Article

Potassium in the nutraceutical quality of hydroponic cucumber fruits

Héctor Armando Díaz-Méndez[1]
Pablo Preciado-Rangel[2§]
Esteban Sánchez Chávez[3]
Juan Ramón Esparza Rivera[4]
Manuel Fortis Hernández[2]
Vicente de Paul Álvarez-Reyna[1]

[1]Antonio Narro Agrarian Autonomous University-Laguna Unit. Peripheral and Highway a Santa Fe S/N, Torreón, Coahuila, Mexico. (hectoriego@hotmail.com; vicpaal@hotmail.com). [2]Center for Research in Food and Development, AC. (esteban@ciad.mx; mforty05@yahoo.com.mx)). [3]Faculty of Chemical Sciences Gómez Palacio, Juarez University of the State of Durango (jresparza02001@yahoo.com). [4]Division of Postgraduate Studies and Research-Technological Institute of Torreón. Road Torreón-San Pedro km 7.5, Torreón, Coahuila, Mexico.

[§]Corresponding author: ppreciador@yahoo.com.mx.

Abstract

The increase in the concentration of phytochemical compounds with antioxidant properties in horticultural crops is an agronomic practice that has recently become important because the consumption of bioactive antioxidant compounds is related to the reduction and prevention of chronic degenerative diseases. The objective of the present study was to determine the effect of potassium concentration (7, 9, 11, 13 and 15 mM) in the nutrient solution on the nutraceutical content of cucumber fruits developed under hydroponic conditions. The nutraceutical quality of the fruit was determined by the content of phenolic compounds and total flavonoids, and the antioxidant capacity *in vitro*. The best nutraceutical quality in cucumber fruits was obtained with the highest dose of potassium in the nutrient solution. The nutraceutical quality of hydroponic cucumber fruits is feasible to be improved by increasing the amount of potassium provided in the nutrient solution. This agronomic practice represents an alternative to increase the phytochemical content and nutraceutical quality of cucumber fruits.

Keywords: *Cucumis sativus* L., phytochemical compounds, nutritive solutions.

Reception date: January 2018
Acceptance date: March 2018

Introduction

Cucumber (*Cucumis sativus* L.) is a horticultural product with high global demand (Eifediyi and Remison, 2010), which has been used in traditional medicine since ancient times due to its chemical content and therapeutic potential (Mukherjee *et al*., 2013). The cucumber is cultivated both in traditional systems in open field and under protected conditions with shade mesh or greenhouses using a pressurized irrigation system to supply the water and nutrient needs, thus obtaining precocity in the crops and increase in yield (Preciado *et al*., 2011). In Mexico, 10% of the total area of this crop is grown in a greenhouse using a hydroponic system (González, 2009). In this system, water and nutritional requirements are provided through a nutritive solution, which is decisive to increase the quality of the fruits or vegetables produced.

Consistent with the fact that current consumers are not only interested in the appearance of the products, but also in their content of antioxidant compounds such as flavonoids, total phenolics, β-carotene and ascorbic acid, among others, which are naturally present in the plant products (Wang and Wu, 2010). The importance of these bioactive compounds is that their consumption is associated with a lower risk of chronic degenerative diseases (Llacuna and Mach, 2012); since these functional foods attenuate oxidative stress, which lead to the disintegration of the cell membrane, protein damage and DNA mutation (Ravishankar *et al*., 2013; Xiao *et al*., 2014). Hence the importance of increasing the concentration of phytochemical compounds with antioxidant properties in fruits and vegetables.

Among the factors that affect nutritional and nutraceutical quality are genotype, environmental conditions and fertilization (Beckles, 2012). In relation to this aspect, it has been reported that potassium (K) is the nutrient that has the greatest influence on the organoleptic quality and the concentration of phytonutrients, which are of vital importance for human health (Lester *et al*., 2010): since it increases the phenolic composition and the antioxidant capacity of the fruit (Constan *et al*., 2014), it plays a role in the synthesis of proteins and photosynthesis (Budiastuti *et al*., 2012). Besides the synthesis of amides and proteins, it is also an enzymatic activator (Devi *et al*., 2012), since it has been related to the production of phytonutrients and therefore, has implications in the biochemical synthesis of metabolism products secondary of the plants (Lester *et al*., 2009), favors the increase of phenolic acids, flavonoids, anthocyanins, chlorophyll, carotenoids, lycopene and vitamins (Ibrahim and Jaafar, 2012). Based on the above, the objective of this study was to determine the influence of the concentration of K in the nutritive solution on the nutraceutical content of cucumber fruits developed in hydroponics.

