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Post-harvest quality and sensory acceptance of Italian tomatoes grown under organic, integrated and conventional management

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ABSTRACT

Some studies comparing the quality of tomatoes under organic and conventional management can be found in literature; they are still inconclusive and many of them do not address integrated management, though. The aim of this study was to evaluate physical, biochemical and sensory traits of Italian tomatoes under organic, conventional and Hightech integrated managements. Physical (firmness, length, width, mesocarp thickness, mass and volume) and biochemical traits (titratable acidity, sugar content, soluble solids content, vitamin C content, lycopene content, beta-carotene content and antioxidant capacity) were evaluated, besides the sensory attributes as appearance, aroma, flavor and texture evaluated by 105 consumers. The organic fruits showed greater width, fresh mass and pericarp thickness, glucose and vitamin C. The fruits grown under integrated management stood out for higher levels of beta-carotene, whereas the fruits grown under conventional management showed greater acidity and higher lycopene content, as well as less firmness. No difference in relation to the acceptance of tomatoes under the different managements used was noticed, although most consumers preferred organic tomatoes, which were the largest and sweetest. No difference in relation to the acceptance of tomatoes produced under different managements was noticed, despite the discrimination in physical and biochemical traits. Hence, the managements affected only the physical and biochemical traits of Italian tomatoes.

Keywords: *Solanum lycopersicum*, production management, post-harvest, consumer test.

RESUMO

Qualidade pós-colheita e aceitação sensorial de tomates italianos produzidos sob manejos orgânico, integrado e convencional

Há estudos que comparam a qualidade do tomate em manejo orgânico e convencional, mas ainda são inconclusivos e muitos deles não abordam o manejo integrado. Objetivou-se avaliar as características físicas, bioquímicas e sensoriais dos tomates italianos produzidos em manejos orgânico e convencional e no manejo integrado *Hightech*. Foram avaliadas características físicas (firmeza, comprimento, largura, espessura do mesocarpo, massa fresca e volume), bioquímicas (acidez titulável, teores de açúcares, de sólidos solúveis, de vitamina C, de licopeno, de betacaroteno e capacidade antioxidante) e a análise sensorial dos frutos, baseada na aparência, aroma, sabor e textura, avaliados por 105 consumidores. Os frutos orgânicos apresentaram maior largura, massa fresca e espessura do pericarpo, glicose e vitamina C. Os frutos do manejo integrado destacaram-se por níveis mais elevados de betacaroteno, enquanto os frutos do manejo convencional apresentaram maior acidez e maior teor de licopeno, bem como menor firmeza. Não houve diferença na aceitação do tomate nos diferentes manejos, embora a maioria dos consumidores preferiram os tomates orgânicos, que eram os maiores e os mais doces. Não houve diferença na aceitação dos tomates produzidos em diferentes manejos, apesar da discriminação em características físicas e bioquímicas. O manejo afetou as características físicas e bioquímicas dos tomates italianos.

Palavras-chave: *Solanum lycopersicum*, manejo de produção, horticultura, pós-colheita, teste com consumidores.

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Tomato is one of the most consumed vegetables worldwide, with an annual production of just about 182.3 million tons in an area of approximately 4.8 million hectares. Its production totaled 64.7 million dollars (FAO, 2020). Brazil is the third largest tomato producer in the American Continent and the tenth in worldwide ranking, with production of 4.1 million tons in 57.1 thousand hectares (FAO, 2020). Family farmers are responsible for most of the production in the country, making it an important income source for small producers (Neto *et al.*, 2018).

The Brazilian tomato culture mostly employs conventional production management, in which synthetic phytosanitary products and soluble fertilizers can be used (Silva *et al.*, 2011). However, family farmers tend to prefer organic management, as it includes environmentally sustainable practices, since consumers are getting more and more interested in pesticide-free vegetables. Organic management is characterized by the use of biofertilizers like tanned manure and pesticides which are alternative to synthetic products such as Bordeaux mixture, natural oils and extracts, use of insect traps and strategies for the biological control of diseases and pests (Muñoz *et al.*, 2016).

In Brazil, many tomato growers adopt cultural practices aiming to reduce the use of synthetic crop protection products, searching for a more sustainable agricultural practice and production cost reduction, using soluble fertilizers for nutritional supplementation via fertigation. This management uses conservation practices and good agricultural practices, for an efficient use of the soil and an appropriate environmental management of pests and diseases (Fadini & Antonio, 2004). One of the models for this management is called Hightech, which uses high technology for an automatic control of the greenhouse, rationally applying fertilizers, regulated by light intensity temperature and humidity, using grafted seedlings and biological pesticides, which guarantee the ideal conditions for the development of the crop in a protected environment.

Some studies can be found in literature comparing the quality of cherry, Santa Cruz and long shelf-life tomatoes grown under organic and conventional managements (Borguini & Silva, 2009; Hallmann, 2012; Vieira *et al.*, 2014). Most of them are inconclusive to report which management enables fruits with better quality, though. Moreover, studies which subjected tomatoes to sensory evaluation using a consumer taste panel, which represents the last link in the vegetable marketing chain, are rare.

Many studies on tomato physicochemical quality in relation to the type of management adopted are controversial. For instance, Chassy *et al.* (2006) observed higher soluble solid content in tomatoes under organic management, whereas Borguini & Silva (2009) verified higher soluble solid content in cultivar Sweet Grape tomatoes grown under conventional management. Furthermore, Juroszek *et al.* (2009) did not verify any difference between soluble solid content in fruits grown under these two production managements. However, considering that tomato is a very popular food in Brazilian cuisine, as well as, in the worldwide cuisine, it is essential to verify the consumer's preference and attest to what level agricultural management affects the quality of the fruit, evaluating its physical, biochemical and sensory attributes (Stone *et al.*, 2012). Borguini & Silva (2009) reported consumer's preference for the flavor of the tomato cultivars Carmen and Débora produced in conventional management, whereas Rodríguez *et al.* (2001) verified no difference in relation to consumer's acceptability for aroma and flavor among field-grown tomatoes, under non-certified organic, conventional and integrated managements, characterized by the minimum use of chemical products.

