Agronomía Colombiana
ISSN: 0120-9965
agrocol_fabog@unal.edu.co
Universidad Nacional de Colombia
Colombia

Martínez-Damián, María Teresa; Cruz-Alvarez, Oscar; Rodríguez-Pérez, Juan Enrique; Colinas-León, María Teresa; Góngora-Canto, Miguel Ángel

Yield, physicochemical quality, and antioxidant capacity of “beef” and wild tomato fruits (Solanum lycopersicum L.) as a function of the electrical conductivity of the nutrient solution

Agronomía Colombiana, vol. 35, núm. 3, septiembre-diciembre, 2017, pp. 330-339
Universidad Nacional de Colombia
Bogotá, Colombia

Available in: http://www.redalyc.org/articulo.oa?id=180357360008

Yield, physicochemical quality, and antioxidant capacity of "beef" and wild tomato fruits (*Solanum lycopersicum* L.) as a function of the electrical conductivity of the nutrient solution

Rendimiento, calidad fisicoquímica y capacidad antioxidante en frutos de tomate bola y silvestre (*Solanum lycopersicum* L.) en función de la conductividad eléctrica de la solución nutritiva

María Teresa Martínez-Damián[1], Oscar Cruz-Alvarez[2], Juan Enrique Rodríguez-Pérez[1]*, María Teresa Colinas-León[1], and Miguel Ángel Góngora-Canto[1]

ABSTRACT

The objective of this study was to evaluate the response of three levels of electrical conductivity (2.0, 2.5 and 3.0 dS m^{-1}) of Steiner's nutrient solution on the yield, physicochemical quality, and antioxidant capacity of fruits from seven tomato genotypes and wild types of tomato (kidney selections). The yield, number of fruits per cluster (NFPC), average fresh fruit weight (AFWF), color, firmness, total soluble solids (TSS), total titratable acidity (TTA), vitamin C (VC), total phenols (TP), lycopene (LY) and antioxidant capacity (AC). The use of 2.5 and 3.0 dS m^{-1} increased the hue angle (49.05°) and TTA (0.35 and 0.36% citric acid). Among genotypes, L-51H and L-76H showed better performance (16.80 and 16.91 kg m^{-2}, respectively), where L-28 stood out for its values of TSS, TTA, VC, TP and AC. Regarding the wild genotypes, the EC modification did not increase the yield; however, the use of 3.0 dS m^{-1} allowed the best results among the wild selections were SS3 (yield, AFWF and LY) and SS5 (NFPC, VC, TP and AC). The modification of the EC did not affect the yield, however, if it affected the physicochemical quality and antioxidant capacity of the analyzed materials.

Key words: total titratable acidity, total soluble solids, ascorbic acid, total phenols, Solanaceae.

RESUMEN

El objetivo de este estudio fue evaluar la respuesta de tres niveles de conductividad eléctrica (CE) (2,0; 2,5 y 3,0 dS m^{-1}) de la solución nutritiva de Steiner, sobre el rendimiento, calidad fisicoquímica y capacidad antioxidante en frutos de tomate bola y silvestre tipo riñón. Se determinó el rendimiento, numero de frutos por racimo (NFPR), peso promedio de fruto fresco (PPFF), color, firmeza, sólidos solubles totales (SST), acidez titulable total (ATT), vitamina C (VC), fenoles totales (FT), licopeno (LI) y capacidad antioxidante (CA). El uso de 2,5 y 3,0 dS m^{-1} incrementaron el ángulo hue (49,05°) y ATT (0,35 y 0,36% de ácido cítrico). Entre genotipos, L-51H y L-76H mostraron mejor rendimiento (16,80 y 16,91 kg m^{-2}, respectivamente), donde L-28 destacó por sus valores de SST, TTA, VC, TP y CA. Con respecto a los genotipos silvestres, la modificación de la CE no incremento el rendimiento; no obstante, el uso de 3,0 dS m^{-1} permitió obtener los mejores resultados. Entre las selecciones silvestres se destacaron SS3 (rendimiento, PPFF y LI) y SS5 (NFPR, VC, FT y CA). La modificación de la CE no modifico el rendimiento, sin embargo, si afectó la calidad fisicoquímica y capacidad antioxidante de los materiales analizados.

Palabras clave: acidez titulable total, sólidos solubles totales, ácido ascórbico, fenoles totales, Solanácea.

Introduction

The fruits of tomato (*Solanum lycopersicum* L.) have a wide versatility as food source whether in fresh or as processed food, tomatoes constitute one of the most widely cultivated and demanded agricultural products worldwide. In Mexico, due to the technological development of protected agriculture and the use of hybrids with high yield potential, between 1980 and 2010 the area under cultivation was reduced by 24%, while production and yield increased by 45% and 90%, respectively (Magaña *et al.,* 2013).

The development of intensive systems of tomato production has led to the import of large volumes of seeds, where the hybrids that are currently cultivated are generated by few transnational companies, so seeds are expensive, not always available, and sometimes inaccessible to small producers. The generation of experimental lines and hybrids as well

Received for publication: 15 May, 2017. Accepted for publication: 31 October, 2017 Doi: 10.15446/agron.colomb.v35n3.64905

[1] Department of Plant Science, Universidad Autónoma Chapingo, Chapingo (Mexico).
[2] Faculty of Agrotechnological Sciences, Universidad Autónoma de Chihuahua, Chihuahua (Mexico).
* Corresponding author: erodriguezx@yahoo.com

as the search for outstanding wild materials in breeding programs can be a good alternative to generate local materials for both regional and national markets. According to Mendez *et al.* (2011), there are large tomato collections in Central and South America where they are widely cultivated, with indigenous kidney-type varieties almost exclusively to regional use. In some regions of Mexico (Puebla and Oaxaca), native materials known as "kidney" are widely used and are cultivated for local consumption (Estrada *et al*., 2011).

The wild genotypes present acceptable levels of total soluble solids, titratable acidity, vitamin C content (Mendez *et al.,* 2011; Vera *et al.,* 2011), total phenols, antioxidant capacity and lycopene (Kavitha *et al.,* 2014); reasons why they have been used to increase the nutritional quality of fruits (Juárez *et al.,* 2013). In all breeding programs, it is necessary to know the genetic characteristics of the populations, as well as the variations due to environmental effects (Gaspar *et al.,* 2012). It has been detected that some management practices, such as the modification of the nutritional concentration, can positively affect agronomic behavior in tomato including yield and physical characteristics of fruits (Flores *et al.,* 2012), as well as its chemical quality and antioxidant capacity (Krauss *et al.,* 2006; Schnitzler and Krauss, 2010). Therefore, the objective of this study was to evaluate the response of three levels of electrical conductivity (2.0, 2.5 and 3.0 dS m^{-1}) of the Steiner nutrient solution on the yield, physicochemical quality and antioxidant capacity in "beef" tomato and wild type kidney fruits.

