Comparison of Fatty Acid Profiles of Sacha Inchi Oil (*Plukenetia huayllabambana*), Sesame Oil (*Sesamum indicum*), and Peanut oil (*Arachis hypogaea*) Using Two Extraction Methods for Food Purposes

Comparación de los perfiles de ácidos grasos del aceite de sacha inchi (*Plukenetia huayllabambana*) aceite de sésamo (*Sesamum indicum*) y aceite de cacahuete (*Arachis hypogaea*) utilizando dos métodos de extracción con fines alimentarios

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Abstract

Vegetable oil consumption has increased in recent decades due to the high content of monounsaturated (Omega 9) and polyunsaturated (Omega 3 and 6) fatty acids. For this reason, this research compared the fatty acid profile of sacha inchi, sesame and peanut oils under two extraction methods for food purposes. A completely randomized experimental design considered an A*B factorial arrangement with 3 repetitions. Factor A corresponds to oilseed type and Factor B is extraction method. The results showed that both factors significantly influenced ($p<0.05$) bromatological characteristics (pH, acidity, peroxide value, relative density and ash). The lowest concentration of saturated fatty acids was obtained in sacha inchi oil + cold pressing (6.80 g/100 g), while monounsaturated fatty acids increased in peanut oil + hot pressing (51.51 g/100 g). Sacha inchi oil + cold pressing had the highest content of polyunsaturated fatty acids (84.36 g/100 g).

Keywords
fatty acids • agri-food • monounsaturated • polyunsaturated • saturated • oilseeds

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Resumen

El consumo de aceites vegetales ha aumentado en las últimas décadas debido a su alta composición de ácidos grasos monoinsaturados (Omega 9) y poliinsaturados (Omega 3 y 6). Por esta razón, la presente investigación comparó el perfil de ácidos grasos del aceite de sacha inchi, ajonjolí *y* maní a partir de dos métodos de extracción con fines alimentarios. Se utilizó un diseño experimental completamente aleatorizado, con arreglo factorial A*B con 3 repeticiones, donde el Factor A correspondió al tipo de oleaginosa y el Factor B es igual a los métodos de extracción. Los resultados mostraron que los factores de estudio influyeron significativamente ($p<0,05$) en los valores de las características bromatológicas (pH, acidez, índice de peróxidos, densidad relativa y cenizas). Por otro lado, la menor presencia de ácidos grasos saturados se obtuvo en el aceite de sacha inchi + prensado en frío (6,80 g/100g), mientras que, los ácidos grasos monoinsaturados incrementaron en el aceite de de maní + prensado en caliente (51,51 g/100g) y el aceite de sacha inchi + prensado en frío, presentó el mayor contenido de ácidos grasos poliinsaturados (84,36 g/100g).

Palabras clave

ácidos grasos • agroalimentario • monoinsaturados • poliinsaturados • saturados • oleaginosas

Introduction

In the constant search for food sources promoting health and well-being, vegetable oils provide unique fatty acid compositions and potential health benefits (36). Additionally, the Amazon region is home to various plant species with crucial roles in global agriculture (36). However, among lesser-known oilseed species with potential economic value due to their chemical properties, sacha inchi oil *(P. huayllabambana)*, sesame oil *(S. indicum),* and peanut oil *(A. hypogaea)* provide diverse nutritional profiles and versatile culinary applications (3).

P. huayllabambana belongs to the *Euphorbiaceae* family, native to the Amazon, known as "wild peanut", "Inca peanut", "Inca inchi" or "mountain peanut" (24). It is widely distributed in South America, particularly in the Amazon River basin. Currently, Peru leads the production and industrialization of this plant material, with annual seed production of approximately 1200 tons (14). However, countries such as Colombia, Ecuador and Bolivia have also begun to venture into agriculture and economy (10).

On the other hand, *S. indicum* is an oilseed plant cultivated in China, India, Sudan, Japan, Mexico, countries in West and Central Africa, and Central America (30). The growing interest in the nutritional value of sesame has led to a significant increase in its consumption and use in baking (9). This shift in consumption habits is reflected in the increasing use of seeds in food products at both domestic and industrial levels (9). Furthermore, *S. indicum* is the sixth most economically important oilseed crop globally, with nutritional value (fats, proteins, minerals, and vitamins) in food security (24).

