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Actinidia (mini kiwi) fruit quality in relation to summer cutting

Monika FIGIEL-KROCZYŃSKA[*], Ireneusz OCHMIAN[*], Sabina LACHOWICZ[**], Marcelina KRUPA-MAŁKIEWICZ[***], Jacek WRÓBEL[****], Renata GAMRAT[*****]

[*]Department of Horticulture, West Pomeranian University of Technology Szczecin, Słowackiego 17 Street, 71-434 Szczecin, Poland;
Monika Figiel-Kroczyńska; monika.figiel-kroczynska@zut.edu.pl ORCID 0000-0003-4378-4004; Ireneusz Ochmian; iochmian@zut.edu.pl, ORCID 0000-0002-3606-1927,
[**]Department of Fermentation and Cereals Technology, Wroclaw University of Environmental and Life Sciences, Chełmońskiego 37 Street, 51-630 Wrocław, Poland; Sabina Lachowicz; sabina.lachowicz@upwr.edu.pl, ORCID 0000-0001-6182-0211
[***] Department of Genetic, Plant Breeding and Biotechnology, West Pomeranian University of Technology Szczecin, Słowackiego 17 Street, 71-434 Szczecin, Poland; mkrupa@zut.edu.pl ORCID 0000-0002-4333-9122
[****]Department of Bioengineering, West Pomeranian University of Technology Szczecin, Słowackiego 17 Street, 71-434 Szczecin, Poland; jwrobel@zut.edu.pl
[*****]Department of Environmental Management, West Pomeranian University of Technology Szczecin, Słowackiego 17 Street, 71-434 Szczecin, Poland

Corresponding author: Ireneusz OCHMIAN, iochmian@zut.edu.pl

ABSTRACT: Recently, there has been a trend towards healthy food. Consumers are looking for products that have health-promoting properties in addition to their taste. Actinidia fruit, apart from being tasty, contains valuable nutrients. They are high in vitamin C, polyphenols, and pectins and low in calories. These pro-health properties allow kiwiberry fruit to qualify in the group of so-called superfoods. All tested cultivars belong to two species of Actinidia, well tolerating conditions of moderate climate with negative temperatures in winter. The cultivars differed significantly in mineral content, color, firmness, weight and content of antioxidant substances. Summer pruning (lightening) increased the content of N, P, K, extract, and NO_3 and resulted in darker fruit color. However, it slightly decreased the content of polyphenols. 'Sientiabrskaja' can be recommended for consumption as the cultivar richest in polyphenols and with the highest health-promoting values.

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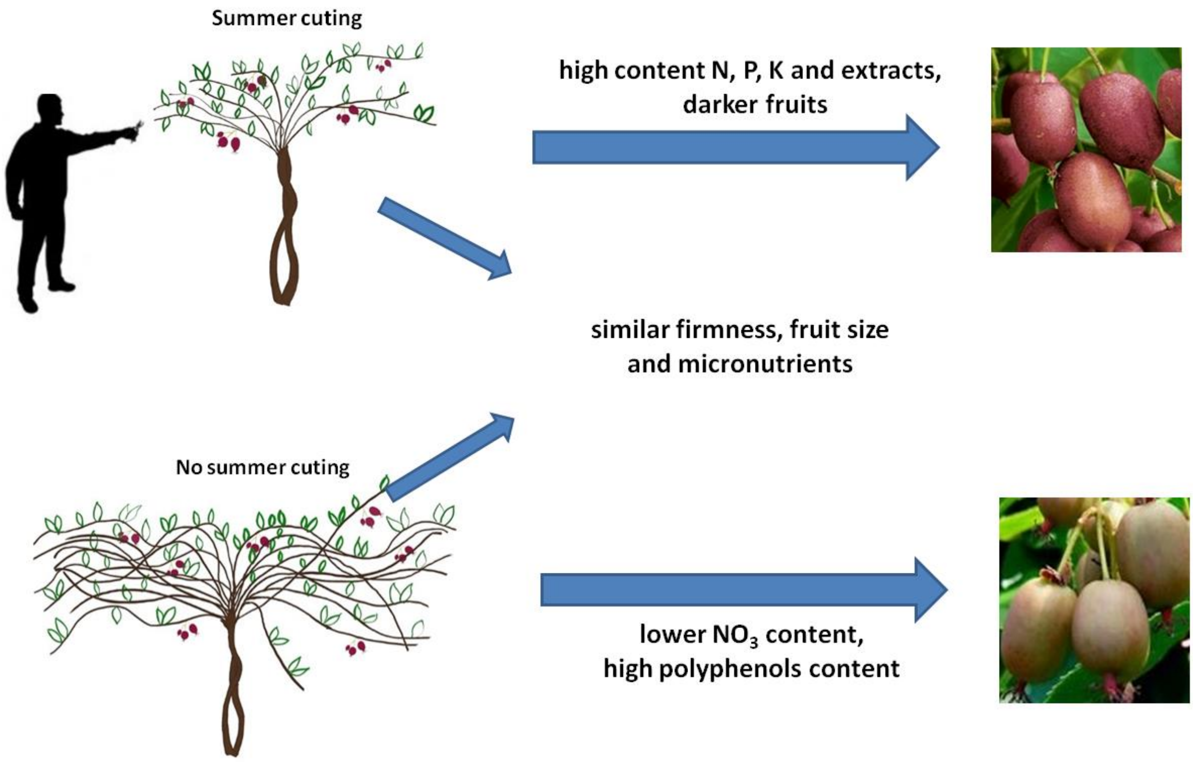

Key words: *Actinidia arguta, Actinidia kolomikta*, colour, firmness, fruit quality, mineral content, polyphenols

Highlights

Fruit quality is strongly influenced by cultivar origin

Additional pruning improves fruit physical parameters, but decreases polyphenol content

Summer pruning influences the content of mineral compounds in fruits

Green fruits have the most polyphenolic compounds

1. INTRODUCTION

The Actinidia genus includes more than 60 species (Nishiyama et al., 2004a). The most common species in the genus are *Actinidia deliciosa*, *A. chinensis, A. eriantha*, *A. arguta*, *A. kolomikta* and *A. purpurea*, which can also grow in colder regions due to their high frost resistance, down to -30 °C (Chesoniene et al., 2004). A common feature of all species of the genus Actinidia is that they fruit only on annual shoots (Volz et al., 1991). Actinidia has shoots with very strong, intensive growth. Annual growth reaches up to (2-3) m.

