
**ASSESSMENT OF IRON CONCENTRATION IN STONE AND BERRY FRUIT: A
CASE STUDY OF CHERRIES, SOUR CHERRIES, RASPBERRIES, AND
BLACKBERRIES**

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Abstract: Iron is an essential mineral that transports oxygen throughout the body in the form of hemoglobin. Iron (Fe) deficiency causes anemia, which is accompanied by fatigue and weakness. Chronic Fe deficiency can lead to organ failure and serious health problems. Fruits can be an important source not only of vitamin C, but also of Fe. Consuming a variety of fruits is good for health and is essential for the intake of essential micronutrients and dietary fiber. Cherries, sour cherries, raspberries and blackberries are used in the diet due to their high nutritional value and benefits in maintaining good physical and mental health. In this study are analyzed two types of fruits: stone fruits (cherries and sour cherries) and berries (raspberries and blackberries). The fruits were grown in three villages in the region of Kosovska Mitrovica, Kosovo. The Fe concentration was determined by an accredited method, including microwave digestion and inductively coupled plasma mass spectrometry (ICP-MS). The samples were dried in a dryer and all samples were determined % of dry matter and % of water. ICP-MS analyses were performed on dry samples. Statistical analysis was carried out with Microsoft Excel 2016, using Pearson's correlation coefficient and Student's t-test for Fe concentration in drupe and berry fruits. The results are presented in dry and fresh weight of the samples. The results show that the mean Fe concentration in fruits, dry weight, from all 3 sites is the highest in sour cherries (194.7 mg/kg), and the lowest in raspberries (115.9 mg/kg). Due to the high water content of sour cherries, the mean Fe value in fruits, wet weight, is the highest in blackberries (35.35 mg/kg), and the lowest in raspberries (17.66 mg/kg). There are differences in Fe concentration between fruits taken from different areas. The lowest concentrations of Fe are found in fruits taken from the Polski area. Statistical analyses show that there is a strong positive correlation between stone fruits and berries. As the concentration of Fe in drupe fruits increases, the concentration of Fe in berries also increases. This means that the concentration of Fe in fruit does not depend only on the type of fruit, but also on the area in which it is grown. Student's t-test showed that there is no significant difference between the concentration of Fe in drupe fruits and berries. The results confirm the need for further research and control measures in the context of agricultural practices and public health. The importance of iron for our health imposes the need for regular monitoring of fruits containing higher concentrations of iron.

Keywords: determination, iron, stone fruits, berries

1. INTRODUCTION

Microelements can have both beneficial and harmful effects on human health. They are divided into three groups: toxic metals (arsenic, cadmium, lead, mercury, nickel, and others), potentially essential (vanadium), and essential metals (copper, zinc, iron, manganese, selenium, and cobalt). However, even essential metals can cause toxic effects if their intake is excessive. Heavy metals are particularly dangerous for humans and animals due to their non-degradability, long biological persistence, and ability to accumulate in the body, as there is no effective mechanism for their elimination (Shaheen et al., 2016). Fruits and their juices are widely consumed by all age groups and are an integral part of the daily diet. They also serve as a significant source of essential nutrients, including vitamins and minerals (Fathabad et al., 2018). Eating fruits contaminated with heavy metals can lead to serious health

consequences, which highlights the need for regular control and analysis of the level of contamination in order to guarantee its quality and safety (Bora et al., 2022). Heavy metals can enter in the human body through the digestive system, skin, or inhalation. They represent a significant health risk, mainly due to their ability to damage cell membranes and DNA, as well as disrupt the normal functioning of proteins and enzymes (Witkowska et al., 2021). Heavy metals represent a serious threat to public health and are known that they accumulate in fruits, which are widely consumed for their pleasant taste and possible health benefits (Amer et al., 2019). Contamination of fruits with heavy metals is a significant problem arising from the intensive use of pesticides and other chemicals, driven by the pursuit of rapid economic development through industrialization and modern agricultural practices (Omoyajowo et al., 2017). The use of artificial and organic fertilizers, sewage sludge, irrigation with polluted water, and the leakage of petrochemicals contribute to the contamination of soil and water with heavy metals (Prabagar et al., 2021). Long-term consumption of foods, including fruits, with high levels of heavy metals can lead to their gradual accumulation in the body, which over time can cause damage to the heart, liver, kidneys, blood, lungs, bones, spleen, and other organs (Fathabad et al., 2018). Heavy metals such as Cu, Fe, Zn and Ni are beneficial micronutrients when they are present in trace amounts and they have a positive effect in human nutrition. Hemoglobin, which is a compound of Fe and it is present in red blood cells, plays a major role in the transport of oxygen throughout the body. Iron deficiency leads to a decrease in red blood cells and as a result, appear fatigue and weakness due to anemia. Chronic Fe deficiency leads to organ failure. Fruits and vegetables, in addition to their high vitamin C content, can also be an important source of Fe (Leung et al., 2024).

