J. Elementol. 2009, 14(1): 13-22

COPPER, ZINC, IRON AND MANGANESE CONTENT IN EDIBLE PARTS OF SOME FRESH VEGETABLES SOLD ON MARKETS IN POZNAŃ

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Abstract

Copper, zinc, iron and manganese contents were determined in edible parts of some fresh vegetables sold on markets in Poznań. The copper and zinc contents in vegetables obtained in the present study were compared to the ones reported from an analogous study carried out in the Department of Horticultural Plant Fertilization in Poznań fifteen years ago. Samples of vegetables were collected from six points distributed in the area of Poznań from March to July at monthly intervals. For the study, vegetables were divided into three groups according to edible parts: leaves (lettuce, cabbage, parsley, leek), roots (carrot, celeriac, parsley) and fruits (tomato, cucumber). The concentration of copper, zinc, iron and manganese was determined by the atomic flame absorption method using an AAS 3 Zeiss apparatus. The highest content of copper was found in roots of celeriac, while the smallest content was shown in cabbage leaves. The highest mean content of zinc was found in lettuce leaves and the lowest one in tomato fruit. The mean content of copper in all the vegetable species was lower in 2005 than in 1993. In 1993 more zinc was found in vegetables whose edible parts were fruits compared to the results of 2005. The vegetables whose leaves and roots are eaten were characterized by a higher zinc content in 2005. The highest content of iron was found in leaves of leek, while the lowest amounts were determined in tomato and cucumber fruits. The highest mean content of manganese was found in leaves of lettuce, while the smallest amount was in carrot roots. The iron content in the vegetables whose leaves and fruits are edible parts was lower in 2005 than in 1993, while the root vegetables were characterized by more iron in 2005. Higher content of manganese in all the vegetable species examined was found in 1993 than in 2005.

Key words: copper, zinc, iron, manganese, heavy metals, fresh market, vegetables.

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ZAWARTOŚĆ MIEDZI, CYNKU, ŻELAZA I MANGANU W CZĘŚCIACH JADALNYCH WARZYW SPRZEDAWANYCH NA RYNKACH MIASTA POZNANIA

Abstrakt

W częściach jadalnych warzyw sprzedawanych na terenie miasta Poznania oznaczono zawartość miedzi, cynku, żelaza, manganu oraz porównano te zawartości z zawartościami w warzywach, które uzyskano w analogicznych badaniach przeprowadzonych w Katedrze Nawożenia Roślin Ogrodniczych w Poznaniu 15 lat temu. Próby warzyw pobierano w okresie od marca do lipca, w odstępach miesięcznych, z 6 punktów rozmieszczonych na terenie miasta Poznania. Do badań wybrano warzywa, których częścią jadalną są liście (sałata, kapusta, pietruszka, por); korzenie (marchew, seler, pietruszka) i owoce (pomidor, ogórek). Stężenie miedzi, cynku, żelaza i manganu określono metodą płomieniowej absorpcji atomowej z użyciem aparatu Zeiss AAS 3. Największą zawartość miedzi stwierdzono w korzeniach selera, natomiast najmniejszą w liściach kapusty. Największą średnią zawartość cynku stwierdzono w liściach sałaty, natomiast najmniejszą w owocach pomidora. Średnia zawartość miedzi w badanych gatunkach warzyw była niższa w 2005 r. w porównaniu z zawartością w 1993 r. Większą zawartość cynku w 1993 r. stwierdzono w warzywach, których częścią jadalną są owoce, w stosunku do warzyw badanych w 2005 r. Warzywa, których częścią jadalną są liście i korzenie, zawierały więcej cynku w 2005 r**.** Największą zawartość żelaza stwierdzono w liściach pora, natomiast najmniejszą w owocach pomidora i ogórka. Największą średnią zawartość manganu stwierdzono w liściach sałaty, natomiast najmniejszą w korzeniach marchwi. Zawartość żelaza w warzywach, których częścią jadalną są liście i owoce, była niższa w 2005 r. w porównaniu z zawartością w 1993 r., natomiast warzywa korzeniowe zawierały więcej Fe w 2005 r. Większą zawartość manganu w badanych gatunkach warzyw stwierdzono w 1993 r. w porównaniu z zawartością tego pierwiastka w 2005 r.

Słowa kluczowe: miedź, cynk, żelazo, mangan, metale ciężkie, warzywa.