A. arguta and *A. kolomikta* are perennial, mostly dioecious plants. Their origin is Asia, and they are mainly cultivated there (Guan et al., 2011). More recently, the fruits of these species have been commercially available under different names: kiwiberry, hardy kiwi, baby kiwi, grape kiwi or mini kiwi (Nishiyama et al., 2004a; Latocha, 2017). They can be eaten raw and whole, in jam form, or made into wine (Latocha, 2017). Contrary to the most popular kiwi (*A. chinensis*), the fruits of these species are very sweet, aromatic and small (grape-sized), with thin skin. They are smooth and devoid of mesquite, and thus they can be eaten whole without peeling (Nishiyama et al., 2004a; Latocha, 2017). The skin color is mostly green, but cultivars with red coloring are also available (Latocha, 2017).

‘Baby’ kiwi fruit is classified as a so-called superfood. These fruits have strong antioxidant and anti-inflammatory effects, influenced by the biologically active substances they contain (Drummond, 2013). They are low in calories, and in China, the leaves and fruits of *A. kolomikta* are used as a medicine for diabetes (Guan et al., 2011; Lu et al, 2019; Drummond, 2013). They are a natural antioxidant because they contain vitamins, phenolics, and carotenoids (Thaipong et al., 2006). *A. arguta* fruits are a better source of health-promoting compounds than popular kiwi fruit (*A. deliciosa* or *A. chinensis*) or fruits of other popular plant species (Latocha, 2017). Kiwiberry fruits are rich in vitamin C (150 mg/100 g FW on average) and β-carotene. They also contain significant amounts of B vitamins, especially B8 (myo-inositol), at the highest level among all foods - 0.575-0.982 g/100 g FW, and vitamin E (4.6-5.3 mg/100 g FW) (Nishiyama et al., 2008; Latocha, 2017; Zuo et al., 2012). Some hybrids, such as Issai, are particularly rich in vitamin C (up to 222 mg/100 g FW). Mini kiwi fruits can be considered the richest source of lutein among commercially available fruits (Nishiyama et al., 2005). Consumption of mini kiwis may reduce some risk factors associated with cancer.

Rush et al. (2006) reported that the protective effects of kiwi fruit on DNA repair persist for up to 24 hours, not just immediately after kiwi consumption. Due to their high fiber content, consumption of *A. arguta* and *A. kolomikta* fruits normalizes intestinal peristalsis and helps to regulate metabolism (Nishiyama et al., 2004b). The health-promoting value of kiwi fruit is highly dependent on climate, soil conditions and agrotechnology (Leontowicz et al., 2016). Growth regulation is an important tool to maintain plant control and produce fruit of adequate quality (Strik, 1998). Lack of adequate pruning during dormancy and summer results in the formation of a very dense crown, with fruits heavily shaded (Tiyayon and Strik, 2004).

The concept of oxygen free radicals and oxidative stress is currently commonplace. In the last two decades, there has been explosive interest in the role of oxygen free radicals, generally known as "reactive forms of oxygen" (Valko et al., 2006). The fast pace of life and stress are not indifferent to our body. We are increasingly seeing the emergence of cancer in society. We are therefore looking for solutions that show an antioxidant effect. Many plants, mainly fruits and leaves, have such an effect. Vitamin C is an important nonenzymatic antioxidant substance. Its antioxidant activity cooperates mainly with vitamin E and carotenoids, as well as with antioxidant enzymes (Valko et al., 2006). Both total polyphenols and vitamin C are major components of the total antioxidant capacity of Actinidia fruit (Du et al., 2009), and β-carotene has been shown to have proapoptotic effects in colon cancer and leukemia cells and to prevent cervical carcinogenesis (Muto et al., 1995 and Karas et al., 2000). DPPH$^{\bullet}$, ABTS, FRAP and ORAC tests are used to assess the antioxidant capacity of fresh fruits, vegetables and foods (Valko et al., 2006). Thaipong et al. (2006) showed that the FRAP technique was reproducible, simple and fast. It showed the highest correlation with both ascorbic acid and polyphenolic compounds.

The high biological value and frost resistance of *A. arguta* and *A. kolomikta* are causing increased interest in the cultivation of this plant among fruit growers in eastern and central Europe. They represent an alternative to kiwi fruit imported from countries with very warm climates. The experiment investigated whether additional shoot pruning (better fruit

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illumination) before harvesting has an effect on changes in physicochemical properties of fruit of cultivars derived from *A. arguta* and *A. kolomikta.*

2. MATERIAL AND METHODS

2.1. Characteristics of the area of research and plant material

The experiment was conducted in the Department of Horticulture at West Pomeranian University of Technology in Szczecin in the 2016-2019 growing season, located in the northwestern part of Poland.

Four cultivars belonging to two species of the Actinidia family were studied in the experiment. The *Actinidia arguta* cultivar Sientiabrskaja and *Actinidia kolomitka* cultivars Geneva, Issai and Ken's Red belong to the species.

In the area of Szczecin and in the nearby northern region, minimal temperatures range from -12 °C to -15 °C, which corresponds to values typical of zone 7B. The average temperature during the growing season (April-October) between 1951 and 2019 was 14.3 °C, and rainfall was approximately 350 mm (Ochmian et al., 2019).

Irrigation of the plantation was carried out annually using a permanently installed T-Tape drip irrigation line with a performance of 4.5 L/1 h/mb. The moisture content of the soil was maintained in the PF 1.8-2.1 range and was determined using contact tensiometers.

The soil in the orchard was an agricultural soil with a natural profile developed from silt-loam with a pH of 6.9. The soil in which the shrubs grew was characterized by a high content of P (88 mg/kg), K (145 mg/kg) and Mg (66 mg/kg). Every spring, nitrogen fertilization was used at a dose of 60 kg N.

2.2. Weather conditions during the experiment

Significant differences in weather were observed between 2016 and 2019. During this period, the weather was significantly different from that typical for this region. The average temperature from April to October was 0.1 to 1.5 °C higher than the average temperature over a long period (1951–2012). In 1950–1989, the average temperature in the vegetation period was 13 °C (Schernewski, 2011), but in some years, it did not even reach 12.5 °C. Between 1990 and 2006, the average temperature in the growing season increased to 13.8 °C but never fell below 13.5 °C. Precipitation varied over the years and in individual months. Extremely low precipitation occurred in 2018, especially during the fruit ripening period, in August and September (Table 1).

Table 1. Temperature and rainfall in the period from April to October (vegetation season) in 2016–2019 compared to the multiannual period (1951–2012) in Szczecin.

