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Research Article

Fatty Acid Profile and Chemical Composition of Oil from Six Varieties of Lupine (*Lupinus mutabilis*) Consumed in Peru

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Background. The characterization and evaluation of the nutritional composition of lupine (*Lupinus mutabilis*) seeds has a long history. However, the determination of the fatty acid profile has only been carried out in a few varieties. *Objective*. This study determined the fatty acid profile and chemical composition of the oil of six varieties of lupine consumed in Peru. *Methods*. The extraction of oil from each lupine variety was carried out using the Soxhlet method. Fatty acids, moisture, acidity index, free fatty acids, peroxide value, iodine value, saponification value, and density were determined using official AOAC methods. *Results*. In general, the average values of saturated fatty acids are lower than those of unsaturated fatty acids. Among the monounsaturated fatty acids (MUFA), oleic acid (C18:1) was the most representative, with values ranging from 41.83% to 54.33%. The "Andenes" variety showed an average oleic acid value of 54.60% compared to the other varieties. The composition of polyunsaturated fatty acids (PUFA) was dominated by linoleic acid (C18:2), and the variety "Cholo fuerte" reported higher values (34.70%) compared to the other varieties. Likewise, the highest average PUFA was 36% and was observed in the "Cholo fuerte" variety. The concentration of linolenic fatty acid (C18:3) ranges from 2.1% for the "Andenes" variety to 2.9% for the common lupine. Additionally, the mean content of linolenic (ω-6) and linoleic (ω-3) acids was 2.33 and 30.89% (13 : 1 ratio), respectively, with the consequent ratio of ω-6/ω-3 fatty acids at the mean level of 0.08. All physicochemical characteristics of lupine seed oil are in accordance with the requirements for edible oils. *Conclusion*. These findings make the six lupine varieties a new source of promising food components of high nutritional value.

1. Introduction

Lupine (*Lupinus mutabilis*), also known as tarwi, is a legume of high nutritional value [1]. It is grown mainly at 1,500 meters above sea level in Andean countries such as Peru, Colombia, Ecuador, Bolivia, Venezuela, Chile, and Argentina [2]. In particular, it was used by the ancient Peruvians as an important part of their daily diet. However, since approximately 500 years ago, lupine cultivation, like other Andean grains, has declined considerably [3]. It is a vegetable whose seed is mainly used in animal feed [4]; however, its seeds are used for human consumption in

different countries of the world, including Peru, particularly in the Andean region [5].

Lupine seeds are characterized by their high content of nutrients, such as proteins, lipids, vitamins, minerals, and biologically active elements [6]. In fact, it is one of the Andean species that occupies one of the first places among native foods with a high oil content and has been shown to provide several health benefits [5]. Previous research on different genotypes reports protein content ranging from 41 to 51%, while lipid content ranges from 14 to 24% [2, 7]. On the other hand, lupine contains genetic diversity; in the Andean regions of Peru, several species of the genus *Lupinus* have been identified [7]. However, there is a constant loss of biological diversity of this plant, which is why its conservation is necessary [3].

Several studies have described the nutritional properties of lupine seeds [1, 8]. However, the nutritional composition is variable according to the different lupine varieties, which are influenced by factors such as genetic variability, climatic factors, and soil [9, 10]. In addition, to our knowledge, few studies have elucidated the nutritional composition and characterization of various varieties of *Lupinus mutabilis* seeds. Therefore, studies of characterization and identification of the fatty acid profile allow a revaluation and use in the formulation of new diets and healthy food products that respond to the needs and realities of the Peruvian population. In addition, the production and commercialization of grain represent a source of work and economic income for farmers and indigenous populations dedicated to its cultivation [11]. Therefore, the objective of this study was to determine the acid profile and oil chemical composition of six varieties of *Lupinus mutabilis* consumed in Peru.

