

Comparison of some physico-chemical parameters of kiwiberry (*Actinidia arguta*) cultivars from a cold climate

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ABSTRACT

The *Actinidia* genus includes a number of commercial fruit species with a wide range of countries of origin. Some species such as *A. arguta* or *A. kolomikta* are characterized by a high level of resistance to frost. The aim of this study was to compare the fruit of selected cultivars of kiwiberry. In the kiwiberry fruit, sucrose was the predominant type of sugar. Citric acid was dominant in all samples; it was most represented in the pulp of kiwiberry seedlings and in the skin of kiwiberry 'Issai'. Kiwiberry fruits feature a higher ascorbic acid content in the skin in comparison with the commercial *A. chinensis* cultivars. Antioxidant activity of kiwiberry fruit skin was up to 18 times higher than that of the pulp. In view of the kiwiberry fruit having no hair, it is possible to eat the whole fruit, including the skin containing substances beneficial to health.

Key words: *Actinidia arguta*, kiwiberry, antioxidant activity, ascorbic acid, skin

INTRODUCTION

Actinidia species are native to China, which currently is the largest global producer of kiwifruit, providing – along with Italy, New Zealand, Chile and Greece – the bulk of global production (Belrose, 2011). The genus *Actinidia* is a member of the Actinidiaceae family and, according to the latest revision of taxonomy, contains 54 species (Huang et al., 2004). The fruits feature a high intra-species and intra-variety variability; they differ in shape, size, colour and hairiness of the skin, plus they differ in terms of sensory properties (Morton, 1987). *Actinidia chinensis* var. *deliciosa* (A. Chevalier) 'Hayward' is a key commercial cultivar, often called Fuzzy Kiwi. Although it can cope with temperatures down to -18°C, it needs at least 240 frost-free days for the fruit to ripen ideally,

hence it is not recommendable for cultivation in a colder temperate climate. As for *Actinidia arguta* (Siebold & Zucc.) Planch. ex Miq., its native regions include Siberia, Japan, and North-East/North-West China (Huang, 2016). An adaptable fruit species, its wide range enables it to be naturally found in a much more northerly areas compared with the range area of *A. chinensis*. *A. arguta* can be grown without any damage with a temperature dropping down to -30°C in its dormancy period (Janick and Paull, 2008; Cossio et al., 2015). Unlike *A. chinensis*, it also has a shorter growing period (Debersaques et al., 2015; Kataoka et al., 2010).

Kiwiberry is a rather more recent, commercially grown fruit species; in comparison with kiwifruit, it also finds itself at the onset of marketing development. Hence finding any precise statistical

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data showing the production per country is not yet possible. A major increase in the production area exists in China (1,200 ha). Examples of European producers include Portugal (107 ha), Italy (85 ha), Benelux (45 ha) and Germany (30 ha) (Latocha et al., 2017; Okamoto and Goto, 2005). Unlike kiwifruit, dominated particularly by the Hayward cultivar, kiwiberry production is represented by a wide range of cultivars (Cossio et al., 2015). In the USA, the cultivars Passion Popper and Aloha Annas prevail, while in Europe the most common cultivar is Weiki, followed by the cultivars Issai, Lucy, Domino, Ananasnaya, Jumbo and others (Ferdinando et al., 2014).

Factors responsible for the popularity of kiwifruit among consumers include, in particular, the excellent taste (Harker et al., 2009), as well as the ever-increasing awareness of the fruit being a very good source of biologically active substances and related health benefits. The fruit contains high quantities of ascorbic acid (Nishiyama et al., 2004), phenolic compounds (Dawes and Keene 1999), mineral substances and colouring agents – mainly chlorophylls and carotenoids (Nishiyama et al., 2005).

The consumption of kiwifruit in the Czech Republic is relatively low – around 0.9 kg per person per year. Currently, the country does not have commercial production of *Actinidia* plants available, so any demand is covered by importing the fruit from abroad. The average quantity of the species imported into the country over the past decade equals to 10 000 tonnes per year. The largest suppliers of kiwifruit are Italy, Greece and Germany. The aim of this study was to compare selected physico-chemical parameters of *A. arguta* fruits produced in a cold climate against commercially available fruits of *A. chinensis*. The monitored parameters included the levels of acids, sugars, antioxidant activity and ascorbic acid.

MATERIAL AND METHODS

Samples

The experiment studied the fruit of *Actinidia arguta* – the cultivars Ananasnaya, Issai, and rooted seedling stock.

