Revista Brasileira de Ciências Agrárias
ISSN (on line) 1981-0997
v.17, n.3, e2438, 2022
Recife, PE, UFRPE. www.agraria.pro.br
DOI: 10.5039/agraria.v17i3a2438 - Protocol 2438
Subm. 22/03/2022 • App. 18/06/2022 • Pub. 08/09/2022

Foliar fertilizers with Ca prolong the firmness of Sweet Grape tomatoes during the post-harvest period

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ABSTRACT: The objective of this study was to evaluate the post-harvest quality of Sweet Grape tomatoes, with and without nutritional deficiency, subjected to sources and frequency of application of foliar fertilizers based on Ca. Two experiments were conducted with storage of the fruit in different climate chambers: 25 and 11 ºC. The experiments were conducted in a randomized block design with subdivided plots. The Ca sources used via foliar fertilization were allocated to the plots: calcium chloride and calcium acetate at a concentration of 0.3% Ca, and deionized water. In the sub-plots the frequencies of foliar fertilizer application (7 or 14 days) were allocated. The sub-sub-plots received the periods of fruit evaluation during storage (0, 9, 18, and 27 days). In each experiment and evaluation period, firmness, pH, soluble solids content, and titratable acidity of the fruit were determined. In both plants that received adequate and low Ca supply in the nutrient solution. Foliar fertilizer applications increased initial fruit firmness, regardless of the frequency of application, enabling longer storage time at both temperatures. There were no differences between the treatments in the evaluations referring to the taste of the fruits during the storage periods.

Key words: mineral nutrition; shelf life; *Solanum lycopersicum* L.

A aplicação de fertilizantes foliares com Ca prolongam a firmeza do tomate *Sweet Grape* durante o período pós-colheita

RESUMO: O objetivo deste estudo foi avaliar a qualidade pós-colheita do tomate *Sweet Grape*, com e sem deficiência nutricional, submetido a fontes e frequência de aplicação de fertilizantes foliares à base de Ca. Foram realizados dois experimentos com armazenamento dos frutos em diferentes câmaras climáticas: 25 e 11 ºC. Os experimentos foram realizados em delineamento de blocos casualizados e arranjo em parcelas sub-subdivididas. Alocaram-se nas parcelas as fontes de Ca usadas via fertilização foliar: cloreto de cálcio e acetato de cálcio na concentração de 0,3 % de Ca, e água desionizada. Nas sub-parcelas foram alocadas as frequências de aplicação dos fertilizantes foliares (7 ou 14 dias). As sub-sub-parcelas receberam as épocas de avaliação dos frutos durante a armazenagem (0, 9, 18 e 27 dias). Em cada experimento e época de avaliação foram determinados firmeza, pH, teor de sólidos solúveis e acidez titulável dos frutos. Tanto nas plantas que receberam suprimento adequado quanto naquelas que receberam baixo suprimento de Ca na solução nutritiva. As aplicações dos fertilizantes foliares aumentaram a firmeza inicial dos frutos, independentemente da frequência de aplicação, possibilitando um maior tempo de armazenamento em ambas as temperaturas. Não foram observadas diferenças entre os tratamentos nas avaliações que remetem ao sabor dos frutos durante os períodos de armazenagem.

Palavras-chave: nutrição mineral; vida de prateleira; *Solanum lycopersicum* L.

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Associate Editor: Severino Matias Alencar

Introduction

Tomatoes are a highly perishable fruit, demanding numerous efforts in their preservation (Menezes et al., 2017). Extending tomato post-harvest quality is an important way to minimize losses by providing greater flexibility for growers, intermediaries, retailers, and consumers during transportation, storage, marketing, and consumption of the fruit (Machado et al., 2020). Increasing the calcium (Ca) content in the fruit through pre-harvest foliar fertilization can be a strategic measure to maintain post-harvest quality longer.

Ca content in tomato fruits prolongs post-harvest quality (Islam et al., 2016). Ca gives stability to the cell wall, as it covalently binds with the pectins, giving rise to calcium pectate, restricting the action of hydrolytic enzymes, responsible for premature softening of the fruit (Aghdam et al., 2012; Pinheiro & Almeida, 2008). Fruit firmness is an important attribute, since a firmer fruit can have its shelf life extended (De Ketelaere et al., 2004).

