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Original article – Thematic Issue

Comparison of fruits chemical composition of selected cultivars wild strawberry (*Fragaria vesca* L.)

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Summary

Wild strawberry (*Fragaria vesca* L.) is a wild growing plant of temperate climate zones. The fruits of wild strawberry have different medicinal properties and reduce the risk of cancer. Currently, in some European countries, also in Poland, small plantations are formed that produce wild strawberries. The chemical composition of fruits between two cultivars of wild strawberry ('Rugia' and 'Yellow Wonder') grown in Poland was compared. During two years cultivation, in two replicates and two harvest times it was determined in fruit: dry matter, the content of macro- (N, P, K, Ca, Mg) and micronutrients (Fe, S, Zn, Cu, Mn), reducing and total sugars and vitamin C. The fruits of 'Rugia' were characterised by a higher average dry matter content (18.51%) and accumulated an average of greater amounts of phosphorus (3.58 g kg^{-1} DM), potassium (14.02 g kg^{-1} DM), calcium (3.06 g kg^{-1} DM), magnesium (1.75 g kg^{-1} DM), iron (81.46 mg kg^{-1} DM), sulphur (626.46 mg kg^{-1} DM), zinc (12.12 mg kg^{-1} DM), copper (5.86 mg kg^{-1} DM) and vitamin C (42.28 mg 100 g^{-1} FM). Fruits of both cultivars harvested at the second date contained higher amounts of all analysed components apart from nitrogen and manganese. In the second year, fruits of both cultivars were generally characterised by lower content of components. Statistical analysis of the results showed that the chemical composition of fruits was significantly dependent on the cultivar, the date of harvesting, and the year of cultivation. From a nutritional point of view, fruits of 'Rugia' have more nutrients than 'Yellow Wonder'.

Keywords

macroelements, microelements, reducing sugars, total sugars, vitamin C

Significance of this study

What is already known on this subject?

- The chemical composition of wild growing red wild strawberry fruit is known. Nowadays, in some European countries (Italy, France, Austria, and recently Poland) wild strawberry cultivars with red or yellow fruits are on a small scale cultivated commercially.

What are the new findings?

- The chemical composition of fruits between two cultivars of wild strawberry ('Rugia' and 'Yellow Wonder') grown in Poland has been compared. The chemical composition of wild strawberry fruits significantly depends on the cultivar, the year of cultivation and the date of harvesting.

What is the expected impact on horticulture?

- The topic could be of great interest for horticulturists dealing with 'health food' and interested in interactions between the growing conditions and the nutritional content of the fruits. Future studies need to test the limits of the growth of the nutritional value of wild strawberry under the influence of applied factors.

Introduction

Wild strawberry (*Fragaria vesca* L.) is a wild growing plant of temperate climate zones. In Poland, it is found in the wild state throughout the whole country (Dyduch, 2008). It grows naturally in sunny areas on dry slopes, forest clearings and edge of forests. It is a well-known plant, valued for its nutritional as well as medicinal properties. Apart from fruits, also leaves and roots of wild strawberry are used as an herbal material (Ożarowski and Jaroniewski, 1987; Dyduch and Najda, 2009; Najda and Dyduch, 2009a; Dias et al., 2015). Garden varieties currently in cultivation are derived from a wild cultivar. The fruits of wild strawberry are exceptionally tasty, aromatic and have low caloric value, i.e., 33 calories per 100 g. Wild strawberry fruits contain easily absorbed monosaccharides, vitamins (C, B1, B2, K) and organic acids (malic, citric and salicylic) (Dyduch, 2008; Doumett et al., 2011; Milivojević et al., 2011; Mikulic-Petkovsek et al., 2012). It is a rich source of macro- as well as micronutrients (calcium, potassium, phosphorus, iron, magnesium and manganese) (Dyduch, 2008; Tomaszewska and Mazur, 2009; Caruso et al., 2011). The fruits have various medicinal properties including diuretic, anti-inflammatory, anti-rheumatic and anti-diarrhoeal effects (Wang et al., 2007; Watson and Preedy, 2008; Mudnic et al., 2009). Moreover, wild strawberry is known to regulate metabolism, delay the ageing process and reduce the risk of cancer (Ożarowski and Jaroniewski, 1987; Wyk and Wink, 2004). In cosmetic industry, wild strawberries are used externally as an ingredient of nourishing face masks.

