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EVALUATION OF THREE OIL EXTRACTION PROCESSES FOR HASS VARIETY AVOCADO (*Persea americana* Mill.)

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ABSTRACT

The pulp of avocados has a high oil concentration that is usually extracted with hexane, a nonpolar solvent that affects yield and poses health and environmental hazards. This problem requires the exploration of alternative extraction techniques, such as centrifugation. In this work, three avocado oil extraction methods were evaluated for Hass avocado (*Persea americana* Mill.) using proton (^{1}H) and carbon (^{13}C) nuclear magnetic resonance (NMR) spectroscopy to assess oil quality. One kilogram of avocado was purchased in 2023 at the Zapata market in Puebla City, Mexico. A controlled experimental design was used, with triplicate replications. Avocado pulp (250 g) was dehydrated at 70 °C for 24 h in a convection oven and then homogenized to a particle size of 250 μm. Oil extraction was performed using three methods with 1 g of dehydrated pulp: 1) Soxhlet extraction with hexane at 60 °C for 4 h, 2) maceration with hexane at 25 °C for 24 h, and 3) centrifugation at 11 000 rpm (15 557 × gravity) at 40 °C for 10 min. Oil quality was evaluated using ^{1}H-NMR and ^{13}C-NMR, with acquisition times of 2049 and 4.5 s, respectively. The highest yield (78 %) was obtained using the first method. However, the second and third methods showed minimal oxidation of their double bonds and lower generation of free fatty acids due to their lower processing temperatures. The third method was the most

effective, as the oil retained its characteristic sensory properties and did not require further refinement.

Keywords: Avocado oil, fatty acids, ^{1}H-NMR and ^{13}C-NMR spectroscopy, traditional extraction.

INTRODUCTION

The avocado (*Persea americana* Mill.) belongs to the Lauraceae family, which includes 45 genera and approximately 2850 species. The Hass variety is the most widely consumed worldwide, with Mexico being the primary producer, exporter, and consumer (FAO, 2024). This fruit consists of three components: shell (15 %), seed (20 %), and pulp (65 %) (García-Vargas *et al*., 2020), with oleic fatty acid predominating in the pulp (43.65–63.73 %), similar to extra virgin olive oil (Barros *et al*., 2016). The extraction process of avocado oil determines the quantity and quality of its bioactive components, facilitating its diversification into various products, including food, cosmetics, and pharmaceuticals (Flores *et al*., 2019).

One of the most common extraction methods is solvent extraction, typically using hexane or n-hexane. Due to its chemical properties, hexane interacts effectively with oils, enhancing extraction efficiency and yield (Badui, 2019). After extraction, the solvent is separated from the oil by distillation and recovered for reuse, yielding crude oil (Rosenthal *et al*., 1996). However, in the oil industry, approximately 350 thousand Mg of hexane are lost annually, contributing to increased atmospheric pollution (European Commission, 2003).

Crude oil can undergo a refining process that includes sample conditioning, degumming, neutralization, bleaching, and deodorization (Cravotto *et al*., 2022). During deodorization (180–220 °C), temperatures exceed the boiling point of hexane (68.7 °C), eliminating the characteristic odor of the solvent and yielding refined oil (Badui, 2019). However, in refined oils obtained by solvent extraction, hexane levels above the permissible limit (0.005 mg kg^{-1}) have been reported, such as in olive and canola oils, with concentrations of 0.4 and 0.233 (European Commission, 2003). If not eliminated from the body, results in its metabolism to 2,5-hexanedione, which causes neurotoxicity (Ruiz-García *et al*., 2020).

