

SUGAR AND ORGANIC ACIDS PROFILE IN THE FRUITS OF BLACK AND RED CURRANT CULTIVARS

Jasminka Milivojević¹, V. Maksimović², and M. Nikolić¹

Abstract: In this study, three black currant cultivars (Ben Sarek, Ben Lomond and Malling Juel) and three red currant cultivars (Industrija, Rondon and Red Versailles) were compared in terms of fruit quality by high-performance liquid chromatography analysis in order to determine sugars and organic acids profiles in their fruits. Among the analysed individual sugars, fructose was determined to be the major component in all studied cultivars. Cv Ben Lomond exhibited the highest levels of glucose (78,8 mg g⁻¹ FW), fructose (117,6 mg g⁻¹ FW) and sucrose (10,1 mg g⁻¹ FW) in comparison to the other tested black currant cultivars. Among investigated red currant cultivars the highest amounts of glucose (81,1 mg g⁻¹ FW), fructose (113,1 mg g⁻¹ FW) and sucrose (14,5 mg g⁻¹ FW) were recorded in the fruits of cv Industrija, as well as the richest content of total sugars (208,7 mg g⁻¹ FW). The same tendency was noticed considering the organic acids content (citric and malic), that is, the highest levels were registered with the cv Industrija (0,32 mg g⁻¹ FW and 0,13 mg g⁻¹ FW, respectively). Black currant cv Ben Sarek displayed the highest contents of citric and malic acids (0,68 mg g⁻¹ FW and 0,14 mg g⁻¹ F, respectively). Generally, dominant share of total acids was exhibited by citric acid in all studied black and red currant cultivars. These results point to the fact that the chemical fruit composition of currants significantly varied among the genotypes of each species analysed.

Key words: black currant, red currant, cultivars, sugars, organic acids.

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Introduction

Raspberry production in Serbia has an important place in total fruit production which makes our country one of the greatest raspberry producers in the world (Nikolić *et al.*, 2008). However, this production has specific demands that regard to sort list innovation and breaking up with monotony of Willamette production, which is predominant cultivar in raspberry commercial plantings in Serbia. It is possible to accomplish it with continual work on introduction and creating new raspberry cultivars, that will, in its genetic base, include all producers, processors, and consumers demands (Stanisavljević *et al.*, 2004).

Raspberry breeding programs are attracting great attention in the world (Finn and Knight, 2002). Universal objectives include good fruit quality, fruit firmness, high yields, extension of the fruiting season, suitability for the fresh and processing market as well as mechanical harvesting (Milutinović *et al.*, 2002; Knight, 2002). Adaptation to different environmental conditions and resistance or tolerance to pests and diseases are also necessary for successful raspberry production (Jennings and Brennan, 2002; Atíla and Ağaoğlu, 2006).

Development of a new raspberry cultivar in the breeding program requires several screening steps, and the entire process can take up to ten years or more before new cultivar is released for nursery propagation and sales (Sjulin *et al.*, 1984).

The main goal of this study was investigation of pomological properties of seedlings obtained by open pollination of Meeker yellow raspberry clone in order to select genotypes that will overcome its parent in morphological, chemical and organoleptic characteristics.

Material and Methods

Black and red currants (*Ribes nigrum* L. and *Ribes rubrum* L.) are randomly grown in Serbia, on relatively small areas with the production which is far behind strawberry, raspberry and blackberry production and it does not meet the needs of the country (Mišić and Nikolić, 2003). These species have been largely neglected as the consequence of the mistakes made in the previous period, especially with the selection of assortment and

uncontrolled multiplication of infertile clones of some cultivars infected with “Black Currant Reversion Virus” (Stanisavljević *et al.*, 1999).

Considering the high fruit quality of black and red currants that is based on the contents of sugars, organic acids, polyphenols and vitamin C, Kampuss (2005) and Rotundo *et al.* (1998) pointed to the significance and the need for a more intensive exploitation of this species. This can be realized not only observing the principle of modern growing technology, but also by the introduction of new cultivars with better fruit quality.