Recent research stresses the importance of differentiating the fatty acid profiles of these oils to optimize their use in nutrition. Notably, sacha inchi oil is characterized by high alpha-linolenic acid (ALA), an essential omega-3 fatty acid with cardiovascular protective effects and contribution to cognitive development (37). Sesame oil is rich in polyunsaturated fatty acids, particularly linoleic and oleic acids with antioxidant and anti-inflammatory properties, positively influencing cardiovascular and metabolic health (25). In comparison, peanut oil has oleic and linoleic acids associated with reduced cardiovascular risk and improved lipid profiles (2). However, the instability of polyunsaturated fatty acids, especially in oils such as sacha inchi, can lead to oxidation and harmful compounds when exposed to high temperatures or improper storage. This instability can negatively affect nutritional quality and safety (37).

Oil extraction methods, such as cold and hot extraction, are crucial in determining oil nutritional quality and sensory properties while influencing the stability of fatty acids, antioxidants, and other bioactive compounds (31). Cold extraction is a mechanical process that better preserves heat-sensitive compounds and maintains oil nutritional and sensory quality (22). In contrast, hot extraction uses high temperatures, accelerating extraction rates and increasing oil yield but degrading heat-sensitive compounds and affecting quality (32).

This study aimed to compare fatty acid profiles of sacha inchi oil (*P. huayllabambana*), sesame oil (*S. indicum*), and peanut oil (*A. hypogaea*) using two extraction methods for food purposes.

Materials and methods

Plant Material

For this study, sacha inchi was obtained from the Lago Agrio canton, Sucumbíos province, Ecuador, located 600 m a. s. l. with coordinates 0°05'05" N 76°52'58" W. Annual temperature ranges between 20 and 35°C, ideal for its cultivation. Sesame was acquired from the Quevedo canton, Los Ríos province, at 150 m a. s. l. with coordinates 1°02'00" S 79°27'00" W, featuring a monsoonal tropical climate and temperatures between 23°C and 32°C, enhancing its quality. *Peanut* seeds were obtained from the Pichincha canton, Manabí province, with an average altitude of 350 m a. s. l. and coordinates 1°02'50" S 79°49'07" W, dry tropical climate and temperatures between 24°C and 30°C, suitable for peanut cultivation.

Oil Extraction Methods

Cold Press Extraction

The seeds were dried at room temperature until 7% humidity. Once dried, 20 kg of each plant material were equally distributed for the different extraction methodologies. The oils were obtained by subjecting the nuts to a hydraulic pressing process between 246 and 250 Bar, with a piston-cylinder mechanism controlled by an electric panel. The nuts were introduced into a perforated basket and pressed. The expelled oil falls onto a stainless steel tray, where it is collected and filtered through a cloth before storage.

Hot Press Extraction

Similarly to cold pressing, seeds were subjected to indirect heating at 90°C for 20 minutes before pressing.

Bromatological Analysis

Oil physicochemical analysis included emulsifying the oils with water to determine pH, and acidity according to NTE INEN 0038:1973 standard (16). Oleic acid was considered the predominant acid. Peroxide evaluation followed the NTE INEN 277:1978 standard (17), and relative density followed the NTE INEN 0035:2012 standard (19). Humidity was analyzed by the Colombian Technical Standard NTC 287:2018 (15). Animal and vegetable fats and oils along with moisture and volatile matter content. Finally, ashes were quantified by the AOAC standard method (920,153).

Fatty Acid Analysis

Before HPLC according to Oubannin *et al.* (2024), all samples were esterified with 2 mL methanol and 0.5% KOH at 60 °C for 10 minutes. Then, fatty acid methyl esters were extracted with 2 mL hexane. This mixture was centrifuged at 3000 rpm for 5 minutes. The upper phase obtained after centrifugation was filtered with a 0.45 µm filter for later analysis. A C18 column (250 mm × 4.6 mm, 5 µm) was mounted in the HPLC system isocratically at 35°C column temperature and operating pressure of 2000 to 2500 psi. Acetonitrile and methanol (70:30 v/v) were passed through the mobile phase at a flow rate of 1 mL/min and detection was performed with a UV-Vis detector at 220 nm. Volumes of 10-20 µL were injected automatically with 30 minutes of analysis time.

Statistical Analysis

An ANOVA was conducted using a completely randomized block design with an A*B factorial arrangement in triplicate. Factors were oilseed (a0: sacha inchi, a1: sesame, and a2: peanut), and extraction method (b0: cold pressing and b1: hot pressing, table 1). The data obtained were analyzed with Statistica (39) including Tukey test at p<0.05 and Statgraphics (40).

