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MINERAL COMPOSITION OF WILD CRANBERRIES HARVESTED FROM APUSENI MOUNTAINS, ROMANIA

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Abstract

Wild cranberries represent a constant source of income for many local communities, however during the last decade, a few studies were published concerning their nutritional quality. The aim of the present study is to identify the influence of harvest time and location on mineral concentrations of wild cranberry berries from Apuseni Mountains, Mărgău County, Romania. Fifteen cranberry samples from Apuseni Mountains from 3 different locations were collected in August and September 2024. Minerals such as Ca, Mg, K, Zn Fe, Cu, B, Sr, were analyzed in all samples by ICP-OES. The highest Calcium concentration (177.40 ± 1.27 mg/kg) was identified for Vlădeasa-Răzoare location (September harvest). No significant differences (P>0.05) were identified for Ca, and K concentrations (regardless of the harvest time) and no significant difference for Zn and Fe total concentrations (August harvest) for berries from Vlădeasa-Răzoare and Vlădeasa-High locations. The characterization of the mineral profile of wild cranberry from Apuseni Mountains, Mărgau County, is facilitating the identification of the best harvest time and location for the development of local produces with protected designation of origin.

***Key words**: cranberry, minerals, harvest time.*

INTRODUCTION

Cranberry (*Vaccinium vitis-idaea* L.) is a perennial species from the Ericaceae family, recognized for its rich content of bioactive compounds, including vitamins, polyphenols, and essential minerals. These fruits are valued both for their nutritional benefits and their traditional and modern applications in phytotherapy. The mineral composition of wild cranberries is influenced by various factors, including edaphic and climatic conditions. Little information on mineral composition of wild cranberries was published, therefore there is a high need for detailed studies on the variability of minerals concentrations depending on the region of origin (Cristea, 2023; Vollmannová, 2018; Karlsons, 2018; Shotyk, 2020).

The Apuseni Mountains represent an ideal natural habitat for the spontaneous flora of cranberries due to their acidic soils and specific climatic conditions. Comparisons between Vaccinium species harvested from spontaneous flora and those from controlled crops have revealed significant differences in the content of macro- and microelements, particularly for elements such as calcium, magnesium, iron, and zinc (Karlsons, 2018; Shotyk, 2019; Vollmannová, 2019; Shotyk, 2020). Moreover, it has been demonstrated that cranberries from unpolluted areas, such as peat bogs and isolated mountain regions, exhibit a distinct mineral profile compared to those from areas affected by anthropogenic activities (Shotyk, 2019; Vollmannová, 2018; Tomáš, 2019; Shotyk, 2020).

Previous studies have shown that fruits of the Vaccinium genus, including cranberries, are influenced by the composition of the substrate on which they grow and the availability of nutrients in the soil (Karlsons, 2022; Vollmannová, 2018; AgricultForest, 2023; Shotyk, 2020). For example, research on cultivated cranberries has demonstrated that nitrogen and phosphorus fertilization can significantly modify the mineral content of the fruits (Karlsons, 2022; Vollmannová, 2018). Additionally, isotopic analyses and chemometric studies have been used in differentiating wild berries from cultivated ones, providing essential information regarding the authenticity and traceability of cranberry products (Cristea, 2023; Karlsons, 2018; Shotyk, 2020).

The mineral content analysis was performed using inductively coupled plasma optical emission spectrometry (ICP-OES), a method recognized for its precision and sensitivity in determining chemical elements in plant matrices (Vollmannová, 2018; Shotyk, 2019; Tomáš, 2019; AgricultForest, 2023; Shotyk, 2020).

In this context, the aim of the present study is to analyze the mineral content of spontaneously growing cranberries harvested from the Apuseni Mountains, highlighting potential differences compared to other regions and identifying the factors contributing to this variability. The study aims to provide relevant data for assessing the quality of these fruits and contribute to the scientific literature on the impact of environmental factors on the mineral composition of wild plants.

