Pol. J. Environ. Stud. Vol. 21, No. 6 (2012), 1543-1550

Original Research

Mineral Composition of Fruits of *Actinidia Arguta* and *Actinidia Purpurea* and Some of Their Hybrid Cultivars Grown in Northeastern Poland

Anna Bieniek*

Department of Horticulture, Olsztyn, University of Warmia and Mazury in Olsztyn,
Romana Prawocheńskiego 21, 10-720 Olsztyn, Poland

Received: 19 June 2012
Accepted: 3 September 2012

Abstract

Actinidia arguta and *Actinidia purpurea* provide tasty and nutritionally valuable fruit that are edible directly or after processing, without peeling. The aim of the study was to determine the content of macro- and microelements in the fruit of three Ukrainian hybrid cultivars of *Actinidia arguta* × *Actinidia purpurea*: 'Figurnaja,' 'Kijewskaja Gibrydnaja,' 'Kijewskaja Krupnopłodnaja,' *Actinidia arguta*: 'Sientiabrskaja,' and *Actinidia purpurea*: 'Purpurowaja Sadowaja' during five years of cultivation (2006-11) in northeastern Poland. Determining the chemical composition of actinidia fruit yields was performed after wet mineralization. The results have shown that fruit of the 'Sientiabrskaja' cultivar of *Actnidia arguta* contained the highest concentrations of N, P, Ca, and Mg, as well as Cu and Mn. Fruit of the 'Purpurowaja Sadowaja' cultivar of *Actinidia purpurea* contained the highest concentrations of K and Zn. Fruit of hybrid cultivars 'Figurnaja,' 'Kijewskaja Gibrydnaja' and 'Kijewskaja Krupnopłodnaja' were found to contain the lowest concentrations of N, Ca, Mg, and Zn. Fruit of 'Figurnaja' and 'Kijewskaja Gibrydnaja' contained similar amounts of P, Ca, and Mg, but their Na content was different.

Keywords: actinidia charta, cultivars, mineral composition, hardy kiwifruit, hybrid cultivars

Introduction

Hardy kiwifruit (*Actinidia arguta* (Siebold et. Zucc.) Planch. Ex Miq.) and actinidia charta (*Actinidia purpurea* Rehd., *A. arguta* var. *purpurea,* Rehd., C. F. Liang) are a species whose fruit, unlike those of *Actinidia chinensis*, are rarely available commercially in Poland. They are becoming increasingly popular and valued from year to year [1]. These species are increasingly regarded as a fruit bush rather than as ornamental shrubs, as they used to be [2, 3]. This is because their fruit satisfies a consumer need for tasty, natural, and functional food produced in a clean environment [4]. A study conducted by Latocha [3] showed that, in terms of the content of bioactive nutrients, the fruit of *A. arguta* and its hybrids with *A. purpurea* are not inferior to fruit of *A. chinensis*, which are regarded as "health fruit," and are even superior to them in some respects [5]. The best-known ingredient of kiwifruit is vitamin C [6]. The quality of fruit of *A. arguta* and its hybrids with *A. purpurea* is affected by a number of factors. It largely depends on the genetic features of a plant and on the cultivation conditions (climate, fertilization, stress) as well as on its ripeness at the time of harvest and on the method of storage. Studies of the growth, yield, and quality of fruit in Poland have been conducted in the central and northeastern parts of the country [1, 3, 7-14]. However, there have been only scarce reports on the mineral compositions of the fruit of *Actinidia arguta* and hybrid forms [3, 15]. The fruits are considered to be rich in K, Fe, Cu, and Mg [5, 16].

*e-mail: anna.bieniek@uwm.edu.pl

According to Danilcenko et al. [17], food quality can be characterized by the content of mineral elements. They are essential for normal growth and maintenance of bones and teeth, provide electric signal transfers, and are a co-factor in oxygen transport. The elements are involved in many important body enzymatic reactions, as well as in the protection of cells and lipids in biological membranes [18, 19]. The World Health Organization (WHO) published recommendations for the daily intake (RDI) of minerals [20]. The more diverse the diet, the more certain the body is to be supplied with sufficient amounts of micro- or macroelements.

The aim of this study was to analyze the mineral composition of the fruits of three Ukrainian hybrid cultivars of *Actinidia arguta* × *Actinidia purpurea*: 'Figurnaja,' 'Kijewskaja Gibrydnaja,' 'Kijewskaja Krupnopłodnaja,' *Actinidia arguta*: 'Sientiabrskaja,' and *Actinidia purpurea*: 'Purpurowaja Sadowaja' during five years of cultivation (2006-11) at the Experimental Station of the University of Warmia and Mazury (UWM) in Olsztyn.

