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Comparative study of extraction and characterization of avocado oil, through processes of: thermobeating, enzymatic, hydraulic pressing and expeller.

Estudio comparativo de extracción y caracterización del aceite de aguacate, mediante procesos de: termobatido, enzimático, prensado hidráulico y expeller.

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Abstract.

Avocado (Persea Americana Mill.) is a raw material rich in oil, which is why its extraction and production can be considered an industrial option, since it is attributed several beneficial properties for health. The objective of this work was to carry out a comparative study to obtain avocado oil, Hass variety, by four different methods (thermobeating, enzymatic, hydraulic pressing and expeller), specifying significant differences and determining the best method in terms of performance and quality. The performance variable was calculated on a dry basis, with the Thermobeating method having the highest percentage with 89.78%. Physicochemical tests such as humidity, density, acidity index, peroxide index, saponification index and iodine index were carried out on the oil samples obtained, obtaining the best results in the thermobeating method, with the exception of the peroxide index and whose values were: 0.054%, 0.9039 g/mL, 3.13 g/100g, 78.87 meqO2/kg, 190.06 mkOH/mg, 84.56cg/g respectively. On the other hand, regarding the composition of fatty acids, High Pressure Liquid Chromatography (HPLC) was carried out, where the hydraulic pressing method generated the best values, which were: 23.57 g/100g, 64.29 g/100g, 12.14 g/100g. 100g, 0.48 g/100g, 11.65 g/100g, 61.07 g/100g, 21.00 g/100g and 1.26 g/100g for Saturated, Monounsaturated, Polyunsaturated Fatty Acids, Omega 3, 6, 9, Palmitic Acid and Stearic Acid, respectively. Finally, these values were contrasted with experimental data from other investigations together with those of a commercial oil, finding values close to those reported.

Keywords: Avocado, thermobeating, enzymatic, hydraulic pressing, expeller pressing, high pressure liquid chromatography (HPLC), fatty acids.

Resumen.

El aguacate (Persea americana Mill.), es una materia prima rica en aceite, por lo cual su extracción y producción puede considerarse como una opción industrial, ya que se le atribuye varias propiedades beneficiosas para la salud. El objetivo de este trabajo fue realizar un estudio comparativo para la obtención de aceite de aguacate, variedad Hass, por cuatro métodos distintos (termobatido, enzimático, prensado hidráulico y por expeller), especificando diferencias significativas y determinando el mejor método en términos de rendimiento y calidad. La variable de rendimiento se calculó en base seca, siendo el método de Termobatido el que presenta el más alto porcentaje con 89,78%. A las muestras de aceite obtenido se les realizó pruebas fisicoquímicas como humedad, densidad, índice de acidez, índice de peróxido, índice de saponificación e índice de yodo, obteniéndose los mejores resultados en el método de termobatido, con excepción del índice de peróxido y cuyos valores fueron: 0.054%, 0.9039 g/mL, 3.13 g/100g, 78.87 meqO2/kg, 190.06 mkOH/mg, 84.56cg/g respectivamente. Por otra parte, respecto a la composición de ácidos grasos se realizó Cromatografía Líquida de Alta Presión (HPLC), donde el método de Prensado hidráulico genero los mejores valores, los cuales fueron: 23.57 g/100g, 64.29 g/100g, 12.14 g/100g, 0.48 g/100g, 11.65 g/100g, 61.07 g/100g, 21,00 g/100g y 1.26 g/100g para Ácidos Grasos Saturados, Monoinsaturados, Poliinsaturados, Omega 3, 6, 9, Acido Palmítico y Acido Esteárico, respectivamente. Finalmente se contrastó estos valores con datos experimentales de otras investigaciones junto a los de un aceite comercial, encontrándose valores cercanos a los reportados.

Palabras clave: Aguacate, termobatido, enzimático, prensado hidráulico, prensado por expulsor, cromatografía líquida de alta presión (HPLC), ácidos grasos.

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1.- Introduction

In Ecuador, about 20 varieties of Avocado are produced; the most well-known are: Guatemalan, Creole, Hass, and Fuerte. In recent years, it has become an agro-export activity. Avocado cultivation in Ecuador is gaining more importance year after year. Its high yield in adequate climatic conditions and the great demand in the international market have placed this product in a privileged position in the country [1].

