Investigation note

The electrical conductivity of the nutritive solution modifies yield and quality of fruits of *Physalis peruviana*

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Abstract

The cape gooseberry (*Physalis peruviana* L.) is a nightshade susceptible to soil diseases, for this reason it is proposed to grow it in Mexico under greenhouse and hydroponics. It is necessary to determine its response to the electrical conductivity of the nutrient solution (EC), which is why plants were exposed to 1, 2 and 3 dS m^{-1}. Sunlight is another factor that affects the quality of the fruits, for which fruits were harvested from inside and outside the plant canopy. The effect of fruit maturity was also determined. The fruits were determined weight, Brix, firmness and color (L, a and b). The EC, location in canopy and fruit maturity generated 12 treatments. The data were compared with a range mean test. Of the fruits, the EC of the nutritive solution affected the firmness and the Brix except the weight. The position of the fruits in the canopy did not affect these variables either. The maturity at harvest affected the quality of the fruits. The fruits harvested 30 days after commercial maturity lost weight and firmness, and increased Brix in more mature fruits. Fruit location and maturity did not affect fruit color.

Keywords: canopy, cape gooseberry, maturity.

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During the development of the fruits metabolic processes occur that are determining in their quality, these processes depend on factors that are not always favorable; for example, the availability of nutrients, temperature, solar incidence, health, among others. The fruits are harvested and marketed seeking to maintain optimum quality during its shelf life and to reduce undesirable effects during its post-harvest life.

The stage of maturity in which they are harvested is a determining factor in the quality of the cape gooseberry since it determines the flavor and texture. The electrical conductivity (EC) of the nutritive solution is decisive in the quality of the fruits, because it is related to soil fertility and salinity. In some studies it has been found that if the EC is high, there may be negative effects for the crops because the assimilation of CO_2 and transpiration is affected, since at high EC the excessive absorption of Na^+ and Cl^- occurs and there is an imbalance in the availability of nutrients (Wu and Kubota, 2008).

Experimental design

The experiment was carried out in a greenhouse at the Postgraduate College. An experiment was designed with three treatments of electrical conductivity (EC) of the Steiner solution: 1, 2 and 3 dS m^{-1}. Each treatment consisted of nine replicates with a total of 27 plants in a completely randomized design. Likewise, the location of the fruit in the vegetable canopy (internal and external) and two dates of fruit harvest were considered: at commercial maturity (MC) and 30 days after MC (MC30).

Harvest

Fruits from the internal part (I) and the external part (E) of the plant canopy were selected and labeled in each treatment. Fruits were harvested when they reached the commercial maturity state (MC) or state 6 according to the Colombian Technical Standard 4580 (NTC) (ICONTEC, 1999). Thirty days after stage 6, fruits (MC30) were harvested from inside the plant canopy and outside it. The fruits were weighed, Brix degrees were determined with a refractometer, color with a Hunter Lab reflection colorimeter, and texture with a Wagner Force Five model FDV-30 texturometer.

Statistical analysis

The data process began with a non-parametric analysis using the Kruskal Wallis test. The statistical model considered factors; 1) electrical conductivity of the Steiner solution (1, 2 and 3 dS m^{-1}); 2) position of the fruit in the canopy of the plant (internal and external); and 3) degree of maturity of the fruit (maturity commercial and commercial maturity plus 30 days). A comparison of means was made to choose the best treatment. The Statistical Analysis System program (SAS version 9, 2002) was used.

Fruit weight

The average weight of the fruits was 3 g. The fruits with the greatest weight were those that were in commercial maturity ($p< 0.05$): from 2.7 to 3 g, the fruits in MC30 had weights between 2.4 and 2.9 g (Figure 1 and 2).

