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Physico-chemical and sensory parameters of tomato cultivars grown in organic systems

Jacqueline C Araujo¹; Paula PM Silva²; Samuel FP Telhado³; Rogério H Sakai⁴; Marta HF Spoto²; Paulo CT Melo¹

¹USP-ESALQ, Depto. Prod. Vegetal, C. Postal 09, 13418-900 Piracicaba-SP; jacqueline.c.a@gmail.com (*autor correspondente); paulomelo@usp.br; ²USP-CENA, Depto. Ciência e Tecnologia de Alimentos, C. Postal 09, 13418-900 Piracicaba-SP; pporrelli@uol.com.br; martaspoto@usp.br; ³Embrapa Mandioca e Fruticultura, 44380-000 Cruz das Almas-BA; samuel.telhado@embrapa.br; ⁴Casa da Agricultura de Registro-CATI, 11900-000 Registro-SP; rhsakai@gmail.com

ABSTRACT

The objectives of this research were to perform the physical, chemical and sensorial characterization, for hybrid and open pollinated tomato, within the Santa Cruz and Italian groups, aiming fresh consumption. A total of 14 fresh market tomato cultivars was used, six of them being experimental varieties and eight were commercial ones. The experimental design was of randomized blocks with six replicates and five plants per plot. For the chemico-physical analysis, samples of ripe fruits were randomly extracted from five plants in each plot, labeled and maintained under refrigeration at 5°C until the next day after harvest. Afterwards, fruits of all cultivars were mixed, ground and divided in triplicates to be submitted to the physicochemical analysis. From the physicochemical analysis it was observed that the value of the ratio between soluble solids (SS)/titratable acidity (TA) was higher in the cultivars IAC 6 and IAC 3. In relation to the SS content, the highest values were obtained by cultivars IAC 1 and IAC 6. In order to evaluate the commercial value of the cultivars, a sensorial analysis was carried out with fruits tasted by 75 individuals, using a hedonic scale of seven points. The data were analyzed by variance analysis and grouping of means. The cultivars of the Italian group IAC 4, IAC 6, Netuno and Bari; as well as the cultivars of the Santa Cruz group IAC 1, IAC 5, HTV 0601 and Débora Victory reached the best scores in all the sensorial traits evaluated. All the cultivars presented reasonable quality of the fruits, with SS/TA ratio values higher than 16 and SS values higher than 4°Brix.

Keywords: *Solanum lycopersicum*, organic production system, organoleptic traits, physico-chemical characteristics.

RESUMO

Parâmetros físico-químicos e sensoriais de cultivares de tomate cultivados em sistema orgânico

Os objetivos do trabalho foram caracterizar física, química e sensorialmente os frutos de tomate de cultivares híbridas e de polinização aberta, dentro dos grupos Santa Cruz e Italiano, visando o consumo *in natura*. Utilizaram-se 14 cultivares de tomate de mesa, sendo seis experimentais e oito comerciais. O delineamento experimental foi de blocos casualizados com seis repetições e cinco plantas úteis por parcela. Para as análises físico-químicas, as amostras dos frutos vermelhos maduros foram retiradas aleatoriamente de cinco plantas de cada parcela, etiquetadas e mantidas sob refrigeração a 5°C até o dia seguinte à colheita. Em seguida, os frutos de cada cultivar foram misturados, triturados e divididos em triplicatas para as análises físico-químicas. Verificou-se que o valor da relação sólidos solúveis (SS)/acidez titulável (AT) foi maior nas cultivares IAC 6 e IAC 3. Com relação ao teor de SS, os maiores valores foram obtidos pelas cultivares IAC 1 e IAC 6. Para constatar a aceitação pública das cultivares, foi realizada uma análise sensorial dos frutos com 75 provadores, utilizando-se uma escala hedônica de sete pontos. Os dados foram submetidos à análise de variância e agrupamento de médias. As cultivares do grupo Italiano IAC 4, IAC 6, Netuno e Bari; bem como as cultivares do grupo Santa Cruz: IAC 1, IAC 5, HTV 0601 e Débora Victory obtiveram as melhores notas em todos os atributos sensoriais avaliados. Todas as cultivares apresentaram frutos de qualidade, com valores da relação SS/AT maiores que 16 e teor de SS maior que 4°Brix.