The fruits of the *Actinidia arguta* varieties were grown on the territory of the Czech Republic. ‘Ananasnaya’ and the rooted seedling stock were grown on the Lednice site; the harvest took place in the last two thirds of October, when the fruits had reached commercial maturity, SSC over 13°Brix,

and a typically coloured skin. The area of Lednice is located at an altitude of 173 m. It is the warmest area in the Czech Republic; the average annual temperature is 9°C and the total annual precipitation is around 530 mm. In terms of soil, the area features chernozem zones. In this soil, a very thick humus horizon was formed by the accumulation of humus under steppe or forest-steppe vegetation (Hladky et al., 2018).

‘Issai’ was grown in the Děčín District and harvested in the last ten days of October. The region is an arid, warm area with the average annual temperature from 8.5 to 9°C and precipitation around 500 mm. In terms of soils, the predominance of eutrophic cambisols is typical of the territory; often, there are gleyish soils in the flat zones at higher elevations. *A. arguta* fruits were harvested by hand, 30-50 fruits from 5 trees for each cultivar. Each sample was represented by 5 fruits in five replicates.

For comparison with commercially available fruits, *A. chinensis* ‘Soreli’ and *A. chinensis deliciosa* ‘Hayward’ were analyzed. The fruits were purchased from markets on three dates (in March, June and October). On each date, 25 fruits from each variety were taken. Each sample consisted of 5 fruits and a total of five replicates were analyzed. The fruit of the two varieties of *A. chinensis* was of Italian origin; ‘Hayward’ originated from the production area of Lazio and ‘Soreli’ came from the production area of Piedmont.

To prepare an extract for analytical analysis, the skin of each of the fruits was separated from the pulp. The two parts of the fruit were weighed and dried using a lyophilizer (Powerdry PL 3000, Thermo Fisher Scientific, Mukarov, Czech Republic). After drying, the dry parts were ground using a blender (IKA MF10 Basic, IKE, Staufen, Germany), through a screen with a mesh size of 0.25 mm. Subsequently, a quantity of 10 grams of the dry material was infused in 50 ml of a solution of 75% methanol for 24 hours in a shaker (PSU-20i, BioSan, Riga, Latvia). This was followed by centrifugation using a centrifuge (Eppendorf AG 570R, Fisher Scientific, Waltham, USA) for 5 minutes at 4,000 RPM. The centrifuged supernatant was separated and 50 ml of methanol (75%) was added to the sediment and the process was repeated twice. The supernatant obtained as part of the infusion process was mixed and filtered through a micro filter (MILLIPORE Millex GP 0.22 µm, Merck, Prague, Czech Republic). Antioxidant activity, organic acids (citric acid, malic acid),

ascorbic acid and individual invert sugars (glucose, fructose, sucrose) were determined in the extracts. With the exception of sugars (which were only determined in the pulp), the parameters mentioned above were determined separately for skins and for pulps.

Chemicals

All chemicals used were analytical chemicals. The malic, citric, ascorbic acid, glucose, fructose, and sucrose standards were of 99% purity (Sigma-Aldrich, St. Louis, USA), acetic acid (99.99%, Penta, Prague, Czech Republic), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) (97%, Sigma-Aldrich), 2,4,6-Tripyridyl-s-Triazine (99%, Sigma-Aldrich), 2,2-Diphenyl-1-picrylhydrazyl (DPPH) (97%, Sigma-Aldrich), hydrochloric acid (>99.8%, Penta), sodium acetate (>99.8%, Penta), iron chloride (98%, Sigma-Aldrich), methanol (99.9%, Sigma-Aldrich), sodium hydroxide (97%, Sigma-Aldrich).

Soluble solids content and titratable acidity

Soluble solid content (SSC) was determined in fresh pulp using a digital refractometer (DR201-95, A. Krüss Optronic, Hamburg, Germany) and specified in °Brix. Titratable acids (TA) were determined in fresh pulp using the titration method. Two grams of the sample were homogenized with 20 ml of deionized water. The suspension obtained was filtered and 10 grams were taken from the amount. The obtained values were recalculated as the equivalent of citric acid and then recalculated and expressed in grams per 100 g fresh mass.

