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REVALORIZATION OF A FOOD WASTE FOR OIL EXTRACTION AND MICROENCAPSULATION: SQUASH SEED *(CUCURBITA MAXIMA DUCHESNE EX LAM)*

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Abstract. Food systems generate a significant amount of food waste, such as pumpkin seeds that are discarded before the pulp is consumed. They are a source of nutrients that can be used to improve human nutrition. The objective of this study was to extract, characterize and microencapsulate oil from peeled and unpeeled discarded pumpkin seeds. Five methods of oil extraction were tested and fatty acid profile was determined. The oil was microencapsulated by spray drying using gum arabic and maltodextrin as wall materials and the microcapsules were characterized. Finally, storage stability was evaluated for a period of 40 days. Peeled pumpkin seeds showed higher fat content (52.33%). Solvent-assisted extraction was effective for oil extraction. The extracted oil showed high contents of linoleic acid (62.98%) and oleic acid (17.69%). The encapsulation efficiency after spray drying was over 90%. The microcapsules were 5-20 μm in size, with spherical and concave shapes, with smooth surface, without pores or cracks, which allowed keeping the active principle inside the capsule and increasing stability. Both pumpkin seed oil and microcapsules were stable against oxidation during storage. The oil presented good nutritional characteristics with a high content of monounsaturated and polyunsaturated fatty acids. The gum arabic-maltodextrin system was effective for microencapsulation with favorable morphological characteristics.

Key words: oil; pumpkin; extraction, microencapsulation; seeds.

REVALORIZACIÓN DE UN RESIDUO ALIMENTARIO PARA LA EXTRACCIÓN Y MICROENCAPSULACIÓN DE ACEITE: SEMILLA DE CALABAZA (*CUCURBITA MAXIMA DUCHESNE EX LAM*)

Resumen. Los sistemas alimentarios generan una cantidad importante de desperdicios alimentarios, como las semillas de calabaza que son descartadas antes del consumo de la pulpa. Éstas son fuente de nutrientes que pueden utilizarse para mejorar la alimentación humana. El objetivo de este estudio fue extraer, caracterizar y microencapsular el aceite de semillas de calabaza descartadas peladas y sin pelar. Se probaron cinco métodos para extraer el aceite y se determinó perfil de ácidos grasos. El aceite se microencapsuló mediante secado por aspersión usando goma arábiga y maltodextrina como materiales de pared y se caracterizó las microcápsulas. Finalmente se evaluó estabilidad al almacenamiento durante un periodo de tiempo de 40 días. Las semillas de calabaza peladas mostraron mayor contenido de grasas (52,33%). La extracción asistida por solvente resultó efectiva para la extracción de aceite. El aceite extraído mostró altos contenidos de ácido linoleico (62,98%) y oleico (17,69%). La eficiencia de encapsulación después del secado por atomización fue superior al 90%. Las microcápsulas tenían un tamaño de 5-20 μm, con formas esféricas y cóncavas, con superficie lisa, sin poros ni grietas, lo que permitió mantener el principio activo dentro de la capsula y aumentar la estabilidad. Tanto el aceite de semilla de calabaza como las microcápsulas se mantuvieron estables frente a la oxidación durante el almacenamiento. El aceite presentó buenas características nutricionales con altos contenidos ácidos grasos monoinsaturados y poliinsaturados. El sistema goma arábiga-maltodextrina resultó eficaz para la microencapsulación con características morfológicas favorables.

Palabras clave: aceite; calabaza; extracción, microencapsulación; semillas.

Introduction

At present, food systems generate significant food losses and waste that are discarded at the different links of the food chain for different reasons, which can be the result of both human action and external factors; environmental or crop factors [(1)].

Reducing food loss and waste (FWL) is an urgent necessity and consumers are one of the fundamental pillars to contribute to this cause, since for every product that is discarded, nutrients, water and energy are wasted, causing not only environmental deterioration but also great economic losses [(2)]. According to research by the Food and Agriculture Organization of the United Nations (FAO), 842 million people in the world suffer from hunger and 30% of the

food produced is lost or wasted, that is, around 1.3 billion tons, equivalent to one third of world production [3].

The pumpkin or squash is one of the species that make up the Cucurbitaceae family, represented by about 120 genera and 800 species. The genus Cucurbita is native to the American continent. It includes about 27 species that can be annual or perennial and are cultivated mainly for the consumption of their fruits at the mature or immature stage, but other parts of the plant such as seeds, leaves and flowers are also consumed [4].

