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Osmotic dehydration of mango with impregnation of inulin and piquin-pepper oleoresin

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ABSTRACT

This study assesses the effect of the osmotic dehydration (OD) of mango slices in an emulsion (600 g solids kg^{-1} emulsion) prepared with inulin and piquin-pepper oleoresin. In addition, mango was osmodehydrated in a sucrose solution for comparative purposes. The influence on water loss (WL) and solids gain (SG) during the OD process was analyzed. Furthermore, color change, oil gain, ascorbic acid, β-carotene, and total free phenolic content, as well as 1,1-diphenyl-2-picrylnydrazyl (DPPH) radical scavenging activity and the antiproliferative effect on breast cancer cell line MDA-MB-231 in mango slices after 120 min, were studied. Samples treated with the emulsion at 40 °C showed highest oil gain and bioactive compound retention. In addition, their ethanolic extract exhibited significant radical scavenging activity and antiproliferative effect against the cancer cell line tested, compared with that of flesh- and sucrose-treated sample extracts, in a dose-dependent manner. Images of mango slices treated in emulsion revealed the presence of inulin microcapsules with oil embedded in mango microstructure. Based on these results, this technique can be used to impregnate mango slices with oils and polymers with functional attributes to produce nutritious foods, which may serve as a potential source of phenolic with anticancer activity.

1. Introduction

Mango (*Mangifera indica* L.) fruits are commercially cultivated in >103 countries worldwide and production is increasing each year due to increasing consumer demand (Jahurul et al., 2015). Approximately 5.5% of the world's mangoes are produced in Mexico. However, the mango is scarcely commercialized, when compared with the quantity produced due to the lack of storage and processing facilities, as well as to a limited knowledge of processing technologies. In Mexico, 40% of mango production is wasted (Sumaya-Martínez, Sánchez-Herrera, Torres-García, & García Paredes, 2012).

Dehydration to a low moisture content can extend the fruit's shelf life and add value to the mango chain. Mango is appreciated by consumers, not only as fresh fruit, but also as an ingredient in processed products such as dairy products, ice creams, fruit salads or snacks. Mango processing that maintains the product's freshness characteristics and stabilizes the product, thus lengthening its shelf life on the market, would be very convenient for increasing the fruit's commercialization in non-producing countries (Giraldo, Talens, Fito, & Chiralt, 2003). In this context, osmotic dehydration (OD) is one of the most employed techniques to improve the organoleptic and nutritional properties of foods, and it has been utilized to improve mango quality (e.g., color, texture, flavor, and nutrients) (Azam, Haq, & Hasnain, 2013; Chakraborty & Samanta, 2015).

OD gives rise to at least two simultaneous major counter-current flows: substantial water flow out of the food into the solution, and

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simultaneous transfer of the solute from the solution into the food, elevating the solid content (Torreggiani & Bertolo, 2001). Sucrose, fructose or sodium chloride comprise the main dehydrating agent of fruits. In addition, other solutes-of-interest such as antioxidants or preservatives could be added to the osmotic solution (Nagai, Santos, Faria, Boscolo, & Mauro, 2014).

High intake of osmotic solutes during OD cannot be desirable, except when the osmotic solution employed possesses beneficial health properties. The use of an emulsion as osmotic solution to prepare dehydrated fruit products enriched with bioactive compounds provides a new approach for developing functional foods aimed at meeting consumer needs (Salazar-López, Jiménez, Salazar, & Azuara, 2015) but, to date, there is little information in the literature on the effect of these osmotic agents on the drying kinetics or quality (e.g., color, phenolic content, antioxidant capacity) of fruits that are highly appreciated by consumers. The demand for fruit has increased due to the greater interest of persons in taking care of their bodies and preventing diseases. Currently, choosing fruit is carried out according to its nutritional benefits instead of its sensory characteristics (Dias, Luzia, & Jorge, 2013).

Considering the previously mentioned material, the objective of the present study was to determine the influence of osmotic solution (sucrose or emulsion) and the temperature of the OD on water loss (WL), solids gain (SG), oil content, color, antioxidant capacity, bioactive compound retention, and the antiproliferative effect on breast cancer cell line MDA-MB-231 of processed mango slices in order to explore novel methodologies for the enrichment and improvement of fruits thorough inulin and piquin-pepper oleoresin fortification.

2. Materials and methods

2.1. Materials

Mangoes (*Mangifera indica* L.) of the creole mango cultivar of similar ripening degree were collected in the region of Atoyac de Álvarez (Guerrero, Mexico). Sucrose, soy bean oil, Tween 80®, and piquin-pepper (*Capsicum annum* L. var. *Aviculare*) were purchased at a local supermarket in Guerrero, Mexico. Inulin derived from agave was obtained from Inulina y Miel de Agave, S.A. de C.V.

