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INFLUENCE OF DRIP IRRIGATION ON NUTRITIVE VALUE OF WINTER SQUASH 'ROUGE VIF D'ETAMPES' AFTER HARVEST AND STORAGE

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Abstract

The aim of the study was to determine the influence of drip irrigation on the nutritive value of winter squash 'Rouge vif d'Etampes' fruits analyzed directly after the harvest and after the storage. The plants were grown on the very light soil in the region of decreased rainfall amounts during the vegetation period. The field experiment was conducted in 2007-2008 at Kruszyn Krajeński near Bydgoszcz on the soil of quality class V-VI (very weak and weak-rye-soil-complex). The field water capacity in the soil layer 0-50 cm was 57.5 mm, while the effective useful retention amounted 29.3 mm. The experiment was designed as one-factorial trial in four replications; drip irrigation as the experiment factor was applied. As the control the plots without irrigation were considered. The single plot area was 11.2 m^2. The drip irrigation was conducted according to the soil tensiometer indications (-0.04 MPa). The research material was the eatable parts of fresh fruits that were analyzed directly after the harvest and after the storage for six months at the temperature 10°C and the relative air humidity 75%. The drip irrigation performed during the cultivation of winter squash increased the content of vitamin C, total carotenoids including ß-carotene, as well sugars in the fruits, both after the harvest and after the storage. After six months of the storage the rise of the content of dry matter, total

carotenoids including ß-carotene, as well monosaccharides was noted, while the level of vitamin C, total sugar, and saccharose have been reduced.

Key words: carotenoids, chemical composition, dry matter, pumpkin, sugars, vitamin C

INTRODUCTION

The chemical composition of pumpkin depends on the cultivar as well as the climate conditions during growing season (Danilcenko *et al.* 2004, Korzeniewska *et al.* 2004, Biesiada *et al.* 2006, Rolbiecki *et al.* 2006). Cucurbitaceous plants due to the high fertility and production of giant aboveground mass, as well the high rate of transpiration, have a large water needs that estimated at 400 mm (Kaniszewski 2005). So, one of the most important factors influenced the quality of pumpkin fruit is irrigation (Rolbiecki *et al.* 2006, Wojdyła *et al.* 2007, Wichrowska and Wojdyła 2011).

The mature fruits that are stored not longer than two months, have the highest nutritional value, especially in terms of the content of provitamin A, vitamin C and sugars. However, with the extension of storage period of fruits, the content of the chemical components is significantly reduced (Arvayo-Ortiz *et al.* 1994, Sokół-Łętowska 2004, Niewczas *et al.* 2005, Niewczas and Mitek 2007, Wojdyła *et al.* 2007, Iacuzzo and Dalla-Costa 2009, Wichrowska and Wojdyła 2011).

The food processing industries mostly uses the pumpkin pulp that is the basis for the production of candies, dried products, frozen food, jam, pickles and pumpkin puree (Gliemmo *et al.* 2009, Nawirska-Olszańska 2010, Ciurzyńska *et al.* 2013). The pumpkin pulp is also used in juice production (Kurzeja *et al.* 2011), while dried pumpkin pulp is suitable for preparing of the roasted snacks (Ciurzyńska *et al.* 2013). Nowadays, the pumpkin pulp is often used as the natural dye for food products. The carotene powder is added to the confectionery, bakery products, pasta and gelled products. Especially appreciated are the pumpkins with orange pulp that contain high level of carotenes, mainly α-carotin, β-carotin and lutein (Murkovic *et al.* 2002, USDA 2004, Kunachowicz *et al.* 2005, Stangret i in. 2001, USDA 2004).

The objective of the researches was to determine the influence of the drip irrigation on the chemical composition, such as the content of dry matter, vitamin C, total carotenoids including ß-carotene, and sugars in the fruits of winter squash ‘Rouge vif d’Etampes’ measured directly after the harvest as well as six months after the storage.

MATERIAL AND METHODS

The field experiment was conducted in the years 2007-2008 on the very light soil of the V-VI quality class, with the weak and very weak rye-soil-complex under the eastern end of Krajeńskie Lake (Kruszyn Krajeński near Bydgoszcz). The water capacity in the soil layer of 0-50 cm was 57.5 mm, while the effective useful retention amounted to 29.3 mm. The plant material was the fruits of winter squash 'Rouge vif d'Etampes'.

