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SODIUM CHLORIDE ON BIOACTIVE COMPOUNDS OF EGGPLANT (*Solanum melongena* L.) GROWN IN HYDROPONICS UNDER TWO PROTECTED STRUCTURES

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ABSTRACT

The consumption of fruits and vegetables of nutritional quality increases due to their high amounts of bioactive compounds with antioxidant activity, to prevent diseases and improve health. The hypothesis is that salinity, light and temperature in different protected structures influence the chemical composition and nutritional value of eggplant (*Solanum melongena* L.) fruits. The objective was to evaluate the effect of different doses of sodium chloride (NaCl) on the concentration of bioactive compounds in eggplant fruits grown in hydroponics under greenhouse and shade mesh. Eggplants were grown in a hydroponic system in pots with tezontle. The experimental design was completely randomized with a 4 × 2 factorial arrangement, four doses of NaCl (0, 15, 30 and 45 mM) and two protected structures (greenhouse and shade mesh). The variables evaluated were fruit weight, firmness, total soluble solids (SST), titratable acidity (AT), sodium, vitamin C, phenols, total flavonoids and antioxidant activity. Fruits obtained from plants grown in greenhouses with 45 mM NaCl decreased 35.9 % in weight compared to fruits from the 30 mM NaCl shade mesh treatment; and increased 51.9 % in firmness compared to the 15 mM NaCl treatment under shade mesh. The 15 mM NaCl dose under shade mesh increased SST by 95.8 % compared to the 30 mM NaCl treatment in the greenhouse. Under shade mesh without salinity, the highest AT in fruits was obtained; also, it was observed that the AT of fruits under shade mesh was 60.5 % higher than the AT of fruits in the greenhouse; regardless of the NaCl dose. The highest fruit concentration was found in the 45 mM NaCl treatment in the greenhouse. Under shade mesh with 15 mM NaCl dose, the lowest concentration of vitamin C in fruit was recorded, being 37 % lower than the concentration of vitamin C with the same dose in the greenhouse. No significant differences were found in phenols and total flavonoids. Fruits from plants under shade mesh with the 30 mM NaCl dose had 165.2 % more antioxidant capacity than fruits from plants under shade mesh without salinity. It is concluded that the environmental conditions of temperature and radiation in the greenhouse promoted an increase in the concentration of bioactive compounds in eggplant fruits, which provides greater nutritional value.

Keywords: environment, antioxidants, stress, health, *Solanum melongena* L.

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INTRODUCTION

Eggplant (*S. melongena*) is an agronomically important plant, grown and consumed in many countries (Cericola *et al*., 2014), contains bioactive compounds considered as nutraceuticals (Lo Scalzo *et al*., 2016). It is among the top 10 vegetables in terms of antioxidant content (Philippi *et al*., 2016). The consumption of fruits and vegetables containing these compounds, have a beneficial effect on health as it helps in the prevention of various diseases in humans (Perin *et al*., 2019).

The generation of technology or agronomic practices that positively regulate the synthesis and accumulation of secondary metabolites in plants is important to influence the antioxidant content in fruits (Perin *et al.,* 2019). Some practices that can be used include fertilizer application, planting date, irrigation efficiency and maturity at harvest, in addition to environmental factors, such as soil moisture, temperature and solar radiation, which stimulate the concentration of certain metabolites (Zou *et al*., 2016). Light conditions inside a greenhouse change according to the cover materials, by filtering solar radiation or reducing light intensity. These materials are associated with plant quality, in visual properties, organoleptic properties and chemical composition (Rouphael *et al*., 2018). Environmental changes affect the production of phenolic compounds as a response and adaptation mechanism of plants (Bacha *et al*., 2017). In strawberry varieties grown under high radiation, the content of total phenols and flavonoids increased (Cervantes *et al*., 2019) and in tomato plants grown under high temperature, the concentration of vitamin C increased (Botella *et al*., 2021).

On the other hand, the response of greenhouse vegetables to salt stress depends on different factors, including genetic material, climatic conditions, phenological stage, duration of stress exposure, concentration and type of salt (Rouphael *et al*., 2018). Salinity by NaCl can cause positive effects on fruit quality, improves bioactive compounds such as vitamin C and antioxidant activity (Petropoulos *et al.,* 2017). With doses of 25 and 50 mM NaCl increases flavonoid content in eggplant (Shishira *et al.,* 2016). Doses of 60 mM NaCl in thyme (*Thymus vulgaris* L. and *Thymus daenensis* L.) increase total phenols (Bistgani *et al*., 2019); likewise, 50 mM NaCl dose increases antioxidant activity in edible flowers of *Tagetes patula* L. (Chrysargyris *et al*., 2018).

According to the above, environmental conditions and salinity affect crop quality, chemical composition and nutritional value. Therefore, the objective of this study was to evaluate the effect of different doses of sodium chloride (NaCl) on the concentration of bioactive compounds of eggplant fruits grown in hydroponics in greenhouse and under shade mesh.