On the other hand, despite concerns about residues, there is no conclusive evidence that trace amounts of residual hexane chemically react with lipids or significantly modify their structure, as hexane is a nonpolar aliphatic hydrocarbon and largely chemically unreactive; moreover, it is almost completely eliminated during refining due to its high volatility (Cravotto *et al*., 2022). However, several studies have shown that hexane extraction can alter the composition of minor compounds, such as tocopherols, sterols, volatile compounds, and phospholipids, which are key determinants of oxidative stability and nutritional quality of the oil. For example, Junyusen *et al*. (2022) reported significant differences in phytochemical and antioxidant contents when comparing solvent-extracted oils with those obtained by cold pressing. These variations directly affect oxidative stability and shelf life. Although residual hexane itself does not

typically chemically alter triglycerides, the solvent-based extraction process and its associated thermal conditions can indirectly influence oil composition and stability (Cravotto *et al*., 2022; Junyusen *et al*., 2022).

Due to the above, alternatives to solvent-based oil extraction are being explored, including solvent-free methods such as centrifugation (Pérez-Saucedo *et al*., 2021), which has emerged as a viable alternative for extracting edible vegetable oils, particularly from matrices such as avocado or olive pulp. This technique separates the oil phase using centrifugal forces without the need for organic solvents like hexane, substantially reducing risks to human health and environmental impact (Zuin *et al*., 2018). Unlike conventional solvent extraction, centrifugation leaves no toxic residues and requires minimal thermal energy, which helps preserve heat-labile compounds such as tocopherols, carotenoids, and phenolic compounds (Mahato *et al*., 2019). This method significantly improves the preservation of bioactive compounds that are crucial for both the oxidative stability and nutritional value of the oil (Gil-Martín *et al*., 2022).

For oils obtained from pulp, such as avocado oil, centrifugation has shown yields that are comparable to or higher than those achieved by mechanical pressing, while preserving a stable fatty acid profile and consistent physicochemical properties. Studies have demonstrated that avocado oil extracted by centrifugation retains good sensory quality and high concentrations of antioxidant compounds, indicating that product integrity is not compromised (Pérez-Saucedo *et al*., 2021). At the industrial scale, this technique has also enhanced the efficiency of olive oil extraction by increasing oil recovery and reducing losses in byproducts such as olive pomace (Ranalli and Martinelli, 1995). In addition to its technical advantages, centrifugation supports cleaner and more continuous processing aligned with green processing principles. From an environmental perspective, it eliminates the need for organic solvents and reduces the generation of polluting effluents, contributing to more sustainable biorefinery designs that enable the efficient recovery of valuable compounds, including oils, proteins, and polyphenols, without producing hazardous byproducts (Zuin *et al*., 2018).

Centrifugation represents a clean, efficient, and safe technology capable of preserving the nutritional and functional quality of vegetable oils from pulp, with both economic and environmental benefits. Its industrial implementation continues to expand as process parameters are optimized and new strategies, such as aqueous and enzyme-assisted extraction, are integrated to further improve performance (Capaldi *et al*., 2024). Therefore, the objective of this work was to evaluate three methods for extracting avocado oil from the Hass variety using proton (^{1}H) and carbon (^{13}C) nuclear magnetic resonance (NMR) spectroscopy to determine its quality.

MATERIALS AND METHODS

The study was conducted in 2023 at the Centre for Research in Applied Biotechnology of the National Polytechnic Institute (CIBA-IPN, by its acronym in Spanish), located in

the municipality of Tepetitla de Lardizábal (19° 15′–19° 19′ N, 98° 20′–98° 25′ W; 2300 m altitude), Tlaxcala, Mexico. Avocado (*Persea americana* Mill. var. Hass) fruits were purchased at the Emiliano Zapata market in Puebla City, Mexico. Fruits were randomly selected based on commercial maturity criteria, including uniform dark green epicarp color with slight purplish tones, firmness between 15 and 25 N measured with a digital penetrometer (FT-327, Italy), individual weight between 180 and 250 g, and absence of mechanical damage or visible deterioration or fungal infection. Physiological maturity was confirmed according to NMX-FF-016-SCFI-2016 (DOF, 2017), which defines the physical and sensory characteristics of avocados at commercial maturity.