Materials and methods

Location of the experiment and plant material

The experiment was carried out from April to September 2016, under medium-tech "full vent" greenhouse conditions, with a 600-gauge polyethylene cover with 70% light transmission, and protected front, side and upper ventilation, protected anti-fouling mesh, located at the Autonomous University of Chapingo, Mexico (19°29' N and 98°53' W; 2,240 m a.s.l.); with an annual average air temperature of 15.9 °C. Eleven tomato materials were used: "beef" type (1 commercial 'Susan' type hybrid (control) and 6 experimental lines (L-51H, L-52, L-43H, L-28, L-76H, and H13-33) as well as 4 selections of wild genotypes ("kidney") (SS1, SS3, SS4, and SS5) (*S. lycopersicum* L.).

Crop management

Sowing was done in expanded polystyrene trays with 200 wells, using peat moss as a substrate. At 30 d, the seedlings were transplanted into black polyethylene bags filled with volcanic rock "tezontle" of 10-20 mm in diameter (13 kg). The plants were led to a single stem with a density of 3.7 m^{-2} plants. The supply of essential elements for the growth and development was performed according to the parameters established by the Steiner solution and complemented with micronutriments at 100, 125 and 150% of its concentration, representing an electrical conductivity of 2.0, 2.5 and 3.0 dS m^{-1}, respectively (Tab. 1) (Steiner, 1984); which was applied by a drip irrigation system with an applied volume of 0.30-2.5 L/plant following each phenological stage.

Harvesting was carried to the fifth cluster, at which point the plant was exposed above the third leaf after the cluster. In order to carry out the corresponding analyzes, the fruits harvested were those located between the second and fourth cluster at the sixth maturity stage, being a stage when the fruit possess 90% red coloration (Choi *et al*., 1995).

Experimental design. The experimental design was completely randomized with six replicates, the experimental unit consisted of one fruit and the variables evaluated were: yield, number of fruits per cluster, average fruit weight, color, firmness, total soluble solids, titratable acidity, vitamin C, total phenols, lycopene, and antioxidant capacity.

Parameter evaluated

Yield. The weight of the fruits (experimental unit) harvested using an OHAUS® portable digital scale was obtained

TABLE 1. Concentration of macroelements and microelements of the nutrient solutions.

Concentration (%)	Anions (meq L^{-1})				Cations (meq L^{-1})				EC (dS m^{-1})
	NO_3	H_2PO_4	SO_4	Total	K^+	Ca^{2+}	Mg^{2+}	Total	
	60	5	35	100	35	45	20	100	
100	12.0	1.00	7.00	20	7.00	9.00	4.00	20	2.0
125	15.0	1.25	8.75	25	8.75	11.25	5.00	25	2.5
150	18.0	1.50	10.50	30	10.50	13.50	6.00	30	3.0

*EC: Electric conductivity (dS m^{-1}).

with approximation to 0.01 g. The data obtained are reported in kg m^{-2}.

Number of fruits per cluster (NFPC). It was obtained by dividing the total of fruits harvested to the total of clusters per experimental unit.

Average fresh weight of fruit (AFWF). The yield value was divided to the total numbers of harvested fruits, the result was expressed in grams (g).

Color. It was determined directly on the epidermis of the fruit with X-Rite® SP62 colorimeter, values L, a, and b were taken in the equatorial region of each fruit. With these values, the tone angle (hue) and the color purity (chromaticity) were calculated applying the formulas: hue=$\tan^{-1}$ (b/a), chromaticity =$(a^2+b^2)^{½}$ and the luminosity L obtained directly with the colorimeter, which correspond to the color space L * a * b (Voss, 1992).

Firmness. The measurement was performed at the equatorial zone of the fruit by means of a Chatillón® AMETEK penetrometer, with a cone-shaped strut. The force applied until the penetration of the strut was expressed in Newtons (N).

Total soluble solids (TSS). The total soluble solids (°Brix) were counted with a PAL-1® portable digital refractometer (ATAGO, USA) using a 0-53° scale. The measurement was carried out by placing a fruit juice drop in the screen of the refractometer to further assessing the result.

Total titratable acidity (TTA). It was determined according to the methodology proposed by the AOAC (AOAC, 1990), with 20 g of pulp neutralized with 0.1 N NaOH, using 1% phenolphthalein as indicator. Results were reported as % citric acid.

Vitamin C (VC). It was estimated according to the method of Tillman (AOAC, 1990), known as DFI-2, 6 dichlorophenol-indophenol, for this 5 g of finely chopped fruit was homogenized with 50 mL of a 5% oxalic acid solution. The titration process was carried out with a 10 mL juice aliquot. The concentration was expressed in mg ascorbic acid 100 g^{-1} by a standard curve of ascorbic acid.

Total phenols (TP). The quantification of the total phenols was carried out by the method of Folin and Ciocalteu described by Waterman and Mole (1994), with the following modifications: 300 µL of ethanolic extract (1.0 g of pulp in 5 mL of ethanol, homogenized with 24 h of rest) to which 8.0 mL of distilled water, 0.5 mL of the Folin and Ciocalteu reagent, respectively, were added and shaken; finally 1.5 mL of a 20% Na_2CO_3 solution was added to each sample and resuspended, allowing it to stand for 2 h under dark conditions. The absorbance reading was taken at 760 nm using a UV-VIS® model digital spectrophotometer (PerkinElmer®, USA). The results were expressed in mg 100 g^{-1} of fresh weight (FW) according to a standard curve of tannic acid.

Lycopene (LY). The determination was realized using the modified method of Sadler *et al*. (1990). 20 g of pulp were homogenized with distilled water, the obtained mixture was placed in a jar wrapped in aluminum foil and dried at 38°C. 0.1 g of the paste was placed in aluminum foil test tubes, 30 mL of a 2: 1: 1 hexane / ethanol / acetone mixture was added and stirred for 10 min. Subsequently, 18 mL of distilled water were added and the mixture was stirred for 5 min. until the aqueous and organic phase separated. The volume of organic phase at which the absorbance value was taken at 470 nm (PerkinElmer UV-VIS®, USA) was measured with separation flasks. Quantification was performed using the formula of Inbaraj and Chen (2008) and the results were expressed in mg 100 g^{-1} FW.

Antioxidant capacity (AC). It was carried out according to the method ABTS (2,2'azinobis (3-ethylbenzothiazolin-6-sulfonic acid) modified by Ozgen *et al*. (2006) $ABTS^{\bullet+}$ was formed after the reaction of ABTS (7 mM) with potassium persulfate (2.45 mM, final concentration) incubated at room temperature and in dark conditions for 24 h. After the $ABTS^{\bullet+}$ radical was formed it was diluted with PBS (sodium acetate buffer solution) (pH 4.5) until an absorbance value of 0.7 ± 0.1 at 734 nm (maximum absorption length) was obtained. For the test, 3.9 mL of the $ABTS^{\bullet+}$ solution and 100 µL of extract from the sample and allowed to stand for 2 h where the absorbance reading was performed at 734 nm. The results are expressed in TEAC (Antioxidant Activity Equivalent to Trolox).

Statistical analysis. An analysis of variance (ANOVA) and Tukey's mean comparison ($P \leq 0.05$) were performed, using the statistical analysis program Statistical Analysis System (SAS), ver. 9.1.