Palavras-chave: *Solanum lycopersicum*, agricultura orgânica, análise sensorial, características físico-químicas.

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The tomato, *Solanum lycopersicum*, is one of the most important crops in the country, entering Brazil among the ten main producers worldwide. In 2011, the world production of tomato, both fresh market and industry, reached 159 million tonnes in a cultivated area of 4.73 million hectares and average yield of 33.6 tonnes/hectare (FAO, 2013).

The area under organic management worldwide reached 37 million hectares in 2010, considering that from 2004 to 2010, the area of organic vegetables grew 34% (Willer & Kilcher, 2012). Thus, prospects for crop growth are promising, considering the market potential of organic tomatoes.

In organic system or conventional

production system, the quality of the tomato for fresh market is determined by appearance, firmness and flavor; whereas the quality of the processing tomato is determined mainly by soluble solids, color, pH and firmness (Clemente & Boiteux, 2012).

The color is the most attractive quality trait which is related to the

appearance, sugar content, acidity, pH, texture, flavor and juiciness (Ferreira *et al.*, 2010).

Several studies have compared qualitative parameters, especially in fruits and vegetables grown in organic and conventional production systems. However, no conclusive evidence on the nutritional or qualitative superiority of either system was noticed (Pieper & Barret, 2009). Other variables influence the nutritional quality of the organic product. For example, the type of fertilizer used in fertilization influences the concentration of antioxidant components, increasing the amount of total phenolics and ascorbic acid, in tomatoes grown with organic fertilization (Toor *et al.*, 2006).

Tomatoes grown under organic management showed levels of titratable acidity (29%), vitamin C (55%) and soluble solids (57%) higher in ripe fruits compared to the tomatoes grown under conventional system (Oliveira *et al.*, 2013).

Under conventional system the plant receives the necessary resources, such as fertilizers, readily available for its development, whereas under the organic system of production, a greater difficulty in the availability of nutrients is observed, causing stress. Analyzing the lipid peroxidation, a greater stress under organic system comparing to the conventional system was observed (Oliveira *et al.*, 2013).

These observations suggest that tomato fruits under organic management underwent stress conditions, resulting in higher soluble solids and other components, contributing to the nutritional quality of the fruit (Oliveira *et al.*, 2013). Thus, given the assumption that evaluating different cultivars under the same production system, these cultivars can be discriminated, and that little scientific information on organic system is available, this work aimed to evaluate and compare the physico-chemical and sensory parameters of experimental and commercial fresh tomato cultivars under organic production system.

MATERIAL AND METHODS

The experiment was carried out in

Piracicaba, São Paulo state, Brasil (540 m altitude), from March to September 2010. The seedlings transplantation in the field took place on April 17 and the last harvest was held on September 18, 2010, in the area of an organic producer certified by Organização Internacional Agropecuária (OIA).

Of the 14 cultivars analyzed (IAC 1, IAC 2, IAC 3, IAC 4, IAC 5, IAC 6, Avalon, HTV 0601, Netuno, Débora Victory, Granadero, Pizzadoro, Bari and Santa Clara), six of them were experimental cultivars from the breeding program of Instituto Agrônômico (IAC), three of the Italian group (IAC 3, IAC 4, IAC 6) and three of Santa Cruz group (IAC 1, IAC 2 and IAC 5). Eight other cultivars were also used. Four of them of Italian group (Netuno, Granadero, Pizzadoro and Bari) and four of Santa Cruz group (Avalon, HTV 0601, Débora Victory and Santa Clara). With Exception of 'IAC 2', 'IAC 4' and 'Santa Clara', which are open-pollinated cultivars, all the other cultivars are hybrids.

The seedlings were grown in polystyrene trays with 128 cells, in aphid-proof screenhouse with plastic covering and substrate containing organic compost and vermiculite was used. The organic compost was produced on site with the use of poultry house litter and mowing grass. The transplant to the definitive site was done in the definitive four-to-five leaf stage.

