Bioactivity and bioavailability of minerals in rats loaded with cholesterol and kiwi fruit

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4 This article was written in memory of my dear brother Prof. Simon Trakhtenberg, who died in November 2011, who encouraged me and our entire scientific group during all his life.

A R T I C L E   I N F O
Article history:
Received 29 October 2013
Received in revised form 22 December 2013
Accepted 22 December 2013
Available online 28 December 2013

Keywords:
Organic and conventional kiwifruit
Bioactive compounds
Total antioxidant capacity
Mineral bioavailability
Liver
Cholesterol
Rats

A B S T R A C T
The aim of this study was to compare the content of polyphenols (TP), minerals, ascorbic acid (AA) and total antioxidant capacities (TAC) of conventional and organic kiwifruit ‘Hayward’ treated with ethylene after harvest and to determine their influence on plasma TAC, mineral content in the liver and bioavailability (RBV — relative bioavailability value) in rats fed diet containing cholesterol. Organic and conventionally grown kiwifruits ‘Hayward’ as supplementation to rat diet were investigated in vitro for their bioactive compounds (polyphenols, flavonoids, flavanols, tannins, dietary fiber, and ascorbic acid), minerals, trace elements and TAC. In the in vivo investigation, 36 male Wistar rats (111 ± 5 g) were randomly divided into six diet groups, each of 6 rats: control without cholesterol (C) and 5 groups with 1% cholesterol (ch). Four cholesterol groups were supplemented with 5% lyophilized kiwifruit: ethylene treated, organic (chOHE) or conventional (chCHE) and untreated, and organic (chOH) or conventional (chCHC). During a period of 33 days of ad libitum feeding feed intake, body weight and feed utilization ration (FER) were controlled. In the end of the experiment rats were anesthetized using Narcotan 5% lyophilized kiwifruit: ethylene treated, organic (chOHE) or conventional (chCHE) and untreated, and organic (chOH) or conventional (chCHC). During a period of 33 days of ad libitum feeding feed intake, body weight and feed utilization ration (FER) were controlled. In the end of the experiment rats were anesthetized using Narcotan

1. Introduction
Kiwifruit is a climacteric fruit, particularly sensitive to ethylene post-harvest treatment. The research of Park et al. [1–3] indicates that the stimulation of this fruit with ethylene increases their bioactivity, reaching the highest value on the sixth day. During this period, the fruit is ready for consumption, because it contains the highest amount of total polyphenol and flavonoids, which affects the total antioxidant capacities. Nowadays, the interest of health food leads to organic production [4]. In organic system different methods are used to maintain

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http://dx.doi.org/10.1016/j.microc.2013.12.015
soil fertility, including addition of organic matter to soil and slow release of nutrients to the soil, in contrast to chemical fertilizer [5]. Conventional agricultural practices utilization of pesticides (and fungicides), which can result in a disruption of phenolic metabolites in the plant, having a protective role in plant defense mechanism [6]. These differences may result in the change of plant composition and nutritional quality, which in turn influences storage performance of products. Hassey et al. [7] found that organically grown kiwifruits are firmer than conventionally grown fruits. Benge et al. [8] did not observe difference between these two systems. Worthington et al. [5] showed that organic products contain more vitamin C and mineral elements (Fe, Mg and P) and less nitrates in comparison with fruit and vegetable crops derived from conventional plants.

It is known that citrus and exotic fruits, including kiwifruit are a good source of bioactive compounds, which have an important role in prevention of diseases [9,10]. On the other hand it must be underlined that bioactive compounds (polyphenols, mainly tannins, dietary fiber) can influence mineral metabolism and change bioavailability of minerals and trace elements. Bioavailability of elements [11] depends on the physiological status of the organism, diet composition, and interaction between nutrients, which can be synergistic and/or antagonistic. In this context it is interesting to compare kiwifruits from ecological or conventional cultivation on the basis of their composition; bioactivity and also organism reaction loaded cholesterol diet supplemented with kiwifruit. Ripening behavior in a population of kiwifruit at harvest is asynchronous, so a short burst of exogenous ethylene is used to synchronize ripening until control fruit softened to an ‘eating-ripe’ firmness.

The aim of this study was to determine the bioactive compounds, minerals and antioxidant potentials of organic and conventional kiwifruit ‘Hayward’, treated with ethylene after harvest, and to compare the antioxidant activity in plasma and bioavailability of minerals in the body of rats fed atherogenic diet. As far as we know no results of such investigations were published before.