	Month							
	IV	V	VI	VII	VIII	IX	X	Mean
Year	average temperature (C°)							
2019	10.1	12.1	21.5	18.8	20.1	14.5	10.7	**15.4**
2018	12.3	16.6	18.5	20.2	20.1	15.4	10.3	**16.2**
2017	6.8	13.5	16.8	17.2	17.9	13.3	11.0	**13.8**
2016	8.8	15.7	18.5	19.0	17.8	16.8	8.6	**15.0**
1951–2012	8.0	13.0	16.4	18.2	17.6	13.8	9.2	**13.7**
	rainfall (mm)							Total
2019	10.7	68.7	70.8	23.5	41.8	39.4	46.1	**301**
2018	26.8	22.5	15.0	92.8 79/3 days	21.4	16.3	20.2	**215.0**
2017	42.3	99.2	118.1	182.4	145.4	31.6	95.1	**714.1**
2016	20.2	18.9	69	50.1	47.8	18.3	55.3	**279.6**
1951–2012	39.7	62.9	48.2	69.6	74.2	58.7	37.3	**390.6**

2.3. Cutting plants

The main cut was made in winter, in the state of dormancy. All shoots that crossed each other, thickened the plant or grew from below were removed. The first backlighting cut was made annually at the turn of May and June. This cut was intended to remove shoots that did not finish growing. They grow throughout the season and thicken the shrubs, which limits the access of light. The second backlighting cut was made at the turn of July and August. This cut was aimed at better lighting of the fruit and was supposed to influence better setting of flower buds, from which fruit will develop in the next year. The shoots on which there was no fruit were cut at the base, leaving approximately 5 mm stubs.

2.4. Elemental analysis

The estimation of the content of minerals in dry weight plants was carried out in accordance with the Polish Standard (IUNG 1990) using certified reagents (Chempur, Poland; Merck, Germany). All tests were performed each year in three replications. After harvest, we prepared a collective sample that was dried and ground.

The contents of elements in fruits were determined after mineralization: N, P, K, Ca and Mg were measured after wet mineralization in H_2SO_4 (96%) and $HClO_4$ (70%). The contents of Cu, Zn, Mn, Fe, and Se were determined after mineralization in HNO_3 (65%) and $HClO_4$ (70%) at a ratio of 3:1.

The total nitrogen concentration in plants was determined by the Kjeldahl distillation method using a Vapodest 30 (Gerhardt GmbH, Germany). The K content was measured with atomic emission spectrometry, and the Mg Ca, Cu, Zn, Mn and Fe contents were measured with flame atomic absorption spectroscopy using iCE 3000 Series (Thermo Fisher Scientific, UK). Phosphorus (P) was assessed by the colorimetric method on a Specol 221 apparatus (Carl Zeiss, Germany) (Ochmian et al., 2018). The Se concentration was measured fluorometrically using an RF-5001 PC Shimadzu spectrophotofluorometer. The excitation wavelength was 376 nm, and the fluorescence emission wavelength was 518 nm.

2.5. General fruits parameters

Every year, the measured fruit weight was measured (RADWAG WPX 4500 ±0.01 g).

The content of soluble solids was determined by an electronic refractometer (PAL-1, Atago, Japan).

Acidity was determined by titration of aqueous extract with 0.1 N NaOH to an end point with pH 8.1 (Elmetron CX-732), according to the PN-90/A-75101/04 standard.

Dry matter content was determined according to the relevant Polish Standard (PN-90/A-75101/03, 1990). Dry weight content was measured after drying at 65 °C, with 3 repetitions of 250 grams from each combination.

The L-ascorbic acid and nitrate contents were measured with an RQflex 10 requantometer (Merck) (Mijowska et al., 2016).

Pectin content was analyzed according to the Morris method described by Pijanowski et al. (1973).

The content of provitamin A in fruits was determined by high-performance liquid chromatography with UV and fluorescence detection (Knauer K-1001 pump and Knauer K2001 UV detector - Knauer GmbH Berlin/Germany); Beckman ODS column (5 μm), dimensions 150×4.6 mm, column temperature 25 °C) (Kruczek et al., 2020).

The firmness of fruits was measured on fresh berries immediately after harvest. Fruit diameter and firmness were measured with a FirmTech2 apparatus (BioWorks, USA) of 100 randomly selected berries from three replicates. The result was expressed as a gram-force causing the fruit surface to bend 1 mm.

2.6. Determination of colour

The pigment (color) of fruits was measured in transmission mode by a photocolorimetric method in a CIE *L*a*b** system (Chełpiński et al. (2019). The diameter of the measurement hole was 3 mm, the observer type was 10° and the illuminant was D65. The value of *a** indicates the surface color of dried fruits of analyzed genotypes in the range from green (-*a**) to red (+*a**). The parameter *b** describes the color in the range from yellow (+*b**) to blue (-*b**). The value of parameter *L** means monochromaticity in the range from 0 (black) to 100 (white).

2.7. Extraction procedure and identification of phenolic compounds, antioxidant activity

Fruits were then prepared and analyzed according to the methodology of Oszmiański et al. (2018). The fruits were extracted with methanol acidified with 2.0% formic acid. Separation was conducted twice by incubation for 20 min under sonication (Sonic 6D, Polsonic, Warsaw, Poland). The sample was shaken several times. Subsequently, the suspension was centrifuged (MPW-251, MPW MED. INSTRUMENTS, Warsaw, Poland) at 19 000×g for 10 min. Prior to analysis, the supernatant was additionally purified with a Hydrophilic PTFE 0.20 µm membrane (Millex Samplicity Filter, Merck). All extractions were carried out in triplicate.

Analyses were performed according to the methodology of Oszmiański et al. (2018). In kiwiberry fruit extracts, polyphenol identification was executed using an ACQUITY Ultra Performance LC system appointed with a binary solvent manager, a photodiode array detector (Waters Corporation, Milford, MA, USA) and a G2 Q-TOF micro mass spectrometer (Waters, Manchester, UK) equipped with an electrospray ionization (ESI) source operating in both negative and positive modes.

2,2'-azo-bis-3-ethylbenzothiazoline-6-sulfonic acid ($ABTS^{\bullet}+$) was used to observe the enzyme kinetics of assays Arnao et al. (2001). Additionally, $DPPH^{\bullet}$ (1,1-diphenyl-2-picrylhydrazyl) and the ferric reducing antioxidant property (FRAP) were also determined (Shimada et al., 1992; Benzie and Strain, 1996). The antioxidant capacity was expressed as millimoles of Trolox per 100 g distilled water. $ABTS^{\bullet}+$ and FRAP assay measurements were carried out on a UV-2401 PC spectrophotometer. The determination was performed in three repetitions.

2.8. Statistical Analysis

All statistical analyses were performed using Statistica 13.0 (StatSoft Polska, Cracow, Poland). Nonparametric methods (Kruskal–Wallis test) were used if neither the homogeneity of variance nor the normality of distribution was established previously. Statistical significance of the differences between means was determined by testing the homogeneity of variance and normality of distribution, followed by ANOVA with Tukey's post hoc test. The significance was set at $p<0.05$.

3. RESULTS AND DISCUSSION

3.1. Mineral compounds in Actinidia fruits

The study of the chemical composition of fruits considered food is important from a nutritional and toxicological point of view. The mineral composition of kiwiberry is quite variable and depends on its genetic characteristics (cultivar) and growth conditions - soil, weather (Latocha, 2017). The contents of macronutrients and trace elements are presented in Table 2 and Table 3.

