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POTASSIUM AND MAGNESIUM CONTENT IN MANDARIN ON MARKET OF CITY OF ZAGREB

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Abstract

Mandarin is a plant species which belongs to the group of winter seasonal fruit. It is highly valued for its vitamin C, potassium and magnesium content. When buying mandarins, consumers do not have the information on the exact mineral composition of mandarins so a study was conducted to determine the content of macroelements potassium and magnesium in mandarins as well as to compare the results with regards to the place of purchase of individual samples. Mandarin sampling was carried out in the city of Zagreb at 3 markets, 3 retail chains and 3 organic product stores. After digestion with concentrated HNO_3 and $HClO_4$ in microwave oven, potassium was determined by flame photometry and magnesium by atomic absorption spectrometry. Dry matter was determined gravimetrically by drying until constant mass. The content of dry weight in the mandarin samples ranged from 7.86% to 8.70%. The content of potassium in dry weight of mandarin ranged from 2.04% to 2.33%, and the content of magnesium from 0.101% to 0.110%. The content of potassium in the fresh weight of mandarin ranged from 235 to 297 mg K/100 g fresh weight, and the content of magnesium ranged from 11.6 to 14.0 mg Mg/100 g fresh weight.

Key words*: fruit, macroelements, minerals, nutritional value.*

INTRODUCTION

The mandarin (*Citrus reticulata* L.) is a perennial green plant species belonging to the Reticulata family and the genus *Citrus*. It has been cultivated in the Mediterranean part of Europe since the mid-19th century and in Croatian coastal region since the beginning of the 20th century (Ferenčić et al., 2016). The mandarin fruits are consumed fresh and can be processed into high-quality food products (Beltran et al., 2008; Purewal et al., 2020).

Potassium plays an important role in regulating water content in plants and adaptation of plants to unfavourable climatic and soil conditions, it is the main electrolyte of living tissues, and strongly influences protoplasm hydration due to its high concentration in protoplasm (Čoga & Slunjski, 2018). Potassium plays an important role in the production of sugars and starch in citrus fruits, so its deficiency negatively affects these processes (Coetzee, 2007). The process of potassium fixation is very fast, while the release process is quite slow due to its strong binding to the clay mineral (Zorb et al., 2014). By increasing the potassium concentration in the soil solution, most of the potassium is converted into an exchangeable and fixed form, and only a small part is leached into deeper soil layers (Čoga & Slunjski, 2018). Potassium is an essential element in human nutrition. In the human body, it plays an important role in cell metabolism by participating in energy transfer, hormone secretion, and regulation of protein synthesis (EFSA, 2016).

Magnesium is a biogenic macroelement that plays an important role in metabolism, it is involved in the movement of carbohydrates and the production of oils and fats, and regulates the absorption of other nutrients (Nikolić et al., 2014). Magnesium ion (Mg^{2+}) in the plant cell is involved in the activation of enzymes that control respiration, photosynthesis, and the synthesis of DNA and RNA molecules

(Lazarević and Poljak, 2019). It affects the movement of carbohydrates from leaves to other parts of the plant and stimulates the uptake of phosphorus (Zekri and Obreza, 2013). Magnesium availability depends significantly on soil pH, ionic interactions with other cations (Mg^{2+} and Ca^{2+}, Mg^{2+} and K^{+}, Mg^{2+} and NH_4^{+}), soil moisture, and plant metabolism (Čoga and Slunjski, 2018). Compared to other cations, such as potassium and calcium, magnesium is more mobile in soil. Its mobility results in significant amounts being leached from the soil (Gransee and Fuhrs, 2013). Magnesium deficiency occurs on acidic soils due to leaching of bases and on alkaline soils due to antagonism with other cations. In addition to the antagonistic relationship, there is also a synergistic relationship between magnesium and phosphorus. Better supply of magnesium to the soil affects better availability of phosphorus and vice versa (Čoga and Slunjski, 2018).

