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THE INFLUENCE OF PLANT CUTTING ON THE FRUIT QUALITY *CUCURBITA MOSCHATA* DUCH.

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Abstract

The study objective was to determine the effect of topping cut of winter squash (Cucurbita moscata) plants on the biological value of the fruit. The experiment included two cultivars; the Italian cultivar 'Waltham' and Bulgarian 'Muscatna'. Moreover, biological value of fruit depending on the order of their growth on the plant (1, 2 and 3 fruit) has been compared. In fresh fruit, dry weight and content of: L-ascorbic acid, chlorophyll pigments (a, b and total chlorophyll), total carotenoids, total polyphenols, and antioxidative activity expressed as percentage of DPPH radical reduction and total acidity have been determined. Among the studied winter squash cultivars, the fruit of the 'Waltham' cultivar was characterized by higher biological value compared to the cultivar 'Muscatna'.

The performed plant cutting procedure behind the third formed fruit had a significant effect on the increase of biological value of yield. Fruit appearing at the earliest date on plants were characterized by higher dry weight and higher total carotenoid, chlorophyll a and total chlorophyll content. Fruit forming as second on plants contained more chlorophyll b, total polyphenols and had higher DPPH activity, while fruit appearing as third contained significantly higher L-ascorbic acid and had higher total acidity.

Keywords: winter squash, plant cutting, biological value, cultivars.

INTRODUCTION

Winter squash, syn. Pepo moschata Duch. is classified in the cucurbits family (Cucurbitaceae). Thus far, two species have been cultivated to a higher extent: pumpkin (C. maxima) and summer squash (C. pepo). Presently, with the growth of awareness of European societies about healthy nutrition, a tendency (not only in Poland but also in other European countries) has been observed for introducing new vegetable types with high health-promoting properties, which include winter squash (Kamarudin et al., 2014). Attempts are made to cultivate it in areas, where it has not yet been grown. Winter squash is closely related to the pumpkin. It is a dicotyledonous, annual plant, with long, trailing stems reaching 5–6 meters in length. A winter squash fruit is a berry fused with the receptacle.

Depending on the cultivar, the fruit may differ in terms of shape and colour of the flesh and the skin. It naturally occurs in South and Central America. Flesh at various stages of physiological ripeness and seeds constitute edible portions of winter squash. Due to high nutritional value and culture efficiency and good storage capacity, squash is in the top of globally cultivated vegetables (Mbogne et al., 2015). Fruit are typically obtained from cultivation, more rarely seed oil or edible flowers. Squash fruit, including winter squash, possess high health-promoting properties. The flesh contains numerous mineral components, including, among others, potassium, calcium, phosphorus, magnesium, iron, zinc and selenium, B vitamins, particularly B1, B2, B3, B6, vitamin C, PP, folic acid and pantothenic acid, and also pectins and organic acids. Pumpkin is an excellent source of vitamin A, with its orange colour indicating high content of β-carotene that is transformed by the organism into vitamin A. The most valuable cultivars of winter squash include those with orange-coloured flesh, which are characterized by high content of carotenes, mainly α-carotene, β-carotene and lutein's (Zaccari et al., 2015). It is also worth emphasizing that squashes are low-energy vegetables, the energy value of which is about 30 kcal and contain a low amount of basic nutrients, such as proteins, fats and carbohydrates (Danilcenko et al., 2004).

MATERIALS AND METHODS

The study was conducted in the period 2013–2014. The field experiment was conducted in the Vegetable Experimental Station of the West Pomeranian University of Technology in Szczecin in the township of Dołuje, while laboratory analyses were conducted in the laboratory of the Department of Horticulture of the West Pomeranian University of Technology in Szczecin. The experiment tested the influence of plant cutting and the order of fruit growing on the plant in two winter squash cultivars on qualitative properties of fruit influencing their biological value. The factors of the experiment were: winter squash cultivar: 'Waltham' (Italian cultivar) and 'Muscatna' (Bulgarian cultivar), plant cutting: behind the third formed fruit, without cutting (control) and order of fruit growing on plant (fruit 1, 2 and 3). Winter squash was cultivated based on seedlings produced in pots with 8 cm diameter, in a reproduction greenhouse. To this end, seeds were sown on 20 April, 2 pieces per each pot filled with the substrate to 2/3 of its height.