The main components of Actinidia fruit were K, N and, in smaller amounts, P, Ca and Mg (Table 2). A different order for macronutrients and micronutrients for kiwiberry was presented by Latocha (Latocha, 2017): macronutrients K> Ca> P> Mg> Na and micronutrients Fe> Zn> B> Mn> Cu. Only the cultivar Ken's Red confirmed these results for micronutrient content; in the other three cases, the Cu content was significantly higher than Mn (Table 3). The fruits of the Sientiabrskaja cultivar were rich in nitrogen and phosphorus, while they had the least potassium, quite the opposite of the Ken's Red cultivar. Differences in the levels of these elements were 28, 33 and 37%, respectively. In addition, the fruits of this cultivar were characterized by the lowest calcium content, as much as 37% lower than that of the Issai cultivar (Table 2). The calcium content also has an effect on the firmness of the fruit, and this relationship can be seen in the cultivar Sientiabrskaja, whose fruits are the softest (Table 4). Nitrogen and phosphorus contents in the fruits of the cv. Sientiabrskaja did not differ significantly from the study of Bieniek (2012), with nitrogen at 12.21 and phosphorus at 4.14 units. The second cutting had no effect on the content of calcium and magnesium in the mini kiwi fruit, while there was an increase in nitrogen, potassium and phosphorus. However, there was no effect of the second cut on changes in the content of the studied micronutrients in the fruit. However, very large differences were found in the content of micronutrients in the fruits of the studied cultivars (Table 4). The greatest differences were found in selenium. In the fruits of Ken's Red cultivar, it was at the level of 0.09 mg/1000 g, while Issai fruits contained selenium at as much as 0.3 mg/1000 g. Mini kiwi fruit can be a good source of minerals and a supplement in the human diet. It has been established that the recommended daily allowance (RDA) should be 2 mg Cu, 18 mg Fe, 400 mg Mg, 2 mg Mn, 1000 mg P, 15 mg Zn and 0.04-0.07 mg Se (Nascimento et al., 2015; Regulation EU 1169/2011). Micronutrients are essential for normal human development and function. Copper is involved in supporting cardiovascular health and glucose and cholesterol metabolism (Dougnon et al., 2012). Copper is toxic to humans when the level in food products exceeds 20 mg/1,000 g. In humans, a deficiency is more unfavorable than an excess of copper, as it disturbs many processes. Iron is an essential micronutrient due to its high functionality. There are no standards defining the acceptable level of Zn in food products. In not very large amounts, it is necessary for the proper functioning of living organisms. According to SCF (1993), it would be unwise to exceed the daily intake of 30 mg in adults. There is little chance of an overdose of copper, zinc, manganese or selenium from the consumption of mini kiwis. The results indicate that on average, approximately 1 kg of fruit meets the daily human requirement for these nutrients, but the micronutrients are absorbed by humans only to a small extent. Selenium is a component of selenoproteins, some of which have important enzymatic functions (Sunde and Raines, 2011). In the case of selenium, the recommended standard and the toxic dose to the body are very similar. If the concentration of this element is exceeded, so-called selenosis occurs, which can be symptomised by hair loss, mood changes, fatigue, weight loss, and a characteristic odor from the mouth, similar to that after eating garlic. With long-term selenosis, damage to the nervous system can occur. Other serious consequences of selenium poisoning are cirrhosis of the liver and swelling of the lungs. Medicine is also aware of fatal cases of selenosis (Ramaekers et al., 1994). Selenium intake in the human diet also varies from high to low depending on geographical location. Human diseases associated with selenium deficiency have been recognized in some regions: Keshan's disease, endemic cardiomyopathy, and Kashin-Beck disease, deforming arthritis, were first identified in an area of China where the soil is extremely selenium deficient (Reilly, 1996). Selenium enters the food chain through plants, which take it up from the soil. Selenium deficiency has therefore been identified in parts of the world characterised by low soil selenium content, such as the volcanic areas of Europe. In general, it was found that the fruit, especially the Issaki cultivar, was rich in this element. The content was similar to some mushrooms, which are rich in this element (Falandysz and Lipka, 2006). They had a higher content than most vegetables but a lower content than nuts (Fairweather-Tait et al., 2010).

Table 2. The contents of macronutritiens in Actinidia fruits depending on the number of summer cuts

Compounds (g/kg)		Cultivar				
		Sientiabrskaja	Genewa	Issai	Ken's Red	**Mean**
	summer cuts					
N	1 cut	9.88f	9.04d	8.15c	7.06a	**8.53A**
	2 cuts	10.23g	9.41e	8.37c	7.45b	**8.87B**
	mean	**10.06D**	**9.23C**	**8.26B**	**7.26A**	
P	1 cut	4.95e	3.89b	4.34cd	3.11a	**4.07A**
	2 cuts	5.11e	4.20c	4.42d	3.64b	**4.34B**
	mean	**5.03D**	**4.04B**	**4.38C**	**3.37A**	
K	1 cut	14.21a	17.23d	15.06b	17.60e	**16.03A**
	2 cuts	15.18b	18.02f	15.87c	17.99f	**16.77B**
	mean	**14.70A**	**17.63C**	**15.47B**	**17.80C**	
Ca	1 cut	2.79a	4.58e	4.11d	3.45c	**3.73A**
	2 cuts	2.83a	4.22d	4.87f	3.03b	**3.74A**
	mean	**2.81A**	**4.40C**	**4.49C**	**3.24B**	
Mg	1 cut	0.94d	0.57b	1.04e	0.83c	**0.85A**
	2 cuts	0.88cd	0.49a	1.23f	0.81c	**0.85A**
	mean	**0.91BC**	**0.53A**	**1.13C**	**0.82B**	

*Means followed by the same letter do not differ significantly at P= 0.05 according to Tukey multiple range; lower-case letters indicate interaction and capital letters the main factors

Table 3. The contents of micronutrients in leaves and fruits of Actinidia.

