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Chemical and technological properties of avocado (*Persea americana* Mill.) seed fibrous residues

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ABSTRACT

In industrial processing of the avocado (*Persea americana* Mill.) fruit only the pulp is used, resulting in thousands of tons of seeds as a waste by-product. Chemical and technological characterizations were done on fiber residues produced with one of two fiber extraction methods: Method A, using $NaHSO_3$; and Method B, using $NaHSO_3$, NaCl and tris-hydroxymethyl-aminomethane. Proximate composition, total, soluble and insoluble dietary fiber, acid and neutral detergent fiber, acid detergent lignin, cellulose and hemicellulose were determined. Also, technological properties were evaluated on fiber residues. The main results were: yield did not differ ($p > 0.05$) between methods (A: 45.63%; B: 48.11%), but they did differ ($p < 0.05$) in ash, moisture and nitrogen-free extract. The residues' relatively high proportions of soluble dietary fiber, neutral detergent fiber and hemicellulose allowed them to retain four times their weight in water and six times their weight in oil. The properties of avocado seed fibrous residues make them promising technological ingredients in industrial food systems.

1. Introduction

Avocado *Persea americana* Mill. is a fruit tree native to Mesoamerica and Central America, but is currently grown worldwide. A member of the Lauracea family, mature trees can reach heights from 15 to 30 m. Its fruit has a dark green, rugose rind that covers a yellow-green pulp rich in oils that is appreciated for its sensory and nutritional characteristics (Giffoni et al., 2009). The large seed accounts for an average of 15–16% of fruit weight. The pulp is a significant source of vitamins (D, E, B_6, B_{12} and C), minerals as potassium, phosphorus, calcium, iron and sodium (Dreher and Davenport, 2013), essential amino acids (valine, lysine, phenylalanine, isoleucine, leucine, threonine and methionine) and unsaturated fatty acids (oleic, linoleic and linolenic) (De Oliveira et al., 2013).

Mexico is the leading avocado producer, accounting for approximately 38% of global production (Gutiérrez et al., 2010). Within Mexico, the state of Michoacán is the primary producer. Avocado fruit is marketed worldwide and processed into value-added products such as guacamole, puree, and oils, among other derivatives. These products utilize only the pulp, leaving behind approximately 148,000 tons of seeds as waste by-product (Gutiérrez et al., 2010). If not discarded properly, these pose a serious disposal challenge and can promote pest vectors such as insects and rodents.

Avocado fruit seeds are a potential alternative fiber source. This makes them a candidate for study as part of the current boom in identifying applications for vegetable by-products, such as dietary fiber (Ceballos and Montoya, 2013). The major potential use in the food industry of these tropical fruit by-products can be as food additives as antioxidants, antimicrobials, colorants, flavorings, and thickener agents. In addition, the complete utilization of fruits by-products could lead the industry to a lower-waste agribusiness, increasing industrial profitability (Ayala-Zabala et al., 2011).

Avocado seed fiber has possible biological and technological uses (Mugdil and Barak, 2013). The seed is high in potassium and antioxi-

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dants, and is one of the best sources of dietary fiber. Has showed had higher amounts of phenolic and a more intense in vitro antioxidant potential than the than the edible portions (pulp) and the common synthetic antioxidants as Trolox due to the content of tannins and polyphenolic compounds within the seed (Rodríguez-Carpena et al., 2011; Segovia-Goméz et al., 2014). Some phytochemical studies on avocado seeds have identified various classes of natural products such as saponin, phytosterols, triterpenes, fatty acids, furanoic acids, flavonol dimers and proanthocyanidins. Some of them are related to antimicrobial, antifungal activities and larvicidal effects (Rodríguez-Carpena et al., 2011; Giffoni et al., 2009). Pahua-Ramos et al. (2012) investigated the effect of methanolic extract of avocado seed flour on the lipid levels in mice on a hyperlipidemic diet and concluded that the antioxidant activity of phenolic compounds and dietary fiber in avocado seeds may be responsible for the hypocholesterolemic activity in a hyperlipidemic model of mice.

Extracting dietary fiber from vegetable by-products provides an opportunity to add value to primary production and mitigate the negative environmental impacts associated with their disposal (Ceballos and Montoya, 2013). Dietary fiber has a number of reported biological effects in humans, including early satiation (Kristensen and Jensen, 2011); retention/excretion of bile acids (Kristensen et al., 2012); gastrointestinal laxative (Jing et al., 2012); hypoglycemia (Post et al., 2012); hypocholesterolemia (Hu and Yu, 2013); as well as prebiotic and cardioprotective properties (Slavin, 2013), among others. It also has useful technological properties such as its capacity to improve softness in bakery products (Mugdil and Barak, 2013) and as a potential emulsifier in meat products (Ospina et al., 2011).

The present study objective was to better understand the potential of avocado (*Persea americana* Mill.) seed fiber produced using two processing methods as an ingredient in food industry processes by chemically and technologically characterizing it.

