The Quality of Fresh Tomato Fruit Produced by Hydroponic

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Summary

The quality of fresh tomatoes (*Lycopersicon esculentum* Mill.) planted in rockwool in hydroponic system is defined by their internal parameters: contents of dry matter and soluble dry matter (°Bx), total acidity (% citric acid), pH, % NaCl and L-ascorbic acid. Research was carried out during 2003 and included 21 cultivars. Tomato plants were planted into rockwool slabs 100 cm x 15 cm x 7.5 cm. Three plants were planted 33 cm apart in 11.25 L of substrate. The trial was laid out according to the randomized complete block design with four replications, and sampling was carried out during three harvests in: June, July and August.

The dry matter content was 4.29% (cultivar 'Syta') to 6.21% (cultivar 'Delfine'), and content of soluble dry matter was 3.0% (cultivar 'Brooklyn') to 4.5% ('Lustro' and '72-503'). Total acidity amounted from 0.19% (cultivar 'Syta') to 0.45% (cultivar 'Lustro'), and pH values ranged from 4.20 (cultivar '20377') to 4.68 (cultivar 'Syta'). Salt content ranged from 0.08% ('Campeon' and 'F 18402') to 0.13% ('Brooklyn' and 'E 27.31299'), and L-ascorbic acid content ranged from 260.40 (cultivar 'Antinea') to 458.30 mg/dry matter (cultivar 'F 18402').

By studying the basic chemical composition of selected cultivars, significant differences in their soluble dry matter and pH were revealed but only at the first sampling.

Key words

tomato, chemical composition, hydroponic system, cultivars

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Introduction

As daily supplies of fresh vegetables are required for the inhabitants of the city of Zagreb, large quantities of tomatoes and other vegetables are produced in its surroundings. Fresh vegetables can be supplied all year long by their greenhouse production, which requires soil sterilization by mechanical or chemical methods. Soilless culture of vegetables is one of the solutions providing both environmental protection and good-quality fresh raw materials. Soilless culture of tomatoes has been used in Croatia since 2001 in order to protect soil and groundwater for the needs of capital city inhabitants. In this production, fertigation is done by nutrient solution of adequate composition of macro and micro-elements, applied by a drip irrigation system. Cultivar quality has an important role for the production and consumption of fresh vegetables. The research objective was to determine the fruit quality of different tomato cultivars produced hydroponically in rockwool and intended for fresh consumption.

Fruits were harvested according to their external characteristics: colour (Angelis et al., 2001), shape and size. Internal quality parameters were determined in the laboratory: contents of dry matter 5.0-10.7%, soluble dry matter 2.4-8.8%, total acidity 0.36-0.89%, pH 3.95-4.8 and L-ascorbic acid 10.56-28.0 mg per 100 g fresh fruit (De Bruyan et al., 1971; Hobson and Kilby, 1985; Kader, 1986; Stevens, 1986; Hettmann, 1998; Pagliarini and Ratti, 1999; Angelis et al., 2001; Elia et al., 2001; Gül et al., 2001; Tüzel et al., 2001; Lešić et al., 2002; D'Amico et al., 2003). Sugar to acid ratio is important for taste formation, which along with colour prefers certain cultivars, as confirmed in numerous investigations. Participation of acids is a very important factor of taste as well; differences in their quantities are seen from the pH and total acids values (Angelis et al., 2001).

Material and methods

Research was done on tomato fruits grown in rockwool. The trial was set up in 2003 in a water-conservation area near Zagreb and included the following cultivars: 'Antinea', 'Belle', 'Brooklyn', 'Campeon', 'Delfine', 'Don Jose', 'E 27.31299', 'E 27.31643', 'F 18402', 'Faustine', 'Hallay 344', 'Lustro', 'Profilo', 'Rapsodie', 'Spacestar', 'Syta', 'Tamaris', 'Tavira', 'Tradiro', '20377' and '72-503'. The average volume of substrate was 3.75 L per plant. The nutrient solution was prepared in a 1000 L container from 100 times concentrated solutions stored in three containers, with addition of water. Container A contained KNO_3, $MgSO_4$, KH_2PO_4, NH_4NO_3, K_2SO_4, Fe-chelate (Fe-EDTA), H_3BO_4, $MnSO_4$, $ZnSO_4$, $CuSO_4$ and Mo_2O_3, container B contained $Ca(NO_3)_2$ and container C contained HNO_3. The composition of a nutrient solution was formulated according to Sonneveld (1988). The nutrient solution was distributed periodically during the day (up to 24 times, depending on the development stage of the plants) by a drip irrigation system. The duration of an individual irrigation dosage was from 2 to 7 minutes, depending on cloudiness and the time of day. Apart from pH and EC-values of the nutrient solution in the container, a pH and EC-meter was used for controlling (once a week) pH and EC-values of the nutrient solution in the root zone. The composition of the nutrient solution from the root zone was determined in the laboratory. Average pH value in the root zone was between 5.9 to 7.2 and the EC value ranged from 4.1 to 7.7 mS cm $^{-1}$.