Results and discussion

Effect of the nutrient solution Electrical conductivity: "beef" type genotypes. The variation in electrical conductivity (EC) of the nutrient solution did not affect the yield (13.83 to 14.74 kg m^{-2}), NFPC (3.99 to 4.43), and AFWF (200.15 to 214.95 g) (Tab. 2). Which concurs to Valenzuela

TABLE 2. Effect of the nutrient solution conductivity on the components of yield, physicochemical quality and antioxidant capacity in tomato "beef" fruits.

EC (dS m^{-1})	TSS (ºBrix)	TTA (% c. acid)	VC (mg 100 g^{-1} asc. acid)	TP (mg 100 g^{-1})	LY (mg 100 g^{-1})	AC (mm TEAC g^{-1})
2.0	3.67 a	0.34 b	3.95 a	2.67 a	16.09 a	33.24 a
2.5	3.72 a	0.35 ba	3.59 a	2.56 a	15.71 a	32.83 a
3.0	3.74 a	0.36 a	3.88 a	2.70 a	17.22 a	34.22 a
MSDH	0.271	0.018	0.856	0.206	3.457	3.274

EC (dS m^{-1})	Y (kg m^{-2})	NFPC	AFWF (g)	L	C	H (ºhue)	F (N)
2.0	14.67 a[§]	4.09 a	214.95 a	43.12 a	40.86 a	47.69 b	1.62 a
2.5	14.74 a	4.43 a	200.15 a	43.78 a	43.35 a	49.05 a	1.61 a
3.0	13.83 a	3.99 a	205.88 a	43.51 a	42.11 a	47.75 b	1.71 a
MSDH	1.609	0.573	18.725	1.133	3.553	1.268	0.196

EC: electrical conductivity. Y: yield, NFPC: number of fruits per cluster, AFWF: average fresh weight of fruit, L: luminosity, C: chromaticity, H: hue angle, F: firmness, TSS: total soluble solids, TTA: total titratable acidity, VC: vitamin C, TP: total phenols, LY: lycopene, AC: antioxidant capacity. MSDH: Minimum Significant Difference Honest. [§]Means with equal letter within the same column are statistically equal according to Tukey`s test ($P \leq 0.05$).

et al. (2014) who reported yield values between 14.49 and 14.99 kg m^{-2} using lower concentrations (50 to 100%) of Steiner's solution (1.0 to 2.0 dS m^{-1}).

The variation of EC did not affect the behavior of two components of fruit color: luminosity (43.12 to 43.78) and chromaticity (40.86 to 43.35), as well as firmness (1.61 to 1.71 N); however, the color hue (hue angle) had an increase from 47.69 to 49.05º (Tab. 2). Similar fruit color results were reported by Cruz and Sandoval-Villa (2012) with values of brilliance (39.57 to 42.75), chromaticity (21.86 and 22.43) and hue angle (58.0 to 62.95°) for tomato fruits grown with conductivity electrical from 50, 75, and 100%. The change in the hue values may be associated with a decrease in the red coloration of the epidermis, from a bright red coloration (41.3º) to a red orange color (48.0º) (Batu, 2004).

"Beef" tomatoes fruit cultivated with a EC of 2.0 to 3.0 dS m^{-1} did not modify the TSS content (3.67 to 3.74 °Brix), however, it was significant in relation to the variation of the organic acids concentration after presenting fluctuations of 0.34 to 0.36% of citric acid (Tab. 2). In this sense, after evaluating five levels of electrical conductivity of nutrient solution (1-5 dS m^{-1}) Brasiliano *et al*. (2006) found a linear increase in the total titratable acidity values of 9.4%. On the other hand, Schnitzler and Krauss (2010) indicated even a higher increase of citric acid contents in tomato fruits (10.7, 52.2, and 78.3%) when using EC of 3.0 to 6.5, 10 and 13.5 dS m^{-1}. These results, according to Wakeel (2013), may be related to the presence of K^+, which directly affects the cation-anion charge balance mechanism that occurs when this nutrient element is transported without the presence of a companion anion in the cytoplasm.

As shown in Tab. 2, EC modification of nutrient solution did not allow significant differences in VC content (3.59 to 3.95 mg ascorbic acid 100 g^{-1}), TP (2.56 to 2.70 mg 100 g^{-1}), as well as LY (16.98 to 18.70 mg 100 g^{-1}) and AC (32.83 to 34.22 mm TEAC g^{-1}). However, Krauss *et al*. (2006); Schnitzler and Krauss (2010) reported a significant increase in vitamin C content (8.1, 10.0, and 11.1 mg ascorbic acid 100 g^{-1}), lycopene (57.5, 112.5 and 135%), total phenols (28.5 to 48.1 mg 100 g^{-1}), and antioxidant capacity (26.1 to 38.8 mm TEAC g^{-1}) after apply a higher electrical conductivity in the nutrient solution (6.5, 10, and 13.5 dS m^{-1}).

Fruit quality: "beef" type genotypes. When comparing genotypes, with exception of L-43H (10.11 kg m^{-2}), all experimental lines showed a similar yield value as commercial 'Susan' (12.90 to 16.91 kg m^{-2}) (Tab. 3). These results contrasted with those reported in twenty-four "beef" type hybrids (6.73 to 11.80 kg m^{-2}) (Martinez *et al*., 2005). Also, our findings agreed with the yield data (10.79 to 15.23 kg m^{-2}) presented by Pérez *et al*. (2012) in four commercial "beef" type hybrids.

All analyzed materials had a NFPC that fluctuated from 2.90 to 4.53, where the experimental line H13-33 (7.65) (Tab. 3) stands out, which main characteristic was a "beef" type with small fruit. Magaña *et al*. (2013) and Pérez *et al*. (2012) reported a number of fruits per similar cluster (2.71 to 3.94 and 2.93 to 5.26) for seven and four commercial fruit "beef" hybrids. In contrast, Martinez *et al*. (2005) reported the highest number of fruits in six bunches per plant in twenty-four "beef" type hybrids (19.0 to 56.3).

The experimental line L-76H presented higher AFWF (282.75 g) than the one observed in commercial hybrid

'Susan' (230.5 g), but with a similar trend to the lines L-51H and L-52 (266.36 and 252.97 g, respectively) (Tab. 3). Similar data are reported by Magaña *et al.* (2013) and Martinez *et al.* (2005) from 104.62 to 151.63 g and 37.1 to 116.3 g respectively, in seven and twenty-four commercial hybrids of beef tomato. Nevertheless, Pérez *et al.* (2012) and Grijalva *et al.* (2011) indicate a lower AFWF (146.5 to 215.4 g and 152.5 to 211.3 g), in four and ten commercial "beef" type hybrids.

The fruits from experimental lines L-51H, L-52, and 'Susan' hybrid had significantly higher values of luminosity (44.5 to 45.49) than the rest of the genotypes (41.41 to 42.64) (Tab. 3). The data obtained in this study are similar to those reported by Hernández *et al.* (2007) in five commercial varieties cultivated in Spain (44.2 and 44.6). On the other hand, Gaspar *et al.* (2012) obtained lower luminosity values in eight advanced lines (33.2 and 37.6). All experimental lines analyzed showed higher brightness values than the optimal levels (38.0 to 40.0) described by Preczenhak *et al.* (2014) for this species, which might indicate that all materials presented fruits with desirable characteristics for this quality character.