Compounds (mg/kg)		Cultivar				
		Sientiabrskaja	Genewa	Issai	Ken's Red	**Mean**
Fe	1 cut	14.07b	12.37a	15.71c	21.44e	**15.90A**
	2 cuts	14.22b	12.52a	15.88c	21.06d	**15.92A**
	mean	**14.15B**	**12.45A**	**15.80C**	**21.25D**	
Zn	1 cut	11.89h	5.44a	6.12d	6.88f	**7.58A**
	2 cuts	11.05g	5.63b	5.91c	6.36e	**7.24A**
	mean	**11.47D**	**5.54A**	**6.02B**	**6.62C**	
Mn	1 cut	2.55e	1.57a	1.73b	2.11c	**1.99A**
	2 cuts	2.34d	1.88b	1.52a	2.40d	**2.04A**
	mean	**2.45C**	**1.73A**	**1.63A**	**2.26B**	
Cu	1 cut	3.84b	4.50e	4.02c	1.62a	**3.50A**
	2 cuts	3.79b	4.28de	4.19d	1.72a	**3.50A**
	mean	**3.82B**	**4.39D**	**4.11C**	**1.67A**	
Se	1 cut	0.13c	0.23d	0.29e	0.09a	**0.19A**
	2 cuts	0.11b	0.19c	0.31f	0.08a	**0.17A**
	mean	**0.12B**	**0.21C**	**0.30D**	**0.09A**	

* for explanation, see Table 2

3.2. Fruit color and quality in Actinidia fruits

The color of the skin of mini kiwi fruits and their flesh varies between cultivars (Latocha, 2017). The fruits of most cultivars are green, but there are also cultivars with a red blush and fruits with a brown-red color. Fruit color affects the appearance and consumer acceptance of the fruit. The lightest fruits were of the Sientiabrskaja cultivar (50.6 and 48.5), and the darkest were of the Ken's Red cultivar (25.9 and 29.1). They were determined by the parameter L*, whose value range is from 0 (black) to 100 (white) (Ochmian et al., 2012). There was a significant effect of the second cut on fruit color, as indicated by the parameter a*, whose value ranged from 7.2 (1st cut) to 9.7 (2nd cut) (Table 4). The fruit after the first cut was greener. After the second cut, a reddish-brown blush or even coloring of the skin appeared. This is a normal process as the fruit gradually ripens. The values of the L* and a* parameters did not change significantly after the second cut. There were also significant differences in the fruit color of the tested cultivars. The fruit of 'Sientiabrskaya' is definitely the greenest (-29.9), while Ken's Red is brown-black (49.6), which is reflected in the botanical description of these cultivars. In addition, the fruits of the 'Sientiabrskaja' cultivar showed the highest value of the b* parameter. Fruit firmness is a basic aspect during storage and transport. It affects the resistance to mechanical damage. It is a characteristic of the cultivar but also depends on the size of the fruit (Ochmian and Kozos, 2015). The initial visual assessment of the fruit can influence consumer decisions. Characteristics such as color and firmness mainly determine purchase and consumption. The fruit of 'Ken's Red' after the first cut were the firmest and up to approximately 37% firmer than the soft fruit of 'Sientiabrskaja' after the second cut (Table 4). This may result in lower suitability of 'Sientiabrskaja' fruits for logistical purposes and for sale in unprocessed (raw) form.

Table 4. Color of leaves and fruits and the quality of Actinidia fruits

Compounds			Cultivar				
			Sientiabrskaja	Genewa	Issai	Ken's Red	**Mean**
Color parameters CIE fruit	*L**	1 cut	50.6f	42.5d	43.8d	29.1b	**41,5A**
		2 cuts	48.5e	42.0d	39.5c	25.9a	**39,0A**
		mean	**49.5C**	**42.2B**	**41.6B**	**27.5A**	
	*a**	1 cut	-29.4b	18.4c	-7.8a	47.5e	**7,2A**
		2 cuts	-30.4b	24.6d	-7.0a	51.8f	**9,7B**
		mean	**-29.9A**	**21.5C**	**-7.4B**	**49.6D**	
	*b**	1 cut	37.2f	24.8a	28.8b	31.6d	**30,6A**
		2 cuts	34.6e	28.9b	29.7b	30.8cd	**31,0A**
		mean	**35.9C**	**26.8A**	**29.2B**	**31.2B**	
Firmness (G/mm)		1 cut	112b	125b	144cd	155d	**134A**
		2 cuts	98a	119b	140c	148cd	**126A**
		mean	**105A**	**122B**	**142C**	**151C**	
Weight of 100 fruits (g)		1 cut	631c	788d	548ab	557b	**631A**
		2 cuts	616c	792d	519a	531ab	**615A**
		mean	**624B**	**790C**	**534A**	**544A**	

* for explanation, see Table 2

The weight of 100 fruits of the studied cultivars ranged from 519-792 g for ‘Geneva’ and ‘Issai’ (Table 4). The average fruit weight of the Geneva cultivar was 34% lower than that of the Issai cultivar. 'Sientiabrskaja' had fruit with a mean weight (624 g), while 'Ken's Red' was not significantly different from 'Geneva'. Bieniek (2012) obtained lower or similar values for 'Sientiabrskaja' in individual years, 4.83-6.27 g. Leontowicz et al. (2016) obtained average fruit masses of 6.8, 7.1 and 7.4 g for the three cultivars 'Ananasnaya', 'Weiki' and 'Bingo', respectively. These are similar values that were obtained for 'Sientiabrskaya' and 'Geneva' (Table 4).

3.3. Basic physical and chemical properties of Actinidia fruits

The number of cuts significantly affected the extract content of the fruit, with an average increase of 0.3 °Bx after the second cut. The analysis shows that the Issai cultivar had the highest extract content after the second cut (14.4 °Bx). Significant differences in extract content dependent on the mini kiwi cultivar were also found. Leontowicz et al. (2016) obtained similar results of percentage extract content in fruit at 11.8% to 15.8%. Many authors indicate high

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vitamin C content in Actinidia fruit (Nishiyama et al., 2004a; Drummond, 2013; Leontowicz et al., 2016; Latocha, 2017). In this study, the L-ascorbic acid content was found to range from 41 mg/1000 g for the Ken's Red cultivar to 70 mg/1000 g for the Sientiabrskaja cultivar after the first cutting. Nishiyama et al. (2004a) obtained results of 37.3 - 184.6 mg/100 g fresh weight TAA. According to Nishiyama et al. (2004a), the consumption of 5-6 medium-sized mini kiwi fruits is required to meet the daily vitamin C content requirement for an adult. The Sientiabrskaya cultivar also had the highest total acid content. Leontowicz et al. (2016) obtained results of total acid content ranging from 1.15 to 1.59%, which allows them to be considered similar to our research results (Table 5).

