**Physico-chemical characterisation of *Capparis scabrida* seed oil and pulp,
a potential source of eicosapentaenoic acid**

Reinier Abreu-Naranjo^{a*}, Wagner Nolasco Ramirez-Huila^b, Jorge Julio Reyes Mera^a,
Derwin Viafara Banguera^a, Manuel León-Camacho^c.

^a Departamento de Ciencias de la Vida, Universidad Estatal Amazónica, Puyo, 160150,
Pastaza, Ecuador

^b Facultad de Ciencias Naturales y de la Agricultura, Universidad Estatal del Sur de
Manabi, Jipijapa, 130651, Manabí, Ecuador

^c Lipids Characterization and Quality Department, Instituto de la Grasa (C.S.I.C.),
Campus Universitario Pablo de Olavide, 41704, Sevilla, Spain

Eicosapentaenoic Acid in *Capparis scabrida* seed oil

* Corresponding author e-mail: reinier.abreu@gmail.com –Universidad Estatal Amazónica, Via Tena
km 2 ½, Puyo, Pastaza, 16150, tel./fax 00593 328 88118. ([Orcid.org/0000-0003-1048-7126](https://orcid.org/0000-0003-1048-7126))

ABSTRACT

The main nutraceutical properties were determined for *Capparis scabrida* fruit seed oil to evaluate the potential of this species as an unconventional source of plant oil. Nutritional properties were compared with commercial edible oils. The fatty acid composition was determined using gas chromatography analysis. The total phenolic content (TPC) and antioxidant activity were determined using the Folin-Ciocalteu method and using radical scavenging activity: 1,1-diphenyl-2-picrylhydrazyl (DPPH) and 2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) assays, respectively. The statistical tools of cluster and discriminant analysis were used to classify *C. scabrida* seed oil in comparison with other seed oils. The *C. scabrida* seed has 31.5% lipid, of which 52.8% is oleic acid. Eicosapentaenoic acid, which is uncommon in the plant kingdom, was found. The omega-6 (7.87%):omega-3 (2.97%) ratio was 2.7:1, which is consistent with recent dietary guidelines. The TPC, DPPH and ABTS value were 150 mg gallic acid equivalents kg⁻¹, 1.11 and 1.94 mM Trolox kg⁻¹, respectively, for *C. scabrida* seed oil.

KEYWORDS: Antioxidant activity; *Capparis scabrida*; eicosapentaenoic acid; omega-3; Zapote.

1. Introduction

Fruits and vegetables have proven to be important sources of bioactive compounds with significant health benefits against various diseases (Carrillo-Perdomo et al., 2015; Charoenkiatkul et al., 2016; Tantamango et al., 2011). Fruit consumption has increased worldwide because fruits are a good source of vitamins, minerals and phenolic compounds (Muhtadi et al., 2016; Ramos et al., 2015). Although the most commonly consumed fruits are cultivated on a large scale, there is potential for fruits consumed locally that are less well-known but might be shown to be beneficial once they are studied and should be investigated (Rodrigues et al., 2018).

Such is the case for *Capparis scabrida* Kunth, a species belonging to the *Capparis* genus in the Capparaceae family, commonly known as *zapote* or *sapote de perro*. It is a tree that is adaptable to desert ecosystems. This species can be found in different geographical environments, such as in the dry forests of northern Peru and central and southern Ecuador at an elevation of 0 to 2500 m above sea level. Its use has been reported since pre-Columbian times, mainly as a forest resource. The Peruvian government has declared this species to be critically endangered due to the extensive deforestation that it is subject to for the value of its wood. The wood from this species is sold in large quantities and used to make handicrafts for the domestic and international markets. It is also used for firewood and charcoal (Rodríguez-Rodríguez et al., 2007).

The conservation of this plant resource should be a priority for countries such as Peru and Ecuador. This will depend in part on the work of the scientific community who can search for new uses for its fruits and other parts that can be obtained without destroying the tree.

Vegetable oils are important sources of lipid-soluble bioactive components and essential fatty acids (FA) for human nutrition (Yang et al., 2011). The application of oil for nutritional, industrial, and pharmaceutical purposes is determined by its FA and triglyceride compositions. No oil from a single raw material has been found to be suitable for all purposes because oils from different sources have different FA profiles. These new oils may provide materials with different functional and nutritional properties. No studies were found dealing with *C. scabrida* fruit seed oil. All previous studies focused on its wood (Herrera et al., 2018; Rodríguez-Rodríguez et al., 2007). The aim of this study was to evaluate the *C. scabrida* species' potential as an unconventional source of plant oil on the basis of its main properties, such as physical and chemical characteristics, FA profile, total phenolic content (TPC) and free radical scavenging activity.

2. Materials and methods

All chemicals and solvents were of analytical grade and were purchased from Sigma-Aldrich Co., (St. Louis, MO, USA).

2.1. Collection of fruits and sample preparation

Fresh *C. scabrida* fruits devoid of any visible microbial infection or mechanical fissures were obtained from the local market of Jipijapa in Manabí Province, Ecuador. A total of 10 fruits were chosen based on being ripe enough for consumption, physically undamaged and uniformly shaped, as well as for their size and colour (Figure 1). The fruits (*C. Scabrida*) collected had an average weight, length and width of 356 ± 20 g, 122 ± 10 mm and 69 ± 9 mm, respectively. The fruits had ~80 seeds embedded in a yellowish edible pulp with a pleasant odour and flavour. Their parts were manually

separated (husk, pulp and seed) and then the seeds were dried in a stove (Model: SFE 700, Memmert, Schwabach, Germany) at a temperature of 45 °C for 48 hr. Subsequently, they were ground in a mill (Model: 4, Thomas Wiley Mill Co., Swedesboro, NJ, USA) until particle sizes were 0.89 mm on average, using the ASTM method using a set of No. 16 (1.18 mm) and No. 30 (0.6 mm) Tyler mesh sieves (ASTM-E1757-01, 2003).

2.2. Characterisation of the *C. scabrida* fruit pulp

Proximate composition was obtained using the standardized methods of AOAC International (2005) proposed by the official methods of analysis of AOAC International (AOAC, 2005) (Table 1).

The energy value has been calculated from the amounts (%) of protein, total lipids, carbohydrates and fibre using the energy conversion factors proposed by Moreiras et al. (2013) and equation 1:

$$\text{Energy value (kcal g}^{-1}\text{)} = 4 * (\text{Protein}) + 9 * (\text{Total lipid}) + 4 * (\text{Carbohydrate}) + 2 * (\text{Fibre}) \quad (1)$$

2.3. Oil extraction

The extraction of the seed oil was carried out using AOAC method 920.39 (AOAC, 2002). The seed flour (30 g) was wrapped in a cellulose paper cartridge (Modelo 2800-338, Whatman Plc, Maidstone, UK) and placed in the Soxhlet apparatus (Glassco Laboratory Equipments Pvt. Ltd., Haryana, India) using n-hexane (250 mL, 95%) for 4 hr. Subsequently, the solvent was eliminated in a rotary vacuum evaporator (Model: RE200A, Yamato, Tokyo, Japan) at 60 °C and 500 mm Hg. Oil samples were stored at -5 ± 2 °C in the dark until analysis for a maximum of 3 wk.

