Investigation note

Evaluation of osmotic dehydration as a tool for enrichment with bioactive compounds in apple

Francisco Xavier Osorio Gutiérrez[1]
Alondra Peñaloza Ortiz[1]
Yanik Ixchel Maldonado Astudillo[1]
Javier Jiménez Hernández[1]
Ricardo Salazar[2§]

[1]Faculty of Biological Chemical Sciences-Autonomous University of Guerrero. Av. Lázaro Cárdenas s/n, South University City, Col. La Haciendita, Chilpancingo de los Bravo, Guerrero, Mexico. CP. 39090. (checo_xavier@hotmail.com, Aloortiz348@gmail.com, yaixma@gmail.com, jjimenezuagro@gmail.com).
[2]CONACYT-Autonomous University of Guerrero. Av. Javier Méndez Aponte no. 1, Fracc. Agrarian Server, Chilpancingo de los Bravo, Guerrero, Mexico. CP. 39070.

[§]Corresponding author: rsalazarlo@conacyt.mx.

Abstract

The present study evaluates the effect of osmotic dehydration (OD) of slices of creole apple harvested in the state of Guerrero in an emulsion (600 g solid kg^{-1} emulsion) prepared with capsul, jamaica and an oleoresin of piquin chili r adurante120 min at 40 °C. In addition, the apple was osmodehydrated in a solution of sucrose and sucrose-jamaica for comparison purposes. The influence of OD on water loss and on the gain of solids during the process was analyzed. In the same direction, the color change, the oil gain, the content of soluble phenols and monomeric anthocyanins were determined, as well as the maximum compression force of the lyophilized osmodehydrated slices. The samples treated with the emulsion showed an increase in the content of oil, soluble phenols and monomeric anthocyanins. The presence of jamaica in the osmotic solution favored the color change of the samples. The micrographs of the osmodehydrated slices with the emulsion revealed the presence of microcapsules with oil soaked in the microstructure of the apple. The obtained results suggest that this technique can be used to impregnate apple slices with oils and functional substances to produce more attractive foods for the consumer.

Keywords: apple, emulsion, functional foods, Jamaica, osmotic dehydration.

Reception date: May 2019
Acceptance date: June 2019

The demand and preference of functional foods that provide welfare to the people who consume them has increased in the last decade. Several studies have been carried out to incorporate bioactive compounds to prepare minimally processed healthy foods. Different fruits such as banana, strawberry and mango (Huerta-Vera *et al*., 2017; Jiménez-Hernández *et al*., 2017) have been investigated for their suitability to be enriched with functional substances. In this sense, the apple has great potential for the purpose mentioned above for its high porosity. Emser *et al*. (2017); Rascón *et al*. (2018), have successfully enriched apple slices with probiotics using the OD.

At present, osmotic dehydration is generally considered as a pretreatment that can be used in the processing of conventional fruits and vegetables, to improve their quality and save energy (Ciurzyńska *et al*., 2016). The primary reason why it is used as pretreatment is the modification that is achieved by the chemical composition of fruits and vegetables; through, the simultaneous loss of water and gain of soluble solids.

Fruits and vegetables can be transformed into new products with different ratios between water and soluble solids, insoluble and soluble solids, sugars, sugars and acids, sugars and salts (Torreggiani and Bertolo, 2001). The high impregnation of solutes during the OD in most cases is not desirable, except when the osmotic solution has functional properties. In this sense, the use of an emulsion as an osmotic solution to prepare osmodehydrated fruits enriched with bioactive compounds, provides a new approach for the development of functional foods (Salazar, 2015).

Due to the above, the objective of the present work was to finish the influence of the osmotic solution (sucrose, sucrose/jamaica, emulsion) on the loss of water (PA), gain of solids (GS), oil content, color, strength of compression, microstructure and the gain of bioactive compounds to explore a new methodology that allows to enrich and improve apple slices through the functional substances of jamaica and piquin chili oleoresin.