2. Material and Methods

2.1. Experimental Materials. Several local varieties of common lupine (*L. albus ssp. albus L.*) cultivated and marketed in Peru were used, including "Cholo fuerte," "Andenes," "Yunguyo," "Patón grande," and "Alta gracia." These varieties were acquired in a local market in the city of Carhuaz, located in the highlands of the Department of Ancash (Peru).

2.2. Oil Extraction. Oil extraction from lupine seeds was performed by the Soxhlet method and applying the procedures of AOAC 920.039 [12]. Oil content was determined by comparing the weights of seed samples of approximately 5 g before and after removal by Soxhlet with petroleum ether for 4 hours. Oil content was determined by comparing the weights of approximately 5 g of seed samples before and after extraction through Soxhlet for 4 h using hexane with a solvent boiling point between 68 and 70°C. A rotary evaporator (Rotavapor R-210, BUCHI) was used for solvent distillation at 45°C under vacuum. The residue was weighed and stored at −20°C until further analysis [13].

2.3. Fatty Acid Analysis. Fatty acid methyl esters (FAME) in the sample were determined according to the AOCS Official Method Ce 1h-05 [14]. A 1 mL sample of oil was placed in a tube, and 1 mL of sodium methylate was added to the mixture. The sample was left at room temperature overnight, and then 0.25 mL of isooctane was added. A 2 μL sample of the mixture was injected into the gas chromatograph. Fatty acid composition was determined by gas-liquid chromatography (GC) performed on a Fison GC equipped with a flame ionization detector (FID) and fitted with a FFAP-DF fused capillary column (25 m × 0.25 mm DI). The detector was operated at 260°C and the injector (split 50 : 1, V_{inj}: 2 μL) at 250°C. The column used in the analysis was DB-23 (J&W Scientific, Folsom, CA, EE. UU) (50% cyanopropyl-poli (methylsiloxane), 60 m × 0.25 × 0.25 μm). The column was heated ballistically from 150 to 200°C at a rate of 5°C min^{-1}. The inlet pressure of the carrier gas (helium) was 0.15 MPa, and the flow rate was 1 mL/min. Fatty acids were identified by retention time relative to the authentic standard (Sigma, 18918). The certified 37-component FAME mix (AccuStandard, Inc., 125 Market Street, New Haven, CT 06513) was used as a reference standard.

2.4. Physicochemical Analysis. Moisture, acidity index, free fatty acids, peroxide value, iodine value, saponification value, and density were analyzed by official AOAC methods [15, 16]. To evaluate the degree of lipid hydrolysis, free fatty acids were determined as % m/m of oleic acid [17]. As indices of primary and secondary oxidation, peroxide indices were evaluated, respectively (method 2.504) [18].

2.5. Statistical Analysis. All sample measurements were performed considering a minimum of triplicate analysis ($n = 3$). A one-way analysis of variance (ANOVA) with Duncan's posthoc multiple comparisons was used for statistical comparisons. All data were expressed as mean value (M) ± standard deviation (SD). Analyses were performed using the IBM SPSS statistical software package (SPSS Inc., Chicago, IL, USA). Values of $p \leq 0.05$ were considered statistically significant.

3. Results and Discussion

In this study, the determination of the fatty acid profile and oil chemical composition of six lupine varieties was carried out, which included physicochemical characterization, saturated, monounsaturated, polyunsaturated, and trans fatty acid content.

3.1. Total Fat. The percentage of total fat in the lupine grain of the "Andenes" variety is higher (21.16 ± 0.03%) in relation to the other varieties analyzed in the current study (Table 1). The range of total fat was between 18.38 ± 0.22% and 21.16 ± 0.03%. These values are similar to those reported (20.4%) in similar studies [19–21]. However, specifically, the value reported for the "Andenes" variety was lower than that observed (29.2%) in the study conducted by Pascual-Chagman et al. [8]. It is worth mentioning that, according to the findings of a study carried out in Europe, fats

Table 1: Physicochemical analysis of lupine varieties.