MATERIALS AND METHODS

Samples collection and preparation

In 2024 fifteen wild cranberry samples were harvested from three different locations in Apuseni Mountains, Mărgău County, Romania, from August to September. For each location, 3 samples formed of 5 g of fresh wild cranberries were used to determine the mineral composition. The samples were prepared based on a modified method of Dróżdż et al. (2018) using 5 grams of fresh cranberries. Fruits were grinded and homogenised, using GrindomixGM200, Retsch GmbH, Haan, Germany.

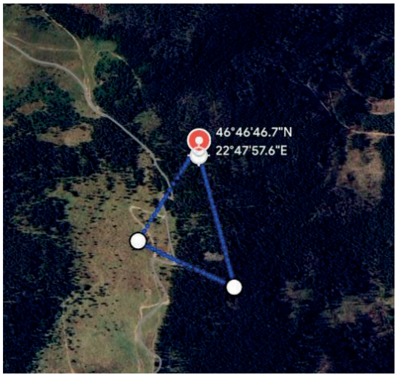

Figure 1. Harvest area in Apuseni Mountains, Romania

For each location 2 kg of fruits were harvested: from location Boaică only one harvest was made on 14 August 2024. Due to extreme drought, no second harvest was possible on Boiacă location. Two harvests were made for locations Vlădesa-Răzoare, VR_1 and VR_2, and Vlădeasa-Sus, VS_1 and VS_2, on 16 August and 7 September 2024 respectively. From each harvest, three samples were extracted and used for mineral analysis.

Macroelements and microelements analysis

Elements Ag, Al, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, K, Li, Mg, Mn, Na, Ni, Pb, Se, Sr, Tl, Zn were analysed by ICP OES Thermo Scientific model iCAP 6000. Only the macroelements Ca, K, Mg, Na and microelements Al, Ba, Cu, Fe, Mn, Sr, Zn concentrations exeeeded the detection limit of the method. The operating parameters of the spectrometer were: Power 1.15 kW, auxiliary Ar gas flow rate 0.2 L/min, nebulizing Ar gas flow rate 0.42 L/min, coolant gas flow rate of 12 L/min. The numberd of redings per sample: 3. The lines selected were: Al 308.2 nm, Ba 233.5 nm; Ca 422.6 nm, Cu 224.7 nm; Fe 255.9 nm; K 766.4 nm; Mg 279.5 nm; Mn 257.6 nm; Na 589.5 nm; Sr 407.7 nm; Zn 206.2 nm. For the others elements, all lines selected showed that the concentrations are below the detection limit of the method.

Statistical analysis

The statistical analysis was performed using MedCalc® Statistical Software version 22.018 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2024).

Comparisons were made for each mineral between locations regardless the harvest time. Data normality was analyzed using Shapiro-Wilk test, equality of error variances was analyzed using Levene's test. When data were normally distributed and ANOVA was significant ($p<0.05$) a post hoc analysis was made using the Tuckey-Kramer test. We found that all data were normally distributed. For samples having unequal variances of elements' concentrations data, the Welch-ANOVA test allowing unequal variance was applied. To compare the data generated by our research with the published data we used one sample t test using the MedCalc software.

RESTULTS AND DISCUSSIONS

Macroelements concentration in wild cramberries fuits from Apuseni mountains

The maximum Ca total concentrations (177.4011 mg/kg fresh weight) was recorded for cranberries harvested in the VR area at the end of the harvesting period (Table 1, Figure 2). The minimum Ca concentration (149.1665 mg/kg fresh weight) was found for the fruits harvested from Boaică area at the beginning of the harvesting period (Table 1).

Table 1. Macroelements concentrations (mg/kg fresh weight) in wild cranberries harvested from Apuseni Mountains, Romania. Data can be compared only between harvests for the same element. Values followed by the same letter are not significantly different (p=0.05)

Harvest	Ca	K	Mg	Na
VR_1	152.65^{a}± 3.63	648.96^{b}± 42.47	62.38^{b}± 3.46	11.76^{ab}± 0.89
VR_2	177.40^{b}± 1.27	811.88^{a}± 6.59	74.78^{a}± 1.29	10.75^{ab}± 1.46
VS_1	155.13^{ab}± 10.11	645.95^{b}± 19.77	62.98^{b}± 3.03	12.10^{ab}± 1.91
VS_2	165.92^{ab}± 15.61	732.18^{ab}± 38.49	66.89^{ab}± 6.70	12.92^{b}± 0.56
BOAICĂ	149.16^{a}± 5.98	750.28^{a}± 19.27	64.00^{ab}± 4.27	8.95^{a}± 0.54