In the plant, Ca moves exclusively through the xylem, so the arrival of the nutrient in the fruit depends on transpiration (Hocking et al., 2016). In tomato, problems caused by low Ca supply in the fruit are common, even with supplementation of the nutrient via soil, especially under conditions that reduce transpiration of the plant, such as: high relative air humidity and low soil water availability (Hagassou et al., 2019). Therefore, foliar Ca fertilization has been indicated in tomato cultivation as a complement to soil fertilization in order to improve plant Ca nutrition (Coolong et al., 2014; Melo et al., 2022). The Ca source, dose, and application frequency used for foliar fertilizer sprays can interfere with the efficiency and potential of this management (Fageria et al., 2009; Fernández et al., 2015).

Coupled with adequate Ca contents in the fruit, cooling is the most effective postharvest technique for shelf life extension, as it promotes the decrease of microbiological, physiological, and biochemical activity of the fruit, with consequent reduction of ethylene production (Samira et al., 2013). The limiting factor of refrigeration can be its high cost, considering its operation, maintenance and energy consumption needs, besides the expenses that involve equipment acquisition (Cortez et al., 2002).

The hypothesis of this study is that different Ca concentrations in the growing nutrient solution, different foliar fertilizers, and different frequencies of foliar Ca application alter the postharvest behavior of Sweet Grape tomato fruit, regardless of storage temperature. The objective of this study was to evaluate the postharvest quality of Sweet Grape tomatoes stored for different periods and at different temperatures in response to the foliar application of two calcium sources and two application frequencies, in plants with and without Ca deficiency.

Materials and Methods

The experiment was conducted from September to December in the greenhouse of the Agronomy Department of the Universidade Federal de Viçosa (UFV), Viçosa, MG, Brazil (20° 45’ 14” S, 42° 52’ 55” W, and 650 m of altitude). Forty days after sowing, the seedlings, with four pairs of fully expanded leaves, were transplanted into 8 L containers filled with coconut fiber (Golden Mix). The plants were spaced at 0.5 m between plants and 1.0 m in inner rows (2 plants m^{-2}), tied with string, driven with two stems, pruned when each plant had three leaves above the sixth flower cluster. Pruning of the lateral shoots was carried out throughout the experiment.

Two experiments were conducted in temperature controlled chambers at 25 and 11 °C. The experiments were conducted in a randomized block design in subdivided plots, with the different active ingredients used as foliar fertilizers allocated in the plots: 0.3% calcium chloride, 0.3% calcium acetate, and deionized water. In the sub-plots the frequencies of foliar fertilizer application (7 or 14 days) were allocated. In the subplots the evaluation periods of the fruits during storage (0, 9, 18, and 27 days). The plants from which the fruit were harvested were grown with and without Ca deficiency, by applying two doses of Ca in the nutrient solution: 1.5 and 3.0 mmol L^{-1} sufficient and deficient, respectively, according to (Fernandes et al., 2002). The experimental unit consisted of five fruits, and four repetitions were used per treatment.

Foliar fertilizer applications were started from the onset of flowering 22 days after transplanting. The amounts of foliar fertilizers applied were calculated according to the doses and spray volume recommended by the manufacturer for the respective products, so that each plant received 0.3% Ca and a fixed volume of 50 mL of solution in each application whatever the source employed. The fertilizers were applied using a handheld sprayer with a full cone nozzle. Plastic curtains were used positioned between the plants at the time of spraying, in order to avoid drifting the spray mixture onto plants that were not part of the treatment in question.

Eighty days after planting, mature commercial fruits from the third and fourth floral cluster were sampled, harvested according to the marketing standards determined by Sakata sudamerica®: weight between 5 to 18 g and absence of damage by cracking, by apical rot and by pests or diseases (Heath, 2012). The fruits were stored in PET packages with 20 units each, totaling approximately 200 g, and submitted to a 27-day storage period in temperature-controlled chambers. Five fruits were removed from each package at each evaluation time (0, 9, 18, and 27 days) to determine firmness, pH, soluble solids content and titratable acidity.

The firmness was determined using a bench penetrometer with 4.0 mm diameter tips. A 10 mL sample of juice was extracted from the fruit to determine the SS content (°Brix) with a digital refractometer, and the pH with a potentiometer. To determine titratable acidity, the juice was diluted with distilled water in a 1:20 ratio and titrated with solution of NaOH 0.005 mol L^{-1} to pH 8.1.

All data obtained in the study were subjected to analysis of variance using R software version 4.0.0 (R Core Team, 2018) and when there were differences or interactions between treatments, the averages were compared by Tukey test at

5% probability. Polynomial regression curves were fitted to measure the effect of storage times on the variables that showed differences between treatments.