Table 1. Factors involved in vegetable oil extraction.

Tabla 1. Factores que intervienen en la extracción de aceite vegetal.

Treatments	Factor A	Factor B	Code
1	Sacha inchi	Cold-pressed	S.I + C.P
2	Sacha inchi	Hot-pressed	S.I + H.P
3	Sesame	Cold-pressed	S.M + C.P
4	Sesame	Hot-pressed	S.M + H.P
5	Peanut	Cold-pressed	P.N + C.P
6	Peanut	Hot-pressed	P.N + H.P

Results and discussion

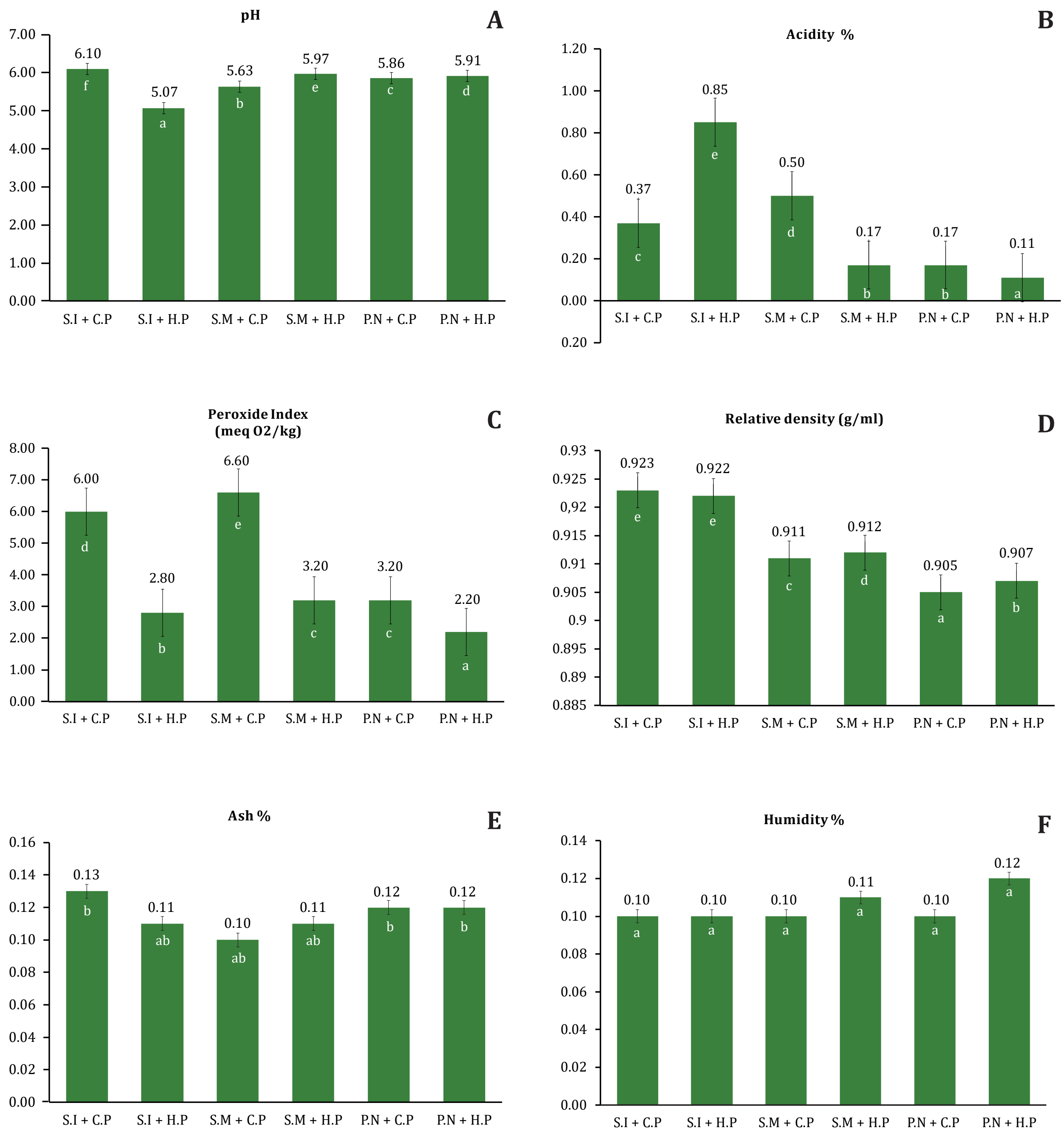
Bromatological Analysis of Oils from Three Oilseeds (sacha inchi, sesame, and peanut) Extracted by Cold and Hot Pressing