After emergence, the weaker seedling was removed, and the pots were filled with the substrate to the top. Squash seedling in the first year of the experiment was planted in the field on 23 May, whereas in the second year on 19 May, in a strip-row system in three repetitions, 6 plants per each experimental field (120-240-120x120). Winter squash fruit was collected after their full growth, on 9 October 2013 and 3 October 2014.

Subsequently, mean samples were collected from fresh raw material to conduct chemical analyses. For flesh, dry weight and the following were determined: L-ascorbic acid, chlorophyll pigments, total carotenoids, total polyphenols.

Moreover, total acidity and antioxidative activity were determined, the latter measured as percentage of DPPH radical neutralization. Dry weight was determined by drying a specified sample at 105°C to constant weight (Krełowska-Kułas, 1993). The vitamin C content, as L-ascorbic acid was determined using the Tilmans method, consisting in reduction of a stained solution of 2,6-dichlorophenolindophenol to colourless leuco compound under the influence of L-ascorbic acid (Krełowska-Kułas, 1993). Determination of chlorophyll a, b and total content and total carotenoids were performed according to Lichtenthaler and Wellburn (1983).

The content of total polyphenols was determined with a spectrophotometric method using the Follin-Ciocalteu's reagent against gallic acid as the standard, according to Singleton and Rossi (1965). Determination of antioxidative activity with the method of DPPH free radical reduction was made according to Yen and Chen (1995) and calculation of DPPH inhibition percentage according to the formula provided by Rossi et al. (2003). Sample absorbance was read on a spectrophotometer at wavelength 517 nm.

The obtained study results were statistically elaborated by performing variance analysis appropriate for the assumed experimental design - random split-blocks. The confidence intervals were determined using the Tukey test at significance level α=0.05.

RESULTS AND DISCUSSION

Content of biologically active compounds in plant material largely depends on external factors, e.g. species or cultivar, and internal factors such as environmental conditions or cultivation methods (Telesiński et al., 2014). One of the basic characters determining the quality of plant products is the dry weight of fresh raw material. Based on results provided in tab. 1, a significantly higher dry weight in the individual study years, as well as mean for study years, was determined in the case of 'Waltham' fruit compared to the 'Muscatna' cultivar. On average, dry weight of 'Waltham' fruit was higher in comparison to 'Muscatna' fruit by over 7%. Independently of the cultivar, fruit collected from plants subject to cutting procedure were characterized by higher dry weight. This tendency was also observed in individual years of the experiment, as well as mean for study years. Despite the statistical differences in dry weight in individual years of the study, based on mean results no significant difference was found in the dry weight of winter squash fruit depending on the order of their growth on plants. According to literature data, squash fruit dry weight is highly variable and depends on the species and cultivar (Chilczuk 2014). The author, by comparing winter squash and pumpkin cultivars was able to demonstrate the highest dry weight in fruit of pumpkin 'Amazonka', and lowest in the fruit of the 'Otylia F1' cultivar. According to Niewczas and Mitek (2004), dry weight of squash fruit may range from 5.0 to 18.0%, depending on the species and type. In the presented study, dry weight of the studied winter squash cultivars differed significantly and amounted from 8.28% in the 'Muscatna' cultivar to 29.84% in the 'Waltham' cultivar.

