EFFECT OF THE TEMPERATURE PRIOR TO EXTRACTION ON THE YIELD AND FATTY ACID PROFILE OF MORETE OIL (*Mauritia flexuosa* L.F.)

EFECTO DE LA TEMPERATURA PREVIA A LA EXTRACCIÓN EN EL RENDIMIENTO Y PERFIL DE ÁCIDOS GRASOS DEL ACEITE DE MORETE (*Mauritia flexuosa* L.F.)

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Abstract

Morete (*Mauritia fleuxosa* L. f.) is a palm from the Amazon that produces a fruit with a pleasant taste, good nutritional value and a high oil content. The aim of the present research was to study the effect of the heat treatment of the different parts of morete on the performance and fatty acids profile of oil obtained by pressing. A randomized complete block design with three replicates was applied, combining the use of pulp and pulp with fruit rind under different heating conditions before pressing: $45°C$ for 30 min, $65°C$ for 20 min and $85°C$ for 10 min. Also, the oxidative stability of oil was measured using the Oxitest Reactor. Oils with different content of saturated, monounsaturated, and polyunsaturated fatty acids were obtained with oleic acid prevalence. The best treatment was using pulp heated at $85°C$ for 10 min and pressing, founding a yield of 56.77% oil with 79.80% oleic acid, and oxidation stability of the oil 14.5 months at $21°C$ was determined, which is the average temperature of the city of El Puyo, Ecuador, where morete was collected. On the other hand, the effect of this temperature prior to extraction on the content of bioactive compounds and the possibility of oxidation of fats must be evaluated. In conclusion, morete is a good source of oil and the heat treatment technology will allow improving extraction, industrializing, and offering an alternative oil for food.

Keywords: Vegetable oil, oxidative stability, oil extraction, acid number, induction period, amazon palm tree.

Resumen

El morete (*Mauritia fleuxosa* L. f.) es una palmera de la Amazonía que produce un fruto de agradable sabor, buen valor nutricional y alto contenido de aceite. El objetivo de la presente investigación fue estudiar el efecto del tratamiento térmico de las diferentes partes del morete en el rendimiento y perfil de ácidos grasos del aceite obtenido por prensado. Se aplicó un diseño de bloques completos al azar con tres réplicas, combinando el uso de pulpa y pulpa con corteza del fruto en diferentes condiciones de calentamiento antes del prensado: 45°C por 30 min, 65°C por 20 min y 85°C por 10 min. También, se determinó la estabilidad oxidativa del aceite empleando un Reactor Oxitest. Se obtuvieron aceites con diferentes contenidos de ácidos grasos saturados, monoinsaturados y poliinsaturados, prevaleciendo el ácido oleico. El mejor tratamiento fue empleando la pulpa calentada a 85°C por 10 min y prensada, encontrándose un rendimiento de 56,77 % de aceite con 79,80 % de ácido oleico, y una estabilidad a la oxidación de 14,5 meses a 21°C, temperatura promedio de la ciudad de El Puyo, Ecuador, sitio donde se recolectó el morete. Por otro lado, se debe evaluar el efecto de esta temperatura previa a la extracción sobre el contenido de compuestos bioactivos y la posibilidad de oxidación de las grasas. En conclusión, el morete es una fuente de aceite y la tecnología de tratamiento con calor permitirá mejorar la extracción e industrialización, y ofrecer un aceite alternativo para la alimentación.

Palabras clave: Aceite vegetal, estabilidad oxidativa, extracción de aceite, índice de acidez, periodo de inducción, palmera amazónica.

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1 Introduction

Vegetable oils are a source of saturated, monounsaturated or polyunsaturated fatty acids, which play an important role in human nutrition (Kumar et al., 2016). Therefore, there is interest in new sources of edible oils, such as those coming from fruits and seeds of plants that possess nutritionally important oils (Amri et al., 2017), among these sources is morete fruit, which has an oil with a high content of monounsaturated fatty acids, superior to that of olive oil (Milanez et al., 2016).

Morete (*Mauritius flexuosa* L. f.) is a palm tree that is found in the Amazon region, it has different names depending on the country in which it grows, such as: morete in Ecuador, moriche in Colombia and Venezuela, aguaje in Peru, real palm in Bolivia and burití in Brazil (Restrepo et al., 2016). It is a monic and arborescent palm with stems higher than 25 meters high and diameter between 30 to 60 cm. It grows in the Amazonian forests on poorly drained soils, marshes and alluvial plains (Montúfar and Brokamp, 2011). Its fruit is a source of food for birds, some species of mammals and native peoples, and is used to produce juices, creams, jellies, jams and oil (Pereira et al., 2016). This palm tree has economic and social importance in the countries where it grows (Bataglion et al., 2015; Forero-Doria et al., 2016).