Considering the above, this study aimed to evaluate physical and biochemical traits, related to consumer's acceptance and preference.

MATERIAL AND METHODS

Tomato seedlings of cultivar Grazianni® were grown on substrate Carolina Soil® by Hidroceres. The seedlings were grafted onto the cultivar Emperador® RZ-F1 (RijkZwaan), which presents high resistance to ToMV Tomato mosaic vírus (ToMV), TSWV (Tomato Spotted Wilt Virus); Ff (*Fulvia fulvum*); Fol (Fusarium wilt, *Fusarium oxysporum f.* sp. *lycopersici*); Va (*Verticilliun Albo-artrum*); Vd (*Verticillium dahliae*). The seedlings were transplanted 28 days after sowing, in areas of commercial production under protected environment.

The experimental design used was randomized block, with three treatments and six replicates; the treatments were the three production managements: organic, integrated and conventional. The plants grown under organic management were cultivated in two certificated properties, one located in Uraí-PR (23º12'5"S, 50º47'43"W, 436 m altitude, humid subtropical climate) and the other one in São Jerônimo da Serra-PR (23°42'53"S, 50°43'46"W, 938 m altitude, humid subtropical climate).

The harvested fruits were mixed to make one sample. The tomatoes grown under the conventional management were grown in a property in Uraí-PR. The tomato production under Hightech integrated management was carried out on Flor do Café farm, located in Londrina-PR (23°17'34"S, 51°10'24''W, 55 altitude, humid subtropical climate), using pots with commercial substrate Carolina Soil®.

The fruits were harvested at breaker stage/phase (fruits showing yellow-reddish color up to 20% of the surface) and, then, stored in paper bags at 25ºC to standardize maturation up to stage 6 (totally red fruits).

Phytometric analysis

Length, width and fruit mesocarp thickness were measured with the aid of a digital caliper (EC799, Starrett®), expressed in mm. The fresh mass was expressed in g, determined using a bench-top semi-analytical balance. To determine the volume, the fruits were immersed in graduated cylinder with a capacity of 2000±20 mL, with distilled water, in order to calculate the density, mass and volume ratio, expressed in g cm^{-3}.

Firmness

Five fruits were evaluated and firmness was determined in newtons (N), using compression and puncture tests with a bench-top texturometer (Model TA.XT Plus, Stable Micro System, the United Kingdom). For the compression tests, a flat aluminum probe 35 mm diameter, with 0.5 mm s^{-1} speed was used, until deforming the fruit surface 2 mm (Arazuri *et al.*, 2007).

Titratable acidity

Titratable acidity was quantified by titration with a standardized 0.1N NaOH solution up to pH 8.2, according to method No. 942.15 of AOAC (1997), the results were expressed in grams of citric acid equivalent/100 g sample.

Sucrose, fructose and glucose contents

The extract for sugar quantification was adapted from Constantino *et al.* (2020) method, using 1.0 g of the sample suspension in 10.0 mL distilled water, shaken for two hours (Orbital-Nova

Orgânica) at room temperature. The suspension was centrifugated at 1013xg (Excelsa 2 Fanem model 205N) for five minutes and the supernatant filtered using 0.45 µm pore size cellulose acetate membrane filter (Millipore®).

The sugars were separated using DIONEX AS-AP chromatographic system (Thermo Scientific) Dionex™ CarboPac™ PA10 4250 mm and electrochemical detector (ICS-5000). The mobile phase consisted of NaOH (20 mmol L^{-1}) from 0 to 52 minutes for separation, NaOH (200 mmol L^{-1}) from 52 to 63 minutes for column regeneration, and NaOH (20 mmol L^{-1}) from 63 to 80 minutes to return to working condition. The injected sample volume was 10 µL and flow rate kept at 1.0 mL min^{-1}. To quantify, we used the external standardization: sucrose, fructose and glucose (Sigma Aldrich, purity >99%) and the results were expressed in g 100 g^{-1} or % (m/m).

Soluble solid contents

The juice of five fruits was extracted and soluble solid content was determined using direct reading with the aid of Atago digital bench-top refractometer, model RX-5000α-Plus, with automatic temperature adjustment to 25°C, and the results expressed in °Brix.

Ascorbic acid content (Vitamin C)

Vitamin C content was quantified using AOAC standard method (1984) modified by Benassi & Antunes (1988), using 10.0 g of the sample and 40 mL of oxalic acid (Synth) at 2% (m/v). After extraction, the suspensions were filtered and the supernatant titrated with 2.6-dichlorophenol-indophenol solution. The method was applied using five replicates and the results expressed in mg of ascorbic acid 100 g^{-1}.

Lycopene and beta-carotene content

Beta-carotene and lycopene extractions adapted from Adalid *et al.* (2010). were prepared with 0.5 mg of a macerated fruit sample with 5.0 mL ethanol and hexane solution (3:2, v/v). Lycopene was quantified according to Rodriguez-Amaya (2001) and Rodriguez-Amaya & Kimura (2004); hexane fraction was read with the aid of a spectrophotometer (Genesys 10, Thermo) at 450 nm for beta-carotene and at 470 nm for lycopene, expressed in mg kg^{-1}.