Despite its flavour and nutritional as well as medicinal properties, for many years wild strawberry has been considered mainly a garden-cultivated plant. Worldwide, wild strawberry is not cultivated on a large scale as the fruits are very delicate, easily damaged, mould quickly and are unfit for storage or transport. The yield is on average 2–3 times lower than the yield of strawberry and, depending on plantation age, amounts to 4–11 t ha^{-1}. The plant produces the highest yield in the second year after planting (Werner, 2002;

Kopytkowski et al., 2006; Paszko, 2009). The consumers are increasingly interested in healthy food which is rich in nutrients and biologically active substances. As a result, wild strawberry began to be recognised as fruit of significance to human health. Nowadays, in some European countries (Italy, France, Austria, and recently Poland) there are small commercial plantations of wild strawberry (Werner, 2002; Doumett et al., 2011) offering wild strawberry cultivars of red and yellow colour. Due to increasing awareness of healthy nutrition, it is expected that the consumers will make the decision which fruit to buy on the grounds on not only its appearance or taste, but also on its pro-health value. Numerous studies (Cordenunsi et al., 2002, 2005; Sturm et al., 2003; Kopytkowski et al., 2006; Najda and Dyduch, 2009b; Doumett et al., 2011; Marjanovic-Balaban et al., 2012; Najda et al., 2014; Dyduch-Siemińska et al., 2015; Jurgiel-Małecka et al., 2015; Goncalves Guimarães et al., 2016) point to significant differences in terms of chemical composition of fruits and vegetables of different cultivars, particularly those of different colour. The available results concerning wild strawberry, both growing wild as well as cultivated, predominantly focus on determination of the content of antioxidant compounds, monosaccharides or organic acids (Doumett et al., 2011; Najda et al., 2014; Dyduch-Siemińska et al., 2015), and disregard the content of macro- and micronutrients essential for the proper functioning of the body (Leśniewicz et al., 2006). Little information on variations in nutritional value of different wild strawberry cultivars is available in the literature on the subject.

The aim of the present paper is to compare the chemical composition and nutritional suitability of fruits belonging to two cultivars of wild strawberry: the red 'Rugia' and the yellow 'Yellow Wonder' grown in Poland (village Stolec, West Pomeranian region).

Materials and methods

Plant material and growth conditions

A two-years experiment with the use of two cultivars of wild strawberry, i.e., 'Rugia' and 'Yellow Wonder', was conducted in Poland, village Stolec, West Pomeranian region locality (53°33'N, 14°18'E, 20 m a.s.l.) on light soil (light loamy sand) with pH of 5.87–6.28. The results of the analysis of soil collected from topsoil (0–20 cm) prior to establishing the experiment are presented in Table 1.

The experimental design was randomized complete block design with two replications. Each replication consisted of 160 plants (80 out of each cultivar). The seedlings were planted in August 2011 on the area of 40 m^2 in a strip-row farming system. In one strip there were two rows of each cultivar at a distance of 40 cm. The spacing of plants in each row was 25 cm. Each year, in April, the plants were supplemented with granular fertilizer – cattle manure 'Doktor O'grodnik' in the amount of 1,000 kg ha^{-1}, applied into the soil in the spaces between rows. The composition of the fertilizer is presented in Table 2.

Standard treatments were performed during the growing season, i.e., weeding, scarification and watering. Weed control together with scarifying the spaces between rows was performed according to the amount of weed present and soil crusting. The plants were watered only when there was no precipitation and irrigation was adapted to production guidelines recommended for strawberry. The weather conditions during growing season in Stolec were developed on the basis of data provided by the Institute of Meteorology and Water Management (2016) (Table 3).