After selection, fruits were washed with distilled water and 0.1 % sodium hypochlorite solution, rinsed, and stored at 20 ± 2 °C and 65 % relative humidity for 24 h before processing to homogenize temperature and maturity conditions. The pulp was manually separated from the epicarp and seed, and 250 g of fresh pulp per fruit were homogenized for 2 min using an immersion blender (FPSTHB2600W-013, China). The pulp was spread on filter paper in stainless steel trays and dried in a convection oven (TE-H80, Mexico) at 70 °C for 24 h. Residual moisture content was determined gravimetrically by weighing the samples before and after drying (AOAC, 2019), with an average moisture loss of 65 ± 2 %. The dried pulp was then re-homogenized using the same blender to obtain a particle size of 250 μm.

Soxhlet extraction

Oil extraction was carried out using 1 g of dehydrated and homogenized avocado pulp. The sample was placed in a cellulose extraction thimble and inserted into a Soxhlet extractor. Analytical-grade hexane (Appcrom, Mexico) was used as the solvent, with 130 mL added to a round-bottom flask attached to the Soxhlet apparatus and equipped with a reflux condenser. The system was maintained at 60 °C for 4 h, facilitating the volatilization, condensation, and percolation of the solvent through the sample to solubilize the lipids in the pulp.

Once the solvent reached the overflow level in the extraction chamber, the contents were siphoned back into the round-bottom flask, initiating a new extraction cycle. This process was repeated continuously for the specified duration to ensure complete extraction of lipid compounds (AOAC, 2019). At the end of the procedure, the oil-solvent mixture was concentrated and purified by vacuum evaporation using a rotary evaporator (B-490, Mexico) at 50 °C and medium speed, coupled to a vacuum pump (V-700, Mexico). The recovered oil was stored in hermetically sealed amber bottles until further analysis.

Extraction by maceration

Avocado oil extraction by maceration was carried out using 1 g of dehydrated and homogenized avocado pulp placed in a 250 mL Erlenmeyer flask with an airtight stopper. Analytical-grade hexane (Appcrom, Mexico; 130 mL) was added, and the mixture was gently stirred in the dark for 24 h at 25 ± 1 °C to prevent photodegradation

of sensitive compounds and promote solvent diffusion throughout the matrix. Manual intermittent stirring was carried out every 6 h to improve extraction efficiency and phase equilibrium (AOAC, 2019).

After maceration, the mixture was gravity-filtered through Whatman No. 1 filter paper (11 μm pore size), previously conditioned with hexane to minimize sample loss by adsorption. The filtrate, containing the oil dissolved in the solvent, was concentrated by vacuum evaporation using a rotary evaporator (B-490, Mexico) at 50 °C, using a vacuum pump (V-700, Mexico), under the same conditions described for the Soxhlet method. The recovered oil was stored in hermetically sealed amber bottles.

Extraction by centrifugation

Oil extraction by centrifugation was based on the methodology proposed by Ariza-Ortega *et al*. (2011). One gram of dehydrated and homogenized avocado pulp was placed in a 15 mL Falcon tube and centrifuged in a refrigerated centrifuge (Hettich Rotina 380R, Andreas Hettich GmbH and Co. KG, Germany) at 11 000 rpm (15 557 × gravity) for 10 min at 40 °C. After centrifugation, three distinct phases were observed: an upper oily phase, an intermediate phase containing impurities, and a lower solid residue. The oily phase was carefully collected using a glass Pasteur pipette (Pyrex, USA), avoiding cross-contamination with the other layers. The recovered oil was stored in airtight amber bottles at 4 °C until further analysis.

