

THE EFFECT OF THE SOWING DATE ON THE CONTENT OF CAROTENOIDS AND L-ASCORBIC ACID IN SPAGHETTI SQUASH (*Cucurbita pepo* L.)

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Abstract. Carotene and ascorbic acid are the most important compounds for human nutrition that are supplied by vegetables. The content of carotene and ascorbic acid in vegetables depends on the species and the cultivar, but it is subject to changes under the influence of environmental conditions and agricultural factors. This study examined the effects of the sowing date (5, 15 and 25 May) on the content of carotenoids and L-ascorbic acid in the fruits of two cultivars of spaghetti squash ('Makaronowa Warszawska' and 'Pyza'). Fruits were harvested in the fully mature, from the beginning of September till the beginning of October. The content of total carotenoid compounds in fruit was higher for the sowing date on 5 May than for the sowing dates on 15 and 25 May, while the content of β -carotene did not significantly differ. The sowing date did not affect the content of L-ascorbic acid in fruits. Fruits of the 'Makaronowa Warszawska' contained more total carotenoids and β -carotene than fruits of the 'Pyza', while the content of L-ascorbic acid in fruits of both cultivars did not significantly differ. Lower air temperatures and higher amounts of precipitation in the spaghetti squash vegetation period resulted in an increase in the β -carotene content.

Key words: spaghetti squash, sowing date, cultivar, chemical composition

INTRODUCTION

Recently, there has been a growing interest in food of plant origin, containing natural antioxidants, particularly carotenoids and vitamin C. The supply of proper antioxidants in the diet can significantly reduce the risk of many tumorous and cardiovascular diseases [Horbowicz and Saniewski 2000, Szeto et al. 2002, Naidu 2003, Sembratowicz and Czech 2005]. Fruit and vegetables are the main source of carotenoids and vitamin C. Consumers can choose from an increasingly growing range of fresh vegetables. Squash fruits are characterized by a high content of carotenoid compounds, particularly

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of β -carotene. Squash cultivars of orange flesh are particularly valuable [Paris 1993, Murkowic et al. 2002]. Spaghetti squash is still little-known in Poland. As this vegetable can be used for preparing interesting and tasty meals, it can be competitive with zucchini and summer squash. The content of carotenoids and L-ascorbic acid in vegetables depends primarily on the species and the cultivar, but it is subject to changes under the influence of environmental conditions and agricultural factors [Murkowic et al. 2002, Wierzbicka and Kuskowska 2002, Urban et al. 2009]. The scientific literature discusses the effects of agricultural factors on chemical composition of various species of squash, but there are few studies concerning spaghetti squash. The research conducted so far have concerned mainly comparison of the content of sugars, carotenoids and mineral components in fruits of several cultivars of spaghetti squash cultivated in Israel and Florida [Paris 1993, Beany et al. 1998, 2002, 2003]. The research conducted in Lithuania demonstrated that fruits of spaghetti squash obtained through organic cultivation contained more β -carotene and vitamin E, and less dietary fibre, vitamin C and mineral components, at a similar content of dry matter as in conventional cultivation [Danilchenko 2002].

The aim of the present research was to examine the effect of the sowing date on the content of carotenoids and L-ascorbic acid in fruits of two cultivars of spaghetti squash entered into the Polish National List of Vegetable Plant Varieties.

MATERIALS AND METHODS

The study was carried out in 2007–2008 at the Department of Vegetable Crops, University of Podlasie in Siedlce. A field experiment was established in the split-block-split-plot desing in three replications, on a loamy soil characterised by low to mean content of available potassium, mean to high content of phosphorus and magnesium, and pH in H₂O of 6.1–6.7. The area of each plot was 20 m². Manure in the dose of 30 t ha⁻¹ was applied in autumn, and mineral fertilizers in doses of 120 kg N (ammonium nitrate), 52 kg P (superphosphate) and 200 kg K (potassium sulphate) per 1 hectare were applied in spring. 2/3 of a nitrogen and potassium dose was applied before sowing and 1/3 while the first fruits were setting. Seeds of the spaghetti squash of the ‘Makaronowa Warszawska’ and ‘Pyza’ cultivars were sown on 5, 15 and 25 May in the plant spacing of 1.0 × 0.8 m (12,500 plants per ha). Fruits were harvested in the fully mature, from the beginning of September till the beginning of October. The ‘Makaronowa Warszawska’ features a medium-sized, oblong, green spotted fruit with an light orange flesh, and the ‘Pyza’ features a medium-sized, elliptical, orange fruit with an cream-coloured flesh. The contents of total carotenoids, β -carotene and L-ascorbic acid were determined. The content of carotenoids was spectrophotometrically determined, according to the Polish Standard [PN-90/A-75101.12], and the content of L-ascorbic acid was determined by Tillmans’s titrimetric method [PN-90/A-75101.11]. The results of the experiment were analysed statistically by means of analysis of variance. The significance of differences was verified using the Tukey’s test at $\alpha = 0.05$.