There are three ecotypes of the palm, three varieties are mentioned by the color of the fruit: (a) yellow or posheco when the mesocarp is yellow, (b) colored when the outer part is red, and (c) shambo when the mesocarp is red (Vásquez et al., 2010). The fruits are from 6 to 7 cm, with brown-reddish color when they reach maturity, with a weight of 50 g. It is formed of an exocarp with imbricated scales and a fleshy mesocarp, and the seed has a subglobous form with a homogeneous endosperm (Trujillo-Gonzalez et al., 2011). Mesocarp is edible, rich in bioactive compounds such as vitamins, antioxidants, unsaturated oils and dietary fiber (Cruz et al., 2020; Rudke et al., 2019). The oil in the bite has a large amount of oleic acid 79.33 % compared to the other fatty acids of its composition (Cândido and Silva, 2017) and the nutritional value of the oil can vary according to the season and the extraction process (Aquino et al., 2012).

The oils used in food are sensitive to oxidation, resulting in stale odors, unpleasant flavors, discoloration and their service life is reduced (Corbu et al., 2020), hence it is important to know the oxidative stability of oils. Its determination is carried out under normal storage conditions, using the peroxide index and accelerated methods using equipment such as Rancimat or Oxitest Reactor (Rodríguez et al., 2015; Caruso et al., 2017). The Oxitest reactor is an instrument for predicting oxidation stability in solid or liquid samples and is a fast and ecological alternative compared to the Rancimat method (Tinello et al., 2018). Oxitest subjects the sample to an environment of oxidative stress at high temperature and high oxygen pressure; the drop in oxygen pressure within the oxidation chambers depends on the composition of the food and is expressed as an induction period (IP), which is the time required to obtain the starting point of lipid oxidation (Riciputi and Caboni, 2017).

Mechanical pressing is generally used extracting oil in rural areas, because it has a low initial investment and does not require highly trained personnel to operate the equipment (Nde and Foncha, 2020), because of the latter, the objective was to study the effect of heat treatment in the different pre-extraction phases of morete on the yield and fatty acid profile of the oil obtained by pressing in order to get a technology that allows to be used in the rural communities where these palms are cultivated.

2 Materials and Methods

2.1 Fruits

Morete fruits (*Mauritius flexuosa* L. f.) of the yellow pulp posheco ecotype, acquired at Los Bananas market, located in the Mariscal area of El Puyo, province of Pastaza, Ecuador, were used.

2.2 Extraction of morete oil by pressing

The process was based on the extraction methodology of olive oil described by (Moreno and López, 2017) with modifications, and described below: morete fruits were cleaned and washed with running water to remove impurities; then the bark, seed and the pulp were manually separated.

In order to improve the extraction of the oil, the pulp and bark were subjected to thermal treatment before pressing, for which 400 g of the different parts of morete were heated in a stainless-steel container using an IKA heating plate. Temperature and warm-up time conditions are shown in Table 1 and were designed according to Adrianzén et al. (2011) and Tambunan et al. (2012). A fully randomized block design was used in the treatment of the parts of morete and in triplicate.

The heat-treated sample was ground using a blender for 3 minutes, then the oil was obtained with a manual Al-Equip press (Figure 1). The extracted oil was set aside in separating funnels in order to separate the water from the oil by difference in density. Finally, the separated oil was filtered with a grade 1 Whatman qualitative filter paper to remove solid waste and obtain an oil without any particles. The oils obtained were packed in amber glass bottles and stored in environment conditions until the next day for their analysis.

Table 1. Treatments for the extraction of mulberry oil.

Experiment, T	Parts of the fruit	Pre-treatment	
		Temperature, $^\circ C$	Time, minutes
T1	Pulp with shell	45	30
T2	Pulp with shell	65	20
T3	Pulp with shell	85	10
T4	Pulp	45	30
T5	Pulp	65	20
T6	Pulp	85	10

Figure 1. Manual press oil extractor

2.3 Analysis of morete fruits

Size and weight

Morete fruits were measured to determine their length (cm) from the base to the apex and the diameter (cm) in the central part using a vernier caliper. The masses of the fruits, shell, pulp and seed were determined on an analytical scale according to the method described by Quispe et al. (2009).