Pumpkin seeds are discarded as vegetable waste before consumption and contain significant amounts of nutritional compounds such as lipids and proteins [5], which provide up to 80-85% of the dry weight of the embryo [4]. They are composed of 40 to 52% oil, of which 29% is oleic acid and 51.9% linoleic acid; they also contain proteins, minerals (magnesium, phosphorus, copper, potassiumiron, zinc, manganese), β-carotene and γ-tocopherol [6].

Oilseeds are used as raw material to obtain edible oils because they accumulate lipids, proteins and carbohydrates as reserve substances [7]. The main characteristic of the cells of these seeds is the existence of cellular organelles called lipid and protein bodies, which contain, respectively, most of the oil and proteins of the grain [8]. Lipid bodies (also called oleosomes or spherosomes) are the site of lipid storage, which are immersed in a cytoplasmic network composed of protein and their frequent size ranges from 1 to 2 μm ([8, 9]. Cell walls are composed of cellulose, hemicellulose, lignin and pectin; and their rupture during the different extraction processes (organic solvents, supercritical fluids, pressing and hydrolytic enzymes) exposes the oil located inside the cell and facilitates the filtration of the solvent, within which the lipids can diffuse [8].

Vegetable oils provide essential fatty acids that the body cannot synthesize and must be ingested with food, such as linoleic and linolenic acid (intake range between 2.5 and 9% of energy), which influence the prevalence and severity of chronic noncommunicable diseases such as diabetes, cancer, heart disease and age-related functional decline [10,11].

Studies on the chemical composition of pumpkin seed oil, from different origins and varieties, describe the presence of four fatty acids in significant amounts, such as linoleic, oleic, palmitic and stearic acids [6, 12, 13, 14], the first two of which are widely recognized for their health benefits [15].

Microencapsulation is a technology that allows the encapsulation of active ingredients (core or central materials) covered by a polymeric wall with hydrophobic and/or hydrophilic properties (encapsulation or wall material). The resulting products are referred to as microparticles [16]with sizes ranging from 1 to 1000 μm ([17]. The food industry applies it for its multiple benefits: it provides protection against factors such as heat, air, light, humidity and oxygen, prevents volatilization and extends the shelf life of oils and essential fatty acids, improves the flavor, aroma, stability, nutritional value and appearance of the processed food, allows the transformation of liquid active substances into solids, facilitates their handling in the industry, provides resistance to processing, storage, transport and marketing, allows controlling the release of microencapsulated substances and facilitates their inclusion as an ingredient in the food industry [16, 18, 19, 20].

Several studies conducted on pumpkin seed oil concluded that its physicochemical characteristics are suitable for use in food or as a raw material in products with various industrial uses [5, 10, 21, 22, 23]. On the other hand, research based on the microencapsulation of oil by spray drying, infer that the use of the polymeric mixture of gum arabic-maltodextrin is appropriate for effectively masking the oil and obtaining microparticles with desirable morphological characteristics that avoid direct contact with oxygen, thus preventing its degradation and

extending its shelf life, in addition to guaranteeing an encapsulation efficiency of over 90% and a loss by desiccation of less than 10% [24, 25].

A report by the Commission for Environmental Cooperation on the characterization and management of food loss and waste in North America prioritizes the reduction of ADP at source and food recovery over recycling and final waste disposal at the post-harvest, processing, distribution, sales, food preparation and catering stages [26]. For this reason, the present research was developed with the objective of extracting, characterizing and microencapsulating pumpkin seed oil recovered from a food service that produces this type of waste on a daily basis, valuing its nutritional properties by reincorporating it into the production cycle as a potential ingredient for the formulation of food products.

Method

An experimental study was proposed.

The seeds of 45 pumpkins were collected from the Student Canteen of the National University of Salta, Argentina. They were washed with cold water [27] and rubbed with a polypropylene mesh (1 mm) to remove pulp remains. Drying of whole seeds (with shells) was carried out in an oven at 40 ± 1 °C with forced air for 16 hours until a humidity of 5.7 ± 1.9% was reached [21]. Those with no surface damage and with the presence of pulp to the touch [27] were selected, vacuum packed in airtight "BoiZip" bags and stored refrigerated at a temperature of 4 ± 2 °C.