Evaluation of avocado oil quality

The quality of the extracted oils was evaluated using ^{1}H and ^{13}C nuclear magnetic resonance (NMR) spectroscopy to identify characteristic proton and carbon signals associated with triacylglycerols and other lipid compounds. Analyses were performed using a Bruker Avance III 400 MHz spectrometer (Bruker BioSpin GmbH, Rheinstetten, Germany), operating at 400 MHz for ^{1}H and 100 MHz for ^{13}C. For each analysis, 10 μL of oil were dissolved in 0.6 mL of deuterated chloroform ($CDCl_3$, Sigma-Aldrich, USA) and transferred to 5 mm diameter glass NMR tubes.

Spectra for ^{1}H were obtained with the following instrumental parameters: 45° pulse, relaxation time of 1 s, acquisition time of 2.049 s, spectral width of 7997.6 Hz, and a line width of 0.2 Hz. A total of 64 scans were collected for each spectrum, with a total acquisition time of 3 min and 21 s per sample. Finally, ^{13}C spectra were obtained using the same equipment and sample preparation conditions, with a spectral width of 195 ppm, relaxation time of 7 s, and acquisition time of 4.5 s.

Experimental design

This study employed a controlled experimental design comparing three avocado oil extraction methods (Soxhlet, maceration, and centrifugation), with three independent replicates per treatment (experimental unit = 1 g of dehydrated avocado pulp), for a total of nine experimental units. Aliquots were randomly assigned to each treatment. Spectral data were processed using CRAFT software integrated into DELTA

version 5.3 (JEOL Resonance Inc., Tokyo, Japan). Peak integration was performed automatically and subsequently verified manually to identify characteristic chemical shifts associated with functional groups present in the oils. Results from the ^{1}H-NMR and ^{13}C-NMR analyses correspond to relative signal intensities of a descriptive nature, which are not comparable through statistical tests. Data were therefore interpreted through descriptive analysis and visual comparison of spectra, focusing on variations in chemical shifts and signal intensities characteristic of lipid compounds.

RESULTS AND DISCUSSION

Oil extraction

The highest extraction yield was obtained using hexane in the Soxhlet extractor (60 °C for 4 h), with an extraction rate of 78 %. This was followed by the maceration method (25 °C for 24 h), which achieved a yield of 58 %, and the centrifugation method, with a yield of 38.3 %. The Soxhlet method (78 %) exceeded values reported by Pérez-Saucedo *et al*. (2021) for Hass avocado oils from Tepic, Nayarit (66.57 %) and those described by Randrianarijaona *et al*. (2023) for avocado oils extracted in Madagascar (40.12 % by Soxhlet and 29.77 % by maceration). The increased oil yield achieved by Soxhlet extraction compared with maceration, and particularly centrifugation, is attributed to differences in physicochemical extraction mechanisms. In Soxhlet extraction, continuous renewal of hot hexane promotes disruption of the cellular matrix and maintains a constant solubility gradient, enabling near-exhaustive recovery of the lipid fraction (Flores *et al*., 2019; Eze *et al*., 2024).

The lower yield obtained by maceration (58 %) could be explained by the limited solvent diffusion within the solid matrix, associated with partial lipid encapsulation by proteins (≈1.9 g per 100 g) and carbohydrates (≈8.6 g per 100 g) present in the pulp (Flores *et al*., 2019; Liu *et al*., 2019). In contrast, centrifugation yielded 38.3 % under the conditions evaluated (11 000 rpm, 40 °C for 10 min), a value comparable to that reported by Pérez-Saucedo *et al*. (2021) (39 % at 10 000 rpm). Buenrostro and López-Munguía (1986) achieved up to 70 % extraction by combining centrifugation (12 300 × gravity) with α-amylase addition (1:5) at 65 °C, while Bizimana *et al*. (1993) reported yields of up to 78 % by increasing centrifugal force from 6000 to 12 300 × gravity. Similarly, Werman and Neeman (1987) obtained 65 % extraction by adding NaCl (5 %) and water to fresh pulp prior to centrifugation, which promoted the disruption of the water-oil emulsion. This effect has been attributed to increased membrane permeability and reduced interfacial tension between phases (Rosenthal *et al*., 1996).