MATERIALS AND METHODS

Plant material and growing conditions

The experiment was conducted in the summer-autumn cycle (June-December) of 2019, in the hydroponics area of the Faculty of Agronomy and Veterinary Medicine, in San Luis Potosi, Mexico. The structures used were a tunnel type greenhouse with dimensions 5.5 x 18 m with a white plastic cover and a chapel type shade mesh with the same dimensions and a black mesh cover. In the greenhouse, the average temperature was 23 °C with an average light intensity of 325.74 μmol m^{-2} s^{-1}; under the shade mesh the average temperature was 17 °C with an average light intensity of 183.22 μmol m^{-2} s^{-1}. This was measured with a HOBO logger (Onset UA-002-08 Pendant Temperature/Light Data Logger) in each structure.

Eggplant 'Black Beauty' (Caloro®) was used as plant material with a germination percentage of 85 %, which was sown in polystyrene trays with 220 cavities, with a commercial substrate based on acid peat BM2 Berger®. At 60 d after sowing, they were transplanted to 10 L black plastic pots, with red tezontle as substrate with a granulometry of 5 to 6 mm. Seedlings with 12 cm height and four true leaves were used for transplanting, with 80 seedlings in each protected structure with a total of 160 plants, under a drip irrigation system.

The crop was irrigated with Steiner's universal solution (molc m^{-3}): 12 NO_3^-, 7 SO_4^{-2}, 1 $H_2PO_4^-$, 9 Ca^{+2}, 7 K^+ and 4 Mg^{+2}. The fertilizers used were $Ca(NO_3)_2$ $4H_2O$, KNO_3, $MgSO_4$ $7H_2O$, K_2SO_4 and H_3PO_4. Micronutrients were added from Carboxy® Micro, which provided in mg L^{-1}: Fe 0.5, Zn 0.25, Mn 0.1, Mg 0.05 and B 0.05 in EDDHA chelated form. The pH of the solution was adjusted with H_3PO_4 to 5.5.

At 54 d after transplanting (start of flowering), the treatments were applied to the two structures, NaCl (J. T. Baker™, USA) was added to the Steiner solution at four doses: 0 (as control), 15, 30 and 45 mM.

Treatment design and experimental design

The experiment was conducted in a completely randomized design. The treatments had a 4 × 2 factorial arrangement, where the four doses of NaCl were 0, 15, 30 and 45 mM and two protected structures, greenhouse and shade mesh. The experimental unit was one plant and 20 replicates per treatment were established.

Determination of weight at harvest, firmness and sodium concentration in fruits

Mature fruits were harvested when they acquired a shiny black coloration, this was from 105 d after the application of the treatments and were weighed on a digital scale (Ohaus® PAJ4102N Gold series, USA), the weight was reported in grams. Firmness was measured with a penetrometer (QA Supplies, USA) with 11 mm plunger tip. For sodium concentration in the fruit, a two gram portion of the fruit was cut, ground in a mortar and pestle, and four drops were added to the ionometer for readings (Na+ Laqua Twin Compact Ion Meter, Horiba, Kyoto, Japan).

Determination of bioactive compounds in fruits

For the evaluation of the concentration of bioactive and organoleptic compounds, four samples of ripe fruits were taken per treatment 100 d after the application of the treatments, washed with distilled water and dried in a forced air drying oven (Omron, Kyoto, Japan) at 70 °C until a constant weight was obtained. The dried fruits were ground (Krups mill, Mexico) to obtain powder, which was used for the analysis.

Total soluble solids (SST) and titratable acidity (AT)

Extracts were prepared with 0.1 g of dry sample in 12 mL of distilled water in a digital T 25 homogenizer (ULTRA-TURRAX®, IKA, USA) and filtered to determine total soluble solids and titratable acidity.

SST were determined in two drops of the filtrate which were placed in a digital pocket refractometer (PAL-1, Atago®, Japan) and the results were reported in °Brix. AT was determined according to the methodology described by AOAC (1990), using phenolphthalein as indicator and the results were expressed as percentage of citric acid.

Vitamin C

For vitamin C analysis, 0.1 g of dry fruit sample was homogenized in 11 mL of distilled water in a digital T 25 homogenizer (ULTRA-TURRAX®, IKA, USA) and filtered. Ascorbic acid was determined according to the spectrophotometric method described by da Silva *et al*. (2017) with some modifications. Briefly, 1 mL of homogenized and filtered sample was added to a beaker, 1 mL of a 1.5 % (w/v) acetate-urea solution, 3 mL of a 0.075 % (w/v) cupric acetate-cuproin solution and 5 mL of absolute ethanol. The absorbance was measured at 545 nm. Quantification was performed with an ascorbic acid calibration curve and the results are reported as ascorbic acid (AA) concentration in mg mL^{-1}.

Phenols

Total phenols were determined using the Folin-Ciocalteu spectrophotometric method (Singleton *et al*., 1999), with some modifications. For the extract, 0.1 g of dry fruit sample was homogenized in 11 mL of distilled water in a digital T 25 homogenizer (ULTRA-TURRAX®, IKA) and filtered. 200 μL of the sample was placed with 300 μL of distilled water in test tubes, plus 2.5 mL of Folin-Ciocalteu and 2 mL of $NaCO_3$. The samples were left to stand in a dark chamber for 2 h and the absorbance was measured at 760 nm. The standard curve was performed with gallic acid and the results are expressed in mg gallic acid equivalents (EAG) g^{-1} dry weight.