The chemical composition of shelled (SCC) and unshelled (SSC) seeds was determined: moisture by drying in an oven at a temperature of 105 ± 1 °C, carbohydrates by Felhing Cause Bonnas method, proteins by Kjeldhal method, fats by Soxhlet method, ashes by calcination in a muffle at a temperature of 600 ± 5 °C, all according to official methods [28].

The oil extraction process was standardized using various methods, in order to select the one that meets the objectives and is effective and efficient for the purposes of the work: EA1 using a hand press and exerting manual pressure on each of the unshelled seeds; EA2 through a hydraulic press and using a stainless steel pillbox as a receptacle, pressure was exerted on the whole seeds (uncrushed) with and without shells, applying a force of 4 to 5 tons; EA3 with a hydraulic press, using two superimposed stainless steel plates, pressure was exerted on the unshelled seeds (placed between the two receptacles) with a force of 4 to 5 tons; EA4 using a homemade press, seeds with and without shells (whole and crushed) were placed in the container intended for this purpose and pressure was exerted manually and EA5 by maceration with organic solvent, adapted to the processes used by Betancurt [23] and González and Yánez [29]. The husk was removed manually, the seeds were crushed in an Arcano stainless steel grinder, model FW 100, 460 W at 24000 rpm and passed through a mortar until a fine paste was obtained. Extraction was performed by mixing with organic solvent in a 1:2 ratio (sample:hexane) [23]. The mixture was allowed to stand for 48 hours under refrigeration with intermittent stirring on a Stir Decalab 2000 rpm magnetic stirrer. Finally, it was centrifuged in a "DAMON/IEC" refrigerated centrifuge for 15 minutes, speed 4 to separate the oil; the solvent was evaporated in a Lavarota 4000 rotary evaporator at 60 - 70 °C at a pressure between 300 - 400 mmHg and stored in amber glass bottles under refrigeration (4 ± 2 °C) [29].

The determination of fatty acids was carried out according to the official method of the AOAC 996.01-1996 [30] starting from a methylation, 3 g of oil obtained by the EA5 method was

placed in a balloon and 10 ml of methanolic solution of NaOH 0.5M was added, it was taken to reflux for 10 minutes. 10 ml of boron trifluoride was added and continued to reflux for 5 minutes. Finally, 10 ml of heptane was added and left for 1 min. The balloon was removed and once cooled, the contents were transferred to centrifuge tubes with the addition of 5 ml of saturated NaCl solution. It was centrifuged for 10 minutes and the top layer was collected for analysis. These were injected into a Clarus 680 gas chromatograph coupled to a Clarus 600 mass spectrometer, Elite-Wax 30 m capillary column, using hydrogen as carrier gas, which were prepared according to the FAMEs method [(30)]. The reading was performed in triplicate and the data were reported as percentages of relative area. The results were expressed in g of fatty acid/100 g of oil through the following calculation:

[(Ai) x (P13:0)/ (A13:0) x (Ri)]

Ai = maximum area of the sample of individual fatty acids as methyl esters

P13:0 = sample weight (mg)

A13:0 = area of the peak of the internal standard

Ri = response factor for each fatty acid.

Microencapsulation was carried out by spray drying. The emulsion was formulated with the following proportions: gum arabic 24%, maltodextrin 12%, oil 18% and the volume was completed with distilled water [(31)]. Homogenization was carried out with a hand blender for 5 minutes and with Ultra Turrax model K41, TRI-R for 5 more minutes until a homogeneous mixture was obtained without phase separation [(24)].

An emulsion stability test was performed according to Carneiro et al. [(32)]: 50 ml of sample was placed in a test tube and stored at room temperature (21 ± 1 ºC) for 24 hours, then the volume of phase separation was measured and the stability was expressed in percentage of separation through the following formula:

$$\%\ \text{Separación} = \left(\frac{\text{E1}}{\text{H0}}\right) \text{x } 100$$

E1: upper phase measurement after 24 hours

H0: initial emulsion value

Mini Spray Dryer Buchi B - 290 equipment was used with a spraying system with a 1.5 mm diameter nozzle. The emulsion was atomized inside a hot air stream with inlet and outlet temperatures of 150 and 100 ± 1 °C respectively [(25)], pumping 25% and air flow 30 - 40 m3/h. The microcapsules were stored in 200 ml amber glass containers with lids at room temperature (21 ± 1 ºC) for 40 days for subsequent measurement of oxidative stability.