Antioxidant activity (DPPH and FRAP)

Determination by means of the FRAP (Ferric Reducing Antioxidant Power) method was performed in a pH 3.6 acetate buffer (23 mmol sodium acetate trihydrate in a solution of 34 mmol acetic acid). The reaction mixture contained 12 mmol of FeCl_3 solution, 10 mmol of 2,4,6-tris(2-pyridyl)-s-triazine in 40 mmol of HCl solution and a buffer in a ratio of 1:1:10. Two ml of the reaction mixture were mixed with 25 μl of diluted sample ($5 \times$) with deionised water in a disposable plastic cuvette (10 mm) and the obtained solution was measured using a Specord 50 Plus spectrophotometer (Analytik Jena, Jena, Germany) after 10 minutes at a wavelength of 593 nm.

For the DPPH method, 1.9 ml of DPPH (2,2-diphenyl-1-picrylhydrazyl) radical solution in methanol (0.1 mmol l^{-1}) was mixed with 0.1 ml of $5 \times$ diluted sample with deionised water in a disposable

plastic cuvette (10 mm). Absorbency at 515 nm was measured after 30 min. using the Specord 50 Plus spectrophotometer (Analytik Jena).

The resulting values of antioxidant activity (Trolox equivalents) for both methods were related to the same molar amount of the studied compounds and Trolox to make them mutually comparable. Antioxidant activity measured by both methods was expressed as millimoles of Trolox per 100 grams of fresh weight (FW).

Organic acids and ascorbic acid

Each sample was diluted with demineralized water (at 1:10) and subsequently filtered through a micro filter, grain size $0.25 \mu\text{m}$. Concentrations of malic, citric and ascorbic acid were determined using an HPLC system with an ECP2010 analytical pump (Ecom, Prague, Czech Republic), an LCO 102 Long thermostat (Ecom) at 60°C and a SAPPHIRE 800 detector (Ecom). The column was: Watrex Polymer IEX H $10 \mu\text{m}$, $250 \times 8 \text{ mm}$ (Watrex, Prague, Czech Republic), mobile phase 2 mmol sulphuric acid, flow: 0.7 ml min^{-1} . The absorbance of the acids was set at a wavelength of 210 nm. Determining the concentration employed a 10-point calibration system using malic, citric and ascorbic acid standards. Sample volume was 20 μl . The resulting values were expressed in grams per 100 g fresh mass.

Individual invert sugars

Concentrations of sucrose, glucose and fructose were determined by using the Megazyme Sucrose/D-Fructose/D-Glucose Assay procedure (K-SURFG) (Megazyme International, Wicklow, Ireland). The resulting values were specified in grams per 100 g fresh mass.

Statistical analysis

One-way analysis of variance (ANOVA) was conducted, followed by Tukey's multiple range test to assess significant differences ($p < 0.05$). The statistical analysis was carried out using the STATISTICA 12 (StatSoft Inc., Tulsa, Oklahoma, USA) software. To verify statistical significance, means $\pm$ SD of five independent samples were calculated. Each sample consisted of 5 whole fruits.

RESULTS AND DISCUSSION

Actinidia arguta produces relatively small fruits in comparison with the commercially grown *Actinidia chinensis* and *A. chinensis* var. *deliciosa* that reaches more than 10 times larger sizes.

A. chinensis ‘Soreli’ fruits can weigh more than 100 g and are typically harvested when the soluble solids reach values above 8°Brix. *A. chinensis* var. *deliciosa* ‘Hayward’ can reach a similar size, with the ripe fruit growing up to 90–110 g (Huang, 2016); like ‘Soreli’, ‘Hayward’ fruits are assumed to reach a minimum value of soluble solids of 6.2°Brix at harvest and at least 9.5°Brix when they enter the commercial chain (OECD, 2008). Equivalent values were achieved by the fruits analyzed in the present study, where the average weight was 99.5 ± 1.9 g for ‘Hayward’ and 79.9 ± 2.7 g for ‘Soreli’. For the fruit of *Actinidia arguta* produced in the Czech Republic, the highest weight of 6.9 ± 0.5 grams was reached by ‘Ananasnaya’ (without confirming any significant difference against *A. arguta* ‘Issai’); clearly the smallest fruit was obtained from *A. arguta* seedlings, which was also found to feature the highest percentage by weight of skin compared to pulp. The exact weight details are shown in Table 1.