Material and Methods

The macroelement content in fruit of *Actinidia purpurea*, *Actinidia arguta* and their hybrid forms was studied in the period between 2006 and 2011. Fruit for analysis was taken from bushes of cultivars whose fruit were picked in the 10th, 12th, 13th, 14th, and 15th years of vegetation. Microelements determined in 2006-09 included zinc, coppers and manganese. No fruit analyses were performed in 2007 because the spring frost froze the flowers of the cultivars under investigation, i.e. a cultivar of *Actinidia arguta* ('Sientiabrskaja'), a cultivar of *Actinidia purpurea* ('Purpurowaja Sadowaja'), and three Ukrainian hybrid cultivars ('Figurnaja,' 'Kijewskaja Gibrydnaja,' and 'Kijewskaja Krupnopłodnaja'). The experiment was set up at the experimental station of UWM in Olsztyn. Plants were planted in A-shaped support frames, spaced at 1.5 × 2 m. One-year plants were brought from the Institute of Pomiculture in Babtai, Lithuania. Five bushes of each cultivar were planted next to each other. Each bush constituted an experimental replication. Male bushes 'Bayern Kiwi' (='Weiki' – cultivar of *A. arguta*) were used as pollinators. The male-to-female bush ratio was 1:5. Fertilization was applied before planting as for all berry plants (40 t·ha^{-1} of manure and 100 kg·ha^{-1} P_2O_5 and K_2O). The plants grew in class IV, cereal-fodder strong complex soil. It is highly clayey sand with a pH of 6.85-7.52. Mineral content in the soil was as follows: N: 9.66, P: 148.84, K: 57.83, Mg: 84.18 mg·kg^{-1} of d.m. The chemical composition of the soil was determined by the universal method developed by Nowosielski [21] in 0.03 M CH_3COOH. The results of the determination are provided as the average values from the years when the study was conducted. The plants were not fertilized or treated with chemical protection agents.

The plot was weeded manually three times every year during the vegetation period. The creepers were pruned (February/March) to enhance fruit-bearing [22].

The fruit was picked at the stage of ripeness. Chemical analysis was preformed in three replications. The samples were prepared from the beginning of the course of analysis. To this end, about 0.5 kg of fruits of each cultivar was taken. Washed fruits were dried in an oven at 105ºC. The dried material was ground in a laboratory mill. Macroelements in fruits of actinidia were determined after digestion (1 g ground plant material) in wet (H_2SO_4 using a oxidant H_2O_2), however the mineralization of microelements (5 g of milled dry fruit) involved a wet mixture of acids: HNO_3 + HCl + $HClO_4$. Mineralized plant material was transferred to 50 cm^3 volumetric flasks for signs of Cu, Zn, and Mn. For the determination of macroelements mineralized material was placed in flasks quantified with a capacity of 200 cm^3. In the prepared samples were determined:

- N – by the distillation method
- P – colorimetrically, by the vanadium-molybdenum method
- K, Ca, Na – by atomic emission spectroscopy ESA
- Mg – by absorption mass spectrometry ASA
- Zn, Cu, Mn – by atomic absorption spectrometry ASA

The analyses were based on certified material CTA-VTL-2. The content of the examined macro- and micronutrients was determined according to Polish Standards [23, 24].

The following determination errors were calculated: N – 3%, P – 4.5%, K – 2%, Ca – 2.8%, Na – 7%, and Mg – 1.5%.

The results were statistically analyzed with the arithmetic average from three simultaneous determinations. The results of the chemical analyses for each year were subjected to a single-factor variance analysis. As there was no fruit in 2007 and chemical analysis of the 'Sientiabrskaja' cultivar was not performed in 2010 and 2011, the analysis of the year-dependent variation of the physicochemical parameters was not performed. Significant differences were determined by Tukey's HSD test at a level of significance of 0.01. The calculations were performed with "STATISTICA 9.1" software.

Results and Discussion

The macroelement content in the dry matter of the fruit of the actinidia cultivars under investigation is listed in Tables 1, 2, and 3. The results show that the macroelement content values can be arranged in the following sequence:

K(16.78)>N (9.8)>Ca(3.55)>P(3.2)>Mg (0.68 g·kg^{-1} of d.m.). In their studies, Latocha and Krupa [15] and Latocha [3] observed that the element content in fruit of *A. arguta* and cultivars and hybrids of *A. arguta* and *A. purpurea* followed the same sequence. Those authors did not determine the nitrogen content in their studies. The chemical composition, and especially vitamin C content in actinidia fruit, is frequently compared to that in blackcurrant fruit [1]. The concentration of minerals in blackcurrant and redcurrant fruit was examined by Grajkowski [25]; he found the following values of the macroelement content in the fruit of the blackcurrant cultivar 'Titania': K – 15.96, N – 14.33, Ca – 1.61, P – 3.86, and Mg – 0.99 g·kg^{-1} of d.m., whereas the content of those elements in the fruit of redcurrant, cultivar 'Rondom', was at the following levels: K – 16.07, N – 15.49, Ca – 1.44, P – 1.89, Mg – 0.86 $g \cdot kg^{-1}$ of d.m. Those listings show that actinidia fruit contains slightly more potassium, less nitrogen, nearly twice as much calcium, and slightly less magnesium and phosphorus than blackcurrant fruit. The concentration of the macroelements in question in redcurrants was slightly different than that in blackcurrants, except for phosphorus. Redcurrants contained the element at much lower concentrations. For comparison, the concentration of minerals in the dry matter of sweet cherries was close to the values for redcurrant; only the zinc concentration was twice lower [26]. The mean concentration of zinc in the fruit of actinidia cultivars under study was 8.61 $mg \cdot kg^{-1}$ (Table 4) and it was much higher than in redcurrants and blackcurrants, which – as determined by Grajkowski [25] – were 2.77 and 2.69 $mg \cdot kg^{-1}$, respectively.