Analytical methods

The fruits used for determination the chemical composition were harvested each year at two dates at the first fruiting stage. They were conducted on 28 June and 9 July 2012, and on 4 and 15 July 2013. The chemical analyses were conducted in two replicates with the use of well-established methods generally accepted in agricultural chemistry (Krełowska-Kułas, 1993). The vitamin C content was determined in fresh matter (FM) by the Tillman's titration method (Krełowska-Kułas, 1993) and other chemical determinations were conducted in dry mass of plants. In order to obtain the dry matter (DM) of wild strawberries, 1 kg of fruits was harvested and then dried at the temperature of 40°C in the dryer with air supply (Mera Lumel, Poland) and ground in the mill (Agrolab, Poland). Determination of the content of reducing and total sugars was performed in an aqueous extract using the Luff-Schoorl method (Lees, 1975). Total macro- and micronutrients content in the analysed material was determined following wet mineralisation in concentrated H_2SO_4 with addition of H_2O_2 or in a mixture (3:1) of HNO_3 and $HClO_4$. In the solutions derived from mineralization of samples in H_2SO_4 with H_2O_2, the following was determined:

- nitrogen – Kjeldahl's method, by distillation method in Parnas-Wagner apparatus (Krełowska-Kułas, 1993);
- potassium, magnesium and calcium – by AAS method (Krełowska-Kułas, 1993), on Thermo Elemental SOLAAR AA apparatus (Thermo Scientific, USA).

Table 1. The nutrient content in the topsoil (0–20 cm).

Element										
Organic matter	N	Ca	Fe	P	K	Mg	Zn	Mn	Cu	S
(g kg^{-1} DM)				(mg kg^{-1} DM)						
53.35	1.35	1.26	4.35	106.1	125.9	117.4	57.4	209.6	9.56	140.8

Table 2. The composition of the granular fertilizer – cattle manure 'Doktor O'grodnik'.

Element												
Organic matter	N	P	K	Ca	Mg	S	Fe	Mn	Mo	Zn	Cu	B
(g kg^{-1})									(mg kg^{-1})			
650.0	20.1	21.8	16.5	18.4	6.4	10.0	9.9	1.5	7.1	740.4	92.0	89.4

In the solutions derived from mineralization in the mixture of HNO_3 and $HClO_4$ the following was determined:

- phosphorus – Barton's method, colorimetrically with ammonium molybdate, at wavelength 470 nm (Krełowska-Kułas, 1993), by using a spectrophotometer Marcel s 330 PRO (Marcel, Poland);
- sulphur – turbidimetrically with $BaCl_2$, at wavelength 490 nm (Tabatabai and Bremner, 1970), by using a spectrophotometer Marcel s 330 PRO (Marcel, Poland);
- iron, zinc, copper, manganese – by AAS method, (Krełowska-Kułas, 1993) on Thermo Elemental SOLAAR AA apparatus (Thermo Scientific, USA).

To determine the dry matter, aliquots of about 5 g (0.0001 g accuracy) of raw fruits were weighed. Samples were placed in a drier and were dried at 105°C until they reached constant weight. From the weight differences before and after drying the percentage of dry matter was calculated.

Statistical analysis

The results were analysed by multi-factorial analysis of variance (ANOVA), using the STATISTICA version 12 software package (StatSoft. Inc., Tulsa, USA). In order to determine the significance of differences in chemical composition of the analysed cultivars of wild strawberry, a post-hoc Tukey HSD test was used for a significance level of 0.05.

Results and discussion

A look at data presented in Table 3 shows that individual years in which the experiment was conducted differed in terms of meteorological conditions. The spring of 2012 was early and dry. High temperatures (exceeding the average of multi-year period) accelerated the growing season. In 2013, the growing season was delayed due to very low temperatures in March. In May and June (i.e., in the period of the most intensive plant growth), the sum of precipitation was two and three times higher, respectively, than the sum of precipitation in the corresponding months of 2012. Varied meteorological conditions resulted in different starting date of the first fruiting stage in the period under analysis. This had a direct effect on the date of sample collection. In 2013, fruit harvesting started a week later than in 2012.

Results of chemical analyzes are presented in Tables 4, 5 and 6. It was found that the chemical composition of wild strawberry fruits was significantly dependent on the cultivar, the date of harvesting and year of cultivation.