The field experiment, designed using the method of drawing blocks, was established as one-factorial study and conducted in four replications. The researched treatment was drip irrigation, while as the control the plants without irrigation were tested .The experiment included 8 plots (2 × 4) and the area of single plot was 11.2 m^2. To determine the timing and dose of irrigation the tensiometers of soil were used. The drip irrigation was started when the soil water pressure was below – 0.04 MPa. The drip irrigation was done using the 'T-Tape' drip line, where the distance between the dripers was 20 cm and an expense of water was about 5 l m^{-1}.

The analyses of the nutritive value of winter squash 'Rouge vif d'Etampes' fruits were performed in 3 replications. The research material was the eatable parts of fresh fruits (6 pieces) that were tested directly after the harvest (AH) and six months after the storage (AS) performed at the temperature 10°C and relative air humidity 75%. The dry matter content of the fruits [g 100 g^{-1} f.m.] was determined by gravimetric method according to PN-A-75101/03 (1990). The sugars content [g 100 g^{-1} f.m.] was measured using a spectrophotometer (600 nm) technique according to Talburt and Smith method (1987). The vitamin C content [mg 100 g^{-1} f.m.] was determined by Tillman's method using PN-A-04019 (1998). The content of carotenoids and ß-carotin [mg 100 g^{-1} f.m.] was measured according to PN-A-75101/12 (1990).

The obtained data were statistically evaluated using computer package ANALWAR-5.FR. The calculations were performed using Fisher-Snedecor test in order to determine the significance of treatments. The differences between the means were estimated using Tukey test at a significance level $P = 0.05$.

The mean air temperature in Kruszyn Krajeński during the growing of winter squash 'Rouge vif d'Etampes' (V-IX) in 2007-2008 was 16.0°C that was 0.3°C higher than the mean temperature for long-period (Table 1). In the first year of the study (2007) the temperatures in May (13.8°C) and June (18.2°C) were higher comparing to the mean temperature for long period. In the second year of the research (2008) the highest temperature was noted in July (19.2°C, ie. 1.0°C above the mean temperature for long period).

The precipitation between 1st May and 30th September in the years 2007-2008, was 273.9 mm on average (Table 1). The higher level of rainfall (358.6

mm) was noted in the first year of the study (2007) comparing to the year 2008 (189.6 mm). Particularly high amounts of rainfalls (103.4 mm and 111.3 mm) were recorded in June and July 2007, respectively. The lowest rainfall (3.2 mm) was noted in May 2008 that was less than 8% of the mean rainfall for long-term. Low rainfalls were also noted in June, July and September of the second year of the study, 59, 71 and 59%, respectively, below the mean for long-term.

The seasonal irrigation water rates applied during the experiment were closely related to the course of thermal and precipitation conditions for the plants of winter squash and amounted to 68.0 and 101.5 mm in the years 2007 and 2008, respectively.

Table 1. Air temperature and rainfall during the vegetation period of winter squash 'Rouge vif d'Etampes' in Kruszyn Krajeński

Study years	Months					Mean
	V	VI	VII	VIII	IX	
Air temperature (°C)						
2007	13.8	18.2	18.0	17.8	12.4	16.0
2008	13.2	17.6	19.2	17.8	12.4	16.0
Mean for 2007-2008	13.5	17.9	18.6	17.8	12.4	16.0
Mean for long-period	13.1	16.2	18.2	17.8	13.0	15.7
Rainfall (mm)						
2007	49.1	103.4	111.3	59.2	35.6	358.6
2008	3.2	32.3	46.6	81.5	26.0	189.6
Mean for 2007-2008	26.1	67.8	78.9	70.3	30.8	273.9
Mean for long-period	40.7	54.8	65.4	51.4	44.3	256.6

