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Content of Total Phenolics, Total Flavonoids and Vitamin C, and Antioxidant Activity of Selected Raspberry Varieties

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Abstract: This paper presents the study of total phenolics (TPs), total flavonoids (TFs), vitamin C and antioxidant activity (AA) of fruits and juices of raspberry varieties from the area of the municipality of Cazin. Five raspberry varieties (Fertodi, Meeker, Polka, Tulameen, and Willamette) grown according to the integral concept, as well as one sample of the Willamette variety grown as a hobby within the homestead - semi-intensive concept (W-sc) were analyzed. The TPs (before and after precipitation with formaldehyde) were quantified using the Folin-Ciocalteu method with gallic acid (GA) as a standard. The TFs were calculated from the difference between the TPs before and after precipitation. To determine the content of vitamin C, L-ascorbic acid (AsA) was utilized as a standard. In addition, the AA of the raspberry samples was tested using the ABTS radical scavenging method, wuth trolox (T) as a standard. The highest TPs content in fresh raspberry fruits (f.f.) was shown by the Tulameen variety (1608.77 mg GAE/100 g), while the W-sc sample showed the highest TPs content (1417.65 mg GAE/100 mL) among fresh raspberry juices (f.j.). The Tulameen variety had the highest TFs in f.f. (1513.81 mg GAE/100 g) and the Willamette variety in f.j. (789.99 mg GAE/100 mL). The highest content of vitamin C was shown by the variety Meeker in both tested raspberry fractions (45.87 mg AsAE/100 g in f.f., and 37.42 mg AsAE/100 mL in f.j.). All samples exhibited AA, whereby the best AA was shown by the Fertodi variety (7.60 mM TE/g) for f.f. samples, while the Meeker variety had the highest value of AA (6.26 mM TE/mL) among f.j. samples.

INTRODUCTION

Phenolic compounds present in plant species are an integral part of human nutrition and are of key interest due to their antioxidant (Cotelle *et al.*, 1996; Zheng and Wang, 2001), anti-inflammatory (Ferrándiz and Alcaraz, 1991; Wu *et al.*, 2006), anticancer (Brusselmans *et al.*, 2005; Angst *et al.*, 2013), antimicrobial and other beneficial effects (López-Lázaro, 2009; Kedika *et al.*, 2016). However, it should be emphasized that many of the phenolic compounds can have harmful effects at specific concentrations and conditions (Boots *et al.*, 2007; López-Lázaro, 2009).

Fruits, vegetables and numerous beverages are the main sources of phenolic compounds in the human diet. Significant amounts of by-products rich in phenols are produced by the food processing industry, which could later be valuable natural sources of antioxidants. Some of these by-products are the subject of research Their antioxidant activity was demonstrated through testing on edible oils, as well as fish and meat products, where the obtained extracts exhibited antioxidant properties comparable to various synthetic antioxidants (Balasundram *et al.*, 2006).

Extraction using organic solvents is the main method of phenols isolation, while the detection, identification and quantification of phenolic compounds use spectrophotometric (Folin-Ciocalteu test, Folin-Denis test, Prussian blue test, etc.), chromatographic (high-performance liquid chromatography), and more recently

mass spectrometry methods (Khoddami *et al.*, 2013; Akimoto *et al.*, 2017).

The aim of this research is the determination of the content of total phenolics (TPs), total flavonoids (TFs) and vitamin C, as well as antioxidant activity (AA) in different raspberry varieties.

MATERIALS AND METHODS

Chemicals and reagents

Formaldehyde was obtained from Analitika, Sarajevo, Bosnia and Herzegovina. Sodium carbonate, hydrochloric acid and ethanol were obtained from Semikem, Sarajevo, Bosnia and Herzegovina. Potassium persulfate was purchased from Kemika, Zagreb, Croatia. Folin-Ciocalteu reagent and ammonium chloride were purchased from Carlo Erba Reagents, Milan, Italy. Gallic acid, L-ascorbic acid, ABTS and trolox were obtained from Sigma Aldrich, and *o*-phenylenediamine (OPD) was purchased from Merck, Darmstadt, Germany. Ammonium hydroxide was obtained from Panreac, Spain. All chemicals and reagents were analytical grade.

