Scientific Papers. Series B, Horticulture. Vol. LXIV, No. 1, 2020
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

MICROELEMENTS STATUS IN CARROT ROOT ACCORDING TO DIFFERENT SALES AND PRODUCTION CHANNELS

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Abstract

Carrot (Daucus carota L.*) is vegetable of Apiaceae family that has a very significant nutritional and health value in human nutrition. Depending on the production system, the mineral composition of the vegetables also differs. Therefore, the aim of this research was to determine the status of microelements in a carrot's root and to compare samples collected at different sales channels on the Zagreb market (Croatia). Carrot sampling was carried out in triplicate in city of Zagreb in 5 retail chains, 5 markets and 5 organic products stores. After digestion of dry plant material with concentrated* HNO_3 *and* H_2O_2 *microelements (iron, manganese, zinc and copper) were determined by atomic absorption spectrometry. The results showed differences among carrots sampled at different sales channels and with different production system. Average content of microelements in retail chains, markets and organic stores ranged from 15.34-19.61 mg Fe* kg^{-1}*, 7.97-9.07 mg Mn* kg^{-1}*, 14.62-14.87 mg Zn* kg^{-1}*, 4.38-6.11 mg Cu* kg^{-1}*. The data obtained from this study showed a statistically greater status of microelements in carrot samples grown in conventional production than in organic ones.*

Key words*: copper, Daucus carota* L.*, iron, manganese, zinc.*

INTRODUCTION

Carrot (*Daucus carota* L.) belongs to the group of the ten most important types of vegetables along with cabbage, tomatoes, onions and peppers (Kantoci, 2014). It provides the human body with a range of minerals and vitamins that have a beneficial effect on eyesight, skin, immunity, digestive and circulatory systems. The most common elements in carrots are potassium and calcium, followed by iron, phosphorus and iodine (Lešić et al., 2004). In addition to vitamin A, carrots also contain B vitamins, vitamins C, D, E and K, and small amount of folic acid (Parađiković, 2009). Disorders of iron metabolism are one of the most common diseases in humans and cover a wide range of diseases with different clinical manifestations like anemia or neurodegenerative diseases (Đokić and Bilandžić, 2012). The World Health Organization (2001) published an estimate that two billion people are anemic in the world, and that 50% of all anemias are caused by iron deficiency. Copper is associated with the formation of red blood cells, therefore deficiency of copper as well as iron causes anemia (Angelova et al., 2011).

Microelements, although required in small quantities, are essential to the plant, meaning that they are needed throughout the life cycle and they perform a function that cannot be replaced by another element. For the plant, iron is essential for chlorophyll synthesis, nitrite and sulfate reduction, nitrogen assimilation, and electron transport (Grabić, 2015). Due to the poor mobility of iron in the plant, its deficiency is manifested by the yellowing of young leaves. According to Brancadoro et al. (1992) plants where iron deficiency occurs accumulate larger amounts of amino acids, nitrates, and organic anions. Unlike other trace elements in the plant that are mainly components of enzymes, manganese acts as an enzyme activator (Burnell, 1988). Manganese has a great influence on photosynthesis, especially on electron transfer in photo system II, and on nitrogen metabolism (Campbell and Nable, 1988). Manganese deficiency in plants most often occurs in the form of chlorosis on young leaves, while in the case of severe deficiency, brown necrotic spots and fallout of leaves may also occur. Excess of manganese can cause deficiency of Fe, Mo and Mg in plants (Vukadinović and Lončarić, 1998). Zinc in the plant plays a role in enzyme activation and auxin formation, so its deficiency manifests itself in the form of small plant growth (Parađiković, 2009). Copper is essential in plant organism for the synthesis of lignin, which is important for cell wall strenght (Gluhić, 2013), also participates in electron transfer in photosynthesis in the form of plastocyanin, is a cofactor in Cu-Zn superoxide dismutase and polyphenol oxidase, and is important for structural stability of chromosomes (Vidaković-Cifrek et al., 2015). Copper deficiency of the plant is manifested by chlorosis and necrosis of young leaves, fading and twisting of the whole plant. Function of copper in the plant is in the formation of auxin, so its deficiency can affect the small growth of the plant (Parađiković, 2009). In addition, it increases resistance to diseases, drought and low temperatures (Grabić, 2015).

