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YIELD AND NUTRACEUTICAL QUALITY OF TOMATO FRUIT PRODUCED WITH NUTRIENT SOLUTIONS PREPARED USING ORGANIC MATERIALS

RENDIMIENTO Y CALIDAD NUTRACÉUTICA DE FRUTOS DE TOMATE PRODUCIDOS CON SOLUCIONES NUTRITIVAS PREPARADAS CON MATERIALES ORGANICOS

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SUMMARY

Increasing public concern about negative environmental effects of agricultural practices like conventional chemical fertilization has promoted the evaluation of alternatives like the use of organic nutrient solutions. This study evaluated the effect on fruit yield and commercial and nutraceutical qualities of fresh tomato (*Solanum lycopersicum* L.) fruits grown under greenhouse conditions fertilized with nutrient solutions prepared from organic materials. Treatments were: a) Inorganic nutritive solution (Steiner); b) Compost tea; c) Vermicompost tea; and d) Vermicompost leachate. Highest fruit yield derived from fertilization with inorganic solution. However, highest antioxidant capacity, soluble solids content and phenolic content were obtained with organic nutrient solutions. Fresh tomatoes obtained with vermicompost leachate had the best nutraceutical quality, higher phenolic content and higher antioxidant capacity, than the inorganically fertilized fruits. Vermicompost leachate is a feasible fertilization alternative for tomato production under greenhouse conditions.

Index words: Protected agriculture, organic production, antioxidants.

RESUMEN

La creciente preocupación pública de los efectos de la fertilización sobre el ambiente, ha promovido la utilización de prácticas agrícolas sostenibles; como el uso de soluciones nutritivas orgánicas. El objetivo de este estudio fue evaluar el efecto de tres soluciones nutritivas preparadas con materiales orgánicos sobre el rendimiento, y la calidad comercial y nutracéutica de frutos de tomate (*Solanum lycopersicum* L.) cultivados bajo condiciones de invernadero. Los tratamientos aplicados fueron: a) Solución nutritiva inorgánica (Steiner); b) Té de compost; c) Té de vermicompost; y d) Lixiviado de vermicompost. El mayor rendimiento se obtuvo utilizando la solución inorgánica; sin embargo, la más alta capacidad antioxidante, contenido de sólidos solubles y fenólicos se obtuvieron con las soluciones nutritivas orgánicas. Los frutos de tomate obtenidos con el lixiviado de vermicompost mostraron la mejor calidad nutracéutica, al obtener mayor contenido fenólico y capacidad antioxidante que los frutos obtenidos inorgánicamente. El uso del lixiviado de vermicompost es una alternativa viable de fertilización para la producción de tomate bajo condiciones de invernadero.

Palabras clave: Agricultura protegida, producción orgánica, antioxidantes.

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INTRODUCTION

Milk production is one of the most important economic activities in the region comprising the Southern Coahuila and Northern Durango in México. Such activity has severe ecological consequences to the region: more than 842,000 t of dry manure per year are produced as waste from dairy activities (Figueroa-Viramontes *et al.*, 2015). This huge amount of organic waste is mostly handled inefficiently and inadequately by untreated application to soil. Environmental impact might be reduced by effective alternatives of manure processing. An alternative is treating manure to obtain compost and vermicompost as substrate components and organic nutrient sources for soil-less crops.

Compost and vermicompost might also be used to obtain highly nutritious aqueous extracts like tea or leachate (Edwards *et al.*, 2010) that contain humic acids (Pane *et al.*, 2016) and plant regulators (Zhang *et al.*, 2014). Interest for usage of compost and vermicompost leachates and teas has increased because of their application flexibility in organic production systems under either protected or open field conditions by pressurized irrigation. Application of these nutritive solutions reduces expenses by substitution of expensive synthetic fertilizers (Preciado-Rangel *et al.*, 2014).

Consumers are interested not only in the commercial quality of horticultural products but also in their nutraceutical quality (Sánchez-Hernández *et al.*, 2016). Consumption of vegetables with high nutraceutical content contributes to positive effects on health, like general physiological improvement and reduction of the advancement of chronic degenerative diseases (Llacuna and Mach, 2012). This study evaluated the application of organic nutritive solutions on tomato (*Solanum lycopersicum* L.) grown under greenhouse conditions to affect fruit yield, as well as their commercial and nutraceutical qualities.