INTRODUCTION

There is a scarcity of papers discussing the problem of copper and zinc content in edible parts of vegetable plants. Copper and zinc are micronutrients necessary for proper plant development. In appropriate amounts, they are essential for plants, but their excessive quantities may cause some disturbances in development of plants and result in their depressed quality. Vegetables are an important source of micronutrients for humans and animals. In some regions of Poland, vegetables can be contaminated with these metals, but most vegetables are characterized by small amounts of copper and zinc. Many researchers undertake trials to assess the content of heavy metals in edible parts of vegetables. Iron deficit in humans and animals is a very urgent global problem. It is estimated that iron deficit affects about 65% of people, particularly in African and Asiatic countries (Brown 2004). Vegetables are a source of microelements in the human diet. They are also fed, fresh or processed, to animals (Grzyś 2004). Production of vegetables which are of suitable quality and consumption value is highly important for people and animals.

The objectives of the present study, carried out in the Department of Horticultural Plant Fertilization of the Poznań University of Life Sciences, were to:

– determine copper, zinc, iron and manganese content in edible parts of vegetables frequently consumed by residents of Poznań;
– compare the current copper, zinc, iron and manganese content in vegetables with results obtained in an analogous study carried out in the Department of Horticultural Plant Fertilization in Poznań fifteen years ago.

MATERIAL AND METHODS

Samples of fresh market vegetables were taken from six points distributed in Poznań, from March to July 2005 at monthly intervals. For the purpose of this study, vegetables were divided into three groups according to edible parts: *leaves* (lettuce, cabbage, parsley, leek – 120 samples), *roots* (carrot, celery, parsley – 90 samples) and *fruits* (tomato, cucumber – 60 samples). In total, 270 samples were taken from nine vegetable species. The material for studies was prepared in the same way as it is done for consumption, i.e., it was washed under running water and cleaned. Washed vegetables were fragmented and dried in an exhaust drier at 55˚C. The dried material was ground in a laboratory mill. From each sample, 2.5 g of dry plant matter was weighed out and mineralised in a muffle furnace at 450˚C. After complete mineralization, combusted samples were solved in 10% HCl and transferred to flasks of 50 cm^3 capacity. The concentration of copper, zinc, iron and manganese was determined by the atomic flame absorption method using an AAS 3 Zeiss apparatus.

The statistical processing of the results included analysis of variance for copper, zinc, iron and manganese content in edible parts of the vegetable species examined. Statistical analyses were carried out using Statobl programme, a univariate analysis of variance for factorial orthogonal experiments. Differences between mean values were determined at the significance level of $\alpha = 0.05$

RESULTS AND DISCUSSION

The content of copper in edible parts of the vegetables studied in 2005 ranged from 0.6 $mg \cdot kg^{-1}$ d.m. in cabbage up to 9.2 $mg \cdot kg^{-1}$ in lettuce (Table 1). While analyzing the mean content of copper in the particular vegetables, the highest amount of this metal was found in leek, while cabbage was characterized by the lowest Cu content. In a study carried out by Tyksiński

Table 1

Extreme values and average contents of copper (mg· kg^{-1} d.m.) in edible parts of vegetables

Species	1993*		2005	
	extreme values	mean	extreme values	mean
Vegetables whose edible parts are leaves				
Lettuce	3.2 - 8.2	5.3	2.0 - 9.2	4.6
Cabbage	1.0 - 3.7	2.7	0.6 - 4.3	2.1
Parsley (top leaves)	3.6 - 7.4	5.2	1.3 - 7.0	4.2
Leek	1.0 - 3.2	2.4	1.2 - 8.7	4.0
Vegetables whose edible parts are roots				
Carrot	2.3 - 6.8	4.2	1.5 - 6.4	4.2
Celeriac	2.1 - 8.3	4.8	2.1 - 8.9	5.4
Parsley	4.7 - 7.6	6.4	1.4 - 6.4	3.6
Vegetables whose edible parts are fruits				
Tomato	1.5 - 5.2	3.5	1.2 - 7.6	3.5
Cucumber	3.9 - 6.3	5.3	1.0 - 4.7	2.6
			$LSD_{0.05}$ = 0.7	

*Tyksiński et al. (1993)

et al. (1993), Cu content ranged from 1.0 mg·kg^{-1} d.m. in cabbage and in leak leaves to 8.3 mg·kg^{-1} d.m. in roots of celery (Table 1). These authors found the highest copper content in parsley roots, where it was 43.7% higher than the Cu content in this vegetable in 2005. On the other hand, the smallest copper content was found in leek, where it was 66.6% smaller than 2005. Small amounts of copper in vegetables are caused by rapid depletion of this metal from the soil (Czuba, Muszyńki 1993) and by lack of routine fertilization with microelements (Sienkiewicz-Cholewa, Wróbel 2004). As reported by Czuba (1996), in whole Poland there are as many as 39% of soils with a low content of copper available to plants