The sugar and organic acid content may reflect changes in quality, since sensory changes are often accompanied by changes in the concentration of sugars and organic acids (Doyon *et al.*, 1991). Also, their ratio determines the sweet and acid taste of the fruits.

The purpose of this study is to characterize the contents of individual and total sugars and organic acids in fruits of six representative black and red currant cultivars using high-performance liquid chromatography (HPLC). In that way, we will make a selection of the cultivars with the best chemical fruit composition which could be important base for further breeding work.

Results and Discussion

Plant material

Ripe fruits of the three black currant cultivars (Ben Lomond, Ben Sarek and Malling Juel) and three red currant cultivars (Industrija, Rondon and Red Versailles) were analysed during a three-year period (2004 – 2006). The fruits of selected cultivars were harvested at the commercial plantation located in the nursery "Omega", the village of Mislodjin near Belgrade.

All samples were extracted immediately after harvesting. Approximately 100 g of fruits were blended to a puree, and 5 g subsamples were homogenised for 1 min in 20 mL of extraction solution containing methanol/water/hydrochloric acid at a ratio of 70:30:5 by volume. The homogenate was filtered through a filter paper and the filtrates were centrifuged for 15 min at 3000 x *g*. The methanol supernatant was divided into aliquots and frozen at -80°C until analysis. Triplicate extractions were prepared for each fruit analysed.

Analytical procedures

A high-performance liquid chromatograph (HPLC; Waters Breeze, Milford, USA) was used for the analysis of individual sugars (glucose, fructose, sucrose) in the fruit samples, whereas the analysis of organic acids (citric, malic) was conducted using Hewlett-Packard HP1100 system (Palo, Alto, CA, USA). The detection of sugars was performed on 2465 Waters electrochemical detector (Waters, Milford, USA), and for organic acids was used HP 1100 photo diode array detector (Palo, Alto, CA, USA) adjusted at 210 nm, with a reference signal at 600 nm. The elution solvent used contained 200 mmol L⁻¹ NaOH for sugars and 5 mmol L⁻¹ sulfuric acid for organic acids analysis. The injection volume was 20 µL and the flow rate was 1 mL min⁻¹ for sugars and 0.6 mL min⁻¹ for organic acids. The column for sugars was CarboPac PA1 (Dionex, Sunnyvale, CA, USA) operated at 30°C and for organic acids an Aminex - HPX-87H column (Bio-Rad Laboratories, Hercules, CA, USA) operated at 40°C.

Statistical analysis

Statistical analysis was performed using software Statistica 6.0 for Windows (StatSoft Inc.). Data of a three-year investigation were calculated by MANOVA for mean comparison, and intergenotype significance of differences were calculated according to LSD test. Data are reported as means ± standard error of the mean. Differences at $P < 0.05$ were considered to be statistically significant.

Results and Discussion

The results of individual sugars content (glucose, fructose and sucrose) detected in the fruits of studied black currant cultivars (Table 1) indicated that cv Ben Lomond expressed the highest average contents of glucose (78,8 mg g⁻¹ FW), fructose (117,6 mg g⁻¹ FW) and sucrose (10,1 mg g⁻¹ FW). The lowest average contents of glucose (52,3 mg g⁻¹ FW) and fructose (73,4 mg g⁻¹ FW) were recorded with the cv Ben Sarek. It was found out that the recorded values of glucose and fructose contents with the cv Ben Lomond are statistically significantly higher in comparison to the values observed with the cvs Ben Sarek and Malling Juel, among which we also registered a significant difference.

Tab. 1. The content of individual sugars in fruits of black currant cultivars (mg g⁻¹ fresh weight)