The characterization of the microcapsules to evaluate their quality was carried out through the following determinations:

- Free or surface oil: 1 g of the microcapsules was weighed and 8 ml of hexane was added. It was shaken manually for 4 minutes and passed through filter paper into a previously treated and weighed beaker. It was evaporated in an oven at 60 °C to dryness and the free oil content was determined by gravimetric method [(32)].

$$\%\ \text{Aceite libre} = \left(\frac{\text{V1} - \text{V2}}{\text{g muestra}}\right) \text{x } 100$$

V1: beaker with sample after the oven

V2: beaker without sample after treatment

- Total oil: 0.5 g of powder was weighed, 4 ml of double-distilled water was added and stirred manually until dissolved. Hexane/isopropanol (3:1 v/v) was added and stirred manually for 5 min. It was transferred to centrifuge tube and centrifuged for 15 minutes. The clear phase was transferred to a previously treated and weighed beaker. It was evaporated in an oven at 60 °C to dryness and the amount of extracted oil was determined gravimetrically [33].

$$\% \text{ Aceite total} = \left(\frac{V1 - V2}{\text{g muestra}}\right) \text{x } 100$$

V1: beaker with sample after the oven

V2: beaker without sample after treatment

- Encapsulation efficiency (EE): was calculated by applying the following equation [32]:

$$\% \text{ EE} = \left(\frac{AT - AS}{AT}\right) \text{x } 100$$

AT: is the total amount of oil contained in the capsule

AS: surface oil

- Payload: was calculated by taking the mass ratio of the encapsulated oil to the total mass of the powder [34].

$$\% \text{ Carga útil} = \left(\frac{MA}{MP}\right) \text{x } 100$$

MA (mass of oil): quantity of oil in grams.

MP (powder mass): quantity of microcapsules in grams

- Microcapsule morphology: the size and geometrical shape of the microcapsules were observed in Jeol scanning electron microscope (SEM) (JSM 6480 LV, Tokyo, Japan), with an accelerating voltage of 15 Kv, including secondary and backscattered electron probes, working with high and low vacuum. The most representative SEM micrograph was selected for presentation [24].

To determine the storage stability of the oil and microcapsules, the samples were packed in amber glass containers at room temperature (21 ± 1° C) and in darkness in a closed place, in order to analyze the changes produced in the oil and microcapsules during a period of 40 days of storage. Then, through the peroxide index (PI) and the thiobarbituric acid test (TBA), the alterations that occurred during the course of time were analyzed.

Method 965.33 [30]was adapted to determine the PI by applying the following procedure:

1 g of oil was weighed into a 250 ml glass-stoppered erlenmeyer, 30 ml of solvent (3 parts glacial acetic acid and 2 parts chloroform) was added and shaken manually for 1 min. Subsequently, 5 ml of the saturated potassium iodide solution was added and allowed to stand for 1 min in the dark with occasional stirring. Then, 50 ml of water was added to stop the reaction and prior to titration, 5 ml of the 1% starch solution was added. It was titrated with 0.01N sodium thiosulfate until final titration. Simultaneously a blank was performed where the

sodium thiosulfate consumption was < 0.2 ml. It was calculated by applying the following equation

$$\text{IP} = \frac{\text{S x N x 1000}}{\text{g muestra}}$$

S: sodium thiosulphate expenditure in ml corrected with blank
N: normality of Sodium thiosulfate

The determination of ATB was carried out by applying the following procedure: 3 g of oil was weighed in a beaker and 10 ml of hexane was added. It was then transferred to a decanting vial and 10 ml of the thiobarbituric acid reagent (dissolved in 50% glacial acetic acid) was added, shaken manually for 5 minutes and allowed to stand until the phases separated. The lower part was collected in a test tube (the lower part is the part containing the malonaldehyde) and placed in a boiling bath for 10 minutes. After this time it was cooled in a cold water bath to room temperature and after 5 minutes the absorbance was read at 530 nm in a spectrophotometer. The value was expressed in mg MDA/kg [35].

$$\text{MDA} = \frac{\text{A530 x 3 x k ext. x 0,926}}{\text{g muestra}}$$

Results are presented as mean ± standard deviation. To find significant differences between the analyses, the Student's t-test for independent samples ($p < 0.05$) was used and the calculation was performed using InfoStat v statistical software. 2016p.

Results

The final moisture content of all whole seeds after oven treatment was 5.33 ± 0.99%. The results of chemical determinations of pumpkin seeds with (SCC) and without (SSC) shell are shown in Table 1.