A study from Poland (Bosiacki and Tyksiński, 2009) presents data on the amount of microelements in the dry matter of carrots, showing a comparison of the amount of microelements from the year in which the work was created, and from the 15 years preceding it by Tyksiński et al. (1993). The results of the study show and increase in the amount of iron (35.0 mg Fe kg^{-1}, Tyksiński et al., 1993, 54.4 mg Fe kg^{-1}, Bosiacki and Tyksiński, 2009) and zinc (19.5 mg Zn kg^{-1}, Tyksiński et al., 1993, 22.3 mg Zn kg^{-1}, Bosiacki and Tyksiński, 2009) in carrots, reducing the amount of manganese (10.0 mg Mn kg^{-1}, Tyksiński et al., 1993, 5.2 mg Mn kg^{-1}, Bosiacki and Tyksiński, 2009) by almost half, while the amount of copper (4.2 mg Cu kg^{-1}, Tyksiński et al., 1993, 4.2 mg Cu kg^{-1}, Bosiacki and Tyksiński, 2009) has not changed.

In order to achieve stable and expected yields, increased use of substances containing metals, and the application of essential microelements such as Cu, Zn, Fe and Mn became common agricultural operation on soils less availability of microelements (Grabić, 2015). Conventional production means the development of mechanization and use of mineral fertilizers that have a higher amount of nutrients than organic fertilizers used in organic production.

The term organic farming refers to a specific system of sustainable management in agriculture with the aim of producing healthy food, that is, meeting the relevant social and economic needs while preserving the natural ecosystem and landscape (Pejnović, 2012).

Therefore, the aim of this research was to determine the amount of microelements in the dry and fresh matter of carrots and to compare the samples collected at the Zagreb market at different selling spots.

MATERIALS AND METHODS

Orange root colored carrots were sampled on the different selling spots in of the city of Zagreb.

Sampling was carried out on 04.12.2017 in triplicate in the city of Zagreb in 5 retail chains (RC), 5 markets (M) and 5 organic products stores (OPS). Informations on the method of cultivation were collected orally through personal communication with the salesperson or by the insight into the declaration. The assumption is that all carrot samples from retail chains were grown in the conventional way because they were not specifically labeled as organic products. According to the sellers, carrots from Dubrava and Kvatrić market were fertilized with mineral manure (conventional production method), while carrots from Britanski trg and Dolac markets were fertilized with manure and from Branimir market with sheep manure (organic production method). All samples of carrots from organic stores were grown in an organic way because only organic products are sold in these stores.

The carrot samples were dried at 105 ° C, after which they were grounded and homogenized. Zinc, manganese, iron, and copper, after digestion with concentrated HNO_3 and $HClO_4$ in a microwave oven, were determined by atomic absorption spectrometry-AAS (AOAC, 2015). The dry matter was determined gravimetrically by drying to a constant mass. The samples, collected in triplicate, were analyzed individually and the results showed average values. Statistical data processing followed the variance analysis model (ANOVA). The SAS System for Win program was used. ver 9.1 (SAS Institute Inc.), and Tukey's significance threshold test (SAS, 2002-2003) was used to test the results.

RESULTS AND DISCUSSIONS

The average value of dry matter in carrot samples ranges from 10.15 to 11.18% (Figure 1). According to Parađiković (2009) amount of dry matter in carrots is in the range of 12-17%, while Kantoci (2014) states 14.5%. The amount of dry matter determined in this study is less than the amount reported in the literature.