2.4. Analytical determinations

Oil density was measured using a 25 mL pycnometer with a thermometer (20 °C) incorporated into it (Thermo Fisher Scientific Inc. Waltham, MA, USA) using the official method of the American Oil Chemists' Society (AOCS-Cc-10c-95(09), 1997). Refractive index was measured at 25 °C using a digital refractometer (Model: DR 301 - 95 Kruss Optronic GmbH, Hamburg, Germany), (AOCS-Cc-7-25(09), 1997). Iodine value was obtained using the Wijs method (AOCS-Cd-1-25(93), 1997). Briefly, oil (0.25 g) was mixed with 25 mL of Wijs reagent, (Sigma-Aldrich Co.) The mixture was allowed to stand in the dark at room temperature (~24 °C) for 30 min; then, 20 mL 15% KI solution and 100 mL distilled water was added. It was titrated using a solution of 0.1 N sodium thiosulfate solution until the yellow colour had almost vanished and 1 - 2 mL (1% amylose and amylopectin) starch solution was added. The titration was continued until the blue colour disappeared. One blank of the mixture without the sample was used. The iodine value was obtained using equation 2:

$$Iodine\ value\left(\frac{g}{100\ g}\right) = \frac{(B - S) * M * 12.69}{W} \quad (2)$$

Where B = titrant volume, mL of blank

S = titrant volume, mL of sample

M = sodium thiosulfate solution molarity

W = sample mass, g

Saponification value. The same steps were carried out for the control without the sample using AOCS Cd 3-25 method (AOCS, 1994). Two g of the oil samples were mixed with 50 mL alcoholic 0.5 N KOH (99.8% ethanol). The samples were boiled for ~30 min and left to cool at room temperature. Phenolphthalein (1 mL) was added and the samples were titrated using 0.5 M HCl until the pink colour disappeared. The same procedure was carried out for the blank without the sample.

The saponification index was determined using equation 3:

$$\text{Saponification value} \left(\frac{\text{mg KOH}}{\text{g}} \right) = \frac{(B - S) * M}{W} * 56.1 \quad (3)$$

Where B = volume of 0.5 M HCl used to titrate the blank, mL

S = volume of 0.5 M HCl used to titrate the sample, mL

M = the HCl solution molarity

W = sample mass, g

Free FA, also referred to as oil acidity, was measured using the AOCS Ca 5a-40 method (AOCS, 1998). Phenolphthalein indicator (0.5 mL) was placed in 125 mL of a mixture that consisted of 50% (v/v) isopropanol and toluene, which was neutralised using 0.1 M KOH to a faint but permanent pink colour. The oil samples (2.5 g) were mixed with 125 mL of the neutralised solvent. The samples were agitated until they dissolved and were then titrated using 0.1 M KOH until a stable pink colour was observed similar to that before the titration. A blank titration was carried out adding 125 mL of the neutralised solvent blend. The acid value was determined using equation 4:

$$\text{Acid value} \left(\frac{\text{mg KOH}}{\text{g}} \right) = \frac{(A - B) * M}{W} * 56.1 \quad (4)$$

Where A = volume of 0.1 M KOH used to titrate the sample, mL

B = volume of 0.1 M KOH used to titrate the blank, mL

M = KOH solution molarity

W = sample mass, g

Peroxide value, which is indicative of the quantity of hydroperoxide in the oil, was determined using AOCS-Cd-8b-90 (2003). Oil (2 g) was mixed with 50 mL of a 3:2 (v/v) acetic acid:isooctane solution. A saturated KI solution (0.5 mL) was added and left to stand for 1 min. The sample was stirred at least three times during the incubation period. Distilled water (30 mL) was added to the samples and then titrated using 0.1 M sodium thiosulfate until the yellow iodine colour disappeared. Sodium lauryl sulfate (0.5

mL 10%) and 0.5 mL (1% amylose and amylopectin) starch indicator solution were added to the samples and titration was done until the blue colour disappeared. A blank titration was implemented using the reagent without the samples. The peroxide value was determined using equation 5:

$$\text{Peroxide value} \left(\frac{\text{mEq peroxide}}{\text{kg}} \right) = \frac{(S - B) * M}{W} * 1000 \quad (5)$$

Where S = the titrant volume for the sample, mL

B = the titrant volume for the blank, mL

M = sodium thiosulfate solution molarity

W = sample mass, g

The FA in the extracted seed oil were converted into FA methyl esters (FAME) using a transesterification process and then measured using gas chromatography (AOCS, 1998). Before analysis, the oil samples were subjected to the transesterification process for conversion into FAME. First, 0.1 g of the oil sample was dissolved in 10 mL hexane and 100 μ L 2M KOH in methanol was added. The mixtures were capped and stirred using Vortex (MX-F Mixer model, Thomas Scientific, Swedesboro, NJ, USA) for 30 s before centrifugation at $400 \times g$ for 10 min (2090 rpm in rotor 12154, Model: Sigma 3-16KL, Sigma Laborzentrifugen GmbH, Osterode am Harz, Germany). Once the phases were separated, aliquots of 2 mL of the n-hexane phase were injected into the gas chromatograph. A Hewlett Packard (Palo Alto, CA, USA) 5890 II gas chromatograph, equipped with a flame ionization detector, a capillary column (30 m x 0.25 mm i.d.) coated using a 0.25 μ m film of a Supelco SP-2330 stationary phase (Sigma-Aldrich Co.) and a Hewlett Packard 5890 automatic injector were used. The oven was operated using an initial temperature of 170 $^{\circ}\text{C}$ and a final temperature of 230 $^{\circ}\text{C}$ increasing at 1 $^{\circ}\text{C}$ min^{-1} . The injector and detector were held at 250 and 270 $^{\circ}\text{C}$, respectively. Helium of 99.9% purity was used as a carrier gas at a constant flow of 2.00 mL min^{-1} , and a split

ratio of 1:50 was used. Air and hydrogen using flow rates of 300 and 30 mL min⁻¹, respectively, were used for the detector. For identification purposes, the standard mixtures K4000 FAME Mix and L209 FAME Mix were used. The quantification of each FA was carried out by determining the relative percentage according to the normalization area procedure assuming that the factor response was the same for all compounds (Garrido-Fernández & León-Camacho, 2019).

Extraction of phenolic compounds from the oil samples was carried out by means of a liquid-liquid extraction using methanol as a solvent using the procedure described by Baiano et al. (2009). A methanol:water solution (2 mL, 70:30, v/v) and 2 mL of hexane was added to 3 g of oil and mixed in the Vortex (MX-F Mixer model), for 10 min. The hydroalcoholic phase containing phenolics was separated from the oily phase by centrifugation at 3180 x g (6000 rpm in rotor 12154 at 4 °C, for 10 min). The hydroalcoholic phases were collected and centrifuged at 14900 x g (13000 rpm in rotor 12158, at room temperature for 4 min). Finally, hydroalcoholic extracts were recovered using a syringe and then filtered using a 0.45 µm nylon filter, (Sigma-Aldrich Co.) before analysis.

Determination of total phenols content (TPC) was done using Folin Ciocalteu's reagent method (Singleton et al., 1999). Approximately 0.1 mL of the oil sample was mixed with 0.5 mL of Folin-Ciocalteu reagent and subsequently 7 mL of distilled water was added. The mixture was left in the dark for 5 min at room temperature. Afterwards, 1.5 mL of sodium carbonate solution was added and the mixture was left at room temperature for another 2 hr. The absorbance was measured at 765 nm (Lambda 25 UV/VIS spectrophotometer, Perkin Elmer, Waltham, MA, USA). GA was used as a standard for the calibration curve and TPC was expressed as mg of GA equivalents

213 (GAE kg⁻¹ of oil). Equation 5 was used in a concentration range of 0.01 – 0.1 mg GA
214 mL⁻¹.

$$215 \quad Y = -0.0409 + 3.55X, R^2 = 0.998 \quad (6)$$

216 2.5. Antioxidant Capacity (AOC)

217 The 1,1-diphenyl-2-picrylhydrazyl free radical (DPPH) assay was carried out in
218 accordance with Thaipong et al. (2006). Oil extract (1.5 mL) was mixed with 1.5 mL
219 0.2 mM methanolic DPPH solution. After an incubation period of 30 min at room
220 temperature, the absorbance at 515 nm (Perkin Elmer, Waltham, MA, USA) was
221 measured. A Trolox calibration curve (equation 6) in a concentration range of 24 - 580
222 µM Trolox (T) L⁻¹, was used and values were expressed as mM T equivalents (mM TE
223 Kg⁻¹ of oil).

$$224 \quad Y = 1.29 \times 10^{-3} - 7.88 \times 10^{-4}X, R^2 = 0.996 \quad (7)$$

225 The 2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) free radical
226 scavenging assay was done as reported by Baqueiro-Peña and Guerrero-Beltrán (2017)
227 with slight modifications. Sodium persulfate (3.3 mg) and 19.4 mg of ABTS were added
228 into an amber bottle wrapped with aluminium foil. Distilled water (5 mL) was added
229 and stored in the dark at room temperature for 16 hr. Once the ABTS⁺ radical was
230 formed, a 1:10 dilution using absolute ethanol was prepared. Subsequently, 3920 µL of
231 the diluted ABTS⁺ radical was placed in a spectrophotometer cell for the reading of the
232 initial absorbance (A_i) at 754 nm. Then, 20 µl of the sample was added, thoroughly
233 mixed, allowed to react for 7 min and the final absorbance (A_f) $Y = (A_i - A_f)/A_f$ was
234 measured. The solutions from 24 to 780 µM T L⁻¹ were used to obtain the standard curve
235 (equation 8):

$$Y = -0.15 - 8.41 \times 10^{-4}X, R^2 = 0.997 \quad (8)$$

The antioxidant activity of the oil was expressed as mM TE (mM TE Kg⁻¹ of oil).