Physicochemical analysis	Cholo fuerte	Andenes	Yunguyo	Patón grande	Alta gracia	Common lupine
Total fat (%)	18.38 ± 0.32^{a}	21.16 ± 0.11^{b}	20.38 ± 0.15^{bcd}	19.80 ± 0.36^{d}	18.80 ± 0.27^{a}	18.38 ± 0.45^{a}
Moisture (%)	0.35 ± 0.11^{a}	0.32 ± 0.23^{a}	0.36 ± 0.4^{a}	0.28 ± 0.35^{a}	0.31 ± 0.09^{a}	0.27 ± 0.02^{a}
Acidity index (mg·KOH/g)	2.30 ± 0.06^{a}	2.36 ± 0.24^{a}	2.45 ± 0.36^{a}	2.52 ± 0.21^{a}	2.45 ± 0.16^{a}	2.36 ± 0.16^{a}
Free fatty acids (%)	1.76 ± 0.02^{a}	1.63 ± 0.12^{a}	1.71 ± 0.12^{a}	1.74 ± 0.24^{a}	1.69 ± 0.51^{a}	1.65 ± 0.51^{a}
Peroxide value ($mEq{\cdot}O_2$)/kg of the sample	2.84 ± 0.05^{a}	2.92 ± 0.26^{a}	3.09 ± 0.3^{a}	3.21 ± 0.22^{a}	2.78 ± 0.26^{a}	2.65 ± 0.28^{a}
Iodine value (mg·I2/g)	68.81 ± 0.01^{a}	61.01 ± 0.16^{b}	65.87 ± 0.11^{c}	67.42 ± 0.11^{d}	68.34 ± 0.36^{a}	69.33 ± 0.36^{ae}
Saponification index (mg·KOH/g)	183.07 ± 0.12^{a}	181.2 ± 0.02^{b}	179.91 ± 0.23^{c}	186.45 ± 0.2^{d}	183.79 ± 0.04^{e}	186.23 ± 0.16^{fd}
Density at 25°C	0.91 ± 0.22^{a}	0.92 ± 0.01^{a}	0.91 ± 0.05^{a}	0.91 ± 0.06^{a}	0.92 ± 0.05^{a}	0.92 ± 0.06^{a}

Note. Results are expressed as means ± standard deviation ($n = 3$). The different superscripts in the same row indicate statistically significant differences ($p < 0.05$).

constitute one of the main macronutrients with the highest concentration in lupine seeds, evidencing 15.4% of this macronutrient [22]. On the other hand, among lupine varieties, the fat content in raw grains can vary between 13.0 and 24.6% and in debittered grain between 8.9 and 20.4% [23]. In any case, it is possible that the differences observed with respect to other authors are due to the varieties studied, the seasonality of the harvest, as well as the geographical conditions in which they grow [8]. The nutritional attributes of lupine seeds are similar to those of soybean, which is another legume, particularly with respect to high fat content [24].

3.2. Moisture. The characterization of the different varieties of lupine seeds (tarwi) consumed in Peru is shown in Table 1. It was found that the moisture content ranged between 0.27 ± 0.02 and $0.36 \pm 0.4\%$, with the variety "Yunguyo" having the highest value ($0.36 \pm 0.4\%$), and no significant differences were found with the common lupine ($0.27 \pm 0.02\%$) (Table 1). Moisture contents are close to previous findings found in a study that analyzed the characterization of the "Andenes" variety grown in Peru ($0.4 \pm 0.0\%$) [8].

3.3. Acidity Index. The acidity index range was between 2.30 ± 0.06 and 2.52 ± 0.21 mg·KOH/kg (Table 1), which shows a value lower than the maximum limit established for edible oils (4.0 mg·KOH/g). All varieties met these requirements. In contrast, these values are slightly lower than those found by Pascual-Chagman et al. [8] (3.2 mg·KOH/g) for the variety "Andenes." On the other hand, Siger et al. [9] found that only two oils of the varieties analyzed met the requirements, alluding that this could be due to the fact that they had used the Soxhlet extraction method with n-hexane as the solvent, which could alter the quality of the oil. In the current study, oil extraction was carried out using the same method.

