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Lycopene-rich avocado oil obtained by simultaneous supercritical extraction from avocado pulp and tomato pomace

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ABSTRACT

Tomato pomace is a residue of tomato processing which contains lycopene and oil, and is generated in large quantities by the tomato processing industry. Raw avocado oil is a special oil similar to olive oil. In order to combine the advantage of using a clean technology with supercritical carbon dioxide ($scCO_2$) to extract avocado oil and use it as a co-solvent with $scCO_2$ in carotenoid extraction from tomato pomace, simultaneous extractions of oil and lycopene were carried out to produce an avocado oil enriched with lycopene and a semi defatted avocado cake of potential commercial value. Therefore, freeze-dried avocado and tomato pomace were placed separately in the same fixed bed extractor, where lipids and lycopene were simultaneously extracted with $scCO_2$, first passing through the avocado bed and then both $scCO_2$ and the oil extracted from avocado passed through the second bed of tomato pomace. Lipids extracted in the first bed served as a co-solvent with $scCO_2$ for lycopene extraction in the second bed. The experiments were performed using different proportions of the raw materials at 50 °C and 400 bar and in equal parts of avocado pulp and tomato pomace while varying the temperature and pressure conditions (40, 50 and 60 °C; 200, 300 and 400 bar). The results showed that the lycopene extraction yields (lycopene recovery) increased as the proportion of avocado increased and the best condition for extraction of lycopene present in tomato pomace was at 400 bar and 50 °C. The extracts are raw avocado oils enriched with about 110–170 μg of lycopene per gram of oil, resulting from up to 80% recovery of oil and lycopene. The resulting avocado cake is a semi-defatted product with potential commercial value.

1. Introduction

Several products based on tomato (*Solanum lycopersicum* L.), such as juice, ketchup, tomato paste, soup and sauce are popular in the human diet [1]. Tomato pomace, which is a solid residue resulting from industrial processing of tomatoes, is composed primarily of peel and seeds in a varied proportion, where these residues represent 3–5% of the total weight of processed tomatoes. The tomato pomace is a source of lycopene and oil, because lycopene accumulates progressively in tomato skin during the ripening process and oil comes from the seeds. At the end of ripening, lycopene levels in the skin are about five times higher than in the pulp [2]. Currently, tomato processing residues are discarded or used as animal feed, but the high content of lycopene and oil makes it an alternative source for low-cost extraction of these compounds [3].

Avocado oil possesses substantial amounts of compounds with health benefits, where its triacylglycerols contain high levels of unsaturated fatty acids, making it a special oil similar to olive oil [4–6]. Mechanical extraction by cold pressing or centrifugation procedures are clean technologies, but are limited by low extraction yields [4]. Extraction with supercritical carbon dioxide produces a product (oil) and byproduct (defatted cake) free of any traces of organic solvents, with high extraction yield [7,8].

Supercritical carbon dioxide is a suitable solvent for the extraction of carotenoids and vegetable oils due to the low polarity of these compounds [9]. Moreover, carotenoids are extremely sensitive to exposure to light, heat, oxygen and acids, and therefore carotenoid extraction via supercritical fluids is a promising alternative to reduce its isomerization and decomposition. The $scCO_2$ is an ideal solvent for extraction of these compounds due to its non-toxic and non-flammable nature. It has a low critical temperature which is desirable for the extraction of many natural compounds that require mild conditions [10].

Studies show that the addition of a co-solvent to $scCO_2$ improves the extraction efficiency [11]. Vegetable oils are indicated as good

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Table 1
Some examples of $scCO_2$ extraction of carotenoids and avocado oil. Raw material, product and experimental extraction conditions.

Raw material and solute	T, P conditions	Results	Ref.
Avocado oil	$scCO_2$ as a solvent at 37 °C and 350 atm,	overall yields of 62.9%	[12]
Avocado oil	$scCO_2$ 37 °C–81 °C 350–540 atm	extracted 94% of the oil	[13]
Avocado oil (variety Haas) and capsanthin from red bell pepper	$scCO_2$ simultaneous extraction 50 °C and 400 bar	88% oil recovery 50% capsanthin recovery	[7]
Avocado oil *Persea americana*	$scCO_2$ and $scCO_2$/ethanol sequential extraction 40–80 °C 200–400 bar	98% recovery oil	[8]
Lycopene Tomato by-product	$scCO_2$ 70–90 °C 200–400 bar	Lycopene recovery 18%–56%.	[14]
Lycopene Sun dried tomatoes	45–70 °C 335–450 bar	60% recovery	[15]
Lycopene Tomato skins	60–80 °C 250–300 bar	80% recovery at 80 °C	[16]
Lycopene Pitanga fruits	40–60 °C 100–400 bar	78% recovery at 60 °C	[17]

$scCO_2$ co-solvents for carotenoid extraction instead of ethanol. Table 1 shows some examples of the extraction of lycopene and avocado oil with $scCO_2$.