Humidity

It was analyzed by weight loss, Official Method 930.15 (AOAC, 2002). 5 g of sample were weighed in previously dried and tarted porcelain capsules, then were carried to a drying oven at 105 °C until a constant weight was achieved, then were placed in a desiccator for cooling. Humidity loss of samples was determined as a percentage.

Fat

It was determined using a solvent for continuous extraction of fat from samples, Official Method 920.39 (AOAC, 2002). 3 g of ground, dry sample were weighed in a cellulose cartridge and 100 mL of hexane were added in a previously heavy glass; both containers were placed on a Goldfish Velp Scientifica machine to extract the fat for 4 hours. The cup was removed with the fat to evaporate the solvent in a stove at 105 °C for 5 hours and was set aside in a desiccator at room temperature before weighing it. In the end, the percentage of fat in the sample was determined by weight difference.

2.4 Analysis of oils extracted by pressing

Oil extraction performance per pressing

It was determined by the ratio of the extracted oil weight, when 400 g of morete are subjected to the pressing and the weight of the fat contained in the sample. The fat of morete was determined by the Official Method 920.39 (AOAC, 2002). The oil extraction performance was expressed as an oil percentage extracted in each treatment using equation 1.

$$Yield\,(\%) = \frac{\text{Weight of oil extracted from morete}}{\text{Weight of fat contained in morete}} * 100\,\% \quad (1)$$

Acidity index

It was determined by base acid titration, Official Method No 940.28 (AOAC, 2002). It was based on the determination of free acids, for which the oil sample was dissolved in ethanol and the free fatty acids were evaluated by an ethanolic solution of sodium hydroxide 0.1M using phenolphthalein as a visual indicator. The acidity index was determined by equation 2 and was expressed as a percentage in oleic acid.

$$OI = \frac{M * V * M_{NaOH}}{10 * m} \quad (2)$$

Where:

OI = oil acidity index (% oleic acid)
M = molecular mass of oleic acid (282 g/mol)
V = Volume of hydroxide solution consumed at titration in cm^3
M_{NaOH} = Molarity of sodium hydroxide solution determined daily against a primary standard.
m = mass of the analyzed sample expressed in grams
10 = conversion factor to percentage

2.5 Fatty acid profile of oils

Oil extraction of morete

The different parts of morete were dried at 80 °C for 24 h, then were ground in a porcelain mortar and the oil was extracted in a Soxhlet. 5 g of the sample were weighed on the cellulose cartridge, 200 mL of hexane were placed on the balloon and brought to boiling for 6 hours. In the end, the solvent was recovered by evaporation at 50 °C in a rotary evaporator selecta brand to obtain solvent-free oil. The oils extracted from the different parts of the fruit were filtered and stored in amber bottles until their analysis.

Esterification of the fatty acids of different morete oils

From 0.020 to 0.025 g of the oil extracted from each sample were placed in test tubes with 15 ml thread, 2 mL of KOH 0.5 M prepared in methanol were added. The tubes were closed and taken to the water bath for 10 min. Then the tubes were set aside in environment conditions and 1 mL of HCl in methanol (1:4 v/v) was added. They were re-capped

and taken to water bath at 50 °C for 25 minutes. The tubes were re-cooled and 3 mL of distilled water with 10 mL of hexane were added to each tube, stirred and set aside for 24 hours. Finally, fatty acid methyl esters were collected from the upper layer of the tubes and placed in amber bottles (Carrillo et al., 2018).

Chromatographic analysis

Esterified fatty acids were characterized by an Agilent Technology 7980A gas chromatograph, coupled with an MSD 5977 mass spectrometer. Separations of esters were performed on Agilent Technologies' HP-88 capillary column (30 m × 0.25 mm i.d., 0.25 μm film thickness). Helium was used as carrier gas at 0.7 mL/min^{-1}, the injector temperatures, GC-MS interface and MSD source were 250, 300 and 230 °C, respectively. The following oven temperature program was used: (a) initial temperature of 80 °C, (b) ramp 10 °C/min up to 120 °C, (c) ramp 20 °C/min up to 140 °C, (d) ramp 2 °C/min up to 200 °C. It was maintained for 10 min and finally (e) ramp 5 °C/min to 240 °C and it was maintained for 4 min. The mass detector operated in full scan mode, with the m/z range being 50 to 500. Additionally, 0.2 μl of ester samples were injected using splitless injection mode. A reference material consisting of 37 methyl esters of Supelco fatty acids (Component Fame Mix) was used to verify their identification and quantification; quantification was carried out by integrating the peak areas resulting from chromatographic analysis and expressed as the mean value of fatty acid ± standard deviation of three injections of each oil

