

Effect of Growing Medium and Harvest Term on Yield and Several Quality Traits of Two Cultivars of “Cherry” Tomatoes

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Abstract

The objective of the study was to determine the effect of growing medium in greenhouse cultivation on the yield and fruits quality of “cherry” tomato two cultivars. Cultivars ‘Dasher F1’ and ‘Pareso F1’ were chosen for the experiment. The growing mediums compared were: standard mineral wool slabs and coconut fibre slabs, chosen as an environmentally friendly alternative to mineral wool. Tomato seeds were sown in December; seedlings were planted to the experimental greenhouse in January. The fruits were harvested at 5th stage of maturity, according to USDA classification (i.e. ‘light-red’), and subjected to analyses. Harvest terms for quality evaluation of the fruits were June and September. There were determined for the fruits: total and marketable yield, and quality parameters: pH of the fruit juice, titratable acidity, total sugars, soluble solids, total phenolic acids, lycopene, α -carotene and β -carotene contents. The results showed that the fruits harvested in September showed a higher dry matter and carotenoid content than the fruits harvested in June. However, the fruits harvested in June were characterized by a higher total sugars content, higher pH of the juice and higher soluble solids content. The plants grown in both mediums had fruits of similar quality, but the plants grown in coconut fibre showed noticeably higher total yield. Therefore, it can be concluded that the coconut fibre can be used as the environmentally friendly medium for greenhouse cultivation of ‘cherry’ tomatoes, the alternative to mineral wool.

Keywords: coconut fibre, mineral wool, soilless culture, growing medium

Introduction

Tomato is one of the most popular vegetables grown in the world (Causse *et al.*, 2003). Currently, “cherry” tomato *Solanum lycopersicum* L. var. *cerasiforme* (previous name *Lycopersicon esculentum* Mill. var. *cerasiforme*) became a popular vegetable and is grown in north Europe under protection (Kowalczyk and Gajc-Wolska, 2011). It is proved that daily intake of fresh or processed tomatoes by human decreases risk of chronic diseases, like cardiovascular diseases and cancer (Ilahy *et al.*, 2011). Tomato fruits are the main source of lycopene, an important source of β -carotene, ascorbic acid, vitamin E and phenolic compounds, which give benefits for humans because of antioxidant activity (Balestrieri *et al.*, 2004; Frusciante *et al.*, 2007; Guil-Guerrero and Reboloso-Fuentes, 2009; Leonardi *et al.*, 2000; Mueller, 1997; Raffo *et al.*, 2006; Rosales *et al.*, 2011; Yahia *et al.*, 2001). Tomato fruit sensory quality relates to several attributes, like dry matter, sugars content and juice acidity (Kowalczyk *et al.*, 2011). Flavour results from combination of odour and taste and is in a large amount based on the balance between sugars and organic acids contents (Oms-Oliu *et al.*, 2011). Many studies indicate that the key factor for plant growth, yield, fruit quality and storage ability is the growing medium used in

greenhouse cultivation (Kowalczyk *et al.*, 2011). Nowadays, the most popular growing medium used in a modern soilless vegetable cultivation is a mineral wool (called also a rock wool). With this sterile inert medium, precise plant nutrition is possible. Such optimisation of growing conditions aims to a high yield of good quality. However, mineral wool is not suitable for recycling, therefore alternative, environmentally friendly, growing mediums are needed. Good alternative for the mineral wool slabs could be a coconut fibre slabs (Gajewski *et al.*, 2010). The coconut fibre is a biodegradable material of good physical and chemical properties (Domeño *et al.*, 2009). After completing the growing season, coconut fibre slabs can be composting and then use as an organic fertilizer.

The objective of the study was to determine suitability of coconut fibre slabs as the alternative growing medium for “cherry” tomato greenhouse cultivation, based on yield comparative study for two tomato cultivars, including several quality traits of the fruits.