Procedures

Apples of the creole variety with a similar state of maturity, sucrose, soybean oil and piquin chili were obtained in a popular market in the city of Chilpancingo, Guerrero.

The Hi-Cap starch was obtained from Ingredion México. All reagents used were purchased from Sigma-Aldrich (St. Louis, MO, USA) or JT Baker (Phillipsburg, NJ, USA) and were analytical grade. The fruits were thoroughly washed with soap and water and peeled manually using a stainless-steel peeler. Two slices were cut parallel to the seed of each fruit and then cut into 5 mm slices using a sharp cutter.

Oleoresin is prepared by mixing ground piquin chili with soybean oil in a 1:3 ratio (w:w). in an amber glass bottle, which was maintained for 48 h to obtain the oily extract. The oleoresin was decanted by gravity, filtered using a sieve (0.5 mm sieve) and stored under a nitrogen atmosphere and protected from light at 4 °C for later use. The hibiscus extract was prepared from the decoction of 100 g of chalices with 1 liter of water at 90 °C for 10 min. The jamaica extract was filtered and stored at 4 °C for later use.

Three osmotic solutions were prepared. The sucrose solution was obtained by dissolving 600 g of refined sugar in 400 mL of distilled water. The sucrose-jamaica solution was prepared by dissolving 600 g of refined sugar in 400 mL of the aforementioned jamaica extract. The emulsion was obtained by mixing 60 g of Hi-Cap starch, 20 g of piquin chili olerresin, 530 of sucrose and 400 g of water.

The apple slices were osmodehydrated in the osmotic solutions using a ratio 1:30 (w:w) fruit: solution for 120 min at 40 °C. The samples were extracted at 15, 20, 45, 60, 75, 90, 105 and 120 min and the excess solution from the surface was removed using paper towels. The loss of water and the gain of solids was calculated using the continuous method proposed by Azuara (1998).

Afterwards, the osmodehydrated samples were lyophilized for 4 days and the oil content (AOAC method 934.01), humidity (AOAC method 960.39), color (Jiménez-Hernández *et al*., 2017), the content of soluble phenols was determined (De La Parra, 2007) and the content of monomeric anthocyanins (Sáyago-Ayerdi, 2013). The microstructure of the osmodehydrated and lyophilized samples was observed in a scanning electron microscope (ESEM, Philips model XL30). The maximum compression force was measured in a texture analyzer TA-XT2. All results were expressed as averages (n= 3). A one-way analysis of variance through a completely randomized design. The differences between the different groups were determined with the Tukey test. All statistical analyzes were carried out with the JMP 9.0 package (SAS Institute Inc., Cary, NC) at the significance level of α= 0.05.

Discussion

Figure 1 and 2 show the effect of the osmotic solutions used during the OD of the apple slices in water loss (PA) and in the gain of solids (GS). The loss of water after 120 min for the apple slices treated in the sucrose, sucrose-jamaica and emulsion solution was 4.42 ±0, 0.37 ±0.01 and 0.36 ±0.01 g water g^{-1} fresh fruit, respectively. On the other hand, the values of the gain of solids after 120 min for the apple slices treated in the solution of sucrose, sucrose-jamaica and emulsion were 0.08 ±0, 0.08 ±0.01 and 0.04 ±0.01 g solids g^{-1} fresh fruit. Each type of osmotic solution had a similar potential (p< 0.05) to remove water. In contrast, during the OD with the emulsion, the number of solids gained showed a different behavior than the solution of sucrose and sucrose-jamaica. When the solution of sucrose and sucrose-jamaica was used, similar values of PA and G were obtained. This difference can be explained based on the size of the starch molecules used in the emulsion, which block the pores of the surface of the apple, decreasing impregnated solids to favor PA by diffusion.