2. Experimental

2.1. Samples and preparation

‘Hayward’ kiwifruits (organic and conventional) at their commercial maturity stage were harvested in orchard (Heanam Country, Jeonnam province, South Korea, 2010). Samples of kiwifruit organic ethylene treated (OHE) and conventional ethylene treated (CHE) were treated with 100 ppm of ethylene for 2 h at 20 °C in a growth chamber (Percival Scientific Inc. Perry, IA, USA). The samples were put into an 18 l glass jar and ventilated with humidified air flow mixed with ethylene at 300 ml min⁻¹. The samples of kiwifruit organic (OHC) and conventional (CHC) were put into 15 l glass jar and ventilated with humidified flow of air. Then the ethylene and air-treated kiwifruits were ripened separately using the same conditions, at 20 °C, in a growth chamber (Percival, USA) for 10 days.

All fruits were cleaned with tap water, and dried, using five replicates of five fruits each. The peeled fruits (without using steel knives) were weighed, chopped and homogenized under liquid nitrogen in a high-speed blender (Hamilton Beach Silex professional model) for 1 min. A weighed portion (50–100 g) was then lyophilized for 48 h (Virtis model 10–324), and the dry weight was determined. The samples were ground to pass through a 0.5 mm sieve and stored at −20 °C until the bioactive substances were analyzed.

2.2. Determination of composition of kiwifruit samples

Polyphenols were extracted from lyophilized fruits with 50% dimethyl sulfoxide (DMSO) (concentration 25 mg/ml) at room temperature twice during 3 h. The new solvent system was chosen on the basis of our previous investigations where various extracts were studied [1–3]. Therefore it was interesting to extract phenolic compounds with DMSO. Polyphenols were determined by Folin–Ciocalteau method with measurement at 750 nm using a spectrophotometer (Hewlett-Packard, model 8452A, Rockvile, USA). The results were expressed as mg of gallic acid equivalents (GAE) per g DM [12]. Flavonoids, extracted with 5% NaNO₂, 0.1 ml of 10% aluminum chloride hexahydrate (AlCl₃), and 1 M NaOH, were measured at 510 nm. The total flavonoids were estimated using the p-dimethylaminocinnamaldehyde (DMACA) method, and then the absorbance at 640 nm was measured [13]. The extracts of condensed tannins (procyanidins) with 4% vanillin solution in MeOH were measured at 500 nm. (+) Catechin served as a standard for flavonoids, flavanols and tannins, and the results were expressed as catechin equivalents (CE). Total ascorbic acid was determined by CUPRAC assay in water extract (100 mg of lyophilized sample and 5 ml of water) [14].

2.2.1. Determination of minerals (Se, Mn, Cu, Zn, Mg, Fe, Ca)

Samples of lyophilized kiwifruit (CHC, CHE, OHC, OHE) were placed in Teflon vessels, and 5 ml of HNO₃ and 1 ml of H₂O₂ were added. The samples were mixed and allowed to stand for 24 h. Mineralization was carried out in the microwave Milestone Ethos 900, USA–Italy. The elements were determined by flame atomic absorption spectrometry in a Perkin-Elmer 1100 B, using cathode ray wavelengths appropriate for the analyzed elements: 422.7, 285.2, 428.3, 324.8, 213.9 and 279.5 for Ca, Mg, Fe, Cu, Zn and Mn, respectively. Selenium was determined using starter with the method of MHS-10 hydride (NaBH₄).

2.3. Determination of total antioxidant capacity (TAC)

The TAC was determined by three complementary assays: (1) 2, 2′-Azino-bis (3-ethyl-benzothiazoline-6-sulfonic acid) diammonium salt (ABTS⁺⁻) was generated by the interaction of ABTS (7 mM) and K₂S₂O₈ (2.45 mM). This solution was diluted with methanol until the absorbance in the samples reached 0.7 at 734 nm [15]. (2) Ferric-reducing/antioxidant power (FRAP) assay measures the ability of the antioxidants in the investigated samples to reduce ferric-tripiridyltirazina (Fe³⁺⁻–TPTZ) to a ferrous form (Fe²⁺⁻), which absorbs light at 593 nm [16]. (3) Scavenging free radical potentials were tested in a methanolic solution of 1, 1-diphenyl-2-picyrylhydrazyl method (DPPH). In its radical form, DPPH has an absorption band at 517 nm, which disappears upon reduction by antiradical compounds. DPPH solution (3.9 ml, 25 mg/l) in methanol was mixed with the sample extracts in DMSO (0.1 ml), then the reaction progress was monitored at 515 until the absorbance was stable [17].