Table 1. Mean air temperature and precipitation sums in the vegetation period of spaghetti squash

Tabela 1. Średnia temperatura powietrza i sumy opadów atmosferycznych w okresie wegetacji dyni makaronowej

Months Miesiące	Temperature – Temperatura (°C)			Rainfalls – Opady (mm)		
	2007	2008	mean – średnia 1981–2005	2007	2008	mean – średnia 1981–2005
May – Maj	14.6	12.7	11.9	59.1	85.6	49.7
June – Czerwiec	18.2	17.4	16.7	59.0	49.0	63.0
July – Lipiec	18.9	18.4	19.5	70.2	69.8	60.3
August – Sierpień	18.9	18.5	18.4	31.1	75.4	59.8
September – Wrzesień	13.1	12.2	13.1	67.6	63.3	53.0

Thermal and humidity conditions that were more favourable for the growth and development of spaghetti squash plants occurred in 2007 (tab. 1). In 2008, low air temperature and intensive precipitation in May were the reason for poor sprouting, and substantially cooler weather starting from the second decade of September, with a drop in air temperature by almost 10°C on average, together with intensive precipitation, delayed fruit ripening.

RESULTS AND DISCUSSION

The content of total carotenoids in spaghetti squash fruits ranged from 32.12 to 78.82 mg kg⁻¹ f. m., β-carotene from 3.96 to 19.24 mg kg⁻¹ f. m., and L-ascorbic acid from 57.67 to 72.67 mg kg⁻¹ f. m. (tabs 2–4). Meteorological conditions in the spaghetti squash vegetation period did not affect the content of total carotenoid compounds, but they significantly differentiated the content of β-carotene. In 2008, with lower air temperature and higher amounts of precipitation during the plant vegetation period, the content of β-carotene in fruits was on average higher by 3.20 mg kg⁻¹ f. m. (37.6%) in comparison to 2007. The diversity of the content of carotenoid compounds and β-carotene in fruits of *Cucurbita pepo* and *Cucurbita maxima* depending on climatic conditions has been confirmed by other authors. The share of β-carotene in total amount of carotenoid compounds in fruits of *Cucurbita maxima* was a more stable feature than the absolute content of those compounds [Murkovic et al. 2002, Korzeniewska et al. 2004]. In the presented study, β-carotene accounted for, on average, 16.2% of total carotenoid compounds in 2007 and 21.1% in 2008.

The sowing date of the spaghetti squash had a significant effect on the content of carotenoid compounds in fruits. The highest content of total carotenoids was found in plants sown on 5 May (tab. 2). The delay of the sowing date resulted in a decrease of those compounds in fruits. The content of total carotenoid for plants sown on 5 May was higher, on average, by 9.17 mg kg⁻¹ f. m. (17.1%) in comparison to plants sown on 15 May, and by 17.47 mg kg⁻¹ f. m. (38.5%) in comparison those sown on 25 May. The sowing date of the spaghetti squash had a more significant effect on carotenoid accumu-

Table 2. Total carotenoid content (mg kg⁻¹ f. m.)
Tabela 2. Zawartość karotenoidów ogółem (mg·kg⁻¹ św. m.)

Years – Lata	Sowing date Termin siewu	Cultivar – Odmiana		Mean – Średnia
		Makaronowa Warszawska	Pyza	
2007	5 May	62.64	44.22	53.43
	15 May	52.58	43.30	47.90
	25 May	54.40	57.72	56.10
	mean – średnia	56.54	48.41	52.50
2008	5 May	73.01	71.60	72.30
	15 May	78.82	40.04	59.40
	25 May	37.21	32.12	34.70
	mean – średnia	63.01	47.92	55.50
Mean – Średnia	5 May	67.83	57.91	62.87
	15 May	65.70	41.67	53.70
	25 May	45.81	44.92	45.40
Mean – Średnia		59.78	48.16	54.00

LSD – NIR_{0.05}: sowing date – termin siewu = 6.36, years × sowing date – lata × termin siewu = 8.99, cultivar – odmiana = 4.09, sowing date × cultivar – termin siewu × odmiana = 6.30, years × sowing date × cultivar – lata × termin siewu × odmiana = 8.91

Table 3. β-carotene content (mg kg⁻¹ f. m.)
Tabela 3. Zawartość β-karotenu (mg·kg⁻¹ św. m.)

