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Chemical composition and mineral content of fresh and dried fruits of the wild rosehip (*Rosa canina* L.) population

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ABSTRACT

Rosa canina L. is a widespread wild species in the temperate zone. The fruit is used for nutritional and pharmacological purposes, due to various chemical composition with considerable therapeutic potential. The fruit is rarely eaten fresh but has to be processed, usually dried. To prolong storage and prevent deterioration of the nutrient composition, it is important to optimize various processing methods. This study aimed to determine the basic chemical composition and content of macro and micro components in fresh and dried wild fruits collected from different microsites in Herzegovina. The method of drying was also varied in the study, both under natural conditions and forced (artificial) by convection. All rosehip fruits from wild populations in Herzegovina represent a potential raw material for further processing by drying, with the fruits from the Poljice site standing out with the highest content of total acids (45.1%) and sugars: Fructose (4.575 g/100 g bw), glucose (3.26 g/100 g bw) and natural invert (7.835 g/100 g bw). Drying naturally resulted in slightly higher values for total acids, ash and mineral constituents (Ca, Na and Fe) in the dried fruits, while drying by convection resulted in higher values for fructose, glucose, natural inversion and K. In general, the dried fruits had slightly higher fructose, glucose, natural inversion and K values. The dried rosehip fruits showed higher levels of the analysed chemical constituents compared to the fresh fruits, suggesting that dried rosehip fruits also represent the potential for further use in various products.

Keywords: location, drying method, individual sugars, sucrose, mineral content, HPLC

INTRODUCTION

Rosa canina L., rosehip is a species of wild plant in the *Rosaceae* family, widespread in Europe, especially in the Mediterranean region and in the territory of Bosnia and Herzegovina. It grows mostly in natural habitats (on mountains, in forests, in meadows) and is harvested as such for processing and marketing. The fresh fruits of the rosehip are most often processed. Due to the particular morphological appearance of the fruit (hairs covering the skin of the fruit) and the chemical composition, which has a high content of vitamin C, minerals and bioactive compounds, the fruit is an important raw material for the food and pharmaceutical industries. For this reason, it is necessary to choose optimal processing methods to preserve the nutritional composition and obtain a high-quality end product (Akagić et al., 2020). Rosehips are usually not conventionally cultivated but collected from natural habitats (wild populations), and there is a lack of systematic studies and data on chemical composition depending on habitat location. For this reason, wild fruits of unknown origin and chemical composition are usually available on the market, which cannot ensure regular supply and traceability of quality (Šindrak et al., 2013). Rosehip grows in different ecological areas, both on fertile and poor soils. It is resistant to drought, diseases and insects, but also to climatic changes. Above all, the rose hip is an extremely resilient plant species that can adapt to a variety of habitats. The fruits are particularly valuable because they contain high levels of vitamins C, B1, B2 and E, sugar, sucrose, tannins, pectin, organic acids (citric and malic acid) and minerals (Damascos et al., 2008; Kazaz et al., 2009; Mabellini et al., 2011; Murathan et al., 2016; Voća et al., 2019; Bilgin et al., 2020) as well as various phytochemicals with a strong antioxidant effect, which has a high therapeutic potential and thus numerous benefits for human health (Šic Žlabur et al., 2019; Paunović et al., 2019). The content of individual chemical compounds in the fresh fruits of rosehip strongly depends on the habitat and biotic factors of the area, i.e. the specific pedoclimatic characteristics of a location (Šindrak et al., 2013; Matleković, 2016). Precisely because of their specific chemical composition, fruits are traditionally processed and used in foods such as jams, compotes, juices, water infusions (tea-based preparations), wine, fruit soups, salads, spices, etc. In addition to its use as a foodstuff, the use of the fruit for phytotherapeutic purposes is also of great importance. While researching the bioactive substances of wild rosehip and its application in nutrition and medicine, some authors (Stanila et al., 2015; Bhave et al., 2017) have confirmed its significant antioxidant, antimutagenic and anticarcinogenic effects. The most popular product made from rosehip fruits is the water infusion, for the preparation of which the fruits are dried. In rural areas, rosehip is traditionally air-dried, which is often associated with numerous disadvantages, from the longer processing time to the need for optimal outdoor weather conditions. Risks also include mold growth, insect damage and oxidation, which can significantly affect the quality of the final product. Precisely for this reason, controlled drying processes, i.e. drying under artificial conditions, allow the optimization of the main drying parameters, temperature, airflow speed and duration, as well as the high quality of the dried fruits (Abdulla et al., 2011; Radojčin et al., 2021).

The chemical composition of the fruit is one of the most important factors in the selection of suitable processing methods, the choice of product type and the post-harvest treatment (storage) of the raw material. Rosehip fruits are particularly suitable for processing by drying due to their high dry matter content. Drying processes primarily ensure the microbiological safety of the product, i.e. they extend the shelf life. Dried fruits are a good source of energy (high sugar content), but also minerals that are not so susceptible to temperature degradation, i.e. thermolabile. The basic task in the application and optimization of the drying process is to preserve the sensory properties of the product (especially color and texture), but also the nutritional quality, i.e. the bioactive compounds (Radojčin et al., 2021).