2.4. Rats and diets

The Animal Care Committee of the Warsaw Agricultural University, Warsaw, Poland approved this study. The mean weight of the male Wistar rats (n = 36) at the beginning of the experiment was 111 ± 5 g. The rats were divided into six diet groups, each six and named Control (C), ch, chHC, chCHE, chOHC and chOHE. During first 5 days of adaptation all groups were fed the basal diet (BD), which included wheat starch, casein, soybean oil, cellulose, vitamin (AIN-93 VX Vitamin Mix Cat. No. 960402) and mineral mixtures (AIN-93-MX mineral mix Cat. No. 960400) of the American Institute of Nutrition for laboratory animals. The rats were housed in metabolic cages (TECNIPLAST S.p.A, 21020, Italy). The rats of the Control group during the 28 days of the experiment received the BD only, and the diets of the other groups were supplemented with 1% of cholesterol (ch), 1% of cholesterol and 5% of lyophilized kiwifruit for chHC, chCHE, chOHC and chOHE, respectively. All rats were fed once a day at 10.00 h ad libitum, having unrestricted access to drinking water. The feed intake and body gains were monitored daily every week. At the end of the experiment after 24 h of starvation, the rats were anesthetized using Halothane (Narcotan–Zentiva), and the blood samples were taken from the left atrium of the heart.
Plasma was prepared and used for determination of TAC by DPPH, ABTS and FRAP assays. From three used assays FRAP is non-responsive to protein thiols in plasma [18].

Samples of liver (from right sole of panel) for the determination of the concentration of some minerals were used. Minerals (Se, Mn, Cu, Zn, Mg, Fe, Ca) in the diets and in the liver were determined by flame atomic absorption (spectrometer Perkin-Elmer 1100 B).

The relative bioavailability value (RBV) of minerals (Mg, Ca, Fe) and trace elements (Se, Zn, Cu, Mn) was estimated on the basis of liver rats. In order to calculate the RBV of the elements a model “tree-point assay” [19] was used, after finding in each group linear dependence (y = a + bx) between the concentration and the content of the element in the liver (y) and its consumption (x). The RBV, according to Ammerman [20], was estimated on the basis of the regression analyses between intake and concentration (RBVc) and content (RBVct) of each element in liver rats.

RBV values were calculated as follows for copper:

\[ \text{RBVc copper} \% = \frac{b \text{tc(Cu)}}{b \text{sc(Cu)}} \times 100, \]

where btsc(Cu) — tangent angle regression curve for the concentration of the element in the liver of experimental rats, bsct(Cu) — tangent angle regression curve for the content of the element in the liver of control rats.

\[ \text{RBVct copper} \% = \frac{b \text{tc(Cu)}}{b \text{sc(Cu)}} \times 100, \]

where btct(Cu) — tangent angle regression curve for the content of the element in the liver of experimental rats, bsct(Cu) — tangent angle regression curve for the content of the element in the liver of control rats.

2.5. Statistical analysis

The results of this study in vitro are mean ± SD of five measurements. One-way analysis of variance (ANOVA) for statistical evaluation of results in vivo was used, followed by Duncan's new multiple range tests to assess differences between the group's means. The P values of <0.05 were considered significant. For the bioavailability of minerals Scheffe test (P < 0.05) was applied (Statgraphics plus 6.0).

3. Results

3.1. In vitro studies

The results of the determination of bioactive compounds in conventional and organic kiwifruit, treated and non-treated with ethylene are summarized in Table 1.

As can be seen, the contents of total polyphenols, flavonols and tannins are higher (P < 0.05) and vitamin C is significantly higher (P < 0.05) in organic than in conventional kiwifruit. It can be mentioned that the contents of polyphenols, flavonoids, flavonols, tannins, vitamin C, dietary fiber and its fraction IDF and SDF were higher in both kiwifruit treated with ethylene.

The antioxidant capacity of organic kiwifruit was higher in conventional (Table 1) and amounted from 19.0 (DPPH) to 25.5 (FRAP) for kiwifruits OHC, in comparison with CHC which was lower (from 16.8 for DPPH to 21.4 μmol TE/g DM for FRAP). The differences between fruits were not significant (P > 0.05). The antioxidant capacity of the kiwifruit treated with ethylene was mostly significantly higher (P < 0.05) than for air treatment. The highest correlation between antioxidant potential (DPPH) and total polyphenols (TP) (R² = 0.9638) (Fig. 1A) and also vitamin C (R² = 0.8999) (Fig. 1B) was determined, lower correlation for flavonoids (TF) (R² = 0.8703) and flavanols (R² = 0.7288) in kiwifruit ‘Hayward’ (from conventional and organic crops, treated with ethylene) were obtained.

