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Quality indicators and characterization of pumpkin seed oil from the macre variety (*Cucurbita maxima Duchesne*) extracted by the expeller method

Indicadores de calidad y caracterización del aceite de semilla de zapallo de la variedad macre (*Cucurbita maxima Duchesne*) extraído por el método expeller

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ABSTRACT

Background: Cucurbit seeds, found in pumpkins and squashes, are part of the discarded material and contribute to the increase of solid waste in the industry, homes and points of sale, when they are separated from the edible part of the fresh fruit during its processing for consumption and marketing. However, these seeds possess nutritional properties that can be used for the benefit of the population. **Objectives**: The objective of this research was to characterize the pumpkin seeds of the macre variety, *Cucurbita maxima Duchesne* species, extract their oil using the expeller method, and determine the quality indicators for human consumption. **Methods**: The pumpkin seeds were selected removing the unusable material. They were then dried to a moisture content of approximately 13.25%, then peeled and characterized. Oil extraction was carried out using the continuous-flow expeller method, evaluating the influence of moisture content and particle size on the yield. The extracted oil was subjected to quality analysis, determining iodine value, saponification value, refractive index, and acid value, to evaluate its quality and compare it with other commercially available edible oils. **Results**: Pumpkin seeds had a fat content of 48.88% and a protein content of 41.94%. Regarding oil extraction, the best yield of 41.50% was obtained at a moisture content of 5.0%. Likewise, an optimal yield of 41.88% was achieved using whole seeds at the same moisture level, indicating that the reduction at moisture positively influenced yield, while particle size had no significant effect, since it was not necessary to reduce the size of the seeds. The quality attributes of the oil showed the following values: iodine value of 116.02 g I_2/100 g, saponification value of 184.45 mg KOH/g, refractive index of 1.471 and acid value of 0.912 mg KOH/g. **Conclusions**: It is concluded that pumpkin seeds of the macre variety contain a high fat content and optimal oil yields when processed at low moisture content using whole seeds. In addition, the quality indicators accredit that extracted oil is suitable for human consumption.

Key words: Cucurbitaceae, pumpkin seeds, oil extraction yield.

RESUMEN

Antecedentes: Las semillas de las cucurbitáceas, presentes en calabazas y zapallos, forman parte del material de descarte y contribuyen al incremento de residuos sólidos en la industria, hogares y puntos de venta, al separarse de la parte comestible del fruto fresco durante su procesamiento para consumo y comercialización. No obstante, estas semillas poseen propiedades nutricionales que pueden ser aprovechadas en beneficio de la población. **Objetivos**: El objetivo de la presente investigación fue caracterizar las semillas de zapallo de la variedad macre, especie *Cucurbita máxima Duchesne*, extraer su aceite mediante el método expeller y determinar los indicadores de calidad para el consumo humano. **Métodos**: Las semillas de zapallo fueron seleccionadas, descartando el material inservible. Posteriormente, se procedió a su secado hasta alcanzar una humedad aproximada de 13,25% y al pelado de las mismas, para luego caracterizarlas. La extracción del aceite se realizó mediante el método expeller a flujo continuo, evaluando la influencia de la humedad y la granulometría en el rendimiento. El aceite obtenido se sometió a un análisis de calidad, determinándose los índices de yodo, saponificación, refracción y acidez, con el fin de evaluar su calidad y compararlo con otros aceites comestibles comercializados. **Resultados**: Las semillas de zapallo presentaron un contenido de grasa del 48,88% y un contenido de proteína del 41,94%. En cuanto a la extracción del aceite, se obtuvo el mejor rendimiento del 41,50% a una humedad del 5,0%. Asimismo, se logró un rendimiento óptimo del 41,88% utilizando semillas enteras con la misma humedad, lo que indica que la reducción de la humedad influyó positivamente en el rendimiento, pero la granulometría no tuvo un efecto significativo, ya que no fue necesario reducir el tamaño de las semillas. Los atributos de calidad del aceite arrojaron los siguientes índices: yodo 116,02 g I_2/100 g, saponificación 184,45 mg KOH/g, refracción 1,471 y acidez 0,912 mg KOH/g. **Conclusiones**: Se concluye que las semillas de zapallo de la variedad macre contienen un alto contenido de grasa, obteniéndose un rendimiento óptimo de aceite con baja humedad y semillas

Palabras clave: Cucurbitáceas, semillas de calabaza, rendimiento de extracción del aceite