In our study, the content of zinc ranged from 4.9 mg·kg^{-1} d.m. in tomato to 118.8 m g·kg^{-1} d.m. in lettuce (Table 2). A study by Gambuś and Wieczorek (1995) also showed the highest amount of Zn in lettuce. The highest mean content of zinc was found in lettuce leaves, while the lowest content was found in tomato fruits. In the vegetables studied by Tyksiński et al. (1993), zinc content ranged from 10.3 mg·kg^{-1} d.m. in carrot roots to 104.6 mg·kg^{-1} in tomato fruits (Table 2). The same authors found the highest amount of zinc in tomato fruits, where it was 245.3% higher than the Zn content in tomato fruits in 2005. Tyksiński et al. (1993) found the smallest amount of zinc in carrot roots, where it was 14.4% smaller in comparison with the content found in 2005. Such significant differentiation of zinc content in edible parts of vegetables is connected with specific characteristic features (Room-Sinhk Sharama, Singh 1994), which strongly affect accumula-

Table 2

Extreme values and average contents of zinc (mg· kg^{-1} d.m.) in edible parts of vegetables

Species	1993*		2005	
	extreme values	mean	extreme values	mean
Vegetables whose edible parts are leaves				
Lettuce	36.2 - 67.7	50.7	17.7 - 118.8	65.1
Cabbage	17.2 - 47.1	30.9	9.4 - 48.9	23.8
Parsley (top leaves)	18.4 - 74.4	40.4	13.8 - 52.7	31.6
Leek	16.8 - 23.9	19.7	9.5 - 38.4	26.1
Vegetables whose edible parts are roots				
Carrot	10.3 - 26.0	19.5	13.8 - 33.5	22.3
Celeriac	24.2 - 34.5	29.1	12.9 - 64.6	32.2
Parsley	16.2 - 28.3	21.5	11.4 - 44.8	21.8
Vegetables whose edible parts are fruits				
Tomato	11.7 - 104.6	51.8	4.9 - 31.9	15.0
Cucumber	25.1 - 32.7	28.7	14.6 - 58.9	28.0
			$LSD_{0.05}$ = 6.8	

*Tyksiński et al. (1993)

tion of Zn in yields of consumable plants (Hryńczuk et al. 1996). Deficit of zinc is the most important deficiency of micronutrients, limiting the world production of food (Takkar, Walker 1993).At present, adhering to admissible contents of copper and zinc in vegetables is no longer obligatory. In spite of that, determination of such metals as copper and zinc in edible parts of vegetables is necessary for constant monitoring of vegetable food products. Bosiacki and Golcz (2004) undertook investigations aimed at determination of the content of zinc and copper in vegetables grown in production farms in Środa Wielkopolska. The authors did not find any cases of excessive copper content in edible parts of plants, but excessive amounts of zinc were detected in two vegetable species: red cabbage and red beet.

The comparison of our results with the results obtained in an analogous study by Tyksiński et al. in 1993, both carried out in the area of Poznań, revealed that the mean content of copper in the vegetable species examined was lower in 2005 than in 1993 (Table 3).

The analysis of changes in the copper content in edible parts of the particular species showed that in 2005 only two vegetables, leek and parsley, contained more copper in edible parts than in 1993 (Table 1). In carrot roots and tomato fruits, the mean copper content remained unchanged between the two years, and in the other vegetable species more copper was determined in 1993.

In 1993, higher zinc content versus the determinations of 2005 was found in vegetables whose edible parts are fruits. Vegetables with edible

Table 3

The comparison of average contents the copper and zinc (mg· kg^{-1} d.m.) in individual groups of vegetables in 1993 and 2005

Group of vegetables	Cu		Zn	
	1993*	2005	1993*	2005
Vegetables whose edible part are leaves	3.9	3.7	35.4	36.7
Vegetables whose edible part are roots	5.1	4.4	23.4	25.5
Vegetables whose edible part are fruits	4.4	3.4	40.3	21.4
Mean	4.5	3.8	33.0	27.9

*Tyksiński et al. (1993)

leaves and roots were characterized by higher zinc content in 2005. The mean Zn content in all the analyzed vegetables was 29.2 mg·kg^{-1} d.m. More zinc content in edible parts of vegetables (33.0 mg·kg^{-1} d.m.) was found by Tyksiński et al. in 1993. The analysis of changes in the zinc content in edible parts of the particular species revealed an increase of this element in 2005, in lettuce and leek leaves as well as in carrot, celeriac and parsley roots, as compared with the results of 1993 (Table 2). The remaining vegetable species were characterized by higher Zn concentrations in 1993.