This study aimed to determine the basic chemical composition, individual sugar content and the content of specific macro- and micronutrients in fresh and dried wild rosehip fruits collected from different microsites in Herzegovina (Herzegovina-Neretvanski Canton). The type of drying was also varied in the study: under natural conditions (air-dried) and under forced (artificial) conditions by convection.

MATERIALS AND METHODS

The study was conducted on wild fruits of the species *Rosa canina* L. collected from four locations in Herzegovina: Čitluk, Poljice, Međugorje and Grude (Bosnia and Herzegovina. The geographic coordinates of each site were recorded using a Garmin Vista e-Trex GPS (Garmin International, Inc, Hampshire, UK), Table 1. Hydrometeorological information (temperature and precipitation) was obtained from the Federal Archive of the Sarajevo Hydrometeorological Institute for the Čitluk, Međugorje, and Grude sites, and the Mostar hydrometeorological station for the year 2020. and the five-year vegetation average for the period (2015-2020), the information is also shown in Table 2. The localities of Čitluk, Međugorje and Grude do not have hydrometeorological stations, so the information shown here is from the Mostar hydrometeorological station archive.

Table 1. Geographic location, elevation, and soil systematics of *Rosa canina* wild fruit sites, for 2020. and the average five-year series (2015-2020)

Location	Geographical location	Meteorological		Date		Pedosystematic Unit soil [c]
		Tm (°C)		Ppt (mm)		
		2020	2015-2020	2020	2015-2020	
Poljice [b]	Altitude 466 m Above sea level 44°29´05.4"N /18°30´31.4"E	13.68	15.07	1124.4	1427.65	Alluvial soil, calcareous, an anthropogenic
Čitluk [a]	Altitude 196 m Above sea level 43°12´46.4´´N /17°41´53.6´´E	16.3	16.22	1066.7	1348.7	Calcocambisol deep, anthropogenic
Međugorje [a]	Altitude 220 m Above sea level 43°11´41.8´´N /17°40´45.2´´E					Terra Rossa, anthropogenic
Grude [a]	Altitude 250 m Above sea level 43°18´56.4´´N /17°27´44.7´´E					Calcocambisol deep, anthropogenic

a) Federal Hydrometeorological Servis, Mostar (Čitluk, Međugorje, Grude)
b) Hydrometeorological Servis of Republic Srpska, Trebinje (Poljice)
c) classification of the soil by Resulović (2008)
Tm- air temperature (°C)
Ppt- quantity of rainfall (mm)

Table 2. Hydrometeorological data for 2020 and the average five-year series (2015 – 2020)

Month/Growing Season	Location/Meteorological Date							
	Hydrometeorological station of Mostar (location Čitluk, Međugorje and Grude)				Hydrometeorological station of Trebinje (location Poljice)			
	Tm (°C) [a]		Ppt (mm) [b]		Tm (°C)		Ppt (mm)	
	2020	2015-2020	2020	2015-2020	2020	2015-2020	2020	2015-2020
March	11.3	11.41	96.6	132.08	10.1	9.9	130.2	177.4
April	15.6	15.35	35.3	94.62	13.7	14.2	95.5	96.8
May	18.9	18.76	52.4	114.93	18.1	18.0	54.2	89.2
June	21.9	23.91	85.9	67.87	20.3	22.5	54.8	56.2
July	26.5	27.16	32.3	68.68	25.3	25.8	0.7	35.8
August	26.4	27.01	80.4	42.13	25.4	25.9	43.4	66.1
September	23.5	21.81	116.5	103.22	21.7	20.5	46.0	95.8
October	15.2	16.13	118.3	154.12	14.9	15.8	148.8	173.5
Average year Tm/Ppt	19.9	20.20	77.2	97.20	18.7	19.1	71.7	98.9

a) Tm- mean air temperature (°C)
b) Ppt- quantity of rainfall (mm).

For Poljice (which belongs to the municipality of Ljubinje, a hydrometeorological archive of the Trebinje Republic of Srpska). Table 1 also lists the pedosystematic units and the classification of the soil by Resulović (2008).

In addition, soil samples were collected simultaneously at the above-mentioned sampling locations of the wild rosehip fruit populations to determine the basic chemical properties of the soil (Table 3).

At each microsite, samples of fresh rosehip fruit were collected from a total of 5 shrubs on average, approximately 1 500 g of fruit from each microsite. Rosehip fruits were harvested at the stage of optimal ripeness, i.e., early morning in dry weather. Immediately after harvest, the fruits were packed in polyethylene bags and transported to the laboratory for analysis. Upon arrival at the laboratory, the fruits were sorted and impurities, stems and possibly damaged fruits were removed. Some of the fruit was sorted out for analysis in the fresh state, while some of the fruit was prepared for drying. The samples intended for drying are divided into two groups: fruits dried in air (natural drying) and drying under artificial conditions (forced drying). Drying under natural conditions was performed by spreading the fruits in a single layer on cardboard paper in a ventilated, dark room at an average temperature of 21 °C and a relative humidity of 80%. Drying lasted 30 days to reach a final water content of about 12%. Drying under artificial conditions was performed by convection in a dryer (BINDER FD 23, GmbH, Germany) at a drying temperature of 80 °C and lasted 1 hour and 45 minutes until the water content of the fruits was 12%. All drying treatments were carried out in the laboratory of the Faculty of Agriculture and Food Technology of the University of Mostar.