Flavonoids

The concentration of total flavonoids was determined according to the modified $AlCl_3$ method (Arvouet-Grand *et al*., 1994). For the extract, 0.2 g of dry sample was used in 12 mL of absolute methanol in a digital T 25 homogenizer (ULTRA-TURRAX®, IKA, USA) and filtered. From this sample, 2.5 mL were taken and 2 mL of $AlCl_3$ were added and incubated in a dark chamber for 10 min. The absorbance of the samples was measured at 415 nm in a UV-Vis spectrophotometer (GENESYS 10S, Thermo Scientific™, USA). A quercetin standard curve was performed and the results were expressed as mg quercetin equivalents (EQ) g^{-1} dry weight.

Antioxidant activity

Antioxidant activity was determined by the ABTS method described by Terán-Erazo *et al*. (2019).

Statistic analysis

With the data obtained, analysis of variance and Tukey mean comparison tests ($p \leq 0.05$) were performed using the SAS statistical program v. 9.0 (SAS Institute Inc., 2002). In addition, a correlation analysis (Pearson correlation coefficients) and a principal component analysis were performed with Minitab v. 16 statistical package (Minitab Institute Inc., 2010).

RESULTS AND DISCUSSION

Fruit weight

Eggplant fruit weight was influenced by the climatic conditions in the structures used; the interaction of the study factors caused significant differences (Table 1). Fruits obtained from eggplant plants grown in greenhouses with 45 mM NaCl were 35.9 % lighter than fruits from the 30 mM NaCl treatment with shade mesh (Table 1). In this study, fruit weight was more affected by NaCl when the greenhouse temperature was 23 °C. In eggplant, it has been reported that, mean air temperature between 22 and 19 °C in greenhouse increases fruit weight compared to those grown at temperatures of 11 °C (Valerga *et al*., 2019). In tomato grown at 25 °C, the application of 60 mM NaCl decreased fruit weight by 35 %; with temperature of 35 °C, NaCl decreased fruit weight by 58 % in regard to the control grown with 1 mM NaCl at 25 °C (Botella *et al.*, 2021). On the other hand, salinity caused by the administration of 30, 60 and 90 mM NaCl decreased yield in native Mexican tomato genotypes, with the greatest decreases recorded in Campeche, in the order of 71.1, 80.1 and 89.6 %, respectively, all cases compared to the control without salinity (Ladewig *et al*., 2021).

Table 1. Quality of eggplant fruits grown under two types of protected structures and different doses of NaCl.

Factor Level	Fruit weight (g)	Firmness (kg)	Total soluble solids (°Brix)	Titratable acidity (%)
Interaction (EP × NaCl)				
I[†], 0	428.43 ab	7.67 abc	8.40 bc	3.57 c
I, 15	453.73 ab	7.50 abc	7.50 bc	2.91 c
I, 30	431.30 ab	8.30 ab	7.20 c	2.83 c
I, 45	346.00 b	9.22 a	9.30 abc	3.36 c
MS[¶], 0	414.38 ab	7.70 abc	12.60 ab	6.48 a
MS, 15	500.20 a	6.07 c	14.10 a	6.16 ab
MS, 30	539.85 a	6.85 bc	9.30 abc	3.97 bc
MS, 45	463.70 ab	6.17 c	9.00 abc	3.73 c
DMSH[§]	147.22	2.02	5.28	22.21
CV[Þ]	14.05	11.63	23.34	22.92

Means with different letters in each column are statistically different (Tukey, $p \leq 0.05$). [†]I: greenhouse; [¶]MS: shade netting; [§]DMSH: least significant difference; [Þ]CV: coefficient of variation.

Firmness

Fruits grown in greenhouse and with 45 mM NaCl doses had 51.9 % higher firmness compared to 15 mM NaCl under shade mesh, this effect can be attributed to increased light and temperature (Table 1). In contrast, Valerga *et al.* (2019) mentioned that firmness in eggplant fruits grown in greenhouse showed dissimilar changes according to harvest conditions; at temperatures of 22 °C, it decreased 38 % compared to temperatures of 11 °C. In tomato plants grown at 35 °C with 60 mM NaCl, fruit firmness decreased by 22 % in relation to fruit grown at 25 °C (Botella *et al*., 2021). In tomato fruits with doses of 30 mM NaCl did not affect firmness, in contrast, with doses of 60 and 90 mM it increased by 10 % (Naeem *et al*., 2020). Garriga *et al*. (2015) mentioned that the toxicity effects of Na^+ and Cl^- ions increase the activity of pectinases and other enzymes that degrade cell wall, therefore, firmness decreases.

