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COMPARISON OF QUALITATIVE TRAITS, BIOLOGICAL VALUE, CHEMICAL COMPOUNDS OF SWEET PEPPER FRUIT

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Abstract

Sweet pepper fruits have a high biological value, a rich content of minerals. At present, large-fruit cultivars, distinguishable by a thick pericarp wall, high processing efficiency, good growth on fields, under covers, dominate in sweet pepper cultivation.

The present research has been conducted to compare the qualitative traits, chemical composition of sweet pepper fruits of the Red Knight F_1 cultivar grown in a greenhouse, on open field. The evaluation of qualitative traits, biological value, chemical composition demonstrated that fruits from the greenhouse cultivation were characterized by significantly larger fruit weight, weight of edible parts as compared to those harvested from a field, although they did not differ significantly in the pericarp thickness. Fruits produced on a field had a higher ratio of the technological to total fruit weight, which proves that the cultivar is an attractive choice for field cultivation of sweet pepper, suitable for processing. Pepper fruits from a field versus the ones grown in a greenhouse contained significantly less dry matter, reducing sugars but more vitamin C. The greenhouse-grown fruits contained higher levels of nitrogen, phosphorus, potassium, calcium, magnesium than those from a field.

Key words: sweet pepper fruit, qualitative traits, biological value, chemical compounds.

PORÓWNANIE CECH JAKOŚCIOWYVCH, WARTOŚCI BIOLOGICZNEJ ORAZ SKŁADU CHEMICZNEGO OWOCÓW PAPRYKI SŁODKIEJ

Abstrakt

Owoce papryki słodkiej mają dużą wartość biologiczną i zawierają wiele składników mineralnych. Aktualnie w uprawie papryki dominują odmiany wielkoowocowe o grubej

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ściance owocni, dużej wydajności technologicznej i nadające się do uprawy zarówno w polu, jak i pod osłonami. Celem pracy było porównanie cech jakościowych oraz składu chemicznego owoców papryki słodkiej odmiany Red Knight F_1 uprawianej w szklarni oraz w otwartym polu. W badaniach dotyczących oceny cech jakościowych owoców oraz wartości biologicznej i składu chemicznego wykazano, że owoce z uprawy w szklarni odznaczały się istotnie większą masą oraz masą części jadalnej w porównaniu z zebranymi z pola, natomiast nie różniły się istotnie pod względem grubości perykarpu. W owocach stwierdzono większy udział masy technologicznej w całkowitej masie owocu z pola, co potwierdza atrakcyjność tej odmiany do uprawy w polu na potrzeby przetwórstwa. Stwierdzono też istotnie mniej suchej masy i cukrów redukujących, a więcej witaminy C w porównaniu z owocami ze szklarni. W owocach z uprawy szklarniowej wykazano większą zawartość azotu, fosforu, potasu, wapnia i magnezu niż z uprawy polowej.

Słowa kluczowe: owoce papryki słodkiej, cechy jakościowe, wartość biologiczna, skład chemiczny.

INTRODUCTION

Sweet pepper fruits are very tasty, healthy owing to their content of biologically active chemicals with antioxidant properties. The vegetable is an abundant source of vitamin C (Kmiecik, Lisiewska 1994, Lee, Kader 2000, Buczkowska, Najda 2002, Gajc-Wolska at el. 2005, 2007, Perucka, Materska 2004, Pokluda 2004, Jadczak et al. 2010, Michalik 2010). Physiologically ripe fruits are abundant in carotenoid pigments (Kmiecik, Lisiewska 1994, Perucka, Materska 2004, Pokluda 2004). Sweet pepper fruits also contain phenolic compounds (Perucka, Materska 2004). Moreover, pepper is an important source of minerals for humans (Kmiecik, Lisiewska 1994, Bubicz et al. 1999, Michalik 2000, Pokluda 2004, Gajc-Wolska et al. 2007, Jadczak et al. 2010).

At present, commercial production of sweet pepper is dominated by heterotic, large-fruit cultivars because consumers prefer large peppers with a thick pericarp. Most of the popular cultivars are well-adapted to growing under less favorable environmental conditions, they are cultivated both in greenhouses, on fields (Buczkowska 2007, Gajc-Wolska et al. 2007, Korzeniewska, Niemirowicz-Szczytt 2007, Jadczak et al. 2010).