Among its qualities, avocado has been attributed characteristics of beautifying the skin and also aphrodisiac properties. The avocado tree, depending on the variety, can grow in territories located both at sea level and at 2,500 m altitude, in the warm inter-Andean valleys of the country

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[2]. Therefore, this research will provide relevant information for both Chemical Engineering students and other related careers, and eventually for people who want to start a profitable business, as they will have the theoretical bases of the different methods and processes of obtaining avocado oil experimented in this work, which will be detailed throughout its content, thus considering its extraction and characterization, for which fatty acid profiles of the various extraction methods were performed, and compared with commercial brands, to achieve in this way the comparative study proposed previously.

To achieve the general objective of: Conducting a comparative study for obtaining avocado oil by four different methods (thermo-beating, enzymatic, hydraulic pressing, and expeller), specifying significant differences and determining the most beneficial method in terms of yield and quality, the following specific objectives were proposed:

- Extract the oil by various extraction methodologies (thermo-beating, enzymatic, hydraulic pressing, and expeller) of avocado oil at laboratory level, and determine the best yield in terms of productivity.
- Physicochemically characterize the extracted oil, through tests of: Moisture, Density, Acidity Index, Saponification Index, Peroxide Index, Iodine Index.
- Perform a Fatty Acid profile of the oils obtained from avocado (Hass Variety) using High-Pressure Liquid Chromatography (HPLC) and determine the best extraction method in relation to the quality of the extracted oil.
- Compare the results obtained through physicochemical analysis and HPLC of the most suitable method found in the research with the best quality characteristics of an experimental product and another present in the market.

This study can be a reason to promote the added value that would be given to the export output of avocado and develop a non-traditional natural export product such as oil, this being a quality product with future perspectives through the use of new and better technologies, and not just commercialize it as a fruit.

1.1.- Thermo-beating Process

According to what Cueva Cabrera [3] indicates, this is the process responsible for separating liquids, oils, and solids, so in the future they will not have much resistance to the extraction of elements. The thermal treatment consists of using the previously obtained pulp and pouring it into a rotating drum, in the rotating drum there is a series of paddles that are responsible for emulsifying the product at low speeds and temperatures not exceeding 45ºC to avoid damaging the product. In some oil extraction processes, when the temperature rises above the specified temperature, many vitamins, aroma and flavor characteristics can be lost; in some cases, when this characteristic exceeds its tolerance, trans fats are often produced. Therefore, this saturated oil does not result in a 100% healthy product.

1.2 Enzymatic Process

The oil extraction technique using enzymes has emerged as a promising method for oil extraction. This process uses suitable enzymes to extract oil from crushed seeds. Among its main advantages, it stands out for being environmentally friendly, as it does not generate volatile organic compounds as is generally the case in the solvent extraction process. However, the processing time for oil extraction is considerably longer compared to the previously described mechanical extraction, which constitutes the main disadvantage associated with this alternative [4].

The use of enzymes shares its own benefit with the environment. Different studies suggest that enzymes can be used to improve oil production in vegetable oil and fat extraction processes, where unconventional solvents are used, and can also be immobilized for recovery and reuse, which can help reduce processing costs [4].

Pectinases. Pectinases hydrolyze different types of pectins, releasing uronic acids. The biodegradation of pectins is carried out thanks to pectinases and specifically endopolygalacturonases, which only act on acid (non-esterified) units. Esterified units are degraded by methyl pectin esterases, which allow the substrate to adapt to react with the previous enzyme. In the case of highly methylated pectins, only pectinlyases of bacterial origin have the ability to hydrolyze them [5].

1.3 Hydraulic Process.

There are several types of compression molding that use different techniques to form a semi-dry method, although most methods are actually the same or similar, the final characteristics of the product justify the use of one technique or another. The hydraulic pressing process is based on the use of a buffer whose pressure is applied by a piston pushed by the pressure of the fluid inside the hydraulic circuit [6]. The pressure applied in any part of the closed and incompressible fluid will be transmitted uniformly in all directions throughout the fluid, that is, the pressure of the entire fluid is constant. According to the inference of physicist Pascal, the larger the size of the element applying pressure, the greater the applied pressure, the greater the force that can be obtained.