Materials and methods

The study was carried out in 2011 in Warsaw University of Life Sciences - SGGW. Two tomato cultivars - ‘Dasher F1’ and ‘Pareso F1’, of similar fruit weight (13-

17 g), colour (red) and shape (rounded) were used in the experiment. Mineral wool slabs (Grodan, 100 × 15 × 10 cm) and coconut fibre slabs (Cocovita, 100 × 15 × 15 cm) were used as the growing mediums. Tomato seeds were sown on January 4th, and the seedlings were planted to the greenhouse on February 8th, at the density of 2.7 plants per m². Drop irrigation system was applied in the greenhouse for watering and fertilizing the plants. Elements concentrations (mg dm⁻³) in the nutrient solution were as follows: N-NO₃ - 210, P - 60, K - 340, Mg - 50, Ca - 200, Fe - 2.0, Mn - 0.6, B - 0.3, Cu - 0.15, Zn - 0.3, Mo - 0.05. Plants fertilizing was applied according to results of nutrients monitoring in the growing mediums. Daily volume of nutrient solution per plant changed from 451 - 449 mL at the beginning of February to 1957 - 2628 mL in November. The pH was kept at the level of 5.7 - 6.6 and the EC of 4.2 - 4.5 mS. Main nutrients levels in the root zone were kept on the levels: P- 73 - 91 mg L⁻¹ and NO₃ - 913 - 944 mg L⁻¹. Average day/night air temperature (°C) for months from February to November was kept on the levels: 18/17, 19/17, 22/18, 23/19, 24/19, 23/19, 24/19, 22/16, 23/18, 21/18 for each month, respectively. The experiment was established as the three-factorial one, in 3 replications with 14 plants in each. Fruits were harvested 28 times, from April 29th to November 17th, and marketable quality yield was determined. Fruits at 5th stage of maturity, according to USDA classification ('light-red') were harvested for chemical analyses two times in the season - in June and September. The analyses were performed after 3-day storage of the fruits at simulated retail conditions (12°C).

Representative samples taken from 5 fruits were taken for the analyses. There were determined: dry matter - with drying at 104°C method, total sugars - with standard Luff-Schoorl's method, total soluble solids content (in °Brix) - with digital refractometer Atago, pH of fruit juice with pH meter (according to the Polish Standard PN-90 A-75 101/06), titrable acidity (according to the Polish Standard PN-90 A-75 101/04), total phenolic

acids content (according to Polish Pharmacopoeia VI, 2002) and carotenoids content (lycopene, α-carotene and β-carotene) with HPLC method (Rodriguez-Amaya DB, 2001). The HPLC analysis was performed using Shimadzu Prominence Liquid Chromatograph (Shimadzu, Japan) equipped with two LC-20AD pumps, SIL-20AC HT auto sampler, CTO-10AS VP oven, photodiode array detector SPD-M20A and LCsolution software. Peak identification was confirmed by comparison of retention time and spectral data with adequate parameters of standards purchased from ChromaDex (α-carotene, β-carotene) and Sigma Life Science (Redivivo™ - lycopene). All analyses were performed in three replicates.

Statistical analysis was performed with ANOVA (StatgraphicsPlus 4.1 software). Comparison of means was performed with the Tukey's HSD test, at the significance level $p = 0.05$.

Results and discussion

On both growing medium, plants produced similar number of clusters. The significant difference for the yield was found between the plants grown in the two growing mediums (Tab. 1). A higher yield was obtained from plants grown in the coconut fibre slabs. The highest yield was obtained for 'Pareso F1' plants grown in the coconut fibre slabs. The results obtained were similar to those obtained by Abukhovich and Kobryń (2010). In their study "cherry" tomato cultivars gave marketable yield on the level of 12.3 kg m⁻² for coconut fibre and 13.2 kg m⁻² for mineral wool slabs. In the present study average weight of the fruit was similar for plants grown in both mediums - 12.9 g for coconut fibre and 12.6 g for mineral wool. The difference in unmarketable yield between the two mediums was insignificant.

The influence of growing medium on dry matter of the fruits was insignificant (Tab. 2), while the influence of harvest term and the cultivar was significant. A higher dry weight showed the fruits harvested in September than

Tab. 1. Effect of growing medium on yield parameters of two cultivars of "cherry" tomatoes

Yield parameters	Growing medium (B)	Coconut fibre		Mineral wool	
	Cultivar (A)	'Dasher'	'Pareso'	'Dasher'	'Pareso'
Number of clusters per plant		33	35	31	34
	Means		34 a		33 a
			LSD _{0.05} (A/B) n.s.		
Marketable yield (kg m ⁻²)		11.62	16.17	11.55	13.58
	Means		13.90 a		12.57 b
			LSD _{0.05} (A/B) n.s.		
Average weight of the fruit (g)		12.95	12.89	12.68	12.43
	Means		12.92 a		12.56 a
			LSD _{0.05} (A/B) n.s.		
Unmarketable yield (kg m ⁻²)		0.97	1.51	0.91	1.55
	Means		1.24 a		1.23 a
			LSD _{0.05} (A/B) n.s.		