The average amount of microelements in the dry matter of carrots is shown in Figure 2. Statistically, highest amount was found for iron (19.61 mg Fe kg^{-1}) at retail chains (RC). The levels of manganese and zinc do not differ significantly from point of sale, while the amount of copper differs and is the largest in organic products stores (OPS) (6.11 mg Cu kg^{-1}). Figure 3 shows the average quantities of microelements in fresh carrot matter by point of sale. Significantly different values were found for iron and copper, while manganese and zinc quantities did not differ significantly between retail chains, markets and organic products stores. The highest amount of iron was found in retail chains (0.19 mg Fe 100 g^{-1} of fresh matter), while the highest amount of copper was found in organic products stores (0.06 mg Cu 100 g^{-1} of fresh matter).

Of all the examined carrot samples, statistically highest amount of iron in dry matter was determined in RC5 and its amount is 24.67 mg Fe kg^{-1} of dry matter and 0.23 mg Fe 100 g^{-1} of fresh matter (Figures 4 and 5). Other retail chains also have high levels of iron (16.26 - 20.49 mg Fe kg^{-1} of dry matter, 0.15-0.21 mg Fe 100 g^{-1} of fresh matter), while markets and organic product stores range from 12.23-18.85 mg Fe kg^{-1} of dry matter and 0.1-0.18 mg Fe 100 g^{-1}, with the exception of the M5 market, which has a higher amount of iron (20.66 mg Fe kg^{-1} of dry matter, 0.2 mg of Fe 100 g^{-1} of fresh matter). Carrots from retail chains generally have higher amount of microelements than markets and organic product stores. The literature reports amount of iron 0.3 mg Fe 100 g^{-1} in fresh matter (USDA, 2018), and in the range of 0.5-2.68 mg Fe 100 g^{-1} in fresh matter (Lešić et al., 2004). In comparison with the results of this study, the amount of iron in dry matter of carrots is less than the amount in the 1993 study (Tyksiński et al.) and 2009 study (Bosiacki and Tyksiński). Possible reason for the low supply of iron in carrots from markets and organic product stores is the ecological way of production and fertilization. A study from Poland conducted between 2011 and 2012 dealt with the controlled cultivation of carrots in a conventional and ecological way. In this study, the amount of iron in carrots ranged from 41.10-61.13 mg Fe kg^{-1} of dry matter in both cultivation methods, and the highest amount of iron was determined in carrots grown without the use of protection against pathogens (Wierzboska et al., 2016). Analysis of carrots fresh matter (mg 100 g^{-1}) from Hisar market in India, found higher amounts of iron (7.7 mg Fe 100 g^{-1}) (Singh et al., 2001) than carrot analysis in Zagreb (0.11-0.2 mg Fe 100 g^{-1}). Accordingly, neither of the maximum amount of iron found in carrots (RC5) is higher than the literature cited. Manganese is a trace element in carrots, so its values do not exceed 0.1 mg Mn 100 g^{-1} in fresh matter, or 11.46 mg Mn kg^{-1} in dry matter (Figures 6 and 7). Statistically lowest value of manganese was determined in carrot from market M1 (0.05 mg Mn 100 g^{-1} of fresh matter, 6.51 mg Mn kg^{-1} of dry matter), and statistically highest in carrot from RC1 (0.1 mg Mn 100 g^{-1} of fresh matter, 11.46 mg Mn kg^{-1} of dry matter). The following maximum values were determined in carrots from the organic product stores OPS3 (0.9 mg Mn 100 g^{-1} fresh matter, 9.99 mg Mn kg^{-1} dry matter) and OPS5 (0.9 mg Mn 100 g^{-1}, 9.57 mg Mn kg^{-1} of dry matter). None of the determined values from this study exceeds the values reported in the literature: 0.14 mg Mn 100 g^{-1} in fresh matter (Parađiković, 2009) and 0.143 mg Mn 100 g^{-1} in fresh matter (USDA, 2018). Also, the amount of manganese in dry matter determined in this study is less than the amount determined in the 1993 study (Tyksiński et al.), but higher than the 2009 study (Bosiacki and Tyksiński). Compared to a study conducted in controlled cultivation in Poland where the lowest amount of manganese (8.70 mg Mn kg^{-1} dry matter) was recorded in carrots from ecological cultivation (Wierzboska et al., 2016), the amount of manganese in carrot samples from organic product stores (OPS) slightly higher in this study (7.63-9.99 mg Mn kg^{-1} dry matter). Carrot samples collected from a market in India show a significantly higher amount of manganese in fresh carrot matter (1.8 mg Mn 100 g^{-1}) (Singh et al., 2001) than samples collected from Zagreb markets (0.05-0.08 mg Mn 100 g^{-1}).