MATERIALS AND METHODS

Plant material and growing conditions

Saladette tomato seeds cvs. Sahel (Syngenta®) were sowed in polystyrene germination containers with 25 mL cavities filled with wet peat moss (Promix PGX™, Quebec, Canada). One seed was placed per cavity. Seeds were covered with black plastic for four weeks until germination; the substrate was kept moist through that period. Four-weeks old seedlings were transplanted to a greenhouse located at Torreón, Coahuila, México (25º 36' 36.54" N, 103º 22' 32.28" W and 1123 masl). The circular greenhouse was covered with a plastic polyethylene layer and equipped with semi-automatic cooling.

Experimental plants were grown in 20-L black polyethylene plastic bags containing a blend of river sand and pearl B12 (80:20, v:v) as substrate. Before mixing, the river sand was washed and sterilized with a 5 % sodium hypochlorite solution. A plant density of 4.2 plants m^2 was used. Pots were drip-irrigated. The total daily irrigation volume was 0.750 L/plant from transplantation to flowering; from flowering to harvest, total daily irrigation volume increased to 2.0 L/plant. Tomato plants were thinned to one stem per plant, and plant support was provided by polypropylene strings tied to the greenhouse ceiling structure. Pollination was performed daily from start of flowering to harvest, from 12:00 to 14:00 h using an electric toothbrush.

Treatments

Four nutritional solutions were applied, (a) Conventional inorganic Steiner nutrient solution (Steiner, 1984); (b) Compost tea; (c) Vermicompost tea; and (d) Vermicompost leachate. The organic solutions were prepared according to the methodology reported by Edwards *et al.* (2010). pH was adjusted to 5.5 with food-grade citric acid ($C_6H_8O_7H_2O$) (Preciado-Rangel *et al.*, 2011). Electrical conductivity was adjusted to 2.0 dS m^{-1} by dilution with tap water to avoid phytotoxic consequences. Solution composition is shown in Table 1.

Fruit yield and commercial quality

The following variables were measured and recorded: fruit yield per plant, polar and equatorial diameter and soluble solids content. Fruits from 10 plants per treatment were harvested at consumer maturity (firm texture, red color, and absence of physical or mechanical damages) from the first to the fifth branch. Yield was calculated as total fruit weight per plant. Polar and equatorial diameter was measured on the harvested fruits. Six fruits per treatment were randomly selected to measure soluble solid content (ºBx) using an Atago® refractometer (Atago Inc., Bellevue, WA, USA).

Nutraceutical quality

Extract preparation. One g of fruit tissue was mixed with 5 mL of methanol in a screw cap plastic tube. The tube was placed in a shaker (ATR Inc., USA) for 6 h (20 *g*) at 5 ºC. The tubes were then centrifuged at 3540 X g for 10 min in a centrifuge Abtek® model J12 (ABTEK, Monterrey, N.L., México) and the supernatant removed for analytical tests.

Total phenolic content. The total phenolic content was determined using a modification of the Folin-Ciocalteau method (Esparza-Rivera *et al.*, 2006). Thirty µL of extract were mixed with 270 µL of distilled water and 1.5 mL of diluted (1:15) Folin-Ciocalteau reagent (Sigma-Aldrich®, St.

Table 1. Chemical composition of the nutritive solutions applied to tomato under greenhouse conditions.

	Steiner solution	Compost tea	Vermicompost tea	Vermicompost leachate
	mg L^{-1}			
N	168	21	24	19
P	31	97	112	113
K	273	151	97	152
Ca	180	415	385	180
Mg	48	2	32	12
$Na^†$	36	70	61	89
S	336	1063	792	438
$Cl^†$	199	190	241	135

†Ions contained in water used for solution preparation.