Ca concentration had a significant variation depending on both the harvest area and the harvest period. Specifically, the Ca concentration in samples collected from the Boaica area at the beginning of the harvest period are significantly lower from those collected in the Vlădeasa-Răzoare (VR_2) area at the end of the harvesting period (Table 1, Figure 2). Additionally, Ca concentrtions in fruits from VR area at the beginning of the harvesting period differ significantly of Ca concentrations from fruits collected in the same area at the end of the harvesting period.

The K (potassium) maximum concentration was measured from the fruits harvested in VR area at the end of the harvesting period (811.8808 mg/kg fresh weight). The minimum K concentration (645.9591 mg/kg fresh weight) was found for the cranberries harvested in the VS area at the beginning of the harvesting period (Table 1, Figure 2). The K concentrtions in cranberries fruits collected from the Boaica area at the beginning of the harvesting period were significantly different from K concentrations in cranberries fruits collected in the VS and VR areas at the beginning of the harvesting period (Table 1, Figure 2).

Additionally, K concentrations for fuits from the VR area at the beginning of the harvesting period differ significantly from the K concentrations of the fruits collected in the same area at the end of the harvesting period. Furthermore, K concentrations in cranberries from VS area at the beginning of the harvesting period differ significantly from those collected in the VR area at the end of the harvesting period. Therefore. K concentration varies depending on both the harvesting area and the harvesting period. For VS and VR location there was no significat difference between K concentrations in cranberries harvested in the same day (Table 1, Figure 2).

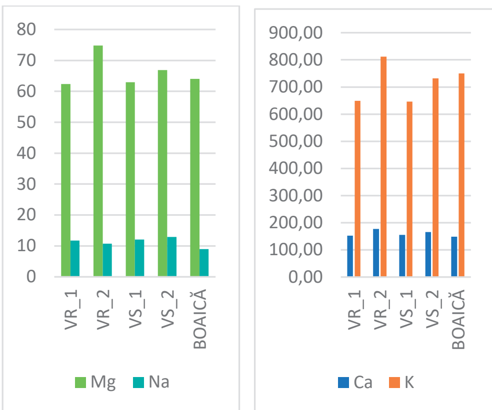

Figure 2. Variation of Ca, K , Mg and Na concentrations by location and harvest time

For Mg, the maximum concentrations is 74.7819 mg/kg fresh weight for VR_2 area and the minimum concentration was found to be 62.9848 mg/kg fresh weight for VS_1 (Table 1, Figure 2). The Mg total concentrations in cranberry fruits collected from the VR area at the beginning of the harvesting period differ significantly from those collected in the same area at the end of the harvesting period (Table 1, Figure 2). Therefore, Mg concentration varies depending on the harvesting time.

For Na, the maximum value recorded for concentration is 12.9299 mg/kg in the VS area at the end of the harvesting period (Table 1, Figure 2). The minimum Na concentration is 8.9581 mg/kg in the Boaica area at the beginning of the harvesting period. The Na concentration in fruits collected from the Boaica area at the beginning of the harvesting period differ significantly from those collected in the VS area at the end of the harvesting period (Table 1, Figure 2). Magnesium and potassium are conssidered to have a high mobility in the phloem, which may explain the significant accumulation of Mg and K during the cranberries fruits development and ripening for the VR and VS locations.

Comparing the data from Ca, K, Mg concentrations of wild cranberries harvested in the Apuseni Mountains with data reported by Karlson et al. (2018) for cultivated varieties of cranberries in Latvia showed that there is a significant difference between cultivated and wild fruits mineral concentrations (Table 2), wild fruits from Apuseni mountains being reacher in macronutrients.