3.4. Peroxide Index. This study also determined the peroxide index (Table 1), which is related to the primary oxidation products. The values found ranged from 2.65 ± 0.28 to 3.21 ± 0.22 $mEq{\cdot}O_2$/kg. This range is well below the maximum limit established by Codex Alimentarius (15 $mEq{\cdot}O_2$/kg) [25]. These results are close to those reported by Pascual-Chagman et al. [8] for the variety "Andenes" (2.7 $mEq{\cdot}O_2$/k) and are higher than those reported by Alamri [26] (1.97 ± 0.18 mEq/kg) and Khalid and Elhardallou [27] (1.89 ± 0.29 mEq/kg). They are also lower than other values reported after analysis of the "Yunguyo" variety (5.1 $mEq{\cdot}O_2$/kg) [28].

3.5. Free Fatty Acids. The percentage of free fatty acids ranged from 1.63 ± 0.12 to $1.76 \pm 0.02\%$ (Table 1). Similar values were found for the variety "Andenes" (1.6%) in another study [8] and were slightly lower than those reported (1.9%) by other authors who studied the "Andino 450" variety [11, 29].

3.6. Density at 25°C. Density at 25°C was also evaluated in the current study, and the values found ranged from 0.91 ± 0.22 g/mL for the "Cholo fuerte" variety to 0.92 ± 0.06 g/mL for the common lupine (Table 1) and are within the limits of the requirements indicated for vegetable oils according to the Codex Alimentarius Commission [25]. These values are consistent with the findings of Pascual-Chagman et al. [8], who evaluated the density of the "Andenes" variety at 25°C (0.90 g/mL). Moreover, other authors who determined the density at 20°C found similar values, 0.92 g/mL [11] and 0.92 g/mL [28]. Density values < 1 are desirable characteristics of edible oils for human consumption [30].

3.7. Iodine Value. The iodine value is significantly different between the varieties "Andenes" (61.01 ± 0.16 $mg{\cdot}I_2$/g), "Yunguyo" (65.87 ± 0.11 $mg{\cdot}I_2$/g), and "Patón grande" (67.42 ± 0.11 $mg{\cdot}I_2$/g), with respect to the common lupine (69.33 ± 0.36 $mg{\cdot}I_2$/g). However, the varieties "Cholo fuerte" (68.81 ± 0.01 $mg{\cdot}I_2$/g) and "Alta gracia" (68.34 ± 0.36 $mg{\cdot}I_2$/g) are not significantly different from the common lupine (Table 1). The iodine index content ranged from 61.01 ± 0.16 to 69.33 ± 0.36 $mg{\cdot}I_2$/g. These values are higher than the content (58 ± 2.0 $mg{\cdot}I_2$/g) found by Pascual-Chagman et al. [8], when studying the physical and chemical characteristics of the "Andenes" variety. However, for the same variety (Andenes), another study conducted by Salvatierra-Pajuelo [31] using lupine from the Ancash region (Peru), reported

a value of 109.75 ± 0.93 mg·I_2/g. The iodine value measures the state of unsaturation of fatty acids. It is argued that the lower the degree of saturation, the higher the iodine value, and the lower the degree of saturation, the lower the saturated fat content [32]. The iodine value found in the present study may be due to the higher content of unsaturated fatty acids in the seed oil of the different lupine varieties evaluated (Table 1).