2.6. Statistical analysis

Statistical analyses were done using IBM SPSS Statistics v. 24, (Armonk, NY, USA).

It is historically known as the "Statistical Package for the Social Science". Data are reported as a mean value $\pm$ standard deviation (SD) for three measurements (n = 3).

Furthermore, a hierarchical cluster analysis was used to show the similarity between *C.*

Scabrida seed oil FA profile and that of other seed oils available in the literature (for more details, see supplementary material S1). Briefly, Ward's method and Squared

Euclidean distance were used for the formation of the clusters and calculation of the

intervals between the groups, respectively. These statistical criteria were used in the

analysis of hierarchical clusters, which are available in all statistical programs.

Afterwards, the discriminant analysis was used to verify the formation of the selected

clusters. Discriminant function analysis was done with stepwise discriminant method

using Wilks' lambda test and as criteria of F-significance (p <0.05).

251

3. Results and discussion

3.1. Physicochemical characteristics of the *C. Scabrida* seed oil

The outer appearance of the *C. Scabrida* fruit and of its different parts are shown in

Figure 1. The seeds represented ~48.6% of the weight of the fruit and they were used

for oil extraction. The main proximal values of the pulp and seed are shown in Table 2.

The content of carbohydrates and total minerals were higher for the pulp. The *C.*

scabrida seed contained enough lipids to be a good source. The lipid contents of a group

of fruit kernels and seeds of commercial importance were summarised by Kamel and

Kakuda (2008) and in most cases, values ranged between 20 and 60%. The lipid content of *C. scabrida* seed was similar to that of *Ficus carica* (30%) and *Ribes nigrum* (30.5%) seeds. Meanwhile, the oil lipid yield in *C. scabrida* seeds was higher than in soybean seeds (16.5 – 17.5%) and safflower (27.5%) (Bozan & Temelli, 2008; Yoshida et al., 2003).

These results showed that *C. scabrida* seeds have a potential as a source of vegetable oil. The principal physical-chemical characteristics of oil extracted from *C. scabrida* seed are shown in Table 3.

The values of the main physical-chemical properties determined for *C. scabrida* seed oil are within the range proposed by the Codex Alimentarius International Food Standards for most commercial edible oils on a global level (FAO, 1999). However, the density value obtained for the *C. scabrida* seed oil was slightly lower than that of most trade oils cited in Codex 210. Oils with lower density values are highly appreciated by consumers and this property is an important parameter to design an industrial-production process (Zahir et al., 2017). The acid value was lower than the value suggested by CODEX STAN 210 for refined edible oil (FAO, 1999). A low acid value is generally associated with good oil stability. Therefore, the oil can be stored for long periods of time without lipid degradation caused by hydrolysis, in accordance with the results reported by Pereira et al. (2017). In addition, the saponification value is within the range reported for rapeseed oil (168 - 193 mg KOH g⁻¹ oil) and the iodine value is inside the range of 35 - 70 g 100 g⁻¹.

Another quality parameter for the seed oil extracted from *C. scabrida* fruit is the low peroxide value (1.08 mEq kg⁻¹), which is considered an indicator of oil deterioration and rancidity. This value was well below the CODEX Alimentarius International Food Standard of <10 mEq. kg⁻¹ for refined oils and <15 mEq. kg⁻¹ for cold-pressed and virgin

oils. The peroxide value was lower than that reported for *Dacryodes rostrata* seed oil (3.5 mEq. kg⁻¹), refined olive oil (6.7 mEq. kg⁻¹) and RBD Palm Oil (7.1 mEq. kg⁻¹) (Tee et al., 2017) and similar to that obtained for *Anacardium occidentale* L. seed oil (1.1 mEq. kg⁻¹) (Lafont & Portacio, 2011). These results indicated that seed oil from *C. scabrida* has good oxidative stability as currently produced. Thus, the main quality characteristics are within the values recommended by Codex (FAO, 1999). Although potentially an edible oil, appropriate toxicological studies would be needed.

3.2. The FA profile of the *C. Scabrida* seed oil

The characterisation of the FA profile is an important step in the search for new sources of edible vegetable oil (Kamel & Kakuda, 2008). Table 4 shows the results of the FA composition for *C. scabrida* oil extracted from its seeds and that in the literature for *Plukenetia volubilis* seed oil (Inca peanut or Sacha-inchi), which is a Latin American crop recognised as a good vegetable source of omega-3 and with viable commercial applications (Wang et al., 2018).

A total of 8 FA were measured as the main components. In the mixture, UFA predominates with 79.3%. The main component was found to be oleic acid, followed by palmitic and palmitoleic acid, respectively (See Table 4). An acceptable level of oleic acid content is considered a good indicator of the nutritional value of vegetable oil and its health benefits. Olive oil, high in oleic acid, has been extensively investigated and its benefits on human health have been established (Foscolou et al., 2018; Pereira, 2013; Visioli et al., 2018; Wani et al., 2018). The chemical characterisation of mesocarp oil from the *Aphandra natalia* fruit from the Ecuadorian Amazon region found similar oleic acid content (57.9%) (Viafara et al., 2018). Stearic and linoleic acid were also found in similar quantities (~7%). The three remaining components (α -linolenic, eicosenoic and eicosapentaenoic) were present, albeit in quantities <4%. Omega-3 eicosapentaenoic

acid (EPA) was also present, whereas omega-3 α -linolenic (ALA) can be found in green leafy vegetables, flaxseed, rapeseed and walnuts or in Inca peanut seed oil. The presence of EPA is unusual in the plant kingdom and had not been previously reported in *C. scabrida*. Dr. Duke's Phytochemical and Ethnobotanical Databases (<https://phytochem.nal.usda.gov/>, accessed: November 22nd, 2018) only reports its presence in trace amounts in the species *Allium sativum* var. *sativum* and *Portulaca oleracea*. At present, there are studies on transgenic plants as sources of long-chain omega-3, which achieve levels equivalent to those in fish oils (*Camelina sativa* seed oil) (Ruiz-Lopez et al., 2014). But marine fish and several types of edible algae are still considered the main sources of EPA.

According to Simopoulos (2002), ALA is not equivalent in its biological effects to the long-chain omega-3 FA found in marine oils. EPA is more rapidly incorporated into plasma and membrane lipids and produces faster effects than ALA.

EPA's beneficial effects on human health include a range of physiological roles as anti-lipogenic and anti-inflammatory effects (Calder, 2013; Nelson et al., 2017). Inoue-Yamauchi et al. (2017) assessed the clinical implication of EPA as a treatment for obesity-related hepatocellular carcinoma. The results showed that the development of carcinogen-induced hepatocellular carcinoma was significantly decreased in mice fed a high-fat diet supplemented with EPA than in those fed a high-fat diet only. The authors suggested that EPA attenuates the development of obesity-related hepatocellular carcinoma. In addition, it helps maintain the inhibition of tumour growth by suppressing the activation of the pro-tumourigenic IL-6 effector STAT3.