Materials and methods

The present research work was established under greenhouse conditions at the Technological Institute of Torreon, located at 25° 36’ 36.54” north latitude and 103° 22’ 32.28” west longitude and 1 123 meters above sea level.

Cucumber cv Poinsett seedlings 76 of 35, were transplanted in black plastic bags of 20 L capacity containing as substrate a mixture of river sand: pearlite in proportion of 80:20 (v:v). The pots with a seedling were arranged in a simple row plantation arrangement spaced at 40 cm between plants and 90 cm between rows with a population density of 2.7 plants per m^2. To order the growth of the plant axillary buds were suppressed as they appeared and was conducted to a single main guide, supported by a polypropylene raffia wire vertically held by a transverse wire.

The treatments were designed from modifications of the nutrient solution of Steiner (1984) and consisted of increasing the concentration of K^+ (7, 9, 11, 13 and 15 mM), in relation to Ca^{2+} and Mg^{2+}, according to the guidelines indicated by Steiner. The resulting solutions were adjusted to an osmotic potential of -0.073 MPa and a pH of 5.5 and contained (in mg L^{-1}) Fe 2.5, Mn 0.5, B 0.5, Cu 0.02 and Zn 0.05. The Faith was provided as Fe-EDTA. Each treatment consisted of a pot with one plant, distributed in a completely random design with 15 repetitions (one pot per repetition) arranged under a completely random design. The irrigation with the nutritious solution consisted of 0.5 L pot^{-1} day^{-1} from the transplant until before the flowering and from the flowering to harvest 1.5 L

In the harvest of each treatment, six fully mature fruits were selected at random to determine the nutraceutical quality of the fruit. The nutraceutical quality of the fruit was determined by the analytical tests of content of phenolic compounds and total flavonoids, and antioxidant capacity *in vitro* (DPPH).

Extracts for analytical tests were obtained by mixing sample (lyophilized cucumber powder) with HPLC grade methanol in a 15 mL Falcon tube, stirring the mixture for 72 h at 20 rpm. Then, the supernatant is separated and centrifuged at 2 000 rpm for 10 min and the upper phase (methanolic extract) is extracted using adjustable micropipette, subsequently the (filtration) was carried out in a cellulose acetate membrane filter, with pore 0.45 microns, placing the extract in 2 mL eppendorf tubes, which were stored at -20 ^oC until the analytical tests were performed.

The determination of the antioxidant capacity was carried out according to the *in vitro* method $DPPH^+$ using a modification of the method published by Brand-Williams (1995). A solution of $DPPH^+$ (Aldrich, St. Louis, Missouri, USA) in methanol was prepared, adjusting the absorbance of the solution to 1 100 ± 0.010 at a wavelength of 515 nm. To determine the antioxidant capacity, 50 µL of sample and 950 µL of $DPPH^+$ solution was mixed and after 3 min of reaction the absorbance of the mixture was read at 515 nm. A standard curve was prepared with Trolox (Aldrich, St. Louis, Missouri, USA), and the results were reported as equivalent antioxidant capacity in µM equivalent in Trolox per 100 g fresh base (µM equiv Trolox/100 g BF).

The total phenolic content was measured using a modification of the Folin-Ciocalteau method (Esparza-Rivera *et al*., 2006). The 30 µL of sample were mixed with 270 µL of distilled water in a test tube, and to this solution was added 1.5 mL of Folin-Ciocalteau reagent (Sigma-Aldrich, St. Louis MO, EU) diluted (1:15), vortexing for 10 seconds. After 5 min 1.2 mL of sodium carbonate (7.5%, p/v) was added stirring for 10 seconds. The solution was placed in a water bath at 45 °C for 15 min and then allowed to cool to room temperature. The absorbance of the solution was read at 765 nm in a DR 5000 spectrophotometer. The phenolic content was calculated by means of a standard curve using (Sigma, St. Louis, Missouri, USA) as standard, and the results were reported in mg of gallic acid equivalent per 100 g of fresh base sample (mg equiv AG/100 g BF).