The nitrogen content in the fruit ranged from 7.78 to 12.91 $g \cdot kg^{-1}$ of d.m. (Table 1). Higher content of the element was found in samples of fruit of the 'Sientiabrskaja' cultivar (12.21 $g \cdot kg^{-1}$ of d.m.). Concentration of nitrogen in samples of fruit of the 'Kijewskaja Gibrydnaja' cultivar was the lowest and equal to 8.96 $g \cdot kg^{-1}$ of d.m. The lowest mean nitrogen content in fruit of the cultivars was recorded in 2008 and 2010, whereas the highest was in 2009. The mean value for the years of the study was equal to 9.80 $g \cdot kg^{-1}$ of d.m.

Nitrogen is regarded as the main yield-affecting element. This stems from the role of nitrogen, which is essential in protein synthesis. The nitrogen content in blackcurrants ranged from 13.5 to 14.8 $g \cdot kg^{-1}$ of d.m. The concentration of this element in larger fruit was higher and it was lower in uncut shrubs [25].

The phosphorus content in fruit of the actinidia cultivars under study ranged from 2.0 to 5.07 $g \cdot kg^{-1}$ of d.m. (Table 1). The variability of the element content during the first two years of the study was low. In 2006 the 'Sientiabrskaja' cultivar was significantly different in terms of the phosphorus content, while no significant differences were found between the cultivars in 2008. Statistical analysis of the 2009 results identified three variability groups, whereas in 2010 and 2011 each cultivar constituted a separated homogenous group. The highest concentration of the element was found in fruit of the cultivar 'Sientiabrskaja,' while the lowest concentrations of phosphorus were found in fruit of the 'Figurnaja' and 'Kijewskaja Gibrydnaja' cultivars. Significant differences also were found during the years of study; each year constituted a separate homogenous group. The lowest values were recorded in the last year and the highest were in 2008.

Latocha and Krupa [15] conducted a study in central Poland in 2004-07 and showed dry matter of fruit of *A. arguta* and hybrid of *A. arguta* and *A. purpurea* to contain lower concentrations of phosphorus – from 0.153 to 0.4014%. Latocha [3] examined five commercially available genotypes of *A. arguta* and four genotypes produced in the breeding programme conducted at the Warsaw University of Life Sciences, including 2 hybrids with *A. purpurea* and found them to contain twice as much of the element as in fruit of *A. deliciosa* 'Hayward.'

Table 1. Nitrogen and phosphorus contents ($g \cdot kg^{-1}$ d.m.) of fruits of *Actinidia* cultivars, 2006-11.

Cultivars	N					Mean for cultivar	P					Mean for cultivar
	2006	2008	2009	2010	2011		2006	2008	2009	2010	2011	
Figurnaja	9.97 b*	9.96 c	9.84 c	8.34 a	9.07 a	9.43 b	3.17 a	3.90 a	2.47 a	2.97 a	2.42 b	2.99 a
Kijewskaja Gibrydnaja	9.57 b	7.78 a	8.12 b	9.09 ab	10.26 b	8.96 a	3.58 a	4.12 a	2.41 a	3.05 b	2.00 a	3.03 a
Kijewskaja Krupnopłodnaja	9.74 b	8.64 b	11.54 a	8.73 a	9.04 a	9.53 b	3.46 a	4.02 a	2.84 b	2.29 d	2.77 c	3.28 b
Purpurowaja Sadowaja	8.11 a	8.04 ab	11.16 a	9.69 b	12.52 c	9.90 c	3.39 a	3.76 a	2.87 b	3.14 c	2.48 b	3.13 ab
Sientiabrskaja	12.91 c	10.89 d	12.82 d	X[2]	X[2]	12.21 d	5.07 b	4.17 a	3.18 c	X[2]	X[2]	4.14 c
Mean for year	10.06 b	9.06 a	10.70 c	8.96 a	10.21 b	-	3.73 d	3.99 e	2.75b	3.11 c	2.42 a	-

* Means followed by the same letters do not differ at α=0.01

[2] lack of data due to the lack of fruit for analysis

Potassium content during the years of study also fluctuated considerably (Table 2). It was the lowest in 2010 and the highest in 2011. The highest significant amount of the element was accumulated in fruit of the 'Purpurowaja Sadowaja' cultivar and the lowest was in fruit of the 'Figurnaja' cultivar. Similar concentrations were found in the cultivars 'Kijewskaja Gibrydnaja' and 'Sientiabrskaja'. The 'Kijewskaja Krupnopłodnaja' cultivar constituted a separate group with only a slightly lower value than the mean value found for fruit of the 'Purpurowaja Sadowaja' cultivar.