2.6 Oxidative stability of morete oil

Oxidative stability was evaluated for the oil obtained from the best treatment, for this purpose an Oxitest reactor of Velp Scientifica (Usmate, Milan, Italy) was used, following the method described by Caruso et al. (2017). 6 g of oil were weighed on each of the titanium plates of the equipment and placed in each oxidation chamber. The following oxidation temperatures were selected: 80, 90 and 100 °C and grade 5 oxygen was used with a pressure of 6 bar to enter the Oxitest reactor. The instrument includes the OXISoft software used to calculate the Induction Period (IP) in hours and minutes for each selected temperature of the experiment, the calcu-

lation is done automatically by a graphical method. IP values are expressed as oxidation stability time, and correspond to the pressure drop due to sample oxidation.

With the IP value and the temperature, a graph was done representing the Ln(IP) on the axis of the orders and the oxidation temperature in the abscissa in Celsius degrees. The line equation (Equation 3) is then estimated using the least squares method. Finally, this equation extrapolated the desired temperature to estimate the IP value. For this study, 21 °C was used, which is the average temperature of the city of El Puyo in Ecuador, where morete is produced and the extracted oil will be stored.

$$y = mx + b \qquad (3)$$

Where:

y : Natural logarithm of the induction period, Ln(IP) in hours.
x : Oxidation temperature: 80, 90 and 100 °C.
m : slope of the regression line.
b : intercept of the regression line.

2.7 Statistical analysis

Tables with their respective means and standard deviations were elaborated with the results obtained from the physico-chemical characteristics of morete, oil extraction yield, acidity index and fatty acid profile. The Statgraphics Centurion XVI statistical package was used to perform the statistical analysis using ANOVA and the significant differences were calculated with Tukey test for 95% confidence.

3 Results and Discussion

3.1 Physico-chemical characteristics of the fruit

Figure 2 shows the typical morete fruit used for this study and the oil obtained. Table 2 shows the results of the characterization of the morete fruit, and it was found that it has dimensions consistent with those reported by Mendieta-Aguilar et al. (2015).

Additionally, it was obtained that the selected morete has on average 56.23% of comparable humidity reported by Sandri et al. (2017) and Darnet

et al. (2011) 59.11 and 50.5%, respectively.

The fruit is made up of pulp, seed and peel, and in this investigation pulp and pulp with shell were used for the treatments indicated in Table 1. It was found that the mass of the fruit corresponds to one fifth of the pulp, one fifth of the shell and three fifths of the seed.

The highest percentage of fat calculated according to 100 g of the part of the fruit considered was found in pulp and pulp with shell (Table 2) and was higher than the 19.0% reported by Darnet et al. (2011); therefore, these parts of the fruit were considered for the extraction of oil.

The differences in fat content with those obtained in this study are because the composition of the fruits is influenced by altitude, temperature, rain and soil, because they control the availability of nutrients to the plants (Nascimento-Silva et al., 2020).

Figure 2. Morete fruit and morete oil obtained in this study

Table 2. Characterization of morete fruit.

|	Length, cm	Diameter, cm	Weight, g
Morete fruit (n=20)	5.47 ± 0.15	4.59 ± 0.18	51.83 ± 0.31
Mendieta-Aguilar et al. (2015)	$5 - 7$	$4 - 5$	–
Part of the fruit	Percentage in fruit	Fat content[2] (g)	
Pulp[1]	20.19 ± 0.46	26.01 ± 0.84	
Shell	19.43 ± 0.73	14.62 ± 0.20	
Seed[1]	59.92 ± 0.31	4.15 ± 0.05	
Pulp with shell[1]	39.62 ± 0.43	22.06 ± 0.64	
Darnet et al. (2011)	–	19.0	

[1] The mean and uncertainty are indicated as the standard deviation for n = 3.

[2] Per 100 g of the parts of the fruit.