The content of L-ascorbic acid in individual years and mean for study years was higher in the ‘Waltham’ cultivar. However, no significant effect of plant cutting on the content of the studied compound in fruit was found. Moreover, differences in the content of L-ascorbic acid in fruit, depending on the order of their appearance on plants were insignificant, despite the fact that in the first year of study fruit growing as first on plant contained higher amount of the acid, while in the second year of study fruit appearing as second on plants. The mean content of L-ascorbic acid in the studied squash fruit ranged from 8.55 $mg \cdot 100\ g^{-1}$ in the ‘Muscatna’ cultivar to 38.52 $mg \cdot 100\ g^{-1}$ in ‘Waltham’. In the study of Niewczas et al. (2005) the content of L-ascorbic acid in pumpkin ranged from 22.0 to 31.0 $mg \cdot 100\ g^{-1}$. In the case of spaghetti squash, Wojdyła (2007) determined the content of L-ascorbic acid at the level from 3.75 to

9.5 mg·100 g^{-1}. As provided in the studies of Jacobo-Valenzuela et al. (2011) and Roura et al. (2007) the content of L-ascorbic acid for winter squash is at the level of 22.9 mg·100 g^{-1}.

The total acidity of fruit flesh as calculated to citric acid remained at a similar level in the fruit of the tested squash cultivars, independently of the applied research factors (0.07-0.18%). It was only determined that in the second study year, fruit of the 'Waltham' cultivar were characterized by a significantly higher content of organic acids in comparison to the fruit of 'Muscatna' cultivar, and the difference was 0.05%. In the same year of study, independently of cultivar, fruit appearing on plants as second and third were characterized by significantly higher total acidity. Plant cutting did not have a significant influence on the acidity of fruit in individual years of study, yet based on mean results significantly higher acidity was found in fruit flesh originating from plants which were not subjected to the cutting procedure. The obtained results are slightly lower than those presented by Sharma and Rao (2013), who demonstrate that general acidity determined for pumpkin fruit remains at the level of 0.64%.

In the first year of the experiment, fruit of the Bulgarian cultivar 'Muscatna' were characterized by higher content of chlorophyll a, b and total chlorophyll. Moreover, it was demonstrated that plant cutting had a significant influence on the content of these components in fruit (tab. 2). In the same year of study, independently of cultivar, fruit growing as first on plant contained more chlorophyll a and b. According to Muenmanee et al. (2016) the content of chlorophyll a, b and total chlorophyll increases with the degree of ripeness of pumpkin fruit. The authors have demonstrated that the content of chlorophyll a, b and total chlorophyll in the fruit of this species was from 15.85 to 49.42 mg·g^{-1}.

The Italian cultivar 'Waltham' of winter squash (in the second year of study and mean for years) was characterized by higher total carotenoid content compared to the Bulgarian 'Muscatna' cultivar (Table 3). It was further demonstrated that in plants subjected to cutting procedure possessed fruit with significantly higher total carotenoid content in comparison to fruit obtained from plants cultivated without cutting. Moreover, in the second year of study, significant differences in carotenoid content were found in fruit, depending on their distribution on plant. The highest carotenoid content was found for fruit appearing on plants as at the earliest date. Carotenoids are among the most important groups of natural pigments with strong antioxidative properties. Carvalho et al. (2012) determined that their content in winter squash fruit ranges from 23.40 to 148.50 mg·kg^{-1}. In the study of Telesiński et al. (2014), the total carotenoid content in fruit of winter squash cv. 'Muscatna' was 57.24 mg·kg^{-1}. According to Biesiada et al. (2006), in certain squash species and their cultivars, the total carotenoid content may exceed 220 mg·kg^{-1}. In the present study, it was determined that their content ranged from 12.44 mg·kg^{-1} in cv. 'Muscatna' to 217.46 mg·kg^{-1} in cv. 'Waltham'.

In the second year of study, as well as mean for years, significantly higher content of total polyphenols was determined in fruit of winter squash cv. 'Waltham'. Moreover, their higher content characterized fruit from cut plants in comparison to fruit collected from plants not subjected to cutting procedure. Also, significantly higher polyphenol content was found for fruit appearing on plant as second.

According to numerous authors, squash constitutes a good source of polyphenols. Telesiński et al. (2014) determined their content in squash cv. 'Kurinishiki F1' at 998.63 mg·kg^{-1}, and in cv. 'Muscatna' at 804.17 mg·kg^{-1}. In the presented study, the mean level of polyphenols for this cultivar was 919.0 mg·kg^{-1}. In the case of cultivar 'Waltham', the determined polyphenol content was 1233.0 mg·kg^{-1}.