Macronutrients (N, P, K, Ca, Mg)

Macronutrients content of wild strawberry fruit is presented in Table 4.

The fruits of 'Rugia' wild strawberry accumulated a significantly larger amount of phosphorus, potassium, calcium and magnesium in comparison with 'Yellow Wonder'. The greatest difference was found with respect to potassium content. Mean potassium content in 'Rugia' was 14.02 g kg^{-1} DM and was by 9.1% higher than the mean content determined as for 'Yellow Wonder'. The differences were smaller in terms of magnesium and calcium content. The fruits of 'Rugia' contained, on average, 1.75 g Mg kg^{-1} DM and 3.06 g Ca kg^{-1} DM – higher by 4.8% and 4.1%, respectively, than the content determined in 'Yellow Wonder'. Comparable content of potassium, magnesium and calcium was determined by Caruso et al. (2011) in 'Regina delle Valli' cultivar of wild strawberry grown hydroponically. Depending on the time of harvesting, winter-spring, the content of the aforementioned elements

Table 3. Air temperature, total precipitation and sunshine duration for Stolec village.

Month	Year						Mean for 1971–2000
	2012			2013			
	Temperature (°C)						
	T_{max}	T_{min}	T_{avg}	T_{max}	T_{min}	T_{avg}	
March	17	-5	7	10	-13	-2	4
April	26	-2	9	21	-4	8	8
May	28	3	15	27	3	14	13
June	29	6	16	28	7	17	16
July	30	9	19	30	10	20	18
August	31	8	18	32	9	19	18
	Amount of precipitation (mm)						
March		20			30		40
April		40			30		40
May		30			90		50
June		60			120		70
July		130			60		70
August		60			40		60
	Sunshine duration (h)						
March		160			150		110
April		190			170		160
May		240			230		240
June		180			270		220
July		220			310		220
August		260			250		220

T_{max}: maximum temperature; T_{min}: minimum temperature; T_{avg}: mean temperature.

amounted to 19.5–19.6 g K kg^{-1} DM, 2.09–1.91 g Mg kg^{-1} DM and 1.00–1.09 g Ca kg^{-1} DM. Dried product obtained from vegetative parts of wild strawberry was characterised by similar content of potassium and magnesium, yet calcium content was found to be higher (Dias et al., 2015). Mean phosphorus content in 'Rugia' was 3.58 g kg^{-1} DM, and was by 5.6% higher than the mean content determined as for the fruits of 'Yellow Wonder'. The amount of phosphorus substantially exceeded the level found in wild strawberry 'Baron Solemacher' fertilized with manure (Tomaszewska and Mazur, 2009).

The analysis of the impact of the date of sample collection showed that fruits of both cultivars of wild strawberry had higher content of potassium, magnesium, calcium and phosphorus when harvested at a later date. The variations in the content of the analysed macronutrients, depending on the date of sample collection, ranged from a few ('Rugia', 2013, potassium 2.1%) to several dozen percentage points ('Rugia', 2012, calcium 31.4%). In the second year of the experiment, mean content of macronutrients in fruits was generally lower than that recorded in the first year of the experiment. The differences ranged from 7.7% (phosphorus, 'Yellow Wonder') to 21.4% (calcium, 'Rugia'). This is in line with the results obtained by Tomaszewska and Mazur (2009), who noted the decrease in macronutrient content in wild strawberry fruit of 'Baron Solemacher' in the second and third year of the experiment. There were no significant differences in terms of total nitrogen between the fruits of 'Rugia' and 'Yellow Wonder'. Moreover, the date of sample collection and crop year did not affect nitrogen content in fruits.