Cultivar	Year	Glucose	Fructose	Sucrose
Ben Lomond	2004	74,2 ± 4,63	118,7 ± 12,51	6,2 ± 1,02
	2005	77,0 ± 3,33	127,2 ± 5,36	14,1 ± 2,81
	2006	85,3 ± 1,09	106,8 ± 3,68	10,0 ± 1,71
	Average	78,8 ± 2,37	117,6 ± 5,02	10,1 ± 1,52
Ben Sarek	2004	51,5 ± 3,47	80,1 ± 5,65	6,8 ± 1,71
	2005	50,3 ± 3,00	70,3 ± 4,35	6,1 ± 0,94
	2006	55,1 ± 4,34	69,7 ± 3,45	6,4 ± 0,13
	Average	52,3 ± 1,96	73,4 ± 2,84	6,4 ± 0,58
Malling Juel	2004	61,2 ± 1,94	94,5 ± 2,05	3,5 ± 0,09
	2005	47,8 ± 2,74	76,2 ± 3,05	2,7 ± 0,24
	2006	64,1 ± 0,60	81,7 ± 2,54	3,9 ± 0,12
	Average	57,7 ± 2,70	84,1 ± 3,01	3,4 ± 0,20

Treatment	Glucose		Fructose		Sucrose	
	LSD _{0.05}	LSD _{0.01}	LSD _{0.05}	LSD _{0.01}	LSD _{0.05}	LSD _{0.01}
Cultivar	5,282	7,236	9,594	13,142	2,271	3,110
Year	5,282	7,236	9,594	13,142	2,271	3,110
Cv x Year	9,150	12,533	16,617	22,762	3,933	5,388

The same tendency is observed regarding the content of sucrose, that is, the highest amount was found in the fruits of cv Ben Lomond (10,1 mg g⁻¹ FW). The obtained value was statistically significantly higher in comparison to the values obtained with the other investigated cvs Ben Sarek and Malling Juel.

The results of total sugars content, obtained as a sum of values of individual sugars, in the fruits of studied black currant cultivars (Figure 1) showed that the average values of total sugars ranged from 132,1 mg g⁻¹ FW (Ben Sarek) to 206,5 mg g⁻¹ FW (Ben Lomond). No significant differences

were observed between the studied years considering the mentioned parameter.

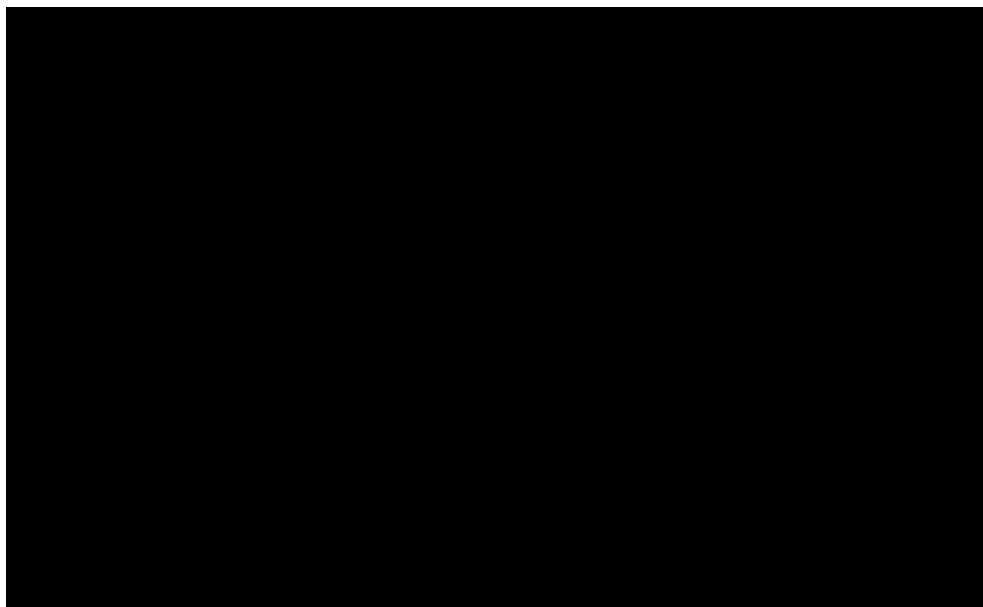


Fig. 1 - Total sugar content in fruits of black currant cultivars
(mg g⁻¹ fresh weight)

Among investigated red currant cultivars the highest amounts of glucose (81,1 mg g⁻¹ FW), fructose (113,1 mg g⁻¹ FW) and sucrose (14,5 mg g⁻¹ FW) were recorded in fruits of cv Industrija (Table 2). The lowest average values for the mentioned parameters were registered with the cv Rondon (50,3 mg g⁻¹ FW; 76,2 mg g⁻¹ FW i 3,6 mg g⁻¹ FW, respectively), which is in accordance with the results of Nikolić *et al.* (2007) who recorded low level of total sugars in the fruits of this cultivar. Fructose was predominant in the structure of total sugars with all three investigated red currant cultivars.