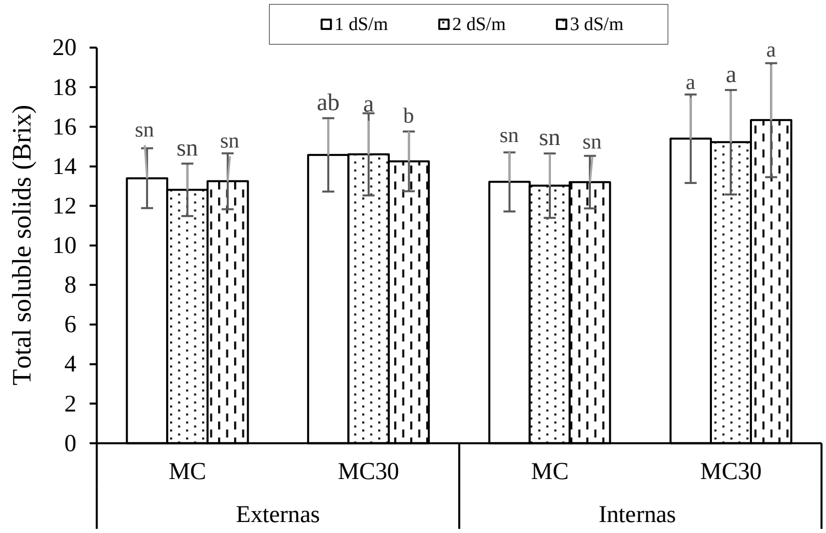

Figure 1. Total soluble solids (Brix) in cape gooseberry fruits by effect of electrical conductivity of the nutritive solution, position in the plant canopy (external and internal) and fruit maturity (MC= commercial maturity, MC30= 30 days after MC). Means with the same letter, indicate that the differences are not significant.

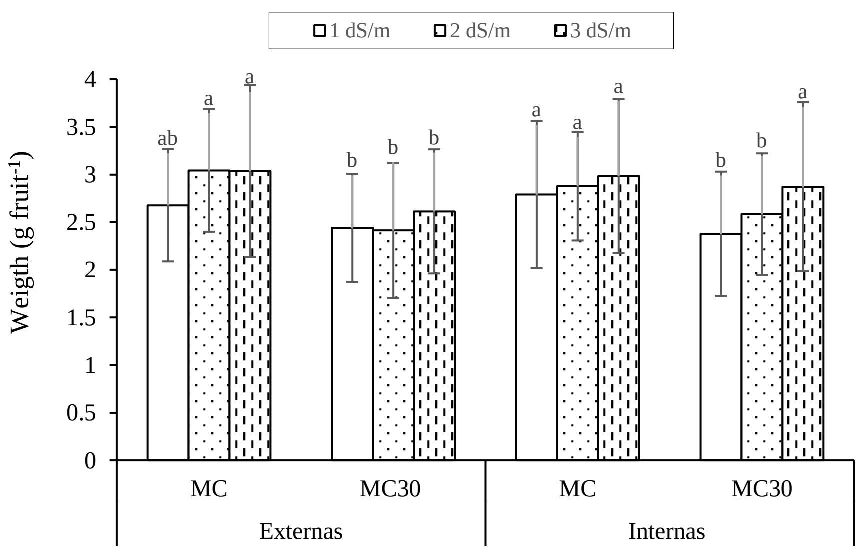

Figure 2. Weight of cape gooseberry fruits by effect of electrical conductivity of the nutrient solution, position in the plant canopy (external and internal) and fruit maturity (MC= commercial maturity, MC30= 30 days after MC). Means with the same letter, indicate that the differences are not significant.

Weight loss in MC30 fruits is attributed to compounds that promote weakening of the cell wall: pectinmethyl esterases and α-galactosidases, which, according to Trinchero *et al*. (1999), increase their concentration when the cape gooseberry fruits are ripening. There was no effect of the position of the fruit in the canopy. Fischer *et al*. (2014) indicate that a good solar incidence provides conditions to obtain good quality fruits.

Muniz *et al*. (2014) state that the fruits of *Physalis* need 1 500 to 2 000 hours of light per year to obtain a good quality of the fruits. Fruits of EC-3 and MC30 were the only ones that showed differences in weight, due to the effect of position, where the external fruits had weights of 2.6 g and the internal ones 2.9 g, contrary to what was expected. This could be due to the fact that in the internal part calyxes and nearby leaves transpire less and save photoassimilates that are translocated to the nearby fruits (Mazorra, 2003).