Micronutrients (Fe, S, Zn, Cu, Mn)

The content of micronutrients in wild strawberry fruit is presented in Table 5. The fruits of 'Rugia' accumulated significantly larger amounts of iron, sulphur, zinc and copper than 'Yellow Wonder'. Mean content of these elements in 'Rugia' amounted to 81.46 mg Fe kg^{-1} DM, 626.46 mg S kg^{-1} DM, 12.12 mg Zn kg^{-1} DM, 5.86 mg Cu kg^{-1} DM, and was by 32.6%, 18.0%, 10.4% and 13.3%, respectively, higher than mean content of the aforementioned elements in 'Yellow Wonder'. Comparable accumulation levels of iron and copper, and slightly higher as for zinc were reported by other authors (Tomaszewska and Mazur, 2009; Caruso et al., 2011; Dias et al., 2015). The literature on the subject is lacking in data on sulphur content in wild strawberry fruit. The content of manganese in both cultivars was found to be comparable (on average 37.49 mg kg^{-1} DM, 'Yellow Wonder' and 37.61 mg kg^{-1} DM, 'Rugia'). According to Tomaszewska and Mazur (2009), mean manganese content determined in 'Baron Solemacher' of wild strawberry fertilized with manure was slightly lower and amounted to 31.46 mg kg^{-1} DM.

In general, fruits of both cultivars harvested at a later date accumulated significantly larger amounts of iron, sulphur, zinc and copper, and substantially less manganese. As for sulphur, zinc and copper, the biggest differences were similar, respectively: 20.1% (sulphur, 'Yellow Wonder', 2012), 19.8% (zinc, 'Rugia', 2012) and 21.3% (copper, 'Yellow Wonder', 2012). Iron content varied significantly and the greatest variation as for iron accumulation due to date of harvest amounted to 72.6% ('Rugia', 2012). Generally, fruits harvested at a later date contained less manganese, yet the greatest variation found for this element was significantly less pronounced than that for the remaining elements – 6.9% ('Yellow Wonder', 2013).

In the second year of the experiment, the fruits of both cultivars of wild strawberry had lower contents of microelements. The greatest variations were found for the amount of accumulated iron and manganese. The fruits of 'Yellow Wonder' harvested in 2013 contained, on average, 26.8% less iron and 25.5% less manganese than the fruits harvested in 2012. Similar effect of decreasing micronutrient content in 'Baron Solemacher' of wild strawberry was observed by Tomaszewska and Mazur (2009).

Table 4. The chemical composition of wild strawberry (*Fragaria vesca* L.) fruits – macronutrients.

Cultivar	Date of harvest	Macronutrients (g kg^{-1} DM)				
		N	P	K	Ca	Mg
'Yellow Wonder'	28.06.2012*	12.39a	3.31d	11.88cd	2.92b	1.69bc
	9.07.2012**	12.95a	3.71b	15.01ab	3.52a	1.86a
	4.07.2013*	12.88a	3.16e	11.13d	2.54cd	1.53e
	15.07.2013**	12.74a	3.37d	13.37bc	2.78bc	1.59de
	$\bar{X}$	12.74	3.39	12.85	2.94	1.67
'Rugia'	28.06.2012*	12.46a	3.58c	12.12cd	2.90b	1.75b
	9.07.2012**	12.88a	3.92a	15.74a	3.81a	1.91a
	4.07.2013*	13.16a	3.31d	13.97b	2.40d	1.65cd
	15.07.2013**	12.46a	3.51c	14.27ab	3.13b	1.70bc
	$\bar{X}$	12.74	3.58	14.02	3.06	1.75
Factors				ρ		
Cultivar		NS	0.0000	0.0005	0.0281	0.0000
Year		NS	0.0000	0.0434	0.0000	0.0000
Harvest date		NS	0.0000	0.0000	0.0000	0.0000
Year × Harvest date		0.0076	0.0008	0.0010	0.0201	0.0003
Year × Cultivar		NS	0.0116	0.0108	NS	0.0065
Harvest date × Cultivar		NS	NS	NS	0.0023	NS
Year × Harvest date × Cultivar		NS	NS	0.0196	NS	NS

Mean values with the same letter in each column are not significantly different according to Tukey HDS test at $\rho \leq 0.05$, $n = 3$ for each date.
* – an earlier harvest date; ** – a later harvest date; NS – non-significant.