Determination of basic chemical composition

Samples of dried fruit for chemical analysis (250 g) were homogenized using a Knifetac mill 195KN (FOSS, Denmark). The following basic chemical composition analyses were performed on fresh and dried fruits: determination of total acid, ash, and water content using validated standard analytical methods (Official Gazette SFRJ 29/83, IHC 2002). The water and ash content was determined (%) by the gravimetric method and the total acidity by the volumetric method (Official Gazette SFRJ 29/83).

Determination of individual sugars by HPLC method

Individual sugar content was determined by the HPLC method with an RI detector (IHC, 2002) on a Waters HPLC instrument (Waters 2414 Refractive Index detector, USA) using a Waters carbohydrate column (Silica Based Propyl Amine Column, 3.9x300 mm). The homogenized, crushed samples were weighed in at 10.00 g and quantitatively transferred to a 100 mL volumetric flask dissolved in deionized water. After homogenization, the samples were filtered using a 0.45 µm nylon syringe and transferred to a vial for chromatographic analysis. The chromatographic separation of the components was performed isocratically with the flow of mobile phase acetonitrile of HPLC purity of deionized water in the ratio 83:17 of 1.5 mL/min at temperatures of 30 °C. The concentration and identification of each sugar component were determined by the method of external standard (fructose, glucose, and sucrose HPLC purity, purchased by Sigma-Aldrich) using Empower software (Waters, Hicrom Ltd UK) and the values are expressed in g/100g of fresh weight (for fresh samples) and dry weight (for dry samples).

Table 3. Chemical characteristics of the soil from the site of wild rose hip

Location	Depth (cm)	pH in H_2O	Value in 1MKCl	$CaCO_3$ (%)	Organic matter (%)	Total N (%)	P_2O_5 mg/100g dw soil	K_2O mg/100g dw soil
Poljice	0-30	7.51	7.18	4.11	7.48	0.307	1.925	35.03
Čitluk	0-30	8.33	7.26	4.25	5.13	0.223	1.83	9.12
Međugorje	0-30	8.07	7.22	2.44	6.75	0.279	39.98	15.75
Grude	0-30	8.28	7.26	1.13	6.47	0.241	15.97	24.55

Determination of mineral components

The content of mineral components: Ca, K, N, Na, and Fe was determined using the AAS flame technique (Agilent 240FS, USA) after the dried ground samples were burned with a microwave digestion (ETHOS EASY MILESTONE; USA). Microwave destruction of the samples was determined at a temperature of 200 °C with HCl and HNO_3 (Fluka, Merck) at 1 2r W and a pressure of 40 bar. Quantitative determination was performed by the external calibration method using standards for each element (Fluka, Merck). The microwave digestion method and the ASS flame technique are described in the standard methods: BAS EN 14084:2005; BAS EN 13804:2005; BAS EN 13805:2005; BAS EN 15505:2005; BAS EN 15505:2008.

Statistical analysis

The fruits of rosehip in the fresh state were analysed by one-way analysis ANOVA, where the factor was the location (microsite), and the differences between the means were tested with the LSD test, considering P = 5% as the statistical significance threshold. A generalized linear model was used for statistical analysis of the dry-fruit results, with repetition, location (L), and drying method (M) included as categorical predictors. The procedure PROC GLM from the SAS software package, version 9.4 (2010), was used for the analysis. The data obtained were processed using analysis of variance, while differences between means were tested using the LSD test, with P = 5% as the statistical significance threshold. In addition to the mean values, the tables show different letters indicating a significant statistical difference at $P \leq 0.0001$, as well as the standard deviation (±SD).

RESULTS AND DISCUSSION

The results of the basic chemical composition of fresh fruits of *R. canina* L. collected from different localities in Herzegovina are presented in Table 4.

The analysis of the results revealed significant differences in the content of total acids in the fresh fruits of wild rosehip between localities. The highest proportion of total acids (45.1%) was determined in fresh fruits harvested at the Poljica locality, compared to other localities, statistically significant differences were found. The reason for the higher content of total acids in the fresh fruit of wild rosehip at the Poljica location is that it is located at a higher altitude compared to other locations, which can be seen in (Table 1). Different altitudes of a climate can often affect the characteristics of the fruit, which was published by the author (Mikulic-Petkovsek et al., 2015; Correia et al., 2016). Gündüz et al. (2018), also determine changes in fruit quality (fruit color, glucose and fructose content, antioxidants and total phenols) at different altitudes, due to the influence of different climatic phenomena and their combinations (temperature, humidity, average daily radiation and precipitation). It is these combinations (higher altitude and climatological parameters shown in Table 2) as well as the chemical characteristics of the soil (Table 3) at the location of Poljica, that ensure a higher content of total acids in the fresh fruit of wild rosehip. Kabata-Pendias (2011) concludes in his research that the chemical composition of the soil is reflected in the chemical composition of the plant, as well as the ability of the plant to accumulate certain elements in the fruit and different climatic conditions at the locations of cultivation. Also, the content of total acids in fresh fruits is higher compared to the results of the author's research (Ercişlii et al., 2007a; Voća et al., 2019). Organic acids are the significant chemical composition of most fruits, and their properties are often associated with antioxidant to neuroprotective effects on human health (Zhang et al., 2019; Niaz et al., 2022). Organic acids form the final aroma and taste of plant raw materials and their products (Liu et al., 2019). Plant raw materials with a higher content of organic acids are better preserved, are less susceptible to changes, and have a longer shelf life. The highest proportion of ash (2.41%) in fresh fruits was found in the Čitluk locality, and statistical differences were found in other localities. These results on the ash content in fresh fruit are lower than the research results published by some other authors (Demir and Özcan, 2001; Kizil et al., 2018). Variations in water content were found in the fresh fruits of wild rosehip according to the cultivation areas of the *R. canina* species (Table 4).