Tab. 2. The content of individual sugars in fruits of red currant cultivars
(mg g⁻¹ fresh weight)

Cultivar	Year	Glucose	Fructose	Sucrose
Industrija	2004	68,5 ± 6,04	112,0 ± 7,48	19,6 ± 4,35
	2005	97,2 ± 1,22	120,7 ± 6,22	11,6 ± 0,31

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	2006	77,7 ± 0,22	106,6 ± 0,59	12,4 ± 0,93
	Average	81,1 ± 4,58	113,1 ± 3,48	14,5 ± 1,81
Rondom	2004	46,0 ± 1,22	74,9 ± 3,96	2,1 ± 0,13
	2005	50,0 ± 4,37	66,1 ± 6,04	5,7 ± 0,15
	2006	54,9 ± 2,50	87,5 ± 5,57	2,9 ± 1,46
	Average	50,3 ± 1,98	76,2 ± 4,07	3,6 ± 0,69
Red Versailles	2004	53,6 ± 4,41	86,4 ± 2,59	3,3 ± 0,26
	2005	57,4 ± 1,05	83,5 ± 0,52	5,5 ± 0,08
	2006	56,8 ± 0,25	78,3 ± 0,42	3,3 ± 0,40
	Average	55,9 ± 1,44	82,7 ± 1,41	4,0 ± 0,39

Treatment	Glucose		Fructose		Sucrose	
	LSD _{0,05}	LSD _{0,01}	LSD _{0,05}	LSD _{0,01}	LSD _{0,05}	LSD _{0,01}
Cultivar	5,285	7,239	7,781	10,658	2,699	3,697
Year	5,285	7,239	7,781	10,658	2,699	3,697
Cv x Year	9,153	12,539	13,477	18,461	4,675	6,404

Observing the years of investigation, the amounts of glucose and fructose in the fruits of red currant cultivars were similar, so we did not establish statistically significant differences.

In accordance to individual sugars content, the highest average value of total sugars content (Fig. 2) was recorded with the cv Industrija (208,7 mg g⁻¹ FW). This confirms the findings of Kampuss (2005) who recommends that this cultivar, due to rich chemical fruit composition, should be used in breeding programs in order to improve the necessary properties in fruit processing.

Organic acid levels (citric and malic) in the fruits of the black currant cultivars (Ben Lomond, Ben Sarek i Malling Juel) are presented in table 3.

Citric acid was predominant ranging from 0,34 mg g⁻¹ FW (Malling Juel) to 0,68 mg g⁻¹ FW (Ben Sarek). Cv Ben sarek also displays the highest content of malic acid (0,14 mg g⁻¹ FW), contrary to the expressed low content of total sugars.

Differences in citric acid content were statistically significant between all the studied black currant cultivars.