In commercial fruit, the quantity of soluble solids is significantly determined, in particular, by the duration and conditions of storage. *A. chinensis* fruit is capable of increasing its soluble solids content up to 5°Brix during post-harvest ripening (Shahkoomahally and Ramezani, 2015; Varoquaux et al., 1990); hence, probably, the relatively high variability of the values of soluble solids found for the ‘Hayward’ and ‘Soreli’ fruits (Tab. 1). Relatively high SSC values were observed for *A. arguta* fruit, which were measured to range between 13.4 and 15.8°Brix. Similar values are provided by Wojdyło et al. (2017) for the fruit grown in Poland; lower values, however, were recorded by White et al. (2005) and Krupa et al. (2011). Along with soluble solids, titratable acids form another important indicator of the quality of taste and acceptability of fruit on the part of consumers. Huang (2016) report for *A. arguta* a titratable acidity between 0.9% and 1.3%; for

A. chinensis it can be higher (0.9–2.2%), while for *A. chinensis* var. *deliciosa* it can reach an average of 1.6%. For either of the two commercially available samples, the titratable acidity was lower than for *A. arguta* samples that reached as much as 1.18% for seedlings. Statistically significant differences in terms of titratable acidity were confirmed only between *A. arguta* and *A. chinensis*. A relatively high variability of titratable acidity in fruit is typical of *A. arguta*, which depends primarily on weather and is also a cultivar-specific trait. In warm areas of China, the fruit shows rather lower titratable acidity values that are around 0.5% (Wang et al., 2015; Nishiyama et al., 2008); conversely, in cold conditions, such as higher-elevation zones in China or the territory of Poland, ‘Issai’ and ‘Ananasnaya’ can reach titratable acidity of up to 1.82% (Krupa et al., 2011; Wojdyło et al., 2017; Wang et al., 2015).

In *Actinidia* fruits, fructose, glucose and sucrose are the predominant sugars. In the course of the ripening on the tree, there is an intense process of starch accumulation from day 40 after blooming. This process takes about 80 days. Starch can make up as much as 40% of the total solids content. In the final stage – that represents the period of approximately 120 days after blooming until harvest – the production of starch stops and the quantity of soluble sugars significantly increases, which chiefly applies to glucose and fructose (Moscatello et al., 2011; Macrae et al., 1992). The ratios of these three sugars are influenced not only by the stage of ripeness, but also by the species and cultivar (Boland, 2013). Observations of 25 cultivars of 6 different *Actinidia* species were used by Nishiyama et al. (2008) to report that the total sugar quantity ranges from 6.15 ± 0.86 to 10.47 ± 0.60 g per 100 g fresh mass. In this study, the investigated samples were found to have very similar concentrations of total sugar, ranging from 7.11 ± 0.87 for ‘Hayward’ to 8.20 ± 2.68 for ‘Issai’ (Tab. 2). Significant differences were found in terms of sugar ratio

Table 1. Weight, soluble solids content and total acidity in tested *Actinidia* fruit

Species	Weight (g)			SSC (°Brix)	TA (%)
	fruit	flesh	skin		
<i>A. arguta</i> ‘Ananasnaya’	6.9 ± 0.5^b	5.9 ± 0.6^b	0.89 ± 0.13^b	13.4 ± 0.2^c	1.10 ± 0.05^{bc}
<i>A. arguta</i> – seedling	5.1 ± 0.5^a	3.9 ± 0.5^a	1.12 ± 0.20^b	15.8 ± 0.8^c	1.18 ± 0.06^c
<i>A. arguta</i> ‘Issai’	6.4 ± 0.2^b	5.8 ± 0.3^b	0.68 ± 0.06^a	14.9 ± 0.3^d	1.05 ± 0.06^b
<i>A. chinensis</i> ‘Soreli’	79.9 ± 2.7^c	72.1 ± 4.4^c	7.85 ± 1.63^c	11.5 ± 0.9^b	0.85 ± 0.04^a
<i>A. chinensis</i> var. <i>deliciosa</i> ‘Hayward’	99.5 ± 1.9^d	88.9 ± 2.1^d	8.66 ± 2.28^c	9.9 ± 0.8^a	0.83 ± 0.08^a

Mean $\pm$ SD (standard deviation) of 5 measurements. Different letters next to values indicate significant differences ($p < 0.05$)