Total soluble solids

The 15 mM NaCl dose in combination with shade mesh increased SST in fruits by 95.8 % compared to 30 mM NaCl doses in greenhouse (Table 1). Ilić and Fallik (2017) report that under black mesh the transmission of blue light is higher and therefore, the plant has higher photosynthate production, which increases soluble solids in fruits. Also, high doses of NaCl promote higher SST content; in tomato plants grown with 60 mM NaCl at 25 and 35 °C, total soluble solids increased by 15 and 10 %, compared to the control with 1 mM NaCl (Botella *et al*., 2021). In native tomato genotypes, doses 30, 60 and 90 mM NaCl caused increases from 25 % in total soluble solids (Ladewig *et al*., 2021). Also in tomato, the addition of 50 and 100 mM NaCl to the nutrient solution increased total soluble solids by 80 % compared to the control (Carbajal-Vazquez *et al*., 2020). In eggplant crop, upon application of 40 mM NaCl sugars such as sucrose, glucose and fructose accumulated in response to salt stress, as they function as osmolytes to maintain cell turgor and protect membranes and proteins (Hannachi and Van Labeke, 2018).

Titratable acidity

The highest fruit AT was obtained in plants grown under shade mesh and without salinity, which exceeded by 128.9 % the value of fruits of plants treated with 30 mM NaCl in the greenhouse. Likewise, the treatment without salinity under shade mesh resulted in an average increase of 104.5 % in fruit AT compared to the value of fruits obtained in the greenhouse with all NaCl levels (0, 15, 30 and 45 mM; Table 1). Salt stress caused by the addition of 50 and 100 mM NaCl to the nutrient solution increased titratable acidity by 63.6 and 65.9 % in tomato fruits, compared to the control (Carbajal-Vázquez *et al*., 2020). Likewise, in tomato fruits from plants treated with 60 mM NaCl at 25 °C increased acidity by 26 %; whereas, at 35 °C there was no effect of NaCl (Botella *et al*., 2021). In tomato, acidity increased by 39 % with 50 mM NaCl, which was attributed to the increase in the content of organic acids involved in the osmoregulation mechanism of plants under high salinity conditions (Costan *et al*., 2020). On the contrary, in pepper fruits the application of 20.1 mM NaCl had no effect on titratable acidity (Giuffrida *et al*., 2014).

Sodium in fruits

Fruits from plants grown in greenhouses with 45 mM NaCl doses showed higher sodium concentrations, exceeding on average 60 % of fruits from plants treated with 30 and 45 mM NaCl under shade mesh (Figure 1). In 'Black Beauty' eggplant plants, NaCl stress elicited an osmoregulatory response by accumulating Na^+ and Cl^- and decreasing K^+, Ca^{+2}, Mg^{+2} and NO_{3-} (Hannachi and Van Labeke, 2018). The WHO recommends an intake of 2 g Na^+ day^{-1} in adults (WHO, 2012). In this case, assuming an annual per capita consumption of eggplant of 700 g in Mexico, the sodium concentration obtained in this study with doses of 30 and 45 mM NaCl in greenhouse-grown fruits represents only 11 % of the recommended daily intake, therefore, the consumption of eggplant fruits with NaCl doses does not represent any health risk.

Flavonoids

The type of structure where the eggplant was grown, the application of NaCl doses and the interaction of the factors under study did not significantly affect the concentration of flavonoids in the fruits (Table 2). Contrary to what was observed here, Cervantes *et al*. (2019) found that flavonoid content increased 29 % in strawberry 'Fortuna' fruits exposed to light intensity of 1100 μmol m^{-2} s^{-1} in macrotunnel, with respect to 440 μmol m^{-2} s^{-1}. Brenes *et al*. (2020) found no effect on total flavonoids in eggplant plants with doses of 50, 100, 200 and 300 mM NaCl. In contrast, Shishira *et al*. (2016) indicated that in eggplant under salt stress the amount of total flavonoids increased with doses of 25 and 50 mM NaCl by 26 and 64 % compared to the control without salinity.

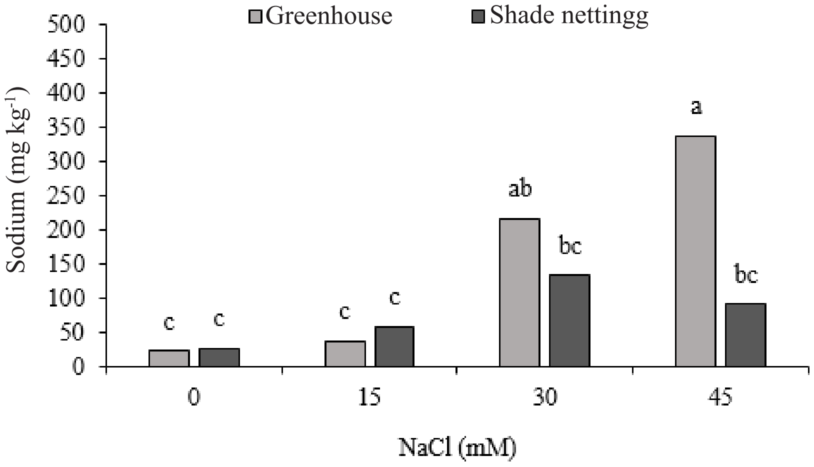

Figure 1. Sodium concentration in eggplant fruits from plants in response to the interaction protected structure and NaCl dose. Means with different letters in each subfigure are statistically different (Tukey, $p \leq 0.05$).