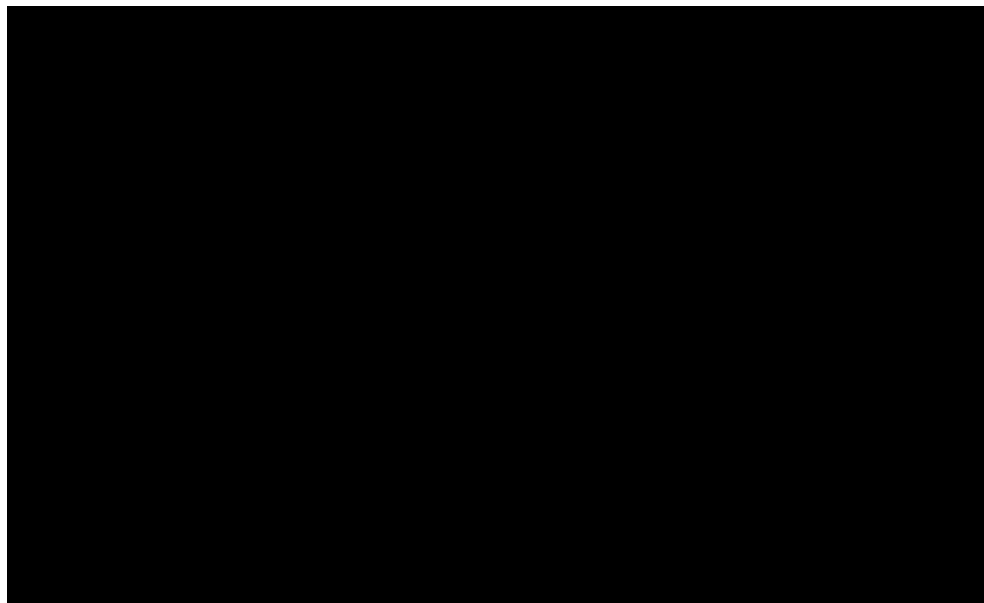


Fig. 2 – Total sugar content in fruits of red currant cultivars
(mg g⁻¹ fresh weight)

Tab. 3. The content of individual organic acids in fruits of black currant cultivars
(mg g⁻¹ fresh weight)

Cultivars	Year	Citric acid	Malic acid
Ben Lomond	2004	0,59 ± 0,04	0,12 ± 0,01
	2005	0,70 ± 0,03	0,15 ± 0, 01
	2006	0,34 ± 0,03	0,12 ± 0,01
	Average	0,54 ± 0,05	0,13 ± 0,01
Ben Sarek	2004	0,66 ± 0,02	0,09 ± 0,01
	2005	0,71 ± 0,03	0,19 ± 0,04
	2006	0,69 ± 0,02	0,14 ± 0,02
	Average	0,68 ± 0,01	0,14 ± 0,02
Malling Juel	2004	0,36 ± 0,03	0,03 ± 0,00
	2005	0,28 ± 0,04	0,10 ± 0,00
	2006	0,38 ± 0,01	0,02 ± 0,01

Average	$0,34 \pm 0,02$	$0,05 \pm 0,01$
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Treatment	Citric acid		Malic acid	
	LSD _{0.05}	LSD _{0.01}	LSD _{0.05}	LSD _{0.01}
Cultivar	0,050	0,068	0,031	0,042
Year	0,050	0,068	0,031	0,042
Cv x Year	0,086	0,118	0,054	0,074

Total acid content, calculated as a sum of citric and malic contents, in the fruits of black currant cultivars is shown in figure 3.

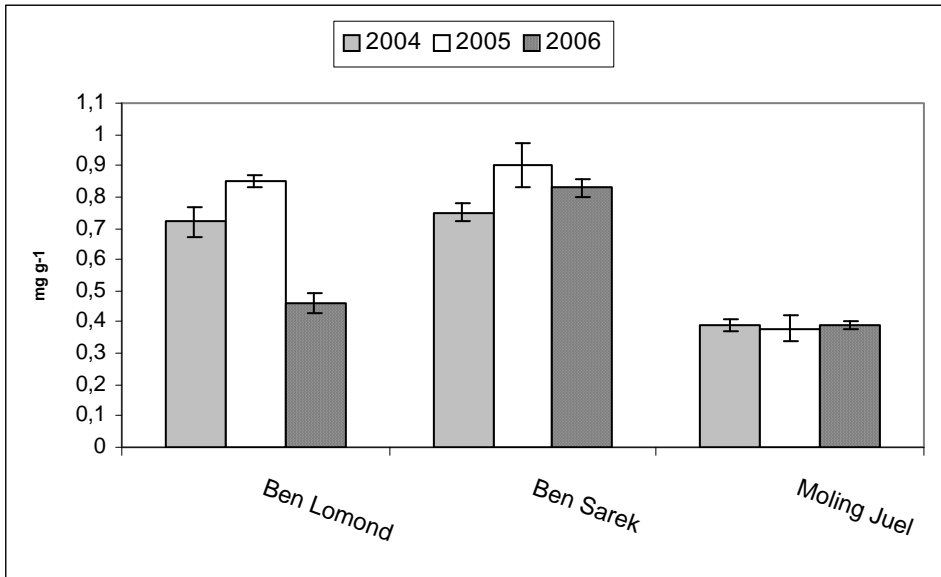


Fig. 3 – Total organic acids content in fruits of black currant cultivars (mg g⁻¹ fresh weight)