The iron content determined in edible parts of the vegetables ranged from 14.8 mg·kg^{-1} d.m. in cucumber fruits to 228.5 mg·kg^{-1} d.m. in leek. Analyzing the mean content of this metal in edible parts of the particular vegetables, we found out that the highest amount of iron occurred in leek. On the other hand, tomato fruits were characterized by the smallest amount of iron. Smaller amounts of Fe were reported by Golcz and Dłubak (1998). Tyksiński et al., who studied vegetables in 1993, found that the Fe content ranged from 14.4 mg·kg^{-1} d.m. in roots of celeriac to 326.9 mg·kg^{-1} d.m. in parsley leaves (Table 4). These authors found that the highest mean content of iron was in lettuce leaves, where it was 120.4% higher than the iron content in lettuce determined in 2005. The lowest amount of Fe found by Tyksiński et al. (1993) appeared in celery, where it was 126.9% lower than the quantity found in 2005. The lowest content of manganese in lettuce leaves was 2.5 mg·kg^{-1} d.m. (Table 5). The highest mean content of manganese was found in lettuce leaves, while the smallest amount was in carrot roots. In the 1993 study, the content of manganese ranged from 4.4 mg·kg^{-1} d.m. in carrot roots to 45.2 mg·kg^{-1} d.m. in cabbage leaves (Table 5). In 1993, the highest mean content of manganese was found in lettuce leaves, where it was 13.5% smaller than the manganese content in lettuce leaves analyzed in 2005. The smallest mean amount of Mn in 1993 was found in carrot roots, where it was 96.1% higher than the content determined in carrot roots in 2005. At present, adhering to the admissible iron and manga-

Table 4

Extreme values and average contents of iron (mg· kg^{-1} d.m.) in edible parts of vegetables

Species	1993*		2005	
	extreme values	mean	extreme values	mean
Vegetables whose edible parts are leaves				
Lettuce	132.3 - 301.7	197.5	34.5 - 205.2	89.6
Cabbage	24.1 - 93.0	37.7	16.2 - 132.0	57.0
Parsley (top leaves)	99.9 - 326.9	191.2	28.0 - 191.1	87.8
Leek	52.8 - 89.0	76.5	17.0 - 228.5	98.8
Vegetables whose edible parts are roots				
Carrot	15.7 - 53.5	35.0	16.2 - 141.7	54.4
Celeriac	14.4 - 52.7	26.0	19.0 - 105.3	59.0
Parsley	40.7 - 64.4	54.7	21.1 - 224.4	59.0
Vegetables whose edible parts are fruits				
Tomato	16.1 - 132.3	49.4	12.9 - 55.4	28.0
Cucumber	26.5 - 48.1	45.7	14.8 - 58.4	31.9
			$LSD_{0.05}$ = 15.0	

*Tyksiński et al. (1993)

Table 5

Extreme values and average contents of manganese (mg· kg^{-1} d.m.) in edible parts of vegetables

Species	1993*		2005	
	extreme values	mean	extreme values	mean
Vegetables whose edible parts are leaves				
Lettuce	17.7 - 43.1	28.8	2.0 - 9.2	32.7
Cabbage	11.9 - 45.2	28.4	0.6 - 4.3	18.2
Parsley (top leaves)	15.3 - 35.0	24.3	1.3 - 7.0	16.7
Leek	8.9 - 26.9	17.3	1.2 - 8.7	14.1
Vegetables whose edible parts are roots				
Carrot	4.4 - 26.5	10.0	1.5 - 6.4	5.1
Celeriac	10.2 - 31.1	21.1	2.1 - 8.9	12.9
Parsley	11.3 - 40.9	24.6	1.4 - 64	9.1
Vegetables whose edible parts are fruits				
Tomato	6.5 - 21.7	10.7	1.2 - 7.6	7.1
Cucumber	10.1 - 13.7	11.5	1.0 - 4.7	11.2
			$LSD_{0.05}$ = 3.4	

*Tyksiński et al. (1993)

nese levels in vegetables is no longer obligatory. However, determination of the content of such metals as iron and manganese in edible parts of vegetables is necessary in order to monitor these food products.