In treatments MC-E, MC30-E and MC-I, EC did not affect fruit weight (Figure 3); however, MC30-I fruits showed greater weight with EC-3 than with EC-1 and EC-2 with the same maturity and position of the fruit within the plant canopy. Aguilar-Carpio *et al*. (2018) obtained similar results: fruits with a concentration of 150% of the Steiner solution had 59% more weight compared to fruits with 50% of the Steiner solution.

Treatments with high EC have high potato productivity (2.2 dS m^{-1}) (Calori *et al*., 2016). On the other hand, Lee *et al*. (2015) mention that high EC decreases water absorption and affects the respiratory rate of plants. The fruits in MC and MC30 were 2.9 g and 2.6 g this affirms that the fruits in MC have a higher weight ($p< 0.05$). The average weight of the external and internal fruits was 2.7 g and without effect of position in canopy ($p< 0.05$). Álvarez-Herrera *et al*. (2015) obtained fruits with 3.33 g.

Brix degrees

In MC30 fruits, high Brix values were found (Figure 3), there was no effect of the position of the fruit within the plant canopy. There were also no significant differences in Brix by EC ($p> 0.05$). The MC fruits varied between 12.8 ±1.4 and 13.4 ±1.6 with an average of 13.1 ±1.5 Brix. According to NTC 4580, the fruits in commercial maturity must have 15.1 Brix this data is close to what was obtained in MC30 harvested fruits, with Brix between 14.3 ±1.5 and 16.3 ±2.9 and average of 15.1 ±2.4 Brix.

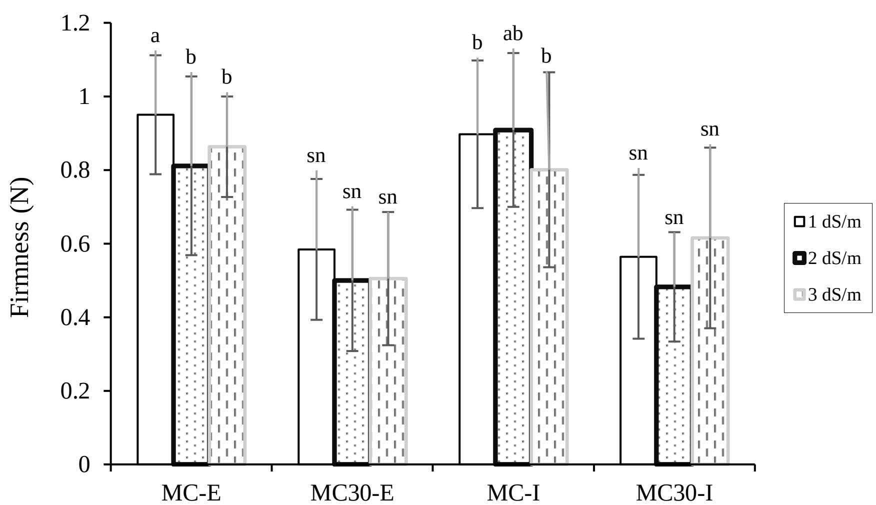

Figure 3. Cape gooseberry fruit firmness due to the electrical conductivity of the nutrient solution, position in the plant canopy (external and internal) and state of maturity (MC= commercial maturity, MC30= 30 days after MC). Means with the same letter, indicate that the differences are not significant.

Similar values were found in Colombian ecotype gooseberry fruits from crops for export by Pinzón *et al*. (2015) where they obtained values of 14.5 and 15.8 Brix stored for 18 days at 2 and 4 C respectively. This could indicate that the Brix obtained in MC30 fruits are similar, with the same effect in fruits stored at low temperatures. Bravo *et al*. (2015) found similar values in fruits in MC (S3-S5 according to NTC4589) with 14.17 and 13.3 Brix.

Pinzón *et al*. (2015) recorded 17.3 Brix in fruits stored at room temperature for 15 days, which is close to that obtained in the 3-MC30-I treatment (16.3 Brix). These similarities can be attributed to the fact that in both cases natural metabolic processes were generated where sugars such as sucrose, glucose and fructose increase (Duque *et al*., 2011), in the first case for not undergoing any post-harvest treatment and in the second for that there was a greater substrate to generate sugars since they were in the internal part and with a higher EC.