The weight of the pericarp, i.e. the edible part of a pepper fruit, which determines the bio-technological efficiency of a given cultivar, its usefulness for industrial processing, is an important feature of sweet pepper (Kmiecik, Lisiewska 1994, Nowaczyk, Nowaczyk 2005, Buczkowska 2007, Korzeniewska, Niemirowicz-Szczytt 2007, Jadczak et al. 2010).

Numerous studies on the use, biological value of sweet pepper fruits have demonstrated their dependence on many factors, mainly cultivar-specific traits (Kmiecik, Lisiewska 1994, Gajc-Wolska, Skąpski 2001, Buczkowska, Najda 2002, Pokluda 2004, Buczkowska 2007, Korzeniewska, Niemirowicz-Szczytt 2007, Jadczak et al. 2010), the weather course or microclimate conditions during the growth, ripening of fruits (Gajc-Wolska, Skąpski 2002, Buczkowska 2007, Gaj-Wolska et al. 2007), plant nutrition (Golcz 2001, Golcz

et al. 2004a,b, PERUCKA, MATERSKA 2004, MICHAŁOJĆ, HORODKO 2006), various treatments that stimulate the yielding (GAJC-WOLSKA et al. 2007).

The present research aimed at comparing the qualitative traits, chemical composition of sweet pepper fruits of the Red Knight F_1 cultivar grown in a greenhouse, on open field.

MATERIAL, METHODS

The material comprised sweet pepper fruits of the heterotic cultivar Red Knight F_1 (Seminis Vegetable Polska S.A.). Fruits from agrotechnical experiments carried out in 2009, 2010 in an unheated greenhouse, on field were used for analytical determinations.

Pepper plants were grown in a greenhouse, in 10 dm^3 plastic cylinders, with 4 plants per m^2. They grew on horticultural peat of the initial pH equal 4.6, later limed with $CaCO_3$ to achieve pH 6.5. There were 20 plants of the cultivar Red Knight F_1, a replication consisted of a pot with a single plant (an experimental unit). Transplants were planted onto the target location at the end of April, the experiment was terminated at the beginning of October.

The following quantities of nutrients were applied during the whole growing season (in g $plant^{-1}$): N – 10 in the form of KNO_3, NH_4NO_3; P – 6.0 as $Ca(H_2PO_4)_2 \cdot H_2O$ with the content of 20.2% P; K – 15 as KNO_3, 37.3% K, 15.5% N; Mg – 7.0 in the form of $MgSO_4 \cdot H_2O$ 17.4% Mg. The microelements were used as EDTA complexes – Fe, $CuSO_4 \cdot 5H_2O$, $ZnSO_4 \cdot 7H_2O$, $MnSO_4 \cdot H_2O$, H_3BO_3, $(NH_4)_2Mo_7O_{24} \cdot 4H_2O$ at amounts as for peat subsoils. Microelements were introduced into the soil once before planting to the permanent place. Phosphorus was applied in the middle of plant setting, in the sixth vegetation week. A quarter dose of nitrogen, potassium,, magnesium was used before plant setting, while the remaining quantities were applied as post-crop in five doses every 10 days. The post-crop N, K, Mg nutrition was completed 2 weeks before the end of the experiment.

The field experiment was carried out in Zezulin (Łęczna district) on lessive soil developed from loess formations, with the organic matter content of 1.8%. The suitability of Red Knight F_1 sweet pepper fruits for food industrial processing was evaluated. The experiment was conducted in four replications, each replication consisting of 20 plants. The surface area of a replication plot was 4.8 m^2. Wheat was the forecrop for pepper in both years of the experiment. Manure at the amount of 40 t ha^{-1} was applied in autumn, while mineral nutrition was performed according to the soil analysis results. Mineral concentrations in 2009, 2010 were as follows (mg dm^{-3}): N – 60, 30; P – 160, 180; K – 320, 180; Ca – 3400, 2600; Mg – 80, 40 at pH 6.8, 6.5. Before planting the seedlings, mineral nitrogen nutrition at the

level of 30 kg N ha^{-1} (2009), 50 kg N ha^{-1} (2010) in the form of nitrogen nitrate was applied. Foliar nutrition was applied as post-crop: twice with Florovit (0.5%), twice with calcium nitrate (1.0%). Transplants were prepared in pots according to the requirements for that species. They were then planted on a field at 4.2 plants m^{-2} spacing in the third decade of May. The experiment was finished at the end of September. Randomly selected, fully ripe fruits harvested at the beginning of September were chosen for analysis. In both years, the qualitative traits were determined on the basis of 20 fruits harvested from the greenhouse, from the field. The technological weight of a fruit corresponded to the weight of the pericarp weight after removing the placenta with seeds, the petiole with sepals (KMIECIK, LISIEWSKA 1994).