In Table 2 the minerals that were not signifficantly different from the publisehed literature (Karlsons et al., 2018) are in italics and in higlighted cells. The Mg concentrations for the V. Macrocarpon cultivar is mostly similar to the Mg concentrations in wild cranberries from Apuseni mountains except for the VR_2 harvest. Due to the fact that Karlsons et al. (2018) did not reported Na concentrations, it was not possible to make a comparison between the Apuseni mountains' wild cranberries fruits Na total concentations and the published data for cultivated cranberries. The Ca concentration values in cranberry fruits collected from the Apuseni Mountains differ significantly from the Ca concentration values reported by Karlsons et al. (2018). Thus, the Ca concentration recorded in VR_1 is 1.20 times higher than the Ca concentration in *V. oxycoccos* (p=0.0068) and 1.50 times higher than in *V. macrocarpon*, as reported by Karlsons et al. (2018).

Table 2. P values for the comparison (one sample t test) between macroelements concentrations (mg/kg fresh weight) in wild cranberries fruits harvested from Apuseni Mountains, Romania and the macroelements concentrations (mg/kg fresh weight) in American cranberry fruits (*Vaccinium macrocarpon*) and European cranberry (*Vaccinium oxycoccus*) fruits cultivated in Latvia (Karlsons et al., 2018)

Element	Location-wiled cranberries	*V. oxycoccos*	*V. macrocarpon*
Ca	VR_1	P=0.0068	P = 0.0017
	VR_2	P = 0.0018	P = 0.0008
	VS_1	P = 0.0416	P = 0.0118
	VS_2	*P = 0.0506*	P = 0.0192
	BOAICĂ	P = 0.0243	P = 0.0053
K	VR_1	*P = 0.4483*	*P = 0.0899*
	VR_2	P = 0.0007	P = 0.0019
	VS_1	*P = 0.1509*	P = 0.0202
	VS_2	*P = 0.1133*	*P = 0.7802*
	BOAICĂ	P = 0.0196	*P = 0.1519*
Mg	VR_1	P = 0.0128	*P = 0.3064*
	VR_2	P = 0.0145	P = 0.0073
	VS_1	P = 0.0094	*P = 0.2164*
	VS_2	*P = 0.0685*	*P = 0.8571*
	BOAICĂ	P = 0.0206	*P = 0.4840*

For K, the values recorded in VR_2 and Boaică differ significantly from the K concentration values reported by Karlsons et al. (2018) for *V. oxycoccos* and *V. macrocarpon*. Specifically, the K value recorded in VR_2 is 1.21 times higher than the value reported by Karlsons et al. (2018) for *V. oxycoccos* (p=0.0007) and 1.12 times higher than the value reported for *V. macrocarpon* (p=0.0019).

For Mg, the values recorded in VR_1, VR_2, VS_1, and Boaică differ significantly from the values reported by Karlsons et al. (2018) for *V. oxycoccos* and *V. macrocarpon*. Thus, the Mg concentration recorded in VR_1 is 0.77 times lower than the value reported by Karlsons et al. (2018) for *V. oxycoccos* (p=0.0128).

Oligoelements concentrations in wild cranberries fruits from Apuseni region.

Microelements such as Cu, Fe, and Mn are associated with plant enzyme systems, therefore, it is expected that their concentration increase in berries over the harvest period. Al does not play a phisiological role.

The maximum Al total concentration was found in VR at the beginning of the harvesting period (15.9519 mg/kg fresh weight) (Table 3, Figure2). The minimum Al total concentration was 4.3644 mg/kg in the Boaica area at the beginning of the harvesting period (Table 3, Figure 3).

Table 3. Oligoelements concentration(mg/kg) in wild cranberries harvested from Apuseni Mountains. Romania. Data can be compared only between harvests for the same element. Values followed by the same letter are not significantly different (p=0.05)

Harvest	Al	Ba	Cu	Fe
VR_1	$15.95^{b}\pm$ 5.15	$1.30^{a}\pm$ 0.04	$1.03^{a}\pm$ 0.11	$3.04^{b}\pm$ 0.16
VR_2	$7.88^{a}\pm$ 3.62	$1.97^{b}\pm$ 0.08	$1.19^{ab}\pm$ 0.07	$3.38^{b}\pm$ 0.52
VS_1	$9.48^{ab}\pm$ 0.86	$2.07^{b}\pm$ 0.05	$1.27^{b}\pm$ 0.04	$3.96^{b}\pm$ 0.31
VS_2	$8.90^{ab}\pm$ 1.49	$2.19^{bc}\pm$ 0.24	$1.24^{ab}\pm$ 0.05	$7.00^{a}\pm$ 1.37
BOAICĂ	4.36^{a} ± 0.09	$1.72^{bd}\pm 0.12$	$1.23^{ab}\pm 0.01$	$2.59^{b}\pm 0.05$