Singh (2012) relates the total soluble solids with the increase of total peptic substances when the fruits are in the process of maturity (1 to 8 weeks after anthesis). On the other hand, Balaguera-López *et al*. (2015) mention that the calyx of the fruits can be an important source of carbohydrates, to which the transformation of these carbohydrates into sugars could be due. The fruits, external and internal, had from 13.77 to 14.4 Brix, so there was no effect due to the Brix position of the fruits.

Firmness of the fruits

The firmness in fruits in MC against MC30 indicates that the latter decreased their firmness (Figure 4). Singh (2012) mentions that during the first stages of development (one to eight weeks after anthesis) the fruits increase their firmness constantly. Majumder (2002) mentions that there is an increase in pectic substances during fruit development and these are responsible for forming new cells in the cell wall. Majumder (2002) found that this is due to the solubilization of pectic substances, by the synthesis of enzymes such as polygalacturonases (PG), which in turn are related to the presence of ethylene.

The firmness in fruits in MC ranges from 0.8 ±0.2 to 1 ±0.2 N, for fruits in MC30 they were obtained from 0.5 ±0.2 to 0.7 ±0.7 N. The firmness in fruits in MC, MC30, External and Internal had 0.87a, 0.57b, 0.73c and 0.71c N, respectively, without considering the EC. These values are below that found by Pinzon *et al*. (2015), 3.4 and 2.3 N under two different temperatures with 15 days of storage.

The treatment with the highest firmness in fruits was MC-E with EC of 1 dS m^{-1} (Figure 4), with a firmness of 1 N, in the other fruits in MC there was no effect. The fruits with EC-2 MC30-I and EC3 MC30-E were those with the highest loss of firmness, 0.5 N. Although in MC30 fruits there was no influence of EC ($p>$ 0.05), the treatment that preserved its firmness was EC-2 MC30-E. The external fruits had greater firmness in EC-1 MC. The MC30-E fruits had their highest firmness in EC-2 and EC-1.

MC30 fruits lose their firmness (Figure 4a). Balaguera-López *et al*. (2015) found a similar trend with fruits with and without calyx where firmness is lost when stored for 15 days at room temperature. Firmness in MC30 was not affected by E C (Figure 4b).

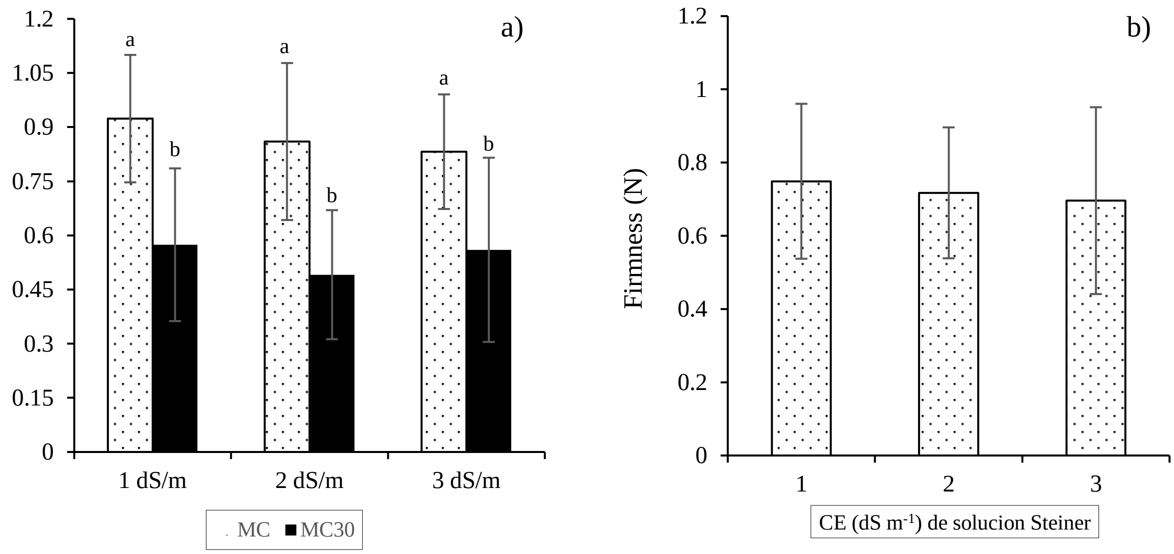

Figure 4. Effect of electrical conductivity (EC) on firmness of cape gooseberry by effect of the date of harvest of the fruit (a); and electrical conductivity of the nutrient solution (b). Means with the same letter, indicate that the differences are not significant.