The following were determined in fresh fruits: dry matter with the dryer method, vitamin C with Tillmann's method, sugars according to Schoorl-Rogenbogen's method. Additionally, dried fruits were analyzed to determine N-total with Kjeldahl's method,, after dry combustion, P by colorimetry using ammonium vanadium molybdate, as well as K, Ca, Mg – by AAS (Perkin-Elmer). All determinations were performed in three replicates.

The results were statistically processed by means of variance analysis according to one-factor experiment in 2009, 2010. Significant differences were verified with T-Tukey multiple confidence intervals at 5% significance level.

RESULTS AND DISCUSSION

The sweet pepper cultivar Red Knight F_1 belongs to large-fruit peppers with a relatively short vegetation period. Fruits of this cultivar have distinctively high weight, a thick pericarp. For this reason, the cultivar is very popular in Poland, grown in greenhouses, foil tunnels, on open field (GAJC-WOLSKA et al. 2007, KORZENIEWSKA, NIEMIROWICZ-SZCZYTT 2007). Fruits harvested at the beginning of September in 2009, 2010 achieved high weight: 246 g in greenhouse, 180 g on field (Table 1). The thermal conditions during the sweet pepper vegetative growth in 2009, 2010 were suitable for thermophilic vegetables (Figure 1). The mean daily air temperature from May to September was higher than the multi-year average for the same period. High air temperatures in July, August favoured the growing, ripening of pepper fruits. Also, the moisture conditions were adequate, the water deficiency which occurred on the field in 2009 was compensated for by irrigation.

Fruits of the examined cultivar were characterized by a thick pericarp: 6.3-6.7 mm on average. No significant differences in this the trait were observed between fruits grown in the greenhouse, on the field, KORZENIEWSKA, NIEMIROWICZ-SZCZYTT (2007) reported similar results for the same cultivar concerning the mean weight of commercial fruits (176-180 g), the average thickness of the pericarp (5.8-6.0 mm).

Table 1

Qualitative traits of fruits of sweet pepper Red Knight F_1 cultivar

Place of cultivation	Fruit weight (g)			Pericarp thickness (mm)			Technological weight (g)			Share of technological weight in total weight of fruit (%)		
	2009	2010	mean	2009	2010	mean	2009	2010	mean	2009	2010	mean
Greenhouse	258	234	246	6.7	6.5	6.6	180	168	174	69.8	71.8	70.7
Field	186	174	180	6.3	6.3	6.3	158	150	154	84.9	86.2	85.5
Mean	222	204	213	6.5	6.4	6.4	169	159	164	76.1	77.9	77.0
$LSD_{\alpha=0.05}$	42.2	38.8	-	n.s.	n.s.	-	32.1	30.2	-	-	-	-

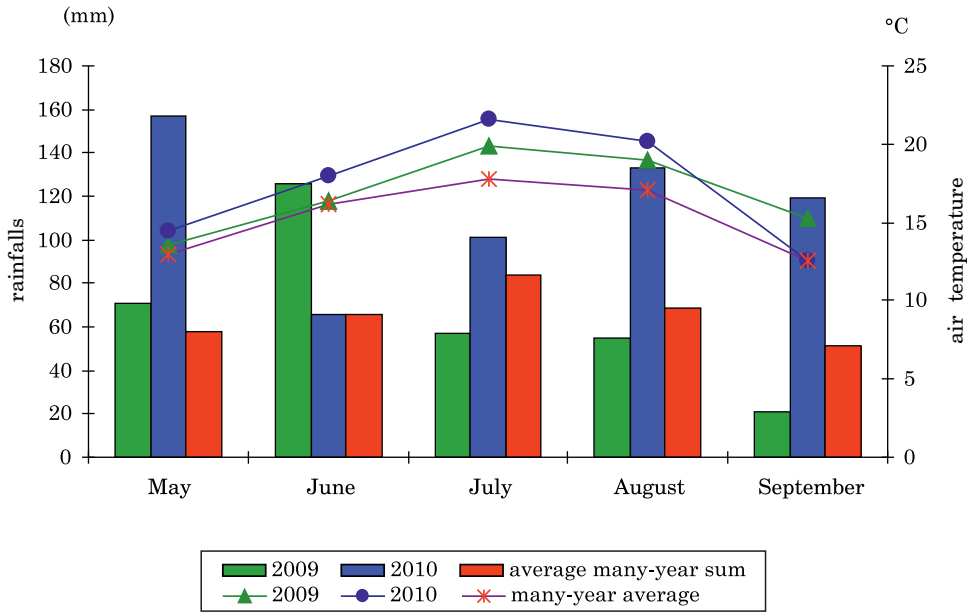

Fig. 1. Average monthly air temperature and sums of rainfalls in 2009-2010 during pepper vegetation in comparison to average multiannual values

