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CONTENT OF POTASSIUM AND IRON IN TOMATO PRODUCTS

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Abstract

Tomato (Lycopersicon esculentum Mill.) is an annual vegetable crop whose fruits can be consumed fresh or processed. The aim of this thesis was to determine the amount of potassium and iron in samples of tomato products from different production batches. Sampling was carried out on six tomato products (ketchup, double concentrate, canned tomatoes, pureed tomatoes and chopped tomatoes from conventional and organic farming). Potassium was determined by flame photometry while iron was determined by AAS (Atomic Absorption Spectroscopy). The determined content of potassium in dry matter ranged from 1.36 to 5.37 % K DW. Potassium levels in fresh matter ranged from 185.19 to 1224, 46 mg K/100 g fresh weight. The determined content of iron in dry matter ranged from 24.30 to 155.07 mg Fe/kg DW. Iron levels in fresh matter ranged from 0.42 to 1.23 mg Fe/100 g fresh weight. The highest potassium content in dry and fresh matter was determined in tomato concentrate. The highest iron content in dry matter was determined in chopped tomatoes, while the highest iron content in fresh matter was determined in tomato concentrate.

Key words: *Lycopersicon esculentum Mill., minerals, microelement, macroelement, processing.*

INTRODUCTION

The tomato (*Lycopersicon esculentum* Mill.) is a herbaceous plant and one of the most famous plants in the Solanaceae family. It originates from South America and was cultivated in Europe in the 16th century (Borošić, 2016; Lešić et al., 2016; Matotan, 2004).

The tomato is a vegetable that is cultivated worldwide due to its high yields, and every year 189,133,955 tons of fruit are harvested from around 5,167,388 hectares of cultivated land with an average yield of 36.6 t/ha (FAO, 2021). The world's largest producers of tomatoes are China and the USA (Lešić et al., 2016).

In developing countries, annual tomato consumption is less than 10 kg per inhabitant, while in developed countries it is three times as high (Lešić et al., 2016).

Tomatoes are most often consumed fresh, but due to their diverse nutritional properties, they are also highly valued in processed products. Tomatoes intended for processing are mostly grown in the open field and their cultivation is based on the use of mechanization. There are numerous products on the market obtained from the processing of tomatoes, such as concentrates, peels, ketchup, passata, chopped tomatoes, juice and dried tomatoes. The processing of tomatoes meets consumer demand for products with a longer shelf life (Thakur et al., 1996; Matotan, 1994).

Ripe tomato fruits can contain different amounts of dry matter: 3-6% (Parađiković, 2009), 5-7% (Lešić et al., 2006), 4-6% (Matotan, 2004), therefore their energy value is low and amounts to only 20-25 kcal per 100 g of fruit (Matotan, 2008).

Tomatoes are also an important source of vitamins and minerals for the human body. Of the minerals, potassium (92-376 mg/100 g fresh matter), phosphorus (7-53 mg/100 g fresh matter), magnesium (13-20 mg/100 g fresh matter), calcium (10-21 mg/100 g fresh matter) and iron (0.4-1.2 mg/100 g fresh matter) are the most abundant (Lešić et al., 2016).

Clay soils with a heavy structure and texture contain the most potassium, in contrast to sandy soils with a lighter mechanical composition, where its amounts are very low. Under humid climatic conditions, there are significant losses of potassium through leaching (Čoga and Slunjski, 2018; Vukadinović, 2011). The decomposition of primary minerals leads to the release of potassium, which is mostly bound to the adsorption complex of the soil (Vukadinović, 2011).

There are two main physiological roles of potassium: the activation of enzymes and the regulation of the permeability of living membranes. Plants do not incorporate it into organic compounds, but it acts as an activator for about 60 enzymes (by changing pH, ion concentration, temperature and the presence or absence of inhibitors). It also plays a very important role in the synthesis of protein, sugar, cellulose and fat (Vukadinović, 2011).