Table 4. The basic chemical composition (%) of fresh wild rosehip fruits from different locations

Location	Total acid (%) of fw	Total ash (%) of fw	Total water (%) of fw
Poljice	45.1 ± 0.51[a]	2.15 ± 0.01[b]	46.39 ± 0.57[ab]
Čitluk	31 ± 0.19[c]	2.41 ± 0.07[a]	47.72 ± 0.79[a]
Međugorje	32.65 ± 0.74[b]	2.25 ± 0.01[b]	44.89 ± 0.15[b]
Grude	33.44 ± 0.54[b]	2.23 ± 0.01[b]	47.01 ± 0.82[a]
ANOVA	$P \leq 0.0001$	$P \leq 0.0086$	$P \leq 0.0455$
LSD	2.4449	0.1676	2.9718

Different letters indicate significant statistical differences between means

The highest water content was found in fruits at the Čitluk and Grude sites, among which no statistically significant differences were found. Data on the water content of fresh fruits following the other authors' research results (Ersoy et al., 2016; Murathan et al., 2016). According to (Kabata-Pendias, 2011), climatic phenomena have a significant impact on the chemical properties of the fruit, so we can conclude that changes in water and total acids can be affected by variations in day and night temperatures that are present in this Mediterranean area. Also, the authors Shiow and Camp (2000) state that if the differences between day and night temperatures are small, the fruits ripen faster, which affects the chemical parameters in the fruit and the speed of ripening, which is also confirmed by the research results of other authors (Demir and Özcan, 2001; Roman et al., 2013; Ersoy et al., 2016; Bilgin et al., 2020). The time of fruit collection is an important factor that affects the chemical properties of the fruit (Roman et al., 2013; Medveckienè et al., 2022). Šindrak et al. (2013) conclude that with a delay in fruit harvesting, there may be a significant decrease in certain chemical parameters and deterioration of the overall quality of the fresh fruit. The content of total and individual sugars in the fruits of the wild species *R. canina* L. from different sites (Poljice, Čitluk, Međugorje and Grude) is presented in Table 5. In the wild fruits from different locations, fructose dominated, followed by glucose, while sucrose content was the lowest, which can be attributed to the high activity of invertase in the last phase of fruit ripening.

The results of single and total sugars are in agreement with the studies of Bilgin et al. (2020). In fresh wild fruits, higher levels of fructose and glucose and inverted sugar were found at the Poljica location, and compared to other locations (lower altitudes), the differences were statistically significant. Seasonal differences in temperature and precipitation have a great influence on the accumulation of sugars and other bioactive compounds. Based on climatological parameters, geographical location and altitude, the Poljice site in 2020. records lower precipitation in summer months, which is also associated with higher solar radiation and favors the accumulation of free sugars in the fruits of wild rosehip (climatological parameters for 2020., see Table 2). Similar trends in the sugar content were established by Doumett et al. (2011) and Shiow and Camp (2000), and the claims are related to the differences between day and night temperatures, if they are small, the fruit ripens faster, and the sugar content in the fruit remains low. The content of individual and total sugar in fresh fruits is lower in relation to the author's research (Murathan et al., 2016; Akagić et al., 2020; Bilgin et al., 2020). Herrington et al. (2007) conclude the different sugar content in the fruit is influenced by several parameters (higher average temperature in the researched area, amount of precipitation during the growing season), but the type of wild rosehip (genotype) at the growing site is also very important. However, the determined content of fructose in the fruit is lower than in other research (Barros et al., 2011; Özrenka et al., 2012; Demir et al., 2014; Öz et al., 2018; Murathan et al., 2016; Akagić et al., 2020; Bilgin et al., 2020), which depends on the genotype of wild rosehip, soil type and location. The glucose content was highest at higher altitudes, such as the Poljice locality, while the lower glucose content was found at lower altitudes (Čitluk, Međugorje and Grude), and statistically significant differences were found between them. The lower glucose content in fruit at lower altitudes is also confirmed in studies by the author (Wang et al., 2002; Herrington et al., 2007; Akagić et al., 2020). A higher ratio of fructose to glucose in the fruit is desirable, especially from a medical point of view, because fructose is absorbed into the blood much faster and does not contribute to an increase in the