The tillage consisted of harrowing followed by rotary hoe, taking into account the ideal point of moisture for tillage. Soil correction and planting fertilization and top dressing were performed according to the soil analysis and the recommendations for tomato crop, distributed based on the stage of development, according to Alvarenga (2004), following the recommendation for organic agriculture. The trickle irrigation system was used and black plastic film "mulching" was used in the lines in order to prevent weed growth.

The experiment was carried out using individual staking system of the plants with ribbon, in one stem. The phytosanitary control of the plants was performed with registered products for the crop whenever it was necessary, all

of them allowed by Brazilian legislation for organic agriculture.

The fruits were harvested at red-ripe stage and stored under refrigeration at 5°C until the following day, at the time of analysis. For the analyzes, fruits were ground, homogenized, packed in identified polystyrene packaging and conducted for the analyzes. Analyses of color, pH, soluble solids and titratable acidity were performed in triplicate for the 14 cultivars.

The coordinates L^* , a^* and b^* were measured using the colorimeter Minolta Chroma Meter CR-400, 8 mm in diameter and standard illuminant CIE C. The peel color was evaluated for intact tomatoes with four readings performed, being two in each of the opposite sides on the equatorial region of the fruits and for chopped tomatoes, with four readings, being two of each side, inside of the fruit, also on the equatorial region. The instrument was previously calibrated on white surface according to the International Commission on Illumination (CIE 1976 L^* , a^* , b^* - CIELAB) using CIE C standard illuminant. Based on the values of L^* , a^* and b^* , the Chroma value (C^*), which is the color saturation, was calculated and from the relation between a^* and b^* , the angle of color Hue (H^*), which indicates de color tone, was obtained.

The pH was determined in potentiometer Tecnal TEC3-MP, from liquid samples, according to method 981.12 of the Association of Official Analytical Chemists (AOAC, 2005). The soluble solids content was quantified in Auto Abbe refractometer, model 10500/10501 Leica, using homogenized pulp in a domestic crusher type "mixer". The results are expressed in "Brix", according to 932.12 (AOAC, 2005) method. The titratable acidity was determined and calculated by titrations from the volume in milliliters of 0.1 M NaOH and potentiometer to pH 8.1, according to method No. 942.15 of the (AOAC, 2005). The results were expressed in g of citric acid per g of pulp. The SS/TA (ratio) was also calculated.

Sensorial evaluation was performed for the 14 tomato cultivars. Seventy five tasters acted as volunteers for the test.

In order to perform the test, pieces of the fruit for each treatment were served at room temperature, in white plastic cups (50 mL capacity), with wooden toothpicks. The containers were coded with random three-digit numbers, and the samples submitted to tasters.

Each taster was asked to taste the samples from left to right and drink some mineral water, served along with the samples, in the beginning and among each taste, and show in a 7-point hedonic scale how much they liked or disliked each of the samples for flavor, color of the pericarp, internal color, texture and overall impression. With the 7-point hedonic scale ranging from 1 (disliked extremely), 2 (disliked very much), 3 (disliked), 4 (neither liked nor disliked), 5 (liked), 6 (liked very much) and 7 (liked extremely).

The experimental design was randomized blocks, with 14 treatments, being 8 commercial cultivars and six experimental cultivars from IAC, in 11 harvestings. The test was conducted under field conditions with six replications and ten plants per plot, five plants being evaluated (useful plants). The spacing used was of 1.20 m between lines and 0.35 m between plants in the row, forming experimental plot with total area of 4.20 m², with 840

total plants, 420 being useful plants. The stand was of 23,809 plants ha⁻¹.

The data for physico-chemical analyzes were subjected to the analysis of variance, considering the randomized block design. The experimental design in incomplete blocks was used for sensorial analysis, using spreadsheet 11.25 according to Cochran & Cox (1957), aiming to eliminate possible error of untrained taster. Each randomized block consisted of 15 tasters and it was repeated five times in order to obtain the required number of responses for each treatment. Each taster received four samples (treatments). For the experimental design 15 treatments were necessary, thus one of the cultivars was repeated in the 15th treatment, whose data were excluded from the statistical evaluation.