The highest values of total acids, ranging from 0,75 mg g⁻¹ FW in the first year of investigation to 0,90 mg g⁻¹ FW in the second year of investigation, were recorded with cv Ben Sarek. Cv Malling Juel expressed the lowest average value of total acids content (0,39 mg g⁻¹ FW), with negligible variations between the investigated years. According to Nikolić *et al.* (2006), cv Ben Lomond showed lower total acids content than cv Ben sarek, which corresponds to the results presented in this paper.

Variations observed among the currant cultivars have already been confirmed by Rubinskiene *et al.* (2006), emphasizing high dependance on total rainfall, especially regarding late-ripening cultivars.

Considering the results of organic acids content in the fruits of red currant cultivars (Table 4), it can be noticed that the highest content of citric acid was obtained with cv Industrija (0,32 mg g⁻¹ FW), whereas the other two investigated cultivars, Red Versailles and Rondon, expressed lower contents (0,24 mg g⁻¹ FW and 0,22 mg g⁻¹ FW, respectively). The same tendency can also be noticed considering the malic acid content, that is, the highest level was registered with the cv Industrija (0,13 mg g⁻¹ FW). Lower and approximate values were recorded with cvs Rondon (0,06 mg g⁻¹ FW) and Red Versailles (0,04 mg g⁻¹ FW).

Tab. 4. The content of individual organic acids in fruits of red currant cultivars (mg g⁻¹ fresh weight)

Cultivar	Year	Citric acid	Malic acid
Industrija	2004	0,29 ± 0,03	0,13 ± 0,02
	2005	0,41 ± 0,03	0,11 ± 0,02
	2006	0,28 ± 0,06	0,15 ± 0,02
	Average	0,32 ± 0,03	0,13 ± 0,01
Rondon	2004	0,24 ± 0,02	0,08 ± 0,02
	2005	0,25 ± 0,04	0,06 ± 0,01
	2006	0,17 ± 0,02	0,03 ± 0,02
	Average	0,22 ± 0,02	0,06 ± 0,01
Red Versailles	2004	0,24 ± 0,02	0,04 ± 0,00
	2005	0,29 ± 0,02	0,06 ± 0,01
	2006	0,18 ± 0,01	0,02 ± 0,00
	Average	0,24 ± 0,02	0,04 ± 0,01

Treatment	Citric acid		Malic acid	
	LSD _{0.05}	LSD _{0.01}	LSD _{0.05}	LSD _{0.01}
Cultivar	0,050	0,069	0,024	0,033
Year	0,050	0,069	0,024	0,033
Cv x Year	0,088	0,120	0,042	0,057

Analysing the results of total acids shown in figure 4 it can be observed that cv Industrija is characterized by the highest average value ($0,45 \text{ mg g}^{-1} \text{ FW}$), which again confirms the findings of Kampuss (2005) about rich chemical fruit composition of this cultivar. The other two studied cultivars, Rondon and Red Versailles, had double lower and identical average value of total acid content ($0,28 \text{ mg g}^{-1} \text{ FW}$), corresponding to low sugar concentration.