3.2 Yield and acidity of morete oil

It was considered as the best treatment that allows the highest oil extraction yield with the greatest amount of oleic acid. The variance analysis for the yield on the extraction of morete oil indicates that there are significant differences ($P<0.05$) between the treatments, obtaining the double extraction yield in the T6 experiment in relation to the T1 treatment (14.76 g of oil extracted in relation to 100 g of morete pulp). Figure 3 illustrates the evolution of the extraction yield of morete oil for each of the treatments.
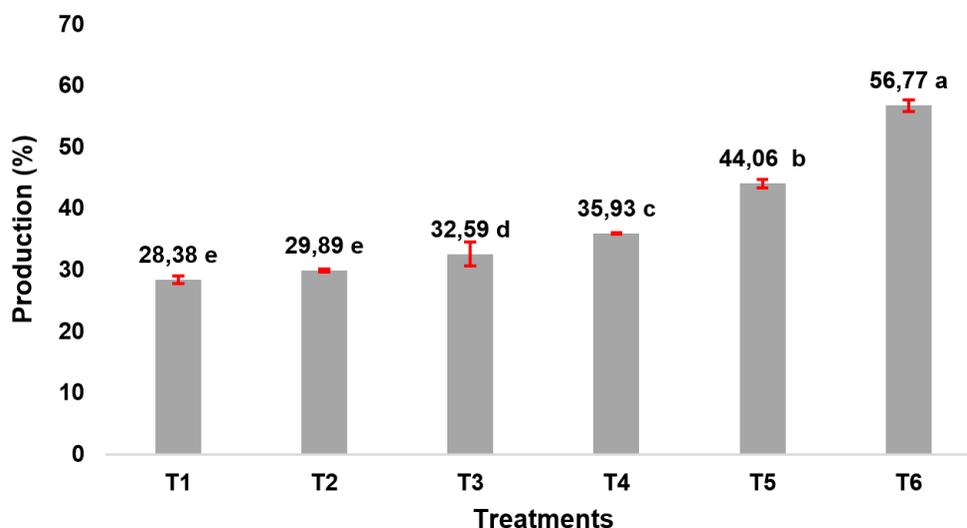
Figure 3. Evolution of the oil extraction yield of the different treatments.
Different letters in the graph indicate significant differences (P<0.05)

It was found that the oil extraction percentage is directly proportional to the heating temperature of the pulp, and it decreases when the pulp with shell is used in the pre-treatment before pressing. The pre-extraction heat supply allows proteins from the cell walls to clot, making them permeable to the passage of oil during pressing, also decreasing the viscosity of the oil, which facilitates the extraction process (Adrianzén et al., 2011). In addition, it may inactivate enzymes responsible for oil deterioration, as indicated by Onyebuchi (2013), who notes that enzymes such as peroxidase drastically decreases activity to 80 °C in seed oils. On the other hand, the stability of the bioactive compounds should be evaluated in order to know the effect of the heat presented in each of the treatments.

The thermal process in the different parts of morete fruit affects the acidity present in the extracted oils (Figure 4), being the one with the lowest acidity when using only morete pulp and the lowest heating temperature (45 °C) before starting the pressing for oil extraction; on the other hand, the acidity is higher when higher temperatures are used or when pulp with shell is used for the extraction. However, the acidity percentage of oils obtained from the different treatments is in the range of virgin olive oil, Standard 29:2012 (INEN, 2012), which states that they must have between 0.8 and 2% acidity, lower percentages than those reported by Vás-

quez et al. (2010), who indicate an acidity value of 2.69% in Peruvian morete oil. Reboredo-Rodríguez et al. (2016) mention that low temperatures reduce the oxidation rate of the oil and cold extraction has less acidity.

3.3 Fatty acid profile of morete oil of the treatments

Ten fatty acids were identified in the lipid profiles of oils, except in experiment T1, where lauric acid, a saturated fatty acid with a content of 1.35% was also found. In another study, Cruz et al. (2020) reported 0.03% of lauric acid in Brazilian morete oil.

For all treatments, high oleic acid (omega 9) content was found to be close to 80% and no significant differences were found between the experiments. In addition, linoleic acid (omega 6) was identified from 1.39% to 1.73% and α-linolenic acid (omega 3) from 0.70% to 1.17%. These results are comparable to those reported by Vásquez et al. (2010) in morete cultivated in Peru, reporting values of 75.6% oleic acid, 2.19% linoleic acid and 0.82% α-linolenic acid.