Results and Discussion

The post-harvest quality analyses of the fruits showed that there was an influence of the application of both foliar fertilizers on the post-harvest quality, by increasing the firmness of the fruits, independently of the frequencies between applications (7 and 14 days). This occurred for the two doses of Ca supplied in the nutrient solution (1.5 and 3.0 mmol L^{-1}) and at the two storage temperatures (11 and 25 °C) (Tables 1 and 2). There was an interaction of active ingredients and storage time for fruit firmness (Table 3). Within the evaluations related to fruit flavor only the pH was altered as a function of the storage period (Tables 1 and 2) regardless of the foliar sprays that occurred on the plants with the different Ca sources (Table 3).

The application of both foliar fertilizers containing 0.3% calcium applied pre-harvest during the experimental period, regardless of the frequency between sprays was responsible for increasing initial firmness and promoting its greater maintenance during the storage period at both 25 and 11 C°. The effects occurred regardless of the Ca concentration in the nutrient solution (deficient or sufficient) (Figure 1). The significant loss of firmness over storage time is a natural process in many climacteric fruits. This occurs due to the increased activity of enzymes that act in the degradation of pectin, present in the cell walls, which have their activity increased as the fruit ripens (Park et al., 2005).

Foliar sprays of calcium chloride or calcium acetate, every 7 or 14 days, regardless of Ca concentrations supplied via roots (sufficient or deficient), elevate Ca contents in Sweet Grape tomato fruit by raising their firmness (Melo et al., 2022). Spraying 2% calcium chloride increases calcium accumulation in the fruit and consequently raises the firmness of cherry group tomatoes, prolonging postharvest quality (Islam et al., 2016).

Other studies have reported the positive influence of calcium chloride application on postharvest quality preservation through tomato fruit firmness (Gharezi et al., 2012; Rab & Haq, 2012; Genanew, 2013; Coolong et al., 2014). However, no studies have been found in the literature where the application of calcium acetate has been tested for post-harvest preservation of tomato fruits. Although the influence of this fertilizer has already been studied on apple trees, it has been shown that calcium acetate in pre-harvest was a possibility to increase the firmness of the fruit compared to the application of fertilizers, which are more usual: calcium chloride and calcium nitrate (Wójcik & Borowik, 2013).

Table 1. Firmness (F), soluble solids (SS), pH, titratable acidity (TA), and soluble solids to titratable acidity ratio (SS/TA) in Sweet Grape tomato fruits harvested from plants grown with 3.0 or 1.5 mmol of Ca in the nutrient solution, receiving different sprays of foliar calcium fertilizer sources: 0.3% calcium chloride or calcium acetate, applied at the frequency of 7 or 14 days after flowering, with storage of the fruits for 0, 9, 18, and 27 days at 25 °C.

Treatments	F (N)	SS (°Brix)	pH	TA (% citric acid)	SS/TA
3.0 mmol of Ca in the nutrient solution and storage at 25 °C					
(1) Spraying with $CaCl_2$	17.06a	7.70a	4.36a	0.54a	14.25a
Spraying with $Ca(C_2H_3O_2)_2$	17.39a	7.65a	4.42a	0.52a	14.71a
Spraying with water	14.40b	7.75a	4.46a	0.56a	13.83a
CV (%)	6.86	5.76	5.98	4.91	7.28
(2) Spray every 7 days	16.74a	7.68a	4.44a	0.55a	13.96a
Spraying every 14 days	15.83a	7.73a	4.38a	0.53a	14.58a
CV (%)	6.73	6.28	5.80	4.76	4.57
(3) 0 day after storage	23.47a	7.65a	4.32a	0.56a	13.64a
9 days after storage	16.82b	7.70a	4.38a	0.53a	14.57a
18 days after storage	15.14c	7.70a	4.46ab	0.55a	13.95a
27 days after storage	9.71d	7.75a	4.49b	0.52a	14.85a
CV (%)	9.90	7.12	9.80	6.65	5.70
1.5 mmol of Ca in the nutrient solution and storage at 25 °C					
(1) Spraying with $CaCl_2$	13.84a	7.67a	4.40a	0.55a	13.94a
Spraying with $Ca(C_2H_3O_2)_2$	12.83a	7.97a	4.38a	0.55a	14.49a
Spraying with water	11.36b	7.97a	4.42a	0.54a	14.75a
CV (%)	7.01	5.98	8.22	8.97	6.20
(2) Spray every 7 days	12.69a	7.80a	4.39a	0.55a	14.18a
Spraying every 14 days	12.67a	7.80a	4.41a	0.54a	14.44a
CV (%)	5.86	4.82	5.84	3.84	4.59
(3) 0 day after storage	20.48a	7.75a	4.32a	0.56a	13.81a
9 days after storage	14.47b	7.70a	4.38a	0.53a	14.57a
18 days after storage	8.71c	7.80a	4.44ab	0.55a	14.22a
27 days after storage	7.06d	7.95a	4.49b	0.54a	14.70a
CV (%)	9.66	8.17	6.88	7.87	12.70

Averages followed by equal letters do not differ by the F test 5% probability for (2) and Tukey test at 5% probability for (1) and (3).