1.4 Expeller Pressing Process.

Continuous pressing is commonly performed in expeller or screw presses. These presses support high pressures; generally, pressing is practiced in two or three pressings, increasing the pressure in each of them [7].

There are several types or models of presses, so the main differences between these are the geometry of the screw, the

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type of orifice or nozzle, the oil outlet, and the residual filter cake [8].

2. Materials and Methods.

2.1 Experimental Procedure for Avocado Oil Extraction Using the Thermo-Batting Method.

The raw material was received and meticulously selected based on the ripeness of the avocados, discarding fruits that did not meet the desired hardness, firmness, texture, and appearance criteria.
Next, the avocados were washed with distilled water to eliminate any impurities that could alter the physicochemical characteristics. They were then disinfected with a 150 ppm bleach solution. The previously selected fruit was weighed on a gravimetric balance, then peeled to obtain the maximum amount of pulp. The seeds were removed, the pulp was cut into pieces, and mashed with a fork to facilitate placing the pulp into the drying trays for optimal drying at 53°C for 24 hours. Once the pulp was dried, it was broken into smaller pieces with a moisture content of approximately greater than 5%, and fed into the Piteba press hopper. The alcohol burner was lit and placed on the equipment, allowing 10 minutes for the press to heat up, which helped extract more oil from the raw material used.
When the oil became too hot, the flame intensity was reduced until it was appropriate. The pressure was applied according to the regulator plug; the tighter the plug, the higher the pressure. The expeller has two outlets: one for the oil and one for the completely dried pulp in strip form. The obtained product was filtered, its volume measured, bottled in amber bottles, and stored at room temperature.
Table 1 describes the main materials, equipment, and reagents used for avocado oil extraction from Hass variety raw material using the Thermo-Batting Method.

Table 1. Materials, Instruments, and Equipment Used for Avocado Oil Extraction by the Thermo-Batting Method.

Materials	Brand/Model	Capacity
Beakers	EISCO	250 ml
Glass jars	N/A	150 ml
Alcohol burner	N/A	50 ml
Filter paper	Whatman	150 mm Ø
Amber bottles	N/A	500 ml
Metal container	N/A	4 Lt
Instruments	**Brand**	**Capacity**
Gram scale	OHAUS	5 Kg
Oven	Dalvo/TDE/70	<= 200°C
Expeller press	Piteba	
Reagents	**Pureza**	
Bleach	75%	
Distilled or deionized water	100 %	
ethyl alcohol	69.99 ° GL	

Figure 1 shows the equipment used for the extraction of avocado oil using the Thermo-Batting method.

Fig 1. Piteba Press, hot pressing with ethanol burner

2.2 Experimental Procedure for Avocado Oil Extraction Using the Enzymatic Method.

After disinfecting the fruit as indicated in process 2.1, the avocados were peeled and pitted. Then, 420 g of avocado pulp was weighed. The obtained pulp was mashed in a metal container, and the pH was adjusted to 5 using 42.5% phosphoric acid and 7.7% ascorbic acid solutions. The mixture was then transferred to a water bath on a stove, and 5 ml of the enzymatic preparation was added when the temperature reached 40°C. The mixture was continuously stirred for approximately 2 hours to facilitate the action of the previously used enzymatic dose. The treated mixture was placed in a hydraulic press, inside a poly-silk cloth and a sieve, which allowed the oil and water to exit. The mixture was manually pressed at 100 Kg/cm², and the resulting liquid phase was centrifuged at 1400 rpm for 15 minutes to separate the crude oil and water. The process was repeated until a considerable amount of sample was obtained and analyzed at the end of the process. The crude oil obtained was neutralized, bleached, and dried using 200 g.

During neutralization, the free fatty acids that cause instability or foaming tendencies at high temperatures were removed. The oil was treated at 80°C with 5N NaOH to form sodium salts. Then, 20 g of magnesium oxide was added, allowed to react for 5 minutes at the specified temperature with moderate and constant agitation.

For bleaching, undesirable compounds that give the oil a bad appearance due to plant fibers and oxidative instability due to chlorophyll were removed by filtering with 1% diatomaceous earth. The mixture was then heated to 120°C under a pressure of 130 mm Hg for 20 minutes in a vacuum

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oven. The earth was then discarded by vacuum filtration using Whatman No. 4 filter paper.