All experimental lines evaluated in this study as well as commercial 'Susan' control showed statistically similar chromaticity values (37.70 to 45.98) (Tab. 3). These results agree with those obtained by Gaspar *et al.* (2012) and Kacjan *et al.* (2011) (44.0 to 53.5 and 39.22 to 43.35, respectively) on eight advanced lines and eleven tomato cultivars; though, those are chromaticity levels higher than the described by Hernández *et al.* (2007) (30.8 to 34.3) in five commercial cultivars of tomato grown in Spain.

Comparing between genotypes (Tab. 3), it was observed that the experimental lines of "beef" tomato H13-33, L-52, L-51H and L43H presented a fruit tonality statistically similar to the control with values that fluctuated between 48.10 and 50.55º. These results are within the range (44.9 and 53.2º) indicated by Kacjan *et al.* (2011) in eleven cultivars managed in different climatic conditions. Likewise, the data obtained surpassed the 35 and 40º mencionated by Cantwell *et al.* (2006) in tomato fruits with red tonality, showing values close to the color red-orange (48.0º).

When evaluating fruit firmness (Tab. 3), it was found that all the experimental lines (except L-76H) and the commercial 'Susan' showed firmness levels (1.50 to 1.93 N) higher than 1.46 N indicated at least by Batu (2004) on tomato fruits intended for fresh consumption. In the same way, they coincide with that reported by Hernández *et al.* (2013) (1.3 to 2.4 N) in mature fruits (90% red) of seven commercial tomato hybrids.

TABLE 3. Yield, physicochemical quality, and antioxidant capacity components of "beef" type tomato fruits.

Genotype	Y (kg m^{-2})	NFPC	AFWF (g)	L	C	H (ºhue)	F (N)
'Susan'	15.44 ba[§]	3.65 cb	230.51 b	44.90 a	44.40 ba	48.10 a	1.69 bac
L-51H	16.80 a	3.43 cb	266.36 ba	45.04 a	41.21 ba	49.66 a	1.88 ba
L-52	13.64 b	2.90 c	252.97 ba	45.49 a	40.67 ba	49.78 a	1.93 a
L-43H	10.11 c	4.53 b	120.14 d	42.41 b	45.98 a	48.94 a	1.78 bac
L-28	12.90 c	3.76 cb	188.35 c	42.64 b	45.20 a	45.62 b	1.51 bdc
L-76H	16.91 a	3.28 c	282.75 a	42.41 b	37.70 b	44.51 b	1.25 d
H13-33	15.12 ba	7.65 a	107.85 d	41.41 b	39.59 ba	50.55 a	1.50 dc
MSDH	3.134	1.117	36.466	2.197	6.890	2.460	0.381

Genotype	TSS (°Brix)	TTA (% c. acid)	VC (mg 100 g^{-1} asc. acid)	TP (mg 100 g^{-1})	LY (mg 100 g^{-1})	AC (mm TEAC g^{-1})
'Susan'	3.07 c	0.35 ba	4.74 ba	2.71 ba	19.65 a	36.84 a
L-51H	3.76 ba	0.33 b	3.09 bdc	2.40 b	15.89 ba	30.48 bc
L-52	3.51 bc	0.35 ba	3.01 dc	2.38 b	19.01 a	32.72 ba
L-43H	4.24 a	0.29 c	4.66 bac	2.99 a	18.74 ba	36.30 ba
L-28	4.21 a	0.38 a	5.19 a	3.09 a	13.28 ba	37.23 a
L-76H	3.13 c	0.35 ba	3.37 bdc	2.41 b	15.77 ba	26.30 c
H13-33	4.06 a	0.38 a	2.61 d	2.51 b	12.04 b	34.14 ba
MSDH	0.525	0.035	1.660	0.399	6.704	6.349

Y: yield, NFPC: number of fruits per cluster, AFWF: average fresh weight of fruit, L: luminosity, C: chromaticity, H: hue angle, F: firmness, TSS: total soluble solids, TTA: total titratable acidity, VC: vitamin C, TP: total phenols, LY: lycopene, AC: antioxidant capacity. MSDH: Minimum Significant Difference Honest. [§]Means with equal letter within the same column are statistically equal according to Tukey`s test ($P \leq 0.05$).

Experimental lines L-43H, L-28, H13-33 and L-51H presented statistically higher TSS contents (3.76 to 4.24 °Brix) to the commercial 'Susan' (3.07 °Brix) commercial indicator (Tab. 3). The results obtained were approximate to those of Gaspar *et al*. (2012), Pérez *et al*. (2012) and Chattopadhyay *et al*. (2013) in eight tomato lines, four commercial cultivars and thirty-one hybrids produced in India (3.9 to 5.2, 4.6 to 5.1 and 3.82 to 5.1 ºBrix, respectively).

When comparing TTA between genotypes (Tab. 3), all experimental lines, except L-43H, showed levels (0.33 to 0.38%) statistically similar to commercial "Susan" hybrid (0.35%). The results found are within the ranges reported by Gaspar *et al*. (2012) and Chattopadhyay *et al*. (2013) (0.24 to 0.39 and 0.27 to 0.52% of citric acid, respectively) in fruits of eight lines and 31 hybrids of tomato.

It was possible to detect that the highest levels of VC (4.66 to 5.19 mg ascorbic acid 100 g^{-1}) were statistically higher than the lines H13-33 and L-52, with the experimental lines L-28, L-43H and the hybrid 'Susan' (2.61 and 3.01 mg ascorbic acid 100 g^{-1}, respectively) (Tab. 3). High concentrations of vitamin C were reported by Gaspar *et al*. (2012) and Chattopadhyay *et al*. (2013) (9.7 to 16.0 mg, and 14.63 to 40.50 mg ascorbic acid 100 g^{-1}, respectively). The variation between the results obtained with respect to those reported in the literature could be related to the freezing (-30 ºC) and thawing to which the fruits were subjected during their analysis, since according to Barankevicz *et al*. (2015) freezing tomato fruits at -18 °C reduces to 67.18% of ascorbic acid content, which is associated to the enzymatic and non-enzymatic oxidation of this acid in the presence of oxygen.

Regarding the TP content (Tab. 3), all the experimental lines and 'Susan' hybrid showed statistically similar levels (2.38 to 3.09 mg 100 g^{-1}). Independently, Hernández *et al*. (2007) and Bhandari *et al*. (2016) reported higher concentrations in commercial tomato cultivars (19.7 to 21.1 and 13.28 to 23.65 mg GAE 100 g^{-1}, respectively).

All experimental lines (except H13-33) and commercial 'Susan' control showed statistically similar LY contents (13.28 to 19.65 mg 100 g^{-1}). This is consistent with those reported in eight advanced tomato lines by Gaspar *et al*. (2012) (9.6 to 16.8 mg 100 g^{-1} FW). Nevertheless, Hernández *et al*. (2007) and Chattopadhyay *et al*. (2013) indicated a lower concentration of lycopene (1.89 to 2.56 and 1.25 to 4.91 mg 100 g^{-1}, respectively).

In relation to AC (Tab. 3), the experimental lines L-28, L-52, H13-33 and L-43H were found to have levels (32.72 to 37.23 mm TEAC g^{-1}) statistically superiors to the commercial control 'Susan' (36.84 mm TEAC g^{-1}). The results of this experiment surpassed those reported by Kavitha *et al*. (2014) (5.5 to 11.1 mm TEAC g^{-1}) in commercial hybrids and tomato varieties.