Another characteristic of *C. scabrida* seed oil is its omega-6:omega-3 ratio of 2.7:1. These results differ from other ratios reported for oils from seeds and the soft parts of

northern berries (species of *Rubus*, *Vaccinium*, *Empetrum*, *Fragaria* and *Hippophaë* with omega-6:omega-3 ratios of 1:1 – 1:2) (Yang et al., 2011) and from the 0.72:0.76 omega-6:omega-3 ratio of *Plukenetia volubilis* seed oil (Wang et al., 2018). In a review by Simopoulos (2002) on the importance of the omega-6:omega-3 ratio, they concluded that the recommended dose varies from 1:1 to 4:1 depending on the disease under consideration, since many chronic diseases are multigenic and multifactorial. James and Cleland (1997) cited the results of Bartram et al. (1995; 1993) , who reported that a ratio of 2.5:1 reduced rectal cell proliferation in patients with colorectal cancer and a ratio of 2:1 – 3:1 suppressed inflammation in patients with rheumatoid arthritis. These were consistent with the results with *C. scabrida* seed oil, therefore it is advisable to carry out studies on its pharmacological properties and a phytochemical analysis.

3.3. Cluster and discriminant analysis

The cluster analysis was used to classify the *C. scabrida* seed oil in terms of its FA composition. Figure 2 shows the dendrogram obtained from the statistical analysis, which shows that the formation of the clusters according to the similarity between the lipid profiles of the seed oils.

Establishing the similarity between subjects is the central target of cluster analysis. However, the number of clusters should be defined by the researcher. The formation of 4 species groups was selected, as indicated by the red dashed line in Figure 2. As can be observed in the dendrogram, the *C. scabrida* seed oil is grouped with a linkage distance value of ~15 with the fruit oils of macadamia, cocoa, guanabana (soursop), olive, almond and hazelnut. However, for linkage distance values of <15, this oil did not form a cluster with any of the other oils. This is probably due to the presence of EPA in its FA composition, which is unique to *C. scabrida*.

A discriminant analysis was used afterwards for statistical validation of the selection of 4 clusters and this determined which FA were significant in the formation of clusters. The classification results from the test of the predicted groups showed that 100% of the original groupings were correctly classified. Capric, lauric, myristic, oleic, linoleic and α -linolenic acids were the FA significant variables ($p < 0.05$), whilst the rest of the FA were not significant in the formation of the 4 clusters. Table 5, shows the classification coefficients obtained using Fisher linear discriminant functions.

3.4. TPC and total antioxidant capacity

Seeds and nuts are often important sources of bioactive compounds, among which are the phenolics compounds. These are molecules that can act as antioxidants and help prevent various diseases (Khoddami et al., 2013).

Polyphenol content and other total antioxidant activities for *C. scabrida* seed oil are shown in Table 6.

The TPC for *C. scabrida* seed oil was similar to values reported for the oil extracted from the Amazonian fruit *Gustavia macarenensis* (157 mg GAE kg⁻¹ of oil) (Mera et al., 2019) and *Rhus chinensis* Mill seed oils (152 mg GAE kg⁻¹ of oil) (Shi et al., 2019). However, this value is higher than that reported for crude palm oil (from 31.2 to 70.2 mg GAE kg⁻¹ of oil) from 6 refineries in different regions of Malaysia (Abdullah et al., 2018) or 100 and 33 mg GAE kg⁻¹ for sesame oil obtained using solvent extraction for roasted and unroasted seeds, respectively (Shi et al., 2018). Palm and sesame oils are traded worldwide. Both have an important role in the pharmaceutical and cosmetic industries, as well as human nutrition (Abdullah et al., 2018; Ribeiro et al., 2016).

A principal feature of polyphenolic compounds is their antioxidant activity. The polyphenolic compounds content is usually between 100 and 300 mg GAE kg⁻¹ (Dimitrios, 2006; Foster et al., 2009; Quiles et al., 2002). The DPPH and ABTS

antioxidant activities of *C. scabrida* seed oil were both much higher than the values reported for sesame oil (0.144 and 0.570 mM TE kg⁻¹ of oil, respectively) (Shi et al., 2018). The DPPH value obtained was also higher than that reported for other oils from fruits of the same region, such as *Plukenetia volubilis* L. (0.0730 mM TE kg⁻¹) and *Gustavia macarenensis* (0.170 mM TE kg⁻¹) (Cisneros et al., 2014; Mera et al., 2019).

4. Conclusions

The values of the main proximal properties determined for *C. scabrida* are consistent with commercial edible oils included in the Codex Alimentarius International Food Standards. Thus, *C. scabrida* seed oil has the potential for human consumption as an edible oil. *C. scabrida* seed oil shows an unusual FA profile (e.g., EPA), which is uncommon in lipid sources from the plant kingdom. In addition, it had a good content of oleic acid (52.8%), rendering it nutritionally valuable. The omega-6:omega-3 ratio obtained was 2.7:1, which is within the recommended range (from 1:1 to 4:1) for the most recent dietary guidelines in Western countries (US and EU). *C. scabrida* seed oil was grouped in terms of similarity of FA composition with the fruit oils of macadamia, cocoa, guanabana, olive, almond and hazelnut. The discriminant analysis showed that the predicted groups were correct statistically. The results for TPC and radical scavenging assay showed that the oil is of good quality and has quality parameter values higher than other globally established commercial sources. Thus, due to its macronutrients, lipid composition and total antioxidant assay, *C. scabrida* seed oil might be developed as a new unconventional source for the cosmetic, pharmaceutical and food industries. Nonetheless, further studies should be carried out into its pharmacological properties and a phytochemical analysis should be done.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgments

This study was supported by the Universidad Estatal Amazónica, Puyo, Ecuador.
We appreciate the comments of the reviewers and Editor-in-Chief who have contributed to improving the manuscript through the peer-review process.

References

- Abdullah, F., Ismail, R., Ghazali, R., & Idris, Z. (2018). Total phenolic contents and antioxidant activity of palm oils and palm kernel oils at various refining processes. *Journal of Oil Palm Research*, 30, 682-692.
doi:<https://doi.org/10.21894/jopr.2018.0058>
- AOAC. (2002). Method 920.39. Fat (crude) or Ether Extract in Animal Feed. *Official Methods of Analysis of the Association of Official Analytical Chemists*. Gaithersburg, MD, USA: AOAC International.
- AOAC. (2005). *Official Methods of Analysis of the Association of Official Analytical Chemists*. Gaithersburg, MD, USA: AOAC International.
- AOCS-Cc-7-25(09). (1997). Refractive Index of Fats and Oils. *Official Methods and Recommended Practices of the American Oil Chemists' Society*. Champaign, IL, USA: AOCS Press.
- AOCS-Cc-10c-95(09). (1997). Determination of Mass per Unit Volume ("Liter Weight") in Air of Oils and Fats. *Official Methods and Recommended Practices of the American Oil Chemists' Society*. Champaign, IL, USA: AOCS Press.

433 AOCS-Cd-1-25(93). (1997). Iodine Value of Fats and Oils, Wijs Method. *Official*
434 *Methods and Recommended Practices of the American Oil Chemists' Society*.
435 Champaign, IL, USA: AOCS Press.

436 AOCS-Cd-8b-90. (2003). Peroxide Value Acetic Acid-Isooctane Method. *Official*
437 *Methods and Recommended Practices of the American Oil Chemists' Society*.
438 Champaign, IL, USA: AOCS Press.

439 AOCS. (1994). *Official Methods and Recommended Practices of the American Oil*
440 *Chemists' Society*. Champaign, IL, USA: AOCS Press.

441 AOCS. (1998). Fatty Acid Composition by GC. Marine Oils. *Official Methods and*
442 *Recommended Practices of the American Oil Chemists' Society*. Champaign,
443 IL, USA: AOCS Press.

444 ASTM-E1757-01. (2003). Standard Practice for Preparation of Biomass for
445 Compositional Analysis. *Annual Book of ASTM Standards*. Vol. (11). West
446 Conshohocken, PA, USA: ASTM International.