Louis, Missouri, USA). The mixture was mixed by vortexing for 10 s. After letting the mixture incubate for 5 min, 1.2 mL of sodium carbonate (7.5 % w/v) were added, and the tube vortexed for 10 s. The tube was then placed in a hot water bath at 45 ºC for 15 min and allowed to cool at room temperature. Absorbance of the solution was read at 765 nm in a spectrophotometer Hach® 4000 (HACH Co., Germany). Phenolic content was calculated using a gallic acid (Sigma-Aldrich®, St. Louis, Missouri, USA) standard curve, as a reference standard, and the results were reported in mg of equivalent gallic acid per g of fresh weight (mg equiv AG per g FW). Analyses were run by triplicate.

Antioxidant capacity equivalent in Trolox (DPPH$^+$ method). Antioxidant capacity was determined using a modification of the DPPH$^+$ method published by Brand-Williams *et al.* (1995). A DPPH$^+$ methanolic solution was prepared adjusting the absorbance of the solution at 1.100 ± 0.010 at a wavelength of 515 nm. The antioxidant capacity test was run by mixing 50 µL of sample extract and 0.950 mL of DPPH$^+$ solution and reading the absorbance of the mixture after 3 min of reaction at a wavelength of 515 nm. A standard curve was prepared with Trolox (Sigma-Aldrich®, St. Louis, Missouri, USA), and the results were reported in equivalent µM in Trolox per g fresh weight (µM equiv Trolox per g FW). Analyses were run by triplicate.

Lycopene content. Lycopene content was determined based on the method proposed by Olives *et al.* (2006) and a modified chromatographic method (Berra, 2012). One gram of fresh tomato was mixed with 5 mL of a chloroform:methanol (5:1) solution in a plastic container with screw cap. The mixture was agitated under dark conditions for 24 h at 20 *g*. Afterwards, the chloroform phase was separated, centrifuged at 4720 Xg for 10 min, and filtered in a separation column packaged with activated sodium sulphate (Sigma-Aldrich®, St. Louis, Missouri, USA). Chloroform was evaporated in a rotary evaporator Buchi® R-210 (Buchi Labortechnik AG, Flawil, Switzerland). The residue was stored at -20 ºC until its reconstitution for analysis.

Each residue was reconstituted with HPLC-grade chloroform (Sigma-Aldrich®, St. Louis, Missouri, USA) and filtered through a cellulose-acetate membrane filter (0.20 µm) before its injection into an HPLC chromatograph (Series 1200, Hewlett Packard™, Palo Alto, California, USA) using the ChemStation software for LC (Agilent Technologies, Santa Clara, CA, USA). Lycopene was eluted in a C18 Supelco column (150 mm x 5.0 µm x 0.5 cm) with a 0.5 mL min^{-1} flow using a 50:50 mixture of acetonitrile and 70 % methanol as a mobile phase. Both solvents were HPLC grade (Sigma-Aldrich®, St. Louis, Missouri, USA). The effluent was monitored at 472 nm in a diode array detector G1315D (Agilent Technologies, Santa Clara, CA, USA). Results were calculated using a standard curve of lycopene (Sigma-Aldrich®, St. Louis, Missouri, USA) and reported as mg of lycopene per g of fresh tomato fruit.

Statistical Analysis

The experimental design was set-up as a random block arrangement, and the obtained data were analyzed through ANOVA. Mean comparison was conducted using the Tukey test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Yield

The type of nutrient solution significantly affected fruit weight ($P \leq 0.05$, Table 2). The Steiner solution treatment produced the highest yield (Table 2). This result agrees with Preciado-Rangel *et al.* (2011), who indicated that using inorganic nutrient solution produced higher yield of tomato fruits. In addition, these authors also mentioned that regular application of organic fertilizer produces lower yield compared to traditional fertilizers (Márquez-Quiroz *et al.*, 2013). Generally, growers involved in organic agriculture accept these results as a rule (Márquez-Quiroz *et al.*, 2014). However, lower yield from organic agriculture systems is usually compensated by premium prices (Leifeld, 2012).

Table 2. Yield and fruit size of tomato fertilized with different nutrient solutions under greenhouse conditions.