The aim of this study is to determine the concentration of Fe in four types of fruit: cherries, cherries, raspberries and blackberries.

2. MATERIALS AND METHODS

Materials

Two types of stone fruit (cherries and sour cherries) and berry fruit (raspberries and blackberries) from the 2023 harvest in their full technological and nutritional maturity were analyzed.

Research area

Two groups of fruit were grown in three villages in the region of Kosovska Mitrovica in Kosovo. Two of the villages (Zvecan and Frasher) are located in the immediate vicinity of a lead and zinc smelter, while the village of Polski is at a significantly greater distance from the smelter.

Preparation of raw materials

All analyzed fruit was first thoroughly washed with clean tap water and then with distilled water. Then, the washed samples were cut into small pieces and subjected to drying in a drying oven (Drying Oven SLN 15, Wodzisław Śląski, Poland) for 24-30 hours, depending on the type of fruit. After the process was completed, the water and dry matter content of each sample was determined. The samples were stored at room temperature until the moment of their analysis.

Determination of Fe in fruit, dry weight

The concentration of Fe in selected species of fruit was determined using an accredited method according to MKC EN ISO/IEC 17025:2018, which allows analyzing the content of 35 elements in different samples. For this purpose, microwave digestion was applied, followed by inductively coupled plasma mass spectrometry (ICP-MS) with a model 7500cx device (Agilent, USA), whereupon the method have a flexible range.

Determination of Fe in fruit, wet weight

The concentration of Fe in stone fruit and berry fruit, wet weight, is calculated using the following formula (EPA, 2018; Zeneli et al., in press):

$$C_{ww} = C_{dw} \left[\frac{100 - W}{100} \right]$$

Where: C_{ww} is the concentration of Fe in fruit, wet weight; C_{dw} is the concentration of Fe in dry fruit, dry weight; W is the content of water in %.

Statistical analysis of data

Statistical analysis of data was conducted using Microsoft Excel 2016. Pearson's coefficient of correlation and Student's t-test were determined for the concentration of Fe in the stone fruit and in the berry fruit (Levine et al., 2008).

3. RESULTS AND DISCUSSIONS

In the Table 1 are presented the values for the concentration of Fe in the stone fruit and the berry fruit grown in three villages in the Kosovska Mitrovica region.

Table 1. Concentration of Fe in the stone fruits and in the berries, dry weight

Concentration of Fe (mg/kg)	Dried stone fruit		Dried berry fruit	
	Cherries	Sour cherries	Raspberries	Blackberries
Settlement				
Zvecan	223	237	128	214
Frasher	152	226	114.6	190.6
Polski	129	121	105.1	152.4
Average value	168	194.7	115.9	185.7

Source: authors' research

Table 1 shows that the average content of Fe is lowest in raspberries (115.9 mg/kg), and highest in sour cherries (194.7 mg/kg). The highest concentrations of Fe in all types of fruit are found in samples taken from the settlement of Zvečan, and the lowest in the settlement of Polski.

To calculate the content of Fe in the analyzed fruit, wet weight, it is necessary to know the % of water in each fruit. The content of water in % ranges from 87.7-89 % in cherries, from 84-86.3 % in sour cherries, from 82.8-86 % in raspberries and from 79.1-81.8 % in blackberries (Zeneli et al., in press).

Table 2 presents the Fe content in fresh stone fruit (cherries and sour cherries) and berry fruit (raspberries and blackberries).