Table 5. The content of individual sugars (g/100 g fw) in fresh rosehip fruit from different locations

Location	Fructose (g/100g fw)	Glucose (g/100g fw)	Total soluble sugar (g/100g fw)	Sucrose (g/100g fw)
Poljice	4.575 ± 0.16[a]	3.26 ± 0.17[a]	7.835 ± 0.33[a]	n.d.
Čitluk	3.345 ± 0.02[b]	2.43 ± 0.04[b]	5.73 ± 0.001[b]	n.d.
Međugorje	3.045 ± 0.04[c]	1.97 ± 0.01[c]	5.015 ± 0.05[c]	0.30[a]
Grude	1.64 ± 0.01[d]	0.355 ± 0.001[d]	1.99 ± 0.01[d]	n.d.
ANOVA	$P \leq 0.0001$	$P \leq 0.0001$	$P \leq 0.0001$	$P \leq 0.0001$
LSD	0.3876	0.4043	0.7742	0.0001

Different letters indicate significant statistical differences between means; n.d.-not determined

glycemic index compared to glucose, which is especially important for people suffering from diabetes (Hecke et al., 2006). Sucrose content was also determined in fresh fruits, but only in fruits from the Međugorje locality, while it was not detected in fruits from other localities. The determined content of sucrose in fresh fruit is still lower compared to the results of the author's research (Barros et al., 2011; Mabellini et al., 2011; Murathan et al., 2016; Akagić et al., 2020). Also, according to Leeuwen et al. (2004), climatic and soil conditions have a greater influence on the chemical composition of the fruit than the cultivar itself.

In addition, it is important to emphasize that the sugar content, together with the content of organic acids of rosehip fruit, has an extremely important influence on the formation of taste (sweetness index), fruit shelf life, and nutritional properties. In addition, the sugar content is also an important factor from a technological point of view, as the amount and type of sugar influence the gel consistency in gelatin products, which is particularly important in the production of juices and jams (Vukoja et al., 2019). The fruits of wild rose hips have a high to good content of minerals (macro and microelements) such as potassium, calcium, phosphorus, magnesium, iron, sodium, copper, manganese and aluminum, which was also investigated by other authors (Aguirre et al., 2016; Kizil et al., 2018; Özcan et al., 2018; Bilgin et al., 2020; Akagić et al., 2020; Medveckienè et al., 2022). These minerals play an important role in various important biochemical and physiological processes in the human body, as reported by the authors Gupta (2014) and Beto (2015). Moreover, the human body cannot synthesize these elements by itself; therefore, we need to consume them through food or supplements. For this reason, awareness is growing that a variety of foods and their chemical components and bioactive compounds can help maintain optimal health and prevent chronic diseases. We call such food functional food. For this reason, chemical and bioactive compounds of wild rosehip species can be a potential source of mineral elements for the benefit of human health (Mármol et al., 2017). The quantitative results of macro- and microelements in the fresh fruits indicated significant statistical differences among the genotypes and locations of wild rosehips, as shown in Table 6.

The macroelements in the fresh fruits of wild rosehip, potassium stands out, with the highest content of 9342.45 mg/kg at the Grude site, and the differences are statistically significant compared to other sites. These results are in agreement with the other research results (Kazaz et al., 2009; Kizil et al., 2018; Medveckienè et al., 2022). However, if we compare the results with those of other authors, the potassium content in fruits is higher compared to the results given by (Demir et al. (2001), Paunović et al. (2019), and Bilgin et al. (2020). Moreover, since statistically significant differences were found in the potassium content of fresh fruit depending on the location, this is also affected by the ripening time of the fruit depending on the location, which is related to weather conditions at different altitudes.

Table 6. The content of individual sugars (g/100 g fw) in fresh rosehip fruit from different locations

Location	Ca (mg/kg fw)	K (mg/kg fw)	Na (mg/kg fw)	Fe (mg/kg fw)
Poljice	4729.4 ± 1.96[b]	5337.8 ± 1[d]	27.95 ± 1.1[a]	13.87 ± 0.11[b]
Čitluk	5477.7 ± 10.79[a]	6213.8 ± 0.54[c]	32.125 ± 2.34[a]	10.745 ± 0.01[c]
Međugorje	3397.7 ± 52.43[c]	6996.95 ± 0.37[b]	18.44 ± 2.31[b]	18.155 ± 0.22[a]
Grude	3581.3 ± 4.71[c]	9342.45 ± 5.96[a]	22.14 ± 1.47[b]	9.015 ± 0.06[d]
ANOVA	$P \leq 0.0042$	$P \leq 0.0001$	$P \leq 0.0067$	$P \leq 0.0001$
LSD	74.649	8.4408	5.226	0.3538

Different letters indicate significant statistical differences between means. fw- fresh weight