Significant differences were determined in terms of antioxidative activity, measured as a percentage of inhibition of DPPH free radicals, in the fruit of the studied winter squash cultivars - higher activity was determined for fruit of the Italian cultivar 'Waltham'. The plant cutting procedure, apart from the second year of study, had a significant effect on the increase in the capacity to reduce the DPPH radical. In the first year of the experiment, higher antioxidative potential was found in fruit appearing as first and second in the plant, whereas in the second year of study only in fruit appearing as a second. However, based on mean results for the years of study, no significant influence of the order of fruit appears on the plant was found for their antioxidative capacity.

Antioxidant activity of vegetables is very important quality trait from a nutritional point of view. Antioxidative properties of the fruit of zucchini, zucchini, pattypan squash and black-seed squash, which are botanical cultivars of summer squash, are lower compared to winter squash fruit Kurzeja et al. (2011). The authors demonstrated that the antioxidative activity of zucchini fruit is 34.0% DPPH, while in zucchini 26.0% DPPH. As provided by Muzzaffar et al. (2016), antioxidative properties of winter squash fruit amount to 34.31% DPPH, and according to Gajewski et al. (2008), in the case of winter squash cv. 'Zemcuzina' this value is 63.1% DPPH.

Table 1. Influence of plant cutting and order of fruit growing on a plant on dry weight and L-ascorbic acid content and total acidity in fruit of the tested winter squash cultivars

Cultivar (A)	Cutting/no cutting (B)	Fruit No. (C)	Dry weight (%)			L-ascorbic acid (mg·100 g-1 fw)			Total acidity (%)		
			2013	2014	2013-2014	2013	2014	2013-2014	2013	2014	2013-2014
'Waltham'	Cutting	1	29,84	19,12	24,48	36,98	26,76	31,87	0,10	0,14	0,12
		2	24,75	18,56	21,65	38,52	24,01	31,27	0,08	0,10	0,09
		3	22,64	16,65	19,64	25,03	25,61	25,32	0,07	0,15	0,11
	Mean		25,74	18,11	21,92	33,51	25,46	29,49	0,08	0,13	0,10
	No cutting	1	15,45	14,02	14,73	23,38	21,84	22,61	0,08	0,13	0,10
		2	13,70	19,24	16,47	14,59	30,92	22,75	0,09	0,18	0,14
		3	17,13	17,99	17,56	31,95	31,75	31,85	0,10	0,16	0,13
	Mean		15,43	17,08	16,25	23,30	28,17	25,74	0,09	0,16	0,12
Mean			**20,59**	**17,60**	**19,09**	**28,41**	**26,84**	**27,61**	**0,08**	**0,14**	**0,11**
'Muscatna'	Cutting	1	15,61	11,78	13,69	15,62	18,32	16,97	0,09	0,07	0,08
		2	12,64	9,77	11,20	14,69	8,55	11,62	0,11	0,05	0,08
		3	8,28	13,62	10,95	11,02	16,95	13,98	0,09	0,10	0,10
	Mean		12,17	11,72	11,95	13,77	14,60	14,19	0,10	0,07	0,09
	No cutting	1	10,79	9,73	10,26	14,64	15,06	15,07	0,08	0,06	0,07
		2	12,26	13,96	13,11	15,96	19,44	17,70	0,08	0,14	0,11
		3	10,34	13,30	11,82	11,93	19,83	15,88	0,09	0,10	0,10
	Mean		11,13	12,33	11,73	14,18	18,26	16,22	0,08	0,10	0,09
Mean			**11,65**	**12,02**	**11,84**	**13,98**	**16,43**	**15,20**	**0,09**	**0,09**	**0,09**
Mean for cutting vs. no cutting	Cutting		18,96	17,68	16,94	23,64	27,98	21,84	0,09	0,11	0,10
	No cutting		13,28	17,31	13,99	18,74	33,47	20,98	0,09	0,11	0,11
Mean for the number of fruit on the plant	1		17,92	15,83	15,79	22,65	29,14	21,63	0,09	0,10	0,09
	2		15,83	19,31	15,61	20,94	33,32	20,83	0,09	0,12	0,10
	3		14,59	17,35	14,99	19,98	29,72	21,76	0,09	0,13	0,11
NIRα=0,05 dla:											
A			1,927	0,840	2,790	6,375	0,469	4,365	NS	0,016	NS
B			1,243	0,140	1,977	2,547	0,224	NS	NS	0,004	0,010
C			0,936	0,200	NS	1,243	1,242	NS	NS	0,010	0,007
Interaction	B/A		1,758	0,240	NS	3,602	0,388	NS	0,010	0,006	NS
	C/B		1,323	0,280	1,115	1,758	1,757	3,094	0,013	0,014	0,016
	C/A		1,323	0,340	NS	1,758	2,151	NS	NS	NS	0,007