Treatment	Yield	Polar diameter	Equatorial diameter
	(kg/plant)	(mm)	
Steiner solution	2.76 a	72.7 a	48.0 a
Compost tea	1.48 b	52.7 b	33.7 b
Vermicompost tea	1.65 b	54.0 b	35.2 b
Vermicompost leachate	1.63 b	47.7 c	32.2 c

Values followed by different letter in the columns are significantly different, according to a Tukey test ($P \leq 0.05$).

Nitrogen is reported as the main nutritional constrain to high crop yield (Fonseca and Piña, 2006); thus, lower yield in crops fertilized with organic nutrient solutions could be attributed to lower N concentration and bioavailability (Preciado-Rangel *et al.*, 2014). The organic nutrient solutions in this study were diluted before their application to avoid phytotoxic effects caused by salinity (Oliva-Llaven *et al.*, 2010) (Table 1). Therefore, prior evaluation of non-synthetic fertilizer alternatives that can fulfill nutrimental crop requirements without toxicity to plants or environment is required. Toxicity might be reduced by application of organic nutrient solutions mixtures (Márquez-Hernández *et al.*, 2013) or higher dilutions of such organic liquid extracts (González-Solano *et al.*, 2013).

Commercial fruit quality

Polar and equatorial diameters of fresh tomato fruits were evaluated as indicators of commercial product quality. Both diameters showed differences among treatments ($P < 0.05$, Table 2). Bigger tomato fruits were obtained from treatments fertilized with Steiner solution. Organic fruits are regularly smaller than those fertilized with inorganic solutions (Rodrigues *et al.*, 2010). However, organic tomato fruits might concentrate more lycopene (Zhang *et al.*, 2016) and have more soluble solids (Preciado-Rangel *et al.*, 2011).

Soluble solid content is an important quality parameter of tomato fruits that mostly suggests sugar content and flavor (Rodrigues *et al.*, 2010). Total soluble solids (TSS) content measured in tomato fruits in this study approximate reported values for fresh or processed tomato (4.5 ºBx) (Márquez-Hernández *et al.*, 2008). Yet, the type of nutrient solution applied affected TSS values in tomato ($P \leq 0.05$, Table 2). Fruits obtained from plants fertilized with vermicompost leachate had the highest TSS (6.0 ºBx).

These results agree with those reported by Preciado-Rangel *et al.* (2011) who obtained higher TSS in organically-fertilized tomato compared to fruits produced with inorganic fertilization. This effect could be attributed to higher saline concentration of the organic solutions and also to Na^+ and Cl^- ion concentration in such nutrient solutions (Wu and Kubota, 2008). Higher salinity compromises water and nutrient uptake in tomato plants (Hassan *et al.*, 2015) and causes oxidative stress that affects normal fruit development.

As a response to higher salinity, fruits accumulate organic solutes like simple sugars (glucose, fructose and sacarose) that reduce the cellular osmotic potential and facilitate water absoption (Goykovic and Saavedra, 2007). Alternative organic nutrient solutions with lower salinity and adequate nutrient content, that fulfill the tomato crop nutritional requirements, need to be evaluated.

Nutraceutical fruit quality

Polyphenols and antioxidant compounds present in fruits are nutraceutical indicators mainly determined by genotype (George *et al.*, 2004) and plant nutritional status (Zhang *et al*., 2016). Nutrient solution applied affected phenolic content and antioxidant capacity of tomato fruits ($P \leq 0.05$, Table 3). Other researchers (Bunea *et al.*, 2012; Omar *et al.*, 2012) have reported that application of organic manure on crops increases fruit phenolic content and antioxidant capacity.

In this research, fruit fertilized with vermicompost leachate had higher phenolic content and antioxidant capacity (higher nutraceutical quality) than inorganically fertilized tomatoes ($P \leq 0.05$, Table 3). These results might be the result of high content of humic acids (Gutiérrez-Miceli *et al.*, 2007) and low N content in the organic solutions applied (Table 1).

Plants respond differently to the N supply: when nitrogen requirements for the crop are satisfied, some N-containing compounds such as amino acids, proteins and alkaloids will be produced (Hallmann and Rembiałkowska, 2012). Contrary to this behavior, plants grown under N-deficient conditions will produce simple and complex

Table 3. Soluble solids, phenolic content and antioxidant capacity of fresh tomato fruits obtained with different nutritive solutions under greenhouse conditions.