Figure 1A (page 181), shows pH variability of oils obtained by cold and hot extraction methods. We demonstrated that both extraction methods significantly (p<0.05) affect pH values. The highest and lowest pH values were 6.10 and 5.07, observed in sacha inchi oil extracted by cold pressing (S.I + C.P) and hot pressing (S.I + H.P), respectively. These results are consistent with previous studies reporting 6.11 for sacha inchi oil, 5.86 for peanut oil and 5.64 for sesame oil (29).

Figure 1B (page 181), shows that oilseed type significantly (p<0.05) affects acidity. Sacha inchi oil extracted by hot-pressing showed higher acidity (0.85%). In contrast, peanut oil showed lower acidity, with values of 0.11% and 0.17% for both extraction methods. These results indicate that oilseed type and extraction process determine free fatty acid content in vegetable oils. A higher free fatty acid content, indicated by higher acidity, can affect oil stability, shelf life and nutritional and sensory quality (12). Additionally Peroné *et al.* (1999) mention that cold extraction methods generally produce oils with lower acidity than methods involving high temperatures and solvents (28).

Figure 1C (page 181), shows how cold extraction significantly increased (p < 0.05) the peroxide content. Sesame oil extracted by cold pressing presented the highest value, with 6.60, while peanut oil extracted by hot pressing (P.N + H.P) showed the lowest value, 2.20. This agrees with previous studies suggesting that increasing temperature and heating time favors hydroperoxide formation. Varying conditions from 80°C for 10 minutes to 200°C for 20 minutes, peroxide content increased from 1.91 to 3.25 mEqO2/kg (6). This increase reflects a greater production of primary oxidation products, attributed to the action of free radicals on unsaturated fatty acids, such as linolenic acid, predominant in sacha inchi oils (37, 38). Our results are within the limit established by the Ecuadorian Technical Standard NTE INEN 34:2012 (20), which stipulates that peroxide index of oils for human consumption must not exceed 10 mEqO/kg.

In the relative density analysis (figure 1D, page 181), a significant influence of the type of oilseed on the variability of this property was observed (p<0.05), highlighting the sacha inchi oil obtained by the cold and hot extraction methods (S.I + C.P and S.I + H.P), with the highest densities of 0.923 g/ml and 0.922 g/ml, respectively. On the other hand, peanut oil presented lower densities, with values of 0.905 g/ml and 0.907 g/ml for the mentioned methods. These results are consistent with previous research indicating that the density of Moringa stenopetala seed oil is 0.9 g/ml and values ranging from 0.99 to 0.97 g/ml for sacha inchi oil when different temperatures (90 to 110°C) are applied (18, 34). In addition, the oil extracted from pumpkin seeds (*Cucurbita pepo*) presented a density of 0.09 g/ml (1).



Sacha inchi + Cold -pressed (S.I + CP), Sacha inchi + Hot -pressed (S.I + HP), Sesame + Cold-pressed (S.M + CP), Sesame + Hot- pressed (S.M + H.P), Peanut + Cold-pressed (P.N +C.P), Peanut + Hot - pressed (P.N + H.P).

Sacha inchi + prensado en frío (S.I + CP), Sacha inchi + prensado en caliente (S.I + HP), Sésamo + prensado en frío (S.M + CP), Sésamo + prensado en caliente (S.M + H.P), Maní + prensado en frío (P.N + C.P), Maní + prensado en caliente (P.N + H.P).

Figure 1. Oil bromatological analyses obtained by two extraction methods.

Figura 1. Análisis bromatológicos de aceites obtenidos por dos métodos de extracción.

Figure 1E details ash contents ranging between 0.11% and 0.13%. No variability was found among oilseeds and extraction methods (p>0.05). These values are lower than the reported by Bonku *et al.* (2020), who determined ranges from 1.2% and 2.3% in peanut oil (*A. hypogaea*). Similarly, a study on sesame oil reported ash values from 1.44% to 5.93%, considering Mida and Woremog, two different study regions (5). Discrepancies in our crude ash content and literature values could be attributed to topographic and climatic differences, and variations in extraction methods.