447 Baiano, A., Gambacorta, G., Terracone, C., Previtali, M. A., Lamacchia, C., & La
448 Notte, E. (2009). Changes in phenolic content and antioxidant activity of
449 Italian extra-virgin olive oils during storage. *Journal of Food Science*, 74(2),
450 177-183. doi:<https://10.1111/j.1750-3841.2009.01072.x>

451 Baqueiro-Peña, I., & Guerrero-Beltrán, J. (2017). Physicochemical and antioxidant
452 characterization of *Justicia spicigera*. *Food Chemistry*, 218, 305-312.
453 doi:<https://10.1016/j.foodchem.2016.09.078>

454 Bartram, H. P., Gostner, A., Reddy, B. S., Rao, C. V., Scheppach, W., Dusel, G.,
455 Richter, A., Richter, F., & Kasper, H. (1995). Missing anti-proliferative effect
456 of fish oil on rectal epithelium in healthy volunteers consuming a high-fat diet:

457 Potential role of the n-3:n-6 fatty acid ratio. *European Journal of Cancer*
458 *Prevention*, 4(3), 231-237. doi:<https://10.1097/00008469-199506000-00004>
459 Bartram, H. P., Gostner, A., Scheppach, W., Reddy, B. S., Rao, C. V., Dusel, G.,
460 Richter, F., Richter, A., & Kasper, H. (1993). Effects of fish oil on rectal cell
461 proliferation, mucosal fatty acids, and prostaglandin E2 release in healthy
462 subjects. *Gastroenterology*, 105(5), 1317-1322.
463 doi:[https://doi.org/10.1016/0016-5085\(93\)90135-Y](https://doi.org/10.1016/0016-5085(93)90135-Y)
464 Bozan, B., & Temelli, F. (2008). Chemical composition and oxidative stability of flax,
465 safflower and poppy seed and seed oils. *Bioresource Technology*, 99(14),
466 6354-6359. doi:<https://doi.org/10.1016/j.biortech.2007.12.009>
467 Calder, P. C. (2013). Omega-3 polyunsaturated fatty acids and inflammatory
468 processes: Nutrition or pharmacology? *British Journal of Clinical*
469 *Pharmacology*, 75(3), 645-662. doi:<https://10.1111/j.1365-2125.2012.04374.x>
470 Carrillo-Perdomo, E., Aller, A., Cruz-Quintana, S., Giampieri, F., & Alvarez-Suarez,
471 J. (2015). Andean berries from Ecuador: A review on botany, agronomy,
472 chemistry and health potential. *Journal of Berry Research*, 5(2), 49-69.
473 doi:<https://doi.org/10.3233/jbr-140093>
474 Cisneros, F. H., Paredes, D., Arana, A., & Cisneros-Zevallos, L. (2014). Chemical
475 composition, oxidative stability and antioxidant capacity of oil extracted from
476 roasted seeds of Sacha-Inchi (*Plukenetia volubilis* L.). *Journal of Agricultural*
477 *and Food Chemistry*, 62(22), 5191-5197. doi:<https://doi.org/10.1021/jf500936j>
478 Charoenkiatkul, S., Thiyajai, P., & Judprasong, K. (2016). Nutrients and bioactive
479 compounds in popular and indigenous durian (*Durio zibethinus* murr.). *Food*
480 *Chemistry*, 193, 181-186. doi:<https://doi.org/10.1016/j.foodchem.2015.02.107>

481 Dimitrios, B. (2006). Sources of natural phenolic antioxidants. *Trends in Food Science*
 482 & *Technology*, 17(9), 505-512. doi:<https://doi.org/10.1016/j.tifs.2006.04.004>

483 FAO. (1999). Codex Standard for Named Vegetable Oils. *Codex Alimentarius*. Vol.
 484 210. Rome, Italy: Food & Agriculture Organization of the United Nations.

485 Foscolou, A., Critselis, E., & Panagiotakos, D. (2018). Olive oil consumption and
 486 human health: A narrative review. *Maturitas*, 118, 60-66.
 487 doi:<https://doi.org/10.1016/j.maturitas.2018.10.013>

488 Foster, R., Williamson, C., & Lunn, J. (2009). Briefing paper: Culinary oils and their
 489 health effects. *Nutrition Bulletin*, 34(1), 4-47.
 490 doi:<https://doi.org/10.1111/j.1467-3010.2008.01738.x>

491 Garrido-Fernández, A., & León-Camacho, M. (2019). Assessing the effect of season,
 492 montanera length and sampling location on Iberian pig fat by compositional
 493 data analysis and standard multivariate statistics. *Food Chemistry*, 295, 377-
 494 386. doi:<https://doi.org/10.1016/j.foodchem.2019.05.123>

495 Herrera, E. L., Feijoo, C. Y., Alfaro, R., Solís, J. L., Gómez, M. M., Keiski, R. L., &
 496 Cruz, G. J. (2018). Producción de biocarbón a partir de biomasa residual y su
 497 uso en la germinación y crecimiento en vivero de *Capparis scabrida* (Sapote).
 498 (in Spanish). [Biochar production from residual biomass and its use in
 499 germination and growth in the *Capparis scabrida* nursery (Zapote)]. *Scientia*
 500 *Agropecuaria*, 9(4), 569-577.
 501 doi:<http://dx.doi.org/10.17268/sci.agropecu.2018.04.13>

502 Inoue-Yamauchi, A., Itagaki, H., & Oda, H. (2017). Eicosapentaenoic acid attenuates
 503 obesity-related hepatocellular carcinogenesis. *Carcinogenesis*, 39(1), 28-35.
 504 doi:<https://doi.org/10.1093/carcin/bgx112>

505 James, M. J., & Cleland, L. G. (1997). Dietary n-3 fatty acids and therapy for
 506 rheumatoid arthritis. *Seminars in Arthritis and Rheumatism*, 27(2), 85-97.
 507 doi:[https://doi.org/10.1016/s0049-0172\(97\)80009-1](https://doi.org/10.1016/s0049-0172(97)80009-1)

508 Kamel, B. S., & Kakuda, Y. (2008). Fatty Acids in Fruits and Fruit Products. *Fatty*
 509 *Acid in Foods and their Health Implication*. Vol. 263. New York, NY, USA:
 510 Marcel Dekker Inc.

511 Khoddami, A., Wilkes, M. A., & Roberts, T. H. (2013). Techniques for analysis of
 512 plant phenolic compounds. *Molecules*, 18(2), 2328-2375.
 513 doi:<https://doi.org/10.3390/molecules18022328>

514 Lafont, J. J., & Portacio, A. A. (2011). Extracción y caracterización fisicoquímica del
 515 aceite de la semilla (almendra) del marañón (*Anacardium occidentale* L). (in
 516 Spanish). [Extraction and physicochemical characterization of seed oil
 517 (almond) of cashew nut (*Anacardium occidentale* L)]. *Información*
 518 *Tecnológica*, 22(1), 51-58.

519 Mera, J. J. R., Abreu-Naranjo, R., Alvarez-Suarez, J. M., Viafara, D., Reyes Mera, J.
 520 J., Abreu-Naranjo, R., Alvarez-Suarez, J. M., & Viafara, D. (2019). Chemical
 521 characterization, fatty acid profile and antioxidant activity of *Gustavia*
 522 *macarenensis* fruit mesocarp and its oil from the Amazonian region of Ecuador
 523 as an unconventional source of vegetable oil. *Grasas y Aceites*, 70(2), 298-298.
 524 doi:<https://doi.org/10.3989/gya.0569181>

525 Moreiras, O., Carbajal, A., Cabrera, L., & Cuadrado, C. (2013). *Tabla de Composición*
 526 *de Alimentos*. (in Spanish). [Table of Food Composition]. Madrid, Spain: Ed.
 527 Pirámide.