In the case where it is not sought to separate the carotenoid from the final extract, it is advantageous to use vegetable oils as co-solvents. Therefore, the objective of this study was to obtain raw avocado oil enriched with lycopene and a semi-defatted avocado cake of potential commercial value, assessing the effect of avocado oil as a co-solvent for the extraction of carotenoids from tomato processing residues.

2. Material and methods

2.1. Raw materials and their characterization

The avocado (variety Haas) was acquired from Jaguacy (Jaguacy Brasil – Bauru/SP/Brazil) and tomato pomace was acquired from Cargill (Cargill Foods Brazil – Tomato Products; Pomace – peel and seed by-product). The samples were frozen at −80 °C in ultra-freezer and they were freeze dried (freeze-dryer Liobras L101, São Carlos, Brazil). The freeze dried samples were crushed in a knife mill (model MA 340, Marconi, Piracicaba SP, Brazil). The moisture content of the fresh raw materials was measured by the gravimetric method [18]. In the dry raw materials we determined the lipid concentration [19], the moisture content by the Karl Fischer method [20], the particle size distribution according to the ASAE method [21], the real density (ρ_r) by helium gas pycnometry using an automatic pycnometer at the analytical center of the Chemistry Institute of UNICAMP, the apparent density (ρ_a) of the avocado bed was calculated from the mass of crushed raw materials required to fill a volume of 10 cm^3. The porosity (ε) of the bed, also called the volumetric fraction of voids in the bed, was calculated from the ratio of the experimental data of apparent (ρ_a) and real density (ρ_r) of the ground material.

2.2. Extraction procedures

2.2.1. Extraction curves

Two extraction curves (extract mass as a function of time), one for avocado and the other for tomato pomace, were constructed and used to measure periods of constant extraction rate (CER) and falling extraction rate (FER), and with this establish the extraction time in the experiments. The methodology used to build these extraction curves was previously discussed in literature [22–24]. It was utilized 5 g of raw material in the bed, $scCO_2$ flow rate of 1.5 L/min (2.475 g/min) at 50 °C and 400 bar, and extract samples were collected at predefined periods, during a total of 3.5 h.

Table 2
Ratios between raw materials and experimental conditions of temperature and pressure.

Ratio of freeze-driedraw materials	Temperature and pressure	
5 g Tomato residue + 2.5 g Avocado 5 g Tomato residue + 5 g Avocado 5 g Tomato residue + 7.5 g Avocado	50 °C and 400 bar	
5 g Tomato residue + 5 g Avocado	40 °C 50 °C 60 °C	200 bar
5 g Tomato residue + 5 g Avocado	40 °C 50 °C 60 °C	300 bar
5 g Tomato residue + 5 g Avocado	40 °C 50 °C 60 °C	400 bar

2.2.2. Simultaneous extraction

In the simultaneous extraction experiments in a fixed bed, the extractor was manually filled with approximately 5 g (or different proportions) of lyophilized and ground avocado pulp in the first half of the extractor and approximately 5 g of crushed tomato pomace in the second half of the extractor, and the remaining volume of the extractor was filled with glass beads (5 mm) to prevent preferential CO_2 paths.

Two types of tests were performed, as shown in Table 2. In the first type, the ratios of raw materials (avocado + tomato residue) were varied and the pressure and temperature conditions were maintained constant; in the second type the proportions of raw materials (avocado + tomato residue) were maintained constant and the pressure and temperature conditions varied. In order to assess the deviations of the experimental points, experiments were performed in triplicate at the average conditions of 50 °C, 300 bar, 5 g of avocado and 5 g of tomato residue.

In the extraction 220 L of CO_2 were used, with a total extraction period of 2.4 h. All flasks were protected from the light from the beginning of extraction until its refrigerated storage to prevent degradation of carotenoids.

2.2.3. Global yield

The overall extraction yield was obtained by the ratio (in %) between the extract mass ($M_{extract}$) obtained and the weight of the raw material ($M_{initial}$) submitted to the extraction process.