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Quality and postharvest life of tomato fruit (*Solanum lycopersicum* L.) produced under saline stress conditions

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ABSTRACT

Objective: To determine the post-harvest physiological behavior and quality changes of tomato fruit (*Solanum lycopersicum* L.) grown under saline stress conditions.

Design/methodology/approach: Tomato fruit quality variables (firmness, total soluble solids, titratable acidity and pH), along with respiration rate and weight loss were assessed at harvest and after seven days of storage at room temperature. These parameters were compared between fruit grown under saline stress (250 mM sodium chloride) and non-stressed control fruit.

Results: Tomato fruit grown under saline stress exhibited higher ($p<0.05$) total soluble solids (6.92 ± 0.22 °Brix) and titratable acidity ($0.39\pm0.03\%$), compared to the control fruit. No significant differences were observed in fruit firmness (13.01 N) or pH (5.86), at harvest time and after storage. The respiration rate decreased in both groups, from 30.77 mL CO_2 kg^{-1} h^{-1} at harvest time to 17.70 mL CO_2 kg^{-1} h^{-1} after storage; however, weight loss was not affected (11.50%).

Limitations on study/implications: Soil sampling in the production area, to measure the fruit quality and its post-harvest physiological behavior are needed on a larger scale.

Findings/conclusions: Saline stress increases the total soluble solids and titratable acidity, but does not affect the firmness, pH, weight loss and respiration rate of tomato fruit at harvest time and after storage at room temperature.

Keywords: Respiration rate, room storage, sodium chloride, saline stress.

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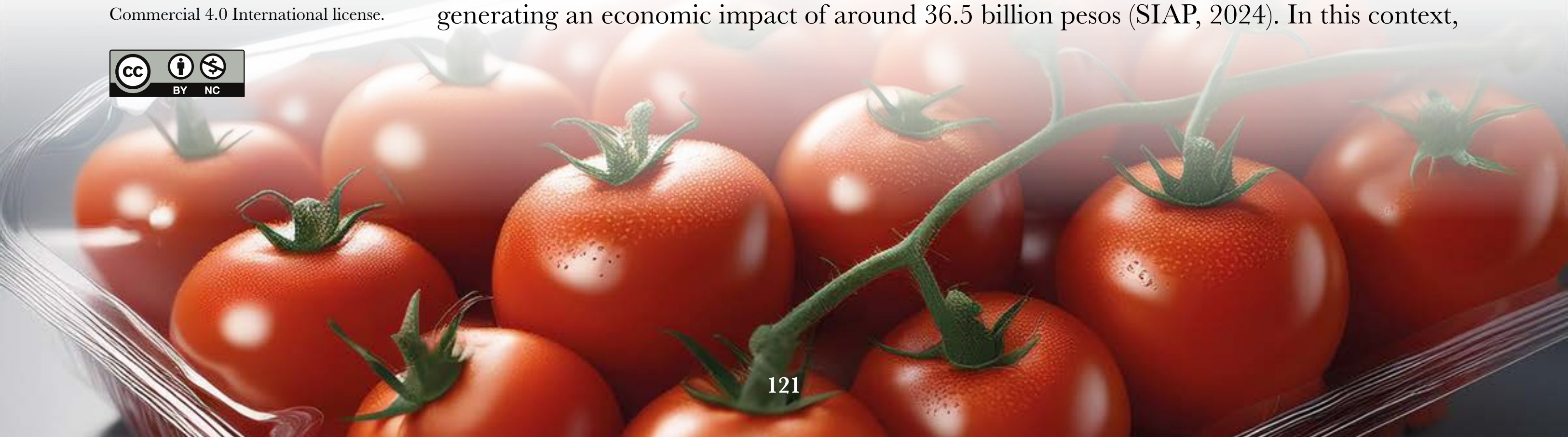
INTRODUCTION

In Mexico, the cultivation of tomato (*Solanum lycopersicum* L.) is carried out for both domestic consumption and export, primarily to North American countries (García-Estrada *et al.*, 2022). In 2023, more than 49,000 hectares in Mexico were dedicated to tomato production at varying technological levels, yielding approximately 3.6 million tons and generating an economic impact of around 36.5 billion pesos (SIAP, 2024). In this context,



San Luis Potosí ranked as the second state with the highest economic benefits derived from tomato cultivation (SIAP, 2024).