Treatment	Total soluble solids (ºBx)	Total phenolic content (mg equiv in gallic acid /100 g FW)	Antioxidant capacity†† (µM equivTrolox/ 100 g FW)	Lycopene content (mg/100 g FW†)
Steiner solution	4.3 c	13.30 b	140.0 b	4.87 a
Compost tea	5.5 ab	14.82 ab	140.6 ab	4.55 a
Vermicompost tea	5.1 b	13.15 b	130.3 b	3.75 b
Vermicompost leachate	6.0 a	15.38 a	160.2 a	4.81 a

†Values followed by different letter in the columns are significantly different, according to a Tukey test ($P \leq 0.05$). ††Method ABTS.

sugars, organic acids, vitamins, secondary metabolites, pigments and antioxidant compounds like terpenoids and phenolics (Nguyen and Niemeyer, 2008).

Additionally, N deficit causes oxidative stress in tomato plants, which results in higher anti-oxidative activity of superoxide dismutase (SOD) (García-Hernández *et al.*, 2001) and higher antioxidant capacity and phenolic content in fruits (Oliveira *et al*., 2013). Fruits obtained from plants fertilized with Steiner solution, compost tea or vermicompost leachate had the highest lycopene content. Potassium present in the nutrient solutions (Table 1) might influence lycopene content, as it improves carotenoid synthesis, increases lycopene content in fruit (Almeselmani *et al.*, 2009), and is a key enzymatic cofactor in lycopene synthesis from ß–carotene (Bramley, 2002).

Application of organic nutrient solutions represents a feasible option that produces fruits free of chemical agents with better nutraceutical quality. These traits provide marketing advantages and promote environment preservation from reduced usage of chemical fertilizers. Organic nutrient solutions with higher K and N content are viable products for increasing yield and nutraceutical quality of tomato fruits produced under greenhouse conditions.

CONCLUSIONS

The source of nutrient solutions applied to tomato plants affect yield, as well as the commercial and nutraceutical fruit quality. The biggest fruit and highest fruit yield was produced with inorganic nutrient solution. However, the tomato fruits produced using organic nutrient solutions had better antioxidant capacity and higher content of soluble solids and phenolic compounds than those produced under inorganic fertilization. Overall, tomatoes produced using vermicompost leachate had the highest nutraceutical quality among all the nutrient solutions.

The application of organic nutrient solutions on tomato produced under greenhouse conditions is a viable alternative that favors high commercial and nutraceutical qualities. Further evaluation of organic nutritive solutions for promoting yield increments, higher commercial value, and better nutraceutical quality of tomato fruits, is required to fine-tune production.

BIBLIOGRAPHY

Almeselmani M., R. Pant and B. Singh (2009) Potassium level and physiological response and fruit quality in hydroponically grown tomato. *International Journal of Vegetable Science* 16:85-99.

Olives B. A. I., M. Cámara H., M. Sánchez M., V. Fernández R. and M. López S. T. (2006) Application of a UV–vis detection-HPLC method for a rapid determination of lycopene and β-carotene in vegetables. *Food Chemistry* 95:328-336.

Berra W. G. (2012) HPLC method optimization and validation for determination of lycopene in tomato (*Lycopersicon esculentum*, Mill.) fruits. *Science, Technology and Arts Research Journal* 1:14-26.

Bramley P. M. (2002) Regulation of carotenoid formation during tomato fruit ripening and development. *Journal of Experimental Botany* 53:2107-2113.

Brand-Williams W., M. E. Cuvelier and C. Berset (1995) Use of a free radical method to evaluate antioxidant activity. *LWT - Food Science and Technology* 28:25-30.

Bunea C. I., N. Pop, A. C. Babes, C. Matea, F. V. Dulf and A. Bunea (2012) Carotenoids, total polyphenols and antioxidant activity of grapes (*vitis vinifera*) cultivated in organic and conventional systems. *Chemistry Central Journal* 6:1-9.