Finally, for drying, a vacuum oven was used at 130 mm Hg pressure and 120°C for 30 minutes. The oil sample was then extracted into an amber bottle, labeled, and stored at room temperature.
The materials, instruments, and equipment used for avocado oil extraction by the enzymatic method are described in Table 2.

Table 2. Materials, Instruments, and Equipment Used for Avocado Oil Extraction by the Enzymatic Method.

Materials	**Brand/Model**	**Capacity**
Probeta	EISCO	50 ml
Poly-silk cloth	S/M	1 m^2
Amber bottles	S/M	500 ml
Metal container	S/M	4 Lt
Plastic test tubes with screw cap Whatman No. 4 filter paper	BOECO Germany	10 ml
Instruments	**Brand**	**Capacity**
Gram scale	OHAUS	5 kg
Single burner electric stove	IMACO	100°C
Hydraulic press	Century	20 ton
pH meter	OAKION ecoTestr	0 – 14
Centrifuge (Washer)	Samsung	1400 rpm
Reagents	**Purity**	
Bleach	75%	
Distilled or deionized water	100 %	
Pectinase enzyme (GranozymePTE 100)	Concentrada	
Phosphoric acid	69,99 ° GL	
Ascorbic acid	7,7%	
Phosphoric acid	42,5%	
Sodium hydroxide	5 N	

2.3 Experimental Procedure for Avocado Oil Extraction Using the Hydraulic Pressing Method.

After selecting, disinfecting, and weighing the avocados, they were cut into pieces and mashed with a fork to facilitate placing the pulp into the oven trays over polyethylene bags for better drying at 53°C for 24 hours. Once the pulp was dried, it was broken into smaller pieces with a moisture content of approximately greater than 5% and fed into a steel sieve connected to the hydraulic press. A flat container was placed on the platens of the equipment and covered with aluminum foil to collect all the oil, which was channeled through a hose connected to a graduated cylinder for sample collection.

A piece of poly-silk was then placed inside the sieve, and pressure was applied by the press every 10 minutes, reaching a force of 6000 lbs, until as much oil as possible was extracted, leaving a dry cake.

The oil was passed through filter paper into a beaker and then decanted over approximately 12 hours to ensure the proper separation of oil from water and other macroparticles. The obtained oil was deposited into 500 ml amber bottles to prevent light from deteriorating the oil, and the bottles were labeled for identification.

Finally, the bottles were stored at room temperature. Table 3 shows the materials, instruments, and reagents used in the hydraulic pressing process.

Table 3. Materials, Instruments, and Equipment Used for Avocado Oil Extraction by the Hydraulic Pressing Method.

Materials	**Brand/Model**	**Capacity**
Beakers	EISCO	250 mL
test tube	EISCO	100 mL
Poly-silk cloth	S/M	1 m^2
Amber bottles	S/M	500 mL
Aluminum foil	S/M	40 x 40 cm
Steel disc	S/M	8 -10 mm Ø
Polyethylene plastic bags	S/M	40 x 25 cm
Instruments	**Brand**	**Capacity**
Gram scale	OHAUS	5 Kg
Hydraulic press	Century	20 Ton
Stove	Dalvo/TDE/70	<= 200°C
Reagents	**Purity**	
Bleach	75%	
Distilled or deionized water	100%	

Figure 2 shows the equipment used for the hydraulic pressing process.
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Fig 2. Hydraulic press with a capacity of 20 tons used for the pressing process

2.4 Experimental Procedure for Avocado Oil Extraction Using the Expeller Press Method

The current method followed the process of selecting and disinfecting the raw material as in the other procedures mentioned earlier. Subsequently, the pulp was cut into pieces and mashed with a fork to facilitate placing the pulp into oven trays for optimal drying at a temperature of 53°C for 24 hours. Once the dried pulp was obtained, it was fragmented into smaller pieces with a moisture content of approximately greater than 5% and fed into the hopper of the Piteba press.

The pressure applied was adjusted according to the regulating plug; tightening this plug increased the pressure. It should be noted that the expeller has two outlets: one for the oil and the other for the completely dried pulp in strip form.