The trial was laid out according to the randomized block scheme with four replications. Tomato fruits were analyzed on 17 June, 14 July and 25 August 2003. These harvest dates were chosen because tomato consumption is the highest at that time. An average sample of each cultivar was analyzed in the laboratory to determine the contents of dry matter (%), soluble dry matter (°Bx), pH, total acidity (% citric acid), NaCl (%) and L-ascorbic acid in mg per 100 g dry matter. Dry matter was determined by drying to constant mass in an etalon drying chamber. Total soluble solids expressed as °Brix, were measured with an Abbe refractometer (A. Krüss, Germany) calibrated against sucrose. Total acidity was measured according to AOAC method 942.15 (AOAC, 1995) and expressed as citric acid, pH was measured with a pH-meter (Mettler-Toledo, Switzerland). Ascorbic acid concentration was determined using 2,6-Dichloroindophenol. A titrimetric test was done according to AOAC method 967.21. Quantity of NaCl was determined titrimetrically with the aid of $AgNO_3$ regarding regulation given by AOAC (AOAC, 2002).

Results were processed by means of the statistical package MSTAT-C (Nissen, 1983). Analysis of variance was done using the F-test, and the differences were determined with Duncan's multiple range test at the significance level $p \leq 0.05$.

Results and discussion

Statistical analysis of the results showed that the quantities of dry matter (Table 1) ranged from 4.29% ('Syta') to 6.21% ('Delfine'). The lowest (4.29%) and highest (6.21%) quantity of dry matter was determined at harvest date in July. There were no statistical differences between cultivars. Most cultivars (61.2%) had the highest dry matter content at the third harvest date in August. Cultivars 'Antinea', 'Campeon', 'Don Jose', 'F 18402', 'Rapsodie', 'Spacestar', 'Syta' and 'Tavira' achieved lower values compared to literature data (Hettmann, 1998; Elia et al., 2001; Tüzel et al., 2001; Lešić et al., 2002; D'Amico et al., 2003).

Table 1.
Dry matter (%) in tomato fruit of different cultivars

Cultivars	Sampling date			Average
	17 June	14 July	25 August	
Antinea	4.68	4.78	4.87	4.78
Belle	4.90	5.20	5.29	5.13
Brooklyn	4.80	5.15	5.40	5.12
Campeon	4.48	4.94	5.49	4.97
Delfine	4.90	6.21	5.68	5.60
Don Jose	5.14	4.50	5.12	4.92
E 27.31299	5.02	4.89	5.37	5.09
E 27.31643	5.62	5.26	5.63	5.50
F 18402	4.90	4.42	5.50	4.94
Faustine	5.25	5.30	5.86	5.47
Hallay 344	5.47	4.57	5.39	5.14
Lustro	4.71	5.35	5.50	5.19
Profilo	5.13	4.86	5.12	5.04
Rapsodie	4.83	4.66	5.00	4.83
Spacestar	4.69	4.54	4.88	4.70
Syta	4.80	4.29	4.74	4.61
Tamaris	4.80	5.40	5.42	5.21
Tavira	4.70	5.35	4.78	4.94
Tradiro	5.30	4.90	5.04	5.08
20377	4.96	5.25	5.62	5.28
72-503	4.70	5.51	5.07	5.09
LSD $_{0.05}$	0.2344	0.2556	0.2712	