528 Muhtadi, M., Haryoto, H., Sujono, T. A., & Suhendi, A. (2016). Antidiabetic and
 529 antihypercholesterolemia activities of rambutan (*Nephelium lappaceum* L.) and

530 durian (*Durio zibethinus* Murr.) fruit peel extracts. *Journal of Applied*
 531 *Pharmaceutical Science*, 6(04), 190-194.
 532 doi:<https://doi.org/10.1016/j.profoo.2015.01.028>
 533 Nelson, J., Wani, O., May, H., & Budoff, M. (2017). Potential benefits of
 534 eicosapentaenoic acid on atherosclerotic plaques. *Vascular Pharmacology*, 91,
 535 1-9. doi:<https://doi.org/10.1016/j.vph.2017.02.004>
 536 Pereira. (2013). Special issue on “Olive oil: Quality, composition and health benefits”.
 537 *Food Research International*, 2(54), 1859.
 538 doi:<https://doi.org/10.1016/j.foodres.2013.11.020>
 539 Pereira, Hamerski, F., Andrade, E., Scheer, A., & Corazza, M. L. (2017). Assessment
 540 of subcritical propane, ultrasound-assisted and Soxhlet extraction of oil from
 541 sweet passion fruit (*Passiflora alata* Curtis) seeds. *The Journal of*
 542 *Supercritical Fluids*, 128, 338-348.
 543 doi:<https://doi.org/10.1016/j.supflu.2017.03.021>
 544 Quiles, J. L., Ramírez-Tortosa, M. C., Gomez, J. A., Huertas, J. R., & Mataix, J.
 545 (2002). Role of vitamin E and phenolic compounds in the antioxidant capacity,
 546 measured by ESR, of virgin olive, olive and sunflower oils after frying. *Food*
 547 *Chemistry*, 76(4), 461-468. doi:[https://doi.org/10.1016/S0308-8146\(01\)00307-](https://doi.org/10.1016/S0308-8146(01)00307-7)
 548 [7](https://doi.org/10.1016/S0308-8146(01)00307-7)
 549 Ramos, A. S., Souza, R. O., Boleti, A. P. d. A., Bruginski, E. R., Lima, E. S., Campos,
 550 F. R., & Machado, M. B. (2015). Chemical characterization and antioxidant
 551 capacity of the araçá-pera (*Psidium acutangulum*): An exotic Amazon fruit.
 552 *Food Research International*, 75, 315-327.
 553 doi:<https://doi.org/10.1016/j.foodres.2015.06.026>

554 Ribeiro, S. A. O., Nicacio, A. E., Zanqui, A. B., Biondo, P. B. F., de Abreu-Filho, B.
555 A., Visentainer, J. V., Gomes, S. T. M., & Matsushita, M. (2016).
556 Improvements in the quality of sesame oil obtained by a green extraction
557 method using enzymes. *LWT - Food Science and Technology*, 65, 464-470.
558 doi:<https://doi.org/10.1016/j.lwt.2015.08.053>

559 Rodrigues, S., de Oliveira Silva, E., & de Brito, E. S. (2018). *Exotic Fruits Reference*
560 *Guide*. London, UK: Academic Press.

561 Rodríguez-Rodríguez, E., Bussmann, R., Arroyo-Alfaro, S., López-Medina, S., &
562 Briceño-Rosario, J. (2007). *Capparis scabrida* (Capparaceae) a species from
563 Perú and Ecuador in urgent need of conservation plans. *Arnaldoa*, 14, 269-282.

564 Ruiz-Lopez, N., Haslam, R. P., Napier, J. A., & Sayanova, O. (2014). Successful
565 high-level accumulation of fish oil omega-3 long-chain polyunsaturated fatty
566 acids in a transgenic oilseed crop. *The Plant Journal*, 77(2), 198-208.
567 doi:<https://doi.org/10.1111/tpj.12378>

568 Shi, L., Zheng, L., Liu, R., Chang, M., Huang, J., Zhao, C., Jin, Q., & Wang, X.
569 (2019). Potential underutilized oil resources from the fruit and seed of *Rhus*
570 *chinensis* Mill. *Industrial Crops and Products*, 129, 339-344.
571 doi:<https://doi.org/10.1016/j.indcrop.2018.12.023>

572 Shi, L. K., Zheng, L., Liu, R. J., Chang, M., Jin, Q. Z., & Wang, X. G. (2018).
573 Chemical characterization, oxidative stability, and *in vitro* antioxidant capacity
574 of sesame oils extracted by supercritical and subcritical techniques and
575 conventional methods: A comparative study using chemometrics. *European*
576 *Journal of Lipid Science and Technology*, 120(2), 1700326.
577 doi:<https://doi.org/10.1002/ejlt.201700326>

578 Simopoulos, A. P. (2002). The importance of the ratio of omega-6/omega-3 essential
579 fatty acids. *Biomedicine & Pharmacotherapy*, 56(8), 365-379.
580 doi:[https://doi.org/10.1016/s0753-3322\(02\)00253-6](https://doi.org/10.1016/s0753-3322(02)00253-6)

581 Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). [14] Analysis of
582 total phenols and other oxidation substrates and antioxidants by means of
583 Folin-Ciocalteu reagent. *Methods in Enzymology*, 299, 152-178.
584 doi:[https://doi.org/10.1016/S0076-6879\(99\)99017-1](https://doi.org/10.1016/S0076-6879(99)99017-1)

585 Tantamango, Y. M., Knutsen, S. F., Beeson, W. L., Fraser, G., & Sabate, J. (2011).
586 Foods and food groups associated with the incidence of colorectal polyps: The
587 adventist health study. *Nutrition and Cancer*, 63(4), 565-572.
588 doi:<https://doi.org/10.1080/01635581.2011.551988>

589 Tee, L. H., Yang, B., Tey, B. T., Chan, E.-S., Azlan, A., Ismail, A., Sun, J., Lau, C. Y.,
590 Palanisamy, U. D., & Ramanan, R. N. (2017). Valorization of *Dacryodes*
591 *rostrata* fruit through the characterization of its oil. *Food Chemistry*, 235, 257-
592 264. doi:<https://doi.org/10.1016/j.foodchem.2017.05.021>

593 Thaipong, K., Boonprakob, U., Crosby, K., Cisneros-Zevallos, L., & Byrne, D. H.
594 (2006). Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating
595 antioxidant activity from guava fruit extracts. *Journal of Food Composition*
596 *and Analysis*, 19(6-7), 669-675. doi:<https://doi.org/10.1016/j.jfca.2006.01.003>

597 Viafara, D., Abreu-Naranjo, R., Alvarez-Suarez, J. M., Reyes-Mera, J. J., & Barreno-
598 Ayala, M. (2018). Chemical characterisation and antioxidant activity of
599 *Aphandra natalia* mesocarp and its oil from the Amazon region of Ecuador.
600 *Journal of Food Measurement and Characterization*, 12(4), 2835-2843.
601 doi:<https://doi.org/10.1007/s11694-018-9898-x>

- Visioli, F., Franco, M., Toledo, E., Luchsinger, J., Willett, W. C., Hu, F. B., & Martinez-Gonzalez, M. A. (2018). Olive oil and prevention of chronic diseases: Summary of an international conference. *Nutrition, Metabolism and Cardiovascular Diseases*, 28(7), 649-656. doi:<https://doi.org/10.1016/j.numecd.2018.04.004>
- Wang, S., Zhu, F., & Kakuda, Y. (2018). Sacha inchi (*Plukenetia volubilis* L.): Nutritional composition, biological activity, and uses. *Food Chemistry*, 265, 316-328. doi:<https://doi.org/10.1016/j.foodchem.2018.05.055>
- Wani, T. A., Masoodi, F. A., Gani, A., Baba, W. N., Rahmanian, N., Akhter, R., Wani, I. A., & Ahmad, M. (2018). Olive oil and its principal bioactive compound: Hydroxytyrosol – A review of the recent literature. *Trends in Food Science & Technology*, 77, 77-90. doi:<https://doi.org/10.1016/j.tifs.2018.05.001>
- Yang, B., Ahotupa, M., Määttä, P., & Kallio, H. (2011). Composition and antioxidative activities of supercritical CO₂-extracted oils from seeds and soft parts of northern berries. *Food Research International*, 44(7), 2009-2017. doi:<https://doi.org/10.1016/j.foodres.2011.02.025>
- Yoshida, H., Hirakawa, Y., Murakami, C., Mizushima, Y., & Yamade, T. (2003). Variation in the content of tocopherols and distribution of fatty acids within soya bean seeds (*Glycine max* L.). *Journal of Food Composition and Analysis*, 16(4), 429-440. doi:[https://doi.org/10.1016/S0889-1575\(03\)00028-0](https://doi.org/10.1016/S0889-1575(03)00028-0)
- Zahir, E., Saeed, R., Hameed, M. A., & Yousuf, A. (2017). Study of physicochemical properties of edible oil and evaluation of frying oil quality by Fourier transform-infrared (FT-IR) spectroscopy. *Arabian Journal of Chemistry*, 10, S3870-S3876. doi:<https://doi.org/10.1016/j.arabjc.2014.05.025>

Figure captions

Figure 1. The outer appearance of the *Capparis scabrida* fruit and its different parts: A: whole *C. scabrida* fruit; B: husk and seeds with pulp; C: Almond (white) and seeds with pulp; D: seeds without pulp and dried.