Table 1
Chemical analysis of shelled and unshelled pumpkin seeds (Cucurbita maxima Duchesne ex. Lam.)

Parameters (100 g)	**SCC**			**SSC**		
Humidity (%)	5,00[a]	±	0,00	4,50b	±	0,00
Carbohydrates (g)	10,26a	±	0,15	7,36b	±	0,43
Protein (g)	37,10a	±	0,74	34,13b	±	0,74
Fats (g)	40,39a	±	0,53	52,33b	±	0,58
Ash (g)	3,62a	±	0,25	4,17a	±	0,29

Different letters between rows indicate significant differences ($p < 0.05$) .

Table 2 summarizes the qualitative characteristics of each method used for oil extraction.

Table 2

Qualitative characteristics of extraction methods

EA1	EA2	EA3	EA4	EA5
				
Difficulty in oil collection Losses and decrease in yield Large amount of remnant in the used containers				Efficient oil collection Lower loss Minor remainder Lower cost for higher yield (31.86 ± 3.98%).

Figure 1 shows the oil resulting from extraction.

Figure 1
Pumpkin seed oil (Cucurbita maxima Duchesne ex Lam)

The presence of four fatty acids was observed in the oil extracted by the EA5 method: linoleic acid (18:2) 62.98 ± 2.47%, oleic (18:1) 17.69 ± 0.64%, palmitic 12.06 ± 1.03% and stearic 6.02 ± 0.90%.

The emulsion prepared for microencapsulation 24 hours after homogenization was kinetically stable (0% phase separation). The percentage loading of gum arabic improved the stability of the encapsulation and the maltodextrin contributed to the formation of a fine, uniformly colored powder as shown in Figure 2.

Figure 2
Pumpkin seed oil microcapsules (Cucurbita maxima Duchesne ex Lam)

The parameters applied to characterize the microcapsules and the results obtained are shown in Table 3.

Table 3
Characterization of pumpkin seed oil microcapsules

Parameters	**Value**		
Free oil (%)	2,33	±	0,57
Total oil (%)	25,33	±	1,15
EE (%)	90,71	±	2,77
Payload (%)	20,59	±	1,15

The morphological characteristics of the microcapsules presented different sizes ranging from 5 to 20 µm, with spherical and concave shapes, smooth surface, without pores or cracks as shown in Figure 3.

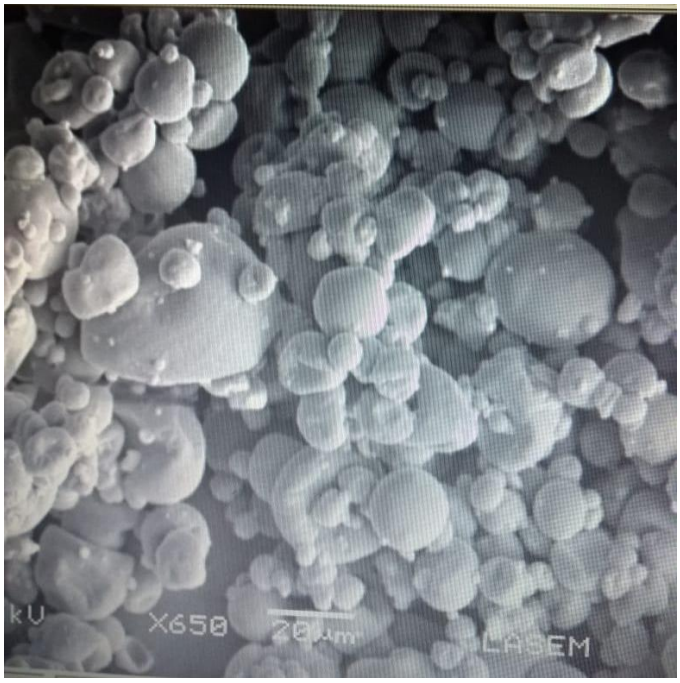

Figure 3
Morphological characteristics of microcapsules

The results of the IP and ATB storage stability tests on the oil and microcapsules are shown in Figure 4.