The study conducted by Latocha and Krupa [15] and Latocha [3] showed the potassium content to vary between different years of study. The authors determined the element content in dry matter of the fruit to range from 0.62 to 1.94% and the values were lower than in the fruit of *A. deliciosa* 'Hayward', whose dry matter contained 2.08% of potassium. The potassium content in this study was higher – it ranged from 8.21 to 25.08 $g \cdot kg^{-1}$ of d.m.

Potassium plays an important role in muscle contraction and nerve transmission in maintaining the body's proper electrolyte and pH balance. When potassium is deficient in the diet, the activity of body muscles and nerves can become compromised [18].

The concentration of calcium in the fruit of the actinidia cultivars varied both over the years of study and from cultivar to cultivar (Table 2). It was the lowest in fruit of the 'Figurnaja' and 'Kijewskaja Gibrydnaja' cultivars and it was the highest in the 'Sientiabrskaja' cultivar. The highest concentrations of Ca were found in fruit during the first two years of study, whereas the concentration of this element in two subsequent years of the study was the lowest. It increased to 3.47 $g \cdot kg^{-1}$ of d.m. in the last year of study.

Latocha and Krupa [15] and Latocha [3] found similar concentrations of calcium (from 0.177% of d.m. to 0.57% of d.m.) in the genotypes of *A. arguta* and *A. purpurea* examined at Warsaw University of Life Sciences in 2004-07. The authors found considerable differences in the calcium content between genotypes, and it was more than three times higher than in fruit of *A. deliciosa* 'Hayward', which was equal to 0.161% of d.m.

Calcium is essential for normal growth and maintenance of human bones and teeth. Hardy kiwifruit berries are a source of calcium without the additional fat of dairy products [20, 27].

The magnesium content was the lowest in the last year of study and it was the highest in 2010 (Table 3). Fruit of hybrid cultivars of *A. arguta* and *A. purpurea* contained magnesium at lower concentrations. Of the three cultivars, the 'Kijewskaja Krupnopłodnaja' cultivar was found to contain the lowest and most stable concentrations of magnesium. The 'Figurnaja' and 'Kijewskaja Gibrydnaja' cultivars contained magnesium at similar concentrations and they were in the same homogenous group. However, based on an analysis of the data for the years of study, it is impossible to prove the stability of magnesium concentrations in fruit. In 2009 the 'Figurnaja' cultivar contained significantly higher concentrations of magnesium than in the other years of study. Only the 'Sientiabrskaja' cultivar contained

Table 2. Potassium and calcium contents ($g \cdot kg^{-1}$ d.m.) in fruits of *Actinidia* cultivars in 2006-11.

Cultivars	K					Mean for cultivar	Ca					Mean for cultivar
	2006	2008	2009	2010	2011		2006	2008	2009	2010	2011	
Figurnaja	8.69 a	12.31 a	17.08 b	8.21 a	15.27 a	12.31 a	3.99 b	3.95 a	2.57 bc	2.0 a	3.15 b	3.13 a
Kijewskaja Gibrydnaja	17.04 d	16.57 c	15.85 a	11.32 b	22.09 b	16.57 b	3.15 a	3.95 a	2.37 a	2.63 b	3.04 a	3.03 a
Kijewskaja Krupnopłodnaja	16.40 c	18.83 d	23.41 d	12.03 b	23.48 c	18.83 c	4.66 c	3.97 a	2.67 c	2.68 b	3.55 c	3.51 b
Purpurowaja Sadowaja	15.67 b	19.62 e	21.37 c	16.35 c	25.08 d	19.62 d	5.09 c	4.41 b	2.48 ab	3.54 c	3.90 d	3.88 c
Sientiabrskaja	16.0 ab	16.13 b	17.13 b	X[2]	X[2]	16.42 b	5.91 d	4.55 c	4.13 d	X[2]	X[2]	4.86 d
Mean for year	14.76 b	16.69 c	18.98 d	11.98 a	21.48 e	-	4.56 d	4.17 c	2.84 a	2.71 a	3.47b	-

* Means followed by the same letters do not differ at α=0.01
[2] lack of data due to the lack of fruit for analysis

magnesium at higher concentrations. It was similar for the 'Kijewskaja Gibrydnaja' cultivar in 2010, when a higher concentration was recorded for the 'Purpurowaja Sadowaja' cultivar of *Actidinia purpurea*. The cultivar was one of those in which the concentration of magnesium over the years of study was stable. The concentration of the magnesium in fruit of the 'Purpurowaja Sadowaja' cultivar was similar to the magnesium content in fruit of the hybrid cultivars, and was lower than in the 'Sientiabrskaja' cultivar of *A. arguta*.