Equipment

UV/Vis spectrometer Lambda 25 (Perkin-Elmer) was used for determining the TPs and TFs contents, and for examining the AA in raspberry samples. The vitamin C content in these samples was determined using the luminescence spectrometer LS 55 (Perkin-Elmer). The samples were centrifuged on the microcentrifuge 22R Hettich. The analytical balance Mettler Toledo AB 104 was utilized for weighing the samples.

Methods

Determination of total phenolics

For the determination of TPs, a spectrophotometric method with Folin-Ciocalteu (F-C) reagent (Singleton and Rossi, 1965) was used, modified and adapted to experimental conditions by Keskin-Šašić *et al.* (2012).

The principle of this method is based on the oxidation of phenol with F-C reagent (yellow color) and the colorimetric measurement of the formed metal complexes (blue color). Under appropriate experimental conditions, the intensity of the blue coloration is directly proportional to the amount of phenol. An aqueous solution of gallic acid was used as a standard (Keskin-Šašić, 2013).

Preparation of standard solution of gallic acid

The amount of 0.0515 g of gallic acid (GA) was dissolved in 200 µL of 96% ethanol and transferred to a 100 mL measuring vessel after washing and refilling with distilled water.

This represented a standard GA solution with a mass concentration of 515 mg/L (stock solution). Working solutions (10.3; 30.9; 51.5; 72.1; 92.7; 113.3; 133.9 and 154.5 mg/L) were prepared from this stock solution to construct the calibration curve.

Recording the spectrum and drawing the calibration curve

After the preparation of GA working solutions of the specified concentrations, GA solutions with F-C reagent and sodium carbonate were prepared as follows:

- 1250 µL of F-C reagent (1:10) was added to 250 µL of GA working solution;
- after 10 minutes, 1000 µL of 7.5% Na_2CO_3 aqueous solution was added;
- with the prepared measurement solutions of GA (which amounted to 1.0; 3.1; 5.1; 7.2; 9.3; 11.3; 13.4 and 15.5 mg/L), absorbances were recorded at the maximum absorption, which was 743 nm.

The absorption maximum was determined by recording the absorption spectrum of a GA solution with a concentration of 5 mg/L, prepared as described above.

The relationship between absorbance and the concentration of GA measuring solutions was demonstrated, and the calibration curve equation was applied for further calculations of the TPs content in the samples. After performing the just-described procedures of appropriate preparation of the samples and recording of their absorbances, the results were converted to the TPs content expressed in GA equivalents by mass or fresh juice of sample [mg GAE/100 g(mL)].

Samples

Samples of five raspberry varieties („Fertodi“, „Meeker“, „Polka“, „Tulameen“ and „Willamette“) grown on plantations using the conventional concept, as well as one sample of the „Willamette“ variety grown as a hobby in the garden (semi-intensive concept) were collected in 2018 year from the area of the municipality of Cazin during the harvest period and were kept at a temperature of -32 °C until analysis.

Sample preparation and absorbance measurement

The amount of 1 g of a raspberry fruit sample was weighed and dissolved in 10 mL of distilled water. For the analysis of raspberry juice, 9 mL of distilled water was added to 1 mL of free-squeezed juice. 1250 µL of F-C reagent (1:10) was added to 250 µL of 10% raspberry homogenate. After 10 minutes 1000 µL of Na_2CO_3 solution was added to the sample. Absorbance was measured after 30 min. incubation at room temperature. All raspberry samples were analyzed in triplicate under the same experimental working conditions as with the GA standard.

Calculation of the content of total phenolics

The TPs content in the tested raspberry samples is expressed in mg GAE/100 g(mL) and can be calculated from the corresponding equation of the calibration curve ($y = 0.0087x - 0.0304$) and using a dilution factor ($f = 2.5$ mL/0.250 mL).

Determination of total flavonoids by the combined technique of spectrophotometric method and precipitation with formaldehyde

Total flavonoids were determined using the method of Ough and Amerine (1988). First, the absorbance was recorded for the tested sample, the value of which corresponds to total phenolics (flavonoid and non-flavonoid fractions). Then the flavonoid fraction was precipitated using formaldehyde (which reacts with flavonoids to form condensed products) and removed by centrifugation. Afterwards, the absorbance corresponding to the non-flavonoid fraction is measured in the remaining supernatant. The difference in the contents of phenolics

obtained from these absorbances (before and after precipitation) corresponds to the flavonoid fraction. The obtained results are expressed as GAE per mass/volume of fresh fruit/juice of raspberry (mg GAE/100 $g_{f.f./f.j.}$).