After obtaining the oil, the process was repeated for filtering, measuring, bottling in amber bottles, labeling, and storing, similar to the Thermo-Batting method. It is important to emphasize that unlike the Thermo-Batting process, the expeller press was not heated to obtain the oil. Table 4 lists the materials, instruments, and reagents used for the expeller press method of avocado oil extraction.

Table 4. Materials, Instruments, and Equipment Used for Avocado Oil Extraction by the Expeller Press Method.

Materials	Brand/Model	Capacity
Precipitation beakers	EISCO	250 ml
Glass jars	S/M	150 ml
Filter paper	Whatman	150 mm Ø
Amber bottles	S/M	500 ml
Metal container	S/M	4 Lt
Instrument	**Brand**	**Capacity**
Gram scale	OHAUS	5 Kg
Stove	Dalvo/TDE/70	<= 200°C
Expeller press	Piteba	
Reagents	**Purity**	
Bleach	75%	
Distilled or deionized water	100 %	

2.5 Yield Determination.

To determine the yield, corresponding measurements were taken for each extraction method in relation to the weight of oil obtained on a dry basis. The yield percentage on a dry basis was calculated using the weight of the dry matter of the pulp employed.

To obtain the percentage yield values on a dry basis for each method, the following equation (1) was applied, considering the Moisture Percentage of Hass Avocado Pulp (Gutarra Sanabria & Vargas Rodríguez, 2018):

$$\%rendimiento\ (bs) = \frac{Peso\ de\ aceite\ (bs)}{Peso\ de\ pulpa\ (bs)} * 100 \qquad (1)$$

2.6 Determination of physicochemical characteristics.

For the evaluation of physicochemical variables, four samples obtained from each extraction method were analyzed for six parameters: acidity index, peroxide value, saponification value, iodine value, density, and moisture. These parameters were compared using a bibliographic reference, a commercially available oil with similar characteristics, and the NTE INEN 29 standard for olive oil, as there is no specific INEN standard for avocado oils.

a) Acidity Index

The AOAC 21TH 2019,940.28 standard was referenced for this technique, which was developed by AVVE Laboratories S.A. and expressed in units of g/100g.

b) Peroxide Value

This test was based on the AOAC 21TH 2019,965.33 standard, conducted at AVVE Laboratories S.A., with measurements in mEqO2/kg.

c) Saponification Value

The methodology used for this parameter was based on the MMQ-87 AOAC 21TH 2019,920.160 standard, developed by AVVE Laboratories S.A., with units in mg KOH/g.

d) Iodine Value

La técnica que se aplicará para este método de ensayo se la realizó de acuerdo a la Norma MMQ-87 AOAC 21TH 2019,920.159, desarrollada en los Laboratorios AVVE. S.A., y sus unidades se expresarán en cg/g.

e) Density

To determine density, an empty and dry graduated cylinder was weighed and tared on a balance. Immediately, it was filled with 100 mL of the sample, and the weight was recorded. Density was calculated using the following formula:

$$\rho = m/V \qquad (2)$$

Where ρ is the density in g/mL, m is the mass in grams, and V is the volume in mL. The procedure was repeated for each sample of oil obtained from each different method.

f) Moisture

This test was conducted according to the NTE INEN 39 standard, which specifies the Determination of Loss on Heating (Moisture) and Other Volatile Matters in animal or vegetable fats and oils.

For the determination of moisture, the sample was checked to ensure it was liquid, clear in appearance, and free of sediment. It was then inverted several times in its container.

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Subsequently, 5 g of the sample was placed in a pre-weighed porcelain dish, which was then placed in an oven heated to 103°C ± 2°C. After heating, the dish was cooled in a desiccator and weighed. These operations were repeated for each sample obtained from each extraction method. The moisture content was calculated using the following formula:

$$\% H = \frac{W_o - W_f}{W_o} \qquad (3)$$

Where W_o represents the initial weight and W_f the final weight.

Table 5 lists the materials, instruments, and reagents used for the determination of density and moisture.

Table 5 Materials, instruments, and reagents used for the determination of density and moisture of avocado oil.