Potassium is required for the formation of adenosine triphosphate (ATP), influences the physiological activity of ribosomes and has a positive effect on the process of photosynthesis. It also improves the quality of the yield and influences the resistance of plants to diseases and drought (Butorac, 1999).

Potassium is one of the most important elements in the human body and is absorbed through plant food. It is contained in large quantities in tomatoes and has a positive effect on the work of the heart and blood vessels and lowers blood pressure and cholesterol levels (Vukadinović, 2011; Butorac, 1999).

Its deficiency in humans is usually the result of excessive secretion during sporting activities or heavy physical work. It also plays an important role in muscle function, and its deficiency can result in muscle cramps, weakening of the heart and weak intestinal function (Vukadinović, 2011).

The daily requirement of an adult for potassium is around 3.5 g, while safe amounts are up to 5 g per day (Vukadinović, 2011).

Iron is mainly present in the ferrous form (Fe2+) in acidic soils and under reducing conditions, while the ferric form (Fe3+) is more common in oxygen-rich soils with a higher pH value. The ferrous form of iron is more easily accessible to plants than the ferric form, which is usually insoluble. In the adsorption complex of the soil, the iron is bound in the exchangeable form as Fe2+, while the Fe3+ form is very tightly bound (Čoga et al., 2010; Butorac, 1999).

Iron plays an important role in the work of various enzymes: peroxidase, catalase and cytochrome. Iron deficiency affects the reduction in the number of photosynthetic units (PS I), the reduction in the number of cytochrome molecules and the decrease in the concentration of carotenoids (Vukadinović, 2011; Butorac, 1999).

Its mobility is low, as 80-90 % of the iron in plants is firmly bound. The uptake of iron can lead to competition with other elements, such as Cu > Ni > Co > Zn > Cr > Mn (Kobayashi et al., 2019).

Iron plays an important role in the human body and is an essential component of hemoglobin. In plants, it regulates plant growth and metabolism and is involved in the process of photosynthesis, which influences plant productivity (Vukadinović, 2011; Butorac, 1999).

Iron deficiency in the human body is a common phenomenon. It occurs most frequently in athletes, women during the monthly cycle, pregnant women and children due to inadequate consumption of fruits and vegetables.

The daily iron requirement of an adult man is about 10-15 mg, for adult women and developping children about 20 mg and for pregnant women about 60 mg (Vukadinović, 2011).

The aim of this work is to determine the amount of potassium and iron in samples of tomato products from different production batches.

MATERIALS AND METHODS

For the purpose of this study, 6 different tomato products were sampled: (i) ketchup, (ii) peels, (iii) chopped tomatoes, (iv) tomato concentrate, (v) pureed tomatoes and (vi) chopped organic tomatoes. Sampling was carried out three times (in triplicate) between December 16, 2022 and February 16, 2023, taking care to sample the same product from the same producer from a different production series (lots) each time (Table 1).

Samples of tomato products were submitted to the Analytical Laboratory of the Department for Plant Nutrition, Faculty of Agriculture, University of Zagreb. The samples were homogenized, prepared for drying and dried at 105°C. After drying, the samples were ground. The dry matter was determined by the gravimetric method by drying to a constant mass. Dry and ground samples of tomato products were digested with concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$) in a microwave oven, after which potassium was determined by flame photometry and iron by atomic absorption spectrometer.