Sample preparation and precipitation with formaldehyde
The sample, hydrochloric acid (HCl, 1:4) and formaldehyde (8 mg/L) were mixed in a ratio of 2:2:1. The solution thus prepared was mixed well and left to stand at room temperature for 24 hours, after which it was centrifuged at 8500 rpm for 10 minutes. The remaining phenolic compounds (non-flavonoid fraction) were determined in the supernatant according to the method for determining of TPs. The difference between the TPs content and the content of the non-flavonoid fraction gives the TFs values.

Determination of vitamin C
The spectrofluorimetric method for quantifying vitamin C/L-ascorbic acid (AsA) is based on its oxidation to L-dehydroascorbic acid, which reacts with *o*-phenylenediamine (OPD) in a basic medium to give an N-heterocyclic compound with a large number of conjugated π-bonds, which can emit strong fluorescence. The fluorescence intensity of the resulting compound is proportional to concentration and is measured at an excitation wavelength (λ_{ex}) of 360nm and an emission wavelength (λ_{em}) of 430 nm (Wu *et al.*, 2003).
The amount of 0.1068 g of AsA was weighed and dissolved in 100 mL of distilled water. This represented a standard AsA solution with a mass concentration of 1068 μg/mL (stock solution). Working solutions (1.07; 10.68; 32.04; 53.04; 74.76 and 96.12 μg/mL) were prepared from stock solution to construct the calibration curve.
Around 1 g of a raspberry fruit sample was weighed and macerated with 9 mL of distilled water, and then centrifuged at 15000 rpm for 15 minutes. A 1/10 diluted sample from the obtained supernatants was prepared. In the case of a raspberry juice sample, the sample was centrifuged under the same conditions and diluted in the same way as a fruit sample.
Solutions of AsA and samples prepared in this way were used for measurement. The solutions were mixed as follows: 1 mL AsA, 1 mL 0.5% OPD, and 1.5 mL buffer NH_4OH-NH_4Cl (pH = 9.4). After that, the solution was diluted to 10 mL with distilled water, mixed well and left to stand for 5 minutes before measuring. Fluorescence intensity was measured in a 1 cm quartz cuvette at an λ_{ex} of 360 nm and an λ_{em} of 430 nm.
Based on the calculated concentrations of AsA in the samples, results were expressed as mg AsA/100 g or mg AsA/100 mL of the sample.

Determination of antioxidant activity by ABTS method
The ability of the sample components to reduce the $ABTS^{\bullet+}$ radical cation (2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid) was measured spectrophotometrically, where during the reaction the green $ABTS^{\bullet+}$ is reduced to its colorless form. Equal volumes of ABTS dissolved in water (7 mM) and $K_2S_2O_8$ (2.45 mM) were mixed and left for 12-16 hours in the dark at a temperature of 4 °C (Scalzo *et al.*, 2005). In this way, ABTS is converted into its $ABTS^{\bullet+}$. This solution is diluted that its absorbance is 0.7-0.9. After adding 100 μL of the sample to the diluted $ABTS^{\bullet+}$ solution, the absorbance is measured after 7 min. at 734 nm. Ethanol was used as a blank test, and trolox was used as a positive test.

The percentage of $ABTS^{\bullet+}$ radical cation inhibition is calculated according to the formula:

$$AA\,(\%) = [(A_a - A_b)/A_a] \cdot 100$$

where is it:
- A_a - the absorbance of the ABTS solution before the addition of the sample (t = 0 min.);
- A_b - the absorbance of the solution after the addition of the sample (t = 7 min.).

The percentage of the antioxidant activity was measured as a function of the sample concentration, and the value of mM TE/g or mM TE/mL of the sample was calculated based on the equation of the calibration curve for trolox.