Table 2. Firmness (F), soluble solids (SS), pH, titratable acidity (TA), and soluble solids to titratable acidity ratio (SS/TA) in Sweet Grape tomato fruits harvested from plants grown with 3.0 or 1.5 mmol of Ca in the nutrient solution, receiving different sprays of foliar calcium fertilizer sources: 0.3% calcium chloride or calcium acetate, applied at the frequency of 7 or 14 days after flowering, with storage of the fruits for 0, 9, 18, and 27 days at 11 °C.

Treatments	F (N)	SS (°Brix)	pH	TA (% citric acid)	SS/TA
		3.0 mmol of Ca in the nutrient solution and storage at 11 °C			
(1) Spraying with $CaCl_2$	17.81a	7.75a	4.46a	0.56a	13.83a
Spraying with $Ca(C_2H_3O_2)_2$	18.61a	7.55a	4.42a	0.54a	13.98a
Spraying with water	15.72b	7.90a	4.49a	0.53a	14.90a
CV (%)	8.97	5.60	4.20	6.90	6.20
(2) Spray every 7 days	17.70a	7.75a	4.47a	0.54a	14.35a
Spraying every 14 days	17.06a	7.70a	4.56a	0.52a	14.80a
CV (%)	8.38	5.20	5.80	5.80	5.50
(3) 0 day after storage	23.38a	7.70a	4.38a	0.56a	13.86a
9 days after storage	18.80b	7.70a	4.36a	0.53a	14.57a
18 days after storage	15.36c	7.75a	4.42ab	0.55a	14.06a
27 days after storage	11.99d	7.80a	4.59b	0.51a	15.31a
CV (%)	8.33	11.1	9.80	6.60	9.70
		1.5 mmol of Ca in the nutrient solution and storage at 11 °C			
(1) Spraying with $CaCl_2$	16.24a	7.85a	4.49a	0.56a	14.00a
Spraying with $Ca(C_2H_3O_2)_2$	14.86ab	7.80a	4.45a	0.54a	14.50a
Spraying with water	12.11b	8.10a	4.48a	0.53a	15.27a
CV (%)	20.00	5.60	4.25	6.51	6.10
(2) Spray every 7 days	14.48a	7.85a	4.47a	0.54a	14.50a
Spraying every 14 days	14.33a	7.90a	4.51a	0.52a	15.14a
CV (%)	3.32	5.30	6.31	6.81	5.02
(3) 0 day after storage	20.42a	7.85a	4.39a	0.56a	14.00a
9 days after storage	16.26b	7.80a	4.39a	0.53a	14.74a
18 days after storage	12.17c	7.90a	4.46ab	0.55a	14.30a
27 days after storage	8.77d	7.94a	4.57b	0.51a	15.56a
CV (%)	10.56	9.28	9.16	7.66	9.10

Averages followed by equal letters do not differ by the F test 5% probability for (2) and Tukey test at 5% probability for (1) and (3).

Table 3. Analysis of variance firmness (F), soluble solids (SS), pH, titratable acidity (TA), and soluble solids to titratable acidity ratio (SS/TA) in Sweet Grape tomato fruits harvested from plants grown with 3.0 or 1.5 mmol of Ca in the nutrient solution, receiving sprays with different sources of calcium: calcium chloride or 0.3% calcium acetate (SC), applied at the frequency of 7 or 14 days after flowering (F), with different storage periods of the fruits for 0, 9, 18, and 27 days (SP) at 25 and 11 °C, as well as their interactions SC × F, SC × SP, F × SP, and SC × F × SP.

Source of variation	F	SS	pH	TA	SS/TA	F	SS	pH	TA	SS/TA
			3.0 mmol of Ca in the nutrient solution and storage at 25 °C					1.5 mmol of Ca in the nutrient solution and storage at 25 °C		
SC	*	ns	ns	ns	ns	*	ns	ns	ns	ns
F	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SP	ns	ns	*	ns	ns	ns	ns	*	ns	ns
SC × F	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SC × SP	*	ns	ns	ns	ns	*	ns	ns	ns	ns
F × SP	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SC × F × SP	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
			3.0 mmol of Ca in the nutrient solution and storage at 11 °C					1.5 mmol of Ca in the nutrient solution and storage at 11 °C		
SC	*	ns	ns	ns	ns	*	ns	ns	ns	ns
F	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SP	ns	ns	*	ns	ns	ns	ns	*	ns	ns
SC × F	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SC × SP	*	ns	ns	ns	ns	*	ns	ns	ns	ns
F × SP	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SC × F × SP	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

* Significant by F test at 5% probability, ns = non-significant.