Mandarin has many proven health benefits due to its richness in vitamins and minerals. Mandarin fruit is classified in the group of important nutrients (Ferenčić et al., 2016; Šic Žlabur et al., 2016). Kaleb (2014) states that 100 g of fresh mandarins contain 210 mg K, 33 mg Ca, 11 mg Mg, and 30 mg vitamin C. Czech et al. (2019) conducted a study to determine and compare the mineral composition of the pulp and peel of various citrus fruits purchased in supermarkets. The study found that fresh mandarin pulp in 100 g contains: 133 mg K 1.11 mg Na, 24.9 mg Ca, 18.7 mg P, 10.4 mg Mg, 0.24 mg Fe, 0.23 mg Zn, 0.04 mg Cu and 0.02 mg Mn. The nutrient content of the whole mandarin fruit (in 100 g) was: 133 mg K, 1.19 mg Na, 30.01 mg Ca, 17.9 mg P, 11.1 mg Mg, 0.29 mg Fe, 0.26 mg Zn, 0.04 mg Cu and 0.07 mg Mn. According to Ferenčić et al. (2016), the mineral content in 100 g of fresh pulp of mandarin fruit is: 37.0 mg Ca, 12.0 mg Mg, 166.0 mg K, 20.0 mg P, 2.0 mg Na, 0.2 mg Fe, and 0.1 mg Zn. Baghurst (2003) states that 100 g of fresh mandarin contain 26 mg Ca, 11 mg Mg, 18 mg P, 141 mg K, 1 mg Na, 0.30 mg Fe, 0.10 mg Zn, 0.03 mg Cu, and 0.03 mg Mn.

The aim of this study was to determine the content of the macronutrients potassium and magnesium in mandarin fruit and to compare the results in relation to the place of purchase of each sample.

MATERIALS AND METHODS

Sampling of mandarin fruit was carried out on 28 Oct 2020 in the market of the city of Zagreb to determine the content of potassium and magnesium in mandarin. The collection of average mandarin samples in the city of Zagreb was carried out in 3 different sales channels, on each sale channel in 3 different sales points:

- 3 markets (M): Dolac (M1), Kvatrić (M2) and Savski most (M3)
- 3 retail chains (RC): Konzum (RC1), Diona (RC2) and Spar (RC3)
- 3 organic products stores (OPS): bio & bio (OPS1), Juice Box (OPS2) and Grga Čvarak (OPS3).

Sampling was performed in triplicate.

Insight into the declarations at sale points provided information on the cultivation of mandarins. Since the mandarin samples from retail chains were not labeled as organic products, it is assumed that they are conventionally grown, i.e., mineral fertilizers were used for their cultivation. Verbal interviews with traders at the markets did not reveal any information about the cultivation of mandarins regarding the fertilization. All samples from organic products stores were organically cultivated, as only products from certified organic cultivation are sold in these stores.

Average samples of mandarins were sent after collection to the analytical laboratory of the Department of Plant Nutrition of the Faculty of Agriculture, University of Zagreb, where chemical analysis of mandarin fruit samples was performed. The mandarin fruits were peeled, sliced, and prepared for drying. The samples were dried at 105 °C, after which were ground and homogenised. The samples were then digested with concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$) in a microwave oven. Potassium was then determined by flame photometry and magnesium by atomic absorption spectrometry (AOAC, 2015). Dry matter was determined gravimetrically by drying to constant mass.

Statistical data processing was performed using the analysis of variance model (ANOVA). The SAS System for Win. ver 9.1 program (SAS Institute Inc.) was used, and the Tukey test for

significant thresholds (SAS, 2002-2003) was used to test the results.

RESULTS AND DISCUSSIONS

The average dry matter content in the analysed samples by sales channels (markets, retail chains, and organic product stores) is shown in Table 1. The average dry matter content in the mandarin samples ranged from 7.86 to 8.70%. Statistically, the highest average dry matter value was obtained at markets (8.70%), compared to the dry matter values obtained in retail chains (7.95%) and organic products stores (7.86%).

Table 1. Dry matter (% DM) content determined in mandarin samples collected from, markets, retail chains and organic products stores

Sales channels		% dry matter			
Markets (M)	M1	8.03	bcd	8.70	a
	M2	8.75	ab		
	M3	9.33	ab		
Retail chains (RC)	RC1	8.60	abc	7.95	b
	RC2	7.86	bcd		
	RC3	7.40	d		
Organic products stores (OPS)	OPS1	7.82	cd	7.86	b
	OPS2	7.63	d		
	OPS3	8.13	bcd		

Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

Table 2 shows the determined content of dry matter at different sales points. The determined value of dry matter in mandarins at markets ranged from 8.03 to 9.33%, from 7.40 to 8.60% in retail chains, and from 7.63 to 8.13% in organic products stores. The statistically highest value of dry matter in mandarins was found at Savski most market (9.33%), which was not statistically different from the values from Kvatrić market and Konzum retail chain, and the statistically lowest values were found at Juice Box organic products store (7.63%) and in the Spar retail chain (7.40%).

Table 2 shows the average values of the percentage of potassium in dry matter (% K DM) of mandarins by sales channels. Equal potassium content in dry matter were found in samples from markets (2.04% K DM) and from retail chains (2.06% K DM), while statistically the highest potassium content in dry matter was found in mandarins from organic products stores (2.33% K DM).