Table 5. The quality, antioxidant capacity and antidiabetic activity of Actinidia fruits

Compounds		Cultivar				
		Sientiabrskaja	Genewa	Issai	Ken's Red	**Mean**
Extracts (˚Bx)	1 cut	12.8a	13.0ab	14.2cd	13.5b	**13.4A**
	2 cuts	13.3ab	13.2ab	14.4d	13.9c	**13.7B**
	mean	**13.1A**	**13.1A**	**14.3C**	**13.7B**	
Dry weight (g/100 g)	1 cut	17.4a	17.7bc	18.6dd	19.3e	**18.3A**
	2 cuts	17.5ab	17.9c	18.8	19.6f	**18.5A**
	mean	**17.5A**	**17.8A**	**18.7B**	**19.5C**	
Pectines (g/100 g)	1 cut	2.44d	2.22bc	2.25bc	1.98a	**2.22A**
	2 cuts	2.52e	2.28c	2.17b	1.91a	**2.22A**
	mean	**2.48C**	**2.25B**	**2.21B**	**1.95A**	
Total acidity (g/100)	1 cut	1.42d	1.17b	1.33c	1.21b	**1.28A**
	2 cuts	1.37cd	1.04a	1.38cd	1.18b	**1.24A**
	mean	**1.40C**	**1.11A**	**1.36BC**	**1.20AB**	
L-ascorbic acid (mg/1000)	1 cut	70d	64cd	58bc	41a	**58A**
	2 cuts	62bc	56bc	51b	43a	**53A**
	mean	**66C**	**60BC**	**54B**	**42A**	
β-carotene - provitamin A (mg/100 g)	1 cut	0.17a	0.32c	0.20b	0.37d	**0.27A**
	2 cuts	0.16a	0.34c	0.22b	0.41e	**0.28A**
	mean	**0.17A**	**0.33C**	**0.21B**	**0.39D**	
DPPH• (µmol T/g)	1 cut	17.7c	14.5b	21.3	12.5a	**16.5A**
	2 cuts	17.5c	12.8a	21.6dd	11.3a	**15.8A**
	mean	**17.6B**	**13.7A**	**21.5C**	**11.9A**	
ABTS (µmol T/g)	1 cut	32.5b	42.5	35.7c	28.9a	**34.9A**
	2 cuts	33.9b	38.6de	32.4b	28.0a	**33.2A**
	mean	**33.2B**	**40.6C**	**34.1B**	**28.5A**	
FRAP (µmol/T g)	1 cut	23.6d	17.4b	21.5c	13.6a	**19.0A**
	2 cuts	21.1c	14.6a	21.3c	14.4a	**17.9A**
	mean	**22.4B**	**16.0A**	**21.4B**	**14.0A**	
NO_3 (mg/1000 g)	1 cut	45.4e	31.7c	27.5bc	22.6a	**31.8A**
	2 cuts	57.7f	40.8d	20.9a	24.2ab	**35.9B**
	mean	**51.6C**	**36.3B**	**24.2A**	**23.4A**	

[*] for explanation, see Table 2

Other parameters that determine the effect of fruit on the human body were also determined. The Sientiabrskaya cultivar had the highest pectin, total acid, L-ascorbic acid, FRAP and harmful nitrate (NO_3) contents, while it had the lowest extract, DW and β-carotene contents. Ken's Red cultivar had the lowest pectin, L-ascorbic acid and NO_3 contents among the cultivars, while it had the highest DW and β-carotene contents. The low pectin content for Ken's Red was confirmed by (Wojdyło et al., 2017). The pectin content for the Actinidia that they tested ranged from 2.17 to 3.3%, which was not far different from the results of the present experiment, where results ranging from 1.91 to 2.52% were obtained. All three methods used in the study to determine antioxidant capacity confirmed that the fruit of the Ken's Red cultivar had the weakest antioxidant capacity. According to the ABTS method, the Geneva cultivar had the highest free radical binding capacity, as much as 40.6 µmol T/g FW. Wojdyło et al. (2017) obtained results of 4.37 mmol/100 g DW for the same cultivar. Research by Zuo et al. (2012) indicates that *Actinidia kolomikta* has stronger antioxidant activity than *A. arguta* or *A. chinensis*. The amount of pruning did not affect the change in the oxidative activity values of Actinidia fruits. The cultivars Sientiabrskaja and Issai had the highest FRAP levels, which did not differ significantly between them (Table 5). From the study, it can be concluded that the higher the SM and *β*-carotene content, the lower the pectin, L-ascorbic acid, FRAP and NO_3 contents. The pectin content for the Actinidia they tested ranged from 2.17 to 3.3%, which was not far different from the results of the experiment, where results ranging from 1.91 to 2.52% were obtained. All three methods used in the study to determine antioxidant capacity confirmed that the fruit of the Ken's Red cultivar had the weakest antioxidant capacity. According to the ABTS method, the Geneva cultivar had the highest free radical binding capacity, as much as 40.6 µmol T g FW. Wojdyło et al. (2017) obtained results of 4.37 mmol/100 g DW for the same cultivar. Research by Zuo et al. (2012) indicates that *Actinidia kolomikta* has stronger antioxidant activity than *A. arguta* or *A. chinensis*. The amount of pruning did not affect the change in the oxidative activity values of Actinidia fruits. The cultivars Sientiabrskaja and Issai had the highest level of FRAP, which did not differ significantly between them (Table 5). From the study, it can be concluded that the higher the SM and β-carotene contents are, the lower the pectin, L-ascorbic acid, FRAP and NO_3 contents are. The second cut significantly affected only the extract and NO_3 contents. For the other traits, the second cut was not significant (Table 5).

3.4. Polyphenolic compounds of Actinidia fruits

Twenty-four different polyphenols belonging to four subclasses - anthocyanins, phenolic acids, flavonols and flavan-3-ols - were identified. Thirteen showed a difference in content depending on the number of shoot cuts.

Anthocyanins are phenolic compounds that contribute to the red, blue or purple color of many fruits and are well known for their antioxidant activity (Wojdyło et al., 2017). Most kiwi fruit cultivars are characterised by the green or yellow color of the flesh of the ripe fruit. Some kiwi species and cultivars (e.g., *A. melanandra* and *A. arguta* or their hybrids) also have small amounts of red pigment-anthocyanins, varying in intensity and distribution in the fruit (Montefiori et al., 2009, Latocha 2017). The whole fruit is not necessarily red in color, and sometimes a red blush appears on the exposed fruit surfaces (Montefiori et al., 2009), as in the case of the *Actinidia arguta* cultivar named Geneva. The concentration of anthocyanins and their composition in fruit depend on environmental factors, postharvest processing and analytical methods (Wojdyło et al., 2013). The only anthocyanin aglycones detected so far in Actinidia fruits are cyanidin and delphinidin.

Fruit coloring influenced the amount of anthocyanins in the fruit. Among the tested Actinidia cultivars, three cyanidins were found: cyanidin-3-*O*-sambubioside, -hexoside and -pentoside. The cultivar Ken's Red had by far the most anthocyanins, and all 3 forms were present in it, as in the cultivar Geneva. The main anthocyanin in Ken's Red cultivar is cyanidin-3-*O*-sambubioside, as confirmed by Wojdyło et al. (2017). Only cyanidin-3-*O*-pentoside was identified in the fruits of the Sientiabrskaja cultivar, and only cyanidin-3-*O*-hexoside was identified in Issai. Additionally, according to Wojdyło et al. (2017), no cyanidin-3-*O*-sambubioside was found in the Issai cultivar, and the Geneva cultivar had a lower value of this compound - 0.7 mg/100 g DW.