In a published study, Ramesh et al. (2020) found that higher levels of potassium stimulate the enzymes responsible for fruit softening. According to data from the scientific literature, the mineral content in rose hips depends on the type of cultivar, growing conditions, weather conditions, and also depends on the degree of maturity (Türkben et al., 2010; Mahmood et al., 2012; Aguirre et al., 2016; Kizil et al., 2018). Also, changes in the potassium content of wild rosehip fruits may be the result of the high mobility in plants. In plants, potassium is an important component in protein and starch synthesis, carbohydrate metabolism and enzymatic processes, as confirmed by a study by the author Trakner (2018 citedinMedveckienèetal., 2022). The second macroelement in terms of mineral content in fresh fruit is calcium. Its content ranged from 5477.7 to 397.7 mg/kg, and statistically significant differences were found among the sites (Table 6). The determined calcium content in fresh fruits of wild fruit is higher compared to the results of other studies (Paunović et al., 2019; Bilgin et al., 2020). The observed differences in fruit calcium content by location and genotype were also noted by other authors (Demir et al., 2001; Türkben et al., 2010; Aguirre et al., 2016; Kizil et al., 2018; Bilgin et al., 2020; Medveckienè et al., 2022). Compared to other fruits (strawberry and cherry), calcium content also tends to decrease with maturity, while the highest calcium content is found in unripe fruits, Mahmood et al. (2012). Such a trend was also noted by Geo et al. (2016), and Hocking et al. (2016), and the relationship between the calcium content in the fruit and the stage of ripeness was determined. The role of calcium, as this macroelement plays an important physiological role in fruit aging and is particularly important for cell division, tissue hardness, and maintenance of cell permeability and cell integrity, all of which directly affect fruit firmness and elasticity. In addition, the content of mineral elements depends on their mobility in the phloem. A relatively immobile element such as calcium does not move in the fruit at later stages of development (Paul et al., 2012). For this reason, we can confirm that the variations in the calcium content of the fresh fruit are related to the cultivation type of the genotype in the locations of wild rose hips. It is also influenced by the speed of fruit ripening, which is influenced by the weather conditions at different altitudes, which is partially confirmed by the available and collected climate parameters from the official hydrometeorological stations (Mostar and Trebinje) in Bosnia and Herzegovina. This statement certainly contributes to the published studies by the above-mentioned authors. In addition to macroelements, microelements also play an important role in the development and growth of plants. As structural components and metabolic regulators, they are directly involved in the protection of plants but are required in lower concentrations than macroelements (Christian et al., 2021). A higher proportion of sodium was found in the fresh fruits of wild rosehip compared to iron, and statistically significant differences by location were found, as shown in Table 5. The highest content of sodium in fresh rosehip fruits was found in Čitluk and

Poljice locations and there were no statistically significant differences between them, but compared to other locations the differences were statistically significant. The determined sodium content in fresh fruits is higher compared to the results published by other authors (Demir et al., 2001; Paunović et al., 2019; Medveckienè et al., 2022). However, the determined values for sodium in fresh fruits are lower compared to the conducted studies (Kazaz et al., 2009; Kizil et al., 2018; Bilgin et al., 2020). From the results presented in Table 6, the highest iron content in fresh fruit was determined at the location of Međugorje, and the differences are statistically significant compared to other locations. The content of iron in the analyzed fresh fruits of wild rose hips varies by location and its content is higher compared to other published research results (Özcan et al., 2018; Paunović et al., 2019). On the other hand, the fruit contains less iron compared to the results of other authors (Demir et al., 2001; Kazaz et al., 2009; Kizil et al., 2018; Medveckienè et al., 2022). Some other authors (Ercişli, 2007b; Kizil et al., 2018; Bilgin et al., 2020; Medveckienè et al., 2022) have determined the variation of iron content in the fruit. The authors conclude that it depends on the type of genotype, and the maturity of the fruit itself, which is influenced by the climatic conditions of the site, altitude, and physiological movements of iron in the phase of vegetation, and ripening of the fruit. Iron plays a key role in pectin metabolism, which affects tissue softening during ripening, and is an integral part of the natural plant heme chelate complex that participates in the transfer of important plant enzymes Bai et al. (2021). Fresh rosehip fruits, despite their relatively low water content, are subject to microbiological spoilage and rotting and are therefore processed into various types of products such as tea preparations, jam, juice, liqueur, wine, etc. The most common method of rosehip fruit processing is drying, which reduces water activity, slows down enzymatic reactions, and increases the microbiological safety of the product, which aims to reduce packaging, transport and storage costs. Dried fruit is a concentrated form of fresh fruit, has higher total energy, nutrient density, fibre content and often significantly higher (AOX) antioxidant activity (Bennett, et al., 2011). Methods of drying and the use of high temperatures can lead to deterioration of product quality and changes in texture, colour and taste, and therefore it is necessary to know the chemical properties. Therefore, it is necessary to optimize the most important factors to maintain the quality of the final product. Table 7 shows the results of the basic chemical composition of rosehip fruits dried naturally and artificially (convection) from different locations. The fruit samples differed significantly in all the basic chemical parameters analysed in relation to the different drying treatments and the location of fruit collection.