The determined potassium content in the dry matter of mandarins according to sales points ranged from 1.89% K DM (Konzum retail chain) to 2.37% K DM (Grga Čvarak organic products store) (Table 2). Statistically, the highest potassium content in dry matter were found in the samples from bio & bio (2.36% K DM) and Grga Čvarak (2.37% K DM) organic products store, and statistically, the lowest contents were found in the samples from Savski most market (1.94% K DM) and Konzum retail chain (1.89% K DM). The highest value among the samples from the markets was found in Kvatrić market (2.15% K DM), and among the samples from the retail chains, the highest value was found in Diona retail chain (2.17% K DM).

Table 2. Potassium content in dry matter of mandarin determined in samples collected from, markets, retail chains and organic products stores

Sales channels		% K in dry matter			
Markets (M)	M1	2.02	d	2.03	b
	M2	2.15	c		
	M3	1.94	de		
Retail chains (RC)	RC1	1.89	e	2.06	b
	RC2	2.17	c		
	RC3	2.12	c		
Organic products stores (OPS)	OPS1	2.36	a	2.33	a
	OPS2	2.26	b		
	OPS3	2.37	a		

Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

The average potassium content in the fresh mass of mandarins, expressed in mg K/100 g of fresh matter (FM) of mandarins, is shown in Table 3. The determined average potassium content in the fresh mass of mandarins ranged from 235 mg K/100 g FM (markets) to 297 mg K/100 g FM (organic products stores) with statistically significant difference.

Table 3 shows the potassium content in the fresh matter of mandarins found in different sales points. The values found ranged from 208 mg K/100 g FM (Savski most market) to 302 mg K/100 g FM (bio& bio organic products store). The statistically highest value of potassium in fresh matter was found in the sample from bio & bio (302 mg K/100 g FM), which was not statistically different from the samples Juice Box, Grga Čvarak and Spar, while statistically the lowest values were found in the samples from Savski most market (208 mg K/100 g FM)

and from Konzum retail chain (222 mg K/100 g FM).

Table 3. Potassium content in fresh matter of mandarin determined in samples collected from, markets, retail chains and organic products stores

Sales channels		mg K/100 g in fresh matter			
Markets (M)	M1	251	bcd	235	b
	M2	246	cd		
	M3	208	d		
Retail chains (RC)	RC1	222	d	263	b
	RC2	278	abc		
	RC3	288	abc		
Organic products stores (OPS)	OPS1	302	abc	297	a
	OPS2	297	abc		
	OPS3	291	abc		

Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

The average magnesium content in the dry matter of mandarins (% Mg DM) according to sales channels is shown in Table 4. The magnesium content in mandarin dry matter ranged from 0.101 (markets) to 0.110% Mg DM (organic products stores).

The determined magnesium content in the dry matter of mandarins according to sales points ranged from 0.097 to 0.121% Mg DM (Table 4). Statistically, the highest magnesium content in dry matter were found among samples from the Diona retail chain (0.121% Mg DM), and bio & bio (0.118% Mg DM) and Juice Box (0.114% Mg DM) organic products store.

Table 4. Magnesium content in dry matter of mandarin determined in samples collected from, markets, retail chains and organic products stores

Sales channels		% Mg in dry matter			
Markets (M)	M1	0.102	bc	0.100	
	M2	0.102	cd		
	M3	0.098	d		
Retail chains (RC)	RC1	0.097	cd	0.109	
	RC2	0.121	a		
	RC3	0.108	ab		
Organic products stores (OPS)	OPS1	0.118	a	0.110	
	OPS2	0.114	a		
	OPS3	0.097	cd		

Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

The highest magnesium content among the samples from the markets were found at Dolac market (0.102% Mg DM) and Savski most market (0.102% Mg DM).

Table 5 shows the average magnesium content in mandarin fresh matter expressed in mg Mg/100 g FM. Almost equal average magnesium content in fresh matter were found in samples from retail chains (13.9 mg Mg/100 g FM) and organic products stores (14.0 mg Mg/100 g FM), which are statistically higher than the magnesium content in samples from markets (11.6 mg Mg/100 g FM).