In arid and semi-arid regions, soils with high salinity levels are common (Bacha *et al.*, 2017), necessitating improvements in agricultural productivity (Wu *et al.*, 2022). Under these conditions, tomato cultivation is feasible despite it being a glycophyte (Hasegawa *et al.*, 2000); however, salinity can negatively impact its yield (Amador, 2022).

Various studies have shown that saline stress affects the physiology of tomato plants, reducing vegetative growth rate, root development, the number of fruit per plant, and consequently, yield (Singh *et al.*, 2011; Amjad *et al.*, 2014; Zhang *et al.*, 2016; Naeem *et al.*, 2020; Aguis *et al.*, 2022). It also induces other morphological and biochemical responses (Raza *et al.*, 2016; Bacha *et al.*, 2017), which are closely linked to the genotype and phenological stage of the plant (Alam *et al.*, 2021). However, subjecting the crop to moderate levels of water and saline stress can improve fruit quality (Ripoll *et al.*, 2016; Wang *et al.*, 2023), increasing the content of total soluble solids, titratable acidity, carotenoid levels, and lycopene content (Goykovic and Saavedra, 2007). Nevertheless, studies on the postharvest behavior of tomato fruit are scarce (Aguis *et al.*, 2022).

In the Potosino-Zacatecano Highlands region, soils and water with high salinity levels can be found, which may cause saline stress in tomato crops. Therefore, the objective of this research was to determine the postharvest physiological behavior and quality of tomato fruit (*Solanum lycopersicum* L.) produced under saline stress conditions.

MATERIALS AND METHODS

Study site and plant material

For this research, tomato fruit (*Solanum lycopersicum* L.) of the saladette type were used, produced under saline stress conditions in a greenhouse at the Experimental Area of the Coordinación Académica Región Altiplano Oeste of the Universidad Autónoma de San Luis Potosí, located in Salinas de Hidalgo, San Luis Potosí (22° 38' 28.5" N, 101° 42' 10.0" W).

Experimental design

The postharvest behavior of tomato fruit produced under saline stress conditions was determined in comparison to a control. For this, 15 tomato plants were irrigated with a solution of 250 mM sodium chloride (NaCl) every 72 hours for three weeks. The experimental unit consisted of five fruit and three replications. Under a completely randomized design with the following treatments: 1) Control at harvest, 2) Control after storage, 3) Saline stress at harvest, and 4) Saline stress after storage.

Response variables

The following quality variables were evaluated: firmness (N), total soluble solids (TSS) (°Brix), pH, and titratable acidity (% citric acid), as well as physiological variables including respiration rate (mL CO_2 kg^{-1} h^{-1}) and weight loss (%). These variables were measured in tomato fruit produced under saline stress and in control plants, both at harvest and after seven days of storage at room temperature.

Fruit firmness was measured using a GY-4 fruit penetrometer (Generic®, BW28) with a 3 mm diameter cylindrical probe, taking two opposite readings in the equatorial region (Al-Dairi *et al.*, 2021). The total soluble solids content was measured using a digital refractometer (Hanna®, HI96801, Japan). pH was measured with a digital potentiometer (OAKTON, pH700), and the titratable acidity was determined by titration, expressed based on citric acid (Flores *et al.*, 2007).

The respiration rate was determined using a closed system according to Pérez-López *et al.* (2014). For this, the fruit were weighed on a balance (OHAUS Scout®, H-7294) and placed inside a hermetic chamber of 3620 mL for 60 minutes. The change in CO_2 concentration was measured with an infrared CO_2 logger (DATALogger, Extech Instruments®, model CO210). The weight loss was determined according to the following equation.

$$wl(\%) = 100 * (w_0 - w_1) * (w_0)^{-1}$$

where: wl is the weight loss (%); w_0 is the initial weight of the fruit (g), and w_1 is the final weight of the fruit (g).