Table 2. Concentration of flavonoids and total phenols in eggplant fruits grown under two types of protected structures and different doses of NaCl.

Factor Level	Total flavonoids (mg EQ g^{-1})	Total phenols (mg EAG g^{-1})
Protected structure (EP)		
I	73.92 a	507.93 a
M	74.79 a	429.81 b
DMSH	11.36	77.44
NaCl (mM)		
0	74.35 a	519.64 a
15	71.33 a	514.91 a
30	72.82 a	381.13 a
45	78.92 a	459.80 a
DMSH	21.65	147.56
Interaction (EP × NaCl)		
I[†], 0	71.65 a	517.09 a
I, 15	66.93 a	543.31 a
I, 30	74.64 a	467.56 a
I, 45	82.60 a	503.74 a
MS[¶], 0	77.07 a	522.19 a
MS, 15	75.74 a	486.50 a
MS, 30	71.02 a	294.70 a
MS, 45	75.34 a	415.85 a
DMSH[§]	37.00	252.18
CV[þ]	20.48	22.14

Means with different letters in each column and study factor are statistically different (Tukey, $p \leq 0.05$). [†]I: greenhouse; [¶]MS: shade netting; [§]DMSH: least significant difference; [þ]CV: coefficient of variation.

Phenols

Fruits harvested from greenhouse-grown plants showed 18.1 % higher phenolic concentrations than fruits of plants under shade mesh (Table 2). Light intensity under shade mesh was 183 µmol m^{-2} s^{-1} and in greenhouse 326 µmol m^{-2} s^{-1}, which increased the total phenolic concentration. With the doses of NaCl applied, no significant differences were detected in phenols in fruits (Table 2), the concentrations ranged between 400 and 580 mg EAG 100 g^{-1}. Brenes *et al*. (2020) found that doses of 50, 100, 200 and 300 mM NaCl did not affect the total phenolic content in eggplant plants. In the interaction of the two factors under study, no significant differences in phenols in fruits were found (Table 2). Bacha *et al*. (2017) mentioned that the production and accumulation of phenolic compounds is a response and adaptation mechanism of plants exposed to stressful conditions.

Vitamin C

The interaction of the two factors under study had significant effects on the concentration of vitamin C in fruits (Figure 2A). Fruits from plants grown with 0, 15 and 45 mM NaCl doses in greenhouse and without salinity under shade mesh had on average 33 % and 41 % higher vitamin C concentration than fruits from plants treated with 45 mM NaCl and 15 mM NaCl under shade mesh, respectively. The 50 mM NaCl dose did not cause differences in vitamin C content in tomato fruits (Costan *et al*., 2020) and with the application of 30 to 90 mM NaCl, it increased from 11 to 25 % (Naeem *et al*., 2020). In tomato plants, vitamin C concentration increased by 16 and 26 % with doses of 1 and 60 mM NaCl with high temperature 35 °C, relative to 25 °C, indicating the effect of heat stress and no effect of salinity (Botella *et al*., 2021). Fenech *et al*. (2019) mentioned that hydrogen peroxide (H_2O_2) is responsible for light-induced oxidative damage. Under high irradiance conditions during photosynthesis, ascorbate is involved in the removal of excess H_2O_2 (Wheeler *et al*., 2015). In this study, the increase in vitamin C concentration could be due to the light intensity in the greenhouse which was 325.74 µmol m^{-2}, higher than that recorded under shade mesh (183.22 µmol m^{-2} s^{-1}).