Table 2.
Total acidity (%) in tomato fruit of different cultivars

Cultivars	Sampling date			Average
	17 June	14 July	25 August	
Antinea	0.25	0.22	0.24	0.24
Belle	0.41	0.36	0.37	0.38
Brooklyn	0.31	0.30	0.31	0.31
Campeon	0.28	0.30	0.33	0.30
Delfine	0.33	0.35	0.29	0.32
Don Jose	0.39	0.29	0.34	0.34
E 27.31299	0.43	0.35	0.33	0.37
E 27.31643	0.34	0.36	0.36	0.38
F 18402	0.29	0.35	0.27	0.30
Faustine	0.34	0.30	0.33	0.32
Hallay 344	0.40	0.30	0.32	0.34
Lustro	0.45	0.23	0.37	0.35
Profilo	0.39	0.32	0.33	0.34
Rapsodie	0.38	0.36	0.33	0.35
Spacestar	0.39	0.31	0.36	0.35
Syta	0.26	0.23	0.19	0.22
Tamaris	0.34	0.30	0.31	0.32
Tavira	0.34	0.25	0.25	0.28
Tradiro	0.37	0.29	0.28	0.31
20377	0.43	0.36	0.38	0.39
72-503	0.37	0.30	0.31	0.33
LSD $_{0.05}$	0.2334	0.0165	0.0165	

Total acidity (Table 2) ranged from 0.19% ('Syta') at the harvest date in August to 0.45% ('Lustro') at the first sampling date, without significant differences between cultivars. While dry matter content is higher at harvest in August total acidity is lower in August than in June (72.6 % of cultivars).

Table 3.
pH values in tomato fruit of different cultivars.

Cultivars	Sampling date			Average
	17 June	14 July	25 August	
Antinea	4.60a	4.55	4.48	4.54
Belle	4.31ab	4.49	4.38	4.39
Brooklyn	4.38 ab	4.50	4.45	4.44
Campeon	4.35ab	4.42	4.33	4.37
Delfine	4.40 ab	4.46	4.43	4.43
Don Jose	4.37ab	4.52	4.43	4.44
E 27.31299	4.34ab	4.41	4.38	4.38
E 27.31643	4.38 ab	4.46	4.35	4.40
F 18402	4.52 ab	4.43	4.5	4.48
Faustine	4.40 ab	4.45	4.45	4.43
Hallay 344	4.38 ab	4.47	4.44	4.43
Lustro	4.32 ab	4.60	4.4	4.44
Profilo	4.38 ab	4.44	4.38	4.40
Rapsodie	4.31 ab	4.37	4.38	4.35
Spacestar	4.36 ab	4.45	4.34	4.38
Syta	4.48 ab	4.55	4.68	4.57
Tamaris	4.34 ab	4.48	4.45	4.42
Tavira	4.38 ab	4.62	4.6	4.53
Tradiro	4.41 ab	4.53	4.48	4.47
20377	4.20 b	4.40	4.38	4.33
72-503	4.30 ab	4.45	4.48	4.41
LSD $_{0.05}$	0.0522	0.521	0.0165	

a b Duncan's Multiple Range Test at a significance level of p≤0.05

Table 4.
Soluble dry matter (%) in tomato fruit of different cultivars.

Cultivars	Sampling date			Average
	17 June	14 July	25 August	
Antinea	4.0 ab	3.6	3.9	3.8
Belle	4.0 ab	4.0	3.8	3.9
Brooklyn	3.0 b	4.1	4.0	4.1
Campeon	4.3 a	4.0	4.2	4.1
Delfine	4.0 ab	4.0	3.8	3.9
Don Jose	4.0 ab	4.0	4.1	4.1
E 27.31299	4.1 ab	3.6	4.0	3.8
E 27.31643	4.0 ab	3.7	4.1	3.9
F 18402	4.0 ab	4.0	4.0	4.0
Faustine	4.0 ab	4.0	4.2	4.1
Hallay 344	4.0 ab	3.9	4.1	4.0
Lustro	4.0 ab	3.8	4.5	4.2
Profilo	4.0 ab	3.7	4.0	3.8
Rapsodie	4.0 ab	4.0	4.0	4.0
Spacestar	4.0 ab	3.9	4.2	4.1
Syta	4.0 ab	3.4	4.0	3.7
Tamaris	3.8 ab	4.0	3.8	3.9
Tavira	4.2 a	3.8	4.0	3.9
Tradiro	3.5 ab	3.9	4.0	4.0
20377	3.8 ab	4.0	4.0	4.0
72-503	4.5 a	4.0	4.2	4.1
LSD $_{0.05}$	0.1808	0.3043	0.1278	

a, b Duncan's Multiple Range Test at a significance level of p≤0.05

Average pH-values (Table 3) ranged from 4.33 ('20377') to 4.57 ('Syta'). At the first sampling date, cultivar 'Antinea' had significantly higher pH-value (4.60) than cultivar '20377' (4.20). At the second sampling date pH-value of tomato fruits varied between 4.37 and 4.62 and at the

Table 5.
NaCl (%) in tomato fruit of different cultivars.