Effect of EC of nutrient solution: wild type tomato. Yield and NFPC were not affected by EC variation in nutrient solution from 2.0 to 3.0 dS m^{-1} (Tab. 5) whose values ranged from 6.95 to 8.81 kg m^{-2} and from 11.63 to 12.29 (Tab. 4); but, AFWF showed a significant decrease (40.69 to 31.81 g). In this sense, Flores *et al*. (2012) obtained a lowest yield (3.17 to 3.27 kg m^{-2}) after evaluating values of electrical conductivity from 2.0 to 3.0 dS m^{-1}. This study coincides with Bertoldi *et al*. (2008) who reported that increasing the conductivity of nutrient solution from 3.0 to 9.0 dS m^{-1} does not generate variations in the NFPC (19.96 to 17.14); nevertheless, the AFWF (7.8 to 6.0 g) is significantly reduced.

TABLE 4. Effect of nutrient solution conductivity on yield components, physicochemical quality and antioxidant capacity of fruit in wild tomato.

EC (dS m^{-1})	Y (kg m^{-2})	NFPC	AFWF (g)	L	C	H (ºhue)	F (N)
2.0	8.81 a[§]	11.63 a	40.69 a	46.37 a	36.72 a	39.22 b	0.74 a
2.5	7.52 a	12.29 a	33.77 b	44.05 b	38.97 a	44.86 a	0.85 a
3.0	6.95 a	12.29 a	31.81 b	44.09 b	38.56 a	41.01 b	0.84 a
DMSH	1.964	3.134	3.918	1.653	2.901	3.108	0.247

EC (dS m^{-1})	TSS (ºBrix)	TTA (% c. acid)	VC (mg 100 g^{-1} asc. acid)	TP (mg 100 g^{-1})	LY (mg 100 g^{-1})	AC (mm TEAC g^{-1})
2.0	4.40 b	0.51 b	6.61 b	3.39 b	22.00 b	52.09 b
2.5	5.16 ba	0.57 a	8.98 ba	3.26 b	19.07 b	50.67 b
3.0	5.59 a	0.56 a	9.38 a	3.90 a	28.42 a	60.37 a
MSDH	0.888	0.036	2.462	0.351	4.281	8.241

EC: electrical conductivity. Y: yield, NFPC: number of fruits per cluster, AFWF: average fresh weight of fruit, L: luminosity, C: chromaticity, H: hue angle, F: firmness, TSS: total soluble solids, TTA: total titratable acidity, VC: vitamin C, TP: total phenols, LY: lycopene, AC: antioxidant capacity. MSDH: Minimum Significant Difference Honest. [§]Means with equal letter within the same column are statistically equal according to Tukey's test ($P \leq 0.05$).

As for the physical variables (Tab. 5), the increase in EC levels of the nutrient solution did not affect the color intensity (chromaticity) (36.72 to 38.97) and fruit firmness (0.74 to 0.85 N). Similar chromaticity values are reported by Cruz and Sandoval-Villa (2012) on "Charleston" tomato fruits (21.86 and 22.43) grown with concentrations of Steiner's solution of 0, 50, 75 and 100%. Flores *et al*. (2012) reported firmness values that surpass what was found in this study (2.45 to 2.59 N) in 10 native genotypes and two commercial hybrids cultivated with three levels of Steiner's solution (1.0, 2.0, or 3.0 dS m^{-1}).

The change on EC values from 2.0 to 2.5 dS m^{-1} caused a significant decrease in fruit brightness of the four wild tomato genotypes evaluated (46.37 to 44.05) (Tab. 5). Non-significant variations on fruit luminosity (31.87 to 32.34) was presented from ten native genotypes of tomato cultivate with three levels of Steiner's solution (1.0, 2.0 and 3.0 dS m^{-1}) (Flores *et al*., 2012). On the other hand, Borghesi *et al*. (2011) found that increasing the conductivity of the nutrient solution from 3.5 to 5.5 dS m^{-1} decrease fruit brightness values by 11.2%.

The wild genotypes fruit tonalities were affected when changing CE values from 2.0 to 2.5 dS m^{-1} (39.22 to 44.86º) (Tab. 5). In contrast, Flores *et al*. (2012) studied ten native genotypes of tomato cultivated with three conductivity levels (1.0, 2.0 and 3.0 dS m^{-1}) and found no significant variation on the hue angle values (33.40 to 34.90°). In this sense, it is important to note that the color of the tomato fruit goes from bright red (41.3º) to orange red (48.0º) (Cantwell *et al.,* 2006); so that the increments found in the hue angle in the present study, reflect a decrease in red coloration.

The variation of the EC from 2.0 to 3.0 dS m^{-1} generated a positive effect on the concentration of the TSS from 4.40 to 5.59 ºBrix, as well as of the TTA (0.51 to 0.57% of citric acid) (Tab. 5). In contrast, Preczenhak *et al*. (2014) found a TSS content maximum of 7.3 °Brix after characterizing sixty-four genotypes of mini tomatoes. Wu and Kubota (2008) reported increases from 5.3 to 6.1 °Brix on tomato fruits by raising the conductivity of the nutrient solution from 2.3 to 4.5 dS m^{-1}. Likewise, Cruz and Sandoval-Villa (2012) found significant increases in percentage of citric acid from 0.348 to 0.383 after increasing concentration of Steiner's solution from 50 to 100%. The behavior observed in data of TSS and TTA according to Ruiz *et al*. (2014) may be related to a decrease in the accumulation of water inside the fruit without a significant change in the sugar concentration.

In this work, the EC modification allowed to detect increases in the VC content from 6.61 to 9.38 mg 100 g^{-1} ascorbic acid. This result differs from the reported by Juárez *et al*. (2013) who evaluating the effect of three levels of the Steiner's solution of EC (1.0, 1.5 and 2.0 dS m^{-1}) did not find variation on the concentration of VC. On the other hand, Krauss *et al*. (2006) indicated an increase in the ascorbic acid concentration up to 35%, when studying the electrical conductivity of 3, 6.5, and 10 dS m^{-1}. The EC of 3.0 dS m^{-1} allowed to increase the TP content (3.90 mg 100 g^{-1}) (Tab. 5). In this sense, Krauss *et al*. (2006) detected significant increases (28.5 to 48.1 mg 100 g^{-1}) on solutions with higher conductivities (6.5 to 13.5 dS m^{-1}), which according to Bhandari *et al*. (2016) is associated to the activation of certain defense mechanisms against the conditions of stress caused by the presence of salts. Non-significant variations on phenols content of tomato fruits was reported by Kubota *et al*. (2012) when evaluating electrical conductivity ranges from 2.4 to 4.8 dS m^{-1}.