Significant differences in the content of phenolic acids in the tested cultivars of Actinidia fruit were observed. Eight phenolic acids were found in the studied Actinidia fruits. The number of cuts had a statistically significant effect on four of the studied acids. The highest number of phenolic acids was found in the fruits of the cv. Sientiabrskaja (Table 6, Fig. 1). The dominant acid among the examined was caffeoyl-*O*-hexoside Tr 2. The highest value of this compound (7.47 mg/100 g) was found in the cultivar Sientiabrskaja after the first cutting. This value was almost 99% higher than that in the cultivar Kens Red after the first cut. Wojdyło et al. (2017) obtained very similar cryptochlorogenic acid values for the Issai cultivar. However, there were large differences in the cultivar Kens Red. Wojdyło et al. (2017) determined this acid at a level of 6.3 mg/100 g, while in our study, the level in the fruit was 0.03 mg/100 g. In addition, Wojdyło et al. (2017) did not report the existence of this acid in the fruit of Geneva, while in our study, it was at a level of 0.62 mg/100 g.

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Table 6. Polyphenols derivative contents in Actinidia fruits

Compounds (mg/100 g)		Cultivar				
		Sientiabrskaja	Genewa	Issai	Ken's Red	**Mean**
Cyanidin 3-*O*-sambubioside	1 cut	n.d.	1.93a*	n.d.	7.81c	**2.44A**
	2 cuts	n.d.	2.44b	n.d.	11.78d	**3.56B**
	mean	**n.d.**	**2.19A**	**n.d.**	**9.80B**	
Cyanidin 3-*O*-hexoside	1 cut	n.d.	0.14b	0.05a	0.19c	**0.10A**
	2 cuts	n.d.	0.17bc	0.02a	0.20c	**0.10A**
	mean	**n.d.**	**0.16B**	**0.04A**	**0.20C**	
Cyanidin 3-*O*-pentoside	1 cut	0.09a	0.22b	n.d.	0.35d	**0.17A**
	2 cuts	0.11a	0.25c	n.d.	0.48e	**0.21A**
	mean	**0.10A**	**0.24B**	**n.d.**	**0.42C**	
Caffeoyl-o-hexoside	1 cut	4.44e	0.41b	0.05a	2.62c	**1.88A**
	2 cuts	3.58d	0.31b	0.08a	3.85d	**1.96A**
	mean	**4.01D**	**0.36B**	**0.07A**	**3.24C**	
Caffeoyl-o-hexoside	1 cut	1.70b	1.06a	5.25e	2.62c	**2.66B**
	2 cuts	1.42b	0.89a	4.93d	2.36c	**2.40A**
	mean	**1.56B**	**0.98A**	**5.09D**	**2.49C**	
Caffeoyl-o-hexoside	1 cut	2.47de	1.81c	2.56e	1.73bc	**2.14B**
	2 cuts	2.30de	1.06a	2.22d	1.58b	**1.79A**
	mean	**2.39B**	**1.44A**	**2.39B**	**1.66A**	
Caffeoyl-malic acid	1 cut	7.47f	2.18d	0.31b	0.10a	**2.52B**
	2 cuts	5.82e	1.69c	0.28b	0.12a	**1.98A**
	mean	**6.65D**	**1.94C**	**0.30B**	**0.11A**	
Chlorogenic acid	1 cut	0.42e	0.36d	0.17a	0.27c	**0.31B**
	2 cuts	0.35d	0.22b	0.14a	0.30c	**0.25A**
	mean	**0.39C**	**0.29B**	**0.16A**	**0.29B**	
Dimethyl caffeic acid hexoside	1 cut	0.22c	0.08b	0.06ab	0.06ab	**0.11A**
	2 cuts	0.25d	0.06ab	0.05a	0.08b	**0.11A**
	mean	**0.24B**	**0.07A**	**0.06A**	**0.07A**	
Feruoylglucoside	1 cut	0.11c	0.04ab	0.02a	0.05b	**0.06A**
	2 cuts	0.13c	0.06b	0.03a	0.04ab	**0.07A**
	mean	**0.12B**	**0.05A**	**0.03A**	**0.05A**	
Cryptochlorogenic acid	1 cut	0.39d	0.60c	0.10b	0.03a	**0.28A**
	2 cuts	0.42d	0.63c	0.12b	0.02a	**0.30A**
	mean	**0.41C**	**0.62D**	**0.11B**	**0.03A**	
Rutin	1 cut	0.39c	0.15b	0.71d	0.01a	**0.32A**
	2 cuts	0.42c	0.18b	1.55e	0.03a	**0.55B**
	mean	**0.41C**	**0.17B**	**1.13D**	**0.02A**	
Quercetin 3-*O*-hexoso-rhamnoside	1 cut	1.83c	1.84c	2.16d	0.98b	**1.70A**
	2 cuts	2.04d	1.78c	2.55e	0.77a	**1.79A**
	mean	**1.94B**	**1.81B**	**2.36C**	**0.88A**	
Quecetin 3-*O*-galactoside	1 cut	0.59d	0.53cd	3.22f	0.04a	**1.10B**
	2 cuts	0.45c	0.28b	1.89e	0.03a	**0.66A**
	mean	**0.52B**	**0.41B**	**2.56C**	**0.04A**	
	1 cut	0.06ab	0.03a	1.68e	0.05a	**0.46A**