Data analysis

An analysis of variance and a mean comparison using the Tukey method (α=0.05) were performed for the quality variables and respiration rate, and the assumptions of normality (Shapiro-Wilk) and homogeneity of variance (Bartlett's test) were verified. Weight loss was compared using a t-test (α=0.05). The analysis was conducted in the R programming language (R-project® 4.3.3) using the RStudio® 2023.12.1 interface.

RESULTS AND DISCUSSION

In the analysis of variance, the assumptions of normality (p>0.60) and homogeneity of variance (p>0.15) were met. No significant difference (F=1.493, p=0.289) was found in the fruit firmness between the two salinity levels, both at harvest (13.54 N on average) and after storage (12.61 N on average) (Table 1). According to Wu *et al.* (2022), salinity stress conditions do not affect the firmness of these fruit. According to Naeem *et al.* (2020), fruit firmness increases under salinity conditions between 60 and 90 mM of NaCl; however, this behavior is related to the age of the plants (Botella *et al.*, 2001), which could explain the results of this study.

Table 1. Change in the quality variables of tomato fruit (*Solanum lycopersicum* L.) produced under different saline stress conditions.

Saline stress	Evaluation time	Firmness (N)	TSS (°Brix)	pH	Acidity (%)
Control	Harvest	14.42 ± 1.31^{a}	6.35 ± 0.14^{b}	6.20 ± 1.02^{a}	0.30 ± 0.04^{b}
Control	Storage	12.16 ± 0.08^{a}	6.32 ± 0.26^{ab}	5.59 ± 0.71^{a}	0.34 ± 0.04^{ab}
250 mM NaCl	Harvest	12.66 ± 1.31^{a}	6.95 ± 0.21^{a}	5.93 ± 0.70^{a}	0.38 ± 0.01^{a}
250 mM NaCl	Storage	13.06 ± 2.04^{a}	6.89 ± 0.28^{a}	5.71 ± 0.23^{a}	0.41 ± 0.04^{a}

* Means whith the same superscript whitin each column, have not significative difference (α=0.05).

The TSS content of the fruit showed a significant difference ($F=6.598$, $p=0.015$) between salinity levels. Fruit produced under high salinity conditions exhibited higher TSS content (6.94 °Brix). According to Wang *et al.* (2023), the increase in total soluble solids content is related to the use of saline water for irrigation. Similarly, Wu and Kubota (2008) state that TSS is directly related to electrical conductivity; higher salinity levels result in higher TSS, with values similar to those found in this study (5.20-6.20 °Brix). This behavior can be explained by the reduction in water content in the fruit (Wu *et al.*, 2022) and the accumulation of calcium, potassium, and chloride ions (Safdar *et al.*, 2019).

On the other hand, an increase ($F=6.556$, $p=0.015$) in titratable acidity was observed, rising from 0.30% to 0.41% in fruit produced under saline stress (Table 1). This behavior contrasts with the findings of Li *et al.* (2022), who report that saline stress reduces the content of organic acids and vitamin C in tomato fruit. However, this change in acidity percentage did not affect the pH ($F=0.999$, $p=0.441$). The fruit exhibited a reduction in respiration rate ($F=9.642$, $p=0.005$), decreasing from 30.77 mL CO_2 kg^{-1} h^{-1} at harvest to 17.70 mL CO_2 kg^{-1} h^{-1} after storage. However, no significant differences were found between fruit produced under saline stress (Table 2). After storage, no significant difference in weight loss were observed ($p>0.05$), with an average loss of 11.51% (Table 2). This result is higher than that reported by Villarreal-Romero *et al.* (2002) for long shelf-life tomatoes after 20 days of storage at 20 °C. The observed difference is attributed to relative humidity conditions and the cultivars used.

Table 2. Changes in physiological variables of tomato fruit (*Solanum lycopersicum* L.) produced under different saline stress conditions.

Saline stress	Evaluation time	Respiration rate (mL CO_2 kg^{-1} h^{-1})	Weigth loss (%)
Control	Harvest	31.00 ± 1.73^{a}	—
Control	Storage	18.42 ± 5.89^{b}	11.65 ± 0.13^{a}
250 mM NaCl	Harvest	30.54 ± 5.49^{a}	—
250 mM NaCl	Storage	16.98 ± 1.89^{b}	11.38 ± 3.39^{a}

* Means whith the same superscript whitin each column, have not significative difference ($\alpha=0.05$).