Table 7. Total acid, ash, and total solids (%) content in dried rose hips from different locations

Location	Total acid (%)	Total ash (%)	Total dry matter content (%)
	Natural drying		
Poljice	45.705	3.665	83.03
Čitluk	52.46	3.635	85.19
Međugorje	57.99	4.59	83.91
Grude	48.39	2.99	77.26
	Artificial drying - convection		
Poljice	50.31	3.465	87.03
Čitluk	50.93	3.68	87.52
Međugorje	52.365	3.81	88.13
Grude	44.115	3.15	80.91
ANOVA	$P \leq 0.0001$	$P \leq 0.0001$	$P \leq 0.0001$
LSD	2.1219	0.2515	0.3245
Signifance of interaction	Pr ≤ F	Pr ≤ F	Pr ≤ F
Location (L)	0.0001	0.0001	0.0001
Method (M)	0.0067	0.0083	0.0001
L x M	0.0004	0.0018	0.0001

L × M- interaction between location (L) and drying method (M). Different letters show significant statistical differences between the mean values

Based on the significance analysis (Pr≤F) of the influence of the individual factors observed, location (L) and drying method (M), but also their interaction (L x M), a statistically significant influence of both individual factors and their interaction is shown. The highest content of total acids was found in the fruits from the Međugorje location, which were dried naturally (57.99%), while the lowest content was found in the two sites, Poljice (45.705%) and Grude (44.115%), which were dried naturally and artificially, with no statistically significant difference between the mentioned sites and the drying method. Based on the results obtained, it can be seen that both factors interact to significantly influence the content of total acids, which is to be expected considering that the results of the chemical composition of the fresh fruits also showed a significant influence of the location on individual chemical properties. According to the significance of the factor, the method of drying ($P \leq 0.0067$) also shows an influence on the total acid content, but considering the influence of the location, no clear conclusion can be drawn as to which method of drying favours the preservation of the total acid content. However, looking at the trend, natural drying preserved a slightly higher total acid content compared to artificial drying. Changes in the content of the total acidity of the fruit during different drying methods were determined by the authors Kolla et al. (2021) and Mohammed et al. (2020). The highest ash content of rosehip fruits (4.59%) was found in naturally dried fruits from Međugorje. Regarding the statistical results of the interaction of the observed individual factors and their interaction, a significant influence was again found for the location (L), more so than for the drying method (M), while their interaction (L x M) again showed a significant influence on the ash content. From the above, again no single factor with a significant influence on the ash content can be filtered out, but again a tendency towards a slightly higher content was found for naturally dried samples, emphasizing that the interaction L x M shows a statistically justified influence on the observed chemical property (Table 7). The greatest decrease in water content was observed in the forced drying by convection, where the highest content of total dry matter was obtained (88.13%). Looking at the significance of the influence of the individually observed factors, it can be seen that each of them individually, the location (L, $P \leq 0.0001$) and the drying method (M, $P \leq 0.0001$), but also in mutual interaction (L x M) significantly influence the dry matter content, which proves and the number of separate groups. All in all, the significant influence of location and drying method is clear, and it is difficult to identify a trend as to which location or drying method will give the best results in total dry matter. Changes in the total dry matter content of other fruit varieties during different drying methods compared to the traditional drying method were determined in previously published studies (Mohammed et al., 2020; Kolla et al., 2021). The content of total sugars, including fructose and glucose, varied considerably depending on the location and drying method (L x M). The statistical analysis of the significance of the interaction of the individual factors and their combination clearly shows that both the location (L, $P \leq 0.0001$) and the drying method (M, $P \leq 0.0001$) significantly influence the content of fructose, glucose and total sugar. Thus, the highest content of fructose (8.89 mg/100 g), glucose (5.225 mg/100 g) and total sugar (14.145 mg/100 g) was found in artificially dried fruits from Poljice. Interestingly, the lowest content of fructose, glucose and total sugars was found in fruits from Medjugorje, but fructose by artificial drying (5.545 mg/100 g) and glucose and total sugars by natural drying (2.115 mg/100 g and 7.815 mg/100 g). For the sucrose content, the significance of the individual factors (L and M) and their interaction (L x M) was again significant, but considering the Pr≤F values, a more significant influence of the drying method (M, $P \leq 0.0002$) and the combination of L x M ($P \leq 0.0029$) in relation to the location (L, $P \leq 0.0065$). The obtained results of sucrose content confirm that the artificial drying of fruits from the Čitluk and Gruda sites determined the sucrose content and that it was significantly higher at the Gruda location compared to the samples dried naturally. The content of minerals (macro and microelements) in dried rosehip fruits is shown in Table 9. According to the statistical analysis, the samples differ significantly due to the observed factors. The analysis of the significance of the influence of the individual factors, the location (L) and the drying method (M) as well as their interaction (L x M), also shows a significant influence of all analysed mineral components of the rosehip fruits. The location (L, *P* ≤ 0.0001), the drying method (M, *P* ≤ 0.0001), but also their combination (L x M *P* ≤ 0.0001) also significantly influenced the content of Ca, K and Na. Based on the above, it is again not possible to identify a stronger influence of one of the individual factors observed, i.e. both the location and the drying method had a significant influence on the mineral components analysed. Thus, the highest Ca content was found in fruits dried under natural conditions from the Čitluk site (8302.3 mg/kg dw), while the highest levels of K and Na were found in artificially dried fruit from different sites; in particular, the highest value of K was found from the Međugorije location (10876.2 mg/kg dw), while Na was found from the Čitluk location (46.305 mg/kg dw). In the case of Fe content, the results are even more scattered, namely a significant influence of the location (L, *P* ≤ 0.0005), but also the drying method (M, *P* ≤ 0.0019), while the most significant is their interaction (L x M, *P* ≤ 0.0003). Considering the above, the highest Fe content was found in fruits dried by different methods and from different locations. The highest Fe values do not differ between the natural drying in Poljica and Međugorje and the artificial drying of fruits in Čitluk, with an average value of 13.61 mg/kg dw. The results obtained indicate a significant influence of the combination of location and drying method on the content of all analysed mineral components. Despite the above statements, the tendency of the occurrence of certain minerals in the dried rosehip fruits can be emphasized as follows: K>Ca>Na>Fe.