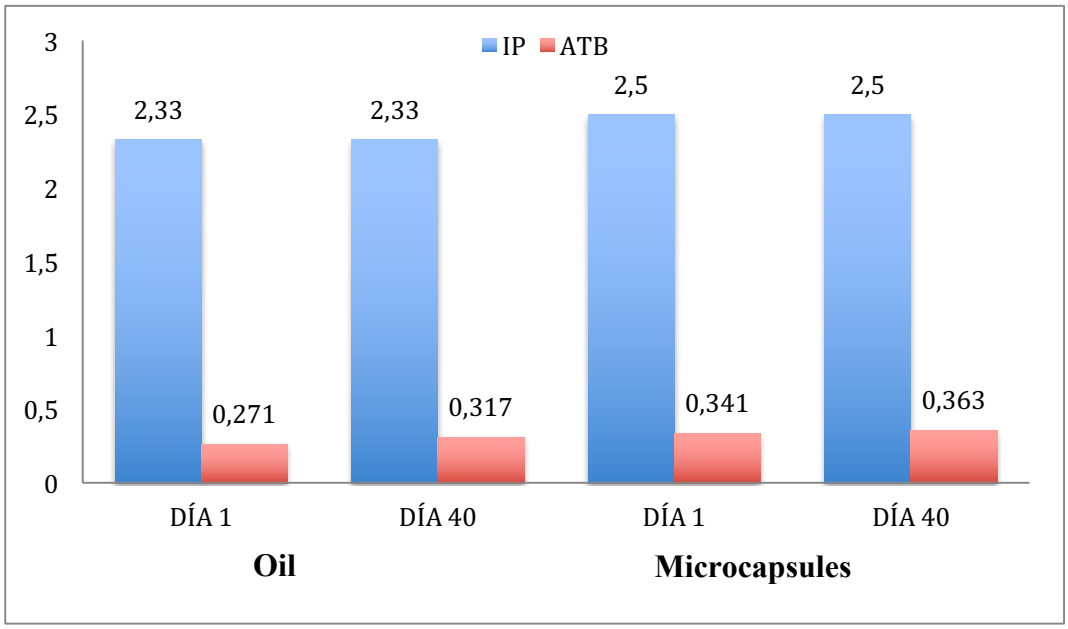

Figure 4
Storage stability of pumpkin (Cucurbita maxima Duchesne ex Lam.) seed oil and microcapsules

The PI in the oil sample was 2.33 ± 0.57 mEq O2/kg on days 1 and 40, a value that remained stable throughout the storage period and without significant statistical differences ($p < 0.05$). The ATB test yielded results of 0.271 ± 0.01 and 0.317 ± 0.01 MDA/kg respectively ($p < 0.05$). In the microcapsules, the PI value was 2.50 ± 0.71mEq O2/kg on day 1 and 40, a behavior similar to that of the oil sample and without significant statistical differences ($p < 0.05$). The ATB result was 0.341 ± 0.01 and 0.363 ± 0.01 MDA/kg respectively ($p < 0.05$).

Discussion and conclusions

The final moisture content of all seeds was adequate to inhibit the growth of microorganisms and inactivate enzymes that could cause seed deterioration [36].

The chemical composition values compared to those reported by Kipping et al. [15] were: moisture similar to that found of 5.58% SCC and 4.45% SSC; carbohydrates higher than 5.57% and 6.99% in SCC and SSC respectively, this difference could be associated with the presence of fiber in them, the method applied for their determination and the variety of the species used [37]; protein and fat values were higher than 28.92% SCC and 24.36% SSC and 35% SCC and 49% SSC respectively, obtained by Kipping et al. [15].

The fat concentration of the present study, compared to other vegetable oils, are similar to those of sunflower 43 - 51.1% [38] and rapeseed 40 - 48% and higher than those of corn 33%, safflower 30 - 35% and soybean 18 - 22% [37], a characteristic that makes the raw material used a potential and valuable source for extraction.

The literature reports differences in ash content of 1.43% SCC and 5.37% SSC [23], 5.3% SCC [37] and 3.95% SSC [39]. Differences in composition could be attributed to species variety, climate, cultivation practices, soil composition, and maturity of the vegetable at harvest [33,37].