The content of studied minerals (Se, Mn, Cu, Zn, Mg, Fe, and Ca) in lyophilized kiwifruit is presented in Table 2. As it was shown, the content of Mn was significantly higher, while Cu and Mg contents were lower (P < 0.05) in conventional kiwifruit in comparison with the organic ones. Ethylene treatment of kiwifruit changed mineral content in different ways: in the case of Cu a significant (P < 0.05) increase in

### Table 1

<table>
<thead>
<tr>
<th>Item</th>
<th>CHC</th>
<th>CHE</th>
<th>OHC</th>
<th>OHE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyphenols, mg GAE</td>
<td>7.1 ± 0.2*</td>
<td>8.7 ± 0.2b</td>
<td>7.9 ± 0.4ab</td>
<td>10.1 ± 0.4a</td>
</tr>
<tr>
<td>Flavonoids, mg CE</td>
<td>2.0 ± 0.1a</td>
<td>2.3 ± 0.1a</td>
<td>2.0 ± 0.1a</td>
<td>3.0 ± 0.1b</td>
</tr>
<tr>
<td>Flavonols, µg CE</td>
<td>150.0 ± 0.2ab</td>
<td>210.0 ± 0.2b</td>
<td>181.0 ± 0.8ab</td>
<td>291.0 ± 10.2c</td>
</tr>
<tr>
<td>Tannins, mg CE</td>
<td>1.8 ± 0.1a</td>
<td>2.3 ± 0.1ab</td>
<td>2.0 ± 0.1a</td>
<td>2.6 ± 0.1b</td>
</tr>
<tr>
<td>Ascorbic acid, mg AA</td>
<td>0.17 ± 0.04a</td>
<td>0.20 ± 0.05b</td>
<td>0.19 ± 0.04b</td>
<td>0.23 ± 0.04b</td>
</tr>
<tr>
<td>TDF, mg</td>
<td>77.2 ± 0.3a</td>
<td>80.9 ± 0.3b</td>
<td>82.5 ± 0.7</td>
<td>84.5 ± 0.4ab</td>
</tr>
<tr>
<td>IDF, mg</td>
<td>54.8 ± 0.6a</td>
<td>56.6 ± 0.2b</td>
<td>54.7 ± 0.4a</td>
<td>54.9 ± 0.3a</td>
</tr>
<tr>
<td>SDF, mg</td>
<td>22.4 ± 0.2a</td>
<td>24.3 ± 0.1b</td>
<td>27.8 ± 0.4</td>
<td>29.6 ± 0.2a</td>
</tr>
<tr>
<td>DPPH, µmol TE</td>
<td>16.8 ± 1.0a</td>
<td>22.0 ± 1.5ab</td>
<td>19.0 ± 1.1ab</td>
<td>25.2 ± 1.4ab</td>
</tr>
<tr>
<td>ABTS, µmol TE</td>
<td>20.0 ± 2.1a</td>
<td>27.0 ± 2.4a</td>
<td>22.3 ± 2.3a</td>
<td>29.1 ± 2.2bc</td>
</tr>
<tr>
<td>FRAP, µmol TE</td>
<td>21.4 ± 3.6a</td>
<td>31.0 ± 0.5b</td>
<td>25.5 ± 2.5a</td>
<td>33.2 ± 1.9b</td>
</tr>
</tbody>
</table>

Mean ± SD (standard deviation) of 5 measurements. Average in lines marked with different letters differ significantly (P < 0.05).

Abbreviations: AA, ascorbic acid; ABTS — 1,2-azino-bis (3-ethyl-benzothiazoline-6-sulfonic acid) diammonium salt; CE — catechin equivalent; DPPH — 1,1-diphenyl-2-picyrylhydrazyl method; FRAP — ferric-reducing/antioxidant power; GAE — gallic acid equivalent; TE — trolox,6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid equivalent; TDF — total dietary fiber; IDF — insoluble dietary fiber; SDF — soluble dietary fiber; CHC — conventional kiwifruit air ripening; CHE — conventional kiwifruit treated ethylene; OHC — organic kiwifruit air ripening; OHE — organic kiwifruit treated ethylene.

![Fig. 1. The correlation between DPPH and total polyphenols (A), DPPH and vitamin C (B).](image-url)
Table 2

Contents of minerals and trace elements in the studies kiwifruit ‘Hayward’ (mg/kg DM).

