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Quality of Italian tomatoes grown with different forms of calcium application

Produtividade e qualidade de tomate italiano cultivado com diferentes formas de aplicações de cálcio

Productividad y Calidad yde tomates italianos cultivados con diferentes formas de aplicaciones de calcio

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Abstract

Tomato is one of the most consumed vegetables in the world. This work aimed to evaluate post-harvest quality of Italian Saladete tomatoes grown in a protected environment, with different ways of calcium application, in the Middle São Francisco Valley. Consisting of five Italian tomato hybrids (Anjico, Gabrielle, Liberty, Ty 2006 and Shanty), and three different ways of calcium application (T0 without application of calcium; T1 application of calcium in the opening flower, and T2 weekly application of calcium in the fruit). Poductivity, average fruit mass, incidence of apical rot, fruit firmness, soluble solids (SS), titratable acidity (AT), and pH, were analized. The experimental design used was a completely randomized block design in a factorial scheme (five cultivars x three ways of calcium application), with three repetition and using two central plants as useful plot for analysis, except for fruit firmness that was carried out in a completely randomized design, using tree fruits per analysis. According to the results obtained, hybrids of Italian saladete tomatoes behaved in a satisfactory manner, therefore it is recommended to cultivate hybrids of Italian saladete tomatoes in the Middle São Francisco Valley, mainly hybrid Anjico. Calcium application way did not interfere with post-harvest attributes.

Keywords: *Solanum lycopersicon* L.; Northeast; Aspect; Flavor.

Resumo

O tomate é uma das hortaliças mais consumida no mundo. O presente trabalho teve como objetivo avaliar a produtividade e qualidade pós-colheita de híbridos de tomate italiano cultivado em ambiente protegido, com diferentes formas de aplicação de cálcio, no Submédio do Vale do São Francisco. Foram avaliados cinco híbridos (Anjico, Gabrielle, Liberty, Ty 2006 e Shanty) de tomate italiano, e tendo três diferentes formas de aplicação de cálcio (T0- sem aplicação de cálcio (controle); T1- aplicação de cálcio na abertura da flor; e T2- aplicação de cálcio semanalmente no fruto). As análises realizadas foram as de produtividade, massa média dos frutos, incidência de podridão apical, firmeza, sólidos solúveis (SS), acidez titulável (AT), e pH. O delineamento experimental adotado foi blocos ao acaso em esquema fatorial (cinco cultivares x três formas de aplicação de cálcio), com três repetições e como parcela útil duas plantas centrais para as análises, exceto para a análise de firmeza, que foi realizada em delineamento inteiramente casualizado, utilizando três frutos nas análises. Diante dos resultados encontrados, pode-se concluir que as diferentes formas de aplicação de cálcio não interferiu nas análises testadas. Entretanto os híbridos de tomate italiano, principalmente o Anjico, se comportaram de maneira satisfatória nas características de avaliação pós-colheita, recomenda-se o cultivo dos híbridos de tomate italiano no Submédio do Vale do São Francisco.

Palavras-chave: *Solanum lycopersicon* L.; Nordeste; Aparência; Sabor.

Resumen

Los tomates son una de las verduras más consumidas en el mundo. Este estudio tuvo como objetivo evaluar la productividad y la calidad poscosecha de los híbridos de tomate italiano cultivados en un ambiente protegido, con diferentes formas de aplicación de calcio, en el submedio del Valle de São Francisco. Se evaluaron cinco híbridos (Anjico, Gabrielle, Liberty, Ty 2006 y Shanty) de tomates italianos, con tres formas diferentes de aplicación de calcio (T0- sin aplicación de calcio (control); T1- aplicación de calcio en la apertura de la flor; y T2- aplicación semanal de calcio a la fruta). Los análisis realizados fueron los de productividad, masa promedio de frutos, incidencia de pudrición apical, firmeza, sólidos solubles (SS), acidez titulable (AT) y pH. El diseño experimental adoptado fue bloques al azar en esquema factorial (cinco cultivares x tres formas de aplicación de calcio), con tres repeticiones y como parcela útil dos plantas centrales para los análisis, excepto el análisis de firmeza, que se realizó en un diseño íntegramente. aleatorizados, utilizando tres frutos en los análisis. A la vista de los resultados encontrados, se puede concluir que las diferentes formas de aplicación de calcio no interfirieron en los análisis ensayados. Sin embargo, los híbridos de tomate italiano, principalmente Anjico, se comportaron satisfactoriamente en las características de evaluación poscosecha, se recomienda cultivar los híbridos de tomate italiano en el submedio del Valle de São Francisco.