RESULTS AND DISCUSSION

The objective of the study was to evaluate the influence of the drip irrigation on the content of dry matter, vitamin C, total carotenoids including ß-carotene, as well sugars measured in the fruits of winter squash 'Rouge vif d'Etampes'. The analysis of nutritive value of the pulp was performed directly after the harvest and after six months of the storage. The drip irrigation treatment significantly increased the content of vitamin C, carotenoids including ß-carotin and sugars, both, in the case of fruits tested directly after the harvest, as well as after the storage (Tables 2 and 3). In the study reported by Wojdyła *et al.* (2007) the irrigation treatment also influenced the growth of vitamin C and carotenoids

content. In comparison with the control, the drip irrigation applied during the growing of winter squash 'Rouge vif d'Etampes' did not influenced the rise of dry matter level measured directly after the harvest but significantly increased the content of dry matter analyzed after the storage (Table 2).

It was noted that the winter squash 'Rouge vif d'Etampes' fruit pulp presented especially intense orange colour, which was caused by the high content of total carotenoids including ß-carotin that during measurement performed directly after the harvest ranged from 6.84 mg 100 g^{-1} f.m. for the control to 7.89 mg 100 g^{-1} f.m. for the irrigated plants and after the storage period ranged from 8.56 mg 100 g^{-1} f.m. for the control to 9.01 mg 100 g^{-1} f.m. for the irrigated plants (Table 2).

The processes, such as respiration and transpiration, occurred in the cells of the stored raw plant products, caused the changes in the content of nutritive compounds. In the present study, after six months of the storage of winter squash fruits under optimum conditions (temperature 10°C and relative air humidity 75%) influenced the increase of dry matter content in the pulp (by 4.5%) as well as raised the level of total carotenoids (by 15%) and monosaccharides (by 5.7%) (Tables 2 and 3). In the research presented by Niewczas and Mitek (2007) during storage of the fruits of winter squash 'Bambino' and 'Justynka' the content of total carotenoids increased from 3.35 mg per 100 g f.w. to 4.60 mg per 100 g f.w. and from 4.74 mg per 100 g f.w. to 9.39 mg per 100 g f.w., respectively. The rise of the carotenoids level after the storage, evaluated in the fruits of different winter squash cultivars, was reported also by Bonina-Noseworthy *et al.* (2016). According to Gross (1991) during the storage of the winter squash the content of total carotenoids also increased, although the level of these changes was dependent on the tested cultivar. Additionally, the differences in the case of the carotenoids level were noted also between different fruits of the same cultivar.

In the present study, the content of vitamin C, total sugar and saccharose, evaluated in the fruit pulp of the winter squash 'Rouge vif d'Etampes', decreased after the storage period (Tables 2 and 3). However, the fall of the total sugar and saccharose contents after storage of the winter squash fruits were caused by the distribution of complex sugars into monosaccharides, which level in the present study increased after the storage. The loss in vitamin C content in fruits after six months of storage was significant and amounted to 34.3%. However, similar waste in the level of vitamin C in the stored fruits has been noted also by Niewczas *et al.* (2005) and Nawirska-Olszańska *et al.* (2011), Nawirska – Olszańska (2011).

Table 2. Influence of drip irrigation on the content of dry matter, vitamin C and total carotenoids including ß-carotin in fruits of winter squash 'Rouge vif d'Etampes'

Treatments	Study years	Dry matter [g 100 g^{-1} f.m.]		Vitamin C [mg 100 g^{-1} f.m.]		Total carotenoids including ß-carotin [mg 100g^{-1} f.m.]	
		AH	AS	AH	AS	AH	AS
Control (without irrigation)	2007	5.89	6.02	12.35	7.89	7.15	8.56
	2008	4.98	5.11	11.58	8.03	6.84	7.99
Mean for control		5.44	5.57	11.97	7.96	7.00	8.28
Drip irrigation	2007	6.00	6.54	12.98	8.15	7.89	9.01
	2008	5.06	5.28	12.04	8.54	7.02	8.54
Mean for drip irrigation		5.53	5.91	12.51	8.34	7.45	8.77
Mean		5.48	5.74	12.24	8.15	7.23	8.53
$LSD_{0.05}$		ns	0.235	0.155	0.188	0.344	0.134