RESULTS AND DISCUSSION

Content of total phenolics in raspberry

The calibration curve method was used to determine TPs in raspberry samples, and it was constructed by measuring the absorbance of standard GA solutions of certain concentrations.
Values of TPs content in the samples of fresh raspberry fruits and juices are listed in Table 1:

Table 1. TPs content in the samples of fresh raspberry fruit and juice.

Raspberry	TPs ± SD (mg GAE/100 g)	TPs ± SD (mg GAE/100mL)
„Tulameen“	**1608.77 ± 72.71**	1003.30 ± 156.98
„Willamette“	1604.81 ± 33.01	998.40 ± 72.07
„Fertodi“	1525.01 ± 65.65	423.27 ± 38.36
W-sc*	1504.09 ± 26.97	**1417.65 ± 132.76**
„Meeker“	1457.06 ± 56.27	1006.45 ± 166.02
„Polka“	1443.82 ± 36.50	154.66 ± 23.10

*a sample of the „Willamette“ variety grown as a hobby within the home garden - a semi-intensive concept.

Content of total flavonoids in raspberry

Values of TFs content in the samples of fresh raspberry fruits and juices are listed in Table 2:

Table 2. TFs content in the samples of fresh raspberry fruit and juice.

Raspberry	TFs ± SD (mg GAE/100 g)	TFs ± SD (mg GAE/100mL)
„Tulameen“	**1513.81 ± 6.86**	636.49 ± 43.08
„Willamette“	1488.40 ± 1.50	**789.99 ± 27.33**
W-sc*	1398.75 ± 7.35	618.80 ± 66.24
„Fertodi“	1386.01 ± 5.28	184.79 ± 6.21
„Meeker“	1353.44 ± 1.89	540.53 ± 6.34
„Polka“	1345.58 ± 1.62	100.43 ± 0.03

*a sample of the „Willamette“ variety grown as a hobby within the home garden - a semi-intensive concept.

Content of vitamin C in raspberry

The calibration curve method was used to determine vitamin C in raspberry samples, and it was constructed by measuring of the relative intensity of fluorescence of standard AsA solutions of certain concentrations.

Vitamin C content in the samples of fresh raspberry fruits and juices is listed in Table 3:

Table 3. Vitamin C content in the samples of fresh raspberry fruits and juices.

Raspberry	Vitamin C (mg/100 g)	Vitamin C (mg/100 mL)
„Meeker“	**45.87**	**37.42**
„Tulameen“	43.96	20.34
„Willamette“	36.27	3.17
W-sc*	32.27	15.76
„Polka“	29.03	5.29
„Fertodi“	28.87	29.68

*a sample of the „Willamette“ variety grown as a hobby within the home garden - a semi-intensive concept.

Antioxidant activity in raspberry samples

The ABTS method was used to determine the antioxidant activity (AA) in raspberry samples.

Values of AA of fresh raspberry fruits and juices are listed in Table 4:

Table 4. Antioxidant activity in the samples of fresh raspberry fruits and juices.

Raspberry	AA ± SD (mM TE/g)	AA ± SD (mM TE/mL)
„Fertodi“	**7.60 ± 4.60**	4.81 ± 0.03
„Meeker“	7.48 ± 2.83	**6.26 ± 0.02**
W-sc*	6.71 ± 1.98	5.20 ± 0.21
„Polka“	4.06 ± 2.79	1.33 ± 0.08
„Tulameen“	3.81 ± 1.44	4.80 ± 0.03
„Willamette“	2.56 ± 0.90	5.07 ± 0.18

*a sample of the „Willamette“ variety grown as a hobby within the home garden - a semi-intensive concept.

Five raspberry varieties grown with the integral concept were analyzed: „Fertodi“, „Meeker“, „Polka“, „Tulameen“, and „Willamette“, as well as one sample of the „Willamette“ variety grown as a hobby within the homestead semi-intensive concept (W-sc). Student's t-test was used for statistical analysis.

The content of TPs in the fresh fruit of the examined raspberries was in the interval from 1443.82±36.50 to 1608.77±72.71 mg GAE/100 g, with the highest average content found in the variety „Tulameen“ (1608.77±72.71), followed by „Willamette“ (1604.81±33.01), „Fertodi“ (1525.01±65.65), raspberry sample W-sc (1504.09±26.97), „Meeker“ (1457.06±56.27), while the lowest TPs content was measured in „Polka“ fruit (1443.82±36.50) (Table 1).