Years – Lata	Sowing date Termin siewu	Cultivar – Odmiana		Mean – Średnia
		Makaronowa Warszawska	Pyza	
2007	5 May	5.53	4.54	5.04
	15 May	14.42	5.43	9.90
	25 May	14.69	6.47	10.60
	mean – średnia	11.55	5.48	8.50
2008	5 May	7.78	19.24	13.51
	15 May	9.19	15.47	12.30
	25 May	14.72	3.96	9.30
	mean – średnia	10.56	12.89	11.70
Mean – Średnia	5 May	6.66	11.89	9.27
	15 May	11.80	10.45	11.10
	25 May	14.70	5.22	10.00
Mean – Średnia		11.06	9.19	10.10

LSD – NIR_{0.05}: years – lata = 1.21, years × sowing date – lata × termin siewu = 2.57, cultivar – odmiana = 1.79, years × cultivar – lata × odmiana = 2.52, sowing date × cultivar – termin siewu × odmiana = 1.85, years × sowing date × cultivar – lata × termin siewu × odmiana = 2.62

lation in fruits in 2008, with lower air temperature and higher amounts of precipitation during the plant vegetation period. In that year, for plants sown on 5 May, the content of total carotenoids was on average almost twice as high as in plants sown on 25 May. Under conditions favouring rapid plant growth and development (2007), the content of β-carotene in fruits of plants sown on 15 and 25 May was on average twice as high as the plants sown on 5 May, while in the year characterized by lower air temperature and

higher amounts of precipitation (2008), the content of β -carotene in spaghetti squash fruits was higher for the earlier sowing date (tab. 3). The study carried out by other authors showed the significant effect of the sowing date on the total carotenoids and β -carotene content in carrot roots and melon fruits [Krzesiński and Knaflewski 2003, Wolbang et al. 2010]. Carotenoids content depends on the amount of absorbed photosynthetically active radiation by plant and temperature during the intensive growth of vegetables [Krzesiński and Knaflewski 2002, Lester 2006]. In the presented study, the differences in total carotenoids and β -carotene content in spaghetti squash fruits were caused by the time of fruit growth and development. Sowing date, as well as weather conditions, changed the amount of solar radiation absorbed. In consequence, it affected carotenoids production. The study did not show any significant effects of the spaghetti squash sowing date on the content of L-ascorbic acid in fruits. However, there was a trend toward a decreased content of those compounds for later sowing dates, particularly in 2008, with lower air temperatures and higher amounts of precipitation during the plant vegetation period (tab. 4).

Table 4. L-ascorbic acid content (mg kg^{-1} f. m.)
Tabela 4. Zawartość kwasu L-askorbinowego ($\text{mg}\cdot\text{kg}^{-1}$ św. m.)

Years – Lata	Sowing date Termin siewu	Cultivar – Odmiana		Mean – Średnia
		Makaronowa Warszawska	Pyza	
2007	5 May	70.67	63.33	67.00
	15 May	57.67	72.67	65.20
	25 May	67.33	65.33	66.30
	mean – średnia	65.22	67.11	66.20
2008	5 May	72.00	72.00	72.00
	15 May	72.67	63.00	67.80
	25 May	67.00	65.33	66.20
	mean – średnia	70.56	66.78	68.70
Mean – Średnia	5 May	71.33	67.67	69.50
	15 May	65.17	67.83	66.50
	25 May	67.17	65.33	66.30
Mean – Średnia		67.89	66.94	67.40

LSD – NIR_{0.05}: years \times sowing date \times cultivar – lata \times termin siewu \times odmiana = 6.45

In the study carried out by other authors, the sowing date had no significant effect on the L-ascorbic acid content in fennel bulb, but significantly affected the content of those compounds in the snap bean pods and sweet pepper fruits [Buczowska and Sawicki 2008, Łabuda and Brodaczevska 2008, Błażewicz-Woźniak 2010]. Among preharvest factors light intensity and temperature are the most important in determining the final vitamin C content in vegetables. Although light is not essential for the synthesis of L-ascorbic acid in plants, the amount and intensity of light during the growing season have a definite influence on the L-ascorbic acid production. L-ascorbic acid is synthesized from sugars supplied through photosynthesis in plants. Fruit exposed to maximum sunlight contain higher amount of vitamin C than shaded fruit on the same plant. In general, the lower the light intensity during growth, the lower the L-ascorbic acid con-

tent in plant tissues [Lee and Kader 2000]. The sweet pepper fruits from the plants transplanting into field in the end of first decade of June contained the most L-ascorbic acid, as compared to earlier transplanting dates [Buczowska and Sawicki 2008]. In the presented study, the content of L-ascorbic acid in spaghetti squash fruits for plants sown on 5 May was a slightly higher in comparison to later sowing dates, but the differences were not statistically confirmed.