Figure 2. Cluster analysis using Ward's method for the similarity classification of *C. scabrida* seed oil with other traditional seed oils according to fatty acids composition.

Figure 1

Figure 2

Table 1. Standards used for the determination of the proximate composition of pulp
from *C. scabrida* fruit.

Component	Standard
Total lipids	AOAC 920.39
Crude fibre	AOAC 935.53
Crude protein	AOAC 954.01
Carbohydrates	By difference
Total Minerals	AOAC 923.03
Moisture	AOAC 925.10
Energy value	Moreiras et al. (2013)

Table 2. Proximal composition of pulp and seed of the *C. scabrida* fruit

Proximate analysis	Value $\pm$ SD	
Component	Pulp	Seed
Total lipids (wt%)	2.5 $\pm$ 0.1	31.6 $\pm$ 0.3
Crude fibre (wt%)	8.1 $\pm$ 0.1	14.4 $\pm$ 0.3
Crude protein (wt%)	22.5 $\pm$ 0.1	38.1 $\pm$ 0.1
Carbohydrates (wt%)	61.7 $\pm$ 0.2	17.5 $\pm$ 0.3
Total m inerals (wt%)	5.4 $\pm$ 0.2	2.9 $\pm$ 0.2
Moisture (%)	71.9 $\pm$ 0.2	5.2 $\pm$ 0.1
Energy value (x100 Kcal 100 g ⁻¹)	3.7 $\pm$ 0.8	5.3 $\pm$ 0.9

All wt% are expressed on a dry basis.

Table 3. Physical-chemical properties of seed oil of the *C. scabrida* fruit.

Component	Value $\pm$ SD	Codex Values**
Density (g mL ⁻¹ at 25 °C)	0.87 $\pm$ 0.01	0.89 - 0.92
Acid value (mg KOH g ⁻¹)	0.27 $\pm$ 0.01	<0.6
Free fatty acid (g oleic Acid. 100 g ⁻¹)	0.14 $\pm$ 0.01	-
Saponification value (x100 mg KOH g ⁻¹)	1.8 $\pm$ 0.1	168 - 205
Unsaponifiable Matter (wt%)	2.9 $\pm$ 0.1	<20
Peroxide value (mEq. kg ⁻¹)	1.1 $\pm$ 0.1	<10*
Iodine value (g 100 g ⁻¹)	67.2 $\pm$ 0.4	35 - 70
Refractive index (25°)	1.46 $\pm$ 0.01	1.46 – 1.47
Moisture (%)	3.2 $\pm$ 0.1	-

*Refined oils. All wt% are expressed on a dry basis. **(FAO, 1999)

Table 4. Fatty acid composition (g 100 g⁻¹) of *C. scabrida* and *Plukenetia volubilis* L. seed oil.

Fatty Acid	<i>C. scabrida</i>	<i>Plukenetia volubilis</i> L.
Saturated		
C14:O (Myristic)	0.160	
C16:O (Palmitic)	12.7	4.67 - 6.30
C18:O (Stearic)	7.67	2.96 - 3.81
Monounsaturated		
Cis-C16:1(n-9) (Palmitoleic)	11.9	
C18:1(n-9) (Oleic)	52.8	8.41 - 10.5
C20:1(n-9) (Eicosenoic)	3.98	
Polyunsaturated		
C18:2(n-6) (Linoleic)	7.87	32.7 - 36.8
C18:3(n-3) (α -Linolenic)	1.50	45.2 - 50.4
C20:5(n-3) (Eicosapentaenoic)	1.46	
Total Omega-3	2.97	45.2 - 50.4
Total Omega-6	7.87	32.7 - 36.8
Total Omega-9	68.6	8.41 - 10.5
Total saturated	20.5	6.74 - 7.70
Total monounsaturated	68.6	7.50 - 10.7
Total polyunsaturated	10.8	78.2 - 84.5

Table 5. Classification coefficients obtained for Fisher linear discriminant functions
from discriminant analysis

Fatty acid	Cluster			
	1	2	3	4
10:0	-266	-447	-216	-13.1 x 10 ³
12:0	38.6	83.3	38.3	41.8 x 10 ²
14:0	-39.0	-37.5	-20.8	12.6 x 10 ²
16:0	7.94	7.65	3.82	-75.9
16:1	11.0	11.2	5.58	-16.2
17:0	-251	-400	-198	-86.8 x 10 ²
18:0	6.85	6.97	3.40	60.9
18:1	6.92	6.72	3.29	3.44
18:2	7.58	8.37	4.08	44.3
Constant	-353	-368	-89.2	-870 x 10 ³

Table 6. TPC, DPPH and ABTS values for *C. scabrida* seed oil

Assay	Mean $\pm$ SD
TPC (mg GAE kg ⁻¹ of oil)	150 $\pm$ 0.5
DPPH (mM TE kg ⁻¹ of oil)	1.11 $\pm$ 0.02
ABTS (mM TE kg ⁻¹ of oil)	1.94 $\pm$ 0.04

CONFLICT OF INTEREST DECLARATION

**Title paper: Physico-chemical Characterisation of *Capparis scabrida* seed oil,
a potential source of Eicosapentaenoic Acid.**

Reinier Abreu-Naranjo^{a*}, Wagner Nolasco Ramirez-Huila^b, Jorge Julio Reyes Mera^a, Derwin Viafara Banguera^a, Manuel León-Camacho^c.

^a Departamento de Ciencias de la Vida, Universidad Estatal Amazónica (UEA), Vía Tena km 2 1/2, Puyo, Pastaza, Ecuador

^b Facultad de Ciencias Naturales y de la Agricultura, Universidad Estatal del Sur de Manabí, Km 1 1/2 Vía Jipijapa-Noboa, **Jipijapa, Manabí, Ecuador.**

^c Lipids Characterisation and Quality Department Instituto de la Grasa (C.S.I.C.), Ctra Utrera km 1, Campus Universitario Pablo de Olavide, Edificio 46, 41013 Sevilla, Spain

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). He is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author.

Author Signature	Print Name
REINIER ABREU NARANJO

On behalf of all authors

* Corresponding author e-mail: reinier.abreu@gmail.com - tel./fax 00593 328 88118. ([Orcid.org/0000-0003-1048-7126](https://orcid.org/0000-0003-1048-7126))

R.A.N: Conceptualisation, drafted the manuscript, coordinated the study and revised the final version. W.N.R.H, J.J.R.M and D.V.B: Laboratory analysis, literature review, and manuscript editing. M.L.C: contributed to the conception of the study, writing—review and editing.

Supplementary Material

Table 1. Fatty acid profile (%) of seed oils considered in the study.