There is a statistically significant difference in the TPs content in the fresh fruit of the variety „Tulameen“ compared to the TPs content in the fresh fruit of the varieties „Meeker“ and „Polka“ ($p^{*}<0.05$; Student's t-test), as well as compared to the TPs content of the fruit W-sc ($p<0.05$). Then, there is a statistically significant difference in the TPs content in the fresh fruit sample of the „Willamette“ variety compared to the TPs content in the fresh fruit of the „Meeker“ and „Polka“ varieties, as well as compared to the TPs content in the fresh fruit of the raspberry W-sc sample ($p^{**}<0.01$). Also, there is a statistically significant difference in the TPs content in the fresh fruit of the W-sc raspberry sample versus the TPs content in the fresh fruit of the variety „Polka“ ($p^{*}<0.05$).

The TPs content in the fresh juice of the tested raspberries ranged from 154.66±23.10 to 1417.65±132.76 mg GAE/100 mL, with the highest average content found in the W-sc raspberry sample (1417.65±132.76), followed by „Meeker“ (1006.45±166.02), „Tulameen“ (1003.30±156.98), „Willamette“ (998.40±72.07), „Fertodi“ (423.27±38.36), while the lowest TPs content was found in the variety „Polka“ (154.66±23.10) (Table 1).

A statistically significant difference was in the TPs content in the fresh juice of the W-sc raspberry sample compared to the TPs content in all the fresh juices of the five raspberry varieties grown with the integral concept on the plantations, $p^{***}<0.001$ compared to the varieties „Fertodi“ and „Polka“, $p^{**}<0.01$ compared to the variety „Willamette“, $p^{*}<0.05$ compared to the varieties „Meeker“ and „Tulameen“.

The content of TFs in the fresh fruit of the tested raspberries ranged from 1345.58±1.62 to 1513.81±6.86 mg GAE/100 g, with the highest average content obtained for the variety „Tulameen“ (1513.81±6.86), followed by „Willamette“ (1488.40±1.50), raspberry sample W-sc (1398.75±7.35), „Fertodi“ (1386.01±5.28), „Meeker“ (1353.44±1.89), while the lowest average TFs content was found in the fruit of the variety „Polka“ (1345.58±1.62) (Table 2).

The content of TFs in the fresh fruit of the variety „Tulameen“ was statistically significantly higher compared to TFs content in all analyzed raspberries, $p^{***}<0.001$ compared to the varieties „Fertodi“, „Meeker“, „Polka“, raspberry sample W-sc, and $p^{**}<0.01$ compared to „Willamette“. Also, the content of TFs in the fresh fruit of the variety „Willamette“ was statistically significantly higher compared to the content of TFs in raspberry varieties „Fertodi“, „Meeker“, „Polka“ and raspberry sample W-sc ($p^{***}<0.001$).

Šapčanin *et al.* (2017) have determined the content of TFs in ethanolic extract of the raspberry. The spectrophotometric method based on forming a flavonoid complex with aluminum and quercetin (Qu) as the standard were used in this study. They found that the content of TFs was 1.02 mg QuE/g of fresh weight of the sample.

Çekiç and Özgen (2010) have examined the content of TPs in raspberry varieties „Heritage“ and „Tulameen“. Obtained values for these varieties were 1795 and 2342 μg GAE/g_{fw}, respectively.

Furthermore, the content of TPs and TFs of the „Willamette“ red raspberry (southwestern Serbia) under conventional farming was estimated by Murtić *et al.* (2023). The results for the previously mentioned raspberry variety from 2021 were 19.11±1.51 mg GAE/g (TPs) and 7.14±0.24 mg CE/g (TFs), and from 2022 were 19.71±1.73 mg GAE/g and 7.18±0.43 mg CE/g.

The content of TFs in fresh raspberry juice ranged in the interval 100.43±0.03-789.99±27.33 mg GAE/100 mL, with the highest average content obtained for the variety „Willamette“ (789.99±27.33), followed by „Tulameen“ (636.49±43.08), sample W-sc (618.80±66.24), „Meeker“ (540.53±6.34), „Fertodi“ (184.79±6.21), while the lowest TFs content was found in the juice of the variety „Polka“ (100.43±0.03) (Table 2).