The oleic acid of morete oil has comparable values to those of the olive oil produced in the region of Extremadura, Spain, where Martínez et al. (2014) report values between 68.82 and 79.30%. In addition, they were superior to those obtained from

olives grown in Turkey and Argentina reported by Ghanbari et al. (2019) and Rondanini et al. (2011), whose content was between 68.64 and 70.56% and 51.8% to 71.9% of oleic acid, respectively.
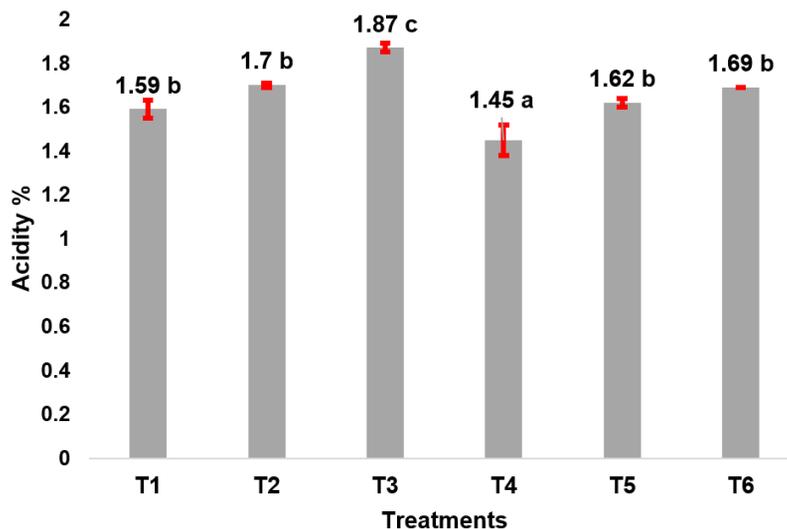
Figure 4. Acidity percentage of oils extracted from the different treatments. Different letters in the graph indicate significant differences (P<0.05)

Other minority fatty acids with less than 0.3% were found: myristic acid, pentadecanoic acid, palmitoleic acid, margaric acid, arachidic acid, and gadoleic acid, followed by stearic acid from 0.75% to 1.51%. Finally, of the saturated fatty acids, palmitic acid proved to be more abundant (16.55% in T5), however, it is less than the mentioned by Cruz et al. (2020); Restrepo et al. (2016) and Vásquez et al. (2010).

Table 3 summarizes the fatty acid profile of oils extracted from morete in each of the different treatments compared to the results of other authors. The best treatment selected was the one that allowed a maximum oil yield with the greatest amount of oleic acid, because in all treatments the oleic acid content was close to 80% with no significant differences with $\alpha = 0.05$. the best result was the one obtained with T6, since it has a higher extraction yield.

The nutritional value with respect to unsatura-ted fatty acids from treatment T6 was: 79.80% of Omega 9; 1.39% of Omega 6 and 0.78% of Omega 3. On the other hand, the content of saturated, monounsaturated and polyunsaturated fatty acids was 17.62%, 80.20% and 2.17%, respectively.

Pereira et al. (2016) mention that oils rich in monounsaturated and polyunsaturated fatty acids have been associated with a decreased risk of cardiovascular disease, hence associating this reduction with the anti-inflammatory effect of fatty acids. Freitas et al. (2017) indicate that oleic acid is considered essential for its beneficial properties in reducing oxidation of LDL cholesterol; in addition, it is a precursor in the production of most other polyunsaturated fatty acids and hormones.

Figure 5 shows the diagram proposed for the extraction of morete oil with the T6 treatment by handmade pressing with previous heat treatment of morete pulp.

Table 3. Fatty acid profile of morete oil extracted in the different treatments and morete oils of Colombia, Peru and Brazil.

