The Journal of Supercritical Fluids 135 (2018) 45–51

Contents lists available at ScienceDirect

The Journal of Supercritical Fluids

journal homepage: www.elsevier.com/locate/supflu

Comparison of subcritical CO_2 and ultrasound-assisted aqueous methods with the conventional solvent method in the extraction of avocado oil

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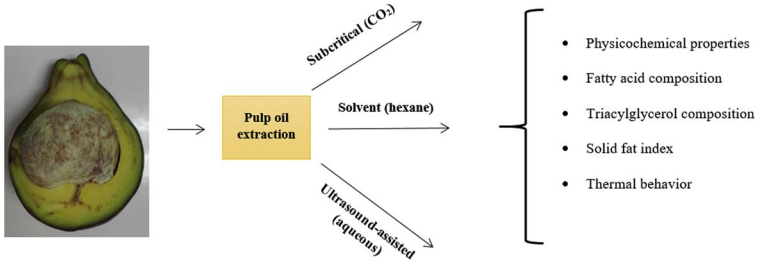
GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Avocado oil
Subcritical CO_2 extraction
Ultrasound-assisted aqueous extraction
Physicochemical properties

ABSTRACT

Avocado (*Persiana americana* Mill) belongs to the Lauraceae family. High level of lipids in the avocado pulp can be served as an important raw material for edible oil extraction. In the present study, the physicochemical properties of avocado oil extracted using subcritical CO_2 extraction (SCO_2) and ultrasound-assisted aqueous extraction (UAAE) were compared with the conventional solvent extraction. In comparison to solvent extraction, the oils extracted using SCO_2 and UAAE were found to have higher iodine values, but lower slip melting points, free fatty acid contents and saponification values. Regardless of the extraction methods, the major fatty acids in avocado oils were oleic (40.73-42.72%) and palmitic (28.12-34.48%) acids whereas the major triacylglycerols in avocado oils were palmitoyl-dioleoyl-glycerol (POO; 22.48-23.01%) and palmitoyl-oleoyl-linoleoyl-glycerol (POL; 17.64-18.23%). SCO_2 and UAAE are effective "solvent-free" methods to extract avocado oils and potentially other edible oils.

1. Introduction

Avocado (*Persiana americana* Mill) belongs to the Lauraceae family. The avocado tree can be grown in tropical and subtropical countries although this plant is native to Central America. An avocado fruit can be divided into three anatomical regions, in which the major portion is the pulp (65%), followed by the seed (20%) and peel (15%) [1]. Unlike oil extracted from other fruits, the oil from avocado fruit is extracted from the pulp rather than the seed as the seed contains a low amount of oil (< 2%) and hepatoxic agents [2]. The latter may alter fat metabolism in the liver by enhancing hepatic lipids secretion, liver lipogenesis and the level of lipid biosynthesis enzymes [2]. In contrast, avocado pulp contains high amount of lipids (10–30%) and minerals [3]. In many countries, the avocado pulp is utilized to produce salads, milk shakes, ice-cream and guacamole [4].

Compared to animal fats (e.g. beef tallow and lard), plant oils contain lower levels of saturated fat, but higher amounts of bioactive components such as vitamin E (tocopherols and tocotrienols) and

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https://doi.org/10.1016/j.supflu.2017.12.036
Received 28 August 2017; Received in revised form 24 November 2017; Accepted 24 December 2017
Available online 27 December 2017

phytosterols [5]. Plants with high amounts of lipids in either the pulp nor the seed can serve as important raw material for edible oil extraction. Several researchers reported on the similarities between olive oil and avocado oil. For example, both oils contain high levels of oleic acid and are highly digestible [6]. Besides, these oils are extracted from the fruit pulp and the oils contain substantial amounts of bioactive components such as phenolic compounds, carotenoids, phytosterols and antioxidant vitamins [3,7]. Thus, avocado oil can potentially be a substitute for olive oil.

Inside the avocado pulp, the evenly scattered thick-walled idioblast cells are surrounded by numerous thin-walled parenchyma cells [2]. These idioblast and parenchyma cells, also known as oil cells, are the oil-containing cells of the avocado pulp [3]. The idioblast cells contain a large oil sac whereas the parenchyma cells contain finely dispersed oil emulsion [2]. Extractions of avocado oil using the organic solvent [4], hot water [8], enzyme [9], centrifugation force [10] and supercritical fluid [11] have been investigated previously. These methods promote the recovery of avocado oil by breaking down the cell walls of the oil cells and the structure of the oil emulsion. However, the use of high temperatures in conjunction with an organic solvent or hot water may cause the oxidative deterioration of polyunsaturated fatty acids in the oil, thereby producing rancid-off flavors [12]. Also, extraction of oil at high temperatures can render some of the bioactive compounds in the plant materials to become inactivated [13].

Subcritical CO_2 extraction (SCO_2) operates in a similar manner to supercritical CO_2 extraction, except that it operates below the critical temperature and pressure (31.10 °C and 72.9 bar, respectively) of CO_2. Unlike supercritical CO_2 extraction, an oil extracted via SCO_2 is usually lighter in color and contains fewer waxes and resins [14]. The mild temperature and pressure used in SCO_2 are able to retain most of the thermally sensitive bioactive components in the plant materials. As evidenced by Chia et al. [15], the concentrations of tocols and oryzanol in rice bran oil extracted by SCO_2 were 10 folds greater than solvent extraction.