Fruit color

Regarding L, the treatments E-C2-MC30-I, EC3-MC30-I, EC1-MC-I, EC1-MC-E were those with the highest luminosity. These fruits were in the internal part of the vegetal canopy. No trend was observed regarding EC and fruit maturity. Color characteristic a was not affected by EC and fruit maturity ($p > 0.05$). Characteristic b had higher values in treatments EC1-MC-I, EC3-MC30-I, EC1-MC-E and EC2-MC30-I, as well as for L, no trends were found for EC, nor for maturity of the fruits, as Table 1 refers.

Table 1. Color characteristics of the fruits due to the effect of harvest maturity (MC commercial maturity and 30 days after MC; MC30), position of the fruits in the canopy and by electrical conductivity (EC) in the nutrient solution.

EC (dS m^{-1})	Position	External to the canopy			Internal to the canopy		
	maturity	L	a	b	L	a	b
1	MC	59 ±4.6 a	19 ±5.6	50.6 ±9.7 a	59.2 ±2.5 a	21.4 ±2.6	54.3 ±2.7 a
	MC30	53.3 ±3.4 c	20 ±5.5	46.8 ±11 b	51.8 ±4.3 c	20.2 ±3.8	46.9 ±7.5 b
2	MC	54.9 ±4.2 b	19 ±6.1	42.5 ±11 b	53.5 ±4 c	19.8 ±4.3	44.7 ±8.5 b
	MC30	56.3 ±5.6 b	16.1 ±5.5	42.5 ±13 b	60.3 ±4 a	20.3 ±4.4	50.4 ±8.3 a
3	MC	55.8 ±4.5 b	19 ±5	43.4 ±10 b	53.5 ±5 b	22.2 ±2.7	49.5 ±4 b
	MC 30	58.4 ±3.2 a	18.3 ±6.4	48.5 ±12 b	59.5 ±3.5 a	20.8 ±3	53.6 ±2.7 a

Conclusions

The electrical conductivity (EC) of the nutritive solution does not affect the weight and the Brix in cape gooseberry fruits. The EC affects the firmness of the fruits: it is higher with an EC of 1 dS m^{-1} with fruits harvested at commercial maturity and from outside the canopy. The position of the fruits in the vegetable canopy (external and internal) does not affect the weight, Brix and firmness of the fruits.

As the fruits become more mature, weight and firmness decrease, and the Brix increase. The EC of the nutritive solution does not affect the color of the fruits, but the position and maturity induce differences for L (lightness) and b (shade from yellow to blue) except in a (shade of green to yellow).

Cited literature

Aguilar Carpio, C.; Juárez López, P.; Campos Aguilar, I.; Alia Tejacal, I.; Sandoval Villa, M. y López-Martínez, V. 2018. Análisis de crecimiento y rendimiento de uchuva (*Physalis peruviana* L.) cultivada en hidroponía e invernadero. Rev. Chapingo Ser. Hortic. 24(3):83-94. http://dx.doi.org/10.5154/r.rchsh.2017.07.024.

Álvarez-Herrera, J. G.; Fischer, G. y Velez, J. 2015. Producción de frutos de uchuva (*Physalis peruviana* L.) bajo diferentes láminas de riego, frecuencias de riego y dosis de calcio. Rev. Colomb. Cienc. Hortíc. 9(2):222-233. https://doi.org/10.17584/rcch.2015v9i2.4177.