It is observed that raspberry fruit is significantly richer in TPs and TFs content than raspberry juice. Statistical analysis showed that the content of TPs in the fruit of the

analyzed raspberries is statistically significantly higher compared to the content of TPs in the juice of the same raspberries ($p^{**}<0.01$), and the same applies when it comes to the content of TFs, with the fact that this difference is still more pronounced ($p^{***}<0.001$).

According to most of the available literature data, the levels of TPs in fresh fruits (fw) of raspberries are in the interval 428-1079 mg/100 g_{fw} for black fruit, 192-512 mg/100 g_{fw} for red fruit, 428-451 mg/100 g_{fw} for pink-red fruit and 241-359 mg/100 g_{fw} for yellow fruit. Anthocyanins are the main phenolics in black raspberries, with levels in the interval 464-627 mg/100 g_{fw} (Zhao, 2007).

Based on the obtained results and comparison with literature data, it can be concluded that raspberries from the area of Cazin municipality are extremely rich in the content of TPs and TFs. Also, for a more complete intake of polyphenols, it is preferable to consume the whole raspberry fruit, in comparison to its juice.

The content of vitamin C in the fresh fruit of the tested raspberries ranged from 28.87 to 45.87 mg/100 g, with the highest content obtained for the variety „Meeker“ (45.87), followed by „Tulameen“ (43.96), „Willamette“ (36.27), W-sc raspberry sample (32.27), „Polka“ (29.03), while the lowest vitamin C content found in the fruit of the variety „Fertodi“ (28.87) (Table 3).

On the other hand, the content of vitamin C in the fresh raspberry juice ranged in the interval 3.17-37.42 mg/100 mL, with the highest content obtained for the variety „Meeker“ (37.42), followed by „Fertodi“ (29.68), „Tulameen“ (20.34), sample W-sc (15.76), „Polka“ (5.29), while the lowest content of vitamin C was found in the juice of the variety „Willamette“ (3.17) (Table 3).

Vitamin C content in the fruit of six different raspberry varieties („Willamette“, „Meeker“, „Malahat“, „Tulameen“, „Chilliwack“, „Glen Ample“) has been estimated by Milivojević *et al.* (2012). Toward their study, the highest vitamin C content was found in the variety „Chilliwack“ (52.3 mg/100 g_{fw}), whereas the „Tulameen“ variety showed the lowest vitamin C content (38.4 mg/100 g_{fw}).

Ponder and Hallmann (2020) have determined the content of vitamin C in the fruit of some raspberry varieties. They have reported that the highest content of vitamin C was found in the „Tulameen“ variety (42.5±2.8 mg/100 g_{fw}), which was collected in 2013 at summer time. However, among the raspberry samples collected in 2014 at summer time, the variety „Glen Fine“ showed the highest content of vitamin C (42.7±4.7 mg/100 g_{fw}).

The values of AA in the fruit of the raspberry samples ranged in the interval 2.56-7.60 mM TE/g. The variety „Fertodi“ showed the best AA (7.60±4.60), while the lowest value of AA was measured in the fruit of the variety „Willamette“ (2.56±0.90) (Table 4).

In the juice of the raspberry samples, the values of AA ranged from 1.33 to 6.26 mM TE/mL. The best AA was shown by the variety „Meeker“ (6.26±0.02), while the variety „Polka“ showed the lowest AA (1.33±0.08) (Table 4).

Sariburun *et al.* (2010) used the ABTS method to estimate the AA in the fruit of certain raspberry varieties, which were collected in the region of Kestel (Bursa, Turkey). The best AA was shown by the methanol extract of the fruit of the variety „Hollanda Boduru“ (117.07±0.94 μmol TE/g_{fw}).