Antioxidant capacity by DPPH assay

To determine antioxidant activity using 2.2-diphenyl-1-picryl-hydrazyl radical scavenging (DPPH•), 50.0 µL of 70% (v/v) ethanol extract were mixed with 1.0 mL of 100 mM acetate buffer (pH 5.5), 1.0 mL ethanol and 0.5 mL of 250.0 µM DPPH ethanolic solution. The tubes were kept at room temperature for 15 min in the dark and the absorbance of the remaining DPPH• radical was measured using a spectrophotometer (Thermo-Genesys) 517 nm wavelengths. Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) was adopted as standard for quantification and the results expressed in µmol of trolox equivalent antioxidant capacity (TEAC) 100 g^{-1} (Brand-Williams *et al.*, 1995).

Antioxidant capacity determined by FRAP assay

FRAP assay (ferric reducing antioxidant power) was adapted by Benzie & Strain (1999), using 50.0 µL ethanol extract and 2.5 mL of FRAP reagent. The results were expressed in µmol of antioxidant capacity equivalent to trolox 100 g^{-1}.

Acceptance and sensory preference of fruits

The acceptance test was carried out in the Laboratório de Análise Sensorial do Departamento de Ciência e Tecnologia de Alimentos at Universidade Estadual de Londrina (UEL) and in the Laboratório de Gastronomia do Centro Universitário Filadélfia (UNIFIL), applied in only one section with 105 panelists: consumers and gastronomy professionals.

For the sensory analysis, the tomatoes of each treatment were cut into 4.0-cm-thick pieces, discarding the fruit ends. The samples were coded with three random digits and served on disposable plates, along with a paper napkin and a glass with drinking water.

For the acceptance test, samples were served one at a time with an individual form to assess size, shape, color, aroma, flavor, texture and global acceptance, using the 10 cm hybrid hedonic scale anchored in the center and ends, proposed by Villanueva *et al.* (2005). For the ranking preference test, the samples were served simultaneously and the panelists ranked them in ascending order according to preference, indicating the most and least appreciated attributes, in addition to a structured questionnaire to assess the panelist's profile. For purchase intent of the samples, a 5-point scale was used (5 = would certainly buy up to 1 = certainly would not buy). The design adopted was a randomized complete block in which the samples were the treatments and the panelists were the blocks.

Statistical analysis

Data showed normality and homogeneity, tested by Shapiro-Wilk and Barlett tests, respectively. Data were submitted to F test (P>0.05) through variance analysis and the averages compared by Tukey test (P<0.05). Additionally, for grouping analysis, we used Euclidean distance and Ward's method applied to the standardized averages, and viewed in the heat map, to verify the groups formed among the samples. R software was used to perform the statistics analysis, using packages *ExpDes.pt* (Ferreira *et al.*, 2018) and *pheatmap* (Kolder, 2018).

RESULTS AND DISCUSSION

Using the variance analysis, we observed a significant effect for most physical and biochemical traits of the fruits, except for length and density, antioxidant activity, soluble solid content and ratio. The fruits produced under organic management showed higher values of width (55.62 mm) and pericarp thickness (9.22 mm), whereas for fresh mass, the value was statistically the same compared with the integrated management and, both were superior comparing with the conventional fruits (Table 1). The highest values of these attributes verified in organic fruits can be explained considering richness of organic substances and greater water retention capacity in soils cultivated under organic management (Stertz *et al.*, 2005).

Stertz *et al.* (2005) observed that the organic fruits showed greater diameter,

Table 1. Physical and biochemical traits of Italian tomatoes grown under organic, conventional and integrated managements. Londrina, UEL, 2019.

Traits	Management systems			CV (%)
	Organic	Integrated	Conventional	
Physical				
Length (mm)	81.82^{ns}	76.60^{ns}	76.57^{ns}	5.15
Width (mm)	55.62 a	51.50 b	51.15 b	4.39
Fresh mass (g)	141.48 a	110.30 ab	93.10 b	17.99
Density (g cm^{-3})	1.16^{ns}	1.05^{ns}	1.00^{ns}	18.75
Pericarp thickness (mm)	9.22 a	7.46 b	6.00c	4.68
Biochemical				
Lycopene (µg 100 g^{-1})	6.34 a	5.43 b	6.56 a	5.40
Beta carotene (µg 100 g^{-1})	2.86 c	8.38 a	4.39 b	10.08
FRAP	94.16^{ns}	86.06^{ns}	91.57^{ns}	12.21
DPPH	842.74^{ns}	835.22^{ns}	845.09^{ns}	1.82
SST (°Brix)	2.96^{ns}	2.86^{ns}	2.88^{ns}	2.67
ATT (% citric acid)	0.26 b	0.22 b	1.22 a	7.50
Ratio	11.64^{ns}	12.96^{ns}	13.56^{ns}	7.98
Vitamin C (mg 100 g^{-1})	19.40 a	12.33 b	11.96 b	9.08
Glucose (g 100 g^{-1})	1.85 a	0.06 b	0.06 b	5.01
Fructose (g 100 g^{-1})	1.92 a	1.85 a	1.55 b	8.11

Means followed by the same letter in the column did not differ significantly from each other by Tukey test ($p<0.05$); Antioxidant activity by FRAP assay (µmol 100 g^{-1}); antioxidant activity by DPPH assay (µmol 100 g^{-1}); SST= total soluble solids; ATT= titratable acidity; Ratio= SST/ATT.

fresh mass and density, comparing with the conventional management. Vieira *et al.* (2014), comparing the post-harvest quality of minitomatoes cultivar Sweet Grape, produced under conventional and organic management, verified greater fresh mass in conventional fruits, showing the same diameter and length, though. Riahi *et al.* (2009) did not observe any difference for fresh mass of the fruits of different tomato cultivars produced under two managements in Tunisia, the production yield was greater under conventional management, though.