For statistical evaluation of both analyzes, the averages of the 14 cultivars were grouped by Scott-Knott test at 5% significance, using the Statistical Analysis System (SAS Institute, 2009).

RESULTS AND DISCUSSION

A significant effect among the cultivars, for variables pH, soluble

solids (SS), titratable acidity (TA), ratio (SS/TA) and chromaticity, was noticed. The cultivars Netuno, Debora Victory and IAC 5 showed the lowest values for pH, 4.20, 4.18 and 4.17, respectively. Cultivars IAC 3, IAC 6 and IAC 4 showed the highest values for pH, 4.41, 4.38 and 4.36, respectively, followed by cultivars IAC 2 and IAC 1, with pH 4.30 and 4.29, respectively (Table 1).

The average pH values were lower than the values found in a research on cultivars San Marzano, Chico Grande, Amish Paste and EUA 05, also in organic system, with values ranging from 4.5 to 4.6 (Rosa *et al.*, 2011). However, cultivars Avalon, Debora Max and Netuno showed very similar pH values found by Shirahige *et al.* (2010), where the values ranged from 4.1 to 4.2.

Despite the soluble solids content (SS) of the fruit can be attributed to intrinsic aspects of each genotype, it is highly influenced by fertilization, temperature, irrigation and climate conditions (Silva & Giordano, 2000). And it is one of the main fruit parameters for the evaluation of the flavor, thus it is in this fraction where acids and sugar can be found. The evaluated cultivars showed, in general, high SS contents, considering that IAC 1 and IAC 6 showed higher value, 6°Brix, followed

Table 1. pH, soluble solids (SS), titratable acidity (TA), correlation between SS/TA, L*, Hue and Croma for tomatoes cultivars [pH, sólidos solúveis (SS), acidez titulável (AT), relação SS/AT, L*, Hue e Croma para cultivares de tomates]. Piracicaba, ESALQ, 2010.

Cultivar	pH	SS (°Brix)	AT (%)	SS/AT	L*	Hue (degree)	Croma
IAC 1	4.29 b	6.00 a	0.27 b	22.30 c	49.90 a	38.71 a	34.40 a
IAC 2	4.30 b	5.00 c	0.22 c	22.75 c	51.38 a	21.51 a	24.36 b
IAC 3	4.41 a	4.97 c	0.19 e	26.21 b	48.90 a	31.84 a	28.93 b
IAC 4	4.36 a	5.03 c	0.21 d	23.26 c	56.90 a	23.62 a	34.70 a
IAC 5	4.17 d	5.00 c	0.30 a	16.78 e	51.59 a	39.05 a	28.51 b
IAC 6	4.38 a	6.00 a	0.21 d	27.84 a	46.50 a	36.87 a	28.27 b
Avalon	4.21 c	5.17 b	0.30 a	17.02 e	42.72 a	38.99 a	32.11 a
HTV 0601	4.23 c	4.00 d	0.23 c	17.21 e	49.32 a	38.37 a	29.67 a
Netuno	4.20 d	5.00 c	0.26 b	19.47 d	48.20 a	24.83 a	21.22 b
Granadero	4.23 c	5.00 c	0.23 c	21.52 c	48.50 a	39.01 a	25.72 b
Debora Victory	4.18 d	5.00 c	0.22 c	22.65 c	46.56 a	40.63 a	32.19 a
Pizzadoro	4.17 d	5.00 c	0.28 b	18.21 e	50.06 a	24.29 a	24.09 b
Bari	4.23 c	5.00 c	0.23 c	21.86 c	53.02 a	34.74 a	27.12 b
Santa Clara	4.25 c	5.00 c	0.22 c	22.58 c	49.47 a	35.33 a	26.99 b
CV (%)	0.77	0.74	4.17	3.45	18.75	44.50	18.18

*Means followed by the same letter in the column allow to the same group by the Scott-Knott test ($p > 0.05$) [*médias seguidas pela mesma letra na coluna pertencem ao mesmo grupo pelo Teste de Scott-Knott ($p > 0,05$)].