Tomato fruit produced under saline stress conditions show improvements in certain quality variables without affecting physiological processes such as respiration rate and weight loss. This prolongs their shelf-life under ambient temperature conditions, potentially increasing the commercialization period in local markets without the need for additional preservation technologies.

CONCLUSIONS

Salt stress increases the total soluble solids content and acidity percentage but does not affect firmness, pH, weight loss, or respiration rate in saladette tomato fruit (*Solanum lycopersicum* L.) at harvest or after 7 days of storage at room temperature.

REFERENCES

García-Estrada, R.S., A. Diaz-Lara, V. H. Aguilar-Molina and J.M. Tovar-Pedraza. (2022). Viruses of Economic Impact on Tomato Crops in Mexico: From Diagnosis to Management—A Review. *Viruses. 14*(1): 1251. https://doi.org/10.3390/v14061251

SIAP, (2024). Servicio de información Agroalimentaria y Pesquera, disponible en: nube.siap.gob.mx/cierreagricola/ (Fecha de consulta, noviembre de 2024).

Bacha H., Tekaya M., Drine S., Guasmi, F., Touil L., Enneb H., Triki T., Cheour F. and Ferchichi A. (2017). Impact of salt stress on morpho-physiological and biochemical parameters of *Solanum lycopersicum* cv. Microtom leaves. *South Afr. J. Bot*., 108, 364-369. https://doi.org/10.1016/j.sajb.2016.08.018

Wu Z., Y. Fan, Y. Qiu, X. Hao, S. Li and S. Kang. (2022). Response of yield and quality of greenhouse tomatoes to water and salt stresses and biochar addition in Northwest China. *Agricultural Water Management. 270*(1):107736. https://doi.org/10.1016/j.agwat.2022.107736

Hasegawa, P. M., R. A. Bressan, J. K. Zhu and H. J. Bohnert. (2000). Plant Cellular and Molecular Responses to High Salinity. *Annu. Revista Plant Physiol. Plant Mol. Biol.* 51:463-499. https://doi.org/10.1146/annurev.arplant.51.1.463

Amador C. Ávila, Algentel-Martínez L., Peñuelas-Rubio O., González Aguilera J. and Reyna I. F. (2022). Response of the tomato crop (*Solanum lycopersicum* L.) to the application of QuitoMax® in salinity conditions. *Research, Society and Development. 11*(12). p. e10111233870. https://doi.org/10.33448/rsd-v11i12.33870

Singh, J., E.V. D. Sastry and V. Singh. (2011). Effect of salinity on tomato (*Lycopersicon esculentum* Mill.) during seed germination stage. *Physiol Mol Biol Plants. 18*(1): 45-50. https://doi.org/10.1007/s12298-011-0097-z

Amjad, M., J. Akhtar, M. Anwar-ul-Haq, R. Ahmad and M. Zaid. (2014). Characterization of Comparative Response of Fifteen Tomato (*Lycopersicon esculentum* Mill.) Genotypes to NaCl Stress. *Revista Sci. Tech.* 16:851-862. https://doi.org/10.1016/j.jssas.2018.11.001

Zhang, P., M. Senge and Y. Dai. (2016). Effects of salinity stress on growth, yield, fruit quality and water use efficiency of tomato under hydroponics system. *Reviews in Agricultural Science. 4*(1): 46-55. https://doi.org/10.7831/ras.4.46

Naeem, M., A. Basit, I. Ahmad, H. I. Mohamed and H. Wasila. (2020). Effect of Salicylic Acid and Salinity Stress on the Performance of Tomato Plants. *Journal of Crop Health. 77*(1): 393-402. https://doi.org/10.1007/s10343-020-00521-7

Aguis, C., S. von Tucher and W. Rozhon. (2022). The Effect of Salinity on Fruit Quality and Yield of Cherry Tomatoes. *Horticulture. 8*(1): 59. https://doi.org/10.3390/horticulturae8010059