The highest beta carotene concentrations were verified in fruits under integrated management, whereas the lowest lycopene concentrations were also verified in these fruits (Table 1). According to Dumas *et al.* (2002), light intensity favors carotenoid production, mainly lycopene, which corroborates the results of this study, in which lycopene content was greater in fruits under conventional and organic managements, considering that the solar irradiation in these managements was more intense when comparing to the integrated management. Tomatoes showing higher lycopene content are desirable, as this carotenoid is an antioxidant compound known to prevent many types of cancer; it represents approximately 90% of this content in tomatoes, which contributes for the functional characteristic of the fruit (Navarro-González & Periago, 2016).

Antioxidant activity both by FRAP method and DPPH did not present any statistical difference among the treatments (Table 1), even having different contents for bioactive compounds like vitamin C, lycopene and beta carotene. Juroszek *et al.* (2009) did not verify any difference for antioxidant activity between fruits produced under organic and conventional managements either. On the other hand, Mergawi & Al-Redhaiman (2010) and Pascale *et al.* (2016) verified superior antioxidant activity in organic fruits comparing with the conventional ones.

The organic tomatoes showed higher average levels of vitamin C (19.40 mg 100 g^{-1}), whereas the conventional fruits showed lower average (12.96 mg 100 g^{-1}), not differing from the integrated management which showed an average of 11.96 mg 100 g^{-1}. According to Pék *et al.* (2010), a great sunlight incidence may result in fruits containing higher concentrations of vitamin C, which can justify the lowest contents of this attribute in fruits grown under integrated managements, considering that the solar incidence is smaller in this management using high tech. Hallmann (2012) also verified higher vitamin C concentration in organic tomatoes than in tomatoes under conventional management, in two years of cultivation, and highlighted that the concentration of this compost can be influenced by the type of nitrogen used. This can also justify the highest content of this vitamin in organic fruits in relation to the other fruits evaluated in this study, since the nitrogen used in organic management shows slow release, compared to the conventional and integrated managements.

In conventional fertilization, nitrogen is available in large quantities for the plant, resulting in an increase in protein synthesis and decrease in carbohydrate synthesis. However, nitrogen availability in organic fertilizers is limited for the plant, as its release is slow, resulting in an increased carbohydrate metabolism. This fact can contribute to a greater production of vitamin C, since this vitamin is metabolized from carbohydrates (Worthington, 2001), which corroborates a higher vitamin C concentration in organic fruits as verified in this study.

Soluble solid contents did not differ among the managements and presented 2.9°Brix average value (Table 1), similar value to the one verified by Ferreira *et al.* (2010) who suggested that the type of management does not interfere in this attribute. However, the results found by Chassy *et al.* (2006) are different. These results showed that organic fruits present higher contents of soluble solids compared to fruits under conventional management. According to Kader *et al.* (1978), tomatoes which show soluble solids and acidity ratio higher than 10 are considered of good flavor, and in this study the values ranged from 11.64 to

13.56. The authors concluded that the tomatoes under the three production managements showed desirable balance between sugars and acids.

Glucose concentration was 96.8% higher in organic fruits comparing with the others, whereas the highest fructose concentrations were verified in fruits under organic and integrated managements (Table 2). According to Leiva-Brondo *et al.* (2015), organic tomatoes have contents of glicose and fructose 7.7 and 10.4% higher than in conventional-grown tomatoes. However, Gilsenan *et al.* (2012) observed higher concentrations of glicose and fructose in tomatoes under conventional management, and justify that the high salt availability in conventional fertilization stresses out the plant, stimulating the sugar production.

The grouping analysis using the heat map (Figure 1) showed higher similarity between the integrated and conventional managements, as the tomatoes grown under these managements present similar fresh mass, pericarp thickness, density, width and vitamin C content. The fertilization may be the principal responsible factor, considering that soluble fertilizers were used in these two managements.

Firmness is a very important trait, considering the shelf-life trait of the product, as well as for marketing chain to the final destination. Some differences were verified considering the fruit firmness in the puncture test (Figure 2A). The fruits which were grown under integrated management showed greater firmness, requiring a force of 0.118 N for exocarp rupture and greater force for mesocarp and endocarp perforation. Firmness of organic tomatoes was intermediate, requiring a force of 0.088 N for exocarp rupture. The conventional-management fruits required a force of 0.062 N for exocarp rupture, as well as longer time to penetrate the mesocarp, which suggests a more flexible shell.

In compression test (Figure 2B), the organic tomatoes showed superior firmness, 7.09 N for 2 mm fruit surface deformation. The tomatoes grown under integrated management were intermediate, 6.08 N for deformation, even though up to 1.5 seconds of compression, the force exerted was greater than in organic fruits. The conventional management resulted in less firm fruits, requiring 3.83 N to deform the fruit surface.

The puncture test can be associated with the canine biting, which ruptures the exocarp and penetrates the mesocarp. The compression test is related to the bite force with the molar teeth pressing the fruit into the bite; this test is associated with actions like squeezing the fruit by consumers (Lucas *et al.*, 2004; Mioche *et al.*, 2004). Fruit firmness responds negatively to an exaggerated increased

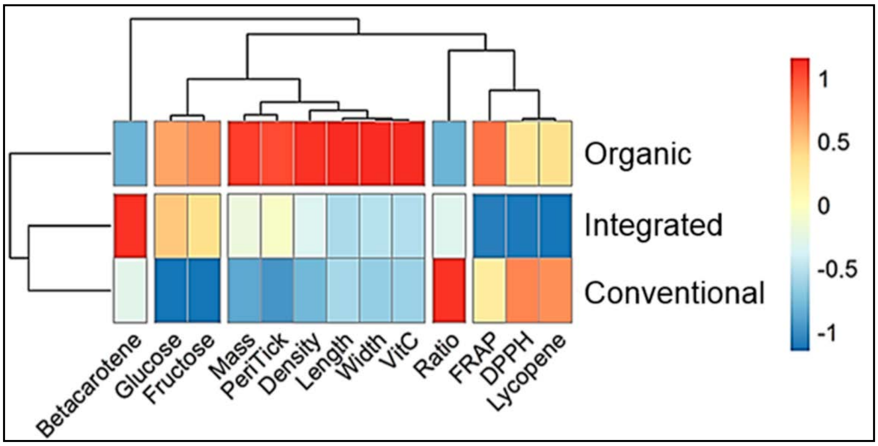

Figure 1. Grouping analysis and heat map of the physical and biochemical traits of Italian tomatoes under different production systems. Londrina, UEL, 2019.