Note: Means marked with different letters differ significantly at $p = 0.05$

those harvested in June. Toor *et al.* (2006) examined two 'cherry' tomato cultivars in respect of dry matter content and found 5.9% of dry matter for 'Flavourion' fruits and 4.5% for 'Tradiro' fruits. Kowalczyk *et al.* (2011) observed for 'Dasher F1' fruits harvested in September a little lower dry matter content than we did. In their study fruits from plants grown in coconut fibre contained 7.9% of dry matter and those obtained from plants grown in mineral wool - 8.1%.

Tomatoes sensory quality is in a large degree determined by sugars content. They represent the major component of soluble solids (Islam *et al.*, 1996). In the case of total sugars content there were not found any significant differences between the fruits from the two growing mediums (Tab. 3). However, the influence of harvest term was significant. Higher total sugars content was found for the fruits harvested in September than for those harvested in June. Causse *et al.* (2003) found that tomato cultivars differed significantly in total sugars content in their fruits (from 3.8 to 6.6 g 100 g⁻¹). According to Abukhovich and Kobryń (2010), tomato fruits showed 3.3 g 100 g⁻¹ and 3.3 g 100 g⁻¹ of total sugars for plants grown in mineral wool and coconut fibre slabs, respectively. Kowalczyk *et al.* (2011) observed for 'Dasher F1' fruits cultivated in coconut fibre and mineral wool slabs a lower total sugars content than in our study - 3.46 and 2.67 g 100 g⁻¹, respectively.

The °Brix value, which indicates soluble solids content in fruit juice, is one of the main technological parameters of tomato concentrate. The value can be explained as the concentration of sucrose in an aqueous solution, having the same refractive index as the product analyzed (Mahieddine *et al.*, 2011). In the case of soluble solids content there was not found a significant difference between fruits from plants grown in the two growing mediums (Tab. 4). However, the influence of the term of harvest was significant. A higher soluble solids content showed the fruits harvested in June compared to fruits harvested in September. Fruits of 'Pareso F1' were characterized by a higher soluble solids content than those of 'Dasher F1'. According to Odriozola-Serrano *et al.* (2008), total soluble solids content in 'Bola' tomatoes ranged from 4.3 to 5.3%, and was markedly lower than values determined in our experiment. Kowalczyk *et al.* (2011) found that fruits of 'Dasher F1' harvested in September showed soluble solids content on the level of 7.40% for coconut fibre and 6.30% for mineral wool grown plants. These values are also lower than the values we recorded in the study.

The influence of growing medium on pH of fruit juice was insignificant, but the influence of harvest term on pH value was significant (Tab. 5). A higher pH showed the fruits harvested in September than the fruits harvested in June. The fruits of 'Dasher F1' showed a higher pH value than the fruits of 'Pareso F1'. According to Odriozola-Serrano *et al.* (2008) pH for 'Bola' tomato fruits ranged

Tab. 2. Effect of growing medium and harvest term on dry matter in two cultivars of "cherry" tomatoes (%)

	Growing medium (B)		Coconut fibre		Mineral wool		Means
	Cultivar (C)		'Dasher'	'Pareso'	'Dasher'	'Pareso'	
Harvest term (A)	June		8.09	7.60	8.16	7.44	7.82 a
	September		8.37	8.07	8.13	8.01	8.15 a
Means		8.04 a		7.93 a			
LSD _{0.05} (A/B) n.s., LSD _{0.05} (A/C) 0.24, LSD _{0.05} (B/C) n.s., LSD _{0.05} (A/B/C) n.s.							

Means marked with different letters differ significantly at $p = 0.05$

Tab. 3. Effect of growing medium and harvest term on total sugars content in two cultivars of "cherry" tomatoes (g 100 g⁻¹ FW)

	Growing medium (B)		Coconut fibre		Mineral wool		Means
	Cultivar (C)		'Dasher'	'Pareso'	'Dasher'	'Pareso'	
Harvest term (A)	June		5.49	5.68	5.35	5.16	5.42 a
	September		3.81	4.12	4.32	4.22	4.12 b
Means		4.78 a		4.76 a			
LSD _{0.05} (A/B) 0.22, LSD _{0.05} (A/C) n.s., LSD _{0.05} (B/C) 0.22, LSD _{0.05} (A/B/C) n.s.							