AH – after harvest; AS – after storage; ns – not significant at $P < 0.05$

Table 3. Influence of drip irrigation on the of content sugars in fruits of winter squash 'Rouge vif d'Etampes'

Treatments	Study years	Monosaccharides [g 100 g^{-1} f.m.]		Total sugar [g 100 g^{-1} f.m.]		Saccharose [g 100 g^{-1} f.m.]	
		AH	AS	AH	AS	AH	AS
Control (without irrigation)	2007	2.38	2.44	3.20	3.01	0.83	0.57
	2008	2.11	2.18	2.95	2.86	0.84	0.68
Mean for control		2.25	2.31	3.08	2.94	0.84	0.63
Drip irrigation	2007	3.24	3.51	4.70	4.53	1.47	1.02
	2008	2.96	3.18	4.11	4.03	1.22	0.85
Mean for drip irrigation		3.10	3.35	4.41	4.28	1.35	0.94
Mean		2.67	2.83	3.74	3.61	1.09	0.78
$LSD_{0.05}$		0.121	0.127	0.230	0.235	0.192	0.201

Explanations: see Table 2

CONCLUSIONS

The drip irrigation applied during the growing of winter squash 'Rouge vif d'Etampes' increased the content of vitamin C, total carotenoids including ß-carotin, as well as sugars in the fruit, both directly after the harvest and after the storage. After six months of the storage of winter squash fruits it was ob-

served the increase in the level of dry matter, total carotenoids including ß-carotene and monosaccharides, while the content of vitamin C and total sugar, as well as saccharose decreased.

REFERENCES

Arvayo-Ortiz R.M., Garza-Ortega S., Yahia E.M. (1994). *Postharvest response of winter squash to hot water treatment, temperature, and length of storage*. HortTechnology, 4(3), 253-255.

Biesiada A, Kucharska A., Sokół-Łętowska A. (2006). *Plonowanie i wartość odżywcza wybranych odmian użytkowych Cucurbita pepo L. oraz Cucurbita Maxima Duch.* Folia Horticulturae, Supl., 2, 66-70.

Bonina-Noseworthy J., Loy J.B., Curran-Celentano J., Sideman R., Kopsell D.A. (2016). *Carotenoid concentration and composition in winter squash: variability associated with different cultigens, harvest maturities, and storage times.* HortScience, 51(5), 472-480.

Ciurzyńska A., Lenart A., Kawka P. (2013). *Wpływ temperatury liofilizacji metod suszenia na wybrane właściwości suszonej dyni.* Acta Agrophysica, 20(1), 39-51.

Danilčenko H., Jariene E., Paulauskiene A., Kulajtiene J., Viskelis P. (2004). *Wpływ nawożenia na jakość i skład chemiczny dyni.* Annales Universitatis Mariae Curie-Skłodowska, 59(4), 1949-1956.

Gross J. (1991). *Pigments In vegetables. Chlorophylls and carotenoids. Carotenoids distribution in vegetables.* Van Nostrand Reinhold, New York, 225-233.

Gliemmo M.F., Latorre M.E., Gerschenson L.N., Campos C.A. (2009). *Color stability of pumpkin (Cucurbita moschata, Duchesne ex Poiret) puree during storage at room temperature: Effect of pH, potassium sorbate, ascorbic acid and packaging material.* LWT – Food Science and Technology, 42, 196-201.

Iacuzzo F., Dalla-Costa L. (2009). *Yield performance, quality characteristics and fruit storability of winter squash cultivars in sub-humid areas*. Scientia Horticulturae, 120, 330-335.

Kaniszewski S. (2005). *Nawadnianie warzyw polowych*. Plantpress, Kraków, 1-85.

Korzeniewska A., Sztangret J., Seroczyńska A., Niemirowicz-Szczytt K. (2004). *Zawartość związków karotenoidowych w owocach dyni olbrzymiej (Cucurbita maxima L.)*. Zeszyty Problemowe Postępów Nauk Rolniczych, 497, 339-345.

Kunachowicz H., Nadolna I., Przygoda B., Iwanowicz K. (2005). *Tabele składu i wartości odżywczej żywności.* Wydawnictwo Lekarskie PZWL, Warszawa.