1. INTRODUCTION

Peru has been identified as a center of great genetic variability of pumpkins and squashes. In this context, the National Institute for the Defense of Competition and the Protection of Intellectual Property (*Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual* - INDECOPI) has developed an informative guide on the designation of origin of the loche squash from Lambayeque. In addition, the Ministry of the Environment (Ministerio del Ambiente - MINAM) has developed a baseline for the diversity of pumpkins and squashes for biosafety purposes. The National Institute for Agrarian Innovation (*Instituto Nacional de Innovación Agraria* - INIA) and the MOL Augusto Weberbauer Herbarium of the National Agrarian University La Molina have enriched the germplasm bank with samples from four species of the *Cucurbita genus: Cucurbita maxima, Cucurbita moschata, Cucurbita ficifolia,* and *Cucurbita pepo.*

To revalue *Cucurbita* crops as a natural and cultural heritage, their consumption at the family level is promoted, as well as the sustainable use of native biological diversity at three levels: ecosystems, species, and genes. This effort is carried out in collaboration with local and regional governments, the agricultural sector, private institutions, and civil society. In addition, the strengthening of research on this heritage is promoted through academia and other institutions involved.

As a result of the use of cucurbits such as pumpkins and squashes, their seeds are commonly considered waste material, which contributes to the increase in solid waste that affects communities and, consequently, the population. However, these seeds, originating from the agricultural sector, contain valuable compounds that can be utilized, giving them a better use or added value within the production chain. Their utilization not only helps to the reduction of solid waste but also contributes to lowering environmental pollution.

The seeds of cucurbits are of different varieties and species, they come from fruits that are also varied, and they receive distinct names depending on their place of origin, being found in several countries around the world. They are identified as squash, winter squash, summer squash (1), yellow squash, wild squash (2), sweet melon, citrus melon (3), creole pumpkin, macre pumpkin, sambo squash, load squash, zucchini squash (4), Lambayeque loche squash (5), and native squash varieties (6). Among the most common species are Cucurbita pepo *L., Cucurbita maxima ssp. Andreana, Cucurbita ecuadorensis, Cucurbita ficifolia, Cucurbita moschata Duchesne* (4), and *Cucurbita maxima Duchesne* (4,7), the latter being an extremely diverse species (8).

The seeds of the *Cucurbita maxima* species are small, thick, elliptical, inflated or tumescent, tan or cinnamon to light brown in color. They have a smooth or slightly striated or dotted surface, with rounded margins that differ in color from the center of the seed (2,7). Their dimensions vary between 13 and 24 mm in length and 8 to 12 mm in width (2), with a thickness of 6.2 ± 0.7 mm (8) and an approximate weight between 50 and 250 mg (1,8).

The chemical composition of *Cucurbita maxima* seeds varies depending on the geographical origin, the variety of the fruit, the species or subspecies, and the degree of maturity of the fruit. The mineral content, as well as the content of fatty acids and amino acids, also varies. As for the seeds of *Cucurbita ficifolia* (pumpkins), their approximate composition in dry weight is 33.92-40.1% protein, 28.3-31.57% fat, 0.11-4.55% carbohydrates, 16.0-21.97% crude fiber, 3.97-4.3% ash, and 6.75-8.46% moisture. In addition, they contain minerals such as potassium, magnesium, sodium, calcium, iron, manganese, zinc, and copper (3,9). On the other hand, *Cucurbita maxima* (pumpkin) seeds have a chemical composition of 41.22% protein, 23.79% fat, 12.04% carbohydrates, 11.07% crude fiber, 5.01% ash, and 6.87% moisture (10).

The fatty acid content in *Cucurbita ficifolia* (pumpkin) seeds is presented as a percentage of fat in dry weight, including myristic, palmitic, palmitoleic, stearic, oleic, linoleic, α-linolenic, and arachidic acids (9,11). In *Cucurbita maxima* (pumpkin) seeds, palmitic, stearic, oleic, elaidic, linoleic, arachidonic, and eicosanoic acids are found (10). As for amino acids, in g/100g of protein, alanine, arginine, aspartic acid, glutamic acid, phenylalanine, glycine, histidine, isoleucine, leucine, lysine, methionine, serine, threonine, tryptophan, tyrosine, and valine are identified in *Cucurbita ficifolia* seeds (12).