Raza, M. A., A. Saeed, H. Munir, K. Ziaf, A. Shakeel, N. Saeed, A. Munawar and F. Rehman. (2017). Screening of tomato genotypes for salinity folerance based on early growth attributes and leaf inorganic osmolytes. *Revista Agron. Soil Sci. 63*(4):501-512. https://doi.org/10.1080/03650340.2016.1224856

Alam, M.S., Tester, M., Fiene, G. and M.A.A. Mousa. (2021). Early Growth Stage Characterization and the Biochemical Responses for Salinity Stress in Tomato. *Plants*.10: 712. https://doi.org/10.3390/plants10040712

Ripoll, J., Urban, J., Brunel, B. and N. Bertin. (2016). Water deficit effects on tomato quality depend on fruit developmental stage and genotype. *J. Plant Physiol.* 190:26-35. http://dx.doi.org/10.1016/j.jplph.2015.10.006

Wang X., W. Tian, W. Zheng, S. Shah, J. Li, X. Wang and X. Zhang. (2023). Quantitative relationships between salty water irrigation and tomato yield, quality, and irrigation water use efficiency: A meta-analysis. *Agricultural Water Management* 280:108213. https://doi.org/10.1016/j.agwat.2023.108213

Goykovic Cortes, V. y G. Saavedra del Real. (2007). Algunos efectos de la salinidad en el cultivo del tomate y prácticas agronómicas de su manejo. *Revista IDESIA*. 25: 47-58. https://www.scielo.cl/pdf/idesia/v25n3/art06.pdf

Al-Dairi, M., Pathare, P.B. and R. Al-Yahyai. (2021). Effect of Postharvest Transport and Storage on Color and Firmness Quality of Tomato. *Horticulturae.* 7:163. https://doi.org/10.3390/horticulturae7070163

Flores, F.B., Romojaro, F., Latché, A., Pech, J.C. and M.C. Martínez-Madrid (2007). Assay of a potential post-harvest handling procedure for Cantaloupe Charentais melon fruit with inhibited ethylene production. *J. Sci. Food Agric*. 87, 2034-2039. https://doi.org/10.1002/jsfa.2955

Pérez-López, A., S.H. Chávez-Franco, C.A. Villaseñor-Perea, T. Espinosa-Solares, L.H. Hernández-Gómez and C. Lobato-Calleros. (2014). Respiration rate and mechanical properties of peach fruit during storage at three maturity stages. *Journal of Food Engineering. 142*(1): 111-117. https://doi.org/10.1016/j.jfoodeng.2014.06.007

Wu, M. and C. Kubota. (2008). Effects of high electrical conductivity of nutrient solution and its application timing on lycopene, chlorophyll and sugar concentrations of hydroponic tomatoes during ripening. *Revista Sci. Hortic*. 116:122-129. https://doi.org/10.1016/j.scienta.2007.11.014

Botella, M.A., F. del Amor, A. Amorós, M. Serrano, V. Martínez and A. Cerdá. (2001). Polyamine, ethylene and other physico-chemical parameters in tomato (*Lycopersicon esculentum*) fruits as affected by salinity. 109(1): 428-434. https://doi.org/10.1034/j.1399-3054.2000.100409.x

Li C., S. Wan, X. Li, Y. Kang and X. Han. (2022). Effect of water-salt regulation drip irrigation with saline water on tomato quality in an arid region. *Agricultural Water Management. 261*(1):107347. https://doi.org/10.1016/j.agwat.2021.107347

Safdar, H., A. Amin, Y. Shafiq, A. Ali, R. Yasin, A. Shoukat, M.U. Hussan and M. I. Sarwar. (2019). A review: Impact of salinity on plant growth. *Nature and Science. 17*(1): 34-40. https://doi.org/10.7537/marsnsj170119.06

Villarreal-Romero, M., R.S. García-Estrada, T. Osuna-Enciso y A.D. Armenta-Bojórquez. (2002). Efecto de dosis y fuente de nitrógeno en rendimiento y calidad postcosecha de tomate en fertirriego. *Terra Latinoamericana. 20*(3): 311-320.