Moreover, centrifugation relies on physical separation rather than chemical solubilization; therefore, only lipids released after initial mechanical disruption are recovered, leaving a substantial fraction retained within the plant matrix (Pérez-Saucedo *et al*., 2021). These observations are consistent with reports indicating that lipid recovery efficiency depends on the extent of cellular disruption, process

temperature, and the method's ability to renew the solvent or extraction medium (Jin *et al*., 2022). The avocado oils extracted using the three different methods (Figure 1) showed variations in color and clarity among the samples.

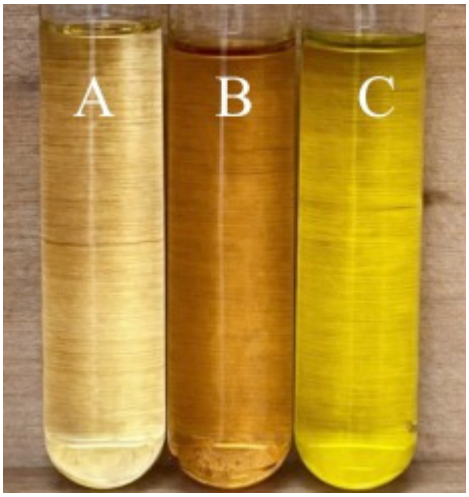

Figure 1. Avocado (*Persea americana* Mill.) oils obtained through three extraction methods. A: Soxhlet; B: maceration; C: centrifugation.

Evaluation of avocado oil quality

The three extraction methods exhibited similar spectral profiles (Figure 2), indicating that the chemical structure of Hass avocado oil was preserved regardless of the method used. However, differences were observed in signal intensities rather than in chemical shifts, suggesting variations in the relative concentrations of extracted triacylglycerols and unsaturated fatty acids (Table 1).

The ^{1}H NMR spectra revealed characteristic shifts at 5.29, 2.02, 2.76, 0.95, and 0.85 ppm, associated with allylic and methylene protons present in unsaturated fatty acid double bonds. These signals are consistent with those observed by Tang *et al*. (2021), who reported dominant peaks at 5.3 and 2.0 ppm for C=C and CH_2–CH=CH bonds in authentic avocado oils analyzed by high-resolution NMR. Such resonances are indicative of the presence of oleic (C18:1), linoleic (C18:2), and linolenic (C18:3) acids, the main components of avocado oil (Pérez-Saucedo *et al*., 2021).

In the ^{13}C NMR, the signals at 129.98, 129.67, 128.06, and 127.86 ppm correspond to the olefinic carbons (C=C) of unsaturated fatty acids, while the resonances at 31.88 ppm indicate saturated methylene carbons (–CH_2-) present in the acyl chains. These results are similar to those of Eze *et al*. (2024), who reported similar shifts in avocado oils, attributing them to the high proportion of monounsaturated fatty acids and the structural stability of the triacylglycerols. Furthermore, the signals at 174–176 ppm are assigned to carbonyls (C=O) of free fatty acids. Their low intensity in all three