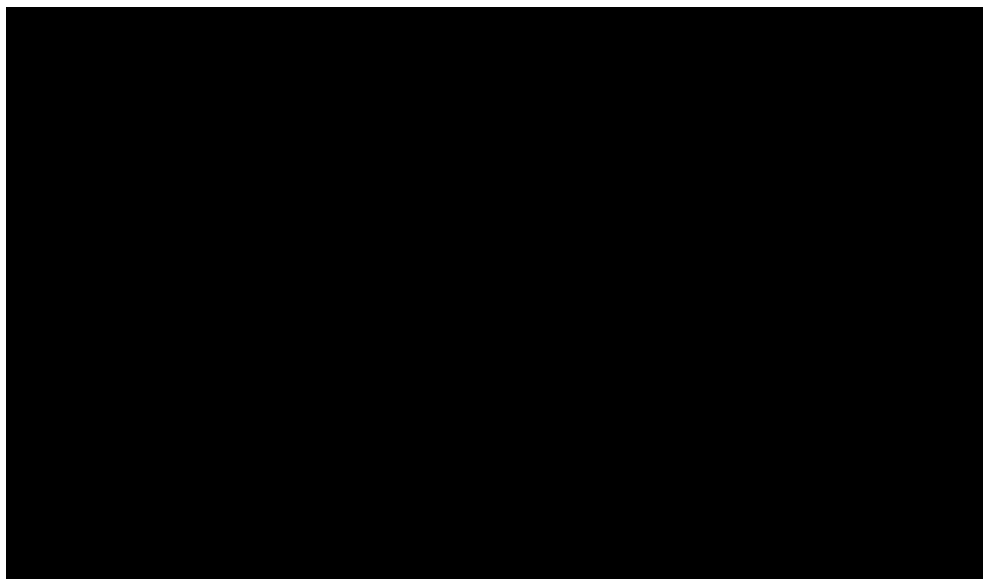


Fig. 4 – Total organic acids content in fruits of red currant cultivars (mg g^{-1} fresh weight)

During the years of investigation, the highest levels of total acid content were obtained with the cvs Industrija and Red Versailles in 2005, whereas cv Rondon expressed similar and higher values in the first and the second investigated year.

Conclusion

Based on the results of individual sugar and acid contents, as well as of the content of total sugars and organic acids, it can be concluded that black currant cvs Ben Lomond and Ben Sarek, and red currant cv Industrija expressed better chemical composition regarding analysed compounds of the fruit quality. These results reflect the genetic differences of the currant

cultivars. Therefore, these quality attributes are important to breeders to develop advanced selections ensuring attractive flavour of the product.

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PROFIL ŠEĆERA I ORGANSKIH KISELINA U PLODOVIMA SORTI CRNE I CRVENE RIBIZLE

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Rezi me

Rad prikazuje rezultate ispitivanja sadržaja šećera i organskih kiselina u plodovima tri sorte crne (Ben Sarek, Ben Lomond i Moling Džul) i tri sorte crvene ribizle (Industrija, Rondon i Versajska crvena), kao determinišućih faktora ukusa ploda. Primenom tehnike tečne hromatografije visokog stepena razdvajanja izvršena je identifikacija i kvantifikacija individualnih šećera (glukoze, fruktoze i saharoze) i organskih kiselina (limunske i jabučne) u plodovima ispitivanih sorti. Ustanovljeno je dominantno prisustvo fruktoze u strukturi ukupnih šećera, sa najvišim registrovanim vrednostima kod sorte crne ribizle Ben Lomond ($117,6 \text{ mg g}^{-1}$ sv.m.pl.) i sorte crvene ribizle Industrija ($113,1 \text{ mg g}^{-1}$ sv.m.pl.). U pogledu sadržaja organskih kiselina, ista tendencija se zapaža među ispitivanim sortama crvene ribizle, odnosno sorta Industrija se odlikuje najvišim vrednostima sadržaja limunske ($0,32 \text{ mg g}^{-1}$ sv.m.pl.) i jabučne kiseline ($0,13 \text{ mg g}^{-1}$ sv.m.pl.). Nasuprot niskom sadržaju šećera, sorta crne ribizle Ben Sarek je ispoljila najviše vrednosti sadržaja limunske ($0,68 \text{ mg g}^{-1}$ sv.m.pl.) i jabučne kiseline ($0,14 \text{ mg g}^{-1}$ sv.m.pl.). Generalno, kod svih ispitivanih sorti crne i crvene ribizle se zapaža dominantna zastupljenost limunske kiseline u strukturi ukupnih kiselina detektovanih u plodu. Dobijeni rezultati ukazuju na činjenicu da hemijski sastav ploda ribizle varira značajno između ispitivanih sorti kod obe analizirane vrste, što može predstavljati značajnu osnovu u daljem oplemenjivačkom radu.

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