2. Materials and methods

2.1. Materials

Persea americana Mill. seeds were obtained in the state of Yucatan, Mexico. The fruits purchased from local market then prepared in laboratory to obtain seeds. Impurities and damaged seeds were removed. Reagents were analytical grade and purchased from J.T. Baker (Phillipsburg, NJ, USA), Sigma Chemical Co. (St. Louis, MO, USA), Merck (Darmstadt, Germany) and Bio-Rad Laboratories, Inc. (Hercules, CA, USA).

2.2. Seed powder preparation

Chopped avocado seeds (*Persea americana* Mill. cv. Hass) were spread onto a tray and placed in an oven at 60 °C until dry. The chopped seeds were turned periodically to ensure uniform dryness. Later, the chopped seeds were finely ground (20-mesh screen, 841 μm) using a Retsch® Ball Mill grinder (Retsch GmbH, Germany) for 20 s. The resulting avocado seed powder with 0.84 mm of average particle size was stored at 4 °C until use.

2.3. Extraction of fiber residues

Avocado seed fibrous residues were produced by wet fractionating the seed powder with two different processes. In the first process (called method A), seed powder was suspended in a sodium bisulphite solution (1500 ppm SO_2) at a 1:5 (w/v) ratio, and the suspension left to soak under constant agitation a room temperature for 1 h (Chel-Guerrero et al., 2016). The suspension was sifted through an 80-mesh sieve (177 μm) to retain a solid fraction containing the fiber residue and letting a slurry fraction containing protein and starch (this fraction is discarded). The fiber fraction was washed in distilled water three times and then re-suspended in distilled water and centrifuged at 1100 × *g* for 12 min (Mistral 3000i, Sanyo MSE, UK) to recover the fiber after the final wash. This washed fiber fraction was dried at 40 °C in a convection oven for 12 h, weighed, and milled in a Cyclotec (Tecator, Sweden) mill until it passed through a 60-mesh screen (250 μm). It was stored at room temperature in a sealed container.

The second process (called method B) was done according to Kahn (1987). Seed powder was immersed in a solution containing 2 mM Tris (pH 7.0), 7.5 mM NaCl and 80 mM $NaHSO_3$ This suspension was wet-milled with a Kitchen-Aid® (Benton Harbor, MI, USA) mill and the resulting slurry passed through a 80-mesh sieve (177 μm). It was then washed twice with solvent A to separate the fiber solids from the starch. The fiber was oven dried at 40 °C for 12 h and then milled in a Mykros (Infraestructura Inteligente, Mexico) impact mill until passing through a 60-mesh sieve (250 μm). The methods used (Kahn, 1987; Chel-Guerrero et al., 2016) raise the integral use of avocado seeds. Both processes propose the use of reagents to solubilize proteins and disperse of the starch granules for obtaining the fibrous residues.

Chemical and technological characterizations were done separately of the fiber fractions obtained from each extraction method. All analyses were done in triplicate.

2.4. Fiber residue proximate composition

Standard AOAC (1997) methods were used to determine nitrogen (method 954.01), fat (method 920.39), ash (method 925.09), crude fiber (method 962.09), and moisture (method 925.09) contents in the fiber residues. Nitrogen (N_2) content was quantified with a Kjeltec Digestion System (Tecator, Höganäs, Skåne län, Sweden) using cupric sulfate and potassium sulfate as catalysts. Protein content was calculated as nitrogen × 6.25 to facilitate comparison with other sources, because there is no specific conversion factor for avocado seed fibrous residues. Fat content was obtained from a 1 h hexane extraction according to Soxhlet principle using a Soxtec System (Tecator, Höganäs, Skåne län, Sweden). Ash content was calculated from sample weight after burning at 550 °C for 2 h. Moisture content was measured based on sample weight loss after oven-drying at 110 °C for 2 h. Carbohydrate content was estimated as nitrogen-free extract (NFE) by difference from the sum of the protein, fat, ash and crude fiber contents.

2.5. Total dietary fiber (TDF), insoluble dietary fiber (IDF) and soluble dietary fiber (SDF)

2.5.1. Total dietary fiber (TDF)

TDF content was measured with the gravimetric enzymatic method (Prosky et al., 1988). Avocado seed fiber residue (1 g) was weighed and 50 mL phosphate buffer (50.0 mM, pH 6) was added. α-Amylase enzyme (0.1 mL, Sigma A-3306) was incorporated and agitated at 60 rpm, 100 °C for 15 min. Protease (0.1 mL, Sigma P-3910) was added and were agitated at 60 rpm, pH 7.5, 60 °C, for 30 min. Amyloglucosidase (0.3 mL, Sigma A-9913) was added and agitated at 60 rpm, pH 4.0, 60 °C for 30 min. Finally, 95% ethanol (v/v), preheated to 60 °C, was added at a 4 volume ethanol for one volume sample. This sample was vacuum filtered into crucibles for dietary fiber at constant weight, into which a 1 g cap Celite (Sigma C-8656) had been previously placed. The residue remaining in the flask