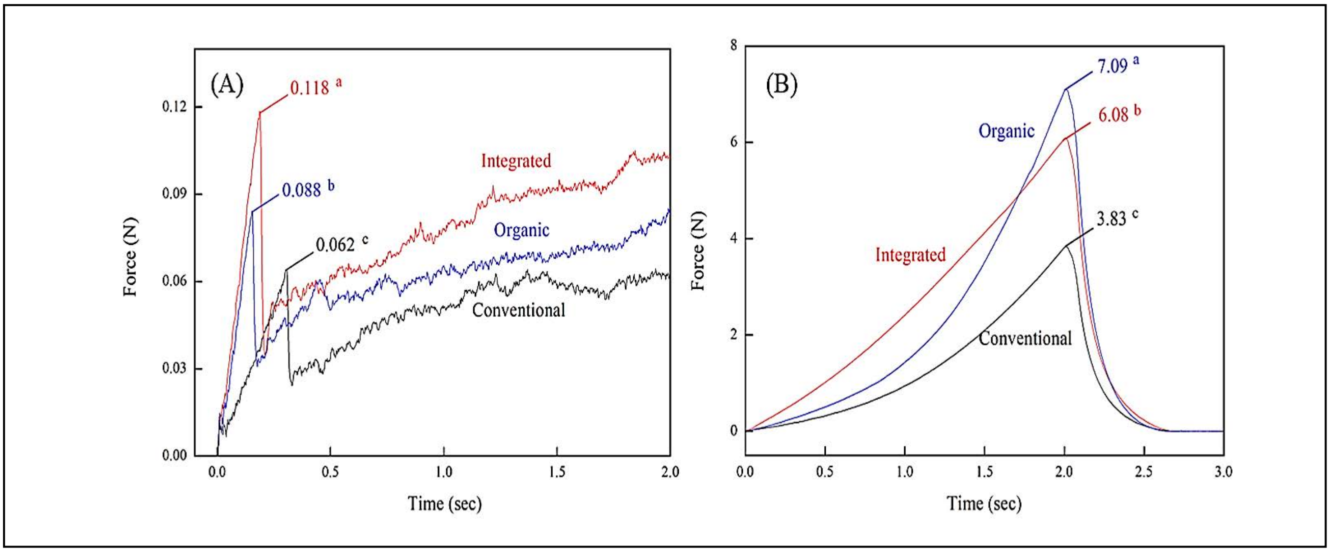

Figure 2. Texturograms of Italian tomatoes under different production systems by the puncture (A) and compression (B) assays. Londrina, UEL, 2019.