Materials	Brand/Model	Capacity
Graduated cylinder	Glassco	100 mL
Porcelain capsules	Canfort	
Instrumentos	**Brand/Model**	**Capacity**
Gram scale	Ohaus	2 Kg
Silica gel desiccator	S/M	
Oven	Dalvo/TDE/70	<= 200°C
Reagents	**Purity**	
Avocado oil	100%	

2.7 Fatty Acid Profile Determination.

The fatty acids of the oils obtained through the four extraction methods were determined using High-Performance Liquid Chromatography (HPLC), following Standard MMQ-HPCL-09, conducted at AVVE Laboratories S.A. These results were compared with a bibliographic reference and the analysis of a commercial oil.

3. Results

3.1 Yield

The yield values obtained for each extraction method are shown in Table 6.

Table 6. Yield values obtained for each extraction method

The yield percentage by extraction method:			
Termobatido	Enzymatic	Hydraulic pressing	Expeller pressing
89.78	6.79	7.57	38.98

In Figure 3, the yield percentages by extraction method are shown.

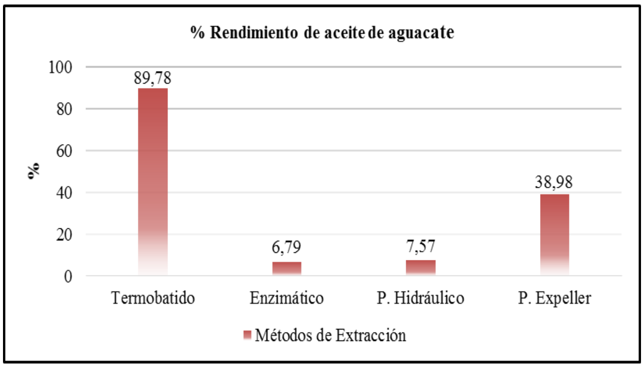

Fig 3. Bar chart comparing yield percentages among extraction methods.

3.2 Results of physicochemical characteristics

able 7 shows the results of the determination of physicochemical characteristics of avocado oil obtained by the 4 processes.

T able 7 Physicochemical Characteristics of avocado oil for each extraction method.

Physicochemical Analysis	Extraction Methods				Units
	A	B	C	D	
Acidity Index	3.13	1.29	0.90	5.05	g/100g
Peroxide Index	78.87	11.36	4.32	49.57	mEqO2/kg
Saponification Index	190.06	189.28	193.87	193.49	mKOH/mg
Iodine Index	84.56	78.25	74.29	84.49	cg/g
Density	0.9039	0.8955	0.8951	0.9007	g/ml
Moisture	0.054	0.048	0.044	0.052	%

A: Thermo-mechanical Method, B: Enzymatic Method, C: Hydraulic Pressing Method, D: Expeller Pressing Method

Figure 4 shows a comparison via bar chart of the Physical Characteristics of oil obtained through different extraction methods.

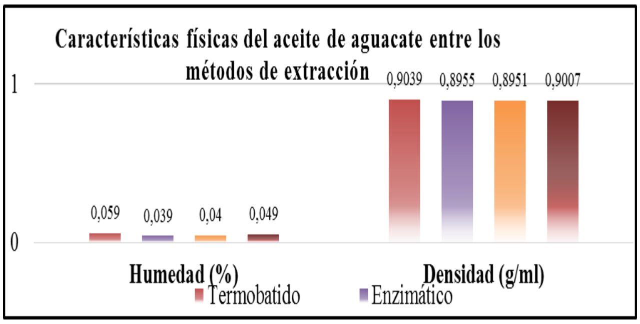

Figure 4: Comparison Chart of Physical Characteristics of oil among extraction methods.

Figure 5 displays the chemical characteristics obtained from the oil corresponding to each extraction method.

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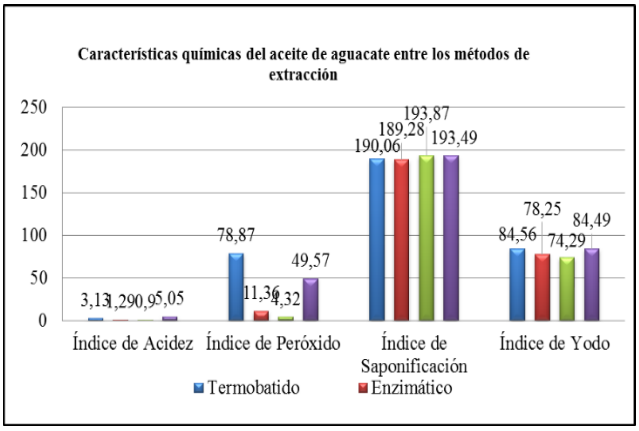

Fig 5 Comparison Diagram of Chemical Characteristics of Oil Obtained by Extraction Methods.