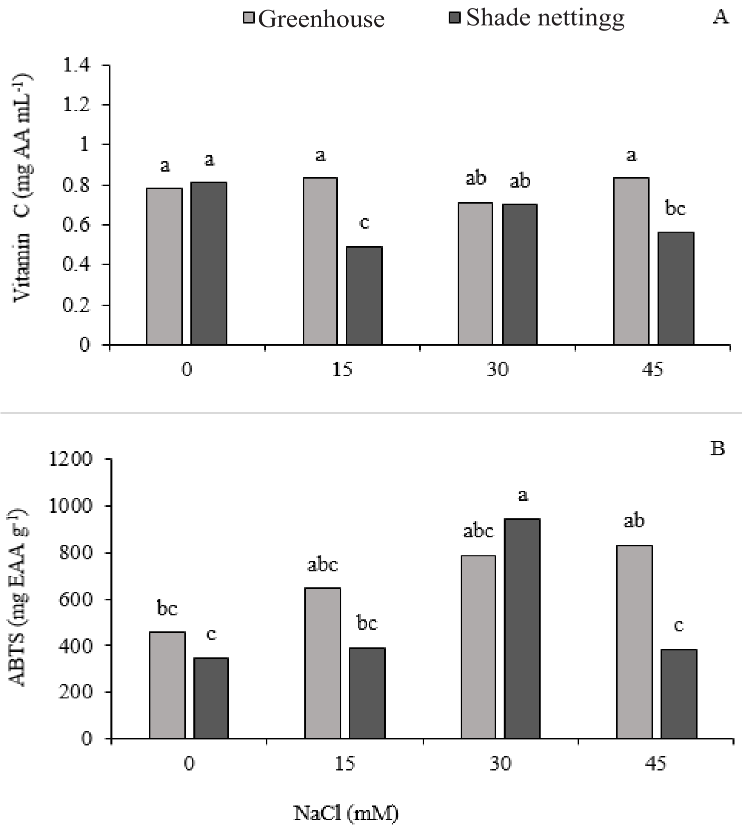

Figure 2. Vitamin C concentration and ABTS antioxidant activity in eggplant fruits from plants grown in response to protected structure and NaCl dosage. Means with different letters in each subfigure are statistically different (Tukey, $p \leq 0.05$).

Antioxidant activity

The interaction of the factors under study had a significant effect on antioxidant activity (Figure 2B). Fruits from plants under shade mesh with the 30 mM NaCl dose increased 165.2 % antioxidant capacity compared to fruits from plants produced under shade mesh without salinity. According to Khanahmadi *et al.* (2010) upon salt stress induction plants increase antioxidant substances for their defense against oxidative stress. In the greenhouse, the light intensity was 326 μmol m^{-2} s^{-1} and under the shade mesh it was 183 μmol m^{-2} s^{-1}, suggesting an increase in antioxidant activity. Plants accumulate a number of phenolic compounds and antioxidants as a protective measure against intense light and UV rays (Ilić and Fallik, 2017). Antioxidant activity increased in edible flowers of *Tagetes patula* L. by 11 % with the dose 50 mM NaCl (Chrysargyris *et al.*, 2018).

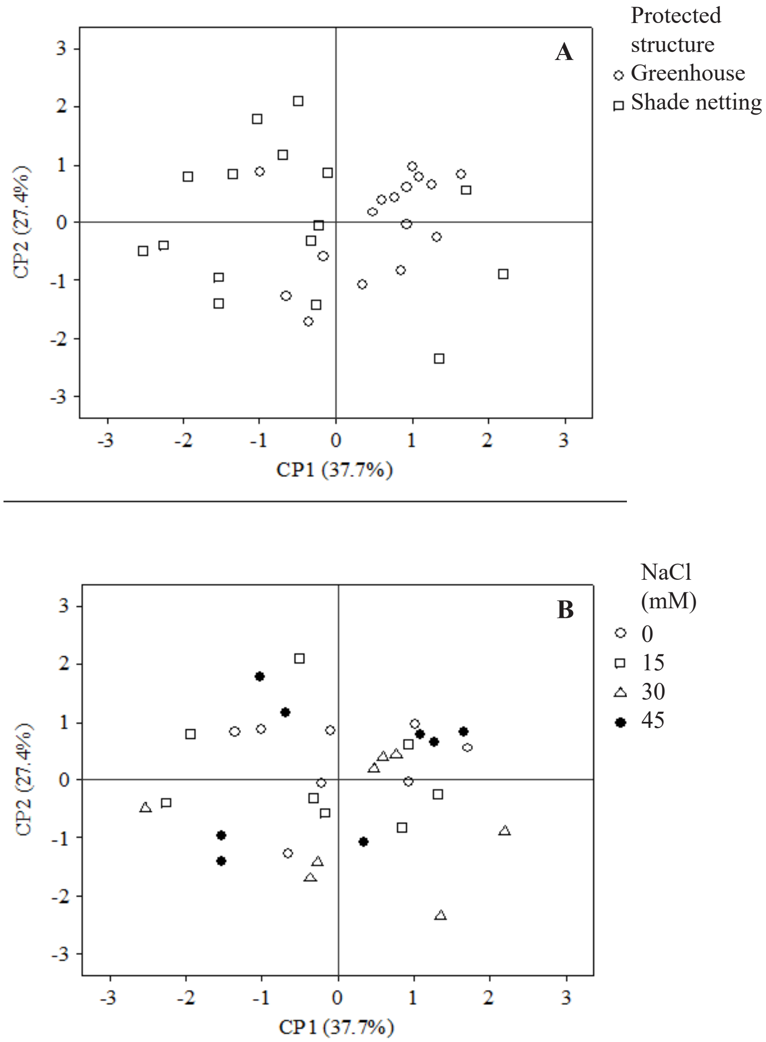

Figure 3. Point distribution derived from principal component analysis of eggplant bioactive compounds in two protected structures and NaCl doses.

Principal component analysis

Principal component analysis was performed on the original data set of bioactive compounds in fruits. The first three components explained 88.6 % of the variability in the data (37.7, 27.4, 23.5 %) obtained from the six bioactive compounds analyzed. The scatter plot was done with PC1 and PC2, which together explained 65.1 % of the variability in the original data (Figures 3A-B). In PC1, the positive correlations with the highest values were ABTS antioxidant activity (0.59) and vitamin C (0.70). Antioxidant activity increases when inducing stress to plants (Chrysargyris *et al*., 2018). Moreover, ascorbic acid acts effectively in response to oxidative stress, it depends on the need generated by the plant environment and physiological situation (Shishira *et al*., 2016). In PC2, the positive correlations with higher values were phenols (0.58) and flavonoids (0.75). The influence of protected greenhouse structure as well as NaCl doses shows data that have an effect on this variability. Also, a group of data distant from the axis related to the 30 mM NaCl dose was distinguished.