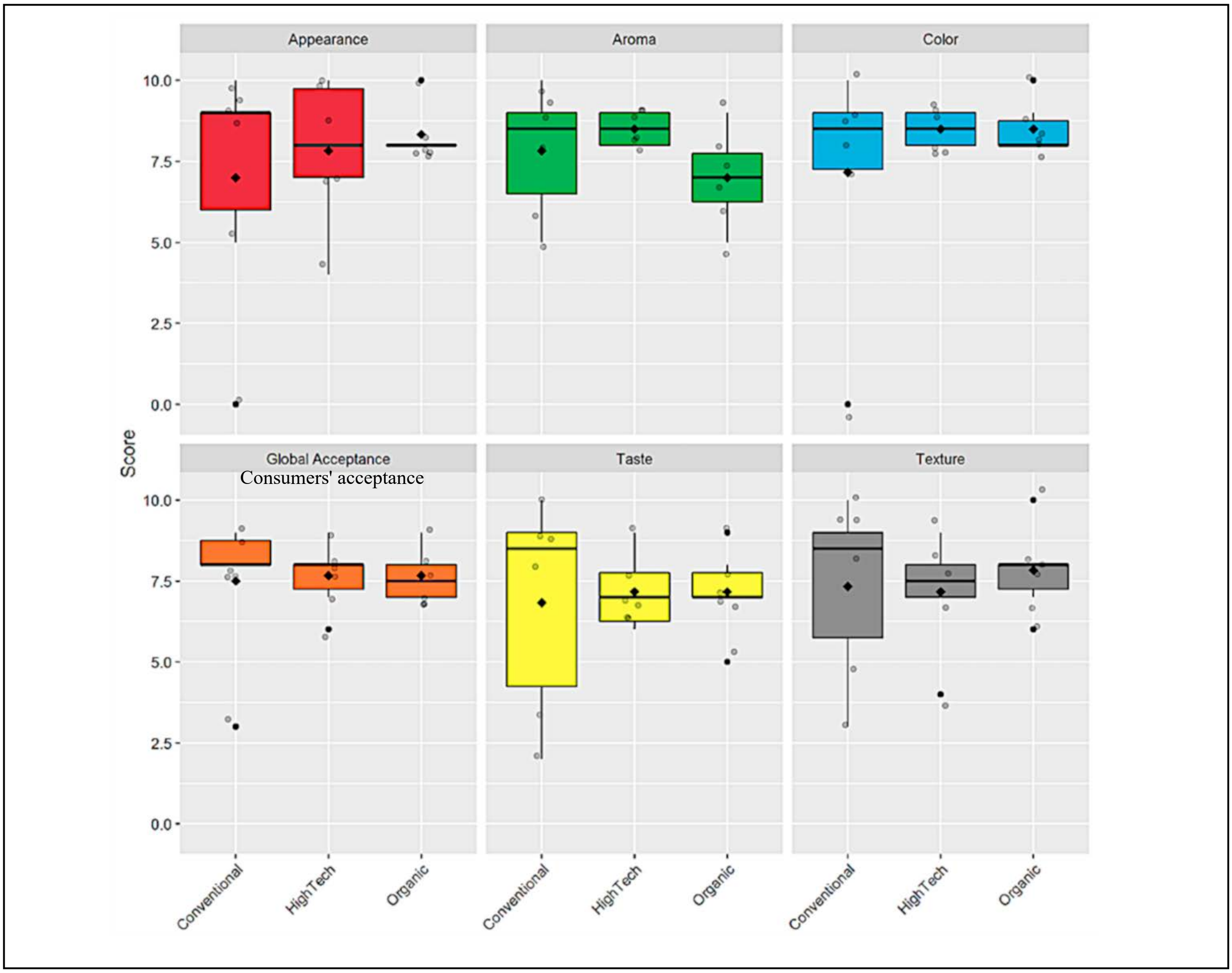

Figure 3. Boxplot of sensory acceptance scores of the tomatoes under different production systems. Londrina, UEL, 2019.

availability of nitrogen in the form of ammonia and potassium for plants, as this trait is directly related to cell turgor pressure (Knee, 2002). In this case, the high fertilizer concentration in the conventional production management may decrease firmness, as it was verified in this study.

In the integrated management, the composition of the nutrient solution is controlled according to the plant demand and its phenological stage, made available, automatically, under the command of a software. The organic farmers, who took part in this study, have plenty of experience in growing tomatoes under this management. In relation to the conventional management, great part of producers overuse high solubility chemical fertilizers (Rahman & Zhang, 2018), influencing, negatively, the fruit firmness.

Riahi *et al.* (2009) verified some organic tomatoes firmer than the conventional ones for just one of the cultivars among the four ones evaluated. According to Caris-Veyrat *et al.* (2004), the firmness of the conventional tomatoes decreased 16% during storage time, whereas the decrease in organic fruits was only 7%. Polat *et al.* (2010) found no difference in firmness among tomatoes grown under organic and conventional managements in Turkey.

More than 50% of the panelists were women, approximately 40% were men, 70% of the total were up to 25 years old. Regarding to occupation, 80% of the consumers were students, 5% public servants, 3% tradepeople and approximately 2% small producers, in which 60% reported being weekly consumers, more than 20% daily consumers, approximately 10% infrequent consumers, less than 10% consume the fruit every fifteen days and the minority consume it monthly.

As for the fruit preference itself, concerning the different production managements, 42% of consumers preferred the organic ones, 30% tomatoes grown under integrated management and 22% under conventional management. Appearance was the most appreciated trait in organic tomatoes and flavor for tomatoes under integrated and conventional managements, whereas the least appreciated traits were texture for organic and integrated tomatoes, and appearance for conventional ones.

No difference was verified in relation to consumers' acceptance regarding to tomatoes under the three production managements (Figure 3). On the other hand, Borguini & Silva (2009) reported that regarding to the evaluated sensory attributes, difference in flavor was verified between fruits grown under organic and conventional managements. However, Ferreira *et al.* (2010) reported that organic tomatoes showed to be firmer according to the consumer's evaluation, whereas conventional fruits were better in relation to flavor and presented greater global acceptance, in this study different cultivars were used in each production management, though.

Concerning the consumer's purchase intention, it is possible to say that 70% of them would buy the fruits grown under organic management, whereas 54 and 53% would buy the fruits under integrated and conventional managements, respectively. Thus, we conclude that although sensory acceptance did not differ for tomatoes, preference and purchase intention indicate a greater appreciation for organic fruits. This finding can be attributed to the superior physical traits of the fruits grown under this management, such as greater mass, volume and thickness of the pericarp, in addition to sugar content, which are directly related to the appearance and flavor of the tomato, attributes that motivate purchase and repurchase by consumers.

Despite the difference in physical and biochemical traits of the fruits grown under different production managements, it is not possible to state that any difference related to the consumer's perception could be noticed, even though organic tomatoes have been notoriously preferred. This difference for the traits, considering the different managements, may not have been expressive to be noticed by the panelists. Vinha *et al.* (2014) stated that conventional tomatoes were preferred in relation to color; however, color and lycopene content showed that organic fruits were more red-pigmented.

Although some difference in relation to the physical and biochemical traits of tomatoes grown under organic, integrated with high technification and conventional managements was noticed, the averages for sensory attributes did not differ. Even so, an expressive consumer's preference for organic fruits was verified.

Considering what was observed in this study, we could conclude that some difference can be noticed in relation to physical and biochemical quality in tomatoes grown under different managements, but no sensory difference was verified, though. The cultivation of tomato under the integrated management was similar to that of the conventional management as they presented tomatoes with similar fresh mass, pericarp thickness, density, width and vitamin C content. Organic tomatoes proved to be of better quality, as they had greater width, fresh mass, pericarp thickness, vitamin C content and glucose content.