NS – not differ significantly
fw – values are in fresh weight basis

Table 2. Influence of plant cutting and order of fruit growing on a plant on content of chlorophyll a, b and total chlorophyll in fruit of the tested winter squash cultivars

Cultivar (A)	Cutting/no cutting (B)	Fruit No. (C)	Chlorophyll a (mg·kg-1 fw)			Chlorophyll b (mg·kg-1 fw)			Total chlorophyll (mg·kg-1 fw)		
			2013	2014	2013-2014	2013	2014	2013-2014	2013	2014	2013-2014
'Waltham'	Cutting	1	2,07	1,36	1,55	1,75	0,37	0,43	0,5	1,35	1,71
		2	1,38	1,27	1,06	0,84	0,86	0,62	0,38	3,35	2,37
		3	2,08	0,44	0,91	1,38	0,71	0,80	0,88	1,31	1,69
	Mean		1,84	1,02	1,17	1,32	0,64	0,62	0,58	2,00	1,92
	No cutting	1	2,06	1,88	1,48	1,07	1,88	1,19	0,50	4,53	3,29
		2	0,69	2,09	1,23	0,37	2,21	1,42	0,63	5,15	2,92
		3	2,75	1,24	1,12	1,00	1,38	1,19	1,00	2,77	2,76
	Mean		1,83	1,74	1,28	0,81	1,82	1,27	0,71	4,15	2,99
Mean			**1,84**	**1,38**	**1,22**	**1,07**	**1,23**	**0,94**	**0,65**	**3,08**	**2,46**
'Muscatna'	Cutting	1	13,02	0,46	2,56	4,66	0,73	4,11	7,49	1,35	7,18
		2	12,99	0,96	2,86	4,76	0,95	3,70	6,44	1,97	7,48
		3	11,09	1,01	2,84	4,66	0,47	3,06	5,65	1,30	6,20
	Mean		12,37	0,81	2,75	4,70	0,71	3,62	6,53	1,54	6,95
	No cutting	1	10,35	1,26	2,57	3,87	0,85	2,92	5,00	2,66	6,51
		2	9,67	1,27	2,27	3,27	0,86	3,05	5,25	2,02	5,84
		3	10,36	1,85	3,12	4,41	1,84	3,55	5,25	5,09	7,73
	Mean		10,12	1,46	2,66	3,85	1,81	3,17	5,17	3,26	6,69
Mean			**11,24**	**1,13**	**2,70**	**4,27**	**0,95**	**3,40**	**5,85**	**2,40**	**6,82**
Mean for cutting vs. no cutting	Cutting		11,02	5,04	1,96	5,89	1,43	2,12	4,33	6,02	4,44
	No cutting		9,28	5,26	1,97	3,94	2,21	2,22	2,68	8,32	4,84
Mean for the number of fruit on the plant	1		9,81	3,74	2,04	5,46	1,69	2,16	3,52	5,63	4,67
	2		8,97	3,47	1,85	4,01	1,41	2,20	3,94	4,55	4,65
	3		8,62	8,23	2,00	5,26	2,35	2,15	3,06	11,32	4,59
NIRα=0,05 dla:											
A			6,133	0,785	NS	1,836	NS	NS	3,359	1,818	NS
B			1,532	NS	NS	0,320	NS	NS	1,218	1,025	NS
C			NS	0,955	0,179	1,214	NS	NS	NS	2,423	NS
Interaction	B/A		2,653	NS	NS	0,555	NS	NS	NS	NS	NS
	C/B		NS	1,351	0,149	NS	NS	0,202	1,182	NS	0,366
	C/A		NS	1,654	0,206	NS	1,840	0,275	1,448	4,196	NS