Table 2. Concentration of sugars in tested *Actinidia* fruit

Species	Glucose	Fructose	Sucrose	G + F + S
	(g 100 g ⁻¹ FW)			
<i>A. arguta</i> ‘Ananasnaya’	1.28 ± 0.19 ^{ab}	1.43 ± 0.20 ^{ab}	4.64 ± 0.65 ^b	7.34 ± 1.16 ^a
<i>A. arguta</i> – seedling	0.95 ± 0.98 ^a	1.19 ± 0.11 ^a	5.86 ± 0.59 ^b	7.95 ± 1.59 ^a
<i>A. arguta</i> ‘Issai’	1.89 ± 0.17 ^b	2.13 ± 0.28 ^b	4.19 ± 0.63 ^b	8.20 ± 2.68 ^a
<i>A. chinensis</i> ‘Soreli’	3.36 ± 0.56 ^c	3.49 ± 0.58 ^c	0.91 ± 0.37 ^a	7.76 ± 1.66 ^a
<i>A. chinensis</i> var. <i>deliciosa</i> ‘Hayward’	3.28 ± 0.39 ^c	3.57 ± 0.35 ^c	0.27 ± 0.10 ^a	7.11 ± 0.87 ^a

Mean ± SD (standard deviation) of 5 measurements. Different letters next to values indicate significant differences ($p < 0.05$)

between the studied species. While glucose and fructose prevailed in *A. deliciosa* and *A. chinensis* fruits, with the representation being approximately identical, sucrose was the major type of sugar and accounted for 74% of total sugars in the case of seedlings (63% in ‘Ananasnaya’ and 51% in ‘Issai’). Similar results had been obtained by Wojdylo et al. (2017), Boland (2013), Kim et al. (2012), Nishiyama et al. (2008) and Boyes et al. (1997).

In the ripe fruit, there are a number of organic acids. In addition to ascorbic acid, this particularly involves citric acid, malic acid and quinic acid, followed by glucuronic acid, galacturonic acid and shikimic acid (McGhie, 2013). In the pulp, there was the largest representation of citric acid, which ranged from 0.96 ± 0.13 (*A. arguta* ‘Ananasnaya’) to 1.10 ± 0.16 g per 100 g FW (*A. arguta* – seedling); in the skin, the acid ranged from 0.39 ± 0.03 (*A. chinensis* ‘Soreli’) to 0.82 ± 0.04 g per 100 g FW (*A. arguta* ‘Issai’). Malic acid was more represented in the skin of fruit in all the investigated samples, with the highest concentration determined in *A. arguta* seedlings: 0.41 ± 0.04 g per 100 g (Tab. 3). In the pulp, most of this acid was found in *A. chinensis* ‘Soreli’ (0.20 ± 0.04 g per 100 g FW). In this experiment, more significant differences between individual samples were found for the level of ascorbic acid. Kiwifruit is a rich source of vitamin C, with the fruit of *A. latifolia* containing the largest

quantity (more than 2,000 mg per 100 g FW), while *A. henryi* fruits feature the lowest level (4–5 mg per 100 g FW). For commercially cultivated species such as *A. chinensis* var. *deliciosa*, *A. chinensis* and *A. arguta*, the ascorbic acid content ranges between 50 and 420 mg per 100 g FW (Huang et al., 2004; Latocha et al., 2010). Clearly, the lowest content of the acid was found in the pulp of fruit in *A. arguta* seedlings (14.2 ± 1.4 mg per 100 g FW). The fruit of *A. chinensis* ‘Soreli’ was identified to contain a ten times higher level of the acid, while a lower value was found for the fruit of *A. chinensis* var. *deliciosa* ‘Hayward’ (67.3 ± 12.3 mg per 100 g FW). Unlike the just-mentioned commercial species, the skin of *A. arguta* fruits contained ascorbic acid in a concentration corresponding to almost two-thirds of the content in the pulp. In the case of *A. arguta* seedlings, the concentration in the skin was even higher – more than double that amount (Tab. 3). In this study, no differences were observed in ascorbic acid levels in the skin of *A. arguta* ‘Ananasnaya’ and those of the seedlings. Higher values of ascorbic acid in the fruit are reported by Latocha et al. (2015), who determined the sum of L-ascorbic acid and dehydroascorbic acid in ‘Ananasnaya’ fruit to be 60.6 ± 3.0 mg per 100 g FW (pulp) and 136.9 ± 13.3 mg per 100 g FW (skin), while detecting similar values of 61.3 ± 4.3 mg per 100 g FW (pulp) and 55.0 ± 3.5 mg per 100 g FW (skin)

