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ASSESMENT OF CHEMICAL COMPOSITION AND SENSORY QUALITY OF TOMATO FRUIT DEPENDING ON CULTIVAR AND GROWING CONDITIONS

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Abstract. In the intensive tomato production under covers, the soilless cultivation dominates. The objective of this study was to assess some quality traits of cherry tomato and middle fruit size tomato, concerning their chemical composition and sensory attributes as well as their correlation to growing medium and harvest time. Cherry tomato (Dasher F_1 and Organza F_1) and middle fruit size tomato (Admiro F_1 and DRW 7594 F_1) cultivars were grown in the years 2008–2009 in the greenhouse with controlled climate and drip fertilizing system, in three different growing media. Organic media – coconut fiber and wood fiber were compared to rockwool, commonly used as a standard horticultural medium. The quality traits that mostly differentiated tomato fruits were the cultivar, harvest time and to the lesser degree the medium quality. Tomatoes harvested in July had a higher sugar content and received a higher sensory evaluation than those harvested in September. The sugars to acids ratio was the highest in fruits grown on coconut fiber. These fruits also obtained higher notes of particular determinants of sensory analysis, especially tomato flavor. The highest quality in respect to the content of the investigated chemical components and sensory evaluation was observed in fruits of Dasher F_1 and Admiro F_1 cultivars. A significant correlation between the content of chemical quality attributes of tomato fruit with such determinants of sensory evaluation as skin firmness, tomato and sweet taste was revealed. Sugar in fruits was positively correlated with the overall tomato assessment. Firmness and sweet taste were significantly correlated with organic acids and soluble solids contents.

Key words: fruit quality, growing media, coconut fiber, rockwool, wood fiber

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INTRODUCTION

Tomato fruits are a very popular vegetable, the source of many nutritional components with antioxidant capacity [Leonardi et al. 2000, Toor and Savage 2005, Thybo et al. 2006]. Nowadays, the increasing consumption of fresh vegetables containing bioactive compounds and consumers' acceptance of the product are very important. Sensory properties are very important in the assessment of vegetable quality and consumers' preferences [Magkos et al. 2003]. Good quality of tomato fruits and their acceptance by consumers describes a high correlation coefficient between the results of sensory assessment and the results of chemical analysis [Auerswald et al. 1999, Gajc-Wolska et al. 2000]. Fruit composition and their desirability are affected by many factors such as growth media, fertilizers, and salinity sources [Haglund et al. 1997, Gundersen et al. 2001, Thybo et al. 2006]. In the intensive tomato production under covers, the soilless cultivation dominates [Gäredal and Lundegärdh 1997, Jensen 1999]. The most popular and efficient growing medium in soilless crop production are rockwool slabs. Wood fiber and coconut fiber are especially promising as organic horticultural media [Gruda and Schnitzler 2004].

The aim of this work was to compare the chemical composition quality traits of cherry tomato and middle fruit size tomato cultivars with sensory attributes and their correlation in relation to growing medium and harvest time.

MATERIALS AND METHODS

The experiments were carried out in a greenhouse with the controlled microclimate in the years 2008 and 2009 at Warsaw University of Life Sciences. Two tomato cultivars: typical cherry tomato one Dasher F_1 with red skin and Organza F_1 with yellow skin and two middle fruit size tomato ones Admiro F_1 and DRW 7594 F_1 (Monsanto Polska Sp. z o.o. earlier De Ruiter Seeds) were used in the study. Tomatoes were cultivated on organic media such as coconut fiber slabs (manufacturer: Ceres Intern.), wood fiber slabs (Steico S.A.) and rockwool slabs (Grodan BV, Master type), commonly used as the standard growing medium for tomato. Slabs dimensions in all cases were 100 × 15 × 7.5 cm (length × width × height). The plants were trained on a single stem up a string according to the high wire system for a long growing cycle with the mean density of 2.7 plants·m^{-2}. Tomatoes were fertigated by a computer controlled drip-irrigation system and fertilized with similar rates of macro- and micro-nutrients, according to the levels recommended for tomato. The amount of the nutrient supply ranged from 70 to 200 cm^3 per plant and was adjusted to the plant growth phase, light conditions as well as growing medium. Nutrients concentration in the solution, EC (electroconductivity) and pH were continuously controlled and kept at uniform levels for all the experimental objects. The concentration of nutrients (in mg·dm^{-3}) was as follows: N-NO_3 – 210, P – 60, K – 340, Mg – 50, Ca – 200, Fe – 2, Mn – 0.6, B – 0.3, Cu – 0.15, Zn – 0.3, Mo – 0.05. The experiment was established in random design, in three replicates, with 8 plants in each.