Table 2. Sensory attributes of organic tomatoes (atributos sensoriais de tomates orgânicos). Piracicaba, ESALQ, 2010.

Cultivar	Taste ¹	Pericarp color ¹	Internal color ¹	Texture ¹	Global aspect ¹
IAC 1	5.35 a	5.85 a	6.05 a	5.50 a	5.11 a
IAC 2	4.75 b	4.30 b	4.60 b	4.95 b	4.63 b
IAC 3	4.85 b	5.90 a	5.63 a	4.90 b	5.25 a
IAC 4	5.10 a	5.60 a	5.35 a	5.70 a	5.31 a
IAC 5	5.65 a	6.05 a	5.95 a	5.50 a	5.75 a
IAC 6	5.25 a	5.90 a	5.60 a	5.79 a	5.65 a
Avalon	4.00 b	3.40 c	3.94 b	4.40 b	3.85 c
HTV 0601	6.00 a	6.05 a	5.95 a	6.00 a	6.05 a
Netuno	5.84 a	6.00 a	5.61 a	5.84 a	5.83 a
Granadero	4.70 b	5.45 a	5.00 b	5.25 a	5.10 a
Debora Victory	5.15 a	6.25 a	6.05 a	5.60 a	5.63 a
Pizzadoro	3.95 b	4.55 b	4.75 b	4.40 b	4.00 c
Bari	5.65 a	5.35 a	5.60 a	5.50 a	5.45 a
Santa Clara	4.65 b	5.80 a	6.05 a	4.70 b	4.84 b
CV (%)	29.40	26.83	25.64	26.80	26.00

¹Notes varying from 1 (disliked extremely) to 7 (liked extremely); *Means followed by the same letter in the column allow to the same group by the Scott-Knott test ($p > 0.05$) [*médias seguidas pela mesma letra na coluna pertencem ao mesmo grupo pelo Teste de Scott-Knott ($p > 0,05$)].

by Avalon, 5.17°Brix (Table 1). The other varieties showed values close to 5°Brix, except HTV 0601, whose value was 4°Brix. The values found for SS content were very close to the value of 4.9°Brix for cultivar Debora under organic system, found by Borguini & Silva (2005). As well as, the value of 4.7°Brix found for cultivar Santa Clara, conducted under organic management (Ferreira, 2004) and the average value of 5.2°Brix for cultivars Chico Grande and San Marzano (Rosa *et al.*, 2011). Shirahige *et al.* (2010) also found high values for SS content of 5°Brix for Avalon and Debora Max and 4.4°Brix for Netuno.

The acidity increased in the early stage of maturation (green, painting and ripe), declining shortly thereafter, whereas the sugar, mainly fructose and glucose, progressively increase with fruit ripening (Ferreira, 2004). In the present work, the values of titratable acidity (TA) ranged from 0.19 to 0.30%. The cultivars IAC 5 and Avalon, both of Santa Cruz group, obtained higher value, 0.3%, followed by Pizzadoro, IAC 1 and Netuno, 0.28, 0.27 and 0.26%, respectively (Table 1). Rosa *et*

al. (2011) obtained average values of TA ranging from 0.22% (IAC 2 and Debora Victory) to 0.30% (IAC 5 and Avalon) for cultivars of Santa Cruz varietal group and from 0.19% (IAC 3) to 0.28% (Pizzadoro) for cultivars of Italian group. Shirahige *et al.* (2010) obtained average values of TA which ranged from 0.41% (THX-02) to 0.34% (THX-01), both cultivars of Santa Cruz group, and average values which ranged from 0.36% (THX-04) to 0.28% (Netuno) for cultivars of Italian group. Ferreira (2004) also found in his work the value of 0.3% for TA for cultivar Santa Clara, conducted under organic management. Also, Monteiro *et al.* (2008) evaluated fruits of Italian tomatoes and obtained TA of 0.39% for fruits with seeds and pericarp.