Table 4. Oligoelements concentration in wild cranberries harvested from Apuseni Mountains. Romania (mg/kg). Data can be compared only between harvests for the same element. Values followed by the same letter are not significantly different (p=0.05)

Location	Mn	Sr	Zn
VR_1	$15.16^{ab}\pm 1.38$	$0.23^{a}\pm 0.007$	$15.23^{b}\pm 0.50$
VR_2	$20.37^{b}\pm 2.73$	$0.30^{a}\pm 0.01$	$4.85^{a}\pm 3.86$
VS_1	$17.88^{b}\pm 1.48$	$0.49^{b}\pm 0.009$	$16.03^{b}\pm 1.12$
VS_2	$15.62^{ab}\pm 2.25$	$0.48^{b}\pm 0.06$	$15.25^{b}\pm 0.16$
BOAICĂ	$11.82^{a}\pm 1.62$	$0.23^{a}\pm 0.04$	$2.18^{a}\pm 0.22$

For cranberries from the VS area, there are no significant differences in Al concentration regardless of the harvesting period. This is probably due to a poor soil Al concentrations in the VS region. Al mobility in soild is higher for acidic and neutral pH soil but lower for alkaline soil, and its mobility is reduced by soil organica matter (Zeiner and Cindric; 2018). We also suspect that VS soils have a higher organic mater and thus reduce aluminium availability for plants. The presence of Al and Fe in the soils of this region has a natural occurance, due to the fact that VS, VR an Boaică areas are situated in metalliferous mountains, naturally rich in non-ferrous and ferrous minerals. For cranberries from the VR area there is a significant difference in Al concentrations depending on the harvesting period.

Zinc is involved in the synthesis of tryptophan (precursor of auxin) therefore it helps in reducing fruit drop. The significant dicrease in fruit Zn For the VR_2 compared to VR_1 might be explained by a redused soil bioavailability during the second harvest period. Soil Zn bioavailability is influenced by organic matter and pH.

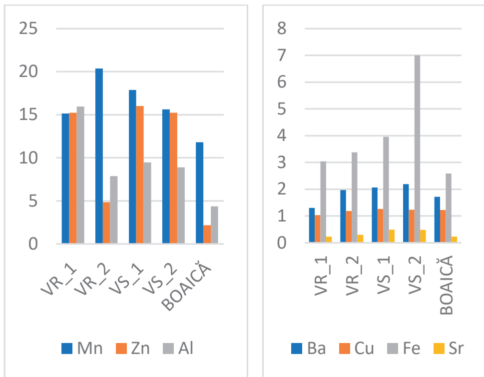

Figure 3. Variation of Al, Ba, Cu Fe, Mn, Sr and Zn concentrations by location and harvest time.

Ba maximum concentration (2.1989 mg/kg fresh weight) was found in berries from VS area at the end of the harvesting period (Table 2, Figure 3). The Ba minimum concentration (1.3031 mg/kg fresh weight) was found for the berries harvested from VR area at the beginning of the harvesting period. However, the berries harvested in VS area did not show significant differences of Ba concentration regardless of the harvesting period. In contrast, VR berries showed significant differences in Ba concentration depending on the harvesting period. Barium is a silvery-white metal which is naturalrely found in soils in combination with chemicals, such as sulfate, carbonate, and hydroxide. Barium may be present in air as a result of antropogenic emissions, in particular by the burning of coal and diesel. Local population of the research area is using coal as well as wood for heating and for daily household needs. As a consequence due to its natural presence in the soil and antropogenic emission, it can enter the food chain through root and foliar uptake by plants. Plants are known to be able to uptake Ba and acumulate in storage organs as well as in leaves, therefore foods such as lettuce, onions, beans, potatoes, nuts, and cereal grains may contain Ba (Lee et al., 2023)

The maximum Cu concentration was recorded in the VS area at the beginning of the harvesting period, reaching 1.2779 mg/kg fresh weight (Table 3, Figure 3). The minimum value was recorded in the VR area at the beginning of the harvesting period (1.0380 mg/kg fresh weight) (Table 3, Figure 3). The Cu concentration does not differ significantly based on the harvesting period, however, it varies significantly depending on the harvesting area. Specifically, the samples from the VR area differ significantly from those in the VS area at the beginning of the harvesting period.