<table>
<thead>
<tr>
<th>Item</th>
<th>CHC</th>
<th>CHE</th>
<th>OHC</th>
<th>OHE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn</td>
<td>10.5 ± 0.1</td>
<td>10.2 ± 0.2</td>
<td>9.2 ± 0.2</td>
<td>8.4 ± 0.2</td>
</tr>
<tr>
<td>Cu</td>
<td>7.0 ± 0.3</td>
<td>8.2 ± 0.1</td>
<td>8.3 ± 0.1</td>
<td>8.8 ± 0.3</td>
</tr>
<tr>
<td>Zn</td>
<td>20.0 ± 0.5</td>
<td>21.0 ± 1.8</td>
<td>20.5 ± 2.9</td>
<td>21.7 ± 1.6</td>
</tr>
<tr>
<td>Mg</td>
<td>8365 ± 192</td>
<td>8912 ± 40.8</td>
<td>10599 ± 17.9</td>
<td>10915 ± 52.6</td>
</tr>
<tr>
<td>Fe</td>
<td>12.3 ± 0.5</td>
<td>12.2 ± 0.7</td>
<td>11.8 ± 0.1</td>
<td>11.9 ± 0.6</td>
</tr>
<tr>
<td>Ca</td>
<td>975.0 ± 113.6</td>
<td>925.6 ± 116.2</td>
<td>939.4 ± 115.2</td>
<td>853.4 ± 118.9</td>
</tr>
</tbody>
</table>

Mean ± SD (standard deviation) of 5 measurements. 

Lack of letters indicates no difference between the mean (P > 0.05).

Abbreviations: CHC — conventional kiwifruit air ripening, CHE — conventional kiwifruit treated ethylene, OHC — organic kiwifruit air ripening, OHE — organic kiwifruit treated ethylene. Content Se — value of the traces.

CHE and OHE in comparison with CHC and OHC was noted. Ethylene treatment of conventional kiwifruit did not change Mn content, but significantly decreased Mn in organic fruits (P < 0.05). No effect of cultivation and ethylene treatment for kiwifruits was seen on Zn, Fe and Ca contents. The content of selenium was below trace amounts.

3.2. In vivo studies

The data of the feed intake, body weight gains, feed efficiency ratio (FER) and rat liver somatic index are not shown in this paper. Supplementation of the ch groups with kiwifruit increased feed intake (12%) and body gains (38%), and decreased FER (21%).

The concentration of some minerals in the diets for rats was presented in Table 3. The content of selenium in the diets of C and ch groups was higher than in diets with kiwifruit. There were no significant differences in Mn, Cu and Fe contents between diets. The highest content of Cu and Zn was 12.3 and 101.2 mg/kg, respectively, in the diet with the addition of kiwifruit from organic farming (chOHC). Magnesium content in atherogenic diets with kiwifruit was significantly higher than in ch diet without fruit supplementation.

A significant decrease of plasma TAC (for DPHH, FRAP and ABTS assays) in cholesterol group vs control group (P < 0.05) was registered. Supplementation of the ch diet groups with 5% lyophilized kiwifruits increased the plasma TAC, evaluated by DPHH (19%), FRAP (68%) and ABTS (62%) assays (Table 3). It was not a significant difference in plasma TAC between conventional and organic groups.

The content of mineral compounds in the liver of rats is shown in Table 4. The highest contents of selenium and manganese were recorded in the liver of rats fed the atherogenic diet with kiwifruit from conventional crops vs ch group (P < 0.05). It was not a significant difference in the content of copper and zinc in the rat’s liver. In diet groups of rats chOHC and chCHC a significant increase of iron and calcium contents in the liver was found in comparison with ch and C groups.

The bioavailability of selected elements is shown in Figs. 2 and 3. A significant decrease (P < 0.05) in the bioavailability of manganese and zinc in rats fed diets supplemented with organic kiwifruit (chOHC) in relation to a group ch was obtained (Fig. 3). Supplementation of kiwifruit (organic and conventional) for atherogenic diet significantly decreased the bioavailability of magnesium in all groups vs C and ch groups (P < 0.05) (Fig. 2). No significant changes were noted in the bioavailability of iron and calcium (Fig. 2), also in the case of selenium (data not shown). The reference group was ch group, which was placed on graphs as 100%. The bioavailability of minerals was defined with respect to this group. Ethylene treatment of kiwifruit (conventional or organic) had no significant effect on the bioavailability of the studied elements in the body, determined on the basis of mineral concentration in the liver.

