (Robbins, Sjulin 1989).

CONCLUSION

Yield is a cultivar specificity considerably influenced by agro-environmental and meteorological conditions. All the studied cultivars had higher yields in the fourth year of study. In our study cvs Willamette and Meeker gave the highest yields, whereas cv. Latham displayed the lowest performance in this respect, which can seriously affect its production efficiency.

In all the cultivars total dry matter and soluble solids contents were highest in the third year of study. Among the cultivars studied, cv. Tulameen displayed extremely high variability due to the long exposure of fruits over extended harvesting period in this cultivar.

Significantly lower total reducing sugars were recorded in the control cultivar which, besides cv. Latham, showed very low variability in this respect. Total pectines were the highest in control cultivar and the lowest in cvs Latham and K81-6 which exhibited exceptionally low consistency values. The highest total anthocyanins were found in fruits of cv. Willamette.

The results of the study also suggest that climatic conditions of Western Serbia are suitable for commercial growing of the studied raspberry cultivars provided that adequate agrotechniques are applied. This particularly goes for cvs Willamette and Meeker which perform best in terms of fruit quality and production. Fruits of cv. Tulameen are attractive, but can be recommended for fresh consumption only. Being a steady cropper, cv. K81-6 can be recommended for growing under unfavourable climate conditions as well as for processing or fast freezing after harvesting. Along with cv. Latham, cv. K81-6 can be interesting for breeding programmes as the source of genetic variability.

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