The physical and chemical properties of the apple slices at the end of the osmotic treatment are shown in Table 1. As can be seen, the use of the jamaica as an osmotic agent had a favorable effect on the content of soluble phenols and monomeric anthocyanins of the slices of processed apple. An increase of 79 and 145% of soluble phenols was obtained in the dehydrated samples in the sucrose-jamaica solution and emulsion, respectively. In the same sense, a significant increase (p< 0.05) in the content of monomeric anthocyanins was obtained.

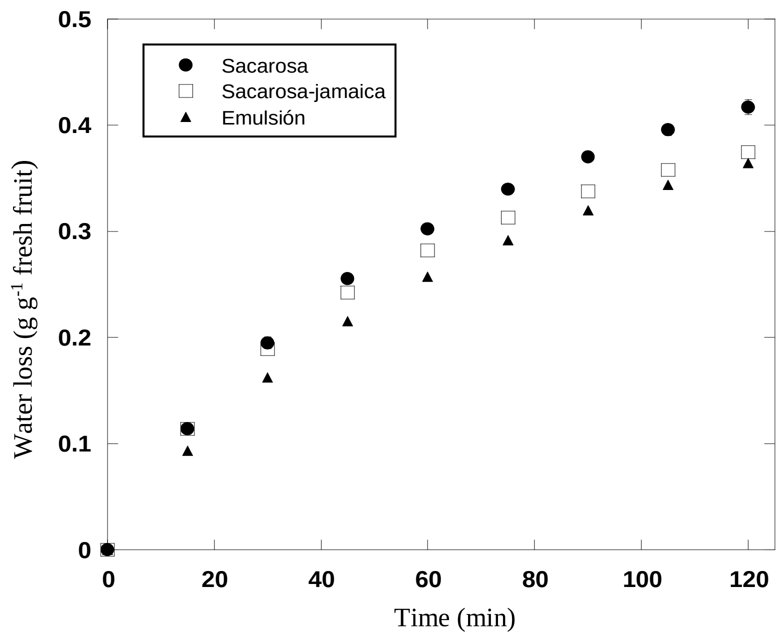

Figure 1. Loss of water during osmotic dehydration of apple slices at 40 °C.

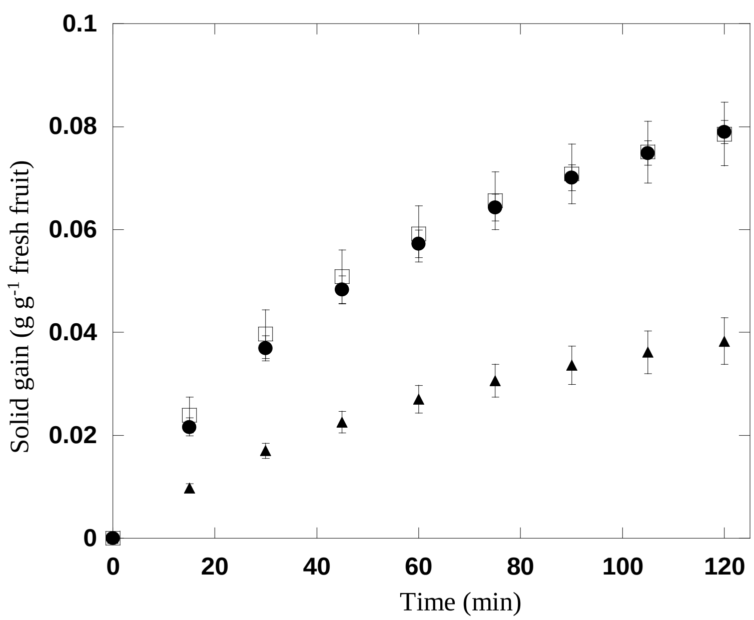

Figure 2. Gain of solids during the osmotic dehydration of apple slices at 40 °C.

The chalices of Jamaica are an important source of natural antioxidants such as anthocyanins and various phenolic compounds due to their high content of red pigments (Cid-Ortega and Guerrero-Beltran, 2015). The color changes are one of the most significant changes observed during the OD. As can be seen in Table 1, the apple slices showed a significant change in their coloration.