4. Discussion

Recently a scientific interest has been directed on healthy food. The question which conditions are better for healthy fruits and vegetables production in organic or conventional system is not answered till now [7,21,22]. It can be underlined that in organic systems only organic matter is used. In conventional systems pesticides and fungicides can influence on disruption of some bioactive compounds (mainly phenolics) or change the amount of other compounds as well [22]. Undoubtedly chemical protection of the plants led to the increase of their production [21], but for consumers the composition and pro-healthy action are nevertheless important. The studies which are presented in this paper are also associated with this direction of research.

For this reason kiwifruit ‘Hayward’ (organic and conventional) was evaluated for its pro-healthy action on the basis of composition (in vitro study) and also firstly based on metabolic reaction of rats loaded with cholesterol. The influence of these factors on lipids, enzyme activity, and hematologic and coagulation parameters in the rats was recently published [23].

As it was presented in this paper amount of total polyphenols, flavonoids, flavanols, tannins and vitamin C in kiwifruit ‘Hayward’, and also the antioxidant capacities depended on cultivation conditions (conventional and organic crops) and also stages of ripening of these fruits after harvest (ethylene treated or non-treated). Generally it can be underlined that the content of bioactive compounds in kiwifruit from organic was higher (apart from flavonoids) (P > 0.05) that from conventional cultivations. Ethylene treatment increased the bioactive compounds: higher in fruits from organic cultivation than from conventional and amounted: 61, 50, 30 and 28% for flavanols, flavonoids, tannins and total polyphenols, respectively, in OHE vs groups (calculated on the basis of results from Table 1). The data presented in Table 1
were slightly different from the previous published results [23], because the studied kiwifruit samples were harvested the same year and from the same orchard. Increase of polyphenols with ethylene treatment can be explained by enzymatic reactions, which was presented by Leong and Shui [24] and by Guo et al. [25]. For kiwifruit ‘Hayward’ this effect was presented in our previous paper [26].

It has been shown that the TAC of exotic fruits depends on phenolic compounds [27–29], mainly flavonoids and flavanols [30]. The contents of bioactive compounds determined in kiwifruit, which were used in this study were correlated with their TAC in a different way. Low correlation between TAC and flavanol contents can be attributed to the low contribution of these compounds to TAC. The high correlation between vitamin C and TAC of kiwifruit corresponds with the obtained results of Tavarini et al. [31]. According to these authors the vitamin C in a greater degree than other antioxidant compounds affects the value of this parameter. In the present study it was shown that the content of vitamin C in lyophilized kiwifruit ranged from 0.17 (CHC) to 0.23 mg/g DM (Table 1). Ethylene treatment of organic kiwifruit (OHE) influenced the increase of vitamin C (21%) higher than in the case of conventional kiwifruit (CHE) (17%). Similar effect of ethylene treatment for other bioactive compounds in kiwifruits was previously presented. According to Beever and Hopkirik [32] kiwifruit is a valuable source of vitamin C, but it contains a small amount of polyphenols [33]. As it was presented in our study polyphenol content in kiwifruits amounted from 7.1 (CHC) to 10.1 mg GAE/g DM and was more than twice higher as in other exotic fruits such as durian [34] and persimmon ‘jiro’ [35]. Amodio et al. [21] showed that organic kiwifruit has a significantly higher polyphenol content and antioxidant capacity than in fruits from conventional farming. The influence of vitamin C on TAC in fruits is still debatable. Some authors claim that TAC of fruits depends mainly on the content of phenolic compounds [36–38], and the influence of vitamin C is small [37]. According to other authors vitamin C plays an important role in the antioxidant capacity of fruits [39].