The flavonoids were determined following a modification of the method cited by Rochín-Wong *et al*. (2009). The 250 µL of methanolic extract were mixed with 250 µL of distilled water, and 75 µL of $NaNO_2$ (50 g L^{-1}) and 750 µL of an $AlCl_3$ solution (100 g L^{-1}) were added. It was left to stand for 1 min, 500 µL of 1 M NaOH was added, and 10 mL was added with distilled water. It was mixed and read spectrophotometrically at 510 nm. The results were expressed as equivalent milligrams of catechin (EC)/100 g fresh weight.

The results obtained were analyzed by an analysis of variance using the statistical software SAS (2001). For comparisons of means, the Tukey test ($p \leq 0.05$) was used. In addition, a correlation analysis between the bioactive compounds was carried out.

Results and discussion

The results of this study showed that the application of differential doses of potassium in the nutrient solution significantly affected ($p \leq 0.05$) the content of phenolic compounds and total flavonoids, as well as the antioxidant capacity of cucumber fruits (Table 1).

Table 1. Effect of the potassium concentration of the nutritive solution on the nutraceutical quality of cucumber fruits.

K (mM)	Total phenolic content *	Total flavonoid content **	Antioxidant capacity ***
7	12.2 c	1.94 c	1084.2 c
9	11.2 c	1.86 c	1029.5 c
11	10.3 c	1.72 c	1026.4 c
13	14.1 b	2.36 b	1223.1 b
15	17.5 a	2.68 a	1621.5 a

In the present study, the best nutraceutical quality was obtained in fruits produced under a 15 mM of K supply (Table 1). Likewise, the correlation between phenolic compounds and total flavonoids and the antioxidant capacity of this product was high (R^2= 0.98 and R^2= 0.93), which indicates that the antioxidant properties of this product depend on the content of these phytochemicals. There is a significant improvement in the antioxidant capacity of the fruits and by increasing the concentration of potassium in the nutrient solution, which suggests that the nutraceutical quality of the fruit can be modified. As pointed out by Nguyen *et al*. (2010) when reporting increases in the amount of phenolic compounds by increasing potassium doses.

On the other hand, Ibrahim Jaafar (2012) indicates increases in the total flavonoid content with increasing doses of potassium. Among the main functions of potassium in the metabolism of plant organisms is the regulation of cell balance to facilitate the absorption and translocation of carbohydrates, and this has a direct impact on the formation of phenylpropanoid compounds, which are precursors of phenolic compounds (Kuum *et al*., 2015). Obtaining fruits with higher phytochemical content is desirable because its consumption is associated with a lower risk of cardiovascular diseases and certain types of cancer (Llacuna and Mach, 2012). Therefore, research on the factors that stimulate its production or affect its content is increasing (Navarro *et al*., 2006). Due mainly to the fact that antioxidant compounds are essential in the nutritional quality of fruits (Frusciante *et al*., 2007) and are classified as an essential factor to determine their price in the market.

Conclusions

The best nutraceutical quality in hydroponic cucumber fruits produced in the greenhouse was obtained with the application of 15 mM of K in the nutrient solution of Steiner. Likewise, the correlation between phenolic compounds and total flavonoids and the antioxidant capacity of this vegetable product was high. The nutraceutical quality of cucumber fruits can be modified by adding potassium to the nutritive solution applied. The contribution of potassium in the nutrient solution represents an alternative to increase the phytochemical content and nutraceutical quality of crops grown under hydroponic conditions.

Cited literature

Beckles, D. M. 2012. Factors affecting the postharvest soluble solids and sugar content of tomato (*Solanum lycopersicum* L.) fruit. Postharvest Biol. Technol. 63:129-140.

Brand, W. C. 1995. Use of a free radical method to evaluate antioxidant activity. Lebenmittel-Wissenschaft und Technologie. 28:25-30.

Budiastuti, S.; Purnomo D.; Sulistyo, T. D.; Rahardjo, S. P.; Darsono, L.; Pardjo, V. 2012. The enhancement of melon fruit quality by application of the fertilizer and gibberellin. J. Agric. Sci. Technol. 2:455-460.

Constán, A. C.; Leyva, R.; Blasco, B.; Sánchez, R. E.; Soriano. T.; Ruiz, J. M. 2014. Biofortification with potassium: antioxidant responses during postharvest of cherry tomato fruits in cold storage. Acta Physiol. Plantarum. 36:283-293.