No significant differences were found for moisture content between groups (p > 0.05), with average values ranging from 0.10% to 0.12% (figure 1E, page 181). These findings are consistent with previous studies reporting similar levels for oils from the same species (13). Other studies showed non-significant differences across production areas of sesame oil, (5.43% - 5.81%) (38), and peanut (4.2 ± 0.5% and 3.8 ± 0.37%) for Huaquechula and Tlapanalá varieties (8). However, other studies reported moisture variability in microencapsulated sacha inchi oil (*P. huayllabambana* and *P. volubilis*), ranging from 3.20% to 5.87% (3).

Profile of Fatty Acids

Saturated Fatty Acids

Most important saturated fatty acids in vegetable oils include C11:0 (undecanoic acid), C16:0 (palmitic acid), C17:0 (margaric acid), C18:0 (stearic acid), C20:0 (arachidic acid), C22:0 (behenic acid) and C24:0 (lignoceric acid). We showed that cold-pressed and hot-pressed peanut oils had the highest values of these acids, with 17.54 g/100 g and 18.05 g/100 g, respectively. In contrast, cold-pressed sacha inchi oil showed a lower value of 6.79 g/100 g, while hot-pressed sacha inchi oil had a similar value, of 7.57 g/100 g (table 2). These values for sacha inchi oils, obtained by both methods, are relatively low compared to those reported by Seid and Mehari (2022), who found a saturated fatty acid composition of 9.38 g/100 g (38), warned that excessive consumption of saturated fatty acids can increase cardiovascular risk. Therefore, the aforementioned oils are interesting alternatives for human diet, keeping cholesterol levels under control (35).

Table 2. Saturated fatty acids in oils (sacha inchi, sesame, and peanut) obtained by cold and hot extraction.

Tabla 2. Ácidos grasos saturados presentes en aceites (sacha inchi, ajonjolí y maní) obtenidos por extracción en frío y caliente.

Saturated Fatty Acids	Oilseed type + Extraction Method						
		S.I + C.P	S.I + H.P	S.M + C.P	S.M + H.P	P.N + C.P	P.N + H.P
Undecanoic acid	C11:0	0.00^{A}	0.00^{A}	0.00^{A}	0.05^{B}	0.13^{C}	0.16^{D}
Palmitic acid	C16:0	4.96^{A}	5.47^{B}	9.24^{C}	11.49^{D}	12.12^{E}	12.09^{E}
Margaric acid	C17:0	0.08^{A}	0.09^{A}	0.05^{A}	0.05^{A}	0.11^{A}	0.54^{A}
Stearic acid	C18:0	1.61^{A}	1.73^{B}	4.83^{F}	4.10^{E}	2.44^{D}	1.99^{C}
Arachidic acid	C20:0	0.10^{A}	0.13^{B}	0.61^{D}	0.57^{C}	0.98^{E}	1.00^{E}
Behenic acid	C22:0	0.04^{B}	0.08^{C}	0.00^{A}	0.22^{D}	1.32^{E}	1.^{5}9F
Lignoceric acid	C24:0	0.00^{A}	0.07^{B}	0.08^{C}	0.14^{D}	0.44^{E}	0.68^{F}
Total Saturated Fatty Acids		6.79^{A}	7.57^{B}	14.81^{C}	16.62^{D}	17.54^{E}	18.05^{E}

Different letters represent statistically significant differences (Tukey p < 0.05).

Diferentes letras representan diferencias estadísticamente significativas (Tukey p < 0,05).

Monounsaturated Fatty Acids

Table 3 (page 183), shows monounsaturated fatty acids in the analysed oils, highlighting the main ones: C16:1 (palmitoleic acid), C18:1 (oleic acid Omega 9), C20:1 (eicosenoic acid) and C24:1 (nervonic acid). The highest values of these fatty acids were observed in hot-pressed peanut oil (51.52 g/100 g) and cold-pressed peanut oil (50.25 g/100 g), close to the monounsaturated fatty acid content of virgin olive oil (73.90 g/100 g), as reported in Spanish diets (37). Hot-pressed sesame oil (35.37 g/100 g) and cold-pressed sesame oil (32.89 g/100 g) present intermediate values, comparable to the 39 g/100 obtained after roasting temperature (4). In this study, the predominant monounsaturated fatty acid is omega-9, known for its ability to improve resistance to LDL oxidation (a crucial factor in atherosclerosis), given its phenolic compounds (23). According to the White Paper on Nutrition in Spain, consuming more than 51 g/100 g of monounsaturated fatty acids per day is inadvisable. In this context, oils obtained from different extraction methods comply with said report (11, 21).