Edwards C. A., A. Askar, M. Vasko-Bennett and N. Arancon (2010) The use and effects of aqueous extracts from vermicompost or teas on plant growth and yields. *In*: Vermiculture Technology: Earthworms, Organic Wastes, and Environmental Management. C. A. Edwards, N. Q. Arancon and R. Sherman (eds). CRC Press. pp:235-248.

Esparza-Rivera J. R., M. B. Stone, C. Stushnoff, E. Pilon-Smits and P. A. Kendall (2006) Effects of ascorbic acid applied by two hydro-cooling methods on physical and chemical properties of green leaf lettuce stored at 5 °C. *Journal of Food Science* 71:270-276.

Rodrigues F. S. M., R. J. Sossela F., E. N. Lazzari K., D. A. Quadros, L. T. Tullio and J. J. Lima (2010) Quality of tomatoes cultivated in the organic and conventional cropping systems. *Food Science and Technology* 30:224-230.

Figueroa-Viramontes U., G. Núñez-Hernández, D. G. Reta-Sánchez y H. E. Flores-López (2015) Balance regional de nitrógeno en el sistema de producción leche-forraje de la Comarca Lagunera, México. *Revista Mexicana de Ciencias Pecuarias* 6:377-392.

Fonseca F. R. y E. Piña A. (2006) Efecto de niveles de nitrógeno sobre el rendimiento y la calidad del fruto del pimiento (*Capsicum annun* L.), cultivar bouquet-50. *Revista Centro Agrícola* 33:15-20.

García-Hernández J., E. Troyo-Diéguez, B. Murillo-Amador, A. Flores-Hernández y A. González-Michel (2001) Efecto de algunos insecticidas y un promotor de crecimiento sobre variables fisiológicas y el rendimiento de tomate *Lycopersicon esculentum* L. cv. Río Grande. *Agrochimica* 45:189-198.

George B., C. Kaur, D. Khurdiya and H. Kapoor (2004) Antioxidants in tomato (*Lycopersium esculentum*) as a function of genotype. *Food Chemistry* 84:45-51.

González-Solano K. D., M. D. L. N. Rodríguez-Mendoza, L. I. Trejo-Téllez, J. Sánchez-Escudero y J. L. García-Cué (2013) Propiedades químicas de tés de vermicompost. *Revista Mexicana de Ciencias Agrícolas* 5:901-911.

Goykovic C. V. y G. Saavedra R. (2007) Algunos efectos de la salinidad en el cultivo del tomate y prácticas agronómicas de su manejo. *Idesia* (*Arica*) 25:47-58.

Gutiérrez-Miceli F. A., J. Santiago-Borraz, J. A. Montes M., C. C. Nafate, M. Abud-Archila, M. A. Oliva Ll., R. Rincón-Rosales and L. Dendooven (2007) Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum esculentum*). *Bioresource Technology* 98:2781-2786.

Hallmann E. and E. Rembiałkowska (2012) Characterisation of antioxidant compounds in sweet bell pepper (*Capsicum annuum* L.) under organic and conventional growing systems. *Journal of the Science of Food and Agriculture* 92:2409-2415.

Hassan M. A., M. Martínez F., F. J. Ramos S., O. Vicente and M. Boscaiu (2015) Effects of salt and water stress on plant growth and on accumulation of osmolytes and antioxidant compounds in cherry tomato. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 43:1-11.

Leifeld J. (2012) How sustainable is organic farming? *Agriculture, Ecosystems & Environment* 150:121-122.

Llacuna L. and N. Mach (2012) Papel de los antioxidantes en la prevención del cáncer. *Revista Española de Nutrición Humana y Dietética* 16:16-24.

Márquez-Hernández C., P. Cano-Rios y N. Rodríguez-Dimas (2008) Uso de sustratos orgánicos para la producción de tomate en invernadero. *Agricultura Técnica en México* 34:69-74.

Márquez-Hernández C., P. Cano-Ríos, U. Figueroa-Viramontes, J. Ávila-Diaz, N. Rodríguez-Dimas and J. L. García-Hernández (2013) Yield and quality of tomato with organic sources of fertilization under greenhouse conditions. *Phyton* 82:55-61.