Table 1. Physical and chemical properties of osmodehydrated apple slices for 120 min at 40 °C and lyophilized.

Osmotic solution	Soluble phenols (mg g^{-1})	Monomeric anthocyanins (mg g^{-1})	Hue angle (°)	Maximum compression force (N)	Impregnated oil (%)
Saccharose	5.64 ±0.73 b	nd	82.1 ±3.2 a	247.6 ±29.06 a	0.1 ±0 c
Sucrose-jamaica	10.13 ±0.3 a	0.07 ±0.01 a	19.96 ±7.01 b	271.5 ±27.65 a	0.6 ±0.3 b
Emulsion	13.86 ±0.6 a	0.11 ±0.03 a	23.5 ±5.73 b	268.38 ±37.02 a	4.33 ±0.01 a

Average ±standard deviation. The averages followed by a different letter, in the same column, are significantly different; nd= not detected.

The presence of the jamaica and the oleorreina favored the change of color of the apple slices from one to a reddish shade with respect to the slices processed in the sucrose solution (yellow tone). It is important to note that the use of emulsion as an osmotic agent significantly increased the oil content in apple slices. At the end of the OD, the emulsion produced apple slices with an oil content of 4.33 g oil 100 g^{-1} of dried fruit. Similar results have been described for pineapple and mango, when emulsions prepared with gum arabic, inulin and oleoresin from piquin chili were used (Salazar-López *et al*., 2015; Jiménez-Hernández *et al*., 2017).

The results in this study suggest that the use of an aqueous extract of jamaica and piquin chili oleoresin as osmotic agents is a simple way to increase the content of bioactive compounds and modify the color of fruits and vegetables during the OD to create food more attractive and healthy for the consumer. No significant changes were observed ($p< 0.05$) in the maximum compression strength of the osmodehydrated and lyophilized apple slices.

This indicates that none of the ingredients used in this study had an impact on the texture of the processed apple slices. Finally, the structural changes of the apple slices after OD and freeze-dried were observed in a scanning electron microscope (Figure 3). During the OD the cells reduced their shape and size due to the loss of water, causing a shrinkage of the cellular tissue. Regardless, of the osmotic solution used, a smooth surface was observed. However, OD with emulsions made it possible to incorporate microcapsules of starch and piquin chili oleoresin on the tissue of the apple slices.

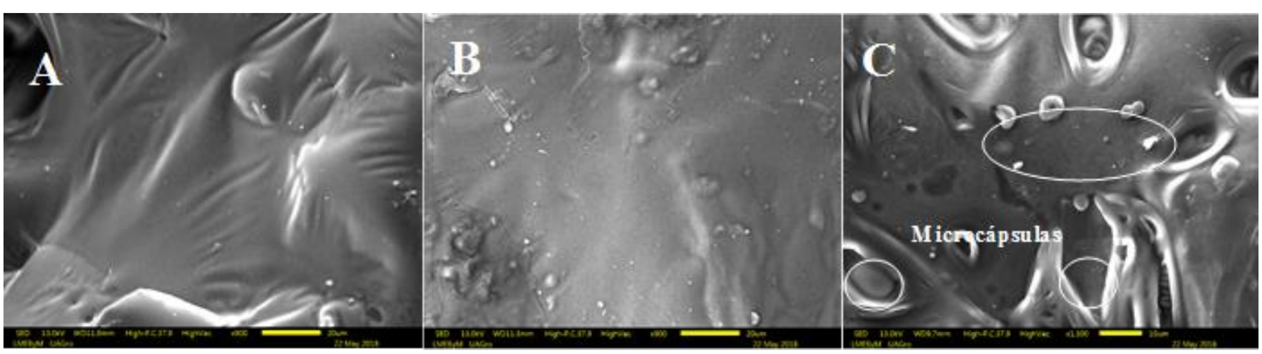

Figure 2. Micrographs of osmodehydrated apple slices for 120 min at 40 °C and lyophilized. (A) sucrose; (b) sucrose-jamaica; and (c) emulsion.