Accumulation of magnesium in the fruit of the cultivars under study was comparable to its content (0.072% of d.m.) in the fruit of *A. deliciosa* 'Hayward,' found by Latocha [3]. The magnesium concentration in fruit of the genotypes of *A. arguta* and *A. purpurea* examined by the author ranged from 0.049 to 0.126% of d.m. The concentration of the element in this study ranged from 0.41 to 0.91 $g \cdot kg^{-1}$ of d.m., depending on the year and the cultivar.

Magnesium is an essential part of many enzymes responsible for the transfer of energy. Almost all human tissues contain a small amount of magnesium [20].

No significant differences between sodium content in the cultivars were found in 2006, 2008, and 2010 (Table 3). The statistical analysis showed significant differences in the years of study, with the lowest values found in 2011 and the highest in 2008. The lowest concentrations of the element were found in 'Purpurowaja Sadowaja' and 'Kijewskaja Gibrydnaja'. Only slightly higher concentrations – 0.66 $g \cdot kg^{-1}$ d.m – were found in 'Kijewskaja Krupnopłodnaja' and 'Sientiabrskaja'; the 'Figurnaja' cultivar contained significantly more sodium.

Latocha [3] found lower concentrations of sodium (from 0.008 to 0.073 % of d.m.) in fruit of the genotypes under study and he did not observe any significant differences between genotypes in 2005 or 2006. However, he found the sodium concentration to be the lowest in 2007 and observed some small, insignificant differences between the genotypes.

Sodium has been identified as having a dietary effect on blood pressure. The ratio of sodium and potassium is very important to the human body. A diet high in sodium and low in potassium can negatively impact potassium status. Many health experts recommend taking in at least three times more potassium than sodium [28]. Fortunately, the fruits of hardy kiwifruit and actinidia charta accumulated low amounts of sodium.

Zinc, copper and manganese are key microelements for body functions. Currently, much greater emphasis is being put on the importance of microelements for body functions because only by maintaining properly balanced amounts of consumed microelements can any disturbances in bodily functions be prevented. The elements were present in actinidia fruit at concentrations that form the following sequence: Zn >Cu > Mn (Table 4).

Fruit of the cultivars in question, examined in 2006 and 2008, contained similar amounts of copper: 2.1 and 2.14 $mg \cdot kg^{-1}$ d.m; the concentration of copper in 2009 increased to 3.09 $mg \cdot kg^{-1}$ of d.m. (Table 4). The lowest mean concentration was found in fruit of the 'Kijewskaja

Table 3. Magnesium and sodium contents ($g \cdot kg^{-1}$ d.m.) in fruits of *Actinidia* cultivars in 2006-11.

Cultivars	Mg					Mean for cultivar	Na					Mean for cultivar
	2006	2008	2009	2010	2011		2006	2008	2009	2010	2011	
Figurnaja	0.58 a	0.73 bc	0.84 d	0.68 a	0.50 b	0.67 b	0.68 a	0.81 a	0.72 c	0.69 a	0.70 b	0.72 b
Kijewskaja Gibrydnaja	0.77 c	0.70 b	0.57 a	0.81 ab	0.53 bc	0.68 b	0.54 a	0.78 a	0.60 a	0.60 a	0.47 a	0.60 a
Kijewskaja Krupnopłodnaja	0.63 b	0.61 a	0.68 b	0.73 ab	0.41 a	0.61 a	0.68 a	0.77 a	0.65 ab	0.56 a	0.63 ab	0.66 ab
Purpurowaja Sadowaja	0.75 c	0.78 c	0.74 c	0.85 b	0.54 c	0.73 c	0.46 a	0.74 a	0.60 a	0.66 a	0.50 ab	0.59 a
Sientiabrskaja	0.91 d	0.63 a	0.89 e	X[2]	X[2]	0.81 d	0.62 a	0.69 a	0.66 b	X[2]	X[2]	0.66 ab
Mean for year	0.73 c	0.69 b	0.74 cd	0.77 d	0.49 a	-	0.60 ab	0.76 c	0.65 b	0.63 ab	0.57 a	-

* Means followed by the same letters do not differ at α=0.01

[2] lack of data due to the lack of fruit for analysis

Krupnopłodnaja' cultivar and the highest was in 'Sientiabrskaja.' Fruit of 'Purpurowaja Sadowaja' contained copper at stable concentrations over the years of study, although the concentrations were not the highest. Concentrations of the element in the 'Figurnaja' hybrid cultivar of *A. arguta* and *A. purpurea* were not found to be very stable.

Latocha [3] determined the copper content in fruit of the genotypes that he examined to range from 2.76 to 10.56 $mg \cdot kg^{-1}$ of d.m. However, the values were lower than the amount of copper accumulated in fruit of *A. deliciosa* 'Hayward,' which contained copper at 11.85 $mg \cdot kg^{-1}$ of d.m. Copper is effective in synthesis of collagen and melanin; it is also important in immune system functioning.