3.8. Saponification Index. The saponification index was more representative in the variety "Patón grande" (186.45 ± 0.2 mg·KOH/g) and was not significantly different with respect to the common lupine (186.23 ± 0.16 mg·KOH/g) (Table 1). In addition, the saponification value ranged from 179.91 ± 0.23 to 186.45 ± 0.2 mg·KOH/g. The saponification value of lupine oil was lower than the results reported by Petkova et al. [33] (231.0 ± 2.0 mg·KOH/g) and Khalid and Elhardallou [27] (193.54 y 190.0 mg·KOH/g). It is worth mentioning that the saponification index values found in the current study are within the limits established by the Codex Alimentarius Commission, which considers values between 184 and 196 mg·KOH/sample to be normal [25].

4. Saturated Fatty Acids (SFA)

4.1. Palmitic Acid. This study also evaluated the relative amount of saturated fatty acids (SFA) present in the different lupine varieties. The SFA with the highest percentage was palmitic acid, whose values fluctuated between 8.83% for the "Andenes" variety and 11.93% for the "Patón grande" variety (Table 2). The "Patón grande" variety had the highest content (11.93%). Furthermore, Petkova et al. [33] found that the main representative of SFA was palmitic acid (11.9%). Similarly, in the study by Siger et al. [9], the most representative SFA was palmitic acid; however, the results reported percentages ranging from 4.55 to 11.75%. On the other hand, in the present study, SFA averages are higher in the varieties "Yunguyo" (20.7%) and "Patrón grande" (21.3%) (Figure 1). These findings are similar to the SFA composition of lupine seed oils grown in Bulgaria where the content was also 20.4% as reported by Petkova et al. [33]. However, it is worth mentioning that the SFA values observed in the current study, as well as those found by Petkova et al. [33] are lower with respect to monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) percentages. Other studies have also reported that palmitic acid was the most abundant SFA in lupine oil [34].

4.2. Stearic Acid. Similarly, another more representative SFA was stearic acid, which showed values between 5.90% (common lupine variety) and 8.6% ("Yunguyo" variety) (see Table 2). Moreover, Pascual-Chagman et al. [8] reported a content of 7.10% for the variety "Andenes." This value was similar to that found in the current study for the same variety (7.7%). However, the evaluation of the Egyptian lupine seed [27] and other varieties evaluated by Al-Amrousi et al. [34] showed much lower values, 1.711% and 1.77%, respectively. It is worth mentioning that, generally, lupine oils are characterized by a balanced fatty acid composition with a total saturated fatty acid content of 10% and a total unsaturated fatty acid content of 90% [10, 35, 36].

5. Monounsaturated Fatty Acids

5.1. Oleic Acid. On the other hand, among the MUFA, oleic acid was the most representative, with values ranging from 41.83% to 54.33% (see Table 2); the "Andenes" variety showed a value higher than 50% (54.33%). This range is comparable with the findings reported by Green and Oram [37] (43.6–54.4%) and Boschin et al. [38] (40.8–50.5%). Likewise, according to the values provided by Siger et al. [9], the oleic acid content varied from 24.61% for the variety "Parys" to the cultivar *Lupinus luteus*, while for the variety "Butan" of the cultivar *Lupinus albus,* the average was 62.77%. On the other hand, in the present study, the average oleic acid content was 45.6% (Table 2). This value was similar to the content found in the Egyptian variety (45.0%) [27] and the one from the Ancash region (Peru) reported by Salvatierra-Pajuelo [31] (45.5%) and was lower compared to the content observed for white lupine (55.7%) [10], Russian lupine (57.0%) [39], and the "Andenes" variety (56.2%) reported by Pascual-Chagman et al. [8]. In addition, it was superior compared to the content of yellow lupine (29.4%), narrow-leaf (39.4%), and Andean lupine (44.8%) [40]. Also, the variety "Andenes" showed the highest average MUFA value compared to the other varieties (54.6%) (see Figure 1). These values are higher than those reported for the variety grown in Bulgaria (33.5%) [33]. Oleic acid plays an important role in the prevention of some chronic noncommunicable diseases, such as atherosclerosis, thrombosis, and some types of cancer [34].