Studies on pumpkin seeds have linked their medicinal benefits to human health. It has been shown that possess high antioxidant activity (13). Their consumption, combined with medications for high blood pressure, can have a beneficial therapeutic effect and slow the progression of hypertension (14). Furthermore, the kernel of the *Cucurbita maxima* seed exerts a hepatoprotective effect (15), and due to its content of lycopene and other carotenoids, they are attributed with beneficial physiological properties against prostate cancer (16). They also exhibit antiparasitic activity for the intestine, with anthelmintic, vermifuge, and tenifuge effects (17).

There are several methods of extracting oil from seeds. These include cold pressing, solvent extraction (ethyl alcohol PA 95.5%), and hot extraction using Soxhlet (with n-hexane PA 98.5%). Another notable method is the expeller or mechanical pressing method, which uses a continuously operating screw press or expeller that applies high pressure to the seeds to extract the oil in a single step. The advantage of this method is that the press can have heating zones if the process requires it, and it can also be adapted to different types of seeds by adjusting the rotation speed and nozzle diameter (18). Another advantage of this method is that it is exclusively mechanical and requires no chemical additives, which ensures a healthier and more natural oil that preserves its organoleptic properties, including flavor, smell, and texture. The solid residues from this pressing process are used as feed for livestock, since they are rich in protein.

In Peru, the most commonly consumed fruit containing cucurbit seeds is the macre variety pumpkin, specifically the *Cucurbita maxima Duchesne* species. The objective of this study was to determine the quality indicators of seed oil from this variety, extracted using the expeller method. The specific objectives included the characterization of macre variety pumpkin seeds, oil extraction, characterization of the extracted oil, the determination of the yield, and, finally, the evaluation of quality indices for consumption. In this way, a pumpkin seed oil with quality indices suitable for human consumption can be obtained, given the beneficial properties of cucurbits. The extraction method applied was adequate for characterizing and evaluating yield, considering moisture and particle size distribution. These seeds can be characterized and evaluated to obtain added value.

2. MATERIALS AND METHODS

The information on cucurbit seeds, their chemical composition, and oil extraction using the expeller method was contextualized. Subsequently, the experimentation was carried out according to the experimental design, obtaining the results, which were discussed to finally reach the conclusions of the research.

2.1 Materials

Samples of pumpkin seeds of the macre variety, of the *Cucurbita* genus, and of the *Cucurbita maxima Duchesne* species were used, according to the classification of the Ministry of the Environment (4) and the identification of the National Institute for the Defense of Competition and the Protection of Intellectual Property (5). These seeds are waste products after using the fruit. 2000 g of fresh seeds were manually cleaned to remove immature, damaged, those of insufficient size, and other foreign materials. They were then placed in a horizontal solar dryer at 60 °C until an average moisture of 13.25% was reached, to facilitate peeling. Peeling was performed using small blades, and the dried and peeled seed samples were placed in plastic bags with a hermetic seal, weighing 200 g each, and stored in a refrigerator at 4 °C for later analysis.

2.2 Characterization of pumpkin seeds

The organoleptic characteristics evaluated in the pumpkin seeds included color, odor, and appearance. Among the physical and chemical determinations, the following tests were performed moisture content using the constant weight oven method, fat content using the Soxhlet extraction method, and protein content using the Kjeldahl method. All tests were carried out in triplicate.

2.3 Extraction of oil from pumpkin seeds

To evaluate the influence of particle size and moisture content on the oil yield of pumpkin seeds (peeled seeds), extractions were performed at different particle sizes and moisture contents. For oil extraction, samples of dried and peeled seeds were used, which have an average moisture content of 13.25%. Five experiments were conducted using particle size and oil yield as variables, and another five experiments were conducted using moisture content and oil yield as variables.

In the first experimental part, the dried and peeled seeds were ground in a grain mill and sieved using mesh sizes between 10 to 40 US STD. The moisture content was kept constant at 13.25%. The oil was extracted by placing the samples in the hopper of the expeller press, operating at a continuous flow rate and with a press head heating temperature of 50 °C. The pressing was carried out using 200 grams of dried and peeled seeds, as per the experimental design. The oil obtained was vacuum-filtered to remove insoluble impurities, and finally, the volume obtained was measured to characterize it and determine its yield and quality indices.

For the second part, with the optimal grain size, five additional experiments were conducted for the moisture and yield variables. In this phase, the size of the seed was kept constant, and extractions were carried out at different moisture percentages with the aim of determining the optimal moisture percentage and the highest oil extraction yield.