NS – not differ significantly
fw – values are in fresh weight basis

Table 3. Influence of plant cutting and order of fruit growth on a plant on content of total carotenoid, total polyphenols and antioxidative activity in the fruit of the tested winter squash cultivars

Cultivar (A)	Cutting/no cutting (B)	Fruit No. (C)	Total carotenoid (mg·kg-1 fw)			Total polyphenols (mg·100 g-1 fw)			Antioxidative activity (% DPPH)		
			2013	2014	2013-2014	2013	2014	2013-2014	2013	2014	2013-2014
'Waltham'	Cutting	1	217,01	64,71	140,86	08,06	15,87	11,96	77,52	53,06	65,29
		2	216,89	83,43	150,16	18,64	20,14	19,39	84,20	45,23	64,71
		3	217,46	94,99	156,22	07,52	17,73	12,62	80,35	48,29	64,32
	Mean		217,13	81,04	149,08	11,40	17,91	14,66	80,69	48,86	64,77
	No cutting	1	215,93	48,40	132,17	05,81	11,40	08,60	68,04	33,29	50,66
		2	217,21	49,46	133,33	05,29	18,53	11,91	44,48	70,53	57,51
		3	215,68	43,94	129,81	02,79	16,24	09,51	59,70	65,67	62,68
	Mean		216,27	47,27	131,77	04,63	15,39	10,01	57,40	56,50	56,95
Mean			**216,70**	**64,15**	**140,43**	**08,01**	**16,65**	**12,33**	**69,05**	**52,68**	**60,86**
'Muscatna'	Cutting	1	213,19	73,57	143,38	04,73	15,50	10,11	49,61	24,00	36,80
		2	211,96	28,51	120,24	08,91	12,04	10,48	46,23	25,87	36,05
		3	215,12	16,21	115,67	06,81	12,74	09,78	20,10	36,24	28,17
	Mean		213,42	39,43	126,43	06,82	13,43	10,12	38,64	28,70	33,67
	No cutting	1	214,41	20,06	117,24	04,28	10,68	07,48	33,14	08,99	21,07
		2	214,43	12,44	113,44	04,37	11,63	07,00	43,14	25,61	34,38
		3	214,40	29,25	121,83	05,76	12,82	09,29	30,40	40,94	35,67
	Mean		214,42	20,59	117,50	04,80	11,71	08,25	35,56	25,18	30,37
Mean			**213,92**	**30,01**	**121,96**	**05,81**	**12,57**	**09,19**	**37,10**	**26,94**	**32,02**
Mean for cutting vs. no cutting	Cutting		214,54	134,72	137,75	09,11	18,38	12,39	59,67	47,20	49,22
	No cutting		215,33	86,19	124,63	04,71	14,99	09,13	46,48	48,03	43,66
Mean for the number of fruit on the plant	1		214,67	126,06	133,41	05,72	15,54	09,54	57,07	39,68	43,45
	2		215,03	101,59	129,29	09,30	17,36	12,44	54,51	53,72	48,16
	3		215,38	103,71	130,88	05,72	17,17	10,30	47,63	49,45	47,71
NIRα=0,05 dla:											
A			NS	14,692	15,971	NS	1,351	1,334	6,671	1,784	9,577
B			0,494	6,262	8,903	0,778	1,357	1,063	2,664	NS	5,276
C			NS	16,407	3,329	2,537	NS	0,865	3,556	2,533	NS
Interaction	B/A		0,855	10,846	NS	1,100	NS	NS	3,767	NS	NS
	C/B		NS	23,204	4,716	3,588	NS	1,689	5,029	3,582	6,224
	C/A		NS	28,418	6,623	3,588	NS	1,332	5,029	4,387	NS

NS – not differ significantly
fw – values are in fresh weight basis

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