Table 3. Monounsaturated fatty acids in oils (sacha inchi, sesame, and peanut) obtained by cold and hot pressing.

Tabla 3. Ácidos grasos monoinsaturados presentes en aceites (sacha inchi, ajonjolí y maní) obtenidos por diferentes métodos de extracción (prensado en frío y en caliente).

		Oilseeds + Extraction Method					
		S.I + C.P	S.I + H.P	S.M + C.P	S.M + H.P	P.N + C.P	P.N + H.P
Palmitoleic acid	C16:1	0.00^{A}	0.13^{B}	0.00^{A}	0.23^{C}	0.00^{A}	0.00^{A}
Oleic acid (omega 9)	C18:1	8.72^{A}	9.56^{B}	32.75^{C}	35.14^{D}	49.34^{E}	50.61^{F}
Eicosenoic acid	C20:1	0.10^{B}	0.16^{C}	0.00^{A}	0.00^{A}	0.90^{D}	0.91^{D}
Nervonic acid	C24:1	0.00^{A}	0.00^{A}	0.14^{B}	0.00^{A}	0.01^{A}	0.00^{A}
Total Saturated Fatty Acids		8.82^{A}	9.85^{B}	32.89^{C}	35.37^{D}	50.25^{E}	51.52^{F}

Different letters represent statistically significant differences (Tukey $p < 0.05$).
Diferentes letras representan diferencias estadísticamente significativas (Tukey $p < 0,05$).

Polyunsaturated Fatty Acids

Oils derived from various oilseeds constitute a significant source of polyunsaturated fatty acids, particularly linoleic acid (C18:2, omega-6) and alpha-linolenic acid (C18:3, omega-3). Our results showed that sacha inchi oil, cold-pressed or hot-pressed, presented the highest concentrations of polyunsaturated fatty acids, with 84.36 g/100 g and 82.55 g/100 g, respectively. In contrast, hot-pressed peanut oil showed a significantly lower concentration, reaching 30.83 g/100 g (table 4). These findings underline the critical influence of extraction methods on preserving polyunsaturated fatty acids in oilseeds. Comparatively, these results exceeded values reported for avocado oil (*Persea americana)* in Ecuador (27), with total polyunsaturated fatty acid content of 62.33 g/100 g, even considering genotype and extraction conditions. The consumption of polyunsaturated fatty acids prevents various chronic diseases, like diabetes mellitus, obesity and cardiovascular diseases. These fatty acids activate the PPARα receptor (peroxisome proliferator-activated receptor alpha), which stimulates lipid oxidation, reduces insulin resistance and prevents hepatic steatosis (33).

Table 4. Polyunsaturated fatty acids in oils (sacha inchi, sesame, and peanut) obtained by cold and hot pressing.

Tabla 4. Ácidos grasos poliinsaturados presentes en aceites (sacha inchi, sésamo y maní) obtenidos por diferentes métodos de extracción (prensado en frío y en caliente).

		Oilseed + Extraction method					
		S.I + C.P	S.I + H.P	S.M + C.P	S.M + H.P	P.N + C.P	P.N + H.P
Linoleic acid (omega 6)	C18:2	27.38^{B}	25.57^{A}	51.81^{F}	47.58^{E}	31.95^{D}	30.47^{C}
Alpha-linolenic acid (omega 3)	C18:3	56.98^{E}	56.98^{E}	0.55^{D}	0.43^{C}	0.23^{A}	0.36^{B}
Total Saturated Fatty Acids		84.36^{F}	82.55^{E}	52.36^{D}	48.01^{C}	32.18^{B}	30.83^{A}

Different letters represent statistically significant differences (Tukey $p < 0.05$).
Diferentes letras representan diferencias estadísticamente significativas (Tukey $p < 0,05$).

Conclusions

This study demonstrated that oilseed type and extraction method significantly influenced bromatological characteristics (pH, acidity, peroxide index, relative density, and ash), except moisture content. Regarding fatty acid profile, sesame and peanut oils (both cold-pressed and hot-pressed) are excellent sources of monounsaturated fatty acids, with higher concentrations of omega-9 than sacha inchi oil. On the other hand, sacha inchi oil constitutes a source of polyunsaturated fatty acids, particularly omega-3 and omega-6. Consequently, these oilseeds may enrich the human diet, while offering industrial and food applications.

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