The zinc content in the fruit of the cultivars under study did not differ significantly over the years of study; three variability groups were created for the cultivars (Table 4). The lowest concentrations were found in fruit of the hybrid forms of *A. arguta* and *A. purpurea*: 'Figurnaja' with the lowest concentration, 'Kijewskaja Gibrydnaja' and 'Kijewskaja Krupnopłodnaja,' which were in the same homogenous group. A third variability group with the highest values were formed by 'Purpurowaja Sadowaja' and 'Sientiabrskaja.'

The zinc content determined in this study ranged from 3.65 to 13.55 $mg \cdot kg^{-1}$ of d.m. (Table 4), whereas Latocha [3] measured values ranging from 4.3 to 27.5 $mg \cdot kg^{-1}$ of d.m. The zinc content in fruit of *A. deliciosa* 'Hayward,' determined by the same author, was equal to 4.7 $mg \cdot kg^{-1}$ of d.m.

Zinc is an important element in numerous proteins and plays an essential role in several cell functions [20]. The element is also essential in hormone functions; it is a component of insulin, which is produced by the pancreas. Zinc is important for young boys and men as an ingredient needed to make the hormone testosterone. It is necessary for healthy hair, nails, eyes, and skin.

The amount of manganese in the fruit of the cultivars under study varied significantly between the cultivars (Table 4). The lowest concentrations were found in fruit of 'Kijewskaja Krupnopłodnaja' and the highest was in 'Sientiabrskaja.' Significantly lower amounts were accumulated in the fruit in 2009, whereas the mean concentration of the element in 2006 and 2008 was similar – 1.94 and 2.04 $mg \cdot kg^{-1}$ of d.m.

According to Galan et al. [28] and Kang et al. [18], manganese is an essential element for enzymes, which are involved in carbohydrate, fat, and protein metabolism, the formation of connective tissue, bone growth, and reproductive functions.

The findings of this study, like those of studies conducted by Latochan and Krupa [15] and Latocha [3], confirm that fruits of winter hardy *Actinidia* contain high concentrations of minerals, especially K, Ca, P, and Mg, and can be classified as healthy fruits. Similar results were obtained by Okamoto and Goto [29] in their study with *A. arguta* cultivated in Japan. All tested genotypes and cultivars are much richer in minerals (excluding K and Cu) than "fuzzy" kiwifruit (*A. deliciosa* cv.'Hayward').

Table 4. Microelements (Cu, Zn, Mn) content ($mg \cdot kg^{-1}$ d.m.) in fruits of *Actinidia* cultivars in 2006-09.

Cultivars	Cu				Zn				Mn			
	2006	2008	2009	Mean for cultivar	2006	2008	2009	Mean for cultivar	2006	2008	2009	Mean for cultivar
Figurnaja	0.87 a*	1.88 a	3.50 b	2.08 ab	6.73 a	4.82 a	3.65 a	5.07 a	1.70 a	2.68 c	2.64 a	2.01 c
Kijewskaja Gibrydnaja	2.58 c	1.95 ab	3.77 b	2.77 c	8.03 ab	5.41 ab	6.73 b	6.72 b	1.55 a	1.72 b	1.63 a	1.63 b
Kijewskaja Krupnopłodnaja	1.61 b	1.76 a	2.09 a	1.82 a	6.69 a	8.14 b	7.41 b	7.41 b	1.53 a	1.31 a	1.42 a	1.42 a
Purpurowaja Sadowaja	2.61 c	2.35 ab	2.08 a	2.35 b	10.84 bc	12.89 c	11.88 c	11.87c	1.56 a	1.62 ab	1.57 a	1.58 ab
Sientiabrskaja	2.83 c	2.74 b	4.02 b	3.20 d	11.07 c	13.55 c	11.32 c	11.76 c	3.34 b	2.89 c	1.62 a	2.62 d
Mean for year	2.10 a	2.14 a	3.09 b	-	8.67 a	8.96 a	8.20 a	-	1.94 b	2.04 b	1.58 a	-

*Means followed by the same letters do not differ at α=0.01

Latocha [3] found the content of bioactive substances to be the highest in fruit of hybrid forms of *A. arguta* and *A. purpurea*, although the content of minerals in them was lower than in *A. arguta*. This may indicate the role of a genetic factor played in accumulation of minerals by the fruit.

Fruit of the hybrid forms examined in this study contained only N, Ca, Mg, and Zn at the lowest concentrations. Skripczenko [30] reports that the mean content of minerals in leaves and fruit of several actinidia species, among them 'Sientiabrskaja' (a cultivar of *A. arguta*), 'Purpurowa Sadowaja' (a cultivar of *A. purpurea*) and a hybrid actinidia cultivar named 'Kijewskaja Krupnopłodnaja.' According to that author, the fruit and leaves of the hybrid form of actinidia contain much more potassium and copper than leaves and fruit of the cultivars of *A. arguta* and *A. purpurea*. Kołbasina [31] found the content of macro- and microelements in the vegetative parts and fruit to depend on the plant species, cultivar and cultivation conditions.