As it was documented in Table 3 supplementation of atherogenic diet with kiwifruit ‘Hayward’ significantly influenced (P < 0.05) the plasma antioxidant activity. For evaluation of this effect different assays were used: the highest increase of plasma TAC in the case of FRAP and ABTS tests (68–62%), less for DPPH (19%) was obtained. Different components of fruits possess antioxidative properties (polyphenols, vitamins and dietary fiber) and influenced the increasing of TAC in blood plasma as well. They are powerful inhibitors of oxidative stress, what leads to increase the level of antioxidant in the blood as was presented by different authors [35,40–42]. As it was shown in our previous papers diets for rats containing 1% of cholesterol supplemented with different exotic fruits (durian, persimmon, kiwifruit) significantly hindered the decrease of plasma antioxidant capacity. These results pointed to an improvement of antioxidant status in the rats loaded with cholesterol. It can be underlined that organic and conventional kiwifruit influenced the plasma TAC in similar way. Ethylene treatment of conventional and organic kiwifruits showed slight increase in the plasma TAC of rats. The differences in the mineral content in fruits may result primarily from variations in the composition of the fruit [43–45]. In our study, the content of minerals (macro elements — Mg, Ca, Fe; trace elements — Se, Zn, Cu, Mn) from organic and conventional kiwifruit crops were determined by flame atomic absorption spectrometry. As it was presented in Table 2 kiwifruit from organic farming showed a significantly higher magnesium level (1076 vs 865 mg/kg DM) and copper (8.6 vs 7.6 mg/kg DM) than from conventional crops, while the fruits from conventional

### Table 4

<table>
<thead>
<tr>
<th>Item</th>
<th>chCHC</th>
<th>chCHE</th>
<th>chOHC</th>
<th>chOHE</th>
<th>C</th>
<th>ch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Se</td>
<td>268.4 ± 17.9</td>
<td>228.4 ± 18.2</td>
<td>231.4 ± 16.0</td>
<td>237.6 ± 16.8</td>
<td>236.4 ± 34.8</td>
<td>243.4 ± 26.2</td>
</tr>
<tr>
<td>Mn</td>
<td>2.8 ± 0.2</td>
<td>2.7 ± 0.3</td>
<td>2.7 ± 0.2</td>
<td>2.7 ± 0.3</td>
<td>2.3 ± 0.1</td>
<td>2.5 ± 0.4</td>
</tr>
<tr>
<td>Cu</td>
<td>7.8 ± 0.6</td>
<td>7.8 ± 0.6</td>
<td>7.4 ± 0.4</td>
<td>7.0 ± 1.3</td>
<td>6.8 ± 0.6</td>
<td>7.2 ± 0.6</td>
</tr>
<tr>
<td>Zn</td>
<td>36.3 ± 1.8</td>
<td>36.3 ± 2.1</td>
<td>33.4 ± 3.7</td>
<td>35.5 ± 1.2</td>
<td>32.0 ± 0.5</td>
<td>35.7 ± 3.7</td>
</tr>
<tr>
<td>Mg</td>
<td>224.9 ± 10.6</td>
<td>213.5 ± 20.6</td>
<td>223.7 ± 13.4</td>
<td>222.9 ± 14.9</td>
<td>236.8 ± 8.9</td>
<td>238.6 ± 8.9</td>
</tr>
<tr>
<td>Fe</td>
<td>83.6 ± 13.4</td>
<td>83.6 ± 13.4</td>
<td>83.5 ± 15.4</td>
<td>72.7 ± 10.4</td>
<td>72.2 ± 9.7</td>
<td>66.5 ± 12.7</td>
</tr>
<tr>
<td>Ca</td>
<td>213.3 ± 2.8</td>
<td>205.5 ± 2.6</td>
<td>21.5 ± 4.4</td>
<td>20.4 ± 2.9</td>
<td>17.4 ± 1.4</td>
<td>18.4 ± 1.5</td>
</tr>
</tbody>
</table>

Mean ± SD (standard deviation) of 5 measurements. Average in lines marked with different letters differ significantly (P < 0.05).

Lack of letters indicates no difference between the mean (P > 0.05).

Abbreviations: chCHC — atherogenic diet with conventional kiwifruit air ripening, chCHE — atherogenic diet with conventional kiwifruit ethylene stimulation, chOHC — atherogenic diet with organic kiwifruit air ripening, chOHE — atherogenic diet with organic kiwifruit ethylene stimulation, C — Control, ch — atherogenic diet (1% cholesterol).

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### Figure 2

**Mineral bioavailability in rats fed atherogenic diets (1% of cholesterol) and kiwifruit Hayward (5%).** Mean ± SD (standard deviation) of 5 measurements. Lack of symbols indicates no difference between the mean (P > 0.05).