Palabras clave: Solanum lycopersicon L.; Noreste; Apariencia; Sabor.

1. Introducion

Tomato (*Lycopersicum esculentum* Mill) is a plant that belongs to the family Solanaceae. This plant is potentially perennial and is easily adapted to a wide variety of climates. Nowadays, its cultivation and consumption have spread so that it is difficult to find another agricultural product that is consumed in the same quantities.

The Submedium São Francisco Valley has favorable edaphoclimatic and logistical characteristics for the commercial exploitation of vegetables. Tomato cultivation becomes an important alternative for the region; however, this crop requires favorable climatic conditions for its agronomic performance to be optimized.

Protected cultivation allows to safeguard the crop from unfavorable climatic conditions such as strong winds and heavy rains. Moreover, it brings benefits such as greater ease in controlling pests and diseases, improving product quality, standardizing production, and increasing yield (Lenhardt, 2016). Notwithstanding, few studies address the cultivation of this vegetable in a protected environment.

Semihydroponic cultivation has been used in protected environments as a preventive measure. In addition to avoiding soil degradation and diseases, this type of cultivation reduces production costs and increases yield and fruit quality (Rodrigues & Goto, 2016). Furthermore, it provides plants with adequate amounts of nutrients for each stage of crop development.

The acceptance of tomatoes in the consumer market is mainly because they are important sources of vitamins and minerals in human diet. These fruits are rich in antioxidants and bioactive compounds, which are secondary metabolites produced by plants. Phenolic compounds, ascorbic acid, and lycopene are examples of compounds found in tomatoes (Rocha; Silva, 2011). These attributes become necessary not only to satisfy consumer requirements, but also to allow genetic selection of new cultivars, selection of production practices, and postharvest handling (Damatto Jr et al., 2010).

In this sense, the present study evaluates the yield and postharvest quality of Italian tomato hybrids grown in a protected environment, with different forms of calcium application, in the Submedium São Francisco Valley.

2. Methodology

We conducted the study in the vegetable section of the Department of Technology and Social Sciences of the State University of Bahia (DTCS - UNEB), in Juazeiro city (09º 24' S, 40º 31' W, and 371 m altitude), Bahia State, Brazil. The experimental period was from March to July 2017. We performed the experiments in a screened greenhouse (40% shading). The experimental design was randomized blocks in a 5x3 factorial scheme. Treatments consisted of Italian tomato hybrids (Anjico, Gabrielle, Liberty, Ty 2006, and Shanty), with Anjico being the only one with indeterminate growth habit; and different forms of weekly calcium application (T0 - without application of calcium (Control); T1 - direct application of calcium to the flower; and T3 - direct application of calcium to the fruit), with three replicates. We used a spacing of 80 cm between plants and 100 cm between rows. We used wires for tutoring tomato plants, and performed fertigation as recommended by Hochmuth (1995); for that, we used an irrigation sprinkler. Each treatment consisted of four plants per plot. The useful plot consisted of the two central plants. We produced seedlings in 128-cell polypropylene trays containing the commercial substrate Plantmax®. At 28 days after sowing (DAS), we transplanted the seedlings to disposable cups containing the same substrate. At 49 DAS, we transplanted the seedlings to their final location (8-liter pots containing sugarcane bagasse as substrate). We performed all cultural treatments recommended for the crop.