Comparing the results of our study with an analogous study carried out by TYKSIŃSKII et al. in 1993, it was found that the iron content in vegetables whose leaves and fruits are the edible parts was lower in 2005 than in 1993. On the other hand, root vegetables were characterized by a higher content of Fe in 2005 (Table 6). The mean content of Fe in all the vegetables analyzed was 56.9 $mg \cdot kg^{-1}$ d.m. Higher mean Fe content (69.2 $mg \cdot kg^{-1}$d.m.) was found by TYKSIŃSKI et al. in 1993. In 1993, more manganese was found in all the vegetables compared to the results obtained in 2005.

Table 6

The comparison of average contents the iron and manganese ($mg \cdot kg^{-1}$ d.m.) in individual groups of vegetables in 1993 and 2005

Group of vegetables	Cu		Zn	
	1993*	2005	1993*	2005
Vegetables whose edible part are leaves	125.7	83.3	24.7	20.4
Vegetables whose edible part are roots	38.6	57.5	18.6	9.0
Vegetables whose edible part are fruits	43.3	30.0	11.1	9.1
Mean	69.2	56.9	18.1	12.9

*TYKSIŃSKI et al. (1993)

CONCLUSIONS

1. The highest content of copper was found in roots of celeriac, while the smallest content of this micronutrient was shown by cabbage leaves.

2. The highest mean content of zinc was found in lettuce leaves. The lowest mean content of zinc was detected in tomato fruits.

3. In 1993, more zinc was found in vegetables whose fruits are the edible parts, when compared with the study performed in 2005. Vegetables whose leaves and roots are the edible parts were characterized by a higher zinc content in 2005.

4. The highest content of iron was found in leaves of leek, while the lowest concentration appeared in tomato and cucumber fruits.

5. The highest mean content of manganese was found in leaves of lettuce, while the smallest amount was in carrot roots.

6. The iron content in vegetables whose leaves and fruits are the edible parts was lower in 2005 in comparison with 1993, while the root vegetables were characterized by a greater amount of iron in 2005.

7. More manganese and cooper in al the vegetable species examined was found in 1993 than in 2005.

REFERENCES

Bosiacki M., Golcz A. 2004. *Zawartość cynku i miedzi w warzywach uprawianych przy trasach komunikacyjnych w gminie Środa Wielkopolska.* Rocz. AR w Poznaniu, Ogrodnictwo, 37: 13-17.

Brown P.H. 2004. *Principles of micronutrient use.* IFA Int. Symp. on Micronutrients, 23-25 II, New Delhi, India 12.

Czuba R. 1996. *Celowość i możliwość uzupełniania niedoborów mikroelementów u roślin.* Zesz. Probl Post. Nauk Rol, 434: 55-64.

Czuba R., Murzyński J. 1993. *Wielkość i jakość plonu siana oraz zmiany zasobności gleby w warunkach stosowania dużych dawek NPK w okresie 20 lat.* Rocz. Nauk Rol. A, 110 (1-2): 52-68.

Gambuś F., Wieczorek J. 1995. *Metale ciężkie w glebach i warzywach krakowskich ogródków działkowych.* Acta Agr. Silv., 33: 13-24.

Golcz A., Dłubak Sz. 1998. *Zawartość metali ciężkich w wybranych gatunkach warzyw.* Rocz. AR w Poznaniu, 304: 95-99.

Grzyś E. 2004. *Rola i znaczenie mikroelementów w żywieniu roślin.* Zesz. Probl. Post. Nauk Rol., 502: 89-99.

Hryńczuk B., Weber R., Gedliga K. 1996. *Relacje w nagromadzeniu cynku pobieranego z gleby i poprzez liście w plonach niektórych roślin uprawnych.* Zesz. Probl Post. Nauk Rol., 434: 19-24.

Room-Sinhk Sharama M.P., Singh R. 1994. *Response of rice to different zinc carriers and their methods of application in partially reclaimed salt affected soil.* Fertilizer News, 39 (7): 51-52.

Sienkiewicz-Cholewa U., Wróbel S. 2004. *Rola miedzi w kształtowaniu wielkości i jakości plonów roślin uprawnych.* Post. Nauk Rol., 5: 39-55.

Takkar P.N., Walker C.D. 1993. *The distribution and correction of zinc deficiency.* Kluver Acad. Publ. Netherlands, 151-165.

Tyksiński W., Breś W., Golcz A., Komosa A., Kozik E., Roszyk J. 1993. *Zawartość Pb, Cd i innych metali ciężkich w warzywach uprawianych na obszarze Poznania.* Biul. Warz., 40: 25-31.