Table 1. Datum uzorkovanja i prikaz šarži uzoraka proizvoda od rajčice

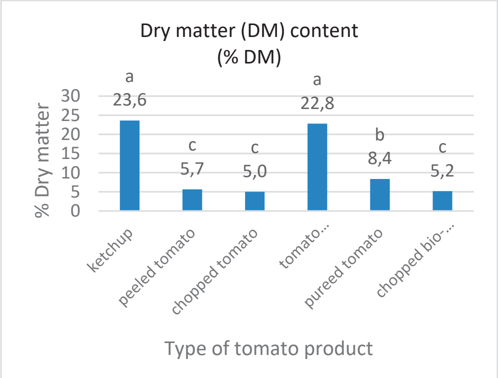
TYPE OF PRODUCTS	LOT NUMBER
SAMPLING 1, Date 16/12/2022	
ketchup	12.04.2024. 18:37
peeled tomato	VTL1 U226 BBE:31/12/2024
chopped tomato	VTL1 E211 31.12.2023.
tomato concentrate	19.06.2024. 19:56
pureed tomato	04.07.2025. L21:38 42078
chopped bio-tomato	L1521 31/05/2023 13:08
SAMPLING 2, Date 16/01/2023	
ketchup	03.07.2024. 18:23
peeled tomato	VTL1 F231 BBE:31/12/2025
chopped tomato	VTL1 U239 BBE:31/12/2024
tomato concentrate	17.07.2024. 16:38
pureed tomato	18.10.2025. L11:31 15514
chopped bio-tomato	VTL1 U210 BBE:30/06/2024
SAMOLING 3, Date 16/02/2023	
ketchup	08.11.2024. 20:09
peeled tomato	VTL1 E218 31/12/2023
chopped tomato	VTL1 E208 BBE:31/12/2025
tomato concentrate	15.12.2024.
pureed tomato	14.11.2025. L21:02 15068
chopped bio-tomato	VTL1 U210 PLP BBE:31/12/2024

Statistical data processing was carried out using the analysis of variance (ANOVA) model. The program used was SAS System for Win, Version 9.1 (SAS Institute Inc.), and the Tukey test of significant thresholds was used to test the results (SAS, 2002-2003).

RESULTS AND DISCUSSIONS

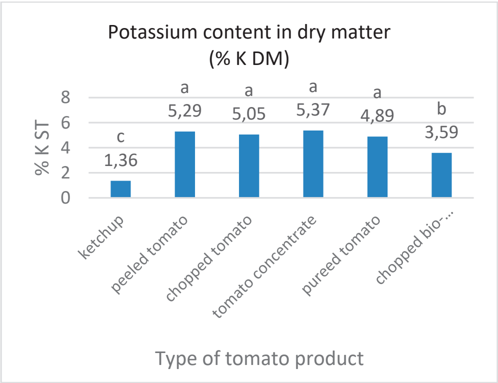
Figure 1 shows the dry matter content of tomato products (% ST). The dry matter in the tested products was determined in a range from 5.02 to 23.62% ST. The statistically significant highest percentages of dry matter were found in ketchup (23.62% ST) and tomato concentrate (22.80% ST). The statistically lowest percentages of dry matter were found in pellets, chopped tomatoes and organically chopped tomatoes.

Figure 2 shows the potassium content in tomato products in relation to dry matter (% K ST). The potassium content, based on dry matter, was determined to be in the range of 1.36 to 5.37% K ST in the products tested. The statistically significant highest proportion of potassium in the dry matter was found in tomato concentrate, pellets, chopped and pureed tomatoes. The statistically lowest proportion of potassium in the dry matter was found in ketchup.



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

Figure 1. Dry matter content (% DM) of investigated tomato products

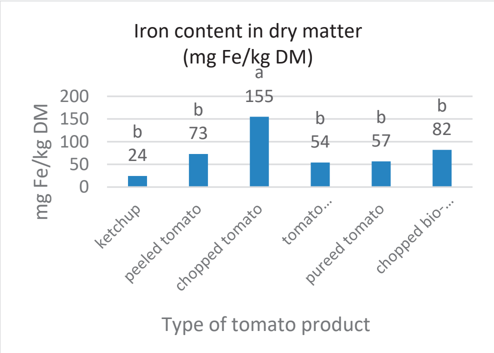


Different letters represent significantly different values according to Tukey's test, $p \leq 0.05$. The non-letter values are not significantly different.