Fatty acid	Lipid number	T1* (Pulp with shell at 45 °C)	T2* (Pulp with shell at 65 °C)	T3* (Pulp with shell at 85 °C)	T4* (Pulp at 45 °C)	T5* (Pulp at 65 °C)	T6* (Pulp at 85 °C)	Colombian oil (Restrepo et al., 2016)	Peruvian oil (Vásquez et al., 2010)	Brazilian oil (Cruz et al., 2020)
Lauric acid	C12:0	1.35 ± 0.09	–	–	–	–	–	–	–	0.03
Myristic acid	C14:0	0.07 ± 0.01 ^{b}	–	0.04 ± 0.01 ^{b}	0.02 ± 0.01 ^{a}	0.03 ± 0.01 ^{ab}	0.02 ± 0.01 ^{a}	0.06 ± 0.01	–	0.12
Pentadecanoic acid	C15:0	0.05 ± 0.01 ^{a}	0.07 ± 0.01 ^{b}	0.05 ± 0.01 ^{ab}	0.08 ± 0.02 ^{b}	0.05 ± 0.01 ^{ab}	0.03 ± 0.01 ^{a}	–	–	0.07
Palmitic acid	C16:0	15.08 ± 0.39 ^{a}	16.05 ± 0.26 ^{b}	16.55 ± 0.33 ^{b}	16.05 ± 0.38 ^{b}	15.93 ± 0.22 ^{b}	15.96 ± 0.24 ^{b}	21.27 ± 0.80	19.61 ± 0.41	22.18
Palmitoleic acid	C16:1	0.06 ± 0.01 ^{c}	0.05 ± 0.01 ^{c}	0.04 ± 0.01 ^{c}	0.07 ± 0.01 ^{c}	0.12 ± 0.01 ^{b}	0.16 ± 0.05 ^{a}	0.29 ± 0.06	0.15 ± 0.01	0.15
Margaric acid	C17:0	0.05 ± 0.01 ^{ab}	0.04 ± 0.01 ^{a}	0.03 ± 0.01 ^{a}	0.05 ± 0.01 ^{ab}	0.07 ± 0.01 ^{b}	0.05 ± 0.01 ^{ab}	–	–	0.12
Stearic acid	C18:0	0.79 ± 0.04 ^{a}	0.75 ± 0.03 ^{a}	0.82 ± 0.03 ^{a}	0.82 ± 0.03 ^{a}	1.27 ± 0.03 ^{b}	1.51 ± 0.25 ^{b}	4.19 ± 0.04	1.57 ± 0.02	2.51
Oleic acid	C18:1 n-9	79.47 ± 0.39 ^{a}	80.09 ± 0.47 ^{a}	79.91 ± 0.40 ^{a}	79.83 ± 0.37 ^{a}	79.85 ± 0.35 ^{a}	79.80 ± 0.64 ^{a}	68.69 ± 1.60	75.6 ± 0.31	72.23
Linoleic acid	C18:2 n-6	1.73 ± 0.07 ^{a}	1.69 ± 0.14 ^{ab}	1.61 ± 0.10 ^{ab}	1.65 ± 0.07 ^{ab}	1.62 ± 0.10 ^{ab}	1.39 ± 0.12 ^{b}	2.05 ± 0.08	2.19 ± 0.25	0.51
α-linolenic acid	C18:3 n-3	1.12 ± 0.16 ^{a}	0.98 ± 0.10 ^{ab}	0.70 ± 0.03 ^{b}	1.17 ± 0.04 ^{a}	0.78 ± 0.05 ^{b}	0.78 ± 0.17 ^{b}	0.87 ± 0.03	0.82 ± 0.06	1.15
Arachidic acid	C20:0	0.06 ± 0.02 ^{b}	0.03 ± 0.01 ^{a}	0.04 ± 0.01 ^{a}	0.04 ± 0.01 ^{a}	0.05 ± 0.01 ^{ab}	0.05 ± 0.02 ^{ab}	–	–	0.16
Gadoleic acid	C20:1 n-9	0.16 ± 0.01 ^{a}	0.23 ± 0.04 ^{a}	0.20 ± 0.07 ^{a}	0.23 ± 0.10 ^{a}	0.24 ± 0.06 a	0.30 ± 0.07 ^{a}	–	–	0.58
Saturated fatty acids		17.46 ± 0.55	16.94 ± 0.24	17.53 ± 0.32	17.05 ± 0.39	17.39 ± 0.24	17.62 ± 0.42	25.52	21.18	25.19
Monounsaturated fatty acids		79.68 ± 0.40	80.38 ± 0.42	80.15 ± 0.36	80.13 ± 0.38	80.21 ± 0.38	80.20 ± 0.64	68.98	75.75	72.96
Polyunsaturated fatty acids		2.85 ± 0.15	2.67 ± 0.18	2.31 ± 0.07	2.82 ± 0.05	2.40 ± 0.15	2.17 ± 0.29	2.92	3.01	1.66