Zinc amount results show a statistically highest value in M5 carrots of 0.21 mg Zn 100 g^{-1} in fresh matter and 21.9 mg Zn kg^{-1} in dry matter, while the next highest value is from RC5 (0.18 mg Zn 100 g^{-1} of fresh matter, 19.47 mg Zn kg^{-1} of dry matter) (Figures 8 and 9). The lowest value was determined in the sample of carrots on M2 and is 0.09 mg Zn 100 g^{-1} of fresh matter and 10.47 mg Zn kg^{-1} of dry matter. Values from organic products stores (OPS) range from 0.09-0.16 mg Zn 100 g^{-1} of fresh matter, or 11.7-17.29 mg Zn kg^{-1} of dry matter. In the case of zinc, there is no significant deviation from the literature data. Parađiković (2009) states the amount of zinc in carrots of 0.2 mg Zn 100 g^{-1} in fresh matter, and USDA (2018) 0.24 mg Zn 100 g^{-1} in fresh matter. As for the 1993 (Tyksiński et al.) and 2009 (Bosiacki and Tyksiński) studies, the amount of zinc in dry matter in this study is less than the amount of zinc in the studies mentioned. Samples were collected in a 2006 study (Radwan and Salama) to determine the amount of heavy metals (Pb, Cd, Cu, and Zn) in fruits and vegetables in Egyptian markets. The amount of zinc found in carrot dry matter is 6.02-11.1 mg Zn kg^{-1} (Radwan and Salama, 2006). Comparing zinc values in carrots from markets in Zagreb and those in Egypt, a possible reason for the low supply, in both cases, is the way of production and fertilization. The amount of zinc in the dry matter in the Polish study was between 8.22-13.0 mg Zn kg^{-1} (Wierzboska et al., 2016). In that study, conventional and organic farming were compared, where carrots grown with conventional way had 25% more zinc than carrots grown with organic way (Wierzboska et al., 2016). Also in this study the amount of zinc is higher in carrots from retail chains (conventional production) than in carrots from organic product stores.

Copper, like manganese, is a trace element in the carrot. The amount of 0.03 mg Cu 100 g^{-1} in fresh matter is the lowest found in this study, repeated at multiple outlets, and most commonly in markets. Statistically highest values of copper were found in carrots from the OPS4 (0.06 mg Cu 100 g^{-1} fresh matter, 6.69 mg Cu kg^{-1} dry matter) (Figures 10 and 11). On markets, the highest amount of copper was determined in the carrot from the M5 market and it is 0.05 mg Cu 100 g^{-1} in fresh matter and 5.97 mg Cu kg^{-1} dry matter. Regarding retail chains, the highest determined quantity of copper in fresh matter is in carrots from retail chain RC3 (0.05 mg Cu 100 g^{-1} of fresh substance), while for the quantity in dry matter it is highest recorded in carrots from shopping center T1 (5 mg Cu kg^{-1} dry matter). The copper values determined in this study do not deviate from the values reported in the literature, namely 0.05 mg Cu 100 g^{-1} in fresh matter (Parađiković, 2009) and 0.045 mg Cu 100 g^{-1} in fresh matter (USDA, 2018). The amount of copper in the dry matter of carrots in the studies in 1993 (Tyksiński et al.) and 2009 (Bosiacki and Tyksiński) do not differ significantly from the values determined in this study. In a 2006 study (Radwan and Salama), where samples were collected from different markets in Alexandria, Egypt, copper values found in the dry matter of carrots (0.99-2.10 mg Cu kg^{-1}) are significantly smaller than the quantities determined from the markets in this study (3.59-5.97 mg Cu kg^{-1}), while the results of the analysis of copper in fresh carrot matter in the market in India (0.8 mg Cu 100 g^{-1}) (Singh et al., 2001) showed higher amounts of copper than in carrots from Zagreb markets (0.03-0.05 mg Cu 100 g^{-1}). A study from Poland (Wierzboska et al., 2016) comparing conventional and organic carrots growing found the amount of copper in the dry matter of carrots from 3.05-4.74 mg Cu kg^{-1}, also showing that carrots grown ecologically have 10.3% more copper than carrots grown by conventional cultivation. In comparison with the results of this study, the amount of copper in carrots from retail chains (conventional cultivation) (3.5-5 mg Cu kg^{-1}) is not significantly different from the amount of copper in carrots grown in conventional cultivation from Poland (3.05-4.35 mg Cu kg^{-1}) (Wierzboska et al., 2016), while the determined quantities of copper in the dry matter in organic products stores (ecological cultivation) (5-6.69