Table 3. Concentration of organic acids in tested *Actinidia* fruit

Species	Malic acid (g 100 g ⁻¹ FW)		Citric acid (g 100 g ⁻¹ FW)		Ascorbic acid (mg 100 g ⁻¹ FW)	
	flesh	skin	flesh	skin	flesh	skin
<i>A. arguta</i> ‘Ananasnaya’	0.08 ± 0.04 ^a	0.32 ± 0.17 ^c	0.96 ± 0.13 ^b	0.56 ± 0.04 ^b	43.2 ± 4.3 ^b	28.3 ± 1.7 ^a
<i>A. arguta</i> – seedling	0.12 ± 0.02 ^b	0.41 ± 0.04 ^d	1.10 ± 0.16 ^c	0.62 ± 0.02 ^b	14.2 ± 1.4 ^a	31.3 ± 2.0 ^a
<i>A. arguta</i> ‘Issai’	0.11 ± 0.02 ^{ab}	0.34 ± 0.03 ^c	1.00 ± 0.12 ^b	0.82 ± 0.04 ^c	59.6 ± 2.7 ^c	46.0 ± 4.6 ^b
<i>A. chinensis</i> ‘Soreli’	0.20 ± 0.04 ^c	0.22 ± 0.03 ^b	0.91 ± 0.11 ^b	0.39 ± 0.03 ^a	140.6 ± 16.3 ^d	ND
<i>A. chinensis</i> var. <i>deliciosa</i> ‘Hayward’	0.09 ± 0.01 ^a	0.19 ± 0.04 ^a	0.79 ± 0.09 ^a	0.43 ± 0.02 ^a	67.3 ± 12.3 ^c	ND

Mean ± SD (standard deviation) of 5 measurements. Different letters next to values indicate significant differences ($p < 0.05$); ND – not detected

in ‘Hayward’ fruits. These different values could be caused by the presence of dehydroascorbic acid, which was not assessed in the study.

In kiwifruit, there are considerable quantities of substances having antioxidant properties. They include phenolic substances, ascorbic acid, carotenoids, and other compounds that – if present together – increase the synergy effect in the uptake of free radicals, which is the benchmark for the determination of total antioxidant activity (Yeomans et al., 2005). In the present study, antioxidant activity was determined using two methods (DPPH and FRAP). Figures 1 and 2 make it clear that both methods proved similar results for all the samples. For the pulp, clearly the highest antioxidant activity was determined for the ‘Soreli’ fruit, whether using FRAP or DPPH (0.846 ± 0.24 and $0.884 \pm$

0.20 mmol TE per 100 g FW, respectively). Despite the relatively high values in the pulp, *A. chinensis* and *A. chinensis* var. *deliciosa* had the lowest antioxidant activity in the skin (Fig. 1). In contrast, the skin of all *A. arguta* samples showed a 10 times higher concentration of antioxidant activity than the pulp. The skin of *A. arguta* ‘Issai’ fruit was observed to possess the highest values: 8.06 ± 0.69 mmol Trolox per 100 g FW (FRAP method) and 10.58 ± 0.31 (DPPH method). A similar experiment had been conducted by Latocha et al. (2015), who used FRAP to evaluate antioxidant activity in six varieties of *A. arguta* and one variety of *A. chinensis* var. *deliciosa*. All the fruits were confirmed to feature a high correlation between the ascorbic acid content and antioxidant activity in both skin and pulp; the highest correlation was seen

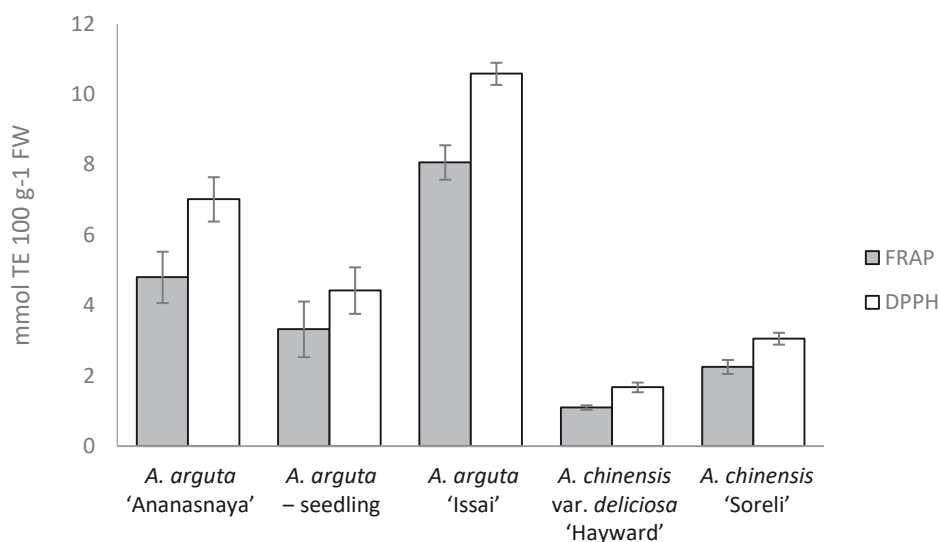


Figure 1. Antioxidant activity of fruit skin in *Actinidia* fruit tested by FRAP and DPPH