Similarly, EC modification favored significantly the LY content in fruits of wild tomato genotypes (22.00 to 28.42 mg ascorbic acid 100 g^{-1}) (Tab. 5), concurring to Krauss *et al*. (2006) whom stablished that the biosynthesis pathway of carotenes (lycopene and β-carotene) is very sensitive to stress caused by environmental factors (light and temperature) and those related to the soil (water deficit and salinity), where the presence of a concentration of salts in the nutrient solution of irrigation may be linked to this behavior (Borghesi *et al.,* 2011). In contrast, Urrieta *et al*. (2012) reported non-significant variations in LY content after evaluating the conductivity levels (1.0 and 2.0 dS m^{-1}). Independently, Juárez *et al*. (2013) reported significant increases of lycopene in cherry-type tomato fruits (42.0 to 49.4 mg 100 g^{-1}) by increasing the conductivity of Steiner's solution from 1.0 to 2.0 dS m^{-1}. These results show that LY content in genotypes of small tomato, such as wild and cherry type, they are more sensitive to variations in the concentration of the nutrient solution, perhaps due to their lower proportion of water compared to fruits of tomato "saladette" and "beef" type. The AC of fruits increased significantly when modifying EC from 2.0 to 3.0 dS m^{-1} with values from 39.44 to 42.93 mm TEAC g^{-1} (Tab. 5). The same behavior was observed by De-Pascale *et al*. (2003) in tomato fruits cultivated in hydroponics using a nutrient solution with a conductivity range between 0.5 and 8.5 dS m^{-1}.

Fruit quality: wild type tomato. When comparing genotypes (Tab. 5), wild selection SS5 presented the statistically highest yield (11.25 kg m^{-2}) relative to SS1 and SS4, which showed the lowest values (5.23 and 5.92 kg m^{-2}, respectively).

These yields were higher than those reported by Vázquez *et al*. (2010) and Ramos *et al*. (2009) (0.46 to 1.66 and 0.53 to 1.53 kg per plant) in wild type kidney fruit. The wild selection SS3 presented the NFPC regarding to SS1, SS4 and SS5 which presented values that fluctuated from 10.51 to 11.04 (Tab. 5). This agronomic characteristic contrasts to those reported by Vázquez *et al*. (2010) and Carrillo *et al*. (2013) (4.2 to 7.2 and 1.86 to 7.33, respectively) in eleven and fifteen collections of kidney-type wild tomatoes. On the other hand, Ramos *et al*. (2009) reported similar of NFPC (60 to 72) in two kidney-like wild genotypes of Oaxaca, Mexico. The same authors also indicate that the great variability in the number of fruits per cluster produced among genotypes of wild tomato is a characteristic directly related to the degree of domestication.

When comparing genotypes (Tab. 5), the wild selection SS5 stands out for its higher AFWF (56.20 g), this result is congruent to the fruit weight ranges indicated by authors such as Vázquez *et al*. (2010) and Carrillo *et al*. (2013) (17.3 to 58.8 and 36.5 to 116.9 g per fruit, respectively); but, AFWF results were lower than those reported by Estrada *et al*. (2011) in four wild type kidney materials with 42.63 and 91.61 g. Among the wild selections, fruits harvested from SS4 wild selection showed the highest color luminosity (43.78 to 44.50) (Tab. 5). These values were lower than those reported for twenty-six genotypes (thirteen wild type kidney and thirteen native and wild) by Vera *et al*. (2011) and Méndez *et al*. (2011) on fruits with brightness ranges from 35.5 to 40.6 and 36.5 to 40.7, respectively). All the wild selections presented fruits that exceed the ideal levels (38.0 and 40.0) described for this species by Preczenhak *et al*. (2014). The chromaticity values of the fruits did not present differences between genotypes (Tab. 6) (37.05 to 39.15). Nevertheless, what was observed for this color component was similar to that reported by Vera *et al*. (2011). As can be seen in Tab. 3, the fruits from the SS3 wild selection showed the highest color tone (45.16°) (Tab. 5) which are within the levels of 35 to 40° of hue angle reported by Cantwell *et al*. (2006) for fruits with red epidermis suitable for commercialization.

The value of firmness found on the wild materials harvested fruits can be considered not adequate (0.73 to 0.92 N), because they did not exceed the minimum firmness level suggested by Batu (2004) for commercial use (1.40 N). This could be considered one of the reasons to consider at the time of marketing these genotypes, and according to Vázquez *et al*. (2010) after 8 d of storage the fruits of these wild genotypes lose consistency being very sensitive to mechanical damage, which makes difficult their postharvest management.

On the other hand, the fruits of the wild selections SS1 and SS3 presented the highest accumulation of TSS (5.35 and 5.86 °Brix) (Tab. 5). This contrasts with the values reported by Vera *et al*. (2011) on 13 samples of kidney type tomato from Mexico (3.4 to 5.2 °Brix). A similar behavior was described by Méndez *et al*. (2011) among 13 native and wild samples from Mexico (4.38 to 8.01 °Brix).

Among genotypes, wild selection SS4 presented a significantly higher percentage of citric acid (0.63%) than the rest of wild materials (0.51 to 0.52%) (Tab. 5). regarding these

TABLE 5. Yield, physicochemical quality and antioxidant capacity components of wild tomato fruits.

Genotype	Y(kg m^{-2})	NFPC	AFWF (g)	L	C	H (°hue)	F (N)
SS1	5.23 c[§]	11.04 b	25.63 b	44.50 b	37.05 a	41.94 b	0.73 a
SS3	8.65 b	15.96 a	29.60 b	43.78 b	38.93 a	45.16 a	0.92 a
SS4	5.92 c	10.51 b	30.26 b	46.90 a	37.21 a	38.89 b	0.81 a
SS5	11.25 a	10.77 b	56.20 a	44.17 b	39.15 a	40.79 b	0.78 a
MSDH	2.507	4.000	5.001	2.104	3.692	3.956	0.315

Genotype	TSS (°Brix)	TTA (% c. acid)	VC (mg 100 g^{-1} asc. acid)	TP (mg 100 g^{-1})	LY (mg 100 g^{-1})	AC (mm TEAC g^{-1})
SS1	5.35 a	0.51b	9.79 b	3.58 b	17.11 c	54.36 ba
SS3	5.86 a	0.5 b	13.23 a	4.10 a	21.92 bc	64.21 a
SS4	4.17 b	0.6 a	6.13 c	3.30 cb	24.81 ba	50.23 b
SS5	4.83 ba	0.5 b	4.13 c	3.08 c	28.81 a	48.70 b
MSDH	1.131	0.046	3.134	0.447	5.449	10.490

Y: yield, NFPC: number of fruits per cluster, AFWF: average fresh weight fruit, L: luminosity, C: chromaticity, H: hue angle, F: firmness, TSS: total soluble solids, TTA: total titratable acidity, VC: vitamin C, TP: total phenols, LY: lycopene, AC: antioxidant capacity. MSDH: Minimum Significant Difference Honest. [§]Means with equal letter within the same column are statistically equal according to Tukey's test ($P \leq 0.05$).

results, Brasiliano *et al*. (2006) indicate a low acidity level when the plants are cultivated in low salinity conditions, but it increase linearly with increasing concentration of salts in nutrient solution. Our results coincide with those reported by Méndez *et al*. (2011) and Vera *et al*. (2011) with values of 0.30 to 0.72 and 0.26 to 0.61%, respectively.

