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The influence of “Hayward” kiwi fruit (*Actinidia deliciosa*) from organic and conventional cultivations on the content of some trace elements in the rat kidneys and assessment of copper, manganese and zinc bioavailability

Wpływ owoców kiwi “Hayward” (*Actinidia deliciosa*) z upraw ekologicznej i konwencjonalnej na zawartość niektórych mikroelementów w nerkach szczura i ocena biodostępności manganu, miedzi i cynku

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Keywords: “Hayward” kiwifruit, organic and conventional cultivation, copper, zinc, manganese, kidneys, bioavailability, rats

Słowa kluczowe: owoce kiwi, uprawa ekologiczna i konwencjonalna, miedź, cynk, mangan, nerki, biodostępność, szczury

Abstract

The conditions of fruit cultivation may affect their content of some mineral elements. The study aims at determining the content of some microelements (Cu, Zn and Mn) in diets with “Hayward” kiwifruits from the organic (ecological) (OHC) and conventional (CHC) cultivation and also determining their effect on the mineral profile of the kidneys of rats loaded for 28 days with a diet containing 1% of cholesterol (C) and the assessment of bioavailability of these elements in rats. The mineral composition of the diets and kidneys was examined using a flame atomic absorption spectrophotometer (Perkin-Elmer 1100B). The bioavailability of Cu, Zn and Mn was calculated using the “three-point assay” [Littell et al. 1995]. In the atherogenic diets containing 5% of “Hayward” kiwifruit, the content of the investigated elements was higher than in the control diet and the highest content was noted in the diet with kiwifruit from the ecological cultivation. The content of Mn, Cu and Zn in rat kidneys was 1.1–1.4, 8.2–8.4 and 36.8–42.4 mg/kg, respectively. The bioavailability of Cu determined in respect to the C group was significantly lower in both CHC and OHC groups, whereas Mn was lower only in the OHC group. There were no significant differences in Zn bioavailability. The obtained results of the bioavailability of selected trace elements, determined on the basis of their concentration in the rat kidneys, did not show a clear evidence of the advantages of organically cultivated “Hayward” kiwifruit over conventional cultivation, in spite of their different contents in the examined fruits.

Streszczenie

Warunki uprawy owoców mogą mieć wpływ na zawartość w nich składników mineralnych. Celem pracy było określenie zawartości niektórych mikroelementów (Cu, Zn, Mn) w dietach z udziałem owoców kiwi Hayward z uprawy ekologicznej i konwencjonalnej oraz określenie ich wpływu na profil mineralny nerek szczurów obciążonych przez 28 dni dietą z cholesterolem (1%) oraz ocena biodostępności tych pierwiastków u szczurów. Skład mineralny diet i nerek zbadano przy użyciu płomieniowego spektrometru absorpcji atomowej (Perkin-Elmer 1100B). Do obliczenia biodostępności Cu, Zn, Mn zastosowano model „three-point assay” [Littell i in. 1995]. W dietach z 5% dodatkiem owoców kiwi Hayward stwierdzono wyższą zawartość badanych mikroelementów względem diety kontrolnej, najwyższą w diecie z kiwi z upraw ekologicznych. Zawartość Mn, Cu i Zn w nerkach szczurów mieściła się w przedziale odpowiednio: 1,1–1,4; 8,2–8,4 i 36,8–42,4 mg/kg. Biodostępność Cu określona względem grupy C była istotnie niższa w obu grupach OHC i CHC natomiast Mn tylko w grupie OHC. W biodostępności Zn nie wykazano istotnych różnic. Uzyskane wyniki biodostępności wybranych mikroelementów, określonej na podstawie ich stężenia w nerkach szczurów, nie wskazują jednoznacznie na przewagę ekologicznej uprawy owoców kiwi Hayward nad konwencjonalną, mimo różnej ich zawartości w badanych owocach.

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1. INTRODUCTION

Kiwifruits are characterised by a number of valuable properties [Duttaroy and Jorgensen 2004; Jung et al. 2005; Park et al. 2006]. They are the source of vitamins, mostly vitamin C, as well as mineral components (Cu, Fe, Mg, Zn, Ca, Mn, K and Na) [Nishiyama et al. 2004; Park et al. 2006]. The oldest and also the most popular cultivar of *Actinidia deliciosa* is “Hayward”, which also contributed to the popularisation of that fruit in the world. Depending on the growth conditions, application of plant protection agents, artificial fertilisers or the lack of them, plants developed various protective

traits. “Hayward” kiwifruits originating from ecological cultivations where only natural fertilisers were used were characterised by thicker peel and smaller flesh surface [Amodio et al. 2007] and were firmer than kiwi from the conventional cultivations [Hasey et al. 1997]. However, Benge et al. [2000] revealed that kiwi from conventional cultivations did not differ in firmness but were characterised by a higher content of soluble stable substances. A global demand for ecologically produced food constantly increases despite the lack of a clear opinion about the advantage of these

products over those produced conventionally. Various conditions of cultivation (the use of pesticides versus organic fertilisers) may affect the plant and fruit concentration of vitamins, minerals, nitrates and polyphenols [Worthington 2001; Lombardi-Boccia 2004; Amodio et al. 2007; Park et al. 2013].