mg Cu kg^{-1}) from this study are slightly higher than the amount of copper in the dry matter of carrots grown ecologically from research in

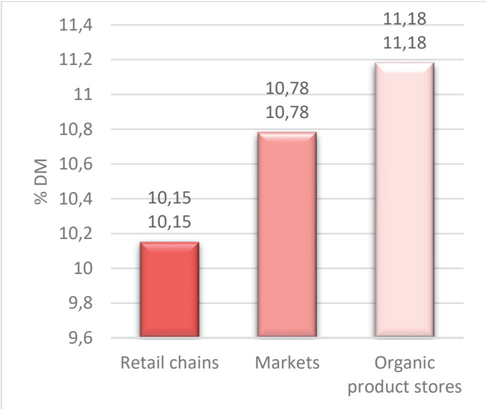

Figure 1. Amount of dry matter (% DM) determined in carrot samples collected from retail chains, markets and organic product stores
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

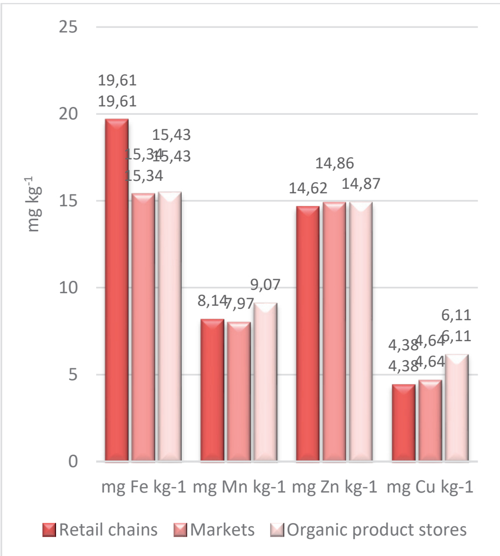

Figure 2. Amount of microelements determined in carrots dry matter (mg kg^{-1}) at different selling points
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

Poland (3.77-4.74 mg Cu kg^{-1}) (Wierzboska et al., 2016).

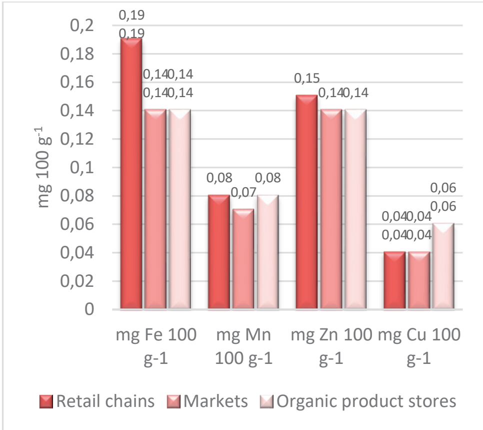

Figure 3. Amount of microelements determined in carrots fresh matter (mg 100 g^{-1}) at different selling points
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

