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Physicochemical properties of oils extracted from γ-irradiated Sacha Inchi (*Plukenetia volubilis* L.) seeds

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ABSTRACT

This study evaluated the physicochemical properties of oils extracted from γ-irradiated Sacha Inchi (*Plukenetia volubilis* L.) seeds (SIS) at four different doses (0, 1, 5 and 8 kGy). Fatty acid composition, tocopherol content, FTIR spectra, density, refractive index, acidity, peroxide value (PV), *p*-anisidine index (*p*-An), oxidation induction period (IP), and color were chosen as test parameters. Overall, the irradiation treatment did not significantly affect the physicochemical properties of the Sacha Inchi oils, although slight increases were found in the PV and *p*-An, as the irradiation dose increased. γ-Irradiation led to a decrease in the concentration of γ- and δ-tocopherol, as well as in the IP. However, according to the FTIR analyses, the functional groups of the oils were not significantly affected by the γ-irradiation. These results suggest that γ-irradiation at 1–5 kGy, might be recommended as a suitable eco-friendly technology for the preservation of SIS used for oil production.

1. Introduction

Sacha Inchi (*Plukenetia volubilis* L.) is a plant of the Euphorbiaceae family with a great economic expansion in Central and South America, as well as in some South East Asiatic Countries, such as China, Thailand and Vietnam. Their seeds, used for centuries as food for the native people of the Amazon rainforest, are a good source of oil (35–60%), protein (25–30%), essential aminoacids, minerals, and vitamin E (Chirinos et al., 2013; Gutiérrez, Rosada, & Jimenez, 2011; Hamaker et al., 1992). Sacha Inchi oil (SIO) has a great nutritional value, because of its high content of polyunsaturated fatty acids (PUFA) and vitamin E. α-linolenic (ALA, C18:3, ω-3) and linoleic (LA, C18:2, ω-6) acids are the main fatty acids present in SIO, with amounts varying between 47–51%, and 34–37%, respectively (Gutiérrez et al., 2011), while γ- and δ-tocopherol are the major tocopherols, ranging between 50–114, and 30–125 mg 100 g^{-1}, respectively (Chirinos, Pedreschi, Domínguez, & Campos, 2015; Follegatti-Romero, Piantino, Grimaldi, & Cabral, 2009).

Like other seeds and nuts, Sacha Inchi seeds (SIS) are susceptible to deterioration by pest infestation and mold contamination during postharvest storage, since at the production regions, the climatic conditions and the agricultural practices may favor the fungal proliferation, with the consequent loss of quality, and possible production of aflatoxins, which are hazardous to man and livestock (Al-Bachir, 2016; Di Stefano, Pitonzo, Bartolotta, D'Oca, & Fuochi, 2014; Di Stefano, Pitonzo, Cicero, & D'Oca, 2014).

Gamma-irradiation is a nonthermal nonchemical technology effective for reducing the microbial loads of molds, yeasts and pathogenic, as well as for controlling pests in seeds and nuts (Arici, Colak, & Gecgel, 2007; Prakash, 2012). It has been successfully used for extending the shelf life of various types of seeds and nuts, since radiation can penetrate through their shell, providing an homogeneous surface treatment, without major alteration in their characteristics, and without leaving any residue (Prakash, 2012). Nevertheless, the effects of irradiation on the physicochemical properties of seeds, nuts, and their derived oils are quite controversial, since it has been demonstrated that they depend on several factors including species, irradiation dose and type (Prakash, 2012). While some studies indicate that irradiation does not cause significant changes neither in the composition and physicochemical properties of seeds and nuts, nor in the quality of their derived oils (Al-Bachir, 2004, 2015a, 2016; Koç Güler, Bostan, & Çon, 2017; Sinanoglou et al., 2014), some others show the contrary (Al-Bachir, 2015b; Barreira et al., 2013; de Camargo, Vieira, Regitano-D'Arce, de Alencar, Calori-Domingues, & Canniatti-Brazaca, 2012; Di Stefano, Pitonzo, Bartolotta, D'Oca, & Fuochi, 2014; Nemţanu & Braşoveanu, 2016). This variability in the published results, suggest that irradiation studies must be

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conducted for each product of interest, because the extrapolation of available data could lead to erroneous conclusions (Prakash, 2012).

Taking into account that currently SIS are mainly used for the production of SIO, and considering that irradiation could be applied as preservation treatment of SIS, this study aimed to investigate some physicochemical properties of oils extracted from γ-irradiated SIS at four different doses: 0, 1, 5 and 8 kGy. To the best of our knowledge, no research had been previously done on the effects of γ-irradiation of SIS on the physicochemical characteristics of their derived oils.

2. Material and methods

2.1. Materials

SIS were kindly supplied by a local grower from Fusagasugá (Cundinamarca, Colombia). The seeds were selected manually for discarding those with physical visible damages, and vacuum packaged in polyethylene bags (25 × 20 cm, ~23 mm thickness) in experimental units of 600 g. SIS were kept at −40 °C until further irradiation treatments. The packaged samples were divided into four groups, one of which was chosen as a control.

All reagents used in the physicochemical analyses were of analytical grade, and purchased from Sigma-Aldrich (St. Louis, MO, USA).