The content of carotenoid compounds in spaghetti squash fruits depended on the cultivar (tabs 2 and 3). Fruits of the 'Makaronowa Warszawska' contained more total carotenoids, on average by 11.62 mg kg⁻¹ f. m. (24.1%), and β -carotene, by 1.87 mg kg⁻¹ f. m. (20.3%), in comparison to the 'Pyza'. Higher differences between the cultivars as regards the content of β -carotene were noticed in 2007. In that year, the content of β -carotene in fruits of the 'Makaronowa Warszawska' was on average twice as high as in fruits of the 'Pyza'. Differences between cultivars in total carotenoids content were greater for the sowing dates of 5 and 15 May than for the sowing date on 25 May, while differences in the content of β -carotene were the largest for the sowing date of 25 May. For the sowing date of 25 May, the content of β -carotene in fruits of the 'Makaronowa Warszawska' was on average three times higher, with a similar content of total carotenoid compounds as in fruits of the 'Pyza'. For this sowing date, larger differences between cultivars as regards the content of β -carotene in fruits were observed in 2008 – a year of lower air temperatures and higher amounts of precipitation during the plant vegetation period. Large differentiation of the content of carotenoid compounds in spaghetti squash fruits has also been confirmed by study carried out by other authors. The study carried out in Florida found that the content of total carotenoids in fruits of the 'Hasta La Pasta' was almost five times higher than in fruits of the 'Vegetable' [Beany et al. 1998, 2003, Paris 1993]. The content of L-ascorbic acid in fruits of the examined cultivars of the spaghetti squash did not significantly differ (tab. 4). Only in 2007, with the sowing date on 15 May, the content of L-ascorbic acid in fruits of the 'Pyza' was higher, on average by 15.00 mg kg⁻¹ (26.0%) than for the 'Makaronowa Warszawska'. In the study carried out by Wojdyła et al. [2007] in the area of Bydgoszcz, the content of vitamin C in fruits of the 'Makaronowa Warszawska' was higher in comparison to the 'Pyza'. In the presented study, the content of β -carotene and L-ascorbic acid in fruits of the 'Makaronowa Warszawska' was lower than in study carried out in Lithuania [Danilchenko 2002]. The total carotenoid content in fruits of the 'Pyza' was higher and the content of L-ascorbic acid was lower in comparison to the results of the study carried out in the area of Wrocław [Biesiada et al. 2006, 2008].

CONCLUSIONS

1. Meteorological conditions in the spaghetti squash vegetation period did not affect the content of total carotenoid compounds in fruits, while lower air temperature and higher amounts of precipitation favoured the accumulation of β -carotene.

2. The content of total carotenoids in fruits was higher for plants sown on 5 May than for plants sown on 15 and 25 May, while the content of β -carotene did not significantly differ. The sowing date did not affect the content of L-ascorbic acid in fruits.

3. The content of total carotenoids and β -carotene in fruits of the 'Makaronowa Warszawska' was higher than in fruits of the 'Pyza', while the content of L-ascorbic acid in fruits of both cultivars did not significantly differ.

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WPLYW TERMINU SIEWU NA ZAWARTOŚĆ KAROTENOIDÓW I KWASU L-ASKORBINOWEGO W DYNI MAKARONOWEJ (*Cucurbita pepo* L.)

Streszczenie. Głównym źródłem karotenu i kwasu askorbinowego są warzywa. Zawartość karotenu i kwasu askorbinowego w warzywach zależy od gatunku i odmiany, ale ulega zmianom pod wpływem warunków środowiska i czynników agrotechnicznych. Badano wpływ terminu siewu (5, 15 i 25 maja) na zawartość karotenoidów i kwasu L-askorbinowego w owocach dwóch odmian dyni makaronowej ('Makaronowa Warszawska' i 'Pyza'). Owoce zbierano w fazie pełnej dojrzałości, od początku września do początku października. Zawartość związków karotenoidowych ogółem w owocach była większa przy siewie 5 maja niż przy siewie 15 i 25 maja, natomiast zawartość β -karotenu nie różniła się istotnie. Termin siewu nie miał wpływu na zawartość kwasu L-askorbinowego w owocach. Owoce odmiany 'Makaronowa Warszawska' zawierały więcej karotenoidów ogółem i β -karotenu niż odmiany 'Pyza', natomiast zawartość kwasu L-askorbinowego w owocach obu odmian nie różniła się istotnie. Niższa temperatura powietrza i większa ilość opadów w okresie wegetacji dyni makaronowej powodowały zwiększenie zawartości β -karotenu.

Słowa kluczowe: dynia makaronowa, termin siewu, odmiana, skład chemiczny

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