Table 2. Concentration of Fe in the stone fruit and in the berry fruit, wet weight

Concentration of Fe (mg/kg)	Stone fruit, wet weight		Berry fruit, wet weight	
	Cherries	Sour cherries	Raspberries	Blackberries
Settlement				
Zvecan	27.88	32.47	22.02	38.95
Frasher	18.70	33.00	16.04	39.84
Polski	14.19	19.36	14.92	27.28
Average value	20.25	28.28	17.66	35.35

Source: authors' research

In fruits, the highest content of Fe in wet weight is found in blackberries (35.35 mg/kg), followed by sour cherries (28.28 mg/kg), then cherries (20.25 mg/kg) and the least in raspberries (17.66 mg/kg).

The lowest concentrations of Fe were determined in cherries and raspberries from Polski (14.19 mg/kg and 14.92 mg/kg respectively), and the highest in blackberries from Zvečan and Frašer (38.95 mg/kg and 39.84 mg/kg respectively). The obtained results are slightly higher than the previous results for Fe in cherries of 10.69 mg/kg (Miftari et al., 2017) and for Fe in sour cherries of 762 µg/100 g or 7.62 mg/kg (Mitic et al., 2011). Grembecka & Szefer (2013) determined the concentration of Fe in raspberries in the range from 0.86 to 1.12 mg/100g or from 8.6 to 11.20 mg/kg. The results of our studies are higher compared to the results from the scientific literature. This is expected because the concentration of iron in different types of fruit depends on several factors such as: the method and conditions of cultivation, the soil quality, and the geographical location (Xi et al., 2022).

Table 3 presents the correlation coefficients of Fe for fruit between different locations.

Table 3. Correlation coefficients of Fe for fruit between different locations

	Zvecan	Frasher	Polski
Zvecan	1		
Frasher	0.959	1	
Polski	0.912	0.939	1

Source: authors' own calculations

The coefficient of correlation between the stone fruit and the berry fruits for Fe was also calculated and it is 0.864. This value shows that there is a positive correlation between the concentrations of Fe in the analyzed stone fruits and berry fruits. This means that with increasing the concentration of iron in the stone fruit, there is a tendency for increasing the concentration of iron in the berry fruit too. When the coefficient of correlation has a value of 0.8 to 1,

the correlation is strong, which means that in this case there is a strong positive correlation between the stone fruit and the berry fruit. The highest correlation is between fruits from the Zvecan and Frasher locations.

Table 4 presents the results of the student's t-test for the concentration of Fe in the stone fruit (cherries and sour cherries) and in the berry fruit (raspberries and blackberries).

Table 4. Student's t-test results: Fe concentrations in stone and berry fruits and between locations

	Stone fruit-berry fruit		Zvecan-Frasher		Zvecan-Polski		Frasher-Polski	
Mean value	24.264	26.508	30.330	26.895	30.330	18.938	26.895	18.938
Value of t-test	-0.407		0.510		2.436		1.235	
Obtained p-value	0.692		0.628		0.051		0.263	
Critical value for t	2.228		2.447					

Source: authors' own calculations

The results show that the mean concentration of Fe in the berry fruit is higher (26.508 mg/kg) compared to the concentration of Fe in the stone fruit (24.264 mg/kg). Since the p-value is greater than 0.05, there is no statistically significant difference in Fe concentration between berry and stone fruits, or between fruits from different locations. Based on the obtained p-values, the differences in Fe concentration between the locations are ranked as follows: Zvecan-Polski, Frasher-Polski and Zvecan-Frasher.

4. CONCLUSIONS

The results of the studies show that the Fe content varies between different types of stone fruit and berry fruit, as well as between different growing locations. The average concentration of Fe is higher in the berry fruit, dry weight compared to the stone fruit, dry weight. When the fruit is in dry form, Fe is highest in sour cherries (194.7 mg/kg), and lowest in raspberries 115.9 mg/kg. When taking into account the water that has evaporated, in the fruit, wet weight, the most Fe is in blackberries (35.35 mg/kg), and the least in raspberries (17.66 mg/kg). Statistical analysis showed that the differences between the two types of fruit are not significant ($p > 0.05$). There is no statistical significant difference in Fe concentrations between most locations. However, the largest difference was observed between Zvecan and Polski ($p=0.051$), which indicates that there is no essential difference between these two groups of fruit in terms of their Fe content. The analysis also showed the existence of a positive correlation between the concentration of Fe in the stone fruit and in the berry fruit, indicating that an increase in the iron content in one type of fruit is associated with an increase in the content in the other type of fruit. These data may be useful for further research of the nutritional composition of different types of fruit and their impact on the diet and health of consumers.

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