We used Cal Super as a commercial calcium source following the manufacturer's recommendation according to number of plants/ha (2 $L.ha^{-1}$). We placed the product in a spray bottle and applied it to the treatments as mentioned above.

We harvested the fruits manually when these started to ripen, at approximately 60 days after transplantation (DAT). We carried out a total of six harvests. We considered the third and fourth harvests for analyses, thus guaranteeing homogeneity, that is, we analyzed fruits in the same maturation stage. We identified and packed the harvested fruits individually in plastic bags. Then, we sent the fruits of the third harvest to the DTCS/UNEB Olericulture Laboratory for analysis of average fruit weight, yield, pH, Soluble Solids (SS), Titratable Acidity (TA), and hydrogen potential (pH). In addition, we sent the fruits of the fourth harvest to the Agricultural Products Storage Laboratory at UNIVASF, located on the Juazeiro-BA Campus, for firmness analysis.

We determined yield from the amount of production, in tons per hectare, and expressed the data in $t.ha^{-1}$. We obtained the average fruit weight by dividing the total production of the plot by the number of fruits therein.

We quantified fruits with apical rot in relation to the total fruits of each plot, obtaining the results in percentage of apical rot.

To determine fruit firmness, we divided the fruits longitudinally into two parts and measured the median region using a penetrometer (Instrutherm, model PTR 100) equipped with an 8 mm diameter tip. We measured 3 fruits per treatment, expressing the results in Newton (N).

We determined soluble solids (ºBrix) directly in the homogenized juice. For that, we used a digital refractometer (Instrutherm, model RTA-50) with automatic temperature correction (scale from 0 to 32%). We determined titratable acidity using 5.0 g of the juice sample, to which we added 50 ml of distilled water and 3 drops of 1.0% alcoholic

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phenolphthalein. Then, we performed titration with 0.1 N NaOH solution, previously standardized. We expressed the results as percentage of citric acid according to the methodology of Instituto Adolfo Lutz (IAL, 2008).

Where: V = amount of mL of the 0.1 M sodium hydroxide solution spent on titration; f = factor of the 0.1 or 0.01 M sodium hydroxide solution; P = amount of g of the sample used in titration; c = correction for NaOH solution.

We submitted the results to analysis of variance and means comparison by the Tukey test at 5% significance, using the program Assistat version 7.7 (Silva & Azevedo, 2016).

3. Results and Discussion

Average fruit weight did not differ significantly as a function of calcium application. However, the interaction of the factors accounted for significant differences (Table 1). The factor hybrid had a highly significant effect on average fruit weight. For this variable, hybrids Gabryelle (83.50 g) and Liberty (65.15 g) had better results. The performance of the hybrid Shanty is variable and dependent on the factor calcium. Direct application of calcium to the flowers and fruits of this hybrid affected its average weight. For the hybrids Gabryelle, Liberty, TY 2006, and Anjico, the control and application of calcium to the fruit behaved statistically similarly.

Table 1. Mean of fruit mass (g) of Italian tomato hybrids grown with diferente ways of application calcium, in a protected environment in Lower-middle São Francisco Valley, Juazeiro-BA (2017).

Average of fruit mass (g)	Application calcium			Average Hybrids
Hybrids	Control	Flower	Fruit	
Shanty	64,36 Aa	33,50 Bab	44,42 ABb	47,43
Gabryelle	60,62 Aa	60,61 Aa	83,50 Aa	68,26
Liberty	43,48 Aab	56,40 Aa	65,15 Aab	55,01
Ty 2006	12,28 Ab	18,82 Ab	14,50 Ac	16,60
Anjico	39,41 Aab	39,94 Aab	39,54 Abc	39,63
Average application	44,83	41,86	49,46	

Average followed by the same lowercase letters in columns and capitals in rows not differ each other by the Tukey test at 5% probabity.
Source: Andrade, (2017).