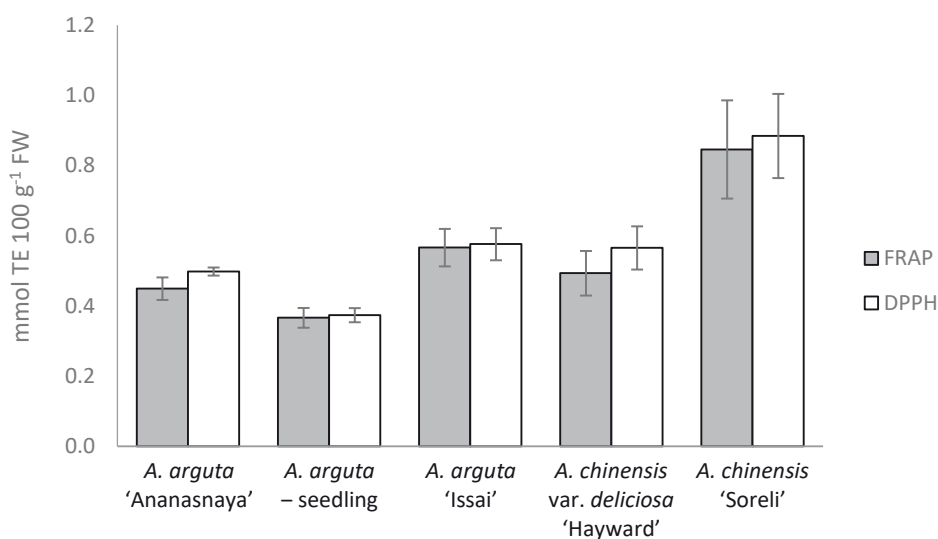


Figure 2. Antioxidant activity of fruit flesh in *Actinidia* fruit tested by FRAP and DPPH