The wild selection SS3 presented the statistically higher content of VC (13.2 mg ascorbic acid 100 g^{-1}), which exceeded the rest of wild materials whose values fluctuated between 2.61 and 5.19 mg ascorbic acid 100 g^{-1}) (Tab. 5). Similar values are reported by Vera *et al*. (2011) (5.5 to 11.6 mg 100 g^{-1}); nevertheless, Méndez *et al*. (2011) found a higher concentration (12.4 to 22.9 mg 100 g^{-1}).

As can be seen in Tab. 5, the TP concentration was higher on the wild selection SS3 (4.10 mg 100 g^{-1}), but was lowest than that reported by Kavitha *et al*. (2014) for four species of wild tomato (53.8 to 96.4 mg GAE 100 g^{-1}). Likewise, LY contents (Tab. 5), wild selections SS4 and SS5 had the highest concentrations (24.81 and 28.81 mg 100 g^{-1}), which exceed those indicated by Méndez *et al*. (2011) on native tomato (12.4 to 22.9 mg 100 g^{-1}) and Vera *et al*. (2011) (10.0 to 16.0 mg 100 g^{-1}) for wild "kidney" type tomato.

The SS3 genotype showed the highest AC value (64.21 mm TEAC g^{-1}) to those observed in SS4 and SS5 genotypes (50.23 and 48.70 mm TEAC g^{-1}, respectively), likewise it was similar to SS1 (54.36 mm TEAC g^{-1}). This result contrasts with that described by Kavitha *et al*. (2014) (30.7 to 48.7 mmol TE·kg^{-1}) in four species of wild tomato.

Conclusions

The EC levels studied in this work did not affect the yield but the physicochemical characteristics and antioxidant capacity of the fruits of "beef" tomato and wild type kidney. So its implementation in the different production systems, can be an alternative of agronomic management that enable obtaining fruits with characteristics of nutraceutical qualities and very attractive for its fresh consumption. Among the kidney genotypes, SS3 and SS5 stood out for their high content of bioactive compounds, which could be very useful as a selection material of genetic breeding.

Literature cited

AOAC. 1990. Association of Official Analytical Chemists. Retrieved from: https://law.resource.org/pub/us/cfr/ibr/002/aoac.methods.1.1990.pdf; consulted: August, 2016.

Barankevicz, G.B., D. Novello, J.T. Resende, K. Schwarz, and E.F. Santos. 2015. Physical and chemical characteristics of tomato hybrids pulp during frozen storage. Hortic. Bras. 33(1), 7-11. Doi: 10.1590/S0102-053620150000100002

Batu, A. 2004. Determination of acceptable firmness and colour values of tomatoes. J. Food Eng. 61(3), 471-475. Doi: 10.1016/S0260-8774(03)00141-9

Bertoldi, F.C., E.S. Sant'Anna, J.L. Barcelos-Oliveira, and R. Simoni. 2008. Antioxidant properties of hydroponic cherry tomato cultivated in desalinized wastewater. Acta Hortic. 843, 197-202. Doi: 10.17660/ActaHortic.2009.843.25

Bhandari, S.R., M.C. Cho, and J.G. Lee. 2016. Genotypic variation in carotenoid, ascorbic acid, total phenolic, and flavonoid contents, and antioxidant activity in selected tomato breeding lines. Hortic. Environ. Biotechnol. 57(5), 440-452. Doi: 10.1007/s13580-016-0144-3

Borghesi, E., M.L. González-Miret, M.L. Escudero-Gilete, F. Malorgio, F.J. Heredia, and A.J. Meléndez-Martínez. 2011. Effects of salinity stress on carotenoids, anthocyanins, and color of diverse tomato genotypes. J. Agric. Food Chem. 59(21), 11676-11682. Doi: 10.1021/jf2021623

Brasiliano, C.C.A., D.F. Pedro, R.G. Hans, F.B. Flávio, B.G. Cira, F.C., and F.C. Selma Aparecida. 2006. Yield and fruit quality of industrial tomato under saline irrigation. Scientia Agric. 63(2), 146-152. Doi: 10.1590/S0103-90162006000200006

Carrillo, R.J.C., H. López-Mendoza, J.L. Chávez-Servia, E. Rodríguez-Guzmán, P. Sánchez-Peña, and R. Lobato-Ortiz. 2012. Phenotypic divergence on growth and productivity of wild and semi-domesticated cherry tomato grown under greenhouse conditions. Acta Hortic. 947, 375-380. Doi: 10.17660/ActaHortic.2012.947.48

Chattopadhyay, A., I.V.I. Chakraborty, and W. Siddique. 2013. Characterization of determinate tomato hybrids: search for better processing qualities. J. Food Proces. Technol. 4, 222. Doi: 10.4172/2157-7110.1000222

Choi, K., G. Lee, Y.J. Han, and J.M. Bunn. 1995. Tomato maturity evaluation using color image analysis. Trans. ASAE 38(1), 171-176.

Cruz, C.E. and M. Sandoval-Villa. 2012. Effect of the nutrient solution concentration and substrates mixture on the quality of tomato. Acta Hortic. 947, 197-202. Doi: 10.17660/ActaHortic.2012.947.24

Estrada, C.J.B., J.C. Carrillo-Rodríguez, M.P. Jerez-Salas, J.L. Chávez-Servia, and C. Perales-Segovia. 2011. Small farmer practices for production improvement of the kidney-type tomato landrace: a case study in Oaxaca. Afr. J. Agric. Res. 6(13), 3176-3182. Doi: 10.5897/AJAR11.538

Flores, G.D., M. Sandoval-Villa, P. Sánchez-García, P. Ramírez-Vallejo, and M.N. Rodríguez-García. 2012. Yield of native genotypes of tomato as affected by electrical conductivity of nutrient solution. Acta Hortic. 947, 69-76. Doi: 10.17660/ActaHortic.2012.947.6

Gaspar, P.P., J.C. Carrillo-Rodríguez, J.L. Chávez-Servia, A.M. Vera-Guzmán, and I. Pérez-León. 2012. Variación de caracteres agronómicos y licopeno en líneas avanzadas de tomate (*Solanum lycopersicum* L.). Phyton 81(1), 15-22.

Grijalva, C.R.L., R. Macías Duarte, and F. Robles Contreras. 2011. Comportamiento de híbridos de jitomate bola en invernadero bajo condiciones desérticas del noroeste de Sonora. Trop. Subtrop. Agroecosyst. 14(2), 675-682.

Hernández, M., E. Rodríguez, and C. Díaz. 2007. Free hydroxycinnamic acids, lycopene, and color parameters in tomato cultivars. J. Agric. Food Chem. 55(21), 8604-8615. Doi: 10.1021/jf071069u

Hernández, L.E., R. Lobato-Ortiz, J.J. García-Zavala, D. Reyes-López, A. Méndez-López, O. Bonilla-Barrientos, and A. Hernández-Bautista. 2013. Comportamiento agronómico de poblaciones F2 de híbridos de jitomate (*Solanum lycopersicum* L.). Rev. Fitotec. Mex. 36(3), 209-215.