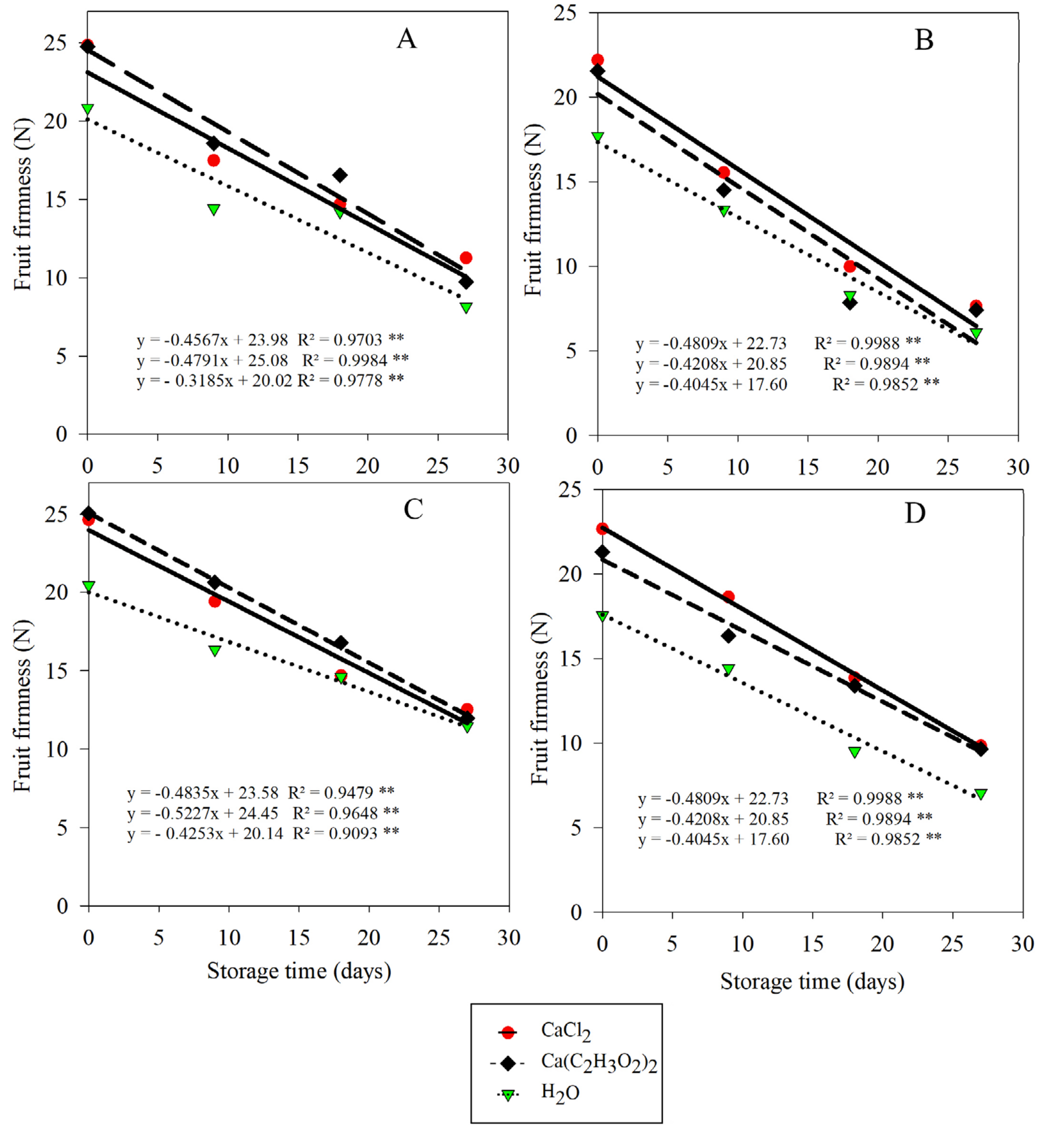

Figure 1. Unfolding of the interactions between storage time and products used in calcium-based foliar spraying: calcium chloride ($CaCl_2$) or calcium acetate [$Ca(C_2H_3O_2)_2$] both at 0.3% or water (H_2O), under the following conditions: (A) plants grown with 3.0 mmol L^{-1} of Ca in the nutrient solution and fruit stored at 11 °C; (B) plants grown with 1.5 mmol L^{-1} of Ca in the nutrient solution and fruit stored at 11 °C; (C) plants grown with 3.0 mmol L^{-1} of Ca in the nutrient solution and fruit stored at 25 °C; and, (D) plants grown with 1.5 mmol L^{-1} of Ca in the nutrient solution and fruit stored at 25 °C.