6. Polyunsaturated Fatty Acids

6.1. Linoleic Acid. Additionally, this study analyzed the PUFA composition, which was dominated by linoleic acid (ω-6). The lowest value of ω-6 was observed in the variety "Andenes" (23.63%). The variety "Cholo fuerte" reported higher values (34.70%) compared to the other varieties (see Table 2). The highest average PUFA value was 36% and was observed in the variety "Cholo fuerte" (Figure 1). The values presented are in agreement with the ω-6 content (35.5%) reported by Salvatierra-Pajuelo [31]. In addition, the values reported are consistent with the contents found in two studies that analyzed the Egyptian variety, 33.2% [10] and 34.48% [34], respectively. Similarly, the values found for ω-6 are similar to the following contents, 24.9% and 23.5% reported by Khalid and Elhardallou [27] and Pascual-Chagman et al. [8], respectively. However, lower values are found for the white lupine variety, showing a mean content of 19.6% [10]. In fact, the lowest range of linoleic acid contents (7.79–15.81) was reported by Boschin et al. [38]. The ω-6 fatty acids have the function of controlling and reducing the cholesterol that saturated fats accumulate in the body [41].

Table 2: Content (relative amount, %) of fatty acids in the form of methyl esters (FAME) present in the different varieties of lupine oil.

Fatty acid	Cholo fuerte	Andenes	Yunguyo	Patón grande	Alta gracia	Common lupine
Saturated						
Lauric (C12:0)	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$
Myristic (C14:0)	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}
Palmitic (C16:1)	11.07 ± 0.45^{a}	8.83 ± 0.06^{b}	10.23 ± 0.25^{c}	11.93 ± 0.15^{d}	10.63 ± 0.15^{ac}	11.2 ± 0.10^{ac}
Pentadecanoic (C15:0)	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$
Heptadecanoic (C17:0)	0.1 ± 0.01^{a}	$<0.1 \pm 0.00^{a}$	0.1 ± 0.01^{a}	$<0.1 \pm 0.01^{a}$	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}
Stearic (C18:0)	6.07 ± 0.06^{a}	7.7 ± 0.00^{b}	8.6 ± 0.00^{c}	7.33 ± 0.06^{d}	6.6 ± 0.00^{e}	5.9 ± 0.00^{f}
Arachidic (C20:0)	0.63 ± 0.06^{a}	0.8 ± 0.00^{b}	0.8 ± 0.00^{cb}	0.8 ± 0.00^{db}	0.7 ± 0.00^{e}	0.6 ± 0.00^{a}
Heneicosanoic (C21:0)	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	0.07 ± 0.01^{a}	$<0.1 \pm 0.01^{a}$	0.1 ± 0.01^{a}
Behenic (C22:0)	0.73 ± 0.06^{a}	0.8 ± 0.00^{b}	0.7 ± 0.00^{a}	0.9 ± 0.00^{c}	0.8 ± 0.00^{db}	0.7 ± 0.00^{a}
Tricosanoic (C23:0)	0.1 ± 0.01^{a}	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	$<0.1 \pm 0.01^{a}$	0.1 ± 0.01^{a}
Lignoceric (C24:0)	0.1 ± 0.01^{a}	0.2 ± 0.01^{b}	0.1 ± 0.01^{a}	0.2 ± 0.01^{cb}	0.17 ± 0.06^{abc}	0.2 ± 0.01^{dbc}
Monounsaturated						
Palmitoleic (C16:1)	0.2 ± 0.01^{a}	0.1 ± 0.00^{b}	0.2 ± 0.01^{a}	0.2 ± 0.01^{a}	0.2 ± 0.01^{a}	0.1 ± 0.01^{cb}
Oleic (C18:1n9c)	42.33 ± 0.15^{a}	54.33 ± 0.06^{b}	43.6 ± 0.10^{c}	41.83 ± 0.06^{d}	43.27 ± 0.06^{e}	48.3 ± 0.00^{f}
Eicosenoic (C20:1n9)	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}	0.1 ± 0.01^{a}
Polyunsaturated						
Linoleic (C18:2n6c)	34.70 ± 0.1^{a}	23.63 ± 0.06^{b}	32.03 ± 0.06^{c}	32.8 ± 0.00^{d}	33.73 ± 0.06^{e}	28.43 ± 0.06^{f}
Linolenic (C18:3n3)	2.20 ± 0.00^{a}	2.1 ± 0.00^{b}	2.3 ± 0.00^{c}	2.3 ± 0.00^{dc}	2.2 ± 0.00^{e}	2.9 ± 0.00^{f}