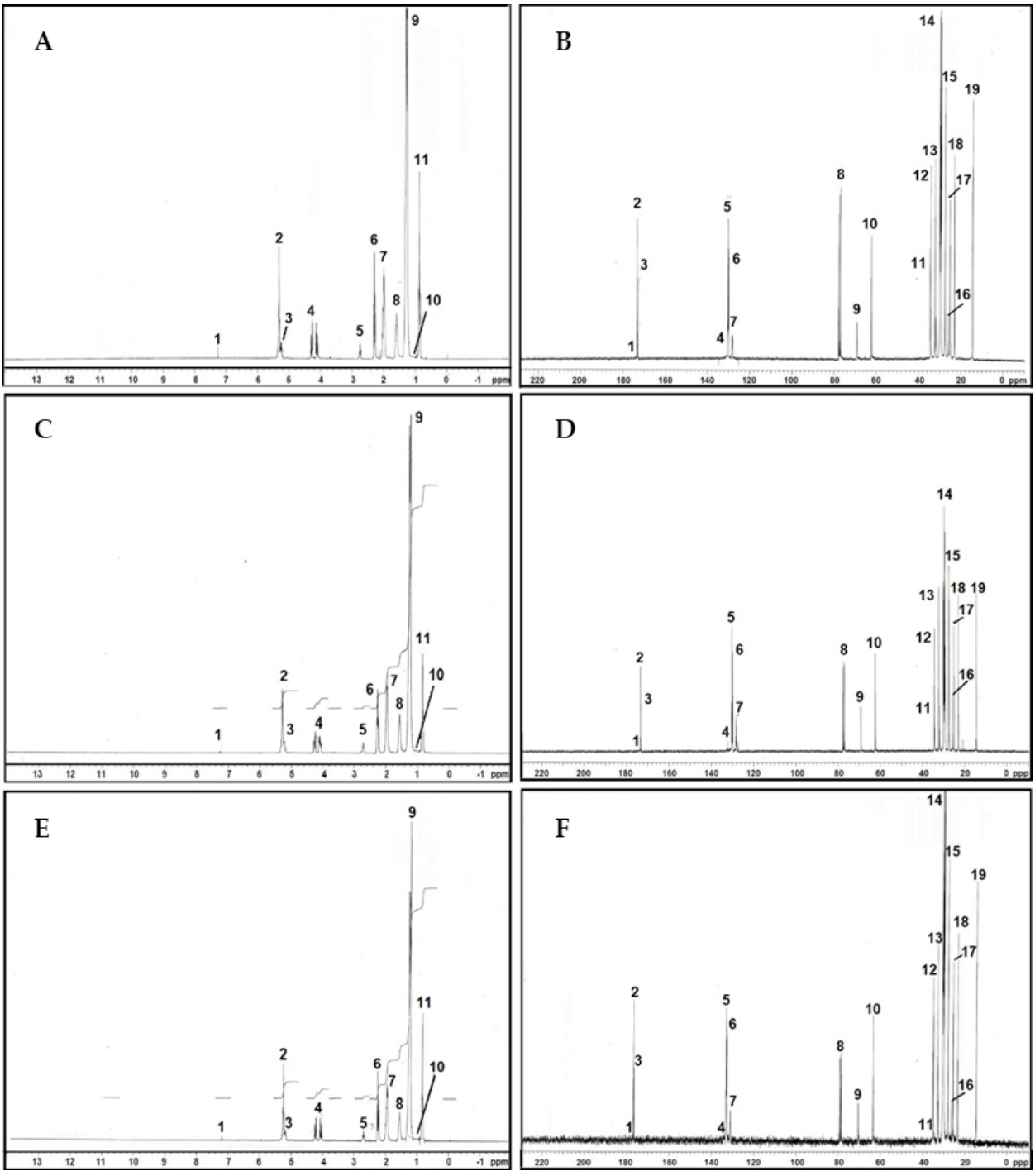

Figure 2. Spectrograms showing the identified signals and chemical shifts of Hass avocado (*Persea americana* Mill.) oils. Panels A, C, and E correspond to ^{1}H nuclear magnetic resonance (NMR) analyses, while panels B, D, and F correspond to ^{13}C-NMR analyses. A, B: Oils extracted via Soxhlet extraction at 60 °C for 4 h; C, D: Oils extracted through maceration at 25 °C for 24 h; E, F: Oils extracted using centrifugation at 11 000 rpm (15 557 × gravity) at 40 °C for 10 min.

Table 1. Chemical shifts (δ) and signals identified by 1H and 13C clear magnetic resonance (NMR) in Hass avocado (*Persea americana* Mill.) oils obtained by different extraction methods.

