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THE ANTIOXIDANT POTENTIAL OF CONVECTIVE AND MICROWAVE-DRIED RASPBERRIES

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Abstract: The present study aimed to evaluate the effect of convective and microwave drying on bioactive compounds in raspberries (*Rubus idaeus* L.) cv. Willamette and Tulameen. Fruits were dehydrated in the convective dryer at temperatures 50 °C and 70 °C and microwave oven at power levels (90, and 240 W). The highest percentage of anthocyanin (11.6 %) and polyphenols (25 %) was retention in microwave-dried Willamette at 90 W. The microwave-dried Willamette at 90 W also had the highest antioxidant potential of 1.53 ± 0.26 mmol TE/100g dry matter.

Keywords: convective drying, microwave drying, raspberry, antioxidant potential.

Introduction

Raspberries are one of the essential fruits in Serbian agriculture. According to the Statistical Office of the Republic of Serbia, in 2022, realized production of raspberries was 114987 t. In Serbia, raspberries are being produced on 19703 ha. The area of Western Serbia is the main production center with 87 % of the total raspberry production in Serbia. The most abundant raspberry cultivars in Serbia are Willamette and Meeker (Petrovic and Leposavic, 2011).

Red raspberries (*Rubus idaeus* L.) are soft, juicy fruits with a specific flavor and high nutritional values. The bioactive compounds and natural antioxidants in raspberries improve human health (Miletić et al., 2015). The raspberry is a rich source of phenolics, including anthocyanins and ellagitannins, and other bioactive. Anthocyanins are the major contributors to the red color pigment in berry fruits (Frías-Moreno et al., 2021). Apart from anthocyanins and ellagitannins, other phenolic compounds include hydroxycinnamic acids (caffeic, p-coumaric, and ferulic acids), flavonols, and condensed tannins (Lebedev et al., 2022). Polyphenols protect the body from oxidative stress

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considered to be the standard mechanism for the occurrence and progression of the most widespread chronic diseases, thereby contributing to the prevention of cardiovascular, cancer, and inflammatory diseases. The concentrations of the bioactive compounds in the fruits are affected by environmental conditions and the genetic characteristics of the varieties (Burton-Freeman et al., 2016).

Fresh raspberries are highly perishable fruits and are frequently dehydrated so that they are available to consumers throughout the year (Si et al., 2015). During traditional convective drying, heated air flows over the surface of the wet material, transferring heat to the wet material. During heating, moisture evaporates from the surface of the material, and at the same time, through the interior of the material, moisture moves towards the evaporation surface. A microwave oven uses electromagnetic waves called microwaves. In conventional drying, moisture is initially flashed off from the surface and the remaining water diffuses slowly to the surface. Whereas, in microwave drying, heat is generated directly in the interior of the material, creating a higher heat transfer and thus a much faster temperature rise than in conventional heating (Kalla and Devaraju, 2017).

The aim of this research was to investigate the influence of convective and microwave drying the antioxidative potential of red raspberry Willamette and Tulameen varieties. Evaluated quality parameters included changes in total phenolic content, anthocyanin content, and antioxidant activity in fresh and dried samples.

Materials and methods

Collecting samples – raspberry varieties Willamette and Tulameen were collected in Dragačevo area, on a family farm (village Gornji Dubac 43°39′54″N 20°21′56″E, altitude 850 m a.s.l.) few hours to each experimet. Raspberries were grown under organic agricultural practise. The fruits were visually selected according to size, color, maturity level, with no mechanical injuries.

Drying processes – raspberry varieties Willamette and Tulameen were subjected to convective (CD) and microwave drying (MW), to the constant mass. Convective drying of raspberries was carried out in a convective dryer (Gorenje Food Dehydrator FDK 500GCW), at an air temperature of 50 °C and 70 °C. Microwave drying was performed at the power levels of 90 W, and 240 W in the microwave oven (Tesla Microwave oven MW2390MB).

Dry matter content (DM), solid soluble content (SSC), mineral matter content (ash, MMC), and pH value were analyzed by the AOAC method, respectively (1995, 1990a, 1990b).

Determination of Total Anthocyanins (TA), Phenolics (TP), and Antioxidant activity (AA) – the monomeric anthocyanin content was determined by the pH differential method (Giusti and Wrolstad, 2001). Pigment content was calculated as milligrams of cyanidin-3-glucoside equivalents/100 g of fruit dried matter (mg cyn-3-glu 100 g^{-1} DM), using an extinction coefficient of 26.900 L cm^{-1} mol^{-1} and molecular weight of 449,2 g mol^{-1}. The total phenolics in ethanol extracts of fresh and dried raspberries were determined by Folin–Ciocalteu spectrophotometric method (Singleton et al., 1999). The results are expressed in milligrams of gallic acid equivalents (GAE) per 100 g of fruit-dried matter (mg GAE 100 g^{-1} DM). The antioxidant activity of the extracts against ABTS radical scavening was determined according to Re et al. (1999) and the results were expressed as Trolox equivalent antioxidant capacity (mmol TE 100 g^{-1} DM).