Cultivars	Sampling date			Average
	17 June	14 July	25 August	
Antinea	0.10	0.09	0.10	0.09
Belle	0.12	0.11	0.11	0.11
Brooklyn	0.13	0.09	0.11	0.11
Campeon	0.08	0.09	0.10	0.09
Delfine	0.10	0.10	0.10	0.10
Don Jose	0.11	0.09	0.11	0.10
E 27.31299	0.13	0.10	0.12	0.12
E 27.31643	0.11	0.10	0.11	0.11
F 18402	0.10	0.08	0.10	0.09
Faustine	0.11	0.10	0.10	0.10
Hallay 344	0.12	0.10	0.10	0.11
Lustro	0.12	0.10	0.12	0.12
Profilo	0.12	0.10	0.11	0.11
Rapsodie	0.11	0.10	0.12	0.11
Spacestar	0.11	0.11	0.11	0.11
Syta	0.10	0.10	0.11	0.10
Tamaris	0.12	0.09	0.10	0.11
Tavira	0.11	0.11	0.10	0.11
Tradiro	0.12	0.10	0.10	0.11
20377	0.12	0.10	0.11	0.11
72-503	0.12	0.09	0.11	0.11
LSD $_{0.05}$	0.0165	0.0165	0.0156	

Table 6. L-ascorbic acid (mg/100 g dry matter) in tomatoes of different cultivars.

Cultivars	Sampling date			Average
	17 June	14 July	25 August	
Antinea	260.40	318.32	334.97	304.56
Belle	326.60	382.18	364.01	359.60
Brooklyn	308.73	373.10	325.01	335.61
Campeon	439.11	441.39	431.16	437.22
Delfine	349.56	280.58	316.47	315.54
Don Jose	278.07	400.70	404.84	361.20
E 27.31299	284.94	302.92	314.23	300.70
E 27.31643	276.25	358.11	388.35	340.90
F 18402	354.52	458.30	361.51	391.44
Faustine	311.72	352.45	316.34	326.84
Hallay 344	274.97	368.23	377.71	340.30
Lustro	335.94	455.93	370.45	387.44
Profilo	285.06	322.15	371.35	326.19
Rapsodie	354.92	422.86	328.63	368.80
Spacestar	274.32	381.86	353.14	336.44
Syta	284.69	397.39	352.72	344.93
Tamaris	351.26	297.89	324.76	324.64
Tavira	381.51	331.48	370.94	361.31
Tradiro	303.04	368.52	352.06	341.21
20377	380.83	346.22	403.72	376.92
72-503	331.24	275.72	333.52	313.49
LSD $_{0.05}$	30.21	34.13	34.54	

third varied from 4.33 to 4.68 but without significant differences.

Cultivar 'Brooklyn' had significantly lower soluble dry matter (Table 4) content (3.0%) than cultivars 'Campeon', 'Tavira' and '72-503' (4.3, 4.2 and 4.5 %) at the first sampling date. During July soluble dry matter content varied from 3.6 to 4.1%, and during August from 3.8 to 4.5% without statistical differences between cultivars.

The content of NaCl in tomato fruits (Table 5) varied from 0.08 to 0.13% depending on sampling date. Both, the lowest and the highest NaCl content was determined at the first sampling date but without significant differences.

The lowest L-ascorbic acid (Table 6) content (260.40 mg/100 g dry matter) was determined in cultivar 'Antinea' fruit at the sampling date in June, while the highest content (458.30 mg/100 g dry matter) was determined in cultivar 'F 18402' fruits in July. In 14.3% of tested cultivars the highest L-ascorbic acid content was determined at sampling in June. Most of the cultivars (47.6%) had the highest L-ascorbic acid content in July, while 38.1% had it in August.

Values obtained by chemical analyses indicated satisfactory quality of tomato fruits (De Bruyan et al., 1971; Hobson and Kilby, 1985; Kader, 1986; Stevens, 1986; Hettmann, 1998; Angelis et al., 2001; Elia et al., 2001; Gül et al., 2001; Tüzel et al., 2001; Lešić et al., 2002; D'Amico et al., 2003).

Conclusion

Based on the achieved results we concluded that 21 cultivars of tomato grown in rockwool showed satisfactory fruit quality. Significant differences in total soluble solids contents and pH values were determined for the first sampling date. Dry matter content, titratable acidity content, NaCl content and vitamin C content showed no significant differences between cultivars at three sampling dates.

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