Sign	δ (ppm)	Functional group	SE Intensity	ME Intensity	CE Intensity	Compound
			Proton (^{1}H) NMR			
1	7.26	$CHCl_3$	High	Low	Medium	Chloroform (solvent)
2	5.29/2.02	$CH=CH/CH_2CH=CH$	High	Low	Medium	All unsaturated fatty acids
7			High	Medium	Low	
3	5.15/4.19	$CHOCOR/CH_2OCOR$	High	Medium	Medium	Glycerol (triacylglycerols)
4			High	Low	Medium	
5	2.76	$CH=CHCH_2CH=CH$	High	Low	Medium	Linoleic and linolenic
6	2.2/1.6/1.2	$CH_2COOH/CH_2CH_2COOH/(CH_2)n$	High	Low	Medium	Glycerol (triacylglycerols)
8			High	Medium	Low	
9			High	Medium	Medium	
10	0.95	$CH_2CH_2CH_2CH_3$	High	Low	Medium	Linoleic
11	0.85	$CH=CHCH_2CH_3$	High	Low	Medium	All unsaturated fatty acids except linolenic
			Carbon (^{13}C) NMR			
1	174–176	C-1	ND	ND	ND	Free fatty acids
2	173.26/172.81	C-1, sn-1,3/C-1, sn-2	High	Low	High	Triacylglycerols
3			High	Low	Medium	
4	129.98/129.67	C-10/C-9	Low	Medium	High	Oleic
5			High	High	High	
6	128.06/127.86	C-10/C-12	High	Low	Medium	Linoleic
7			Low	High	High	
8	77.01	$CDCl_3$	High	Low	Low	Solvent
9	68.92/62.18	CHO–, sn-2/CH_2O–, sn-1,3	Low	High	Medium	Triacylglycerols
10			High	Medium	High	
11	34.18/34.02	C-2, sn-2/C-2, sn-1,3	Medium	Low	High	All acyl chains
12			High	Low	High	
13	31.88	ω-3	Medium	Low	High	Saturates, ω-9 and ω-6
14	29.1–29.8	$(CH_2)n$	High	Low	High	All acyl chains
15	27.16	C-8–C-11/C-8–C-14	High	Low	High	Allyl position: oleic and linoleic, respectively
16	25.81	C-11/C-11–C-14	High	High	High	Allyl position: linoleic and linolenic, respectively
17	24.84, 22.65/14.15	C3, ω-2/ω-1(–CH_3)	Medium	Low	High	All acyl chains
18			Medium	Low	High	
19			Medium	Low	High	

SE: Soxhlet extraction (60 °C, 4 h); ME: maceration extraction (25 °C, 24 h); CE: centrifugation extraction (11 000 rpm, 40 °C, 10 min); ND: not detected.

extraction methods indicates minimal hydrolysis and good oil stability, which in turn results in a low free fatty acid content. This finding aligns with research conducted by Flores *et al*. (2019), as avocado oils with low acidity demonstrated reduced oxidative degradation and enhanced stability during storage.

The NMR results, together with fatty acid composition data, show that oil obtained by Soxhlet extraction had the highest signal intensities associated with aliphatic (0.85–2.8 ppm) and olefinic (5.3 ppm) groups, reflecting a higher concentration of triglycerides and unsaturated fatty acids. Oils obtained by maceration and centrifugation exhibited a similar spectral pattern but with lower intensities, indicating partial lipid extraction, consistent with reports of avocado oil extracted by Soxhlet extraction, maceration, and centrifugation (Table 2).

Table 2. Fatty acid percentages in Hass avocado (*Persea americana* Mill.) oil (Ariza-Ortega *et al*., 2011).