No differences were noted, of fruit firmness by varying the frequency of foliar fertilizer application (Tables 1, 2, and 3). The results indicate that there is no need to make weekly applications of calcium chloride or calcium acetate to maintain fruit firmness longer. Other studies show that sprays with foliar fertilizers containing Ca every two weeks are also sufficient to increase yield and reduce the number of tomato fruits with apical rot (Zamban et al., 2018; Melo et al., 2022).

When comparing the firmness values found for the doses of Ca applied in the nutrient solution (sufficient or deficient), it was possible to notice that the initial firmness of the fruits (0 days after harvest) was on average 13% higher when a dose of 3.0 mmol L^{-1} of Ca was applied in the nutrient solution compared to the use of 1.5 mmol L^{-1} of Ca (Tables 1 and 2). Similarly, the final firmness (27 days after harvest) of the fruit at was on average 26% higher when the adequate dose of Ca in the nutrient solution was employed compared to the insufficient dose (Tables 1 and 2).

Another factor that positively influenced the final firmness of the fruit was refrigeration, which guaranteed a 19 and 21% higher firmness at (27 days after harvest) for the sufficient and insufficient dose of calcium respectively (Tables 1 and 2). Low temperatures are the most effective means for extending the post-harvest shelf life of fruits and vegetables because they decrease the physiological, biochemical, and microbiological activities that cause the product to deteriorate and change its characteristics, including firmness (Samira et al., 2013).

As with fruits kept under refrigeration (Figure 1A and 1B), when both foliar fertilizers were applied pre-harvest, the firmness of fruits kept at room temperature was higher during the storage period (Figures 1C and 1D). Due to the high costs of keeping the fruits under refrigeration (Cortez et al., 2002), obtaining fruits with higher Ca contents by spraying with foliar fertilizers containing calcium chloride or calcium acetate at pre-harvest (Melo et al., 2022), may be an important measure to reduce the acceleration of firmness loss under the impossibility of preserving the fruits at low temperatures (Figures 1C and 1D).

The content of soluble solids (SS) was not influenced by the foliar application of Ca in the form of calcium chloride or calcium acetate, in the two doses of calcium supplied in the nutrient solution (1.5 and 3.0 mmol L^{-1}) and in the two storage conditions (11 and 25 °C). Nor was there significant variation in SS over storage time (Tables 1, 2, and 3). In tomatoes picked ripe the SS content varies very little during storage (Chitarra & Chitarra, 2005; Sati & Qubbaj, 2021). Other studies have also found that foliar application of calcium chloride (Rab & Haq, 2012; Coolong et al., 2014; Mazumder et al., 2021; Melo et al., 2022) or calcium acetate (Melo et al., 2022) does not influence the SS contents of tomato fruits.

There was no significant difference for fruit pH as a function of foliar application of calcium sources (Tables 1, 2, and 3). Similar behavior was verified for tomatoes of the Santa Cruz group that received foliar application of a calcium silicate-based fertilizer during their production phase (Coutinho et al., 2020). The pH of the pH of the fruit had increased with storage time, regardless of whether the plants were sprayed with foliar fertilizers (Tables 1, 2, and 3). This is possibly due to an increase in the population of microorganisms that consume organic acids predominant in tomato composition, causing an increase in pH and a decrease in acidity (Alshaibani & Greig, 1979).

The titratable acidity (TA) of the tomato flesh was not influenced by the application of both foliar fertilizers used (Tables 1, 2, and 3). Similar behavior was observed by Mazumder et al. (2021), who found that the application of calcium chloride at 1.0, 1.5, and 2.0% to tomatoes did not alter TA. Nor was there significant variation over storage time, regardless of the treatments (Tables 1, 2, and 3).

Like pH, SS, and TA, the SS/TA ratio did not vary in fruit harvested from plants that did or did not receive foliar sprays with both formulations (Tables 1, 2, and 3). The SS/TA ratio is a variable that relates greatly to fruit flavor (Chitarra & Chitarrra, 2005). Therefore, it is important that this variable remains stable throughout the shelf life.