The importance of these parameters lies in the fact that the combination of SS and TA promotes the characteristic flavor of the tomato. The higher the value of SS/TA, the smoother the flavor of the fruit, due to the optimal combination of sugar and acid; whereas lower values are correlated with acid, that means worse flavor (Ferreira, 2004). The SS/TA ratio was highest for the

cultivar IAC 6, Italian group, value of 27.84, followed by the cultivar IAC 3, value of 26.21 (Table 1).

Cultivar Santa Clara showed the value between soluble solids (SS)/titratable acidity (TA) of 22.58, higher than the value found by Ferreira (2004), 18.28, also under organic management. The average values of SS/TA ratio found were high and, in most cultivars, exceeded values found by Rosa *et al.* (2011) 12.7, 19.2, 15.5 and 15.7 in San Marzano, Chico Grande, Amish Paste and EUA 05, respectively.

The fruit color is one of the main parameters to characterize the quality by consumers. Hue angle (°Hue) indicates the basic color of the samples and represents the average color of the tomato samples. In this research, no statistical difference in relation to shades of red for cultivars was noticed, for Hue and L values (Table 1).

The parameter chromaticity (chroma) represents the color intensity or saturation. Thus, the higher the chroma, more saturated and more intense the color (Borguini & Silva, 2005). The cultivars IAC 4, IAC 1, Debora Victory, Avalon and HTV 0601 showed more intense color (Table 1). These data corroborate Borguini & Silva (2005), who found the value of 36.6 for chroma in cultivar Debora under organic system.

Regarding the evaluation of data on sensorial evaluation, a significant effect of cultivars for all traits was noticed.

In sensorial analysis, in relation to flavor parameter, the cultivars HTV 0601, Netuno, IAC 5, Bari, IAC 1, IAC 6, Debora Victory and IAC 4 differed statistically from the others and they were the most accepted (Table 2). In the pericarp color trait, the cultivars which were better classified were IAC 1, IAC 3, IAC 4, IAC 5, IAC 6, HTV 0601, Netuno, Granadero, Debora Victory and Bari. These same cultivars except Granadero, obtained the highest scores for the internal color (Table 2).

Events that occur during the ripening (ethylene biosynthesis, modifications in the cell wall) also control texture features, which are important both for the organoleptic quality and also for the quality of the processing tomato

(Causse *et al.*, 2007). The texture trait showed the highest scores for cultivars IAC 1, IAC 4, IAC 5, IAC 6, HTV 0601, Netuno, Granadero, Debora Victory and Bari (Table 2). According to Chitarra & Chitarra (1990), a strong correlation between firmness and the content of pectic substances in fruits and vegetables can be noticed. The pectic substances are the key members of the tissues, which cause changes in the texture of fruits and vegetables. Thus, as the fruits ripen, degradation of pectic substances occurs, causing the softening of the pulp.

With respect to the overall impression, the cultivars with better classification were IAC 1, IAC 3, IAC 4, IAC 5, IAC 6, HTV 0601, Netuno, Granadero, Débora Victory and Bari (Table 2).

The cultivars of Italian group IAC 4, IAC 6, Netuno and Bari, as well as the cultivars of Santa Cruz group IAC 1, IAC 5, HTV 0601 and Debora Victory, obtained the best scores in all sensorial traits evaluated (Table 2).

Borguini & Silva (2005) evaluated fruits of the hybrids Carmen and Debora, from organic and conventional production systems. No statistical difference between data for flavor and color traits was found. However, with respect to terms of flavor, samples of conventional Carmem and Debora obtained higher score than the organic samples. The general appearance trait for Debora showed no significant difference, however, Carmem from organic system, showed higher score than the sample from the conventional management.

In the conditions in which this work was performed and based on the results obtained, the authors concluded that the value of SS/TA ratio was higher in the

cultivars IAC 6 and IAC 3. In relation to the SS content, the highest values were obtained by the cultivars IAC 1 and IAC 6. The cultivars of the Italian group IAC 4, IAC 6, Netuno and Bari; as well as the cultivars of Santa Cruz group IAC 1, IAC 5, HTV 0601 and Debora Victory obtained the best scores in all sensorial traits evaluated. All the cultivars presented reasonable quality of the fruits, with SS/TA ratio values higher than 16 and SS content higher than 4°Brix.

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