The aim of this study was to investigate whether the presence of kiwi fruits in a diet, originating from various cultivations, affects the mineral metabolism of a rat fed a diet containing cholesterol. A particular ability for the cumulation of some elements is revealed by the liver and kidneys of animals. The present study aimed at determining the content of Mn, Cu and Zn in the rat kidneys and uses them for calculating their bioavailability in the organism. In the case of Cu, the liver is a better source for estimating the bioavailability of this trace element and these results will be published soon [Leontowicz et al. in press]. Zinc, copper and manganese are among the elements that are considered to be essential, as their presence conditions a proper course of metabolic processes and their deficit or excess leads to serious disturbances of the health state [Kośła et al. 2004; Skibniewski et al. 2010; Skibniewska et al. 2012].

2. MATERIALS AND METHODS

Kiwifruit (*Actinidia deliciosa*) of “Hayward” cultivar were collected from the Muan area in South Korea (National University, Muan, Jeonnam, South Korea). The experiment was performed on the ecological and conventional plantations. In the ecological plantation, an organic method was applied, which excludes the use of pesticides and synthetic fertilisers. The soil was only enriched by organic matter (bird droppings). Chemicalisation in the form of synthetic mineral fertilisers and plant-protecting agents were used on the conventional plantation. Fruits were thoroughly washed under the running water and then dried, peeled, weighed, chopped up and homogenised in a high-speed mixer (Hamilton Beach Silex professional model) for a minute. Kiwifruit samples were freeze-dried for 48 h (Virtis model 10-324). Fruits comprised 5% of the semisynthetic diet with 1% of cholesterol added.

The experimental model comprised the male Wistar rats fed the diet containing cholesterol for 28 days. The animals were divided into three groups: control (C) and two experimental CHC – with kiwi fruits from the conventional cultivations included in the diet and OHC with the share of fruits from ecological cultivations. The content of the investigated microelements in the diets and kidneys was determined using a flame atomic absorption spectrophotometer (Perkin-Elmer 1100B). The bioavailability of these elements was

calculated using the “three-point assay” [Littell et al. 1995]. That model was used after a prior observation in particular groups a rectilinear dependence ($y = a + bx$) between the concentration of the element in the organ (y) and its consumption (x).

One-way analysis of variance for statistical evaluation of results was used, followed by Duncan’s test to assess differences in group’s means; in the case of some elements bioavailability, Scheffe’s test was used. Results were expressed as arithmetic means \pm standard deviation (SD).

3. RESULTS AND DISCUSSION

A growing interest in “healthy food” contributes to the appearance of new ecological farms in which the plant-protecting agents or artificial fertilisers are not applied [Carey et al. 2009]. It seems that such a population of “healthy food” among the consumers results from the belief that it is safer for people and the environment. However, the views concerning a high health value of ecological food are controversial. According to some authors, ecological food is more healthy, according to some others it does not differ from food produced using the plant-protecting agents [Brandt and Molgaard, 2001; Dangour et al. 2009; Stracke et al. 2009].

While analysing the mineral composition of the experimental diets, no significant differences in the content of Mn, Cu and Zn were observed, only an increasing tendency was noted in the diets containing “Hayward” kiwifruit (Table 1). The lowest content of the investigated elements was noted in the control diet (C) and the highest in the diet supplemented with kiwi fruits from the ecological cultivation. In the rat kidneys from the CHC group, the highest Mn content was obtained, which was significantly ($P \leq 0.05$) different from the C group (Table 2). Similar results were obtained in the rat liver [Leontowicz et al. in press]. The highest Zn content in kidneys was noted in the OHC group, significant ($P \leq 0.05$) in relation to the C and CHC group. The copper content in the rat kidneys was equal in all groups and on the average amounted to 8.3 mg/kg.