Figure 2. Potassium content in dry matter (% K DM) of investigated tomato products

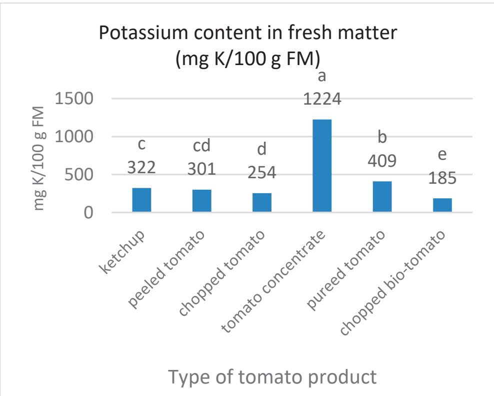
Figure 3 shows the amount of potassium in fresh mass in tomato products (mg K/100 g fresh mass). The potassium content in the fresh matter of the tested products was determined in a range from 185.19 to 1224.46 mg K/100 g fresh matter. The statistically significant highest potassium content in fresh matter was found in tomato concentrate. The statistically lowest potassium content in fresh matter was found in organically crushed tomatoes.

Figure 4 shows the iron content of tomato products in relation to the dry matter (mg Fe/kg ST). The iron content, based on dry matter, was between 24.30 and 155.07 mg Fe/kg ST in the products tested. The statistically significant highest iron content was found in chopped tomatoes. The statistically lowest iron contents in the dry matter were found in organically chopped tomatoes, pellets, tomato concentrate and pureed tomatoes.



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

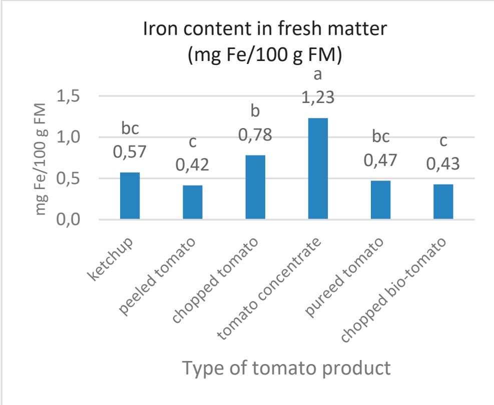
Figure 3. Iron content in dry matter (mg Fe/kg DM) of investigated tomato products



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

Figure 4. Potassium content in fresh matter (mg K/100 g FM) of investigated tomato products

Figure 5 shows the iron content in fresh matter in tomato products (mg Fe/100 g fresh matter). The iron content of the products tested was between 0.42 and 1.23 mg Fe/100 g fresh substance. The statistically significant highest amount of iron in fresh matter was found in tomato concentrate. The statistically lowest iron contents in fresh matter were found in ketchup, seals, pureed tomatoes, chopped and organically chopped tomatoes.



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

Figure 5. Iron content in fresh matter (mg Fe/100 g FM) of investigated tomato products

Tomatoes can be eaten fresh or processed into various products due to their perishable nature: Peels, tomato juice, concentrated tomato juice, tomato puree or pureed tomatoes (Bannwart et al., 2008).

Petek et al. (2021) state that the nutritional value of tomatoes and tomato products can be improved by fertilization.

Budak et al. (2016) state that there are highly significant differences in the composition of fresh tomatoes and tomato-based products in terms of sodium, phosphorus, calcium, copper, zinc and molybdenum, while no significant differences were found for magnesium, potassium, iron and manganese. Similarly, the content of microelements in food depends on soil properties, such as organic matter content, pH and clay mineralogy.

Budak et al. (2016) state that tomato juice and chopped tomatoes are most similar to fresh tomatoes in terms of mineral content and are the best choice for consumption in the human diet compared to other tomato products.