Abbreviations: chCHC — atherogenic diet with conventional kiwifruit air ripening, chCHE — atherogenic diet with conventional kiwifruit ethylene stimulation, chOHC — atherogenic diet with organic kiwifruit air ripening, chOHE — atherogenic diet with organic kiwifruit ethylene stimulation, C — Control, ch — atherogenic diet (1% cholesterol).
cultivation had higher content of manganese (10.4 vs 8.8 mg/kg DM) (P < 0.05). Ethylene treatment of kiwifruit ‘Hayward’ significantly changed trace element content. The increase of Cu content in both kiwifruit was estimated. Mn decreased only in organic kiwifruit. There were no significant differences in the other studied elements between kiwifruit cultivations and ethylene treatment of crops. According to Worthington et al. [5] fruits and vegetables from organic crop have higher content of manganese (10.4 vs 8.8 mg/kg DM) than those from conventional cultivation with utilization of pesticides, fungicides and fertilization. Amodio et al. [21] showed a significant increase not only of Mg content in organic kiwifruit ‘Hayward’, but also of other minerals (N, K, P, Ca).

Determination of element cumulation in tissues is one of the better methods to assess their bioavailability from the diet. In the present study the effect of organic or conventional kiwifruit on bioavailability of selected elements in the organism, evaluated on the basis of its concentration in the rat’s liver, according to Ammermann [20] formula was determined. These are the first results in the literature in which the influence of kiwifruit from organic and conventional cultivations treated with ethylene or air on mineral bioavailability in rats loaded during 4 week diets with cholesterol was evaluated.

As it was presented in Table 4 trace element (Se, Mn) concentrations in the rat liver from chCHC group were significantly higher (P < 0.05) than in ch group. It can be pointed that the concentration of Fe in rat liver from chCHC and chOHC groups was also significantly higher (P < 0.05) than in ch group. Concentration of other elements in the liver was similar in all groups with cholesterol. Mineral concentration in kidney and spleen was also determined (data not shown). Kiwifruits significantly increased Mg content in kidney (in all groups) but Mn increased only in chCHC and chCHE groups. Data obtained for spleen differ from previous results. Mn and Cu concentrations were significantly higher in all groups with kiwifruits than in ch group. In the case of Fe a tendency for increase in all groups with kiwifruits (vs ch) was obtained. These results cannot be compared with those obtained in other papers.

Mineral content in the liver was chosen for the calculation of the bioavailability (RBV-relative value) of minerals in the body of rats. It can be mentioned that the RBV of some elements may be associated also with the presence of the other components of the diet (cholesterol), and also with compounds of the fruit such as vitamin C, polyphenols and dietary fiber. As it was presented in Fig. 2 addition of kiwifruits to the atherogenic diet significantly decreased Mg bioavailability in all groups of rats. Zinc and manganese only decreased in chOHC group. There was no significant difference in the RBV of Fe and Ca in rats loaded with cholesterol and supplemented with kiwifruits from different cultivations and treatments. Davidson et al. [46] reported an increase of iron absorption after the administration of ascorbic acid. Tannins decrease Fe(III) absorption from the diet by selective ferric-complexation, but vitamin C reduces Fe(III) to Fe(II) and reduces this inhibitory effect of tannins [47]. The action mentioned above was not shown in our study. Gralak et al. [48] reported that high doses of vitamin C can reduce the content of magnesium in the rat liver, on the contrary dietary fiber from different sources also reduced the absorption of magnesium, iron, calcium, zinc, and copper in rats [49]. Fiber from apple pulp decreased also the bioavailability of Zn and Cu in rats loaded with cholesterol from the diet (1%) [50]. Addition of cholesterol to the diet causes a significant increase in the concentration of copper in plasma and liver of rats [51]. Results obtained in our study pointed only for the tendency of the increase of Cu concentration in the rat liver loaded with cholesterol in comparison to the control (negative). There were no clear differences in the RBV of the studied minerals in the rat body loaded with cholesterol, resulting from the use of kiwifruit conventional and organic and treated with ethylene. It can be only suggested that Mg supplementation in the diet with these fruits is important.

5. Conclusion

‘Hayward’ kiwifruit organic contains more bioactive compounds (mainly polyphenols) and higher antioxidant capacity than conventional. Ethylene treatment of fruits after harvest can increase their bioactivity. Magnesium content was significantly higher and Mn was lower in organic kiwifruit ‘Hayward’. Manganese in conventional kiwifruit was lower than that in organic. Kiwifruit which was supplemented to the atherogenic diet increased plasma antioxidant capacity in rats, without differences between organic and conventional cultivations. Ethylene treatment of kiwifruits stimulates their maturation after harvest and significantly decreases magnesium bioavailability, determined on the basis of its concentration in the liver. This points to the desirability of supplementing Mg content in atherogenic diet and in human with cardiovascular diseases.

References


Y.Y. Lim, T.T. Lim, J.J. Tee, Antioxidant properties of guava fruit: comparison with some local fruits, Sunway University, Malaysia, 2003.