Means marked with different letters differ significantly at $p = 0.05$

Tab. 4. Effect of growing medium and harvest term on total soluble solids content in two cultivars of "cherry" tomatoes (°Brix)

	Growing medium (B)		Coconut fibre		Mineral wool		Means
	Cultivar (C)		'Dasher'	'Pareso'	'Dasher'	'Pareso'	
Harvest term (A)	June		8.47	8.36	8.71	8.53	8.52 a
	September		8.50	8.34	8.63	8.34	8.45 a
Means		8.42 a		8.45 a			
LSD _{0.05} (A/B) n.s., LSD _{0.05} (A/C) 0.16, LSD _{0.05} (B/C) 0.16, LSD _{0.05} (A/B/C) 0.23							

Note: Means marked with different letters differ significantly at $p = 0.05$

from 4.06 to 4.90. Kowalczyk *et al.* (2011) reported that fruits of tomato plants grown in coconut fibre showed pH of about 4.30 and those from mineral wool of about 4.20. These values were lower than observed in the present study.

In the case of fruit titrable acidity, there was found insignificant difference between the fruits from plants grown in the two growing mediums (Tab. 6). However, the influence of the harvest term was significant. A higher acidity was found for the fruits harvested in June, compared to the fruits harvested in September. The fruits of 'Pareso F1' were characterized by a higher acidity than the fruits of 'Dasher F1'. Odriozola-Serrano *et al.* (2008) reported that titrable acidity for 'Bola' tomato fruits was equal to 0.61%. Toor *et al.* (2006) found that titratable acidity for 'Flavouriono' "cherry" tomato fruit was on the level of 0.45 - 0.55% and for 'Tradiro' fruits 0.60-0.71%. Kowal-

czyk *et al.* (2011) reported that for 'cherry' tomato fruits obtained from coconut fibre and mineral wool cultivated plants titratable acidity was equal to 0.44 % and 0.45 %, respectively.

Phenolic acids are important compounds due to their antioxidant activity. Tomato fruit is a good source of phenolic acids for humans (Luthria *et al.*, 2006; Martinez-Valverde *et al.*, 2002). Neither growing medium nor harvest term influenced total phenolic acids content in the fruits (Tab. 7). The content ranged from 0.17 to 0.29% FW.

Tomatoes are rich in carotenoid, lycopene especially. These pigments are important in human nutrition. The amounts found in the "cherry" tomato fruits in our experiment differed significantly between harvest terms, but was similar for both growing mediums (Tab. 8). The lycopene content differentiation among tomato fruits reported by

Tab. 5. Effect of growing medium and harvest term on acidity of juice of two cultivars of "cherry" tomatoes (pH)

	Growing medium (B)		Coconut fibre		Mineral wool		Means
	Cultivar (C)		'Dasher'	'Pareso'	'Dasher'	'Pareso'	
Harvest term (A)	June		4.01	3.93	4.03	3.92	3.97 a
	September		4.52	4.47	4.53	4.54	4.52 a
	Means		4.23 a		4.25 a		
LSD _{0.05} (A/B) n.s., LSD _{0.05} (A/C) 0.04, LSD _{0.05} (B/C) n.s., LSD _{0.05} (A/B/C) n.s.							

Note: Means marked with different letters differ significantly at $p = 0.05$

Tab. 6. Effect of growing medium and harvest term on titrable acidity of two cultivars of "cherry" tomatoes, expressed as citric acid equivalents (%)

	Growing medium (B)		Coconut fibre		Mineral wool		Means
	Cultivar (C)		'Dasher'	'Pareso'	'Dasher'	'Pareso'	
Harvest term (A)	June		0.49	0.54	0.49	0.64	0.54 a
	September		0.52	0.51	0.49	0.47	0.50 b
	Means		0.51 a		0.52 a		
LSD _{0.05} (A/B) 0.03, LSD _{0.05} (A/C) 0.03, LSD _{0.05} (B/C) 0.03, LSD _{0.05} (A/B/C) 0.04							