Conclusions

The present study explored the potential of OD with emulsions to incorporate bioactive compounds into apple slices. The results obtained showed that the use of an aqueous extract of jamaica as an osmotic agent has the potential to modify the color and increase the content of soluble phenols and monomeric anthocyanins. In the same sense, the emulsion prepared with jamaica and the piquin chili oleoresin allowed apple slices with a significantly higher oil content to be obtained by the incorporation of starch microcapsules and piquin chili oleoresin on the apple slices tissue. The methodology shown in this work can be used to improve the taste and color of the apple through impregnation with oils and compounds with functional attributes.

Cited literature

Azuara, E.; Beristain, C. I. and Gutiérrez, G. F. 1998. A method for continuous kinetic evaluation of osmotic dehydration. LWT. Food Sci. Technol. 31(4):317-321.

Cid-Ortega, S. and Guerrero-Beltrán, J. A. 2015. Roselle calyces (*Hibiscus sabdariffa*), an alternative to the food and beverages industries. J. Food Sci. Technol. 52(11):6859-6869.

Ciurzyńska, A.; Kowalska, H.; Czajkowska, K. and Lenart, A. 2016. Osmotic dehydration in production of sustainable and healthy food. Trends Food Sci. Technol. 50(1):186-192.

De La Parra, C.; Serna Saldivar, S. O. and Liu, R. H. 2007. Effect of processing on the phytochemical profiles and antioxidant activity of corn for production of masa, tortillas, and tortilla chips. J. Agric. Food Chem. 55(10):4177-4183.

Emser, K.; Barbosa, J.; Teixeira, P. and Bernardo de Morais, A. M. M. 2017. Lactobacillus plantarum survival during the osmotic dehydration and storage of probiotic cut apple. Journal of Functional Foods. 38(1):519-528.

Huerta-Vera, K.; Flores-Andrade, E.; Pérez-Sato, J. A.; Morales-Ramos, V.; Pascual-Pineda, L. A.; and Contreras-Oliva, A. 2017. Enrichment of Banana with *Lactobacillus rhamnosus* using double emulsion and osmotic dehydration. Food Bio. Technol. 10(6):1053-1062.

Jiménez-Hernández, J.; Estrada-Bahena, E. B.; Maldonado-Astudillo, Y. I.; Talavera-Mendoza, Ó.; Arámbula-Villa, G.; Azuara, E. and Salazar, R. 2017. Osmotic dehydration of mango with impregnation of inulin and piquin-pepper oleoresin. LWT. Food Sci. Technol. 79(1):609-515.

Rascón, M. P.; Huerta-Vera, K.; Pascual-Pineda, L. A.; Contreras-Oliva, A.; Flores-Andrade, E.; Castillo-Morales, M. and González-Morales, I. 2018. Osmotic dehydration assisted impregnation of *Lactobacillus rhamnosus* in banana and effect of water activity on the storage stability of probiotic in the freeze-dried product. Lwt. 92(3):490-496.

Salazar-López, E. I.; Jiménez, M.; Salazar, R. and Azuara, E. 2015. Incorporation of microcapsules in pineapple intercellular tissue using osmotic dehydration and microencapsulation method. Food Bio. Technol. 8(8):1699-1706.

Sáyago-Ayerdi, S. G.; Velázquez-López, C.; Montalvo-González, E. and Goñi, I. 2013. By-product from decoction process of *Hibiscus sabdariffa* L. calyces as a source of polyphenols and dietary fiber. J. Sci. Food Agric. 94(5):898-904.

Torreggiani, D. and Bertolo, G. 2001. Osmotic pre-treatments in fruit processing: chemical, physical and structural effects. J. Food Eng. 49(2-3):247-253.