CONCLUSIONS

Eggplant production in greenhouse with doses of 30 and 45 mM NaCl increased vitamin C concentration and antioxidant activity in fruits. Under shade mesh, the 30 mM NaCl dose increased antioxidant activity. Thus, the environmental conditions of temperature and radiation in the greenhouse promoted an increase in the concentration of bioactive compounds in eggplant fruits, which in turn provides greater nutritional value.

REFERENCES

AOAC. 1990. Official Methods and Analysis. Association of Official Analytical Chemists (AOAC). Helrich, K. (ed.). Arlington, Virginia USA. 1298 p.

Arvouet-Grand A, Vennat B, Pourrat A, Legret P. 1994. Standardisation dun extrait de propolis et identification des principaux constituents. Journal Pharmacie de Belgique 49 (6): 462–468.

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

Bistgani ZE, Hashemi M, DaCosta M, Craker L, Maggi F, Morshedloo MR. 2019. Effect of salinity stress on the physiological characteristics, phenolic compounds and antioxidant activity of *Thymus vulgaris* L. and *Thymus daenensis* Celak. Industrial Crops and Products 135 (1): 311–320. https://doi.org/10.1016/j.indcrop.2019.04.055

Botella MÁ, Hernández V, Mestre T, Hellín P, García-Legaz MF, Rivero RM, Martínez V, Fenoll J, Flores P. 2021. Bioactive compounds of tomato fruit in response to salinity, heat and their combination. Agriculture 11 (6): 534. https://doi.org/10.3390/agriculture11060534

Brenes M, Solana A, Boscaiu M, Fita A, Vicente O, Calatayud Á, Prohens J, Plazas M. 2020. Physiological and biochemical responses to salt stress in cultivated eggplant (*Solanum melongena* L.) and in *S. insanum* L., a close wild relative. Agronomy 10 (5): 651. https://doi.org/10.3390/agronomy10050651

Carbajal-Vazquez VH, Gomez-Merino FC, Herrera-Corredor JA, Contreras-Oliva A, Alcantar-Gonzalez G, Trejo-Téllez LI. 2020. Effect of titanium foliar applications on tomato fruits from plants grown under salt stress conditions. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 48 (2): 924–937. https://doi.org/10.15835/nbha48211904

Cericola F, Portis E, Lanteri S, Toppino L, Barchi L, Acciarri N, Pulcini L, Sala T, Rotino GL. 2014. Linkage disequilibrium and genome-wide association analysis for anthocyanin pigmentation and fruit color in eggplant. BMC Genomics 15: 896. https://doi.org/10.1186/1471-2164-15-896

Cervantes L, Ariza MT, Gomez-Mora JA, Miranda L, Medina JJ, Soria C, Martínez-Ferri E. 2019. Light exposure affects fruit quality in different strawberry cultivars under field conditions. Scientia Horticulturae 252 (4): 291–297. https://doi.org/10.1016/j.scienta.2019.03.058

Chrysargyris A, Tzionis A, Xylia P, Tzortzakis N. 2018. Effects of salinity on tagetes growth, physiology, and shelf life of edible flowers stored in passive modified atmosphere packaging or treated with ethanol. Frontiers in Plant Science 9: 1765. https://doi.org/10.3389/fpls.2018.01765

Costan A, Stamatakis A, Chrysargyris A, Petropoulos SA, Tzortzakis N. 2020. Interactive effects of salinity and silicon application on Solanum lycopersicum growth, physiology and shelf-life of fruit produced hydroponically. Journal of the Science of Food and Agriculture 100 (2): 732–743. https://doi.org/10.1002/jsfa.10076

da Silva TL, Aguiar-Oliveira E, Mazalli MR, Kamimura ES, Maldonado RR. 2017. Comparison between titrimetric and spectrophotometric methods for quantification of vitamin C. Food Chemistry 224: 92–96. https://doi.org/10.1016/j.foodchem.2016.12.052

Fenech M, Amaya I, Valpuesta V, Botella M.A. 2019. Vitamin C content in fruits: Biosynthesis and regulation. Frontiers in Plant Science 9: 2006. https://doi.org/10.3389/fpls.2018.02006

Garriga M, Muñoz CA, Caligari PD, Retamales JB. 2015. Effect of salt stress on genotypes of commercial (*Fragaria x ananassa*) and Chilean strawberry (*F. chiloensis*). Scientia Horticulturae 195: 37–47. https://doi.org/10.1016/j.scienta.2015.08.036

Giuffrida F, Graziani G, Fogliano V, Scuderi D, Romano D, Leonardi C. 2014. Effects of nutrient and NaCl salinity on growth, yield, quality and composition of pepper grown in soilless closed system. Journal of Plant Nutrition 37: 1455–1474. https://doi.org/10.1080/01904167.2014.881874