The content of minerals in fruit found in the study conducted by Latocha [3] and in this study between seasons, may indicate a significant effect of environmental conditions (cultivation conditions, soil fertility and fertilization applied) on the level of their accumulation. Samadi-Maybodi and Shariat [32] examined four cultivars of *A. deliciosa* grown in various parts of Iran and found the content of micro- and macroelements to vary from cultivar to cultivar. They also observed great differences depending on the fruit parts. The content of minerals in fruit did not depend on their content in the soil.

Conclusions

1. Fruit of the cultivar of *Actinidia arguta*: 'Sientiabrskaja' contained the highest concentrations of nitrogen, phosphorus, calcium, and magnesium as well as copper and manganese.
2. Fruit of the cultivar of *Actinidia purpurea*: 'Purpurowaja Sadowaja' accumulated the largest amounts of potassium and zinc.
3. The lowest concentration of nitrogen, calcium, magnesium and zinc were found in fruit of hybrid forms of *A. arguta* and *A. purpurea*: 'Figurnaja,' 'Kijewskaja Gibrydnaja,' and 'Kijewskaja Krupnopłodnaja.'
4. Fruit of cultivars 'Figurnaja' and 'Kijewskaja Gibrydnaja' contained similar amounts of P, Ca, and Mg, whereas the differences between sodium content in them were significant. The lowest amount of sodium was accumulated in fruit of 'Purpurowaja Sadowaja' and 'Kijewskaja Gibrydnaja.'

References

1. MAROSZ A. Cultivation and yield of *Actinidia arguta* in a central Poland. In: Proceedings of the National Conference on Science-Practice. Intensification of production of berry bushes by the implementation the latest research results. "Growing blueberries and little-known berry bushes." 23 March 2012, Skierniewice, pp. 45-47, **2012** [In Polish].
2. KAWECKI Z. (Ed.). Giving fruit trees and shrubs colder climate zones. Ed. UWM. Olsztyn, pp. 173, **2005** [In Polish].
3. LATOCHA P. Morfology and using value of aktinidia arguta and hybrid cultivars of *Actinidia arguta* (Siebold et Zucc.) Planch ex. Miq., *A. arguta* × *A. purpurea* Rehd. SGGW. Warszawa, manuscript, pp.106, **2010** [In Polish].
4. LATOCHA P., JANKOWSKI P. Genotypic difference in post-harvest characteristics of hardy kiwifruit (*Actinidia arguta* and its hybrids), as a new commercial crop. Part II. Consumer acceptability and its main drivers. Food Res. Int. doi: 10.1016/j.fodres.2011.01.032. **2011**.
5. FERGUSON A.R., FERGUSON L.R. Are kiwifruit really good for you. Acta Hort. **610**, 132, **2003**.
6. NISHIYAMA I., YAMASHITA Y., YAMANAKA M., SHIMOHASHI A., FUKUDA T., OOTA T. Varietal difference in vitamin C content in the fruit of kiwifruit and other Actinidia species. J. Agric. Food Chem. **452**, (17), 5472, **2004**.
7. BIENIEK A. Yield, morphology and biological value of fruits of *Actinidia arguta* and *Actinidia purpurea* and some of their hybrid cultivars grown in north-eastern Poland. Acta Sci. Pol., Hortorum Cultus **11**, (3), 117, **2012**.
8. KAWECKI Z., BIENIEK A., TOMASZEWSKA Z., PIOTROWICZ-CIEŚLAK A., STANYS V. Yield, morphology and chemical composition of the fruit of several cultivars of *Actinidia arguta* (*Actinidia arguta* Sieb. et PLANCH). Zeszyty Naukowe Instytutu Sadownictwa i Kwiaciarstwa, **9**, 289, **2001** [In Polish].
9. KAWECKI Z., BIENIEK A., STANYS V. Growth and yield of five varieties of bower actinidia in the climatic conditions of north-eastern Poland. Scientific works of the Lithuanian Institute of Horticulture and Lithuanian University of Agriculture. Horticulture and Vegetable Growing. **23**, (2), 321, **2004**.
10. KAWECKI Z., BIENIEK A., STANYS V. Yielding and chemical composition of fruits of *Actinidia arguta* in climatic conditions of Olsztyn. Folia Univ. Agric. Stetin., Agricultura **240**, (96), 91, **2004** [In Polish].
11. KAWECKI Z., BIENIEK A. Influence of climatic conditions of north-eastern Poland on growth of bower actinidia. Scientific works of the Lithuanian University of Agriculture. Sodininkyste ir darzininkyste. **27**, (2), 307, **2008**.
12. KRUPA T., LATOCHA P. The antioxidant activity and content of witamin C and phenolic compounds in the fruits of different genotypes of actinidia (*Actinidia* Lindl.). Żywność. Nauka. Technologia. Jakość. **5**, (54), 237, **2007** [In Polish].
13. LATOCHA P., KRUPA T. Morphological, chemical and sensory analyses of promising genotypes of hardy kiwifruit (*Actinidia* Lindl.) obtained in the breeding programme at WULS. Ann. Warsaw Univ. of Life Sc. – SGGW, Horticult. And Landsc. Architect. **28**, 111, **2007**.
14. LATOCHA P., JANKOWSKI P., RADZANOWSKA J. Genotypic difference in postharvest characteristics of hardy kiwifruit (*Actinidia arguta* and its hybrids), as a new commercial crop. Part I. Sensory profiling and physiochemical differences. Food Res. Int. doi: 10.1016/j.fodres.2011.01.033. **2011**.
15. LATOCHA P., KRUPA T. The mineral composition of new genotypes of hardy kiwifruit (*Actinidia* Lindl.) bred at SGGW. Ann. Warsaw Univ. of Life Sc. – SGGW, Horticult. and Lands. Architect. **29**, 105, **2008**.
16. SKRIPCZIENKO I.W., MOROZ P.A. Actinidia (cultivars, cultivation, propagation). Nacionalnyj Botaniczeskij Sad MM Griszka, NAN Ukrainy, Kijew. **2002** [In Ukrainian].