2.4 Determination of the quality of pumpkin seed oil

The organoleptic characteristics evaluated in the pumpkin seed oil were color and odor. The physical and chemical characteristics were assessed using Peruvian Technical Standards (NTP). The relative density was determined using the pycnometer method, according to NTP 209.128:1980. To evaluate the quality index, the acidity index was determined by the NTP 209.005:1968 method, the saponification index by the NTP-ISO 3657:2016 method, the iodine index by the NTP-ISO 3961:2017 method, and the refraction index according to NTP 209.121:1975.

3. RESULTS

The pumpkin seed samples were identified as the macre variety and the Cucurbita maxima Duchesne species, according to the baseline of the Diversity of Peruvian Pumpkin and Squash for Biosecurity Purposes, published by the Ministry of the Environment (4).

3.1 Characterization of pumpkin seeds

The dried and peeled pumpkin seeds were characterized, obtaining results of the proximate chemical analysis, as shown in Table 1. The peeled pumpkin seeds presented an opalescent/fern green coloration and a coarse, rough texture. The analysis revealed a fat content of 48.88% (w/w) on a dry matter (DM) basis and a protein content of 41.94% at 5% moisture.

Table 1. Proximate chemical composition of macre variety pumpkin seeds, *Cucurbita Maxima Duchesne* species.

Component	Average (%)
Moisture	5.00
Fat	48.88
Protein	41.94
Carbohydrates	9.56
Crude fiber	5.50
Ash	5.20

3.2 Extraction of oil from pumpkin seeds

Table 2 presents the oil extraction yield from pumpkin seeds of the macre variety, *Cucurbita maxima Duchesne* species, according to different particle sizes. The best yield was obtained using whole seeds, with an oil yields of 41.50%, which decreased as the degree of grinding increased.

Table 2. Oil extraction yield from pumpkin seeds of macre variety at different particle sizes

Treatment	Granulometry (mm)	Yield (%)
1	0.354	23.61
2	0.841	25.30
3	1.650	28.95
4	Whole	41.50

Table 3 shows the extraction yield as a function of seed moisture content. The highest yield was obtained from seeds with 5% moisture. Yield decreased progressively as seed moisture content increased.

Table 3. Oil extraction yield from pumpkin seeds of the macre variety at different moisture contents

Treatment	Moisture (%)	Yield (%)
1	13.25	35.05
2	11.12	36.86
3	9.31	38.90
4	7.08	40.17
5	5.00	41.80

3.3 Quality indices of pumpkin seed oil

The quality index of edible oils evaluates the organoleptic characteristics, such as color, odor, and aroma. It also assesses aspects such as the determination of the acidity, saponification, iodine, refraction and peroxide values. In the present study, pumpkin seed oil presented an opalescent green color. A good-quality oil must have a low or zero acidity index to be considered in good condition for conservation. The results of the quality indices of the macre variety pumpkin seed oil are presented in Table 4 and refer to the physicochemical characteristics.

Table 4. Quality indices of pumpkin seed oil, macre variety, *Cucurbita maxima* Duchesne species.

Indices	Expeller method
Acidity index (mg de KOH/g)	0.912
Saponification index (mg de KOH/g)	184.450
Iodine index (g I_2/100 g)	119.020
Refraction index	1.471
Density (g/cm^3) a 20 °C	0.920

Table 5 presents the quality indices of different types of edible vegetable oils, which were used as a comparison with the oil extracted from pumpkin seeds.

4. DISCUSSION

4.1 Characterization of pumpkin seeds

The fat content of the macre pumpkin seeds was 48.88%, a value higher than that reported by Artica et al. (2016), whose pumpkin seeds contain 23.79% fat, and values higher than those reported for pumpkin seeds by Shalaby et al. (2020) of 28.3% and Rezig et al. (2012) of 31.57%. The protein content was 41.94%, slightly higher than that reported by Artica et al. (41.22%), Shalaby et al. (40.10%), and Rezig et al. (31.57%) (these last two in the case of pumpkin seeds). The working moisture content was 5% lower than the values reported by the authors mentioned above, which were 6.87%, 5.6% and 8.46%. The carbohydrate content was 9.56%, a very different figure from that reported by Artica et al. (12.04%), while Shalaby et al. (4.55%) and Rezig et al. (0.11%) showed much lower values and were in the form of total sugars. The crude fiber content was 5.50%, a much lower value than that reported by Artica et al. (11.07% for pumpkin seeds), as well as those reported by Shalaby et al. (16%) and by Rezig et al. (21.79%). Finally, the ash content was 5.20%, slightly higher than those reported by the three reference authors (5.01%, 4.3% and 3.9%).