Table 5. Magnesium content in fresh matter of mandarin determined in samples collected from, markets, retail chains and organic products stores

Sales channels		mg Mg/100 g in fresh matter			
Markets (M)	M1	12.66	bc	11.6	b
	M2	11.76	cd		
	M3	10.47	d		
Retail chains (RC)	RC1	11.38	cd	13.9	a
	RC2	15.55	a		
	RC3	14.64	ab		
Organic products stores (OPS)	OPS1	15.10	a	14.0	a
	OPS2	14.92	a		
	OPS3	12.02	cd		

Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

The magnesium content found in the fresh matter of mandarins at different sales points ranged from 10.5 to 15.5 mg Mg/100 g FM (Table 5). Magnesium values in samples from the market ranged from 10.5 to 12.7 mg Mg/100 g FM, in samples from retail chains from 11.4 to 15.5 mg Mg/100 g FM, and in samples from organic products stores from 12.0 to 15.1 mg Mg/100 g FM. Statistically the highest values of magnesium in fresh matter were found in samples from the Diona retail chain (15.5 mg Mg/100 g FM) and from bio&bio (15.1 mg Mg/100 g FM) and Juice Box (14.9 mg Mg/100 g FM) organic products stores, and the statistically lowest value was found in a sample from Savski most market (10.5 mg Mg/100 g FM).

Kaleb (2014) states that 100 g fresh mandarin contains 210 mg K and 11 mg Mg. Czech et al. (2019) state that fresh mandarin pulp contains 133 mg K/100 g and 10.4 mg Mg/100 g. According to Ferenčić et al. (2016), 100 g of fresh mandarin pulp contains 166 mg K and 12 mg Mg. Baghurst (2003) states that 100 g of

fresh mandarin contains 141 mg K and 11 mg Mg.

The potassium content in the fresh matter of all the samples studied is higher than the values reported in the literature. Statistically, the highest potassium content in fresh matter were determined in samples from organic products stores, compared to the values determined in samples from markets and retail chains. Statistically, higher magnesium values in fresh matter were found in samples from retail chains and stores for organic products than in samples from markets. In comparison with the mentioned literature data, higher magnesium content in fresh matter was found in mandarin samples from Dolac market, retail chains Diona and Spar, and organic products stores bio&bio and Juice Box. The reason for the increased magnesium content in the mandarin samples from Dolac market and from the retail chains Diona and Spar is probably the conventional production method. This production method uses mineral fertilizers, which contain more nutrients per unit mass than organic fertilizers (Petek et al., 2018). However, on average, the highest content of potassium and magnesium in mandarins were found in samples of mandarins grown organically, where the use of mineral fertilizers is not allowed. Organic fertilizers are much lower in nutrient content than mineral fertilizers, but their chemical composition has a variety of positive effects. They have a positive effect on the chemical and physical properties of the soil, but also on the activity of the microbiological phase of the soil (Bogunović et al., 2018). Mostafa & Abdel-Rahman (2015) state that organic and biological fertilizers improve the uptake and utilization of many nutrients by plants, as they increase their availability in the soil by improving soil structure, moisture, pH and many soil biological properties. According to the results of their research, they concluded that the use of natural or biological fertilizers, singly or in combination, as well as the use of these fertilizers in combination with mineral NPK fertilizers improves yield, fruit quality and nutrient status in mandarins.

According to Regulation (EU) No. 1169/2011 of the European Parliament and of the Council on consumer information, the recommended daily intake of potassium for adults is 2000 mg, while the recommended daily intake of magnesium is 375 mg. Consumption of 100 g of mandarins from this research from the market can provide 11.75% of the adult daily requirement of potassium and 3.2% of the daily requirement of magnesium. Consumption of 100 g of mandarins from retail chains can meet 13.15% of the daily requirement of potassium and 3.73% of the daily requirement of magnesium. The consumption of 100 g of mandarins from organic products stores can cover 14.85% of the daily requirement of potassium and 3.73% of the daily requirement of magnesium.

CONCLUSIONS

In this study, the content of dry matter in mandarins, and the content of potassium and magnesium both in the fresh and dry matter of mandarins were determined. The average content of dry matter in mandarin samples from markets was 8.70%, in samples from retail chains 7.95% and in samples from organic products stores 7.86%. The average potassium content in dry matter of mandarins ranged from 2.04 (market) to 2.33% K DM (organic products stores), while the average magnesium content in dry matter ranged from 0.101 (market) to 0.110% Mg DM (organic products stores). The average potassium content in fresh matter ranged from 235 to 297 mg K/100 FM, depending on the sales channels. Statistically significantly, the highest average potassium content in fresh matter were found in samples of mandarins from organic products stores, while the lowest average potassium content were found in samples from markets. Nearly equal average magnesium content in fresh matter were found in samples from retail chains (13.9 mg Mg/100 g FM) and organic products stores (14.0 mg Mg/100 g FM), while statistically the lowest content was found in samples from markets (11.6 mg Mg/100 g FM). As by consumption of 100 g of fresh mandarins from this research 11.75-14.85% of the adult daily requirement of potassium can be provided, it can be concluded that mandarins are good source of the potassium.

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