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Edible coatings from native and modified starches retain carotenoids in pumpkin during drying

E.S. Lago-Vanzela [a,*], P. do Nascimento [b], E.A.F. Fontes [a], M.A. Mauro [c], M. Kimura [c]

[a] Universidade Federal de Viçosa – UFV, Departamento de Tecnologia de Alimentos, CEP 36570-000, Viçosa, MG, Brazil
[b] Instituto de Biociências, Letras e Ciências Exatas, Universidade Estadual Paulista – UNESP, Campus de São José do Rio Preto, 15054-000 São Paulo, Brazil
[c] Departamento de Engenharia e Tecnologia de Alimentos, Instituto de Biociências, Letras e Ciências Exatas, Universidade Estadual Paulista – UNESP, Campus de São José do Rio Preto, 15054-000 São Paulo, Brazil

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ABSTRACT

The goal of this study was to evaluate the effect of edible coating pre-treatments on the retention of provitamin A during pumpkin drying. The coatings used were based on native and modified maize and cassava starch. To evaluate the effects of these coatings, slices of 'Dry Rajada' pumpkin were dried at 70 °C both with and without starch coatings applied at 30 and 80–90 °C. Carotenoid content was determined through HPLC using a C_{30} column. Significant losses (12–15%) of *trans*-α-carotene and *trans*-β-carotene were observed when slices were dried without the coating. Significant improvement of carotenoid content was observed for dehydrated slices that were previously coated with a native maize starch solution at 90 °C, as well as with a modified maize starch solution at 30 °C and also with a modified cassava starch solution at 90 °C. The application of these starch solutions probably produced a more uniform film that adhered to the slices, minimizing carotenoid degradation during pumpkin drying and, as a consequence, resulting in a product that can be considered a good source of provitamin A.

1. Introduction

Over the last twenty years, there has been an increase in studies that point toward an inverse relationship between fruit and vegetable intake and the risk of degenerative illnesses, especially cancer and cardiovascular diseases (Kaur & Kapoor, 2001). The increase in awareness of the importance of consuming fruits and vegetables contributed greatly to the development of better quality processed products. The versatility available, as well as their high nutritional value makes vegetables from the family Cucurbitacea stand out in the vegetable market. Some pumpkin varieties are sources of carotenoids (Arima & Rodriguez-Amaya, 1988; Kurz, Carle, & Schieber, 2008; Murkovic, Mülleder, & Neunteufl, 2002), and are being processed for many products, such as juices (Kreck, Kurbel, Ludwig, Paschold, & Dietrich, 2006) and ready-to-eat dehydrated products (Konopacka et al., 2010). The Rajada Seca variety in particular possesses a good pulp yield and an intense orange color, which are desirable characteristics for the production of other processed products with pro-vitamin A activity.

Drying or dehydration is a simple procedure and is oftentimes less expensive than other food conservation techniques, and is therefore frequently used to give products additional benefits, such as longer shelf life and easier transportation and commercialization. However, drying may alter color and taste, and can also cause nutrient loss due to oxygen and relatively high temperature exposure, especially when carried out using conventional hot air processes. Due to the problems of conventional drying, many researchers have invested in treatment prior to drying, such as dipping in solutions with antioxidant compounds (Bechoff, Westby, Menya, & Tomlins, 2011), blanching (Nascimento, Fernandes, Mauro, & Kimura, 2009), osmotic dehydration (Shi, Le Maguer, Kakuda, Liptay, & Niekamp, 1999) and edible coatings that may be combined with the other two pre-treatments (Baloch, Buckle, & Edwards, 1986; Emam Djomeh, Dehghannya, & Gharabagh, 2006; Zhao & Chang, 1995) to improve sensory qualities and nutrient retention of the dehydrated vegetables.

Edible coatings are fine layers of digestible material added to a food product. There is some indication that, during the drying process, the application of these coatings may reduce the loss of aroma, color and nutrients by reducing oxygen diffusion into the food, minimizing solute incorporation and maintaining the product's physical integrity (Baloch et al., 1986; Zhao & Chang, 1995). Films and

* Corresponding author. Tel.: +55 17 96046083, +55 31 38991845.
E-mail addresses: ellen.lago@ufv.br, ellenlagovanzela@hotmail.com (E.S. Lago-Vanzela), priscila.eng@uol.com.br (P. do Nascimento), eaffontes@ufv.br (E.A.F. Fontes), cidam@ibilce.unesp.br (M.A. Mauro), kimura@ibilce.unesp.br (M. Kimura).

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coatings must include at least one basic component that is able to form an adequate, continuous and cohesive matrix, which may be classified into three categories: polysaccharides, lipids and proteins. Coatings made up of polysaccharides generally present good oxygen barrier properties, particularly under low moisture conditions (Cuq, Gontard, & Guilbert, 1995). Good results have been presented by Baloch et al. (1986) and Zhao and Chang (1995), who evaluated the effect of applying a starch solution to carrot cubes prior to hot air drying. The former authors blanched the samples before applying the coatings, whereas the latter authors boiled the carrots in a starch solution. Both teams suggested that, when the coating was adequately applied to the surface of the carrots, it blocked the contact between tissue pigments and oxygen in the air, which minimized the degradation of provitamin A carotenoids present in carrots.

The goal of this study was to evaluate the effect of the presence of starch-based coatings on the carotenoid content of pumpkin slices dehydrated using hot air. These factors were evaluated in an attempt to find new techniques to obtain a dehydrated product with high provitamin A content.