Kurzeja E., Synowiec A., Stec M., Kudelski A., Chrobok M., Pawłowska-Góral K. (2011). *Ocena potencjału antyoksydacyjnego soków z wybranych warzyw z rodziny dyniowatych*. Bromatologia i Chemia Toksykologiczna, 3, 911-915.

Murkovic M., Hillderbrandt A., Winkler J., Pafannhauser W. (2002). *Variability of vitamin E in pumpkin seeds (Cucurbita pepo L.)*. Zeitschrift für Lebensmittel-Untersuchung und – Forschung, 4, 275-278.

Nawirska-Olszańska A., Kucharska A.Z., Sokół-Łętowska A., Biesiada A. (2010). *Ocena jakości dżemów z dyni wzbogaconych pigwowcem, dereniem i truskawkami.* Żywność. Nauka. Technologia. Jakość., 1(68), 40-48.

Nawirska-Olszańska A., Biesiada A., Sokół-Łętowska A., Kucharska A.Z. (2011). *Content of bioactive compounds and antioxidant capacity of pumpkin puree enriched with Japanese quince, cornelian cherry, strawberry and apples*. Acta Scientiarum Polonorum. Technologia Alimentaria, 10(1), 51-60.

Nawirska-Olszańska A. (2011). *Przydatność owoców dyni jako surowca do przetwórstwa spożywczego.* Monografie CXXXII, Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu.

Niewczas J., Szweda D., Mitek M. (2005). *Zawartość wybranych składników prozdrowotnych w owocach dyni olbrzymiej (Cucurbita maxima)*. Żywność. Nauka. Technologia. Jakość., Supl., 2(43), 147-155.

Niewczas J., Mitek M. (2007). *Wpływ przechowywania nowych odmian dyni olbrzymiej na wybrane parametry składu chemicznego*. Żywność. Nauka. Technologia. Jakość., 5(54), 155-164.

PN-A-04019:1998. *Produkty spożywcze. Oznaczanie zawartości witaminy C.*

PN-A-75101/03:1990. *Przetwory owocowe i warzywne. Przygotowanie próbek i metody badań fizykochemicznych. Oznaczanie zawartości suchej masy metodą wagową.*

PN-A-75101/12:1990. *Przetwory owocowe i warzywne. Przygotowanie próbek i metody badań fizykochemicznych. Oznaczanie zawartości sumy karotenoidów i beta-karotenu.*

Sokół-Łętowska A. (2004). *Rośliny dyniowate w medycynie i kosmetyce.* In: *Seminarium „Rośliny dyniowate"*, Wrocław.

Rolbiecki R., Rolbiecki S., Wojdyła T., Wichrowska D., Weltrowska-Medzińska B. (2006). *Wpływ nawadniania kroplowego na plon i jakość dyni bezłupinowej 'Junona' uprawianej na glebie bardzo lekkiej*. Folia Horticulturae, Supl. 2, 87-91.

Sztangret J., Korzeniewska A., Niemirowicz-Szczytt K. (2001). *Ocena plonowania oraz zawartości suchej masy i związków karotenoidowych w nowych mieszańcach dyni olbrzymiej*. Folia Horticulturae, 13/1A, 437-443.

Talburt W., Smith O. (1987). *Potato processing*. Thea AVI Publishing Comp. INC Westpost Connection, 796.

USDA National Nutrient Database for Standard Reference (2004). *Nutritional value of pumpkin and winter squash*. Release 17.

Wichrowska D., Wojdyła T. (2011). *Wpływ nawadniania kroplowego na zawartość przeciwutleniaczy w owocach dyni świeżej i utrwalonej*. Zeszyty Naukowe, Uniwersytet Ekonomiczny w Poznaniu, 205, 85-91.

Wojdyła T., Wichrowska D., Rolbiecki R., Rolbiecki S., Weltrowska-Medzińska B. (2007). *Zawartość wybranych składników chemicznych w dyni makaronowej świeżej i po przechowywaniu oraz konserwowanej w zależności od nawadniania i odmiany.* Żywność. Nauka. Technologia. Jakość., 3(52), 82-89.

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