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Fatty acid composition and rheological behaviour of prickly pear seed oils

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Abstract

Prickly pear fruits constituted valuable foodstuff for humans and animals in arid and semi-arid regions. Two species of prickly pear from Tunisia, *Opuntia ficus indica* and *Opuntia stricta*, were investigated for fatty acid composition and physicochemical parameters of the seed oil. No significant difference in either physical or chemical parameters was found between the species. The main fatty acids of prickly pear seed oil were C16:0, C18:0, C18:1, C18:2. With an exceptional level of linoleic acid, up to 70%, the content of unsaturated fatty acids was high, at 88.5% and 88.0% for *O. ficus indica* and *O. stricta*, respectively.

Rheological properties were analysed with changes of temperature and shear stress. Variations of viscosity were measured and the viscoelastic parameters were determined during heating and cooling cycles between 20 and 70 °C. Curves of flow were established with up and down cycles of shear stress at different temperatures. These measures highlighted the presence of large aggregates of crystal fatty acids in both *Opuntia* crude oils. Shearing and temperature destroyed this structural state and gave birth to an homogeneous stable suspension.

The structural state of crude oil was confirmed using a contrast phase microscope, and the particle size distribution was obtained by laser granulometry.

Keywords: Prickly pear; Fatty acid; Seed oil; Rheology; Microscopy; *Opuntia*

1. Introduction

About 1500 species of cactus belong to the genus *Opuntia* and are distributed mainly in Africa, Mediterranean countries, southwestern United States, northern Mexico and other areas (Hegwood, 1990). The main studies on the *Opuntia* fruits were the chemical analysis of pulp, skin and seeds (El Kossori, Villaume, El Boustani, Sauvaire, & Mejean, 1998), analysis of volatile constituents of pulp (Di Cesare & Nani, 1992; Flath & Takahashi, 1978), use of pulp in juice production (Espinosa, Borrocal, Jara, Zorilla, & Medina, 1973), production of alcoholic beverage (Bustos, 1981), jam production (Sawaya, Khatchadorian, Safi, & Al-Mohammad, 1983) and the production of cocoa butter equivalents from prickly pear juice fermentation by an unsaturated fatty acid auxotroph (Hassan, Blanc, Pareilleux, & Goma, 1995). An overview of processing technologies concerning the fruits and cladodes of cactus pear has recently been published by Saenz (2000). Other authors have studied the nutritional significance of *Opuntia* sp. (Stintzing, Schieber, & Carle, 2001).

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Crude young 'nopal' have been studied as a source of fibres (Majdoub et al., 2001), proteins and amino acids (Teles, Whiting, Price, & Borges, 1997), and processed in Taifi prickly pear sheets (Ewaidah & Hassan, 1992). The extraction and the characterization of the prickly pear mucilage from sheets was optimized by several authors (McGarvie & Parolis, 1979; Medina-Torres, Brito-De La Fuente, Torrestiana-Sanchez, & Katthain, 2000; Trachtenberg & Mayer, 1981, 1982).

Prickly pear seeds were first characterized by Sawaya, Khalil, & Al-Mohammad (1983), who demonstrated that the seeds of *Opuntia ficus indica* are rich in minerals and sulphur amino acids. A reserve protein from the seeds has been isolated and characterized by Uchoa, Souza, Zarate, Gomez-Filho, & Campos (1998). The prickly pear seed oil composition and its chemical characteristics were investigated by Sawaya & Khan (1982), and then by Salvo, Galati, Lo Curto, & Tripodo (2002).

Coskuner & Tekin (2003) studied the seed composition of prickly pear fruits during the maturation period. Ramadan & Morsel (2003) compared the seed and pulp oil compositions. However, the physical characteristics of prickly pear oil are up to now unknown. The major objective of the present work was to study the physicochemical properties of the seed oil of the *O. ficus indica* and *O. stricta* fruits which are the most abundant species in Tunisia. Rheological behaviour and microscopic structure have been studied and special attention was paid to the effect of temperature, since every food technological operation requires a thermal treatment.

2. Materials and methods

2.1. Prickly pear seed

Mature Prickly pear fruits, *O. ficus indica* and *O. stricta*, were collected, respectively, in August and February from the same area (Sfax, Tunisia). The fruits were immediately sorted, washed with running water, air-dried and hand-peeled. A pulper finisher was used to separate the seeds from the pulp. The seeds were washed with distilled water several times, air-dried at ambient temperature and then ground with a Diez crusher.

2.2. Oil extraction

The seed powders oils of *O. ficus indica* and *O. stricta* were extracted with hexane in a Soxhlet extractor for 9 h. The organic phase was then removed using a rotary evaporator under reduced pressure; the oil was flushed with a stream of nitrogen and stored at −20 °C in sealed tubes prior to analyses.

2.3. Physicochemical analyses

The seed weight was appraized, at random, on one hundred seeds. Moisture content was determined by the AOAC method (AOAC, 1984). The oil yield was determined on a seed powder of 5 g. Nitrogen was determined by the Kjeldahl procedure and crude protein was calculated as $N \times 6.25$ (Balogun & Fetuga, 1986). The ash content was determined according to the AOAC method (AOAC, 1990). Refractive index was determined at 20 °C with an Abbe refractometer with temperature adjustment. The density was measured with a densimeter PAAR DMA 60. Saponification number and iodine value were determined using the official method (American Oil Chemists' Society, AOCS, 1993).

2.4. Fatty acid analysis

The fatty acid compositions of both oil samples were analyzed by GC–MS after transesterification. Fatty acid methyl esters were prepared in the presence of 2 N potassium hydroxide in methanol and analyzed on a Hewlett-Packard model 5890 series II gas chromatograph equipped with a flame ionization detector and a polar capillary column: HP Innowax cross-linked PEG, Carbowax 20 M (0.32 mm internal diameter, 30 m length and 0.25 μm film thickness). The operational conditions were: injector temperature 220 °C; detector temperature 275 °C; column temperature 50 °C for 5 min then a gradient of 10 °C/min to 240 °C; carrier gas was nitrogen at a flow of 1.47 ml/min. Three injections were done.

2.5. Rheological measurements

2.5.1. Instrument

The rheological properties were measured using a controlled stress Haake rheometer (Rheostress RS 100). All the rheological studies were conducted using cone-plate geometry: 35 mm diameter and 2° cone. The volume of the sample was 0.4 ml. That equipment is able to control temperature on a plate sensor system to within ±0.1 °C.

For the measures at variable temperature, the variation was at the rate of 5 °C/min.

2.5.2. Flow curves

In order to determine the influence of temperature and the shear rate, measures of viscosity were conducted at constant shear stress (10 Pa) across increasing temperatures from 20 ° to 70 °C and immediately decreasing temperature to 20 °C.

To follow the influence of shear rate on the viscosity, increasing and immediately decreasing cycles of shear stress at constant temperature were performed.