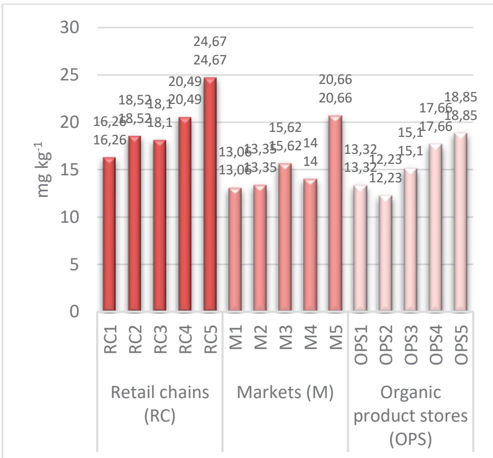

Figure 4. Amount of iron determined in the dry matter of the carrot (mg kg^{-1})
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

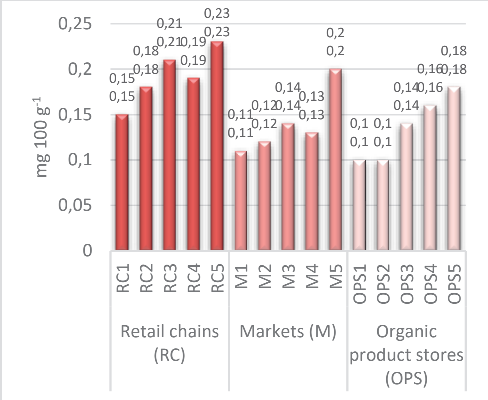

Figure 5. Amount of iron determined in the fresh matter of the carrot (mg 100 g^{-1})
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

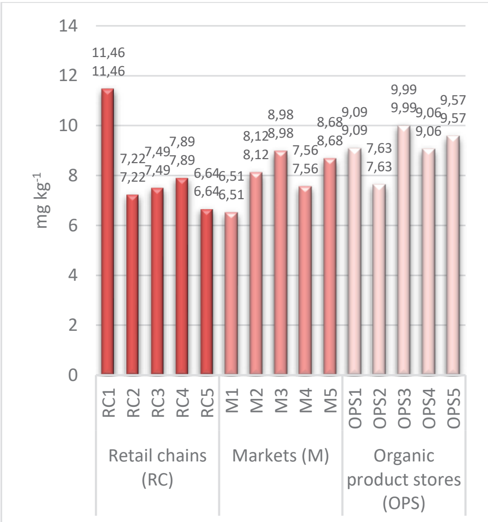

Figure 6. Amount of manganese determined in the dry matter of the carrot (mg kg^{-1})
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

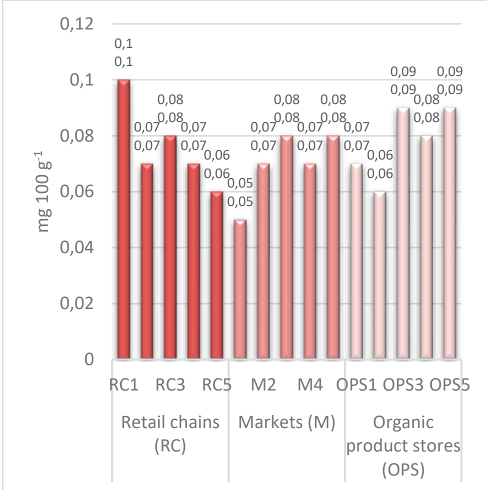

Figure 7. Amount of manganese determined in the fresh matter of the carrot (mg 100 g^{-1})
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