Reducing and total sugars

Statistical analysis of the data presented in Table 6 shows that the content of reducing and total sugars in both cultivars was comparable and was dependent on the date of harvesting and the year of cultivation rather than on the cultivar. The fruits harvested in 2013 contained less reducing and total sugars by a few percent than the fruits of 2012. As for 'Yellow Wonder', the variation was greater and amounted to 7.3% in reducing sugars and 9.7% in total sugars. Significantly greater differences in the content of reducing and total sugars were found regarding the date of harvest. The fruits harvested at a later date were characterised by higher content. The greatest variation in content of reducing and total sugars content was found in fruits of 'Rugia' harvested in 2013. The content in fruits harvested at a later date was by 12.7% higher for reducing sugars and by 14.3% higher for total sugars. This may be linked to the high level of sunshine in July 2013. A similar influence of sunshine on sugar content in strawberry fruit is confirmed by the results by Watson et al. (2002). The fact that the content of reducing sugars determined in wild strawberry fruit is comparable to that of total sugars suggests that sugars found in wild strawberry are monosaccharides with a free, reactive aldehyde group. Mean content of reducing and total sugars determined in wild strawberry of both cultivars was 251.80 g kg^{-1} DM and 260.69 g kg^{-1} DM, which is in line with literature data. According to Caruso et al. (2011), the content of total sugars in wild strawberry fruits of 'Regina delle Valli' was 305.8–310.2 g kg^{-1} DM. Mikulic-Petkovsek et al. (2012) determined the sugars content in wild growing wild strawberry at 54.55 g kg^{-1} FM which, considering the 15–20% content of dry matter in fruits, translates into 272.7–363.7 g kg^{-1} DM.

Vitamin C

Vitamin C content in the analysed cultivars of wild strawberry was at a similar level (Table 6). The fruits of 'Rugia' had higher content of vitamin C than that determined for 'Yellow Wonder' – 42.28 mg 100 g^{-1} FM and 37.80 mg 100 g^{-1} FM, respectively. Similar vitamin C content in wild strawberry fruits from the Black Sea area, i.e., 38.55–57.37 mg 100 g^{-1} FM, was determined by Yildiz et al. (2014), and by Doumett et al. (2011) in wild strawberry grown in Italy, i.e., 28.4–30.4 mg 100 g^{-1} FM.

The literature on the subject, generally, gives a higher content of vitamin C – 72 mg 100 g^{-1} FM (Skender et al., 2015) and 80.4 mg 100 g^{-1} FM (Jabłońska-Ryś et al., 2009). In both cultivars, the content is significantly higher when the fruits are harvested at a later date. The greatest difference in vitamin C content was found for 'Rugia' in 2012 – vitamin C content was by 14.6% higher when the fruits were harvested at a later date.

Dry matter

The fruits of wild strawberry 'Rugia' were characterised by significantly higher content of dry matter (Table 6). Mean content of dry matter in fruits of this cultivar amounted to 18.51% and was by 2.85% higher than the mean dry matter content determined in fruits of 'Yellow Wonder'. These findings are consistent with results obtained by other authors. In 'Regina delle Valli', Caruso et al. (2011) determined the content of dry matter at a level of 18.0–18.7%. According to Najda and Dyduch (2009a), dry matter content in wild growing wild strawberry was 21.4%, and in 'Regina' 19.7%. Mean content of dry matter in 'Yellow Wonder' determined in the course of this study was 15.66% and was higher than the content determined for the same cultivar by Dyduch-Siemińska

Table 5. The chemical composition of wild strawberry (*Fragaria vesca* L.) fruits – micronutrients.