Fruits of the examined pepper cultivar also attained a high pericarp weight. The average weight of the pericarp of fruits grown in the greenhouse was 174 g, whereas that of the fruits grown in the field 154 g. The results on the ratio of technological weight to the total weight of fruits appeared to be very interesting. For fruits harvested in the field, the percent ratio was about 85-86%, while for those from the greenhouse it was

70-72%, which was probably because fruits harvested from the field formed a lighter placenta but did not differ considerably in the pericarp thickness from the greenhouse fruits. Considering the technological value of sweet pepper cultivars, fruits whose technological weight or bio-technological efficiency is above 75% of the total fruit weight are assumed to be valuable (KMIECIK, LISIEWSKA 1994, NOWACZYK, NOWACZYK 2005, JADCZAK et al. 2010).

The results, the literature references on qualitative traits of stable, heterotic sweet pepper cultivars demonstrate that Red Knight F_1 is very useful economically, recommendable for cultivation on fields, indoors, to be consumed fresh or processed (KMIECIK, LISIEWSKA 1994, GAJC-WOLSKA, SKĄPSKI 2002, B UCZKOWSKA 2007, GAJC-WOLSKA et al. 2007, KORZENIEWSKA, NIEMIROWICZ-SZCZYTT 2007, GAJC-WOLSKA et al. 2007).

Fruits of Red Knight F_1 are also attractive because of their quantity, shape (Table 2). The mean shape coefficient was close to a unit (1.03-1.07), while the mean diameter, length were 8.8, 9.3 mm, respectively. Significantly larger fruits were harvested from the greenhouse.

Table 2

Biometric traits of fruits of sweet pepper Red Knight F_1 cultivar

Place of cultivation	Fruit length (cm)			Fruit diameter (cm)			Shape coefficient		
	2009	2010	mean	2009	2010	mean	2009	2010	mean
Greenhouse	9.8	9.6	9.7	9.2	9.2	9.2	1.07	1.04	1.05
Field	8.9	8.8	8.9	8.5	8.5	8.5	1.05	1.03	1.05
Mean	9.4	9.2	9.3	8.8	8.8	8.8	1.05	1.04	1.05
$LSD_{\alpha=0.05}$	0.72	0.70	-	0.58	0.61	-	-	-	-

The dry matter of the fruits was highly varied, ranging from 8.97 to 10.70% in dependence on the cultivation localization (Table 3). Less dry matter was determined in fruits harvested from the field in 2009, when the rainfall deficiency during the fruit ripening was compensated for by intensive irrigation. The results on the dry matter content in fruits from the present experiment were higher than reported by other authors for sweet pepper cultivars (5.24-10.29%) (GAJC-WOLSKA, SKĄPSKI 2001, 2002, GAJC-WOLSKA et al. 2005, 2007, JADCZAK et al. 2010), but close to the data (10.10-11.59%) recorded earlier by BUCZKOWSKA, NAJDA (2002) as well as MICHAŁOJĆ, HORODKO (2006).

A higher vitamin C concentration was determined in pepper fruits from the field cultivation (200.98 mg 100 g^{-1} f.m.) as compared to the greenhouse (178.62 mg 100 g^{-1} f.m., on average). These results confirmed that insolation during fruit ripening had a positive influence on the vitamin C accumu-

lation (LEE, KADAR, 2000). Comparable content of vitamin C in hybrid sweet pepper cultivars was reported by other authors, e.g. 168.7-202.5 mg 100 g^{-1} (BUCZKOWSKA, NAJDA 2002), 176.3-197.3 mg 100 g^{-1} (GAJC-WOLSKA, SKĄPSKI, 2002), 150.1-242.6 mg 100 g^{-1} (POKLUDA, 2004). Demonstrably more vitamin C (200.3-289.3 mg 100 g^{-1}) was determined in pepper fruits tested in 1999--2000 by GAJC-WOLSKA, SKĄPSKI (2001). In contrast, less vitamin C was found in 2005-2006 by GAJC-WOLSKA et al. (2007; 70.39-137.46 mg 100 g^{-1}), in 2006--2008 by MICHALIK (2010; 110.46-148.77 mg.100 g^{-1}). These results indicate that the vitamin C concentration in sweet pepper fruits depends mainly on the cultivar-specific traits, but is also affected by weather conditions, agrotechnical treatments (GAJC-WOLSKA, SKĄPSKI 2001, GAJC-WOLSKA et al. 2007).