Results and discussion

The CD of Willamette at temperatures of 50 °C and 70 °C occurred at 2923 min and 1870 min, and Tulameen at 6010 min and 2094 min, respectively. CD at 70 °C the volume of the raspberries was preserved, while the long drying time at 50 °C caused the raspberry's shrinkage. MD drying the Willamette at microwave powers of 90 W, and 240 W occurred at 254 min, and 88 min, respectively. Drying of these varieties at 90 W and 240 W lasted 232 min and 99 min, respectively. MD led to greater changes in fruit volume than CD.

Values of DM in fresh Willamette and Tulamen were 13.18 ± 0.19 and 15.29 ± 0.98 %, SSC 9.4 ± 0.17 and 11.4 ± 0.17 %, MMC 0.41 ± 0.01 and 0.36 ± 0.01 %, and pH 2.91 ± 0.03 and 2.66 ± 0.03, respectively. The comparative analysis of DM and SSC in these cultivars showed higher values in Tulameen than in Willamette. Analysis of the pH value of fruits showed slight variation among cultivars. The results of chemical properties in this study agree with reports by Miletić's and Anjo's reports (Miletić et al., 2012; Anjo et al., 2020).

The antioxidative properties of fresh and dehydrated raspberries are presented in Table 1. The antioxidative potential varies in raspberry cultivars and depended on methods of drying. TA and TP in fresh fruits of Willamette were significantly higher than in Tulameen.

Table 1. Total anthocyanin and total phenolic contents and the antioxidant capacities (ABTS assays)

	TA (mg 100^{-1} g^{-1} DM)		TP (mg 100^{-1} g^{-1} DM)		AA (mmol TE 100^{-1} g^{-1} DM)	
	Willamette	Tulameen	Willamette	Tulameen	Willamette	Tulameen
fresh fruit	654.13	346.57	1686.56 ± 199.57	1038,00 ± 269.39	8.32 ± 1.30	5.41 ± 0.42
50 °C	21.76	4.23	251.65 ± 8.36	47.44 ± 3.28	1.16 ± 0.16	0.59 ± 0.11
70 °C	63.99	20.18	425.32 ± 6.30	344.75 ± 13.02	1.14 ± 0.02	0.95 ± 0.21
90 W	76.13	5.90	432.34 ± 4.49	131.21 ± 27.49	1.53 ± 0.26	0.57 ± 0.07
240 W	26.32	15.05	241.41 ± 25.73	319.06 ± 62.84	0.91 ± 0.11	0.85 ± 0.00

High temperature, long drying time, and power of the microwave oven caused a huge degradation of bioactive compounds in the samples. Increasing the dehydration temperature in CD, the antioxidative potential increased, and as well as increasing the microwave power in MD, the antioxidative potential decreased. The samples with CD of fresh raspberries at T = 70 °C and MD at 90 W had the lowest degradation of TA and TP in both varieties, with the highest AA (0.95 ± 0.21 mmol TE 100^{-1} g^{-1} DM for CD on 70 °C, and 0.85 ± 0.00 mmol TE 100^{-1} g^{-1} DM for MD on 90 W). Raspberry fruits dried at high microwave powers showed better preservation of bioactive materials, probably due to the shorter drying time (Si et al., 2015). Although the TA and TP in fresh raspberries were higher or similar than in other studies, during CD there was a significant decrease in the content (Miletić et al., 2012; Stamenković et al., 2019). The long drying time of the Tulameen variety at a temperature of 50 °C led to almost complete degradation of these bioactive components. It can be noticed that the Tulameen variety is more sensitive to the drying process than the Willamette regarding the loss of bioactive components.

AA of raspberries was significantly affected by drying methods. The initial AA of fresh raspberries of Willamette varieties was higher than that of Tulameen and these results are in correlation with reports by Rodriguez and Miletić (Miletić et al., 2015; Rodrigues et al., 2019). The CD method of Willamette did not significantly affect AA, unlike the MD; the highest percentage of antioxidant retention was 18.4 % for MD dehydrated raspberry on 90 W (1.53 ± 0.26 mmol TE 100^{-1} g^{-1} DM). For Tulameen, the highest retention of antioxidants was 17.6 % (CD at 70 °C). The results show a significantly lower percentage of retention of antioxidants (Rodriguez et al., 2019). Increasing the dehydration temperature in CD, the AA increased, and as well as increasing the microwave power in MD, the AA decreased. A more precise change in the

antioxidant capacity will be clearer when the influence of the drying method on the content of flavonoids and other bioactive substances is analyzed.

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Conclusion

Both applied methods of raspberry drying, traditional convective and microwave, reduced the content of bioactive compounds with antioxidant potential. The microwave drying significantly reduced the drying time compared to convective drying. The microwave-dried Willamette at 90 W had the highest antioxidant potential of 1.53 ± 0.26 mmol TE 100^{-1} g^{-1} dry matter and the highest percentage of anthocyanin (11.6 %) and polyphenols (25 %) retention. The Tulameen variety proved to be extremely sensitive to both dehydration methods.

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