Cultivar	Date of harvest	Micronutrients (mg kg^{-1} DM)				
		Fe	S	Zn	Cu	Mn
'Yellow Wonder'	28.06.2012*	53.94c	497.55e	10.56cd	5.03de	41.81a
	9.07.2012**	83.47b	597.40bcd	11.56bc	6.10b	41.65a
	4.07.2013*	44.42c	497.55e	10.56cd	4.61e	34.36b
	15.07.2013**	63.95bc	530.85de	11.23bcd	4.94de	32.15b
	$\overline{X}$	61.45	530.84	10.98	5.17	37.49
'Rugia'	28.06.2012*	64.88bc	614.05bc	12.03b	5.68bc	41.42a
	9.07.2012**	112.01a	697.25a	14.41a	6.72a	41.99a
	4.07.2013*	67.49bc	547.50cde	10.15d	5.37cd	34.19b
	15.07.2013**	81.45b	647.05ab	11.87bc	5.66bc	32.84b
	$\overline{X}$	81.46	626.46	12.12	5.86	37.61
Factors				ρ		
Cultivar		0.0002	0.0000	0.0002	0.0000	NS
Year		0.0014	0.0023	0.0001	0.0000	0.0000
Harvest date		0.0000	0.0000	0.0000	0.0000	0.0266
Year × Harvest date		0.0069	NS	NS	0.0010	0.0090
Year × Cultivar		NS	NS	0.0003	NS	NS
Harvest date × Cultivar		NS	NS	0.0070	NS	NS
Year × Harvest date × Cultivar		NS	NS	NS	NS	NS

Mean values with the same letter in each column are not significantly different according to Tukey HDS test at $\rho \leq 0.05$, $n = 3$ for each date.
* – an earlier harvest date; ** – a later harvest date; NS – non-significant.

et al. (2015), i.e., 11.11%. In both years of the experiment, the fruits harvested at a later date were characterised by higher content of dry matter. The greatest difference due to date of harvest was found in 2013 in 'Rugia', respectively 16.79% and 20.13%.

Conclusions

The chemical composition of wild strawberry fruits was significantly dependent on the cultivar, year of cultivation and the date of harvesting. The fruits of 'Rugia' were characterised by a substantially higher content of dry matter, and accumulated significantly larger amounts of phosphorus, potassium, calcium, magnesium, iron, sulphur, zinc, copper and vitamin C. From a nutritional point of view, fruits of this cultivar are more nutritious. In the second year of the experiment, fruits of both cultivars were generally characterised by lower content of the analysed components. In both years of the experiment, fruits of both cultivars harvested at a later date (second date) contained significantly larger amounts of all analysed components apart from nitrogen and manganese. The results of this study are certainly very interesting for horticulturists dealing with 'health food' and interested in interactions between the growing conditions and the nutrient content of the fruits. Future studies need to test the limits of the growth of the nutritional value of wild strawberry under the influence of applied factors.

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Table 6. The chemical composition of wild strawberry (*Fragaria vesca* L.) fruits – sugars, vitamin C and dry matter.

Cultivar	Date of harvest	Reducing sugars (g kg^{-1} DM)	Total sugars (g kg^{-1} DM)	Vitamin C (mg 100 g^{-1} FM)	Dry matter (%)
'Yellow Wonder'	28.06.2012*	260.50ab	264.35ab	36.10c	15.58bc
	9.07.2012**	263.60ab	276.85a	40.53b	16.35bc
	4.07.2013*	235.20ab	236.80c	35.71c	14.49c
	15.07.2013**	253.15ab	256.50b	38.85b	16.20bc
	$\overline{X}$	253.11	258.63	37.80	15.66
'Rugia'	28.06.2012*	243.45ab	251.85bc	39.09b	17.06b
	9.07.2012**	266.80a	276.85a	44.82a	20.07a
	4.07.2013*	231.20b	243.70c	40.02b	16.79b
	15.07.2013**	260.50ab	278.60a	45.19a	20.13a
	$\overline{X}$	250.49	262.75	42.28	18.51
Factors			ρ		
Cultivar		NS	NS	0.0000	0.0000
Year		0.0141	0.0007	NS	NS
Harvest date		0.0028	0.0000	0.0000	0.0000
Year × Harvest date		NS	NS	NS	NS
Year × Cultivar		NS	0.0036	0.0089	NS
Harvest date × Cultivar		NS	0.0266	0.0096	0.0057
Year × Harvest date × Cultivar		NS	NS	NS	NS

Mean values with the same letter in each column are not significantly different according to Tukey HDS test at $\rho \leq 0.05$, $n = 3$ for each date.
* – an earlier harvest date; ** – a later harvest date; NS – non-significant.

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