Inbaraj, B.S. and B.H Chen. 2008. Carotenoids in tomato plants. pp. 133-164. In: Preedy, V.R. and R.R. Watson (eds.). Tomatoes and tomato products: nutritional, medicinal and therapeutic properties. CRC Press, UK. Doi: 10.1108/nfs.2009.39.6.702.1

Juárez, L.P., R. Medina-Torres, E. Cruz-Crespo, D.W. Reed, M. Kent, L. Cisneros-Zevallos, and P. Ramírez-Vallejo. 2013. Effect of electrical conductivity of the nutrient solution on fruit quality of three native tomato genotypes (*Lycopersicon esculentum* var. cerasiforme). Acta Hortic. 1034, 505-508. Doi: 10.17660/ActaHortic.2014.1034.63

Kacjan, M.N., L. Gašperlin, V. Abram, M. Budič, and R. Vidrih. 2011. Quality parameters and total phenolic content in tomato fruits regarding cultivar and microclimatic conditions. Turk. J. Agric. For. 35(2), 185-194. Doi:10.3906/tar-0910-499

Kavitha, P., K.S. Shivashankara, V.K. Rao, A.T. Sadashiva, K.V. Ravishankar, and G.J. Sathish. 2014. Genotypic variability for antioxidant and quality parameters among tomato cultivars, hybrids, cherry tomatoes and wild species. J. Sci. Food Agric. 94(5), 993-999. Doi: 10.1002/jsfa.6359

Krauss, S., W.H. Schnitzler, J. Grassmann, and M. Woitke. 2006. The influence of different electrical conductivity values in a simplified recirculating soilless system on inner and outer fruit quality characteristics of tomato. J. Agric. Food Chem. 54(2), 441-448. Doi: 10.1021/jf051930a

Kubota, C., M. Kroggel, M. Torabi, K.A. Dietrich, H.J. Kim, J. Fonseca, and C.A. Thomson. 2012. Changes in selected quality attributes of greenhouse tomato fruit as affected by pre-and postharvest environmental conditions in year-beef production. HortScience 47(12), 1698-1704.

Magaña, L.N., A. Peña-Lomelí, F. Sánchez-del Castillo, J.E. Rodríguez-Pérez, and E.D.C. Moreno-Pérez. 2013. Comportamiento productivo de híbridos F1 de jitomate y sus poblaciones F2. Rev. Fitotec. Mex. 36(4), 371-379.

Martínez, S.J., A. Peña-Lomelí, J.E. Rodríguez-Pérez, C. Villanueva-Verduzco, J. Sahagún-Castellanos, and M.G. Peña-Ortega. 2005. Comportamiento productivo en híbridos de jitomate y sus respectivas poblaciones F2. Rev. Chapingo Ser. Hortic. 11(2), 299-307. Doi: 10.5154/r.rchsh.2004.04.028

Méndez, I.I., A.M. Vera G., J.L. Chávez S, and J.C. Carrillo R. 2011. Quality of fruits in Mexican tomato (*Lycopersicon esculentum* Mill.) landraces. Vitae 18(1), 26-32.

Ozgen, M., N.R. Reese, Z.A. Tulio, C.J. Scheerens, and R.A. Miller. 2006. Modified 2,2-Azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) method to measure antioxidant capacity of selected small fruits and comparison to ferric reducing antioxidant power (FRAP) and 2,2´-diphenil-1-picrylhydrazyl (DPPH) methods. J. Agric. Food Chem. 54(4), 1151-1157. Doi:10.1021/jf051960d

Pérez, R.M. P., M. Albarracín, H. Moratinos, and F.Z. Navas. 2012. Rendimiento y calidad de fruto en cuatro cultivares de jitomate (*Solanum lycopersicum* L.) bajo condiciones protegidas. Rev. Fac. Agron. 29(3), 395-412.

Preczenhak, A.P., J.T. Resende, R.R. Chagas, P.R. Silva, K. Schwarz, and R.G. Morales. 2014. Caracterização agronômica de genótipos de minitomate. Hortic. Bras. 32(3), 348-356. Doi: 10.1590/S0102-053620140003000018

Ramos, P.M., J.C. Carrillo-Rodríguez, R. Enríquez-del Valle, and V. Velasco-Velasco. 2009. Fertilizantes orgánicos en la producción de jitomate tipo riñón en Oaxaca, México. Natur. Desar. 7(1), 39-44.

Ruiz, E.F.H., R.L.V. Gutiérrez, B.M. Amador, F.A.B. Morales, and L.G.H. Montiel. 2014. Respuesta diferencial a la salinidad de genotipos de tomate (*Lycopersicon esculentum* Mill.) en primeras etapas fenológicas. Terra Latinoamer. 32(4), 301-309.

Sadler, G., J. Davis, and D. Dezman. 1990. Rapid extraction of lycopene and β-Carotene from reconstituted tomato paste and pink grapefruit homogenates. J. Food Sci. 55(5), 1460-1461. Doi: 10.1111/j.1365-2621.1990.tb03958. x

Schnitzler, W.H. and S. Krauss. 2010. Quality and health promoting compounds tomato fruit (*Lycopersicon esculentum* Mill.) under salinity. Acta Hortic. 856, 21-30. Doi: 10.17660/ActaHortic.2010.856.2

Steiner, A.A. 1984. The universal nutrient solution. pp. 633-650. In: Proc. 6th International Congress on Soilles Culture. Wageningen, The Netherlands.

Urrieta, V.J.A., M.D.L.N. Rodríguez-Mendoza, P. Ramírez-Vallejo, G.A. Baca-Castillo, L.D.M. Ruiz-Posada, and J.A. Cueto-Wong. 2012. Variables de producción y calidad de tres selecciones de jitomate de costilla (*Solanum lycopersicum* L.). Rev. Chapingo Ser. Hort. 18(3), 371-381. Doi: 10.5154/r.rchsh.2010.05.016

Valenzuela, L.M., L.P. Ruvalcaba, T.D. Valdez, T.J.V. Alcaraz, G.B. Bojórquez, and T.E. Osuna. 2014. Respuesta del tomate cultivado en hidroponía con soluciones nutritivas en sustrato humus de lombriz-fibra de coco. Rev. Mex. Cienc. Agric. 5(5), 807-818.

Vásquez, O.R., J.C. Carrillo-Rodríguez y P. Ramírez-Vallejo. 2010. Evaluación morfo-agronómica de una muestra del jitomate nativo del centro y sureste de México. Natur. Desar. 8(2), 49-64.

Vera, G.A.M., J.L. Chávez-Servia, and J.C. Carrillo-Rodríguez. 2011. Variación en calidad de frutos de poblaciones de jitomate (*Solanum lycopersicum* L.) tipo riñón. J. Interam. Soc. Trop. Hortic. 55, 82-85.

Voss, D.H. 1992. Relating colourimeter measurement of plant colour to the royal horticultural society colour chart. HortScience 27 (12), 1256-1260.

Wakeel, A. 2013. Potassium-sodium interactions in soil and plant under saline-sodic conditions. J. Plant Nutr. Soil Sci. 176(3), 344-354. Doi: 10.1002/jpln.201200417

Waterman, P.G. and S. Mole. 1994. Analysis of phenolic plant metabolites. Blackwell Scientific Publications. Oxford, UK.

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. Sci. Hortic. 116(2), 122-129. Doi: 10.1016/j.scienta.2007.11.014