Table 8 Physicochemical Parameters from Bibliographic References for Respective Comparison.

Table 8 Physicochemical Characteristics of Avocado Oil Obtained by Thermo-mechanical Extraction, Rapid Evaporation, and Pressing.

Physicochemical Characteristics	Extraction Method		Units
	Termo-mechanical Extraction [a]	Rapid Evaporation and Pressing [b]	
Acidity Index	0,38	0,10	g/100g
Peroxide Index	5,56	2,20	$mEqO_2/kg$
Saponification Index	195,55	130,00	mKOH/mg
Iodine Index	80,94	69,91	cg/g

[a] [9]. [b] [10]

3.3 Fatty Acid Profile Results of the Oils Obtained.

Table 9 shows the fatty acid profile results of the oils obtained through the processes of Thermobatido, Enzymatic, and Hydraulic pressing, while Table 10 presents the fatty acid profile results of the oil obtained through the expeller pressing process, the lipid profile of a bibliographic reference, and that of a commercial oil branded MIRA.

Table 9 Fatty Acid Profile Results of Avocado Oil Obtained by Thermobatido, Enzymatic, and Hydraulic Pressing Processes.

Lipid Profile of Fatty Acids	Extraction Methods			Units
	Termobatido	Enzimático	Hydraulic pressing	
Saturated Fatty Acids	17,93	17,12	23,57	g/100g
Monounsaturated Fatty Acids	71,38	72,23	64,29	g/100g
Polyunsaturated Fatty Acids	10,69	10,65	12,14	g/100g
Linolenic Acid (Omega 3)	0,76	0,66	0,48	g/100g
Linoleic Acid (Omega 6)	9,93	9,99	11,65	g/100g
Oleic Acid (Omega 9)	67,03	67,02	61,07	g/100g
Palmitic Acid	17,23	14,93	21,00	g/100g
Stearic Acid	0,51	1,05	1,26	g/100g
Vitamin E	-	-	-	mg/100g

Table 10 Fatty Acid Profile Results of Avocado Oil Obtained by Expeller Pressing Process, Thermomechanical Extraction, and Commercial Oil Brand MIRA.

Lipid Fatty Acid Profile	Extraction Methods			Units
	Expeller Pressing	Mechanical Extraction	MIRA brand Avocado Oil	
Saturated Fatty Acids	18,68	22,1059	21,3	g/100g
Monounsaturated Fatty Acids	69,99	63,7555	78,7	g/100g
Polyunsaturated Fatty Acids	11,33	13,6216	-	g/100g
Linolenic Acid (Omega 3)	0,91	0,7599	1,4	g/100g
Linoleic Acid (Omega 6)	10,41	12,8726	8,9	g/100g
Oleic Acid (Omega 9)	65,72	53,2511	56,62	g/100g
Palmitic Acid	17,73	21,5194	-	g/100g
Stearic Acid	0,57	0,4806	-	g/100g
Vitamin E	-	10,11	13,28	mg/100g

4. Discussion

4.1 Yield Analysis

Once the yield percentages for each extraction method were calculated, it was determined that the highest percentage was achieved by the Termobatido method with 89.78%, followed by the Expeller Pressing method with 39.98%. Consequently, Hydraulic Pressing yielded 7.57% and the Enzymatic method 6.79%. Therefore, it is established that the Termobatido method yielded the best results in terms of yield.

Regarding the Termobatido method, it applies high-temperature pressure, which helps to break down more oil particles. However, a disadvantage is its appearance, as it results in oil with a darker hue compared to the other methods.

4.2 Analysis of Physicochemical Characteristics

In the research by Candori Cahui [10] it is noted that "Physicochemical properties are the most common indices for evaluating the quality of seed oils in the food industry. However, determinations of the physicochemical properties of vegetable oil are necessary to judge the suitability of oil for a particular application."