The use of ultrasound extraction techniques, particularly ultrasound-assisted aqueous extraction (UAAE) in extracting oils from plant materials is becoming the interest of food industry. Unlike conventional extractions, UAAE does not require the use of organic solvent and the operating procedure is relatively simple. UAAE can be carried out using an ultrasonic bath or an ultrasonic horn transducer. Both types of equipment utilize the cavitation forces produced by acoustic waves to break down the cell walls of the oil cells and the structure of the oil emulsion. UAAE has been well documented for its effectiveness in recovering oil from plant materials [16,17]. For instance, the yield of rice bran oil extracted using UAAE and solvent extraction were almost similar [17].

Previous studies pointed out the commercialization potential of SCO_2 and UAAE in extracting oil from plant materials. However, there is little or no study on the extraction of avocado oil by SCO_2 and UAAE. Thus, the purpose of this study was to compare the extraction efficiencies and physicochemical properties of avocado oils extracted by SCO_2 and UAAE. Conventional solvent extraction served as the control method of the study.

2. Materials and methods

2.1. Sample preparation

Avocado fruits were collected from Universiti Putra Malaysia campus, Malaysia in February 2016. Ripened avocado fruits were manually cut into halves and the pulp was separated from the peel and the seed. The pulp was wrapped with aluminum foil and a tray type dryer (Memmert UFB 400, Schwabach, Germany) operating at 35 °C was used to dry the pulp for three consecutive days. The dried avocado pulp (moisture content: 2–3%) was ground into powder using a home blender (Panasonic MS801S, Petaling Jaya, Malaysia) and sieved through a 360 µm stainless steel sieve. The powdered samples were then stored in an air-tight plastic container at −20 °C until use.

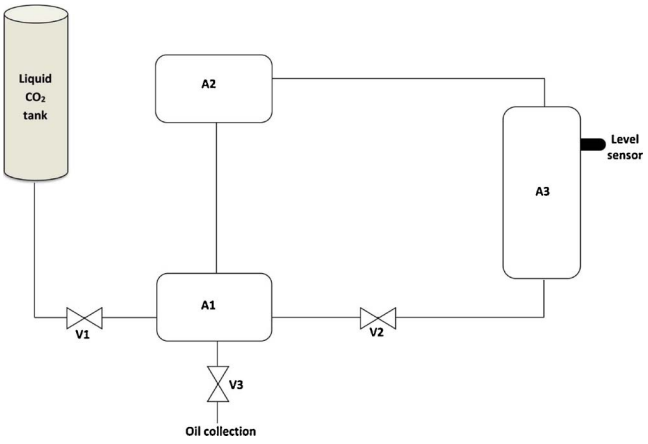

Fig. 1. Schematic diagram of SCO_2 extraction system. A1: reboiler unit; A2: condenser unit; A3: extractor unit; V1, V2 and V3: valves.

2.2. Solvent extraction

A semi-continuous solvent extraction method as described by AOAC 920.39 [18] was used. Ten grams of avocado powder was extracted with 200 mL of hexane in a Soxhlet apparatus for 8 h at 70 °C. The hexane was removed by evaporation using a rotary evaporator at 70 °C. To remove residual hexane, the oil was dried in an oven at 70 °C for 15 min. Oil yield was expressed as the percent based on the weight of avocado pulp powder used.

2.3. Subcritical carbon dioxide extraction (SCO_2)

Fig. 1 shows the schematic diagram of SCO_2 instrument (FeyeCon Development, Weesp, Netherland). Three hundred grams of avocado powder was initially loaded into the extractor unit. Liquid CO_2 from the liquid CO_2 tank was supplied to the reboiler unit via the V_1 valve and was converted into CO_2 gas. The CO_2 gas was channeled to the condenser unit and condensed into liquid CO_2 again. Liquid CO_2 was continuously supplied to the extractor unit until it was detected by the level sensor and a signal was then sent to the V_2 valve. This allows the oil containing-liquid CO_2 (extracted from the avocado powder) to flow into the reboiler unit. Inside the reboiler unit, the liquid CO_2 evaporated whereas the avocado oil was sedimented at the bottom of the reboiler unit. A complete cycle (about 3 mins) of extraction was achieved when the CO_2 gas from the reboiler flowed back into the condenser unit and condensed into liquid CO_2. The extraction was carried out at 27 °C and 68 bar. Oil yield was expressed as the percent of oil obtained based on the weight of sample used.

2.4. Ultrasound-assisted aqueous extraction (UAAE)

Ultrasound-assisted aqueous extraction (UAAE) was carried out using the method described by Tan et al. [19]. Ten grams of avocado powder was mixed with 60 mL of distilled water and sonicated in an ultrasonic water bath (Thermo-10D, with an internal dimension of 500 × 300 × 150 mm) operated at an ultrasonic output power of 240 W and a frequency of 40 kHz. The sonication time and temperature were 30 min and 35 °C, respectively. A laboratory scale screw press was used to press the mixture to obtain an aqueous-oil mixture. The aqueous-oil mixture was centrifuged at room temperature for 8000 rpm and 20 min to separate the oil from the water layer. A Pasteur pipette was used to remove the top oil layer. Oil yield was expressed as the percent of oil obtained based on the weight of sample used.