While calcium and manganese have a low phloem mobility, elements such as copper. iron and zinc have a variable or conditional phloem mobility depending on plant species, environmental influences, plant tissue and growth stage. For VR and VS locations there is an evident increase of Fe concentration during the ripening period. For Fe, the maximum value was recorded in the VS area at the end of the harvesting period, reaching 7.0075 mg/kg fresh weight (Table 3, Figure 3). The minimum value was recorded in the Boaica area at the beginning of the harvesting period, at 2.5966 mg/kg fresh weight (Table 3, Figure 3). Significant differences in Fe concentration were observed based on both the harvesting area and the harvesting period. A possible explanation for this situation is the existence of a higher moisture and raifall in the VS region compared to the other regions which were drastically affected by drought. Despite copper and iron are conssidered to have a variable or conditional phloem mobility, their accumulation continued throughout the cranberry fruits development and ripening. Therfore their accumulation into the fruits might conssidered to be through the phloem.

For Mn, the maximum recorded value was 20.3713 mg/kg fresh weight in the VR area at the end of the harvesting period (Table 4, Figure 3). The minimum value was recorded in the Boaică area at the beginning of the harvesting period, at 11.8236 mg/kg fresh weight (Table 4, Figure 3).

Regarding Fe concentration, the cranberry fruits collected from the Boaica area differ significantly from those collected in the VR area at the end of the harvesting period, as well as from those collected in the Vlădeasa Sus area at the beginning of the harvesting period (Table 4, Figure 3). Therefore, Fe concentration differs significantly depending on both the harvesting area and the harvesting period.

For Sr, the maximum recorded value is 0.4948 mg/kg fresh weight in the VS area at the beginning of the harvesting period (Table 4, Figure 3). The minimum value was recorded in the Boaică area, at 0.2305 mg/kg fresh weight, also at the beginning of the harvesting period (Table 4, Figure 3). The Sr concentration differs significantly depending on the harvesting area, with cranberry fruits from the Boaică and VR areas differing significantly from those in the VS area.

The maximum Zn concentration was recorded in the VS area at the beginning of the harvesting period, reaching 16.0337 mg/kg fresh weight (Table 4, Figure 3). The minimum value was recorded in the Boaică area, also at the beginning of the harvesting period, at 2.1806 mg/kg fresh weight (Table 4, Figure 3). Zn concentration values differ significantly depending on both the harvesting area and the harvesting period. Specifically, the fruits collected from the Boaica area at the beginning of the harvesting period and those from the VR area at the end of the harvesting period differ significantly from the fruits collected from the VR area at the end of the harvesting period, as well as from those collected in the VS area during both harvesting periods (Table 4, Figure 3).

In Table 5 the minerals that were not signifficantly different from the publisehed literature (Karlsons et al.,2018) are in italics and in higlighted cells. Due to the fact that Karlsons et al.(2018) did not reported Al, Ba and Sr concentrations, it was not possible to make a comparison between the Apuseni mountains' wild cranberries fruits Al, Ba and Sr total concentations and the published data for cultivated cranberries. The Cu concentration values in cranberry fruits collected from the Apuseni Mountains differ significantly from the Cu concentration values reported by Karlsons et al. (2018) for both *V. oxycoccos* and *V. macrocarpon*. Thus, the Cu concentration in fruits collected from VR_1 is 1.72 times higher than the value reported by Karlsons et al. (2018) for *V. oxycoccos* (P = 0.0211) and 2.10 times higher than the Cu concentration reported for *V. macrocarpon* (P = 0.0136).