Table 8. Content of individual sugars (g/100 g dry matter) and natural invert in dried rosehip fruits from different locations

Location	Fructose (g/100g dw)	Glucose (g/100g dw)	Total sugar (g/100g dw)	Sucrose (g/100g dw)
		Natural drying		
Poljice	8.11	4.31	12.41	n.d.
Čitluk	6.785	3.125	9.91	n.d.
Međugorije	5.7	2.115	7.815	0.30
Grude	5.865	2.825	8.69	n.d.
		Artificial drying - convection		
Poljice	8.89	5.255	14.145	n.d.
Čitluk	6.17	3.47	9.64	0.30
Međugorije	5.545	2.53	8.075	0.30
Grude	7.015	4.505	11.52	0.635
ANOVA	*P* ≤ 0.0001	*P* ≤ 0.0001	*P* ≤ 0.0001	*P* ≤ 0.0008
LSD	0.1136	0.1105	0.22	0.1765
Signifance of interaction	Pr ≤ F	Pr ≤ F	Pr ≤ F	Pr ≤ F
Location (L)	0.0001	0.0001	0.0001	0.0065
Method (M)	0.0001	0.0001	0.0001	0.0002
L x M	0.0001	0.0001	0.0001	0.0029

L × M interaction between location (L) and drying method (M). Different letters show significant statistical differences between the mean values; n.d.- not detected

Table 9. The content of mineral compounds (mg/kg dw) in dried rosehip fruits from different locations

Location	Ca (mg/kg dw)	K (mg/kg dw)	Na (mg/kg dw)	Fe (mg/kg dw)
		Natural drying		
Poljice	7030.9	7304.25	37.32	13.195
Čitluk	8302.3	9119.45	44.975	11.82
Međugorije	5766.8	10429.5	40.975	14.275
Grude	5060.1	3910.1	38.52	9.855
		Artificial drying - convection		
Poljice	6824.8	7619.6	29.815	8.39
Čitluk	7268.8	8223.6	46.305	13.35
Međugorije	5503.9	10876.2	20.16	11.565
Grude	5397.8	5918.45	42.455	10.545
ANOVA	$P \leq 0.0001$	$P \leq 0.0001$	$P \leq 0.0001$	$P \leq 0.0002$
LSD	0.1136	0.1105	0.22	0.1765
Signifance of interaction	Pr ≤ F	Pr ≤ F	Pr ≤ F	Pr ≤ F
Location (L)	0.0001	0.0001	0.0001	0.0005
Method (M)	0.0001	0.0001	0.0001	0.0019
L x M	0.0001	0.0001	0.0001	0.0003

L × M- interaction between location (L) and drying method (M). Different letters show significant statistical differences between the mean values

It is important to emphasize that in addition to temperature, oxygen is also an important factor in maintaining quality during the drying process. Indeed, exposure to oxygen (natural drying conditions) increases oxidative stress, which can negatively affect certain components of the chemical composition of the material, including organic acids, minerals, etc. (Radojčin et al., 2021). The content of sugars and organic acids, and especially their ratio in the dried product, is a very important factor in maintaining the quality over some time (microbiological safety), as well as in forming the final taste of the product (Sikora et al., 2020).

CONCLUSIONS

Fresh wild fruits of the *R. canina* L. population collected from different places in Herzegovina represent a suitable and potential raw material for processing by drying. Namely, a relatively low water content of about 45%, a favourable ratio of total acids and sugars, and a good content of macro and microelements were found in all fresh rosehip fruits from the studied sites. Among the studied sites, wild fruits from the Poljica site were the most suitable for further processing (drying). The drying process did not have a negative effect on the chemical constituents studied, on the contrary, a higher content of all constituents, except iron, was found in the dried fruits. However, it is not possible to draw a clearer conclusion as to which of the drying methods had a greater influence on the preservation of the chemical composition of the analysed components. Both factors analysed had a significant influence in combination, which clearly shows that the location and drying under natural and artificial conditions have a significant influence on the chemical composition of the reship fruits. Precisely for this reason, it is necessary to single out the fruits with the best properties based on the analysis of the fruits in their fresh state in relation to the harvest location and then to optimize the drying conditions more precisely, especially under artificial conditions. From all this, it can be concluded that dried wild rose hips are a rich source of macro and micro minerals, sugars and total acids and are a good basis for designing a final product from the category of functional foods, such as healthy snacks or additives to individual products.

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