Porretta et al. (1993) state that despite the large market for tomato products in many countries, chopped tomatoes tend to be neglected in the technical and scientific literature. Lovrić and Piližota (1994) state that double tomato concentrate should generally contain 28-38% ST, while the dry matter in ketchup should be 25-35% ST. In the analyzed samples of tomato concentrate (22.80% ST) and ketchup (23.62% ST), lower values were found than those given by Lovrić and Piližota (1994). The lowest proportion of dry matter in the analyzed samples was found in chopped tomatoes (5.02%). In the production of ketchup, a concentrate is made according to the usual procedure or by diluting a concentrate containing larger amounts of dry matter, to which various spices are then added. In the production of chopped tomatoes, on the other hand, the end product consists of finely chopped tomatoes with a juice content of at least 30%. In most cases, the tomatoes are peeled, the stems removed and the core cleaned, which may be the reason for the lower dry matter content (Lovrić and Piližota, 1994).

The percentage of dry matter in the tomato varies depending on the variety, soil properties and especially the amount of irrigation and rainfall during the growth and harvest phase (Barringer, 2004). In this study, the dry matter in tomato products was determined in a range from 5.02 to 23.62% ST. The highest proportion of dry matter was found in ketchup, the lowest in chopped tomatoes.

In the literature, data on the dry matter content can only be found for three tomato products: peel, concentrate and ketchup. Peels contain an average of 5.64% dry matter (Lončarić et al., 2015, after Petek et al., 2021). Petek et al. (2021) state that 26.75% ST was found in tomato concentrate and 30.45% ST in ketchup. The following amount of dry matter was determined in the tomato products tested Peels (5.67% ST), concentrate (22.80% ST), ketchup (23.62% ST). Compared to the data cited by Lončarić (2015), a higher proportion of dry matter was found in the pellets examined here. On the other hand, the data reported by Petek et al. (2021) for the proportion of dry matter in concentrate and ketchup are higher than the data obtained in this study.

Maher (1976) states that 4.5% K ST was found in tomato fruits. The potassium content of the products examined was determined to range from 1.36 to 5.37% K ST. The highest potassium content in the dry matter in this study was found in tomato concentrate (5.37% K ST). The determined potassium content in the dry matter of the concentrate is higher than the values given by Maher (1976) for tomato fruits. It is assumed that the higher amounts of potassium in tomato concentrate compared to other processed products are due to the high proportion of dry matter in the end product. Concentrates are categorized according to the proportion of dry matter: rare juice (no prescribed proportion of dry matter), single concentrate (14-16 %), double concentrate (28-30 %), triple concentrate (36 %) and sixfold concentrate (55%) (Lovrić and Piližota, 1994). The tomato concentrate investigated in this study belongs to the double concentrate category. As a rule, it should have an ST content of 28 to 30%, and a dry matter content of 22.80% ST was determined.

The potassium content in the fresh mass of the tested products was determined in a range of 185.19 to 1224.46 mg K/100 g fresh mass. The highest potassium content in fresh mass was found in tomato concentrate, the lowest in organically chopped tomatoes. The amount of potassium in fresh tomatoes varies between 244 (Sainju et al., 2003), 279 (Breecher, 1998) and 376 mg K/100 g fresh mass (Lešić et al., 2016). In the tomato concentrate, a higher potassium content was determined in the fresh substance than in the data reported by various authors for fresh tomatoes.

Ayari et al. (2015) state that pureed tomatoes can contain 249-332 mg K/100 g fresh mass, tomato concentrate 890-1110 mg K/100 g fresh mass and ketchup 243-334 mg K/100 g fresh mass. In this study, it was found that pureed tomatoes contain 408.61 mg K/100 g fresh matter, tomato concentrate 1224.46 mg K/100 g fresh matter and ketchup 321 mg K/100 g fresh matter. The determined data on potassium content in fresh matter in pureed tomato and concentrate are higher than the data reported by Ayari et al. (2015), while the data on potassium content in ketchup do not differ.