Hannachi S, Van Labeke MC. 2018. Salt stress affects germination, seedling growth and physiological responses differentially in eggplant cultivars (*Solanum melongena* L.). Scientia Horticulturae 228: 56–65. https://doi.org/10.1016/j.scienta.2017.10.002

Ilić ZS, Fallik E. 2017. Light quality manipulation improves vegetable quality at harvest and postharvest: A review. Environmental and Experimental Botany 139: 79–90. https://doi.org/10.1016/j.envexpbot.2017.04.006

Khanahmadi M, Rezazadeh SH, Taran M. 2010. *In vitro* antimicrobial and antioxidant properties of *Smyrnium cordifolium* Boiss. (Umbelliferae) extract. Asian Journal of Plant Sciences 9 (2): 99–103. https://doi.org/110.3923/ajps.2010.99.103

Ladewig P, Trejo-Téllez LI, Servín-Juárez R, Contreras-Oliva A, Gomez-Merino FC. 2021. Growth, yield and fruit quality of Mexican tomato landraces in response to salt stress. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 49 (1): 12005–12005. https://doi.org/10.15835/nbha49112005

Lo Scalzo RL, Fibiani M, Francese G, D'Alessandro A, Rotino GL, Conte P, Mennella G. 2016. Cooking influence on physico-chemical fruit characteristics of eggplant (*Solanum melongena* L.). Food Chemistry 194: 835–842. https://doi.org/10.1016/j.foodchem.2015.08.063

Minitab Inc. 2010. Statistical Software; Minitab version 16: State College, PA, USA.

Naeem M, Basit A, Ahmad I, Mohamed HI, Wasila H. 2020. Effect of salicylic acid and salinity stress on the performance of tomato plants. Gesunde Pflanzen 72: 393–402. https://doi.org/10.1007/s10343-020-00521-7

Perin EC, da Silva Messias R, Borowski JM, Crizel RL, Schott IB, Carvalho IR, Rombladi CV, Galli V. 2019. ABA-dependent salt and drought stress improve strawberry fruit quality. Food Chemistry 271: 516–526. https://doi.org/10.1016.j.foodchem.2018.07.213

Petropoulos SA, Levizou E, Ntatsi G, Fernandes A, Petrotos K, Akoumianakis K, Barros L, Ferreira IC. 2017. Salinity effect on nutritional value, chemical composition and bioactive compounds content of *Cichorium spinosum* L. Food Chemistry 214: 129–136. https://doi.org/10.1016.j.foodchem.2016.07.080

Philippi K, Tsamandouras N, Grigorakis S, Makris DP. 2016. Ultrasound-assisted green extraction of eggplant peel (*Solanum melongena*) polyphenols using aqueous mixtures of glycerol and ethanol: optimisation and kinetics. Environmental Processes 3: 369–386. https://doi.org/10.1007/s40710-016-0140-8

Rouphael Y, Kyriacou MC, Petropoulos SA, De Pascale S, Colla G. 2018. Improving vegetable quality in controlled environments. Scientia Horticulturae 234: 275–289. https://doi.org/10.1016/j.scienta.2018.02.033

SAS Institute Inc. 2002. Statistical Analysis System version 9.0. Windows. Cary, NC, USA: SAS Institute, Inc.

Shishira T, Nivedita P, D'souza Myrene R, Singh Kavitha G. 2016. Antioxidant marker response of *Solanum melongena* to salinity stress. Journal of Chemical and Pharmaceutical Research 8 (7): 533–539.

Singleton VL, Orthofer R, Lamuela MR. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods in Enzymology 299: 152–178. https://doi.org/10.1016/S0076-6879(99)99017-1

Terán-Erazo B, Alia-Tejacal I, Balois-Morales R, Juárez-Lopez P, López-Guzmán GG, Pérez-Arias GA, Núñez-Colín CA. 2019. Caracterización física, química y morfológica de frutos de guanábana (*Annona muricata* L.). Agrociencia 53 (7): 1013–1027.

Valerga L, Darré M, Zaro MJ, Arambarri A, Vicente AR, Lemoine ML, Concellón A. 2019. Microstructural and quality changes in growing dark-purple eggplant (*Solanum melongena* L.) as affected by the harvest season. Scientia Horticulturae 244: 22–30. https://doi.org/10.1016/j.scienta.2018.09.032

Wheeler G, Ishikawa T, Pornsaksit V, Smirnoff N. 2015. Evolution of alternative biosynthetic pathways for vitamin C following plastid acquisition in photosynthetic eukaryotes. Elife 4: e06369. https://doi.org/10. 7554/eLife.06369

WHO (World Health Organization). 2012. Guideline: Sodium intake for adults and children. Geneva, Italy. 46 p.

Zou Z, Xi W, Hu Y, Nie C, Zhou Z. 2016. Antioxidant activity of *Citrus* fruits. Food Chemistry 196: 885–896. https://doi.org/10.1016/j.foodchem.2015.09.072