Note: Means marked with different letters differ significantly at $p = 0.05$

Tab. 7. Effect of growing medium and harvest term on total phenolic acids content in two cultivars of "cherry" tomatoes, expressed as caffeic acid equivalents (% FW)

	Growing medium (B)		Coconut fibre		Mineral wool		Means
	Cultivar (C)		'Dasher'	'Pareso'	'Dasher'	'Pareso'	
Harvest term (A)	June		0.28	0.24	0.29	0.22	0.26 a
	September		0.23	0.26	0.26	0.17	0.23 a
	Means		0.25 a		0.26 a		
LSD _{0.05} (A/B) n.s., LSD _{0.05} (A/C) n.s., LSD _{0.05} (B/C) n.s., LSD _{0.05} (A/B/C) n.s.							

Note: Means marked with different letters differ significantly at $p = 0.05$

Tab. 8. Effect of growing medium and harvest term on lycopene content in two cultivars of "cherry" tomatoes (mg 100 g⁻¹ DW)

	Growing medium (B)		Coconut fibre		Mineral wool		Means
	Cultivar (C)		'Dasher'	'Pareso'	'Dasher'	'Pareso'	
Harvest term (A)	June		16.6	17.2	56.8	16.8	26.8 b
	September		79.4	57.8	99.8	74.3	77.8 a
	Means		42.7 b		61.9 a		
LSD _{0.05} (A/B) n.s., LSD _{0.05} (A/C) n.s., LSD _{0.05} (B/C) n.s., LSD _{0.05} (A/B/C) n.s.							

Note: Means marked with different letters differ significantly at $p = 0.05$

Tab. 9. Effect of cultivar, growing medium and harvest term on α -carotene content in two cultivars of “cherry” tomatoes (mg 100 g⁻¹DW)

	Growing medium (B)		Coconut fibre		Mineral wool		Means
	Cultivar (C)		‘Dasher’	‘Pareso’	‘Dasher’	‘Pareso’	
Harvest term (A)	June		1.04	1.01	1.09	0.98	1.03 b
	September		1.24	1.45	1.45	1.54	1.42 a
	Means		1.03 b		1.42 a		
LSD _{0.05} (A/B) n.s., LSD _{0.05} (A/C) n.s., LSD _{0.05} (B/C) n.s., LSD _{0.05} (A/B/C) n.s.							

Means marked with different letters differ significantly at $p = 0.05$

Tab. 10. Effect of growing medium and harvest term on β -carotene content in two cultivars of “cherry” tomatoes (mg 100 g⁻¹DW)

	Growing medium (B)		Coconut fibre		Mineral wool		Means
	Cultivar (C)		‘Dasher’	‘Pareso’	‘Dasher’	‘Pareso’	
Harvest term (A)	June		3.26	1.86	3.16	1.49	2.44 b
	September		7.06	8.29	7.57	8.07	7.75 a
	Means		5.12 a		5.07 a		
LSD _{0.05} (A/B) n.s., LSD _{0.05} (A/C) n.s., LSD _{0.05} (B/C) n.s., LSD _{0.05} (A/B/C) n.s.							

Means marked with different letters differ significantly at $p = 0.05$

other authors was also quite broad (Martinez-Valverde *et al.* 2002).

In this study it was found that α -carotene content in “cherry” tomatoes was generally lower than lycopene and β -carotene and content and was higher for mineral wool grown plants and also for fruits harvested in September (Tab. 9).

The content of β -carotene was not affected by growing medium, but was significantly higher for fruits harvested in September than in June (Tab. 10). Higher content of carotenoid compounds in the fruits harvested in September could be explained by different temperature/light conditions in the greenhouse during period of the fruit development. Fruits harvested in September ripened at higher temperatures and under more intensive sunlight, what could be the reason of more intensive pigments accumulation in the fruit. This phenomenon was observed for both tomato cultivars.

Conclusions

In the study “cherry” tomato plants cultivated in coconut fibre slabs gave a higher yield than the plants cultivated in mineral wool slabs. There were not found significant differences in chemical composition between the fruits from plants grown in the two growing mediums. Therefore, it can be concluded that the coconut fibre is technologically suitable as the growing medium for “cherry” tomato greenhouse cultivation. Since it is more environmentally friendly growing medium than mineral wool, it should be more widely used in greenhouse cultivation of tomato. It was also found that “cherry” tomatoes chemical composition is significantly influenced by harvest term.

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