Fruits for quality evaluation were harvested at the full colour maturity stage at two different dates: at the beginning of July and at the end of September. At each harvest time, 40 fruits were collected from each combination. One part was examined for the chemical quality attributes of tomato fruit, such the content of total soluble solids (TSS) using the digital refractometer and expressed in per cent, titratable acidity (TA) was measured with the potentiometric method according to the Polish standard PN-90 A-75 101/04 and expressed as g of citric acid per 100g of fresh weight, and total sugars (TS) were analyzed according to the Luff-Schoorl method. The sugar to acid ratio was also determined as the TS:TA quotient. Another part of fruits was subjected to sensory analysis done by the scaling method. The trained panel of 10 persons evaluated tomato fruit samples in relation to their skin firmness, flesh texture, juiciness of flesh, tomato smell, strange smell, taste (sweet, sour, typical tomato, strange) and overall quality. Each attribut of sensory analysis was expressed in a scale from 0 to 10.

Statistical analysis was performed using three-way analysis of variance. Results for individual years were regarded as repetitive values in a statistical test. Detailed comparison of means was performed by the Tukey's test at the significance level of $\alpha = 0.05$. For the needs of chemical analysis and sensory assessment the correlation coefficient was calculated (linear dependence between two traits) using the Statgraphics Plus program.

RESULTS AND DISCUSSION

The results of the experiment show that harvest time and tomato cultivar as well as growth medium significantly influenced fruit quality. Tomatoes harvested in July had a higher content of TS and TA than fruits harvested in September (tab. 1). Fruits harvested in July obtained higher note of all the investigated discriminants in sensory evaluation than fruits harvested in September (tab. 2). They were characterized by stronger smell and the taste typical for tomato, they were sweeter and evidently more juicy. Their skin was firmer. The overall assessment was higher than in September. It is confirmed by the results of the investigations showing that the growing time, which is connected mostly with the light and thermal conditions, significantly affects the quality of vegetables [Thybo et al. 2006, Hernández Suárez et al. 2008].

Fruits obtained from cultivation on coconut fiber were characterized by the highest TS:TA ratio as compared to fruits cultivated on rockwool. The ratio between sugars and organic acids shapes the taste of the tomato. It is confirmed by the obtained results of sensory analysis in which fruits cultivated on coconut fiber received a higher note of tomato smell and a higher overall note than fruits grown on the remaining media, however, the differences were not significant statistically. A significant difference was observed in the case of typical tomato smell which obtained the highest note in the case of fruits cultivated on coconut fiber. Halmann and Kobryń [2003] also obtained a higher quality in the case of tomatoes grown on coconut fiber than on rockwool. However many authors report that it is not the type of the medium but electrical conductivity (EC) in the growth media that has more pronounced effects on tomato quality [Gundersen et al. 2001, Arena et al. 2003, Thybo et al. 2005, Thybo et al. 2006, Fanasca et al 2007, Hernández Suárez et al. 2007].

Table 1. Chemical related traits of tomato fruits as affected by harvest time, growing media and cultivar (mean values for 2008–2009)

Tabela 1. Cechy chemiczne owoców pomidora w zależności od terminu zbioru, podłoża i odmiany (średnie wartości dla 2008–2009)

Factor Czynnik		Total sugars Cukry ogółem	TA Kwasowość potencjalna	TSS Składniki rozpuszczalne w soku komórkowym %	Total sugars – TA Cukry ogółem – Kwasowość
		g·100 g fw^{-1} g·100 g św.m.$^{-1}$			
Date of harvest Termin zbioru	July lipiec	2.54 a*	0.36 a	4.23 a	6.91 a
	September wrzesień	2.28 a	0.34 a	4.22 a	7.12 a
Growing medium Podłoże	coconut fiber włókno kokosowe	2.58 a	0.34 a	4.48 a	7.75 a
	wood fiber włókno drzewne	2.42 a	0.34 a	3.99 a	7.15 ab
	rockwool wełna mineralna	2.23 a	0.38 a	4.29 a	6.13 b
Cultivar Odmiana	Dasher F_1	3.66 a	0.46 a	6.47 a	8.14 a
	Organza F_1	2.66 b	0.34 b	3.92 b	7.04 ab
	Admiro F_1	1.95 b	0.29 b	3.48 b	6.85 ab
	DRW 7594 F_1	1.76 b	0.31 b	3.04 b	5.99 b