3. Methods

3.1. Preparation of oleoresin

Piquin-pepper was ground and mixed with soy bean oil at a ratio of 1:3 (w/w) in an amber-colored glass bottle and maintained for 48 h in order to obtain the oleoresin (oily extract). Oleoresin was decanted by gravity, filtered using a sieve (0.5-mm screen), and stored under a nitrogen atmosphere and protected from light at 4 °C for further use.

3.2. Preparation of osmotic solutions

A solution of inulin (120 g) and Tween 80® (20 g) in deionized water (380 g) was prepared. Emulsion was performed by dispersing piquin-pepper oleoresin (30 g) in the inulin solution to obtain an oil/inulin ratio of 0.25 utilizing a high-speed homogenizer at 3500 × *g* and 25 °C for 30 min. Then, the solids concentration of the emulsion was adjusted to a 600 g solids kg^{-1} emulsion with sucrose (450 g). Subsequently, the emulsion was agitated for 60 min before use. On the other hand, sucrose osmotic solution was prepared dissolving 600 g of sucrose in deionized water (400 g) to obtain a concentration of 600 g solids kg^{-1} solution.

3.3. Impregnation-dehydration procedure

The mangoes were washed thoroughly and peeled manually utilizing a stainless steel peeler. Two slices parallel to the seed were cut from each fruit and were then further sliced into 30 × 25 × 5 mm pieces employing a sharp slicer.

Mango slices were osmo-dehydrated in both the emulsion and the sucrose solution, using a fruit: solution ratio of 1:30 (w/w) during 120 min at 30, 40 and 50 °C. Samples were withdrawn at 10, 20, 30, 40, 60, 80, 100 and 120 min and the excess solution from the surface was blot-dried utilizing paper towels. WL and SG during OD were calculated according to Azuara, Beristain, and Gutiérrez (1998).

After the OD process, the water activity of the treated mango was reduced from 0.97 to 0.87–0.90. Osmodehydrated mango and fresh mango samples were dried at 80 °C in for 24 h in an oven (Luzeren, DHG-9070A with forced convection; Beijing, China). The final water activity of fresh and treated mango was 0.49 and 0.47, respectively.

3.4. Analysis of osmo-dehydrated mango slices

Moisture and total oil content were evaluated by the 934.01 and 960.39 (AOAC) methods, (1997) at the beginning and ending of the OD process, respectively. Sample water activity was determined using a dew-point water activity meter (Decagon Devices, Inc., Pullman, WA, USA) at 25 °C. During the OD process, osmodehydrated mango samples in emulsion and sucrose solution were removed at different times (10, 20, 30, 40, 60, 80, 100 and 120 min) to measure color changes by employing a portable colorimeter (X-Rite Spectrophotometer Model Ci62, X-Rite Incorporated, Grandville, MI, USA). The Hue angle (H*) at different time periods was calculated from the determined CIELAB L* a* b* values: $H^* = \tan^{-1}(b^*/a^*)$, where a* = [negative (green) to positive (red)], b* = [negative (blue) to positive (yellow)]. The illuminant employed was D65 and the standard observer position was 10°.

β-carotene and ascorbic acid (AA) content were measured at the beginning and the end of the OD process with the spectrophotometric method reported by Biswas, Sahoo, and Chatli (2011) and Pfendt, Vukašinović, Blagojević, and Radojević (2003), respectively.

Total free phenolic content in mango samples was extracted according to the procedure described by De la Parra, Serna-Saldivar, and Liu (2007) and modified in our laboratory. Briefly, one gram of sample was blended with 10 mL of 95% chilled ethanol for 10 min and then centrifuged at 2000 × g for 15 min. The supernatant was removed and stored at −20 °C until use. Total free phenolic content in mango samples was quantified utilizing the Folin-Ciocalteau method. The standard was gallic acid (GA) and the results were expressed in μg of GA equivalents per g of dry weight (DW) of sample.

Total free flavonoid content was determined from the previously mentioned extracts employing a colorimetric method that was described previously (Adom & Liu, 2002). The standard was (+)-catechin and results were expressed in μg of catechin equivalents per g of DW of sample.

The free-radical scavenging activity by the DPPH free-radical scavenging assay of the sample extracts was analyzed according to the method of Sulaiman and Ooi (2012). The unique modifications of the described method included the reference employed in this assay. A standard curve was obtained using different concentrations (0–1 mg/mL) of ascorbic acid standard solution. The absorbance of the extract was compared with that of the ascorbic acid standard to obtain median effective concentration (EC50) values, which are the concentrations of the extract required to scavenge 50% of DPPH radical. The results of the ethanolic extracts