2.2. Gamma irradiation of in-shell SIS

The irradiation experiments were carried out using a ^{60}Co semi-industrial γ-irradiator Category IV, available in the γ-irradiation plant of the Servicio Geológico Colombiano (Bogotá, Colombia). The activity of the ^{60}Co source was around 66 kCi. The packaged SIS samples were placed at 10 cm from the source, where the dose rate was estimated in 15.1 ± 0.95 kGy h^{-1}, and irradiated at room temperature (~25 °C) and atmospheric pressure. The absorbed doses (1, 5 and 8 kGy) were determined using a Harwell Perspex Polymethylmethacrylate Amber dosimeters (PMMA Instruments, Harwell, UK) placed at the geometric center of the packaged samples. The absorbance of the dosimeters was measured at 603 nm using a visible spectrophotometer (Genesys 20, Thermo-Scientific). The thickness of the dosimeters was calculated with a digital micrometer Digitrix II (NSK). The irradiation process was carried out individually for each one of samples, in triplicate. The irradiated in-shell SIS samples were kept at room temperature until their oil was extracted.

2.3. Oil extraction

The oil extraction was performed after the irradiation treatments. The shelled SIS were ground using a domestic grinder, and mixed with hexane in a 2:7 (w/v) SIS to solvent ratio. The mixture was magnetically stirred during 18 h at room temperature. The extraction vessels were covered with aluminum foil, for avoiding light interferences. After vacuum filtration, the solvent was removed in a rotary vacuum evaporator (IKA RV-10 digital, IKA®, Germany). The obtained SIO were stored at room temperature in sealed amber glass bottles, until analyzed.

2.4. Physicochemical characteristics of oils

2.4.1. Fatty acid composition

The fatty acid composition of the extracted SIO was determined by gas chromatography, as indicated by Gutiérrez and Belkacemi (2008). The fatty acid methyl esters (FAME), obtained by alkaline methylation with sodium methoxide in methanol 0.5 M (Sigma-Aldrich, St. Louis, MO, USA), were analyzed on an Agilent model 7890A gas chromatograph (Santa Clara, CA, USA). The oven temperature was programmed as follows: from 60 °C (isothermal for 1 min) to 190 °C at 20 °C min^{-1}, and isothermal period of 30 min at 190 °C. Helium was used as carrier gas at 1.5 mL min^{-1}. GC separation peaks was performed on a HP-88 (100 m × 0.25 mm id × 0.20 μm film thickness; Agilent J&W GC Columns, Santa Clara, CA, USA). The fatty acids were identified by comparing their retention times with those of the FAME standards (F.A.M.E Mix C4-C24) purchased from Sigma Aldrich (St. Louis; MO, USA) under the same conditions. Peaks were integrated using Agilent ChemStation software.

2.4.2. Tocopherol content

The tocopherol content of the SIO was determined according to AOCS Ce 8-89 (AOCS., 1997) with slight modifications. 180 mg SIO were dissolved in 1 mL *n*-hexane and filtered through the 0.45 μm PTFE filters prior to HPLC injection. The analysis was performed in a HPLC chromatograph Prominence series 20 (Shimadzu, Kyoto, Japan) equipped with a Luna® 5μ Silica column (150 mm × 4.6 mm id, 5 μm particle size, 100 Å pore size; Phenomenex, Torrance, CA, USA) and a diode array detector (DAD) programed at 292 nm. The mobile phase was composed of *n*-hexane/2-propanol (99.5:0.5 v/v) at a flow rate of 1 mL min^{-1}. The injection volume was 10 μL. Tocopherol isomers (α-, β-, δ-, and γ-tocopherol) were quantified using standard curves in a range of 0.5–100 mg kg^{-1}, prepared under the same conditions as the analyses.

2.4.3. Fourier Transform Infrared (FTIR) spectroscopy

FTIR analyses were carried out using a FT/IR-4100 spectrometer (JASCO, Japan). The essays were performed at room temperature and the spectra were recorded in a range from 4000 to 500 cm^{-1}, with a resolution better than 4 cm^{-1}, at a scanning speed of 2 mm s^{-1}. Spectra of SIO samples were obtained through a semi-permanent liquid cell method. A film of a small amount of SIO was carefully placed between two discs of KBr, avoiding the presence of air. The results were expressed in absorbance and the assignment of bands to a specific functional group vibration mode was made by comparison with spectra reported in literature.

2.4.4. Chemical and physical indices

The density of the extracted SIO was determined pycnometrically at 25 °C according to AOAC Official Method 9201.212 (AOAC, 2010). The refractive index was measured at 25 °C following to the AOAC Official Method 921.08 (AOAC, 2010). The acid value (AV, mg KOH g^{-1} oil) (AOCS Cd 3d-63), peroxide value (PV, mEq O_2 kg^{-1} oil) (AOCS Cd 8–53), and *p*-anisidine index (*p*-An, AOCS 18-19) were determined by following the standard methods of the American Oil Chemist's Society (AOCS, 1997). The total oxidation value (TOTOX) was calculated by means of Eq. (1).

$$TOTOX = (2 \times PV) + p - \text{An} \quad (1)$$

The oxidation stability of the extracted SIO samples was evaluated by means of the Rancimat test, using an 892 Professional Rancimat instrument (Metrohm, Switzerland). Samples of SIO (~6 g) were carefully weighed in glass test tubes, and analyzed under constant airflow of 20 L h^{-1} within the thermostat-controlled block heater at 100 ± 1.4 °C. The volatile oxidation products generated during the accelerated oxidation were collected in a vessel containing 50 mL of deionized water, where the conductivity was continuously measured. The induction period (IP) was defined as the time taken from the start of the test to the onset of oxidation, and determined from the second derivative of the conductivity curve automatically. The experiments were carried out at least in duplicate.