Name	Formula	Soxhlet extraction	Maceration extraction	Centrifugation extraction
Capric	C10:0	0.04	ND	0.02
Lauric	C12:0	0.02	ND	1.30
Myristic	C14:0	0.04	0.01	0.31
Palmitic	C16:0	13.70	17.00	17.06
Palmitoleic	C16:1	8.00	ND	7.10
Estearic	C18:0	5.50	5.10	6.90
Elaidic	C18:1t	0.10	0.10	0.10
Oleic	C18:1	59.10	60.60	58.70
Trans-linoleic acid	C18:2t	3.10	1.20	ND
Linoleic	C18:2	9.20	10.30	7.30
Linolenic	C18:3	0.04	0.10	0.06
Arachidic	C20:0	0.17	0.90	0.10
Eicosenoic	C20:1	0.17	ND	ND
Eicosadienoic	C20:2	0.73	ND	0.48

ND: Not detected.

The fatty acid percentages (Table 2) confirm that the oils obtained by the three methods primarily contain oleic (C18:1), palmitic (C16:0), and linoleic (C18:2) acids, with proportions of 58–61, 13–17, and 7–10 %, respectively. These values are consistent with those reported by Eze *et al*. (2024), who found that avocado oil exhibits a high oleic/palmitic ratio (>3.5), which indicates a healthy and oxidatively stable lipid profile.

According to Tang *et al*. (2021), the homogeneity of chemical shifts in genuine avocado oils can be used to verify their purity, since adulteration with soybean or sunflower oils alters the resonances in the 5.2–5.4 and 172–174 ppm regions. In this study, the spectra obtained by Soxhlet extraction, maceration, and centrifugation are similar to standard values, indicating that the oils are authentic and show no signs of contamination or significant degradation.

The low intensity of the carbonyl peaks (174–176 ppm) also indicates minimal oxidation and a low presence of free fatty acids, which coincides with reported acidity index values between 0.14 and 2.8 mg KOH g^{-1} (Ortiz-Moreno *et al*., 2003; Varzakas, 2021). According to Flores *et al*. (2019), this parameter confirms that high-quality avocado oil maintains its molecular integrity and antioxidant properties, even after moderate thermal processes such as those performed by the Soxhlet extractor.

Compared to other edible oils, such as that of *Dacryodes edulis* studied by Eze *et al*. (2024), avocado oil showed a higher proportion of monounsaturated fatty acids (C18:1) and a lower content of saturated fatty acids (C16:0, C18:0) (Table 2), which translates into better oxidative stability and a favorable nutritional profile. According to Flores *et al*. (2019), this composition makes it a functional oil with beneficial properties for cardiovascular health and potential applications in the cosmetic and pharmaceutical industries.

The spectral similarity among extraction methods suggests that thermal or mechanical conditions do not significantly modify the structure of triglycerides (Tang *et al*., 2021). However, comparative studies that include Soxhlet extraction have shown that this method tends to yield a more concentrated and stable lipid fraction (Flores *et al*., 2019; Eze *et al*., 2024). In contrast, research on centrifugation and cold extraction methods reports similar lipid profiles but lower signal intensity and reduced yield compared to solvent-based extraction, which is attributed to the partial recovery of triglycerides due to physical separation limitations (Pérez-Saucedo *et al*., 2021).

Studies using NMR techniques confirm that triglyceride signals remain consistent across extraction methods, although process parameters such as temperature, time, and centrifugal force influence yield and signal intensity (Tang *et al*., 2021; Jin *et al*., 2022). Therefore, increasing centrifugal force or improving phase separation efficiency may enhance both the recovery and the purity of the extracted oil.

CONCLUSIONS

Hass avocado oils obtained by Soxhlet extraction, maceration, and centrifugation have a stable molecular structure, with a predominance of triacylglycerols and monounsaturated fatty acids. The Soxhlet method yielded the highest yield and exhibited the most intense signals, indicating a higher concentration of lipid compounds. In contrast, maceration and centrifugation preserved oil quality, albeit with a slight decrease in spectral intensity.

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