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REFERENCES

ADALID, AM; ROSELLÓ, S; NUEZ, F. 2010. Evaluation and selection of tomato accessions (Solanum section Lycopersicon) for content of lycopene, β-carotene and ascorbic acid. *Journal of Food Composition and Analysis* 23: 613-618. https://doi.org/10.1016/j.jfca.2010.03.001

AOAC. 1984. Official methods of analysis. *Association of Official Analytical Chemists*. Washington, DC: AOAC International.

AOAC. 1997. Official methods of analysis. *Association of Official Analytical Chemists*. Washington, DC: AOAC International.

ARAZURI, S; JARÉN, C; ARANA, JI; PÉREZ, CJJ. 2007. Influence of mechanical harvest on the physical properties of processing tomato (*Lycopersicon esculentum* Mill.). *Journal of Food Engineering* 80: 190-198. https://doi.org/10.1016/j.jfoodeng.2006.05.008

BENASSI, MT; ANTUNES, AJ .1988. A comparison of metaphosphoric and oxalic acids as extractans solutions for the determination of vitamin C in selected vegetables. *Arquivos de Biologia e Tecnologia* 31: 507-513.

BENZIE, IF; STRAIN, JJ. 1999. Ferric reducing/antioxidant power assay: direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. *Methods in Enzymology* 299: 15-27.

BORGUINI, RG; SILVA, MV. 2009. Características físico-químicas e sensorias do tomate (*Lycopersicon esculentum*) produzido por cultivo orgânico em comparação ao convencional. *Alimentos e Nutrição Araraquara* 16: 355-361.

BRAND-WILLIAMS, W; CUVELIER, ME; BERSET, C. 1995. Use of a free radical method to evaluate antioxidant activity. *LWT* 28: 25-30.

CARIS-VEYRAT, C; AMIOT, MJ; TYSSANDIER, V; GRASSELLY, D; BURET, M; MIKOLAJCZAK, M; GUILLAND, JC; BOUTELOUP-DEMANGE, C; BOREL, P. 2004. Influence of organic versus conventional agricultural practice on the antioxidant microconstituent content of tomatoes and derived purees; consequences on antioxidant plasma status in humans. *Journal of Agricultural and Food Chemistry 52*: 6503-6509. https://doi.org/10.1021/jf0346861

CHASSY, AW; BUI, L; RENAUD, ENC; VAN, HM; MITCHELL, AE. 2006. Three-year comparison of the content of antioxidant microconstituents and several quality characteristics in organic and conventionally managed tomatoes and bell peppers. *Journal of Agricultural and Food Chemistry54*: 8244-8252. https://doi.org/10.1021/jf060950p

CONSTANTINO, LV; ZEFFA, DM; KOLTUN, A; URBANO, MR; SANTOS SAW; NIXDORF, SL. 2020. Extraction of soluble sugars from green coffee beans using hot water and quantification by a chromatographic method without an organic solvent. *Acta Chromatographica* 32: 242-246. https://doi.org/10.1556/1326.2020.00704

DUMAS, Y; DADOMO, M; LUCCA, G; GROLIER, P. 2002. Review of the influence of major environmental and agronomic factors on the lycopene content of tomato fruit. *Acta Horticulturae* 579: 595-601. https://doi.org/10.17660/ActaHortic.2002.579.105

FADINI, M; ANTONIO, M. 2004. Controle de ácaros em sistema de produção integrada de morango. *Ciência Rural* 34: 1271-1277.

FAO: Agriculture, Food and Organization of the United Nations. 2020. Produtividade Mundial Available at: http://www.fao.org/faostat/en/#home . Accessed May 10, 2020.

FERREIRA, EB; CAVALCANTI, PP; NOGUEIRA, DA. 2018. ExpDes.pt: Pacote Experimental Designs (Portuguese). *Applied Mathematics*.

FERREIRA, SMR; FREITAS, RJS; KARKLE, ENL; QUADROS, DA; TULLIO, LT; LIMA, JJ. 2010. Quality of tomatoes cultivated in the organic and conventional cropping systems. *Ciencia e Tecnologia de Alimentos* 30: 224-230.

GILSENAN, C; BURKE, RM; BARRY-RYAN, C. 2012. Do organic cherry vine tomatoes taste better than conventional cherry vine tomatoes? A sensory and instrumental comparative study from Ireland. *Journal of Culinary Science and Technology* 10: 154-167. https://doi.org/10.1080/15428052.2012.679232

HALLMANN, E. 2012. The influence of organic and conventional cultivation systems on the nutritional value and content of bioactive compounds in selected tomato types. *Journal* *of the Science of Food and Agriculture* 92: 2840-2848. https://doi.org/10.1002/jsfa.5617

JUROSZEK, P; LUMPKIN, HM; YANG, RY; LEDESMA, DR; MA, CH. 2009. Fruit quality and bioactive compounds with antioxidant activity of tomatoes grown on-farm: Comparison of organic and conventional management systems. *Journal of Agricultural and Food Chemistry 57*: 1188-1194. https://doi.org/10.1021/jf801992s

KADER, AA; MORRIS, LL; STEVENS, AM; ALBRIGHT-HOLTON, M. 1978. Composition and flavor quality of fresh market tomatoes as influenced by some postharvest handling procedures. *Journal of the American Society for Horticultural Science* 103: 6-13.

KNEE, M. 2002. Fruit quality and its biological basis (2002nd ed.). Sheffield Academic Press. Canadá p.1-27.

KOLDER, R. 2018. Implementation of heatmaps that offers more control over dimensions and appearance.

LEIVA-BRONDO, M; MATÍ, R; MACUA, JI; LAHOZ, I; GONZÁLEZ, Á; CAMPILLO, C; ROSELLÓ, S; CEBOLLA, CJ. 2015. Sugar and acid profile of processing varieties of tomato grown under conventional or organic conditions. *Acta Horticulturae*, 1081: 181-186.