Quecetin 3-*O*-glucoside	2 cuts	0.05a	0.12b	1.23d	0.38c	**0.45A**
	mean	**0.06A**	**0.08A**	**1.46C**	**0.22B**	
Kaempferol 3-rutinoside	1 cut	0.14d	0.09bc	0.08b	0.04a	**0.09A**
	2 cuts	0.07ab	0.05a	0.25e	0.12cd	**0.12B**
	mean	**0.11B**	**0.07A**	**0.17C**	**0.08AB**	
Kaempferol 3-*O*-glucorhamnoside	1 cut	1.23e	0.70c	1.03d	0.35a	**0.83B**
	2 cuts	0.58b	0.32a	0.47b	0.51b	**0.47A**
	mean	**0.91C**	**0.51A**	**0.75B**	**0.43A**	
Kaempferol 3-*O*-galactoside	1 cut	0.52e	0.15bc	0.34d	0.10a	**0.28A**
	2 cuts	0.37d	0.11ab	0.19c	0.38d	**0.26A**
	mean	**0.45C**	**0.13A**	**0.27B**	**0.24AB**	
Kaempferol 3-*O*-glucoside	1 cut	0.17bc	0.18bc	0.19c	0.16b	**0.18A**
	2 cuts	0.10a	0.12a	0.34d	0.48e	**0.26B**
	mean	**0.14A**	**0.15A**	**0.27B**	**0.32B**	
Kaempferol 3,7-dirhamnoside	1 cut	0.06b	n.d.	0.01a	n.d.	**0.02A**
	2 cuts	0.12c	n.d.	n.d.	n.d.	**0.03A**
	mean	**0.09B**	**n.d.**	**0.01A**	**n.d.**	
Proanthocyanidin dimer	1 cut	4.13d	2.77b	3.05b	5.12e	**3.77B**
	2 cuts	3.67c	1.89a	2.28a	5.89f	**3.43A**
	mean	**2.33A**	**2.67B**	**2.33A**	**5.51C**	
Proanthocyanidin dimer	1 cut	0.83b	2.45e	1.22d	0.58a	**1.27A**
	2 cuts	1.16d	3.89f	0.87bc	0.99cd	**1.73B**
	mean	**1.00B**	**3.17C**	**1.05B**	**0.79A**	
(+)Catechin	1 cut	18.20g	10.55d	5.86b	8.64c	**10.81A**
	2 cuts	15.33f	11.57e	4.25a	10.35d	**10.38A**
	mean	**16.77D**	**11.06C**	**5.06A**	**9.50B**	
(-)Epicatechin	1 cut	5.38f	2.78b	3.92c	3.83c	**3.98B**
	2 cuts	4.89e	2.55ab	2.47a	4.52d	**3.61A**
	mean	**5.14D**	**2.67A**	**3.20B**	**4.18C**	
total	1 cut	45.46d	28.27b	28.12b	31.90b	**33.44A**
	2 cuts	38.74c	28.09b	23.74a	40.74c	**32.83A**
	mean	**42.10D**	**28.18B**	**25.93A**	**36.32C**	

* for explanation, see Table 2

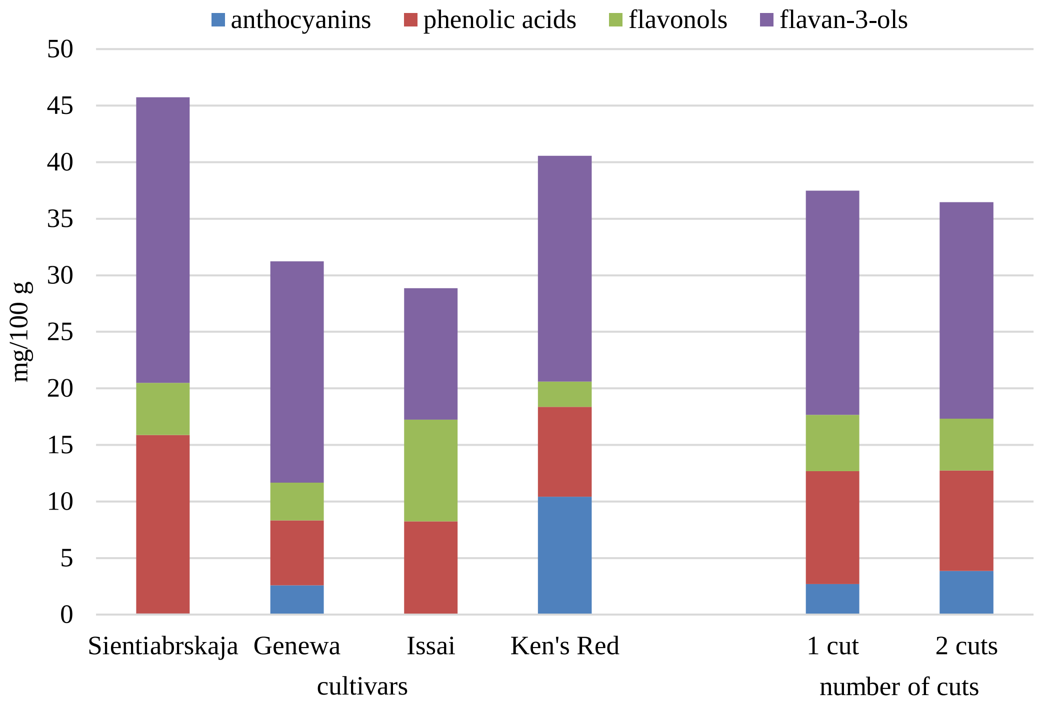

Figure 1. Sum of polyphenols in the studied cultivars of Actinidia

Nine flavonols were found. The highest contents of five of them were found in Ken's Red fruit. The number of cuts affected the values of five of the studied flavonols. The first cutting increased the content of rutin, kaempferol 3-rutinoside and kaempferol 3-*O*-glucoside. After the second cut, the contents of quercetin 3-*O*-galactoside and kaempferol-3-*O*-glucorhamnoside decreased. The largest differences occurred in the content of quercetin 3-*O*-galactoside. The amount of this compound after the first cut in the Issai cultivar was 99% higher than that for the Ken's Red cultivar after the second cut.

Of the identified flavone-3-ols, catechins were the most numerous, especially in Sientiabrskaya fruit after the first cut - 18.20 mg/100 g. The second cut caused a decrease in the content of compounds from this group (Fig. 1). The cultivar Sientiabrskaja contained the highest amount of polyphenolic compounds - 42.10 mg/100. The cultivars Issai, Geneva and Ken's Red had 38.4, 33.06 and 13.7% fewer polyphenols, respectively. Catechin had the highest amount in this group of compounds, with an average content of 19.5-39.7%. Analyzing the content of polyphenols for individual cultivars, it can be concluded that in the three cultivars, there was a decrease in their content after the second cut.

CONCLUSIONS

Actinidia fruits are a rich source of mineral compounds and bioactive substances. Fruit quality was influenced by an additional cutting of plants (the second one), performed during their ripening period. After the second pruning of Actinidia shoots, an increase in the content of N, P and K in fruits was observed. This treatment had no effect on the micronutrient content of the fruit. The second shoot pruning had a positive effect on fruit color change. The fruits were darker, especially in the cultivars Geneva and Ken's Red. This is connected with the ripening of fruits and the increase in anthocyanin content. It was not found that additional pruning had a significant effect on fruit firmness.

Fruits of the studied cultivars differed in weight, hardness and peel color. The lightest and greenest fruits were 'Sientiabrskaja', while the darkest and reddest fruits were 'Ken's Red'. The fruits of 'Sientiabrskaja' were also very soft, which could be caused by their low calcium content. However, it was characterized by high health-promoting properties - high content of pectin, L-ascorbic acid, polyphenols and antioxidant properties. The red color of 'Ken's Red' was reflected in the highest content of anthocyanin pigments, especially cyanidin-3-O-sambubioside. The content of this compound was 78% higher than that of the cultivar Geneva. This compound was not found in the cultivars Sientiabrskaja and Issai, whose fruits were green. Catechin was the most abundant of the identified polyphenols, ranging from 19.5 to 39.7% depending on the cultivar.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Compliance with ethics requirements

This article does not contain any studies with human or animal subjects.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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