Relatively high levels of total sugars (5.15%), reducing sugars (4.64%, on average) were recorded in Red Knight F_1 fruits. Slightly more sugars were determined in fruits of Red Knight F_1 in 2010. This value is comparable to that recorded in other heterotic cultivars studied by MICHAŁOJĆ, HORODKO (2006; 5.26-6.05%), GAJC-WOLSKA et al. (2007; 3.80-5.26%) but lower than found by BUCZKOWSKA, NAJDA (2002; 3.86-4.44%). No unambiguous influence of the cultivation site on sugar accumulation was observed.

The content of total nitrogen in fruits ranged from 20.80 to 24.87 g N-tot. kg^{-1} d.m. (Table 4). Slightly higher concentrations of the element were recorded in fruits harvested from the greenhouse (24.50 g N-tot. kg^{-1} d.m.) than from the field (21.65 g N-tot. kg^{-1} d.m.). Moreover, less nitrogen was determined in fruits grown outdoors in 2010. During the fruit ripening (August-September 2010), the rainfall sum was twice as high as the multiyear average for that period (Figure 1). The nitrogen concentration in fruits of the examined cultivar is similar to that in cv. Rebeka F_1 determined by MICHAŁOJĆ, HORODKO (2006). JADCZAK et al. (2010) also confirmed a similar N-total content in fruits of several hybrid cultivars originating from Israel. Comparable quantities of N-total were also found by GOLCZ et al. (2004) in fruits of some hot pepper cultivars grown in an experiment on various potassium nutrition variants.

The phosphorus content in fruits harvested from the greenhouse (2.18 g P kg^{-1} d.m.) was slightly higher than that from the field (2.05 g P kg^{-1} d.m.). More phosphorus in fruits grown on field was recorded in 2009 (2.20 g P kg^{-1} d.m.) than in 2010 (1.90 g P kg^{-1} d.m.). The results on the phosphorus concentration in fruits of Red Knight F_1 obtained in the present experiment are comparable to the ones reported by KMIECIK, LISIEWSKA (1994), who evaluated the usefulness of stable cultivars for processing. Much more phosphorus than in sweet pepper fruits of heterotic cultivars was determined by JADCZAK et al. (2010), in fruits of hot pepper cultivars in experiments performed by GOLCZ et al. (2004) as well as JADCZAK, GRZESZCZUK (2004). GAJC--WOLSKA et al. (2005, 2007) observed distinctly less phosphorus in fruits of heterotic cultivars, including Red Knight F_1, i.e. 0.38 g P kg^{-1} d.m.

Table 3

Content of some chemical compounds in the fruit of sweet pepper Red Knight F_1 cultivar

Place of cultivation	Dry matter (%)			Vitamin C (mg 100 g^{-1} f.m.)			Sugars (g 100^{-1} f. m.)					
							reducing			total		
	2009	2010	mean	2009	2010	mean	2009	2010	mean	2009	2010	mean
Greenhouse	10.70	10.20	10.50	176.25	180.99	178.62	5.04	4.74	4.89	5.43	4.82	5.12
Field	8.97	10.32	9.65	209.47	192.50	200.98	4.75	4.05	4.40	5.50	4.87	5.18
Mean	9.87	10.26	10.50	192.86	186.75	189.80	4.89	4.39	4.64	5.46	4.84	5.15
$LSD_{\alpha=0.05}$	0.855	n.s.	-	17.326	9.275	-	0.062	0.085	-	0.047	0.038	-