Note. Results are expressed as means ± standard deviation ($n = 3$). The different superscripts in the same row indicate statistically significant differences ($p < 0.05$).

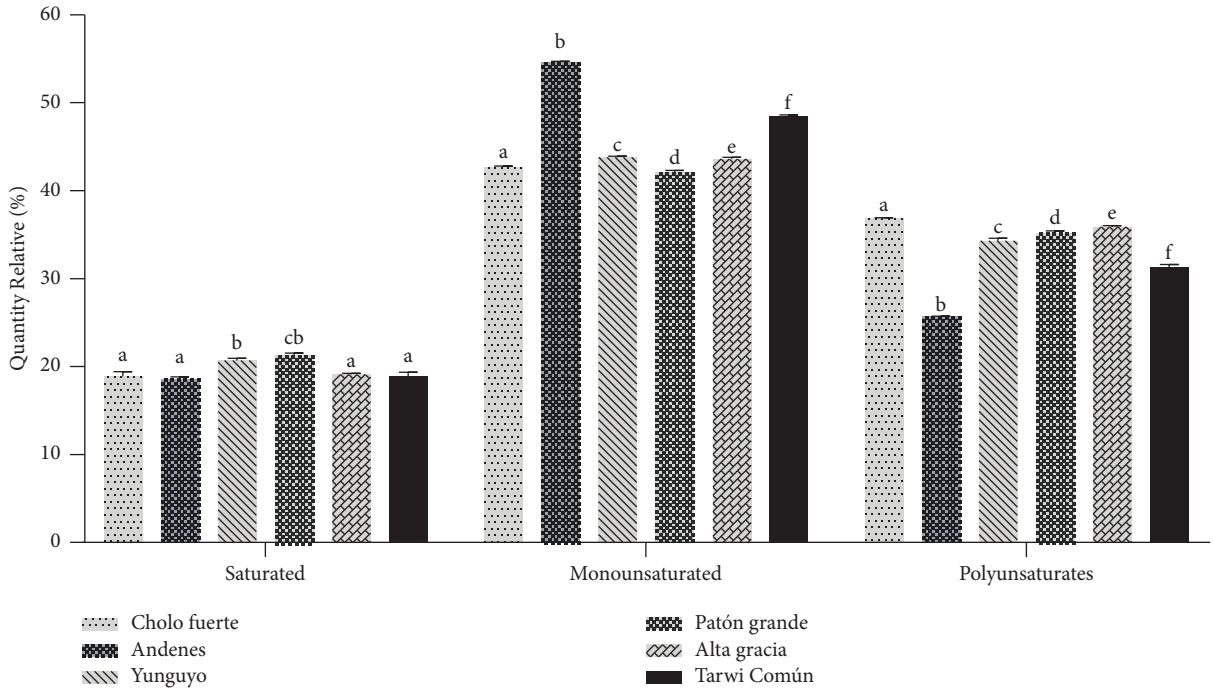

Figure 1: Relative amount (%) of saturated, monounsaturated, and polyunsaturated fatty acids in the form of methyl esters (FAME).