LUCAS, PW; PRINZ, JF; AGRAWAL, KR; BRUCE, IC. 2004. Food texture and its effect on ingestion, mastication and swallowing. *Journal of Texture Studies* 35: 159-170. https://doi.org/10.1111/j.1745-4603.2004.tb00831.x

MERGAWI, RA; REDHAIMAN, K. 2010. Effect of organic and conventional production practices on antioxidant activity, antioxidant constituents and nutritional value of tomatoes and carrots in Saudi Arabia markets. *Journal of Food, Agriculture & Environment* 8: 253-258.

MIOCHE, L; BOURDIOL, P; PEYRON, M. 2004. Influence of age on mastication: effects on eating behaviour. *Nutrition Research Reviews* 17: 43–54. https://doi.org/10.1079/NRR200375

MUÑOZ, CMG; GÓMEZ, MGS; SOARES, JPG; JUNQUEIRA, AMR. 2016. Normativa de produção orgânica no Brasil: A percepção dos agricultores familiares do assentamento da Chapadinha, Sobradinho (DF). *Revista de Economia e Sociologia Rural*, *54*: 361-376. https://doi.org/10.1590/1234.56781806-947900540209

NAVARRO-GONZÁLEZ, I; PERIAGO, MJ. 2016. Is tomato a healthy and/or functional food? *Revista Espanola de Nutricion Humana y Dietetica 20*: 323-335. https://doi.org/10.14306/renhyd.20.4.208

NETO, ASM; PONCIANO, NJ; SOUZA, PM; GRAVINA, GA; DAHER, RF. 2018. Costs, viability and risks of organic tomato production in a protected environment. *Revista Ciencia Agronomica*, 49: 584-591. https://doi.org/10.5935/1806-6690.20180066

PASCALE, S; MAGGIO, A; ORSINI, F; BARBIERI, G. 2016. Cultivar, soil type, nitrogen source and irrigation regime as quality determinants of organically grown tomatoes. *Scientia Horticulturae* 199: 88-94. https://doi.org/10.1016/j.scienta.2015.12.037

PÉK, Z; HELYES, L; LUGASI, A. 2010. Color changes and antioxidant content of vine and postharvest-ripened tomato fruits. *HortScience*, 45: 466-468. https://doi.org/10.21273/hortsci.45.3.466

POLAT, E; DEMIR, H; ERLER, F. 2010. Yield and quality criteria in organically and conventionally grown tomatoes in Turkey. *Scientia Agricola*, 67: 424-429. https://doi.org/10.1590/s0103-90162010000400008

RAHMAN, KMA: ZHANG, D. 2018. Effects of fertilizer broadcasting on the excessive use of inorganic fertilizers and environmental sustainability. *Sustainability* 10. https://doi.org/10.3390/su10030759

RIAHI, A; HDIDER, C; SANAA, M; TARCHOUN, N; KHEDER, MB; GUEZAL, I. 2009. Effect of conventional and organic production systems on the yield and quality of field tomato cultivars grown in Tunisia. *Journal of the Science of Food and Agriculture* 89: 2275-2282. https://doi.org/10.1002/jsfa.3720

RODRÍGUEZ, A; BALLESTEROS, R; CIRUELOS, A; BARREIROS, JM; LATORRE, A. 2001. Sensory evaluation of fresh tomato from conventional, integrated, and organic production. *Acta Horticulturae* 542: 277-282.

RODRIGUEZ-AMAYA, DB. 2001. A guide to carotenoid analysis in food. Washington, USA: International Life Sciences Institute. p. 1-60.

RODRIGUEZ-AMAYA, DB; KIMURA, M. 2004. *HarvestPlus handbook for carotenoid analysis*. Campinas, São Paulo: Unicamp. p. 2-51.

SILVA, EMNCP; FERREIRA, RLF; NETO, SEA; TAVELLA, LB; SOLINO, AJS. 2011. Qualidade de alface crespa cultivada em sistema orgânico, convencional e hidropônico. *Horticultura Brasileira* 29: 242-245. https://doi.org/10.1590/S0102-05362011000200019.

STERTZ, SC; ESPÍRITO SANTO, AP; BONA, C; FREITAS, RJS. 2005. Comparative morphological analysis of cherry tomato fruits from three cropping systems. *Scientia Agricola* 62: 296-298. https://doi.org/10.1590/s0103-90162005000300015

STONE, H; BLEIBAUM, RN; THOMAS, HA. 2012. Sensory evaluation practices. 425p.

VIEIRA, DAP; CARDOSO, KCR; DOURADO, KKF; CALIARI, M; JÚNIOR, MSS. 2014. Physical and chemical quality of mini-tomato Sweet Grape grown under organic and conventional cultivation. *Revista Verde de Agroecologia e Desenvolvimento Sustentável* 9: 100-108.

VILLANUEVA, NDM; PETENATE, AJ; SILVA, MAAP. 2005. Performance of the hybrid hedonic scale as compared to the traditional hedonic, self-adjusting and ranking scales. *Food Quality and Preference*, 16: 691-703. https://doi.org/10.1016/j.foodqual.2005.03.013

VINHA, AF; BARREIRA, SVP; COSTA, ASG; ALVES, RC; OLIVEIRA, MBPP. 2014. Organic versus conventional tomatoes: Influence on physicochemical parameters, bioactive compounds and sensorial attributes. *Food and Chemical Toxicology*, 67: 139-144. https://doi.org/10.1016/j.fct.2014.02.018

WORTHINGTON, V. 2001. Nutritional quality of organic versus conventional fruits, vegetables, and grains. *Journal of Alternative and Complementary Medicine*, 7: 161-173. https://doi.org/10.1089/107555301750164244