Table 4

Content of macronutrients in the fruit of sweet pepper Red Knight F_1 cultivar

Place of cultivation	Macronutrients (g kg^{-1} d.m.)														
	N-total			P			K			Ca			Mg		
	2009	2010	mean	2009	2010	mean	2009	2010	mean	2009	2010	mean	2009	2010	mean
Greenhouse	24.13	24.87	24.50	2.20	2.17	2.18	23.40	26.87	25.14	0.50	0.51	0.51	0.97	0.97	0.97
Field	22.50	20.80	21.65	2.20	1.90	2.05	20.63	20.20	20.42	0.39	0.58	0.48	0.70	0.90	0.80
Mean	23.31	22.84	23.08	2.20	2.04	2.12	22.01	23.54	22.78	0.44	0.54	0.49	0.84	0.94	0.89
$LSD_{\alpha=0.05}$	1.250	1.528	-	n.s.	0.155	-	1.562	2.375	-	0.081	0.063	-	0.187	0.057	-

The mean potassium content was 22.78 g K kg^{-1} d.m. More potassium was found in fruits from the greenhouse (mean 25.14 g K kg^{-1} d.m.), particularly in 2010 (26.87 g K kg^{-1} d.m.). The concentration of potassium in fruits harvested from the field was 20.42 g K kg^{-1} d.m., did not vary between the years of the experiment. Similar potassium levels were reported by KMIECIK, LISIEWSKA (1994) in sweet pepper fruits of stable cultivars,, by GAJC-WOLSKA et al. (2005), GOLCZ et al. (2004) in fruits of heterotic cultivars. Fruits of stable Czech cultivars grown on field in Moravia contained more potassium (POKLUDA 2004), same as hybrid cultivars in studies on the influence of Goteo, BM 86 preparations on the yield, quality of sweet pepper fruits (GAJC-WOLSKA et. al. 2007). Similarly, more potassium in Delphin F_1 cultivar fruits was reported by GOLCZ (2001), who evaluated the effects of diverse potassium nutrition on sweet pepper yielding.

The average calcium concentration was 0.49 g Ca kg^{-1} d.m. Slightly more calcium was determined in the greenhouse fruits (0.51 g Ca kg^{-1} d.m.) than in the field ones (0.48 g Ca kg^{-1} d.m.). Much higher contents of calcium were recorded in fruits cultivated in the field in 2010 (0.58 g Ca kg^{-1} d.m.) than in 2009 (0.39 g Ca kg^{-1} d.m.). This could be the result of different moisture conditions in 2009, 2010 (Figure 1). GAJC-WOLSKA et al. (2007) reported comparable, while KMIECIK, LISIEWSKA (1994), MICHALIK (2000), as well as GAJC-WOLSKA et al. (2005) found lower calcium concentrations in sweet pepper. Much more calcium (0.90-2.62 g Ca kg^{-1} d.m.) was found in sweet pepper fruits by other authors (BUBICZ et al. 1999, GOLCZ 2001, GOLCZ et al. 2004, POKLUDA 2004, JADCZAK et al. 2010).

The average magnesium content in fruits of the Red Knight F_1 cultivar was 0.89 g Mg kg^{-1} d.m. Significantly different concentrations of the element in fruits from the greenhouse (0.97 g Mg kg^{-1} d.m.), from the field (0.80 g Mg kg^{-1} d.m.) were recorded. The years of the experiment did not differentiate the content of magnesium in fruits grown in the greenhouse. However, fruits from the field cultivation contained more magnesium in 2010 (0.90 g Mg kg^{-1} d.m.) than in 2009 (0.70 g Mg kg^{-1} d.m.). Comparable magnesium levels in sweet pepper fruits were found by other researchers (BUBICZ et al. 1999, MICHAŁOJĆ, HORODKO 2006, GAJC-WOLSKA et al. 2007, JADCZAK et al. 2010), whereas some reported much higher (1.90-3.18 g Mg kg^{-1} d.m.; GOLCZ, 2001, GOLCZ et al. 2004, POKLUDA 2004) or much lower content (0.104 g Mg kg^{-1} d.m., MICHALIK 2000).

CONCLUSIONS

1. The greenhouse fruits were characterized by substantially higher fruit weight, weight of edible parts as compared to those harvested from the field, although they did not differ significantly in the pericarp thickness.

2. Fruits harvested from the field were distinguished by a higher share of the technological weight in the total weight, which makes the tested cultivar suitable for in the field for processing purposes.

3. Significantly less dry matter, reducing sugars, but more vitamin C were found in fruits from the field than from the greenhouse cultivation.

4. Higher concentrations of nitrogen, phosphorus, potassium, calcium, magnesium were determined in fruits grown in the greenhouse than in the field.

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