4.2 Extraction of oil from pumpkin seeds

Regarding oil extraction to assess the influence of particle size on yield, the results showed that, for fine particle sizes, the yield was quite low; thus, for a particle size of 0.354 mm, a yield of 23.61% of oil was obtained. Furthermore, due to the fineness of the particles during oil extraction, problems with the accumulation of insoluble impurities arose. On the other hand, with the whole seed, better results were achieved, reaching a yield of 41.50%.

Table 5. Comparison of macre pumpkin seed oil quality indices with other vegetable oils.

Indexes	Pumpkin macre	Soybean	Corn	Sunflower	Olive
Acidity index (mg KOH/g)	0.912	≤ 2.0	≤ 2.0	≤ 2.0	≤ 2.0
Saponification index (mg KOH/g)	184.45	189 - 195	187 - 195	182 - 194	184 – 196
Iodine index (g I_2/100 g)	119.02	124 - 139	103 - 135	94 – 122[b]	75 – 94
Refractive index	1.471	1.466 - 1.470	1.465 - 1.468	1.467 - 1.471[a]	1,4677-1,4705
Density (g/cm^3)	0.92	0.919 - 0.925	0.917 - 0.925	0.909 - 0.915[a]	0.910 - 0.916

Note: a) Data reported are at 25 °C, b) The reported value is medium oleic acid

This result was different from other extraction methods that require prior grinding; for example, Artica et al. (2016) applied cold-press extraction methods, obtaining oil yields of 22.13%, while with ethanol solvent extraction they obtained yields of 24.85%, and in Soxhlet (hexane) extraction they achieved yields of 26.03%. As can be seen, the maximum yield obtained by these authors was by the Soxhlet method, while in the present investigation higher yields were achieved by the expeller method.

Regarding the influence of moisture content on yield, it was observed that oil extraction increases with decreasing moisture, reaching an optimal yield of 41.80% at a moisture content of 5%. There was not much difference with the moisture content reported by Artica et al. (6.87%), Shalaby et al. (6.75%) and Rezig et al. (8.46%).

Regarding the extraction method, in the evaluation of the influence of particle size and moisture on the extraction yield by the continuous flow expeller method, it is observed that in both cases higher yields were generated (41.50% and 41.80%) compared to the results reported by Artica et al., who applied cold pressing extraction methods (22.13%), ethanol solvent extraction (24.85%) and Soxhlet extraction with hexane (26.03%). This shows that the continuous process in the expeller type press is the most suitable method for the extraction of oil from pumpkin seeds. In addition, this method provided the advantage of obtaining a clarified oil with minimal presence of sludge or insoluble impurities.

4.3 Quality indices of pumpkin seed oil

4.3.1 Acidity index (AI)

A good quality oil must have a low or zero acidity index (IA) to be considered in good condition of conservation. In the experiment carried out, a content of 0.912 mg KOH/g of oil was obtained, a value much lower than that reported by Artica et al. (2020), of 2.30-2.709 for pumpkin seed oil and 2.071-2.19 for pumpkin seed oil. On the other hand, Shalaby et al. reported a value of 0.42 for pumpkin seed oil and Rezig et al. reported a value of 7.54 for the same type of oil. The extracted pumpkin seed oil did not show significant increases due to the hydrolysis process of the triglycerides present, indicating that the extraction conditions were adequate. Comparing the results obtained with the CODEX Alimentarius standards (CXS 210-1999) (19), it is established that the acidity index for all edible vegetable oil must be ≤ 2, for the macre pumpkin seed oil, an acidity index lower than this value was obtained.

4.3.2 Saponification index (SI)

The saponification index (SI) that characterizes the pumpkin seed oil obtained experimentally is 184.45 mg KOH/g of oil. A low saponification index suggests that this oil contains long-chain fatty acids and is suitable for human consumption. A high saponification index would not be suitable for food, but rather for the manufacture of other products, such as soaps. The saponification index obtained is very close to the values reported by Artica et al. (191.1-193.53) and Shalaby et al. (109.13-111.19), while Rezig et al. reported a value of 175. The CODEX Alimentarius standards for oils (CXS 210- 1999) (19) specify that the saponification index for soybean oil ranges from 189 to 195, for corn oil from 187 to 195, and sunflower oil from 189 to 194. In addition, CODEX standards (CXS 33-1981) (20) indicate that the saponification index for olive oil is 184-196, which shows that the values are very similar to those reported in these standards for soybean, corn, sunflower, and olive vegetable oils