Vukadinović (2011) states that potassium plays an important role in human nutrition. It is important for the work of muscles, and as a result of its deficiency, muscle cramps, weakening of the heart and weak intestinal activity can occur. An adult's daily requirement for potassium is around 3,500 mg, while safe levels are up to 5,000 mg per day. According to the results of this study, tomato concentrate contains the most potassium (1224.46 mg K/100 g fresh mass). About 35% of the daily potassium requirement can be met by consuming 100 g of tomato concentrate. It was found that pureed tomatoes contain the most potassium in the fresh mass after the concentrate (408.61 mg K/100 g fresh mass). Only 12% of the daily potassium requirement can be met by consuming 100 g of pureed tomatoes. Lovrić and Piližota (1994) state that tomato products are mostly used as an addition to certain dishes and are not consumed as a meal in their own right. Considering the fact that the consumption of tomato products analyzed in this study can cover a maximum of 35% of the daily potassium requirement, it is necessary to include other potassium-rich products in the daily meal, for example bananas, spinach, milk and dairy products, etc.

The iron content, based on dry matter, was determined to be in the range of 24.30 to 155.07 mg Fe/g ST in the products tested. The highest iron content, based on dry matter, was found in chopped tomatoes, the lowest in ketchup. Chopped tomatoes and organically grown chopped tomatoes are produced using a similar process to peelings, with the difference in the production process being that the tomatoes are cut into small pieces. The process is based on steaming the raw material, which, unlike other tomato products, does not require prolonged heat treatment (Lovrić and Piližota, 1994).

The iron content in the fresh mass of the tested products was between 0.42 and 1.23 mg Fe/100 g fresh mass. The highest iron content in the fresh substance was found in the tomato concentrate, the lowest in the pellets. It is assumed that the higher iron content in the concentrate compared to other processed products is a result of the high proportion of dry matter in the end product.

The potassium content in fresh tomatoes varies between 244 (Sainju et al., 2003), 279 (Breecher, 1998) and 376 mg K/100 g fresh mass (Lešić et al., 2016).

The iron content in fresh tomatoes varies between 0.33 (Matotan, 1994), 0.5 (Sainju et al., 2003) and 1.2 mg Fe/100 g fresh mass (Lešić et al., 2016). The values determined in this study for the iron content in fresh matter agree with the values of other authors. Barringer (2004) states that 100 g of tomato juice contains at least 1.0 mg of iron.

Kabore et al. (2022) state that iron and iodine are very important minerals for the normal functioning of human metabolism. Vukadinović (2011) states that iron in the human body is an integral part of red blood cells and hemoglobin, whose task is to transport oxygen from the lungs to the tissues. Iron deficiency leads to migraines, deconcentration, poor mobility and poor blood circulation in the skin. The daily iron requirement for an adult male is around 10-15 mg, for adult women and developing children around 20 mg and for pregnant women around 60 mg. The toxic effect occurs with an intake of more than 5 g of iron per day. According to the results of this study, the highest iron content in fresh material was found in tomato concentrate (1.23 mg iron/100 g fresh material). Only about 6% of the daily potassium requirement can be met by consuming 100 g of tomato concentrate. Since the consumption of the tomato products examined in this study can cover at most 6% of the daily iron requirement, it is necessary to include other iron-rich foods such as beans, red meat, walnuts, millet and lentils in the daily meal.

CONCLUSIONS

An analysis of tomato products showed that tomato concentrate contains the highest levels of potassium and iron in fresh mass. It is assumed that the highest content of potassium and iron in the fresh substance was determined due to the high proportion of dry matter (22.80% ST) in the tomato concentrate. A high proportion of dry matter (23.62% ST) was also found in the ketchup. The determined amount of potassium and iron in the fresh substance of ketchup is lower compared to the tomato concentrate. The production of ketchup is based on single, double or triple concentrate to which a considerable amount of sugar and various spices are added, resulting in a lower potassium and iron content in the fresh substance.

The daily requirement of potassium and iron in the human diet cannot be met by consuming tomato concentrate and other tomato products. It was found that 35% of the daily requirement of potassium and only 6% of the daily requirement of iron can be met by consuming tomato concentrate.

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