Devi, B. S. R.; Y. J. Kim, S. K. Selvi, S. Gayathri, K. Altanzul, S. Parvin, D. U. Yang, O. R. 2012. Influence of potassium nitrate on antioxidant level and secondary metabolite genes under cold stress in Panax ginseng. Russian J. Plant Physiol. 59:318-325.

Eifediyi, E. K. y Remison, S. U. 2010. Growth and yield of cucumber (*Cucumis sativum* L.) as influenced by farm yard manure and inorganic fertilizer. J. Plant Breed. Crop Sci. 2:216-220.

Esparza, R. J. R.; Stone, M. B.; Stushnoff, C.; Pilon, S. E. y Kendall, P. A. 2006. Effects of ascorbic acid applied by two hydrocooling methods on physical and chemical properties of green leaf lettuce stored at 5 °C. J. Food Sci. 71:270-276.

González, N. J. F. 2009. La agricultura protegida. Horticultivos. Editorial Agro Síntesis SA. de CV. México, D. F. 6 p.

Ibrahim, M. H. and Jaafar, H. Z. 2012. Primary, secondary metabolites, H_2O_2, malondialdehyde and photosynthetic responses of Orthosiphon stimaneus Benth. to different irradiance levels. Molecules. 17:1159-1176.

Kuum, M.; Veksler V. and Kaasik, A. 2015. Potassium fluxes across the endoplasmic reticulum and their role in endoplasmic reticulum calcium homeostasis. Cell Calcium. 58:79-85.

Lester, G. E.; Jifon, J. L. and Makus, J. D. 2009. Impact of potassium nutrition on postharvest fruit quality: Melon (*Cucumis melo* L.) case study. Plant Soil. 335:117-131.

Lester, G. E.; Jifon, J. L. and Makus, D. J. 2010. Impact of potassium nutrition on postharvest fruit quality: Melon (*Cucumis melo* L.) case study. Plant Soil. 335:117-131.

Llacuna, L. and Mach, N. 2012. Papel de los antioxidantes en la prevención del cáncer. Rev. Esp. Nutr. Humana Dietét. 16:16-24.

Mukherjee, P. K.; Nema, N. K.; Maity, N. and Sarkar, B. K. 2013. Phytochemical and therapeutic potential of cucumber. Fitoterapia. 84:227-236.

Navarro, J. M.; Flores, P.; Garrido, C. and Martínez, V. 2006. Changes in the contents of antioxidant compounds in pepper fruits at different ripening stages, as affected by salinity. Food Chem. 96**:**66-73.

Nguyen, P. M.; Kwee, E. M. and Niemeyer, E. D. 2010. Potassium rate alters the antioxidant capacity and phenolic concentration of basil (*Ocimum basilicum* L.) leaves. Food Chem. 123:1235-1241.

Preciado, R. P.; Fortis, V.; García, J. L.; Rueda, E.; Esparza, R. J. R.; Lara, A.; Segura, M. A. y Orozco, V. 2011. Evaluation of organic nutrient solutions for greenhouse tomato production. Interciencia. 36(9):689-693.

Ravishankar, D.; Rajora, A.; Greco, F. and Osborn, E. 2013. Flavonoids as prospective compounds for anti-cancer therapy. The Inter. J. Biochem. Cell Biol. 45:2821-2831.

Rochín. W. C. S.; Gámez, M. N.; Montoya, B. L. C. y Medina, J. L. A. 2009. Efecto de los procesos de secado y encurtido sobre la capacidad antioxidante de los fitoquímicos del chiltepín (*Capsicum annuum* L. var. *glabriusculum*). Rev. Mex. Ing. Quím. 8:232-241.

SAS. 2001. (Statistical Analysis System) Institute. SAS user’s guide. Statistics. Version 9.0. SAS Inst., Cary, NC. USA.

Steiner, A. A. 1984. The universal nutrient solution. Sixth Int. Congr. On Soilless Culture. I.S.O.S.C. Proceeding. The Netherlands. 633-649 pp.

Wang, Y. and Wu, W. H. 2010. Plant sensing and signaling in response to K^+ deficiency. Mol. Plant. 3:280-287.

Xiao, J.; Muzashvili, T. and Georgiev, M. 2014. Advances in the biotechnological glycosylation of valuable flavonoids. Biotechnol. Adv. 32:1145-1156.