	Capric 10:0	Lauric 12:0	Myristic 14:0	Palmitic 16:0	Palmitoleic Cis-16:1(n-9)	Margaric acid 17:0	Stearic 18:0	Oleic acid 18:1 (n-9)	Linoleic 18:2 (n-6)	α -Linolenic 18:3	Arachidic 20:0	Eicosenoic C20:1(n-9)	Eicosapentaenoic 20:5 (n-3)	Behenic 22:0	Lignoceric 24:0
Cocoa butter	-	-	0.10	26.0	0.20	-	35.0	34.5	3.50	-	0.40	-	-	-	-
Corn	-	-	-	12.4	0.09	-	1.99	30.7	52.7	0.54	0.51	0.33	-	0.17	0.23
Cottonseed	-	0.10	0.75	23.5	0.60	-	3.00	18.5	52.0	0.20	0.35	-	-	-	-
Linseed	-	-	-	7.00	-	-	4.00	20.0	17.0	52.0	-	-	-	-	-
Olive	-	-	0.10	13.7	1.90	-	2.25	69.0	12.3	0.75	0.40	-	-	0.10	-
Palm kernel	3.55	48.0	16.0	8.50	-	-	1.50	15.5	1.50	0.35	0.15	-	-	-	-
Peanut	-	-	0.03	11.1	0.15	-	2.66	38.4	44.6	0.58	1.57	-	0.02	0.10	-
Sesame	-	-	-	10.1	0.13	-	6.72	40.6	40.7	0.29	0.62	0.23	-	0.20	0.14
Soybean	-	-	0.07	11.2	0.11	-	4.46	21.2	53.2	8.10	0.36	0.31	-	0.44	0.15
Sunflower	-	-	-	6.50	0.09	-	4.27	27.5	59.6	0.18	0.32	0.21	-	0.95	0.32
Sacha inchi	-	-	-	5.49	-	-	3.39	9.43	34.7	47.8	-	-	-	-	-
<i>Capparis scabrida</i>	-	-	0.16	12.7	11.9	-	7.67	52.8	7.87	1.50	-	3.98	1.46	-	-
Guanabana	0.17	-	0.67	15.5	-	-	8.14	48.5	23.4	2.18	-	-	-	-	-
Barinas nut	-	-	0.10	10.3	0.10	0.20	3.40	-	85.6	-	0.50	-	-	-	-
Chortaduro	-	33.3	27.8	9.60	-	-	5.10	24.3	-	-	-	-	-	-	-
Chia	-	-	-	7.06	-	-	3.23	7.48	20.5	60.7	-	-	-	-	-
Hazelnut	-	-	0.13	5.25	0.20	-	2.45	81.6	10.2	0.13	0.13	0.14	-	0.04	-
Macadamia	-	-	0.95	8.37	17.3	-	3.17	65.2	2.31	0.06	2.28	-	-	0.20	-
Walnut	-	-	0.13	6.70	0.23	-	2.27	21.0	57.5	11.6	0.08	-	0.06	0.07	-
Almond	-	-	0.06	6.85	0.63	-	1.29	69.2	21.5	0.16	0.16	-	-	0.05	-
Amaranthus	-	0.70	0.20	20.4	0.40	0.10	3.90	32.1	38.2	0.70	0.80	-	-	-	-

Species	References
Cocoa butter	Firestone, D., & Reina, R. (1996). Authenticity of vegetable oils. In <i>Food Authentication</i> (pp. 198-258): Springer.
Corn	Xing, C., Yuan, X., Wu, X., Shao, X., Yuan, J., & Yan, W. (2019). Chemometric classification and quantification of sesame oil adulterated with other vegetable oils based on fatty acids composition by gas chromatography. <i>LWT - Food Science and Technology</i> , 108, 437-445.
Cottonseed	Firestone, D., & Reina, R. (1996). Authenticity of vegetable oils. In <i>Food Authentication</i> (pp. 198-258): Springer.
Linseed	Firestone, D., & Reina, R. (1996). Authenticity of vegetable oils. In <i>Food Authentication</i> (pp. 198-258): Springer.
Olive	Firestone, D., & Reina, R. (1996). Authenticity of vegetable oils. In <i>Food Authentication</i> (pp. 198-258): Springer.
Palm kernel	Firestone, D., & Reina, R. (1996). Authenticity of vegetable oils. In <i>Food Authentication</i> (pp. 198-258): Springer.
Peanut	Maguire, L., O'Sullivan, S., Galvin, K., O'Connor, T., & O'Brien, N. (2004). Fatty acid profile, tocopherol, squalene and phytosterol content of walnuts, almonds, peanuts, hazelnuts and the macadamia nut. <i>International Journal of Food Sciences and Nutrition</i> , 55(3), 171-178.
Sesame	Xing, C., Yuan, X., Wu, X., Shao, X., Yuan, J., & Yan, W. (2019). Chemometric classification and quantification of sesame oil adulterated with other vegetable oils based on fatty acids composition by gas chromatography. <i>LWT - Food Science and Technology</i> , 108, 437-445.
Soybean	Xing, C., Yuan, X., Wu, X., Shao, X., Yuan, J., & Yan, W. (2019). Chemometric classification and quantification of sesame oil adulterated with other vegetable oils based on fatty acids composition by gas chromatography. <i>LWT - Food Science and Technology</i> , 108, 437-445.
Sunflower	Xing, C., Yuan, X., Wu, X., Shao, X., Yuan, J., & Yan, W. (2019). Chemometric classification and quantification of sesame oil adulterated with other vegetable oils based on fatty acids composition by gas chromatography. <i>LWT - Food Science and Technology</i> , 108, 437-445.
Sacha inchi	Wang, S., Zhu, F., & Kakuda, Y. (2018). Sacha inchi (<i>Plukenetia volubilis</i> L.): Nutritional composition, biological activity, and uses. <i>Food Chemistry</i> , 265, 316-328.
<i>Capparis scabrida</i>	The authors.

Guanabana	Abdualrahman, M. A. Y., Ma, H., Zhou, C., Yagoub, A. E. A., Ali, A. O., Tahir, H. E., & Wali, A. (2019). Postharvest physicochemical properties of the pulp and seed oil from <i>Annona squamosa</i> L.(Gishta) fruit grown in Darfur region, Sudan. <i>Arabian Journal of Chemistry</i> , 12(8), 4514-4521.
Barinas nut	Radice, M., Viafara, D., Neill, D., Asanza, M., Sacchetti, G., Guerrini, A., & Maietti, S. (2014). Chemical characterization and antioxidant activity of Amazonian (Ecuador) <i>Caryodendron orinocense</i> Karst. and <i>Bactris gasipaes</i> Kunth seed oils. <i>Journal of Oleo Science</i> , 63(12), 1243-1250.
Chontaduro	Radice, M., Viafara, D., Neill, D., Asanza, M., Sacchetti, G., Guerrini, A., & Maietti, S. (2014). Chemical characterization and antioxidant activity of Amazonian (Ecuador) <i>Caryodendron orinocense</i> Karst. and <i>Bactris gasipaes</i> Kunth seed oils. <i>Journal of Oleo Science</i> , 63(12), 1243-1250.
Chia	Coates, W. (2011). Protein content, oil content and fatty acid profiles as potential criteria to determine the origin of commercially grown chia (<i>Salvia hispanica</i> L.). <i>Industrial Crops and Products</i> , 34(2), 1366-1371.
Hazelnut	Bada, J. C., León-Camacho, M., Prieto, M., & Alonso, L. (2004). Characterization of oils of hazelnuts from Asturias, Spain. <i>European Journal of Lipid Science and Technology</i> , 106(5), 294-300.
Macadamia	Maguire, L., O'Sullivan, S., Galvin, K., O'Connor, T., & O'Brien, N. (2004). Fatty acid profile, tocopherol, squalene and phytosterol content of walnuts, almonds, peanuts, hazelnuts and the macadamia nut. <i>International Journal of Food Sciences and Nutrition</i> , 55(3), 171-178.
Walnut	Maguire, L., O'Sullivan, S., Galvin, K., O'Connor, T., & O'Brien, N. (2004). Fatty acid profile, tocopherol, squalene and phytosterol content of walnuts, almonds, peanuts, hazelnuts and the macadamia nut. <i>International Journal of Food Sciences and Nutrition</i> , 55(3), 171-178.
Almond	Maguire, L., O'Sullivan, S., Galvin, K., O'Connor, T., & O'Brien, N. (2004). Fatty acid profile, tocopherol, squalene and phytosterol content of walnuts, almonds, peanuts, hazelnuts and the macadamia nut. <i>International Journal of Food Sciences and Nutrition</i> , 55(3), 171-178.
Amaranthus	León-Camacho, M., García-González, D. L., & Aparicio, R. (2001). A detailed and comprehensive study of amaranth (<i>Amaranthus cruentus</i> L.) oil fatty profile. <i>European Food Research and Technology</i> , 213(4-5), 349-355.