According to Hazera (2017), the average fruit weight of hybrids Gabryelle and Shanty is 130-150 and 140-170 grams, respectively. In turn, hybrids Ty 2006 and Anjico have an average weight of 180 and 100-150 grams, respectively (Isla, 2017), while for the hybrid Liberty this value is 160-180 grams (Feltrin, 2017).

The values of those reports were higher than those found in this experiment. For a good performance of hybrids, with weight gain, proper use of agronomic techniques must be ensued, mainly in a protected environment (Santos et al., 2017). An example is the practice of pruning, in which the drain force of an organ depends on its potential demand or capacity to accumulate photoassimilates (Almanza-Merchán et al., 2016). Moreover, adjustments in irrigation and nutrition are needed so as to avoid tomato yield losses.

Table 2 shows yield averages. This variable did not differ significantly for the isolated factors calcium application and tested hybrids, but the interaction of the studied factors again accounted for significant differences.

Table 2. Mean of total productivity in tons per hectare of Italian tomato hybrids grown with diferente ways of application calcium, in a protected environment in Lower-middle São Francisco Valley, Juazeiro-BA (2017).

Productivity ($t.ha^{-1}$)	Application calcium			Average Hybrids
Hybrids	Control	Flower	Fruit	
Shanty	25,28 Aa	21,47 Aab	16,26 Bcd	21,00
Gabryelle	17,69 Ab	22,33 Aab	22,68 Ab	20,90
Liberty	27,79 Aa	19,26 Bbc	30,75 Aa	25,90
Ty 2006	10,56 Ac	14,29 Ac	12,43 Ad	12,42
Anjico	26,52 Aa	27,19 Aa	19,62 Bbc	24,44
Average application	21,57	20,91	20,33	--

Average followed by the same lowercase letters in columns and capitals in rows not differ each other by the Tukey test at 5% probabity.
Source: Andrade, (2017).

The application of calcium did not increase the yield of the studied hybrids. However, the Italian tomato hybrids behaved differently for this factor, which indicated a significant difference between them. Hybrids Liberty and Anjico explored the environment better than the others, with increased yield. The yield of the hybrid Shanty decreased when calcium was applied to the fruit. Pimenta et al. (2016) state that some characteristics are not modified in phenotypic expression when subjected to environmental changes.

Shirahige et al. (2010a) studied the yield and quality of Santa Cruz and Italian tomatoes as a function of fruit thinning. The authors found a yield of 126.2 and 141.3 $t.ha^{-1}$ for Italian hybrids Neptune and Sahel, respectively, when the fruits were thinned. Abortion of flowers, apical rot, and phytotoxicity due to the attempt to control fruit moth (which led to the end of the experiment at 105 days after transplanting) caused the yield of this experiment to be lower than those found by other authors.

All hybrids tested in the present study showed apical rot (AR); however, the hybrid Ty 2006 had a significantly higher incidence of this disease when compared to the other hybrids, which, in turn, did not differ for this variable (Table 3). When growing tomatoes on seven different substrates, Carrijo et al. (2004) found percentage values of fruits with apical rot per plant ranging from 8.3 to 15. These results are similar to those observed for the hybrid Shanty, and inferior to those observed for the other hybrids. According to Taiz & Zeiger (2013), increased transpiration rate with subsequent closing of stomata decreases transpiration flow. This leads to less absorption and translocation of calcium, which causes apical rot. This type of rot is among the main problems in tomato cultivation, significantly reducing yield. The disease, commonly caused by calcium deficiency, showed some significant differences between hybrids.

Table 3. Mean percentage of fruits with blackground of Italian tomato hybrids grown with diferente ways of application calcium, in a protected environment in Lower-middle São Francisco Valley, Juazeiro-BA (2017).

Blackground (%)	Application calcium			Average Hybrids
Hybrids	Control	Flower	Fruit	
Shanty	7,49 ^{ns}	19,55	14,25	13,76 b
Gabryelle	21,14	29,67	11,00	29,60 b
Liberty	46,84	24,99	20,98	30,94 b
Ty 2006	82,14	83,59	58,84	74,86 a
Anjico	27,75	27,32	33,88	29,65 b
Average application	37,07 A	37,03 A	27,79 A	--

Average followed by the same lowercase letters in columns and capitals in rows not differ each other by the Tukey test at 5% probabity. ns: no significant.
Source: Andrade, (2017).