Conclusions

Fruits from plants that receive foliar sprays every 14 days with calcium chloride or 0.3% calcium acetate have higher firmness, regardless of whether the plants are grown with different doses of Ca in the nutrient solution, and, whether they are stored at room temperature or under refrigeration.

Fruits from plants that receive foliar sprays every 7 or 14 days with calcium chloride or 0.3% calcium acetate do not have their flavor-related characteristics altered during storage.

Compliance with Ethical Standards

Author contributions: Conceptualization: ROM, HEPM; Data curation: ROM; Formal analysis: ROM, BCPR; Funding acquisition: HEPM; Investigation: ROM, HEPM; Methodology: ROM, HEPM; Visualization: ROM, HEPM, BCPR; Writing - original draft: ROM, HEPM; Writing - review & editing: ROM, HEPM, BCPR.

Conflict of interest: The authors declare that there are no conflicts of interest that could influence the article.

Financing source: The Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

Literature Cited

Aghdam, M.S.; Hassanpouraghdam, M.B.; Paliyath, G.; Farmani, B. The language of calcium in postharvest life of fruits, vegetables and flowers. Scientia Horticulturae, v.144, p. 102-115. 2012. https://doi.org/10.1016/j.scienta.2012.07.007.

Alshaibani, A.M.H.; Greig, J.K. Effects of stage of maturity, storage, and cultivar on some quality attributes of tomatoes. Journal of American Society for Horticultural Science, v.104, p.880-882, 1979.

Chitarra, M. I. F.; Chitarra, A. B. Pós-colheita de frutos e hortaliças: fisiologia e manuseio. Lavras UFLA, 2º edição revisada e ampliada, 2005. 783p.

Coolong, T.; Mishra, S.; Barickman, C.; Sams, C. Impact of supplemental calcium chloride on yield, quality, nutrient status, and postharvest attributes of tomato. Journal Plant Nutrition. v.37, n.14, p.2316-2330, 2014. https://doi.org/10.1080/01904167.2014.890222.

Cortez, L. A. B.; Honório, S. L.; Moretti, C. L. (Orgs.). Resfriamento de frutas e hortaliças. Brasília: Embrapa Hortaliças, 2002. 428 p.

Coutinho, P. W. R.; Echer, M. M.; Braga, G. C.; Guimarães, V. F.; Lana, M. C.; Alves, T. N.; Brito, T. S. Effect of pre-harvest calcium silicate on post-harvest quality of tomatoes. Research, Society and Development, v. 9, n.11, e74791110148, 2020. https://doi.org/10.33448/rsd-v9i11.10148.

De Ketelaere, B.; Lammertyn, J.; Molenberghs, G.; Desmet, M., Nicolaï, B.; De Baerdemaeker, J. Tomato cultivar grouping based on firmness change, shelf life and variance during postharvest storage. Postharvest Biology and Technology, v.34, n.2, p.187-201, 2004. https://doi.org/10.1016/j.postharvbio.2004.03.007.

Fageria, N.K.; Barbosa Filho, M.P.; Moreira, A.; Guimarães, C.M. Foliar fertilization of crop plants. Journal of Plant Nutrition, v. 32, p. 1044-1064, 2009. https://doi.org/10.1080/01904160902872826.

Fernandes, A. A.; Martinez, H. E. P; Fontes, P. C. R. Produtividade, qualidade dos frutos e estado nutricional do tomateiro tipo longa vida conduzido com um cacho, em cultivo hidropônico, em função das fontes de nutrientes. Horticultura Brasileira, v.20, n.4, p.564-570, 2002. https://doi.org/10.1590/S0102-05362002000400011.

Fernández, V.; Sotiropoulos, T.; Brown, P. Adubação foliar: fundamentos científicos e técnicas de campo. São Paulo: Abisolo, 2015. 150p.

Genanew, T. Effect of postharvest treatment on storage behavior and quality of tomato of fruit. World Journal of Agricultural Science, v.9, n.1, p.29-37, 2013.

Gharezi, M.; Joshi, N.; Sadeghlan, E. Effect of post-harvest treatment on stored cherry tomatoes. Journal of Nutrition & Food Sciences, v.2, n.8, e 1000157, p.1-10, 2012. https://doi.org/10.4172/2155-9600.1000157.

Hagassou, D.; Francia, E.; Ronga, D.; Buti, M. Blossom end rot in tomato (*Solanum lycopersicum* L.): A multi-disciplinary overview of inducing factors and control strategies. Scientia Horticulturae, v. 249, p.49-58, 2019. https://doi.org/10.1016/j.scienta.2019.01.042.