Márquez-Quiroz C., S. T. López-Espinosa, E. Sánchez-Chávez, M. García-Bañuelos, D. Cruz-Lázaro and J. Reyes-Carrillo (2014) Effect of vermicompost tea on yield and nitrate reductase enzyme activity in saladette tomato. *Journal of Soil Science and Plant Nutrition* 14:223-231.

Márquez-Quiroz C., S. T. López-Espinosa, P. Cano-Ríos y A. Moreno-Reséndez (2013) Fertilización orgánica: Una alternativa para la producción de chile piquín bajo condiciones protegidas. *Revista Chapingo Serie Horticultura* 19:279-286.

Nguyen P. M. and E. D. Niemeyer (2008) Effects of nitrogen fertilization on the phenolic composition and antioxidant properties of basil (*Ocimum basilicum* L.). *Journal of Agricultural and Food Chemistry* 56:8685-8691.

Oliva-Llaven M. A., L. Rodríguez-Hernández, P. Mendoza-Nazar, B. Ruiz-Sesma, J. D. Álvarez-Solís, L. Dendooven and F. A. Gutiérrez-Miceli (2010) Optimization of worm-bed leachate for culturing of tomato (*Lycopersicon esculentum* Mill.) inoculated with *Glomus fasciculatum* and *Pseudomonas fluorescens*. *Electronic Journal of Biotechnology* 13:4-5.

Oliveira A. B., C. F. Moura, E. Gomes-Filho, C. A. Marco, L. Urban and M. R. A. Miranda (2013) The impact of organic farming on quality of tomatoes is associated to increased oxidative stress during fruit development. *PLoS One* 8:1-8.

Omar N. F., S. A. Hassan, U. K. Yusoff, N. A. Abdullah, P. E. M. Wahab and U. R. Sinniah (2012) Phenolics, flavonoids, antioxidant activity and cyanogenic glycosides of organic and mineral-base fertilized cassava tubers. *Molecules* 17:2378-2387.

Pane C., A. M. Palese, R. Spaccini, A. Piccolo, G. Celano and M. Zaccardelli (2016) Enhancing sustainability of a processing tomato cultivation system by using bioactive compost teas. *Scientia Horticulturae* 202:117-124.

Preciado-Rangel P., J. L. García-Hernández, M. A. Segura-Castruita, L. Salas-Pérez, A. V. Ayala-Garay, J. R. Esparza-Rivera y E. Troyo-Diéguez (2014) Efecto del lixiviado de vermicomposta en la producción hidropónica de maíz forrajero. *Terra Latinoamericana* 32:333-338.

Preciado-Rangel P., M. Fortis-Hernández, J. L. García-Hernández, E. O. Rueda-Puente, J. R. Esparza-Rivera, A. Lara-Herrera, M. A. Segura-Castruita y J. A. Orozco-Vidal (2011) Evaluación de soluciones nutritivas orgánicas en la producción de tomate en invernadero. *Interciencia* 36:689-693.

Sánchez-Hernández D. J., M. Fortis-Hernández, J. R. Esparza-Rivera, J. C. Rodríguez-Ortiz, E. de la Cruz-Lázaro, E. Sánchez-Chávez y P. Preciado-Rangel (2016) Empleo de verrmicompos en la producción de frutos de melón y su calidad nutracéutica. *Interciencia* 41:213-217.

Steiner A. A. (1984) The universal nutrient solution. *In*: Proceedings 6th International Congress on Soilless Culture. International Society for Soilless Culture (ed)., Lunteren, Netherlands. pp:633-649.

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. *Scientia Horticulturae* 116:122-129.

Zhang E., Y. Duan, F. Tan and S. Zhang (2016) Effects of long-term nitrogen and organic fertilization on antioxidants content of tomato fruits. *Journal of Horticulture* 3:172-176.

Zhang H., S. N. Tan., W. S. Wong, C. Y. L. Ng, C. H. Teo, L. Ge, X. Chen and J. H. W. Yong (2014) Mass spectrometric evidence for the occurrence of plant growth promoting cytokinins in vermicompost tea. *Biology and Fertility of Soils* 50:401-403.