Therefore, these characteristics allow identifying if the oils are in the appropriate state for subsequent quality testing, or if they should be rejected if their quality is not adequate.

Regarding the physical characteristics developed in this research, the values of moisture (Loss on Heating) and relative density achieved results that are in accordance with the NTE INEN 29 [11], standard, which is similar to the products obtained in this project, such as Olive Oil. The standard specifies a maximum of 0.050% for moisture and a range of 0.840 to 0.960 g/ml for relative density.

According to the data obtained, the Termobatido, Enzymatic, and Hydraulic Pressing methods show acidity index values established by the NTE INEN 29 [11] between 0.8 and 3.3 g/100 g. Regarding the peroxide index, only the Hydraulic Pressing method shows a value below 10 mEqO2/kg according to the mentioned standard. Comparing the iodine index with the NTE INEN 29 [11] which indicates values between 79 and 89 cg/g, all four extraction methods comply with the comparison standard.

4.3 Analysis of Fatty Acid Profile Results
According to the analyses and comparisons of results regarding the main fatty acids - Oleic (C18:1), Linoleic (C18:2), Alpha Linolenic (C18:3), Palmitic (C18:0), and Stearic (C18:0) acids - tabulated, it can be observed that the Termobatido method performs better in terms of oleic acid percentage. This is due to the sensitivity of oleic acid to heat, where products with higher proportions of unsaturated fatty acids are more prone to oxidation compared to those with smaller amounts.

Regarding Linoleic Acid, the Enzymatic method shows the highest percentage, similar to the value obtained by Yepes Betancur [9].

Concerning Alpha Linolenic Acid, the Expeller method resulted in the highest percentage. Subsequently, for Palmitic Acid, which is a saturated acid, the Enzymatic method is better due to its lower percentage, unlike the other techniques with higher saturation due to exposure to pressure and temperature treatments. [12]

Bergh [13] Concerning Alpha Linolenic Acid, the Expeller method resulted in the highest percentage. Subsequently, for Palmitic Acid, which is a saturated acid, the Enzymatic method is better due to its lower percentage, unlike the other techniques with higher saturation due to exposure to pressure and temperature treatments.

In contrast, Stanley [14], states that without neglecting the importance of unsaturated fatty acids such as oleic and linoleic acids, these are hypocholesterolemic, thus decreasing LDL cholesterol concentrations deposited in arteries and enhancing beneficial actions of HDL cholesterol.

For these reasons, oils extracted by different methods such as Termobatido, Enzymatic, Hydraulic Pressing, and Expeller comply with nutritional requirements, thereby contributing to consumer health. It is noted that their results exhibit some similarities in relation to the analyzed fatty acids.

The minimal differences found in this study regarding physicochemical properties and fatty acid composition of avocado oil are likely due to extraction techniques, environmental conditions of the fruit, its variety, or maturity state.

5. Conclusions
The extraction of Hass Avocado oil using four methods allowed for the evaluation and verification of differences and similarities in both the execution of techniques and results. Subsequently, the best process that offers the best quality conditions can be selected for implementation at the pilot plant level and finally at the industrial level with properly tested process and operation conditions until optimization is achieved.

Significant differences were found in terms of yield, with the Termobatido method yielding the highest percentage at 89.78%, and the Enzymatic method yielding the lowest at 6.79%. Comparing the four extraction methods, it is concluded that the Hydraulic Pressing process presents the highest values concerning the content of saturated fatty acids, polyunsaturated fatty acids, linoleic acid, palmitic acid, and stearic acid, respectively.

Considering the process yield, which is important in terms of productivity, as well as the quality of the product obtained in relation to its physicochemical properties and fatty acid profile, it is concluded that quality is related to a low yield of oil obtained. The Hydraulic Pressing process presents the best product quality conditions but with a relatively low yield (7.57%). If the objective of an industrial plant is to achieve high yield, the most suitable method would be Termobatido, albeit with a decrease in oil quality, particularly concerning physical properties rather than the fatty acid profile, which provides a beneficial contribution, especially from unsaturated fatty acids for health.

Given that the yield in the Termobatido process is the highest, it is recommended to study its implementation using antioxidants to reduce the peroxide index related to oil oxidation.

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