* Mean values for factors which do not differ according to Tukey's HSD test at P = 0.05 are marked with the same letters. Interaction insignificant – Średnie wartości dla czynników nieróżniących się przy p = 0,05 oznaczono tą samą litera. Interakcje nieistotne

Fruits of Dasher F_1 cultivar were characterized by the highest content of TS, TA, TSS and TS/TA as compared to other investigated cultivars. However, no significant differences in the sugars to acids ratio were observed in fruits of the Dasher F_1 or Organza F_1 or Admiro F_1 cultivars. In the sensory analysis fruits of the Dasher F_1 cultivar also obtained the highest notes proving their high quality but their overall quality value was similar to that of the standard tomato cultivar – Admiro F_1. Fruits of those two cultivars were similarly assessed in relation to their tomato smell which would testify to the fact that this is the fruit trait connected with the presence of volatile compounds and the above mentioned TS/TA ratio which affects the high evaluation of Admiro F_1 cultivar.

Some determinants of the sensory assessment were significantly correlated with the content of sugars and organic acids as well as compounds dissolved in the cell sap of tomato fruits. A significant correlation between those chemical components and the firmness of the skin and sweet taste of fruits was observed (tab. 3). However, in the case of tomato taste and the overall quality assessment such correlation was proved only in relation to the sugar content in tomato fruits. In the case of other analyzed determinants of sensory analysis such correlations with TS, TA or TSS were not observed. Fruits containing more sugars obtain a higher overall note but also the content of organic acids

Table 2. Effect of harvest time, growing media and cultivar on sensory attributes of tomatoes (mean values for 2008–2009)
Tabela 2. Wpływ terminu zbioru, podłoża i odmiany na wyróżniki oceny sensorycznej owoców pomidora (średnie wartości dla 2008–2009)

Factor Czynnik		Smell – Zapach		Tough of skin Twardość skórki	Flesh texture Mięsistość miąższu	Juiciness of flesh Soczystość miąższu	Taste – Smak				Overall quality Ocena ogólna
		tomato pomidorowy	strange obcy				typical tomato typowo pomidorowyo	sour kwaśny	sweet słodki	strange obcy	
Date of harvest Termin zbioru	July lipiec	5.98 a	0.05 a	4.31 a	5.34 a	6.43 a	6.33 a	4.10 a	3.20 a	0.07 a	7.39 a
	September wrzesień	5.60 b	0.02 b	3.88 b	5.07 a	6.14 b	5.81 b	3.98 a	2.85 b	0.05 a	6.64 b
Growing medium Podłoże	coconut fiber włókno kokosowe	5.93 a	0.07 a	4.06 a	5.04 a	6.30 a	6.16 a	4.13 a	3.02 a	0.06 a	7.09 a
	wood fiber włókno drzewne	5.69 b	0.02 a	4.012 a	5.14 a	6.31 a	6.02 a	4.05 a	2.97 a	0.06 a	6.98 a
	rockwool wełna mineralna	5.75 ab	0.01 a	4.11 a	5.43 a	6.24 a	6.03 a	3.93 a	3.08 a	0.05 a	6.97 a
Cultivar Odmiana	Dasher F_1	6.26 a	0.02 a	6.11 a	5.74 a	6.19 b	6.83 a	4.51 a	4.47 a	0.00 b	7.52 a
	Organza F_1	5.04 c	0.04 a	3.93 b	3.96 b	6.58 a	5.30 d	3.41 c	2.56 bc	0.04 b	6.68 b
	Admiro F_1	6.04 ab	0.07 a	3.41 bc	5.48 a	6.57 a	6.28 b	4.02 b	2.67 b	0.02 b	7.15 a
	DRW 7594 F_1	5.81 b	0.02 a	2.94 c	5.64 a	5.80 c	5.87 c	4.20 b	2.38 c	0.17 a	6.69 b

* see tab 1 – patrz tab. 1

Table 3. Significant correlations between the content of total sugars, titratable acidity and solube solid content of tomatoes (respectively) and sensory attributes of the scaling method (mean values for 2008–2009)