CONCLUSIONS

In this study, the content of certain bioactive compounds (total phenolics, total flavonoids, vitamin C), as well as the antioxidant activity of the selected raspberry varieties were estimated. The obtained results showed that the tested raspberry varieties from the area of Cazin municipality are extremely rich in total phenolics and total flavonoids content. Statistical analysis showed that the fruit of the analyzed raspberries possesses a statistically significantly higher content of total phenolics and total flavonoids compared to their juice. Therefore, it is more advisable to consume the whole raspberry fruit. Based on the comparison with the literature data, it can be concluded that raspberry fruits are a very good source of vitamin C. Also, the raspberry samples showed significant antioxidant activity, which correlates with the presence of previously determined bioactive compounds.

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REFERENCES

Akimoto, N., Ara, T., Nakajima, D., Suda, K., Ikeda, C., Takahashi, S., Muneto, R., Yamada, M., Suzuki, H., Shibata, D., Sakurai, N. (2017). Flavonoid Search: A system for comprehensive flavonoid annotation by mass spectrometry. *Scientific Reports*, *7(1)* 1243.

Angst, E., Park, J.L., Moro, A., Lu, Q.Y., Lu, X., Li, G., King, J., Chen, M., Reber, H.A., Go, V.L.W., Eibl, G., Hines, O.J. (2013). The flavonoid quercetin inhibits pancreatic cancer growth *in vitro* and *in vivo*. *Pancreas*, *42*(*2*), 223-229.

Balasundram, N., Sundram, K., Samman, S. (2006). Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. *Food Chemistry*, *99*(*1*), 191-203.

Boots, A.W., Li, H., Schins, R.P.F., Duffin, R., Heemskerk, J.W.M., Bast, A., Haenen, G.R.M.M. (2007). The quercetin paradox. *Toxicology and Applied Pharmacology*, *222*(*1*), 89-96.

Brusselmans, K., Vrolix, R., Verhoeven, G., Swinnen, J.V. (2005). Induction of cancer cell apoptosis by flavonoids is associated with their ability to inhibit fatty acid synthase activity. *Journal of Biological Chemistry*, *280*, 5636-5645.

Cotelle, N., Bernier, J.L., Catteau, J.P., Pommery, J., Wallet J.C., Gaydou, E.M. (1996). Antioxidant properties of hydroxy-flavones. *Free Radical Biology and Medicine*, *20*(*1*), 35-43.

Çekiç, Ç., Özgen, M. (2010). Comparison of antioxidant capacity and phytochemical properties of wild and cultivated red raspberries (*Rubus idaeus* L.). *Journal of Food Composition and Analysis*, *23*(*6*), 540-544.

Ferrándiz, M.L., Alcaraz, M.J. (1991). Antiinflammatory activity and inhibition of arachidonic acid metabolism by flavonoids. *Agents and Actions*, *32*(*3-4*), 283-288.

Kedika B., Thotla K., Noole V., Chepyala K.R. (2016). Research Progress of Chrysin derivatives with potential biological activities. *Journal of Chemical and Pharmaceutical Research*, *8*(*8*), 1210-1222.

Keskin-Šašić, I. (2013). Sadržaj ukupnih fenola i antioksidativni kapacitet protiv peroksidnih slobodnih radikala u nekim prirodnim voćnim sokovima, Završni-magistarski rad, University of Sarajevo – Faculty of Science, p. 52-54.

Keskin-Šašić, I., Tahirović, I., Topčagić, A., Klepo, L., Salihović, M., Ibragić, S.,Velispahić, E. (2012). Total phenolic content and antioxidant capacity of fruit juices. *Bulletin of the Chemists and Technologists of Bosnia and Herzegovina*, *39*, 25-28.

Khoddami, A., Wilkes, M.A., Roberts, T.H. (2013). Techniques for analysis of plant phenolic compounds. *Molecules*, *18*(*2*), 2328-2375.

López-Lázaro, M. (2009). Distribution and biological activities of the flavonoid luteolin. *Mini-Reviews in Medicinal Chemistry*, *9*(*1*), 31-59.

Milivojević, J., Nikolić, M., Radivojević, D., Poledica, M. (2012). Yield components and fruit quality of floricane fruiting raspberry cultivars grown in Serbia. *Acta Horticulturae*, *946*, 95-99.

Murtić, S., Đurić, M., Fazlić, J., Behmen, F., Haseljić, S., Šerbo, A., Berbić, H. (2023). Organic versus conventional 'Willamette' raspberry: yield, bioactive compounds and antioxidant properties. *Horticultural Science*, *50*(*4*), 275-282.