In general, the hybrid Ty 2006 is twice as susceptible to apical rot than the other hybrids. There was no significant difference for the application of calcium or interaction between the factors. The incidence of apical rot also relates to the number of fruits per plant, since the greater the number of fruits, the greater their demand for calcium.

When studying the phenology and effect of boron and calcium doses on the production of Italian tomatoes in two growing seasons, Zamban (2014) observed that the incidence of apical rot in the hybrid Neptune decreased with weekly and biweekly calcium application.

The high transpiration of plants due to the high temperatures and low relative air humidity recorded during the cultivation cycle led to apical rot in the fruits. This physiological disorder limits fruit growth, decreasing fruit weight and, consequently, total yield. Evapotranspiration interferes with calcium (Ca) concentration, and lack of Ca in the fruits can be either caused by its deficiency in the medium or induced by other factors such as soil moisture; high availability of nutrients such as N, K, Mg, and Na; use of ammonia sources; intensity of leaf transpiration; and cultivar, being responsible for apical rot (Alvarenga, 2004). According to Olle & Williams (2016), apical rot causes the fruit to ripen prematurely and makes it unfit for consumption.

The different ways of applying calcium in the plants of the tested hybrids did not change the firmness of the evaluated tomatoes. However, the analyses showed a difference for this variable between the compared hybrids (Table 4). Fruit firmness is an essential postharvest conservation characteristic during marketing and transportation, which also relates to storage capacity or shelf life.

Table 4. Mean of soluble firmness and solid of fruits (ºBrix) of Italian tomato hybrids grown with diferente ways of application calcium, in a protected environment in Lower-middle São Francisco Valley, Juazeiro-BA (2017).

	Firmness(N)				Sólid (ºBrix)			
	Application calcium			Average Hybrids	Application calcium			Average Hybrids
Hybrids	Control	Flower	Fruit		Control	Flower	Fruit	
Shanty	7,08 ns	6,23	4,66	5,99 ab	7,91ns	7,35	7,14	7,47 a
Gabryelle	5,83	5,47	5,22	5,51 b	6,48	6,26	6,62	6,45 b
Liberty	7,38	7,58	6,91	7,29 a	7,18	7,10	6,68	6,99 ab
Ty 2006	5,91	6,58	6,54	6,34 ab	6,71	6,60	6,72	6,67 b
Anjico	4,89	6,09	5,19	5,39 b	6,94	7,01	6,74	6,90 ab
Average application	6,22 A	6,39 A	5,79 A	--	7,05 A	6,86 A	6,78 A	--

Average followed by the same lowercase letters in columns and capitals in rows not differ each other by the Tukey test at 5% probabity. ns: no significant.
Source: Andrade, (2017).

Regarding the tested hybrids, Liberty, Ty 2006, and Shanty showed better firmness averages: 7.29 N, 6.34 N, and 5.99 N, respectively, followed by the hybrids Gabryelle (5.51 N) and Anjico (5.39 N), which are statistically similar to Shanty and Ty 2006. When testing the postharvest quality of tomato fruits as a function of calcium sources, Vilas Boas (2014a) found a firmness of 6.59 N, which is close to the values found in this experiment.

Plant nutrition plays a fundamental role in fruit quality. In this context, reports show that the nutrients nitrogen, phosphorus, potassium, and calcium promote firmness (texture) (Sams, 1999). When testing the effect of calcium sources on the firmness of tomato fruits, Kano et al. (2012) also report that the application of calcium did not contribute to obtaining tomatoes with greater firmness. Fruits with less firmness are more susceptible to mechanical damage (Kirimi et al., 2011) and deterioration (Soares; Rangel, 2012).