Heath, D.W. Sweet grape tomato line CHD 15-2114. Inventor: Douglas William Heath. US Patent US 8,097,792. Assignee: Seminis Vegetable Seeds. Concession: 17 Jan. 2012. https://www.google.com/patents/US8097792B2. 18 Mar. 2022.

Hocking, B.; Tyerman, S.; Burton, R.; Gilliham M. Fruit calcium: transport and physiology. Frontiers in Plant Science, v.7, e 00569, 2016. https://doi.org/10.3389/fpls.2016.00569.

Islam, M. Z.; Mele, M. A.; Baek, J. P.; Kang, H. M. Cherry tomato qualities affected by foliar spraying with boron and calcium. Horticulture, Environment, and Biotechnology, v.57, n.1, p.46-52, 2016. https://doi.org/10.1007/s13580-016-0097-6.

Machado, T. D. A.; Costa, A. G.; Rodrigues, R. E.; Santos, M. A. D.; Ribeiro, A. C. D. L.; Megguer, C. A. Quality of tomatoes under different transportation conditions by principal component analysis1. Revista Ceres, v.67, n.6, p.448-453, 2020. https://doi.org/10.1590/0034-737X202067060004.

Mazumder, M. N. N., Misran, A., Ding, P., Wahab, P. E. M., & Mohamad, A preharvest foliar spray of calcium chloride on growth, yield, quality, and shelf life extension of different lowland tomato varieties in Malaysia. Horticulturae, v.466, p.1-20, 2021. https://doi.org/10.3390/horticulturae7110466.

Melo, R. O.; Martinez, H. E. P.; Rocha, B. C P.; Garcia Junior, E. Production and quality of Sweet Grape tomato in response of foliar calcium fertilization. Revista Ceres, v. 69, n.1, p.48-54, 2022. https://doi.org/10.1590/0034-737X202269010007

Menezes, K. R. P.; Santos, G. C. S.; Oliveira, O. M., Sanches, A. G., Cordeiro, C. A. M.; Oliveira, A. R. G. Influência dos revestimentos comestíveis na preservação da qualidade pós-colheita de tomate de mesa. Cólloquium Agrariae, v. 13, n. 3, p.14-28, 2017. https://doi.org/10.5747/ca.2017.v13.n3.a170.

Park, S.; Ning H.C.; Jon, K.P.; Kil S.Y.;Park, J. Increased calcium levels and prolonged shelf life in tomatoes expressing arabidopsis H^+/Ca^{2+} transporters. Plant Physiology, v.139, n.3, p.1194-1206, 2005. https://doi.org/10.1104/pp.105.066266.

Pinheiro, S.C.F.; Almeida, D.P.F. Modulation of tomato pericarp firmness through pH and calcium: Implications for the texture of fresh-cut fruit. Postharvest Biology and Technology, v.47, n.1, p.119-125, 2008. https://doi.org/10.1016/j.postharvbio.2007.06.002.

R Core Team. R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing, 2018. https://www.R-project.org. 10 Dec. 2021.

Rab, A.; Haq, I. Foliar application of calcium chloride and borax influences plant growth, yield, and quality of tomato (*Lycopersicon esculentum* Mill.) fruit. Turkey Journal Agriculture, v.36, p. 695-701, 2012. https://doi.org/10.3906/tar-1112-7.

Samira, A.; Woldetsadik, K.; Workneh, T.S. Postharvest quality and shelf life of some hot pepper varieties. Journal of Food Science and Technology, v. 50, p.842-855, 2013. https://doi.org/10.1007/s13197-011-0405-1.

Sati, F.; Qubbaj, T. Effect of calcium chloride postharvest treatment in combination with plant natural substance coating on fruit quality and storability of tomato (*Solanum lycopersicum*) fruits during cold storage. Journal of Applied Botany and Food Quality, v.94, p.100-107, 2021. https://doi.org/10.5073/JABFQ.2021.094.012.

Wójcik, P.; Borowik, M. Influence of preharvest sprays of a mixture of calcium formate, calcium acetate, calcium chloride and calcium nitrate on quality and 'jonagold' apple storability. Journal of Plant Nutrition, v.36, n.13, p.2023-2034, 2013. https://doi.org/10.1080/01904167.2013.816730.

Zamban, D.T.; Prochnow, D.; Caron, B.O.; Turchetto, M.; Fontana, D.C.; Schmidt, D. Applications of calcium and boron increase yields of Italian tomato hybrids (*Solanum lycopersicum*) in two growing seasons. Revista Colombiana de Ciencias Hortícolas, v.12, n.1, p.82-93, 2018. https://doi.org/10.17584/rcch.2018v12i1.7338.