Ough, C.S., Amerine, M.A. (1988). *Methods for analysis of musts and wines*. (2nd Ed.) Wiley.

Ponder, A., Hallmann, E. (2020). The nutritional value and vitamin C content of different raspberry cultivars from organic and conventional production. *Journal of Food Composition and Analysis*, *87*, 103429.

Sariburun, E., Şahin, S., Demir, C., Türkben, C., Uylaşer, V. (2010). Phenolic content and antioxidant activity of raspberry and blackberry cultivars. *Journal of Food Science*, *75*(*4*), C328-C335.

Scalzo, J., Politi, A., Pellegrini, N., Mezzetti, B., Battino, M. (2005). Plant genotype affects total antioxidant capacity and phenolic contents in fruit. *Nutrition*, *21*(*2*), 207-213.

Singleton, V.L., Rossi, J.A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture*, *16*(*3*), 144-158.

Šapčanin, A., Salihović, M., Uzunović, A., Osmanović, A., Špirtović-Halilović, S., Pehlić, E., Jančan, G. (2017). Antioxidant activity of fruits and vegetables commonly used in everyday diet in Bosnia and Herzegovina. *Bulletin of the Chemists and Technologists of Bosnia and Herzegovina*, *49*, 15-18.

Wu, X., Diao, Y., Sun, C., Yang, J., Wang, Y., Sun, S. (2003). Fluorimetric determination of ascorbic acid with *o*-phenylenediamine. *Talanta*, *59*(*1*), 95-99.

Wu, Y., Zhou, C., Li, X., Song, L., Wu, X., Lin, W., Chen, H., Bai, H., Zhao, J., Zhang, R., Sun, H., Zhao, Y. (2006). Evaluation of antiinflammatory activity of the total flavonoids of *Laggera pterodonta* on acute and chronic inflammation models. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, *20*(*7*), 585-590.

Zhao, Y. (Ed.) (2007). *Berry fruit: value-added products for health promotion*. (1st Ed.) CRC Press, Taylor & Francis Group, Boca Raton, London, New York.

Zheng, W., Wang, S.Y. (2001). Antioxidant activity and phenolic compounds in selected herbs. *Journal of Agricultural and Food Chemistry*, *49*(*11*), 5165-5170

Summary/Sažetak

U ovom radu prikazano je istraživanje ukupnih fenola (UF), ukupnih flavonoida (UFL), vitamina C i antioksidativne aktivnosti (AA) plodova i sokova sorti maline sa područja općine Cazin. Analizirano je pet sorti maline (Fertodi, Meeker, Polka, Tulameen i Willamette) uzgajanih integralnim konceptom, kao i jedan uzorak sorte Willamette uzgajan iz hobija unutar okućnice - poluintenzivni koncept (W-pk). UF (prije i poslije taloženja formaldehidom) kvantificirani su Folin-Ciocalteu metodom sa galnom kiselinom (GA) kao standardom. UFL izračunati su iz razlike između UF prije i poslije taloženja. Za određivanje sadržaja vitamina C korištena je L-askorbinska kiselina (AsA) kao standard. Osim toga, AA uzoraka maline ispitana je metodom hvatanja ABTS radikala, koristeći troloks (T) kao standard. Najviši sadržaj UF u svježim plodovima (s.p.) maline pokazala je sorta Tulameen (1608,77 mg GAE/100 g), dok je uzorak W-pk pokazao najviši sadržaj UF (1417,65 mg GAE/100 ml) među svježim sokovima (s.s.) maline. Sorta Tulameen imala je najviše UFL u s.p. (1513,81 mg GAE/100 g), a sorta Willamette u s.s. (789,99 mg GAE/100 ml). Najviši sadržaj vitamina C pokazala je sorta Meeker u obje ispitivane frakcije maline (45,87 mg AsAE/100 g u s.p., odnosno 37,42 mg AsAE/100 ml u s.s.). Svi uzorci pokazali su AA, pri čemu je najbolju AA pokazala sorta Fertodi (7,60 mM TE/g) za uzorke s.p., dok je među uzorcima s.s. sorta Meeker imala najvišu vrijednost AA (6,26 mM TE/ml).