*The mean and uncertainty are indicated as the standard deviation for n = 3.
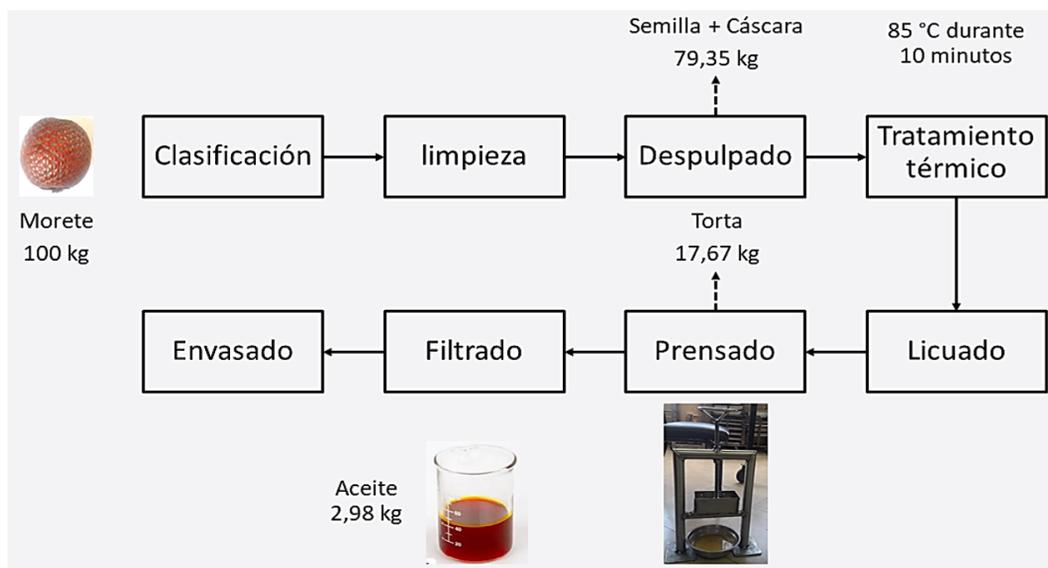Different letters in rows indicate significant difference (P<0.05)

Figure 5. Proposed diagram for the extraction of Morete oil.

3.4 Oxidative stability of morete oil

This study did not evaluate the influence of thermal treatment on the potential loss of bioactive compounds from extracted oil; however, it was observed that the variation in the acidity of the oil in all treatments remained below the standard 29:2012 (INEN, 2012).

The oil obtained from the best treatment was subjected to accelerated oxidation conditions using Oxitest equipment. For each of the temperatures selected in the oxidation chamber of the equipment, the IP value (Table 4) expressed in hours and minutes was determined.

Table 4. Values of the IP induction period (hours) at different temperatures.

Temperature ($°C$) in the oxidation chamber of the Oxitest	IP (hours) in morete oil of the best treatment
80	37.58 ± 0.27
90	17.55 ± 0.23
100	5.77 ± 0.11

Average and uncertainty are indicated as standard deviation for n = 3

With the values found in Table 4, the IP value (Ln IP) is transformed from minutes to hours and then to natural logarithm; then equation 3 is estimated as described in section 2.6. The Ln IP was plotted against the temperature of the oxidation chamber and equation 3 was found by linear regression, obtaining the expression $y = -0.09425x + 11.22917$.

Equation 3 was extrapolated, for which 21 $°C$ was replaced as the x value representing the average temperature of the city of El Puyo. The IP value was then cleared and the corresponding change from units to months was made and T6 was achieved to have an oxidative stability of 14.45 months when stored at 21 $°C$. Landeo (2019) used the peroxide index to estimate the stability time of morete oil grown in Peru, and reported 7.5 months at 18 $°C$ storage; this shelf life is lower than the determined in this work.

Morete oil has high oleic acid content with values close to olive oil, which could have a useful life compared to olive oil. Irigaray et al. (2016) indicate that Uruguay's extra virgin olive oil has a useful life of 12 to 18 months of storage in bottles at room temperature. Martínez-Robinson et al. (2019) note that the oxidation stability of oils provides a good estimate of susceptibility to self-oxidation, leading to their aging and deterioration of their quality.

4 Conclusions

In the samples studied, it was found that the fat content in all treatments was higher in the pulp, followed by the bark and the seed. It was established that the best extraction process of morete oil was using pulp by pressing after treatment at 85 °C for 10 minutes. The morete oil obtained under the best conditions used in this work proved to be a source of oleic acid, with a useful life compared to that reported for extra virgin olive oil.

Oxitest equipment was used to evaluate the oxidative stability of the oil extracted from morete under accelerated conditions. An equation was obtained to estimate the induction period and, consequently, the life time of the morete oil at any storage temperature.

The proposed extraction technology made it possible to obtain 2.98 kg of oil for every 100 kg of morete; thus, producers of this fruit could move toward industrialization and offer a new type of oil which is high in oleic acid.

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