2. Materials

Ripe pumpkins from the Rajada Seca variety were obtained at São José do Rio Preto Supplying Center (CEAGESP; São José do Rio Preto, São Paulo, Brazil). Native maize, cassava and potato starches were also purchased at the local market. Modified cassava starch (intercrossed and acetylated), commercial name Amidomax 5800, and modified maize starch (acid-hydrolyzed), commercial name Gomagill 50, were provided by Cargill Agricola S/A. The modified starches used were food-grade and safe for consumption.

3. Processing

The pumpkins were transversely cut into three to four pieces and their ends were discarded. Each piece was cut lengthwise into 6–8 parts. After removing the peel and seeds, the parts were sliced (4.5 mm thick) using an electric slicer (Eco). Slices were homogenized and divided into portions of approximately 45 units. One portion of the raw pumpkin was used to determine moisture and carotenoids content. A second portion was used as the control in the drying experiments, and was dehydrated without a coating application in a forced air oven at 70 °C for a period of 8–10 h until reaching a moisture content of approximately 10 g/100 g. The other portions were used for pre-treatment with solutions prepared with different maize and cassava starches, both native and modified.

The solutions were made by heating native cassava starch suspension (1.5 g/100 g of water) and native maize starch suspension (2.5 g/100 g of water) for 10 min at 80 and 90 °C, respectively. These periods were visually determined in preliminary tests, considering the time needed for the suspensions to achieve an increase in viscosity and a loss of opacity (related to starch gelatinization). Modified maize and cassava starch solutions were prepared according to the manufacturer's instructions: heating the cassava starch suspension (1.5 g/100 g of water) at 95 °C for 10 min; and heating the maize starch suspension (2.5 g/100 g of water) at 90 °C for 2 min.

In order to evaluate the effects of the starch and of the application temperature of the edible coating on the carotenoid content of slices of dried pumpkin, native starch coating and modified corn and cassava coating were applied at the gelatinization temperature (80–90 °C) and in the previously cooled solution (30 °C). The slices were soaked in the starch solutions for 1 min, pre-dried through draining, on perforated stainless steel trays at room temperature for 50 min in the dark. They were turned over at 25 min and dried in a forced air oven at 70 °C for a period of 8–10 h until moisture content of approximately 10 g/100 g.

4. Analytical methods

To determine moisture and carotenoids content (*trans*-α-carotene and *trans*-β-carotene), the samples were taken at random and homogenized using a food processor (Philips Walita, Model RI7774/90).

4.1. Moisture determination

Moisture content was determined in triplicate after drying at 100 °C until the weight remained constant using 4.0 and 2.0 g of raw and dried samples, respectively.

4.2. Carotenoid analysis

To make extraction easier, raw samples were kept for 20 min in the extraction solvent and dried samples were hydrated in distilled water for 30–60 min. Carotenoids were extracted with methanol:tetrahydrofuran (1:1) using a Polytron homogenizer (Kinematica AG, Switzerland). They were then filtered using a vacuum in a funnel with plate of sintered glass, and this procedure was repeated until the residue was colorless (2–5 extractions that lasted 1 min each). Next, carotenoids were transferred to petroleum ether in a separation funnel with the addition of distilled water. After complete removal of methanol and tetrahydrofuran, the extract was collected and saponification was completed with an equal volume of methanol solution with 10 g/100 g KOH for 14 h, both in the dark and at room temperature. The saponified extract was washed according to De Sá and Rodriguez Amaya (2003). After the complete removal of the ether, the residue was completely redissolved with HPLC grade acetone and filtered directly into the sample vial using a 0.22-mm PTFE filter (Millipore).

Carotenoids analysis was performed in a Waters HPLC (Model 2695) connected to a UV–visible photodiode array detector (Waters, Model 2996), controlled by Millenium software (version 2110). The separation of the carotenoid was performed in a polymeric C_{30} column (YMC Carotenoid, 3 μm, 4.6 × 150 mm) that was kept between 25 ± 0.5 °C and mobile phase consisting of methanol:ethyl acetate at 70:30 (0.1 g/100 g TEA) at a flow rate of 0.5 mL/min. Peak identification was carried out through the combined analysis of retention time, absorption spectra, and co-chromatography with carotenoid standards (Rodriguez-Amaya, 1999). Quantification was completed using external calibration and expressed as μg carotenoids per g of initial dried pumpkin mass.

Carotenoid retention was calculated by the following equation: % Retention = 100 × (μg carotenoids per g of dried pumpkin) × g of pumpkin after drying/(μg carotenoids per g of raw pumpkin) × g of pumpkin before drying. According to Murphy, Criner, and Gray (1975), this is the most adequate and accurate equation for the calculation of nutrition retention during processing either through incorporation or through loss of water or soluble solids.

4.3. Vitamin A calculation

Vitamin A activities of the samples were determined in retinol activity equivalent (RAE) units, with conversion factors (12 μg of dietary *trans*-β-carotene and 24 μg of *trans*-α-carotene corresponding to 1 μg of RAE) of provitamin A carotenoids (Trumbo, Yates, Schlicker, & Poos, 2001) and parallel presentation of carotenoid levels has been reported.

4.4. Statistical analysis

To evaluate the effect that the application of edible starch coatings had on the retention of *trans*-α-carotene and *trans*-β-carotene and vitamin A of hot-air-dehydrated pumpkins, the data were