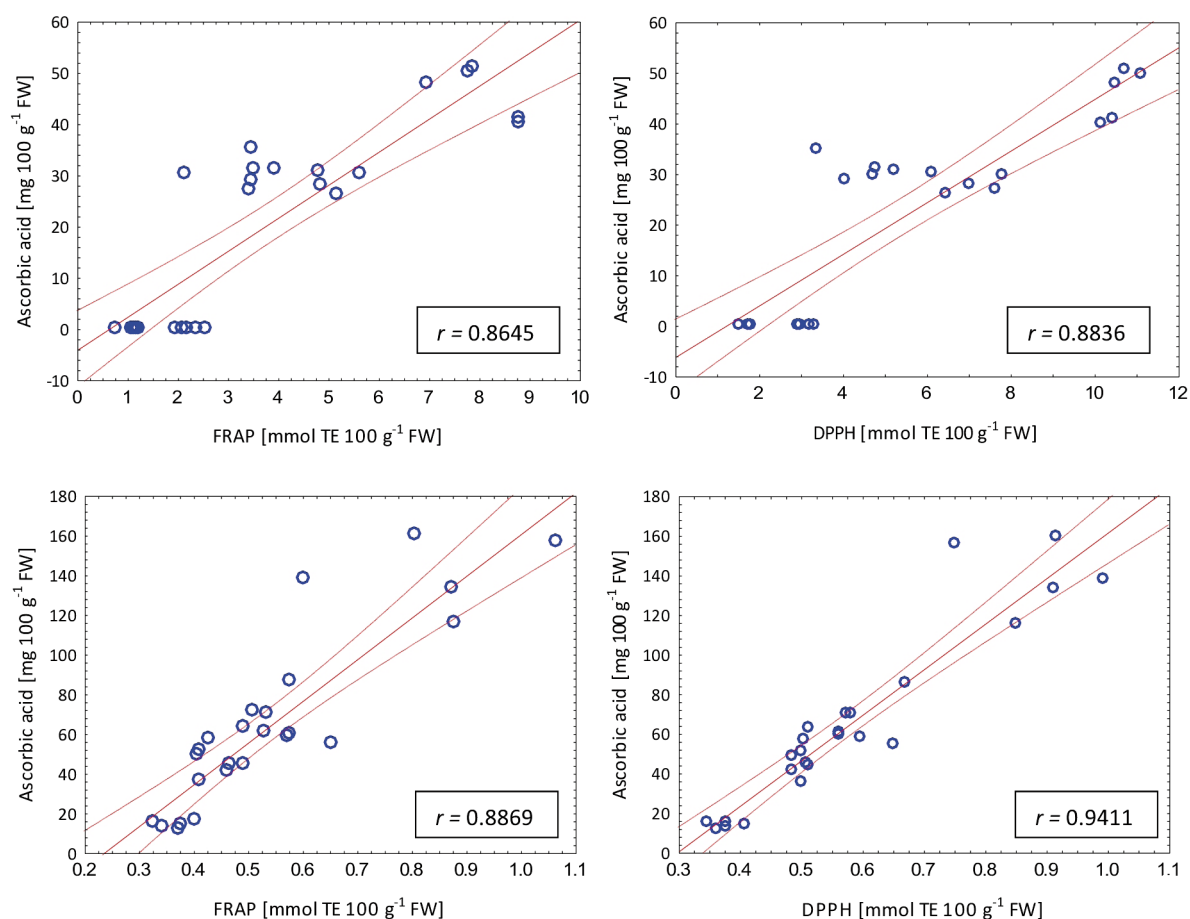


Figure 3. Correlation between ascorbic acid content in fruit peel (top) and flesh (bottom) and antioxidant activity as determined by FRAP (left) and DPPH (right)

when the DPPH method was used ($r = 0.9411$). All the correlation data are shown in Fig. 3. A positive correlation between total antioxidant activity and the ascorbic acid content has also been confirmed by other authors for other crops (Džugan et al., 2018; Silva and Sirasa, 2018; Alves et al., 2018).

The surface of *A. chinensis* fruit skin features a considerable quantity of hairs, which is the reason why most consumers deem the skin inappropriate to eat and remove it before eating. In contrast, *A. arguta* cultivars have mostly smooth skin on the fruit with no hairs, which makes the whole fruit suitable for direct consumption without having to remove the skin (Jackson and Harker, 1997). With regard to the mass content of the skin in the case of *A. arguta* 'Issai', when consuming the whole fruit, we receive almost a three-fold greater quantity of antioxidants than when consuming the pulp of *A. chinensis* var. *deliciosa* 'Hayward' and almost twice the quantity than when consuming the pulp of the *A. chinensis* 'Soreli' fruit. In comparison with other fruit species, kiwifruit is a rich source of substances with an antioxidant effect. They

constitute a richer source of antioxidants than apples, bananas, white grapes, pears or melons. Higher values are present in, for example, strawberries, plums, oranges and red grapes (Balík et al., 2009; Deighton et al., 2000; Gardner et al., 2000; Wang et al., 1996).

CONCLUSIONS

The present study evaluated the quality of kiwiberry produced on the territory of the Czech Republic. Even despite the smaller size, the fruits of *A. arguta* are capable of achieving the corresponding physico-chemical parameters in cold climate conditions. Sufficient ripeness was confirmed through a high level of soluble solids in fruits, which in some cases even exceeded 15°Brix. Although the titratable acidity content was higher than was the case in the commercially grown kiwifruit cultivars 'Hayward' and 'Soreli', it still remained within the range of the standard for this species. Interesting results were revealed through an analysis of antioxidant activity which was not very high in the pulp of the fruit; however, considerably high values were

measured in the skins, which particularly applied to the 'Issai' variety. Whereas the smooth skin – typical of most *A. arguta* cultivars – is distinctively more suitable for direct consumption compared to the hairy skin in *A. chinensis*, it is not necessary to remove it given its high levels of health-promoting substances. *A. arguta* seems to be a representative of kiwi fruit species that is suitable for cultivation in the conditions found in the Czech Republic as its fruits become sufficiently ripe in that country, cope well with the low winter and spring temperatures, and present a suitable source of ascorbic acid and other substances with antioxidant effects.

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AUTHOR CONTRIBUTIONS

M.H., J.B. – concept of the study; M.H., I.O. – field research; M.H., P.Š. – data analyses; M.H., I.O., J.B., S.V. – writing of the manuscript; M.H., B.P., I.O., J.B., S.V. – comments on the manuscript.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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