6.2. Linolenic Acid. The concentration of essential linolenic fatty acid (ω-3) ranged from 2.1% for the "Andenes" variety to 2.90% for the common lupine (Table 2). Ranges reported by Petkova et al. [33] for the variety "Boregine" grown in southern Bulgaria showed values ranging from 1.0 to 3.8%. Similarly, the linolenic acid content of Andean lupine seeds was 2.6% [42] and 2.86% [43]. These ranges are lower than the contents reported by Rybiński et al. [10] and Boschin et al. [38], 5.6–12.8% and 5.31–10.36%, respectively. Other literature evidence reported higher values than ours in yellow lupine (4.20%) [42], narrow-leaf lupine (6.2%) [44], and in studies by Rybiński et al. [43] (4.9% and 8.13%), Al-Amrousi et al. [34] (6.58%), and Mierlita [45] (8.88%). In any case, according to Khalid and Elharadallou [27] and Hassanein et al. [46], lupine oil has a significant concentration of ω-3 ranging from 9.95% to 14.9% [34]. The other fatty acids showed negligible contents (0.1–1.0%). On the other hand, regarding average

PUFA values, the variety "Cholo fuerte" has the highest content (36%), followed by "Alta gracia" (35.90%), "Patón grande" (35.20%), "Yunguyo" (34.30%), and common lupine (31.30%) (Figure 1).

A higher PUFA content represented by linoleic (ω-6) and linolenic (ω-3) fatty acids is considered desirable for human food [10]. It is suggested that, within the diet, biologically active fatty acids play an important role in the prevention of noncommunicable diseases and maintenance of health [47, 48]. Both fatty acids (ω-6 and ω-3) are necessary because the human body cannot produce them; consequently, they must be obtained from food [34]. Therefore, in many countries, there is a growing interest in promoting the intake of foods with higher amounts of ω-3, particularly [10]. In the context of food and human health, the ratio of ω-6/ω-3 fatty acids is important and should be 1 : 1 to 4 : 1, whereas in the Western diet it is estimated to be 10 : 1 to 30 : 1 [49]. In the present study, the difference in unsaturated fatty acid composition among the varieties analyzed showed a ratio of ω-6/ω-3 acids with values ranging from 9.8 ("common lupine") to 15.7 ("Cholo fuerte"). Additionally, the mean linolenic and linoleic acid contents were 2.33 and 30.89% (13 : 1 ratio) with the consequent ratio of ω-6/ω-3 fatty acids at the mean level of 0.08. However, findings from other studies reported a mean linolenic and linoleic acid content of 10.07 and 19.62% (2 : 1 ratio) with a consequent ω-6/ω-3 fatty acid ratio at the mean level of 0.51 [10].

7. Conclusion

The findings found in this study confirmed that the lipid profile and oil chemical characterization of six varieties of lupines consumed in Peru have a valuable composition. Lupine oil is presented as a desirable alternative source of oil for human food, demonstrating a long shelf life due to its lower degree of unsaturation and high oxidative stability, reporting low ranges of acid and peroxide values. The mean content of saturated fatty acids was lower compared to unsaturated fatty acids. Oleic acid was the most representative among the MUFA. The "Andenes" variety showed a higher mean oleic acid value than the other varieties. The linoleic acid content was the highest among the PUFA; the "Cholo fuerte" variety reported higher values than the other varieties. Additionally, the ω-6 and ω-3 ratios were 13 : 1. All physicochemical characteristics of lupine seed oil were in accordance with the requirements for edible oils. These findings make the six lupine varieties a new source of a promising natural food component with high nutritional value.

Data Availability

Data supporting the conclusions of this research are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

AS-M and GP-C designed the study; JS-C-O and ENM developed the study methods; YEC-M and JS conducted the formal analysis of the study; JS wrote the original draft; AH-J, EVT, and JS reviewed and edited the study. All authors have read and approved the final version of the manuscript.

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