Table 5. P values for the comparison (one sample t test) between oligoelements concentrations (mg/kg fresh weight) in wild cranberries fruits harvested from Apuseni Mountains, Romania and the oligoelements concentrations (mg/kg fresh weight) in American cranberry fruits (*Vaccinium macrocarpon*) and European cranberry (*Vaccinium oxycoccus*) fruits cultivated in Latvia (Karlsons et al., 2018)

Element	**Location-wild cranberries**	***V. oxycoccos***	***V. macrocarpon***
Cu	VR_1	P = 0.0211	P = 0.0136
	VR_2	P = 0.0047	P = 0.0033
	VS_1	P = 0.0012	P = 0.0009
	VS_2	P = 0.0020	P = 0.0015
	BOAICĂ	P = 0.0001	P = 0.0001
Fe	VR_1	*P = 0.5826*	P = 0.0005
	VR_2	*P = 0.4495*	P = 0.0061
	VS_1	P = 0.0407	P = 0.0030
	VS_2	P = 0.0388	*P = 0.8240*
	BOAICĂ	P = 0.0032	P < 0.0001
Mn	VR_1	P = 0.0055	P = 0.0036
	VR_2	*P = 0.0725*	P = 0.0072
	VS_1	P = 0.0112	P = 0.0028
	VS_2	P = 0.0156	P = 0.0088
	BOAICĂ	P = 0.0044	P = 0.0088
Zn	VR_1	P = 0.0004	P = 0.0004
	VR_2	*P = 0.2717*	*P = 0.2821*
	VS_1	P = 0.0020	P = 0.0020
	VS_2	P < 0.0001	P < 0.0001
	BOAICĂ	P = 0.0332	P = 0.0448

The Fe concentration values in cranberry fruits collected from VS_1, VS_2, and Boaică differ significantly from the Fe concentration values reported by Karlsons et al. (2018) for *V. oxycoccos*. Specifically, the Fe concentration in fruits from VS_2 is 2.26 times higher than the Fe concentration reported by Karlsons et al. (2018) for *V. oxycoccos* (P = 0.0388).

The Fe concentration values in fruits collected from VR_1, VR_2, VS_1, and Boaică differ significantly from the Fe concentration values reported by Karlsons et al. (2018) for V. macrocarpon. For instance, the Fe concentration in cranberries collected from Boaică is 0.36 times lower than the value reported by Karlsons et al. (2018) for V. macrocarpon (P < 0.0001).

The Mn concentration values in fruits collected from VR_1, VS_1, VS_2, and Boaică differ significantly from the Mn concentration values reported by Karlsons et al. (2018) for *V. oxycoccos*. Specifically, the Mn concentration in fruits collected from VR_1 is 0.59 times lower than the Mn concentration reported by Karlsons et al. (2018) for *V. oxycoccos* (P = 0.0055).

The Zn concentration values in cranberry fruits collected from VR_1, VS_1, VS_2, and Boaică differ significantly from the Zn concentration values reported by Karlsons et al. (2018) for both *V. oxycoccos* and *V. macrocarpon*. Thus, the Zn concentration in fruits collected from VR_1 is 10.15 times higher than the value reported by Karlsons et al. (2018) for *V. oxycoccos* and 9.25 times higher than the Zn concentration reported for *V. macrocarpon* (P = 0.0004).

CONCLUSIONS

The highest concentration of Fe was recorded in the samples collected from the Vlădeasa Sus area at the end of the harvesting period being significantly different from the samples collected from the other regions. The Mg, K and Ca total concentrations are significantly higher for the September harvest. The Na total concentrations were not significantly different over the whole harvest period. However, these results have to be considered with caution due to the large variability of the measurements. The Zn and Al total concentrations are decreasing during the harvest period, the cranberry fruits from the Boaică area contains the lowest concentrations of Zn and Al compared to the cranberry fruits harvested from the other Apuseni Mountains studied regions. The Fe total concentrations are significantly higher in the cranberry fruits harvested in September.

However, the Cu total concentrations are not significant.

Compared with the published total concentrations of Ca, K, Mg, Cu, Fe, Mn and Zn from *V. macrocarpon* cranberry cultivar and *V. oxycoccos* the cranberry variety from the Apuseni Mountains is reacher in minerals with few exceptions.

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