Tabela 3. Istotne zależności między zawartością w owocach pomidora cukrów ogółem, kwasowości potencjalnej i składników rozpuszczalnych w soku komórkowym, a wyróżnikami sensorycznej metody skalowania (średnie wartości dla 2008–2009)

Sensory attributes Wyróżniki sensoryczne	Correlation coefficient – Współczynnik korelacji		
	total sugars cukry ogółem	TA kwasowość potencjalna	TSS składniki rozpuszczalne w soku komórkowym
Tough of skin Twardość skórki	0,65**	0,75**	0,81**
Typical tomato taste Smak typowo pomidorowy	0,54**		
Sweet taste Smak słodki	0,71**	0,71**	0,73**
Overall quality Ocena ogólna	0,57**		

**significant at P = 0,01 – istotne przy p = 0,01

in tomato fruits, due to its high correlation of the amounts of those compounds with sweet taste felt by the consumers, affects their quality. Among others, such a high assessment of the quality of Dasher F_1 fruits which contained the biggest amounts of acids, confirms these correlations. Hobson and Bedford [1989] and Auerswald et. al [1999], among others, also reported that the content of sugars and acids positively correlates with the sweet and sour tastes and overall sensory quality of tomato fruits. Particular quality traits of tomato were mostly differentiated by the type of cultivar but also by the date of fruit harvest and, although to a lesser degree, by the medium traits.

CONCLUSIONS

1. Tomatoes harvested in July had a higher sugar content and received a higher sensory evaluation note than those harvested in September.

2. The sugars to acids ratio was the highest in fruits cultivated on coconut fiber. These fruits also received a higher note of particular determinants, especially in the case of the tomato smell.

3. The highest quality in relation to the content of the investigated chemical components and sensory evaluation had fruits of Dasher F_1 and Admiro F' cultivars.

4. A significant correlation was proved for such determinants of sensory evaluation as skin firmness, tomato taste and sweet taste.

5. The sugar content in fruits was positively correlated with the overall evaluation of tomato fruits.

6. Skin firmness and sweet taste were significantly correlated with the content of organic acids and soluble solids.

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OCENA JAKOŚCI OWOCÓW POMIDORA POD WZGLĘDEM SKŁADU CHEMICZNEGO I JAKOŚCI SENSORYCZNEJ W ZALEŻNOŚCI OD ODMIANY I WARUNKÓW UPRAWY

Streszczenie. W intensywnej uprawie pomidora pod osłonami dominuje uprawa bezglebowa. Obiektem badań była ocena jakości owoców pomidora cherry i średnioowocowego, na podstawie wybranych chemicznych i sensorycznych cech jakościowych owoców pomidora i ich korelacji w zależności od rodzaju podłoża i terminu zbioru. Pomidor typu cherry (Dasher F_1 i Organza F_1) i średnioowocowy (Admiro F_1 i DRW 7594 F_1), uprawiano w latach 2008–2009 na trzech podłożach w kontrolowanych i monitorowanych warunkach mikroklimatu szklarni oraz fertygacji roślin. Przyjazne dla środowiska podłoża, takie jak włókno kokosowe i drzewne, porównywano z wełną mineralną jako powszechnie używanym podłożem w uprawach hydroponicznych warzyw. Jakość pomidora w istotny sposób zależała od odmiany i terminu zbioru owoców, a w najmniejszym stopniu od podłoża. Pomidory zebrane w lipcu miały wyższą zawartość cukrów i otrzymały wyższą ocenę sensoryczną niż zbierane we wrześniu. Stosunek cukrów do kwasów był najwyższy w owocach z uprawy na włóknie kokosowym. Owoce te uzyskały także wyższe oceny poszczególnych wyróżników oceny sensorycznej, szczególnie zapachu pomidorowego. Najwyższą jakość pod względem zawartości badanych składników chemicznych i oceny sensorycznej miały owoce odmiany Dasher F_1 oraz Admiro F_1. Wykazano istotną korelację zawartości składników chemicznych decydujących o jakości owoców pomidora z takimi wyróżnikami oceny sensorycznej, jak twardość skórki, smak pomidorowy i słodki. Zawartości cukrów w owocach była dodatnio skorelowana z oceną ogólną pomidora w metodzie profilowej. Twardość skórki i smak słodki były istotnie skorelowane z zawartością kwasów organicznych i ekstraktu cukrowego.

Słowa kluczowe: jakość owoców, podłoża, włókno kokosowe, wełna mineralna, włókno drzewne

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