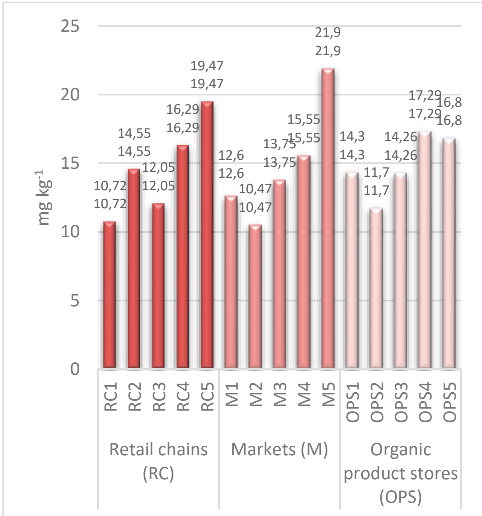

Figure 8. Amount of zinc determined in the dry matter of the carrot (mg kg^{-1})
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

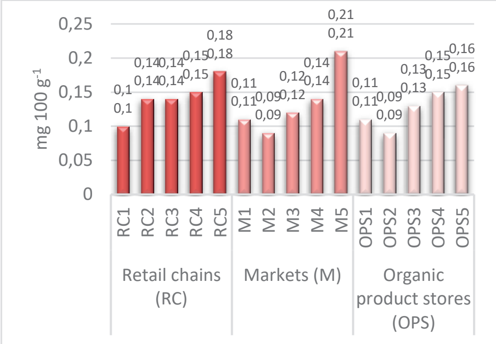

Figure 9. Amount of zinc determined in the fresh matter of the carrot (mg 100 g^{-1})
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

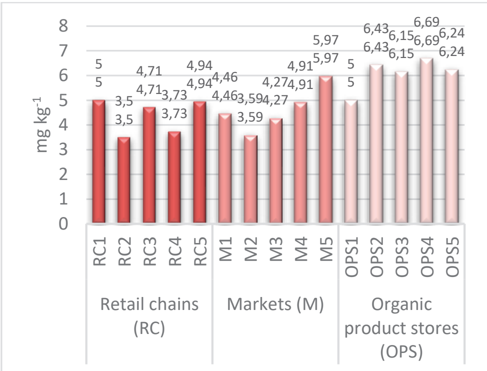

Figure 10. Amount of copper determined in the dry matter of the carrot (mg kg^{-1})
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

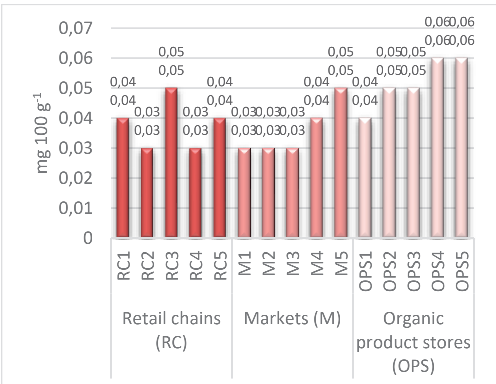

Figure 11. Amount of copper determined in the fresh matter of the carrot (mg 100 g^{-1})
Different letters represent significantly different values according to Tukey's test, p≤0.05. The non-letter values are not significantly different

CONCLUSIONS

In this study, the quantities of microelements were determined in the orange colored carrot roots, sampled at different outlets in the City of Zagreb.
The amounts of microelements expressed in mg kg^{-1} of the dry matter of the orange colored carrot root were: 12.23-24.67 Fe, 6.51-11.46 Mn, 10.47-21.9 Zn and 3.5-6.69 Cu.
The amounts of microelements expressed in mg 100 g^{-1} of the fresh matter of orange colored carrot root were: 0.1-0.23 Fe, 0.05-0.1 Mn, 0.09-0.21 Zn and 0.03-0.06 Cu.
Differences were identified with consideration to the different selling points. Namely, carrots from retail chains were grown in a conventional way, while most carrots were grown ecologically from markets and organic products stores. Generally, the highest values of microelements are found in carrots from retail chains. Considering that the production conditions are not known (soil type, agricultural practices, fertilization), it can be assumed that the conventional way of producing and using mineral fertilizers containing more nutrients than organic fertilizers is probably reason for higher quanities of microelement in carrots from conventional cultivation.

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