4.3.3 Iodine index (II)

The iodine index (II) obtained was 119.02 g/100 g of oil, indicating the presence of a high number of unsaturations, i.e. a high amount of unsaturated fatty acids. This type of oil falls within the range of 100 < II < 130, where it is classified as semi-drying or oxygen-absorbing in the presence of air, and is suitable for consumption. The iodine values reported by Artica et al. ranged between 103.06-113.17 and 137.46-140.73; Shalaby et al. reported 89.3, and Rezig et al. 153.66. According to the CODEX Alimentarius standards (CXS 210-1999) (19), the iodine value expressed in g/100g for soybean oil is 124 to 139, for corn oil 103 to 135, and sunflower oil 94 to 122. The CODEX standards (CXS 33-1981) (20) indicate that the iodine value for olive oil ranges from 75 to 94. It is observed that the value obtained is within the ranges of vegetable oils, with the exception for olive oil, which has lower values.

4.3.4 Refractive index (RI)

The refractive index (RI) determined was 1.471, similar to the values reported by Artica et al. (1.468-1.472 and 1.47-1.473), by Shalaby et al. (1.4294), and by Rezig et al. (1.46). According to the CODEX Alimentarius standards (CXS 210-1999) (19), the refractive index for soybean oil is 1.466-1.470, for corn oil it is 1.465-1.468, and for sunflower oil it is 1.467-1.471. Likewise, the CODEX standards (CXS 33-1981) (20) indicate that the refractive index for olive oil is 1.4677-1.4705. It is observed that the value obtained is within the limits or ranges of vegetable oils of soybean, corn, sunflower, and olive, which confirms that this oil is suitable for human consumption.

Finally, the density obtained was 0.92, similar to the values reported by Artica et al. (0.92-0.93 for pumpkin and 0.91-0.93 for squash). According to the CODEX Alimentarius (CXS 210-1999) (19), the densities for peanut oil, almond oil, corn oil, and coconut oil are 0.909 (g/cm³), 0.911-0.929 (g/cm³), 0.917-0.925 (g/cm³), and 0.928-0.921 (g/cm³), respectively.

The results obtained from the seed oil of Cucurbita maxima Duchesne, known as macre pumpkin, show that it is an ideal ingredient for human nutrition. Like pumpkin seeds, which are used as a supplement in the treatment of metabolic syndrome, these seeds belong to the Cucurbitaceae family (21). Rezig et al. (2012) also mention that pumpkin seeds are a rich source of many nutrients, which seem to have a very positive effect on human health. Lemus-Moncada et al., (2019) add that the edible seeds of Cucurbita maxima are rich in nutrients and can be used for various applications, such as the enrichment of food products and the extraction of bioactive compounds. In addition, they can be considered as a functional food, thanks to the multiple benefits they offer for human health. Boujemaa et al. (2020) suggest that pumpkin seed oil can be used as an alternative source of oil, mainly due to the high content of fatty acids present in the species *Cucurbita maxima*, *Cucurbita moschata* and *Cucurbita pepo*. This indicates that the pumpkin seed oil of the macre variety, specifically the species Cucurbita maxima Duchesne, obtained in the experiment, has a higher quality compared to the oil obtained by Artica et al. (2016).

CONCLUSIONS

The seeds of *Cucurbita maxima Duchesne*, commonly known as the macre pumpkin, have a high fat content of 48.88% and a protein content of 41.94%, which classifies them as a resource that can be utilized as a potential nutrient in human nutrition. Furthermore, the continuous flow expeller extraction method allows for a higher yield in obtaining pumpkin seed oil compared to the cold pressing method, the solvent extraction method (ethanol), and the Soxhlet method (with hexane).

The particle size and moisture content of pumpkin seeds are determining parameters in the oil extraction process using the expeller method, as they influence the equipment operation and enable the production of clean oil with minimal contamination. This method also produces high-quality oils compared to traditional methods; it can be considered an ecological and environmentally friendly process, since its waste can be reused through processes suitable for human consumption. Finally, due to the quality attributes it presents, it can be concluded that the oil from pumpkin seeds is a valuable ingredient.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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AUTHORS' CONTRIBUTIONS

Marleni Gonzáles Iquira: Investigation and experimentation, Nidia Pompilla Cáceres: Writing - review and editing original draft. Irina Acosta Gonzáles: Experimentation and writing. Paúl Tanco Fernández: Supervision, review, and editing.

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