Methods EA1, EA2, EA3 and EA4 could generate higher costs if they are to be implemented on a pilot or industrial scale for oil extraction. The extraction percentage obtained by the EA5 method exceeds that reported in the literature with 5 and 9% [14, 23]. The use of hexane as solvent provided good oil solubility and easy separation of the oil in the evaporation process. The green color, similar to olive oil, could be attributed to the presence of chlorophyll in the seeds of pumpkin *C. maxima Duchesne ex Lam.*

Regarding the fatty acid profile, the linoleic acid content (62.98 ± 2.47%) was higher than that reported by Kipping et al. [15] of 51.87%. This fatty acid is considered essential together with linolenic acid, since its formation in the body is not possible and the balance between the two is crucial in the regulation of inflammatory processes such as metabolic syndrome, diabetes and obesity [11]. The oleic acid value (17.69 ± 0.64%) was lower than those found by other authors of 29.04% [15], 31.34% and 32.40% [39]. This could be attributed to the variety and the species [5, 37]; and be compensated by the higher linoleic content in the seeds studied compared to the literature cited. The consumption of this monounsaturated fatty acid prevents and reduces the risk of coronary accidents and metabolic diseases [11]. Palmitic acid content (12.06 ± 1.03%) was similar to that reported by Kipping et al. [15] of 11.64% and lower than those of Kim et al. [40] of 13.14 and 14.07%. Although this saturated fatty acid does not have a beneficial effect on the body, its concentration is low, and with regular consumption of this oil, it would not exceed 10% of the recommended daily energy [11]. With respect to stearic acid (6.02 ± 0.90), it was lower than the 7% [15], 7.33% and 4.67% [40]observed in the literature. The differences could be attributed to genetic diversity [37].

The stability of the emulsion could be attributed to the emulsifying capacity of the wall materials used, which kept the mixture invariable [24, 32].

Free oil was similar to that reported by López et al. [24] of 2.3%, which also establishes a limit of 10% for this parameter. The low percentage could be attributed to the role played by gum arabic and maltodextrin in containing the active ingredient inside the capsule [33].

The proportion of total oil is related to %EE, and these were higher than those achieved by Klinkesorn et al. [33] of 18.37% and 86.94%, respectively. According to Barbosa et al. [41] the more stable the emulsion is from the beginning, the higher the %EE; this characteristic can be attributed to the process of elaboration of the mixture and to the gum arabic-maltodextrin system that maintained the stability of the preparation prior to spray drying [24].

The payload (amount of powder resulting after drying) suggests that the product yield was lower than reported by other authors of 63.2% [31], 82.1% [25] and 97.4% [24]; which could be attributed to particle deposits around the spray lid and on the chamber wall of the equipment used, inlet temperature, polymer concentration and the sprayer model used [42].

According to different authors, the characteristics obtained by SEM are advantageous, since they prevent degradation and extend the shelf life of the encapsulates [24, 25].

Fat oxidation is one of the main causes of food spoilage. According to Jiménez [35], the increase in ATB could be related to the initiation of the formation of carboxylic compounds resulting from the degradation of fatty acids or peroxides; however, the figures obtained do not exceed the reference value of 0.7 to 1 mg MDA/kg.

The storage stability values of the oil and the microcapsules show that both samples tend to behave in a stable manner, with no evidence of oxidation according to the results obtained. In the oil, it could be attributed to the presence of natural antioxidants such as tocopherols (non-glyceride components of great importance in vegetable oils) responsible for oxidative stability during processing and storage [21, 39, 36, 43]; and in the microcapsules, to the polymers used as wall material (gum arabic and maltodextrin) and to the %EE obtained, which provided protection and preserved the particles adequately.

The results of this work show that it was feasible to reuse a waste product, such as *Cucurbita maxima Duchesne ex Lam*. pumpkin seeds, for the extraction of oil with good nutritional characteristics, especially linoleic and oleic acid. It was possible to microencapsulate the oil by spray drying and the gum arabic-maltodextrin system allowed obtaining stable and homogeneous emulsions, with a high percentage of encapsulation efficiency. The extracted oil and the microcapsules remained stable during 40 days of storage, showing no evidence of deterioration caused by oxidation phenomena.

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List of symbols and abbreviations

%EE: Encapsulation efficiency percentage
AOAC: Association of Official Agricultural Chemists
ATB: Thiobarbituric acid
EA1: Oil extraction with hand press
EA2: Oil extraction with hydraulic press + pill dispenser
EA3: Oil extraction with hydraulic press + plates
EA4: Oil extraction with home-made presses
EA5: Oil extraction by maceration with organic solvent
FAMEs: Fatty acid methyl esters
FAO: Food and Agriculture Organization of the United Nations
IP: Peroxide value
MDA: Malonaldehyde
NaOH: Sodium hydroxide
NaCl: Sodium chloride
SCC: Shelled seeds
SEM: Scanning Electron Microscope
SSC: Shelled seeds
PDA: Food loss and waste