Balaguera-López, H. E.; Martínez, C. A. y Herrera A. A. 2015. Refrigeration affects the postharvest behavior of 1-methylcyclopropenetreated cape gooseberry (*Physalis peruviana* L.) fruits with the calyx. Agronomía Colombiana. 33(3):356-364. Doi: 10.15446/agron.colomb. v33n3.51896.

Bravo, K.; Sepúlveda-Ortega, S.; Lara-Guzmán, O.; Navas-Arboleda, A. A. y Osorio, E. 2015. Influence of cultivar and ripening time on bioactive compounds and antioxidant properties in Cape gooseberry (*Physalis peruviana* L.). J. Sci. Food Agric. 95(7):1562-1569. Doi: 10.1002/jsfa.6866.

Calori, A.; Factor, T.; Feltran, J.; Watanabe, E.; Moraes, C. and Purquerio, L. 2016. Electrical conductivity of the nutrient solution and plant density in aeroponic production of seed potato under tropical conditions (winter/spring). Bragantia, Campinas. 76(1):23-32. Doi: 10.1590/1678-4499.022.

Duque, A. L.; Giraldo, G. A. y Quintero V. D. 2011. Caracterización de la fruta, pulpa y concentración de uchuva (*Physalis puruviana* L.). Temas Agrarios. 16(1):75-83.

Fischer, G.; Almanza-Merchan, P. y Miranda, D. 2014. Importancia y cultivo de la uchuva (*Physalis peruviana* L.). Rev. Brasileña Frutic. 36(1):1-15. http://dx.doi.org/10.1590/0100-2945-441/13

ICONTEC. 1999. Instituto Colombiano de Normas Técnicas y Certificación. Frutas frescas. Uchuva. Especificaciones. Norma Técnica Colombiana NTC 4580. Instituto Colombiano de Normas Técnicas y Certificación, Bogotá.

Lee, Y.; Yoo, C.; Park, N. and Yeoung, Y. 2015. Influence of various nutrient concentration on the growth and yield of summer strawberry cultivars cultivated in a hydroponic system. Hortic. Environ. Biotechnol. 56(4):421-426.

Majumder, K. and Mazumdar, B. 2002. Changes of pectic substances in developing fruits of cape-gooseberry (*Physalis peruviana* L.) in relation to the enzyme activity and evolution of ethylene. Sci. Hortic. 96(1):91-101. https://Doi.org/10.1016/S0304-4238(02)00079-1.

Mazorra, M.; Quintana, A.; Miranda, D.; Fischer, G. y Cháves, B. 2003. Análisis sobre el desarrollo y la madurez fisiológica del fruto de la uchuva. Agronomía Colombiana. 21(3):175-189.

Muniz, J.; Kretzchmar, A.; Rufalo, L.; Pelizza, T.; Rufalo, A. and de Macedo, T. 2014. General aspects of physalis cultivation. Ciencia Rural, Santa María. 44(6):964-970. http://dx.Doi.org/10.1590/S0103-84782014005000006.

Pinzón, E.; Reyes, A.; Álvarez-Hernández, J; Leguizamo, M. y Joya, J. 2015. Comportamiento del fruto de uchuva *Physalis peruviana* L. bajo diferentes temperaturas de almacenamiento. Ver. Cienc. Agríc. 32(2):26-35. doi: http://dx.Doi.org/10.22267/rcia.153202.10.

Singh, D. B.; Pal A. A.; Lal, S.; Ahmed, N. and Mirza, A. 2012. Growth and developmental changes of cape gooseberry (*Physalis peruviana* L.) fruits. Asian J. Hortic. 7(2):374-378.

Trinchero, G.; Sozzi, G.; Cerri, A.; Vilella, F. and Fraschina, A. 1999. Ripening-related changes in ethylene production, respiration rate and cell-wall enzyme activity in goldenberry (*Physalis peruviana* L.) a solanaceous species. Posharvest Biol. Technol. 16(2):139-145.

Wu, M. and Kubota, C.2008. Effect of high electrical conductivity of hydroponic nutrient solution and its application timing on lycopene, chlorophyll and sugar concentration of hydroponic tomatoes during ripening. Sci. Hortic. 116(2):122-129. https://doi.org/10.1016/j.scienta.2007.11.014.