In this test, tomato fruits did not show statistically different average soluble solids (SS) contents neither in response to treatments with different calcium applications nor in the interaction between hybrids and calcium application (Table 4).

Hybrids Shanty, Anjico, and Liberty obtained better results for this variable, with 7.47, 6.90, and 6.99 ºBrix, respectively, followed by Ty 2006 (6.67 ºBrix) and Gabryelle (6.45 ºBrix), which are statistically similar to Anjico and Liberty. These results are superior to those observed by Pacheco (2017), who found 5.7 °Brix for cherry tomato cultivar BRS Iracema.

On the contrary, the results are inferior to those observed by Santiago et al. (2018) when cultivating the tomato hybrid Wanda in the São Francisco Valley, with an average of 10.29 °Brix.

The pH of the fruits did not differ significantly for the tested hybrids, neither for different calcium applications nor for the interaction between hybrids and calcium application, as shown in Table 5.

Table 5. Mean of pH and acidity tritatable (AT) fruits of Italian tomato hybrids grown with diferente ways of application calcium, in a protected environment in Lower-middle São Francisco Valley, Juazeiro-BA (2017).

	pH				AT (%)			
	Application calcium			Average Hybrids	Application calcium			Average Hybrids
Hybrids	Control	Flower	Fruit		Control	Flower	Fruit	
Shanty	4,88 ns	4,86	4,88	4,87 a	0,115ns	0,132	0,113	0,120 a
Gabryelle	4,91	5,01	4,95	4,95 a	0,108	0,873	0,085	0,093 a
Liberty	4,87	5,00	5,02	4,97 a	0,115	0,098	0,098	0,103 a
Ty 2006	4,82	4,82	4,94	4,86 a	0,109	0,111	0,108	0,109 a
Anjico	4,84	5,08	5,13	5,02 a	0,109	0,100	0,093	0,101 a
Average application	4,86 A	4,96 A	4,98 A	--	0,111 A	0,105 A	0,099 A	--

Average followed by the same lowercase letters in columns and capitals in rows not differ each other by the Tukey test at 5% probabity. ns: no significant.
Source: Andrade, (2017).

The pH is a quality characteristic that influences the duration of thermal processing of the tomato pulp to obtain safe products (Asri et al., 2015). Thus, pH values above 4.5 require longer periods of sterilization of the raw material in thermal processing, leading to higher energy consumption and higher processing costs.

The tested hybrids obtained pH averages between 4.86 and 5.02, values higher than those found by Vieira et al. (2015) when studying the yield of table tomato varieties: 4.36 and 4.42. When evaluating the postharvest quality of tomato fruits as a function of calcium application, Vilas Boas (2014b) found a pH of 4.56. In turn, studying planting density and humic substances in tomato (*Solanum lycopersicum* L), Benetti et al. (2018) found pH values of 4.25 and 4.26.

Acidity is a factor of recognized importance when analyzing market acceptance. This factor regulates many chemical and microbiological reactions. In this test, acidity was not affected neither by the treatments nor by the interaction between the factors. The hybrids obtained similar results for the analysis, ranging from 0.093 to 0.120% (Table 5).

The titratable acidity (TA) value recommended for commercialization of fresh tomatoes is 0.4% (Vieira et al., 2014). In the present experiment, the TA found was lower than recommended, corroborating with Santos Neto et al. (2016). It should be noted that several factors interfere with the levels of organic acids in the fruits, such as maturation stage, nutrition, climatic condition, and mainly cultivar. It appears that the genetic variety of the material influences the analyzed variable. Most studies with Italian tomatoes report acidity values below 0.32%.

4. Conclusion

With the conditions described in this experiment, the different forms of calcium application have not proved to be very effective in reducing apical rot in the tested hybrids. Thus, further studies are needed addressing both the calcium source and its form of application. The different forms of calcium application in the plants of the evaluated hybrids had no effect on any of the evaluated characteristics. The hybrid Anjico stood out in postharvest quality assessments, with recommended cultivation in the Submedium São Francisco Valley.

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