Most publications concerning conditions of the conventional or ecological cultivation are devoted only to fruits [Anttonen and Karjalainen 2006; Wang et al. 2008] and there are only some informing about their effect on human beings and animals. There are many factors affecting the absorption of Mn, Cu and Zn, which may be both activators and inhibitors of that process. What is more, most elements demonstrate synergistic or antagonistic action towards each other [Kośła et al. 2004; Skibniewska et al. 2012]. It is suggested that the effect of kiwi fruits on the bioavailability of

Table 1. The content of the investigated elements in the diets of rats (mg/kg)

Diets	Mn	Cu	Zn
CHC	11.0 \pm 1.5	11.8 \pm 1.5	90.4 \pm 3.1
OHC	12.1 \pm 2.9	12.3 \pm 0.9	101.2 \pm 4.9
C	9.8 \pm 1.5	10.3 \pm 1.2	89.1 \pm 0.2

Mean \pm SD (standard deviation), $n = 5$. The lack of letters means the lack of differences between means ($P > 0.05$). CHC – a diet with 1% cholesterol content and 5% supplement of kiwi fruits from conventional cultivations; OHC – a diet with 1% cholesterol content and 5% supplement of kiwi fruits from ecological cultivations; C – semisynthetic diet with the addition of 1% cholesterol.

Table 2. The content of the investigated elements in the rat kidneys (mg/kg)

Groups	Mn	Cu	Zn
CHC	1.4 \pm 0.2b	8.3 \pm 0.7	37.1 \pm 1.5a
OHC	1.2 \pm 0.1ab	8.4 \pm 0.5	42.4 \pm 3.9b
C	1.1 \pm 0.1a	8.2 \pm 0.5	36.8 \pm 3.8a

Mean \pm SD (standard deviation), $n = 6$; means in columns marked with different letters differ among themselves in a statistically significant way ($P \leq 0.05$). The lack of letters means the lack of differences between means ($P > 0.05$). CHC – animals from a group fed with the diet containing 1% share of cholesterol and 5% addition of kiwi fruits from the conventional cultivations; OHC – animals from a group fed with the diet containing 1% share of cholesterol and 5% addition of kiwi fruits from ecological cultivations; C – animals from the control group, fed with a diet containing 1% cholesterol.

the chosen elements may be connected with the presence of other components in a diet (cholesterol) or in fruits themselves (vitamin C, polyphenols and tannin) [Siegenberg et al. 1991; Salgueiro et al. 2000]. It was revealed that also the dietary fibre, whose valuable source are fruits and vegetables, has the hypolipidemic properties, decreases the absorption of food cholesterol and bile acids [Leontowicz et al. 2001; Duttaroy and Jorgensen 2004], but it also affects the decrease of the iron, calcium, zinc and copper absorption [Gralak et al. 2004].

A significant drop of manganese and copper bioavailability determined on the basis of the concentration of those elements in kidneys was obtained in rats fed with the diet with the addition of kiwi fruits from ecological cultivation towards the C group (Fig. 1), which was the reference group and comprised 100%. In the case of relative bioavailability determined on the basis of the liver, similar results were obtained [Leontowicz et al. in press]. The manganese bioavailability in the OHC group was significantly lower

($P \leq 0.05$) than in the CHC group (Fig. 1); the results of bioavailability obtained on the basis of the concentration of that element in the liver also confirm that difference although it was not statistically significant [Leontowicz et al. in press]. A decreasing tendency of zinc bioavailability in both the groups containing kiwi fruits in relation to the C group was also demonstrated (Fig. 1).

4. CONCLUSIONS

- The addition of 5% "Hayward" kiwifruit into the atherogenic semisynthetic diet caused the increase in the dietary content of the investigated elements: Mn, Cu and Zn without significant differences resulting from different conditions of the kiwifruit (*Actinidia deliciosa*) cultivation.
- The conditions of "Hayward" kiwifruit cultivation did not have a significant effect on the investigated microelements bioavailability.

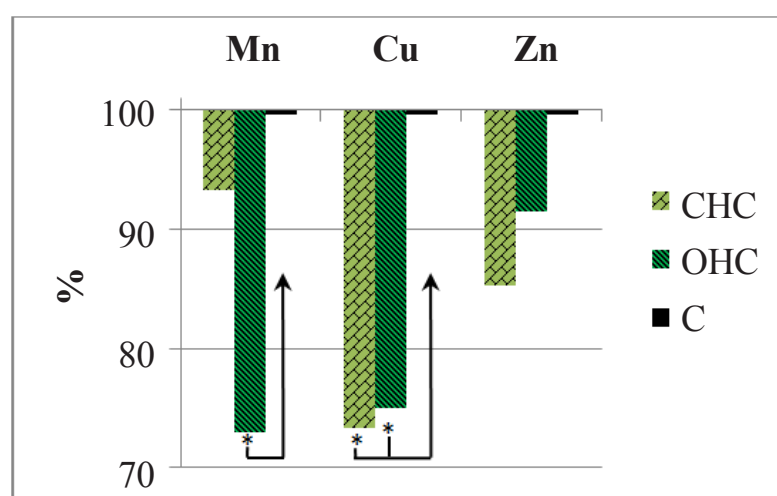


Fig. 1. The relative bioavailability (%) of the investigated elements: Mn, Cu and Zn.

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