17. DANILCENKO H., JARIENE E., GAJEWSKI M., CERNIAUSKIENE J., KULAITIENE J., SAWICKA B., ALEKNAVICIENE P. Accumulation of elements in some organically grown alternative horticultural crops in Lithuania. Acta Sci. Pol., Hortorum Cultus **10**, (2), 23, **2011**.
18. KANG I., YU SUK KIM M.D., CHOONGBAI KIM M.D. Mineral deficiency in patients who have undergone gastrectomy. Nutrition **23**, 318, **2007**.
19. EKHOLMA P., REINIVUOB H., MATTILAC P., PAKKALAB H., KOPONEND J., HAPPONEND A., HELLSTROOM J., OVASKAINENB M.L. Changes in the mineral and trace element contens of cereals, fruits and vegetables in Finland. J. Food Comp. Anal. **20**, 487, **2007**.
20. FAO/WHO. Vitamin and mineral requirements in human nutrion. Report of joint FAO/WHO expert consultation. United Nations, 341, **2004**.
21. NOWOSIELSKI O. Methods for determining fertilizer needs. PWRiL, Warszawa, 720, **1974** [In Polish].
22. LATOCHA P. Actinidia fruit and ornamental plant . Hortpress Sp. z o.o., Warszawa, 80, **2006** [In Polish].
23. PN-91/R-04014. Analysis of chemical and agricultural products. Methods of digestion of plant material for the determination of macro- and micronutrients. **1991** [In Polish].
24. Laboratory methods In chemical and agricultural stations. Part II. The study of plant material. IUNG, Puławy. **1972** [In Polish].
25. GRAJKOWSKI J. Studies on the growthy field and utility values of blackcurrant and red currant undergoing rejuvenating cutting. Treatise No. 422. Ed Uniwersytet Przyrodniczy in Poznan. Manuscript, 142, **2011** [In Polish].
26. CHEŁPIŃSKI P. Influence of selected rootstocks on growth and field and chemical composition of leaves and fruits of cherries in Western Pomerania. Treatise No. 242. Ed. Scienc. AR in Szczecin. Manuscript. **2007** [In Polish].
27. GALAN P., ARNAUD K.J., CZERNICHOW S., DELABROISE A.M., PREZIOSI P., BERTRAIS S., FRANCHISSEUR C., MAUREL M., FAVIER A., HERBERG S. Contribution of mineral waters to dietary calcium and magnesium intake in a French adult population. Research, **102**, 1658, **2002**.
28. ADROGUÈ H.J., MADIAS N.E. Sodium and potassium in the pathogenesis of hypertension. N. Engl. J. Med. **356**, 1966, **2007**.
29. OKAMOTO G., GOTO S. Juice Constituens in *Actinidia arguta* Fruits Produced in Shinjo, Okayama. Sci. Fac. Agr. Okayama Univ. **94**, 9, **2005**.
30. SKRIPCZIENKO N. State and perspectives of actinidia culture development in Ukraine. Procedings of 9th International Conference of Horticulture, September 3th-6th 2001 Lednice, Czech Republic, ISBN 80-7157-524-0, **1**, 219, **2001**.
31. KOŁBASINA E.I. Actinidia and Schizandra chinese. Niola –Press, Moskwa, pp.175, **2007** [In Russian].
32. SAMADI-MAYBODI A., SHARIAT M.R. Characterization of elemental composition in kiwifruit grown in northern Iran. J. Agric. Food Chem., **51**, 3108, **2003**.