Effect of Extraction Method and Sesame Oil (Sesamum indicum L)Type on Lecithin Yield and Study of Its Physicochemical Properties

Hajar Emad Kadhim[1], Laith Fareed Hasan Al-Obaidi[2]

[1,2] Department of food science, Faculty of Agriculture, University of kufa, 54001, Iraq
EMAIL: hajiri.alakayshee@student.uokufa.edu.iq , laithf.alobaidi@uokufa.edu.iq

Abstract
The aim of this study was to evaluate the effect of the type of sesame oil (roasted and unroasted) and different extraction methods on the yield of lecithin and its physicochemical properties, Three methods were used to extract lecithin, including aqueous extraction, acid extraction, and ultrasonic-assisted extraction at different times (10, 20, 30) minutes, The results showed significant differences in the lecithin yield depending on both the type of oil and the extraction method, as well as their interaction. The ultrasonic extraction method for 10 minutes achieved the highest lecithin yield of 3.912% ,whilst the aqueous method recorded the lowest yield of 0.510%, Unroasted oil also yielded a higher average yield compared to roasted oil. The results of the chemical analysis showed that the crude lecithin contained 28.14% moisture and 7.01% ash. The lecithin possesses good quality characteristics, with an acid value (AV) of 1.597 mg KOH/g and a peroxide value (PV) of 2.610 meq O_2/kg, while the free fatty acid (FFA) was 2.173%, Antioxidant activity testing showed that the extracted lecithin possessed good free radical scavenging capacity, with activity increasing with concentration; the highest inhibition rate for DPPH free radicals was 81% at a concentration of 0.8 mg/ml, FTIR analysis also confirmed the presence of functional groups characteristic of phospholipids, such as CH_2, C=O and $^{-}PO_2$, and the results generally indicate that the ultrasonic extraction method is one of the most efficient methods for extracting sesame lecithin.

Keywords: lecithin, sesame, ultrasound, degumming, phospholipids, antioxidants, FTIR.

1Introduction

Sesame (Sesamum indicum L) is a member of the Pedaliaceae family and is considered an economically and nutritionally important crop; it is one of the oldest and most valuable oilseeds, it is widely available and inexpensive, and is renowned for its oil, global market demand for sesame is increasing in line with growing health awareness, it is widely cultivated in both tropical and subtropical regions [1].

Sesame seeds contain a high oil content ranging (44–58)% depending on a number of factors such as variety and environmental conditions [2].

Sesame seeds also contain high levels of proteins, carbohydrates and essential minerals, as well as methionine, tryptophan, fiber and antioxidants such as lignans (sesamolin and sesamin), saponins, flavonoids and phenolic compounds, they are rich in vitamins E and B, as well as other nutrients that are lacking in most plant crops, which classifies sesame seeds as a functional [3].

In addition to these components, sesame oil contains phospholipids, which are the main component of lecithin; it can therefore be utilized as a source for lecithin extraction, rather than being treated as an undesirable by-product during certain stages of refining, Hence the importance of utilizing sesame oil as a raw material for the extraction of lecithin and the evaluation of its qualitative and functional properties [4].

Lecithin is considered an important functional ingredient in the food industry due to its amphiphilic nature, which enables it to act as an effective emulsifier in various food systems; it also plays a role in improving the oxidative stability and rheological properties of food products, particularly in emulsified systems such as mayonnaise, sauces and margarine [5].Lecithin is also classified as Generally Recognised as Safe (GRAS) by international bodies, which promotes its use in food applications [6], and there has been growing interest in the use of vegetable lecithin, which has similar or even better functional properties in some cases than animal lecithin, as a substitute for egg yolk in food products, due to consumer concerns regarding cholesterol, as well as the high cost and the trend towards plant-based products [7].

Although soya is considered the main commercial plant source of lecithin, recent studies have focused on identifying alternative plant sources such as sesame, due to its distinctive nutritional and functional properties. Although lecithin is present In many foods, those rich in lecithin are usually also high in cholesterol and fat, such

as eggs; therefore, producing lecithin from vegetable oils, such as sesame oil, could be a solution for providing a plant-based source of lecithin [8].

2Materials And Methods

2.1 Raw Materials

Local sesame seeds purchased from the local market in the city of Babylon were used. They were cleaned to remove impurities and divided into two batches. The first portion was roasted in an oven at 150°C until the seeds reached the desired color, while the second portion remained unroasted. Crude oil was extracted from each type of sesame using the cold-pressing method.

2.2 Extraction of Lecithin

Three methods were used to extract lecithin from crude sesame oil

2.2.1 Aqueous extraction method for lecithin

The method described by [4]was followed with some modifications: the lecithin was extracted from crude sesame oil by heating 100 ml of the crude oil in a water bath at 60°C until the required temperature was reached; 3 ml of warm distilled water was then added, and the mixture was placed on a magnetic stirrer and stirred for 60 minutes while maintaining the temperature. The mixture was then left to cool and placed in a centrifuge at 4500 rpm for 20 minutes, the clear middle layer, representing the crude lecithin, was then collected and dried at 40°C until all moisture had been removed.

2.2.2 Acidic extraction method for lecithin

The method described by [9] [10] was followed with some modifications: 100 ml of oil was heated in a water bath until it reached a temperature of 60°C, then add 0.3% of phosphoric acid with a concentration of (85%) to the crude oil, The mixture was placed on a magnetic stirrer for 30 minutes while maintaining the temperature , Next, 3ml warm distilled water was added to hydrate the phospholipids, and the mixture was left on the stirrer for 15 minutes ,It was then left to cool and placed in a centrifuge at 4500 rpm for 20 minutes ,then carefully collected the crude lecithin layer and dried it in an oven at 40°C.

2.2.3 Ultrasonic extraction method

The method described by [11] with some modifications was followed: lecithin was extracted from crude sesame oil by heating 100 ml of the crude oil in a water bath until it reached a temperature of 60°C, then adding 3 ml of warm distilled water and placing the mixture in an ultrasonic bath at a frequency of 30 kHz, maintaining a temperature of 60 °C for varying durations (10, 20, 30) minutes, then left to cool and placed in a centrifuge at 4500 rpm; the transparent middle layer, representing crude lecithin, was collected and dried in an oven at 40°C.

2.2.4 Calculation of Lecithin Yield

The yield of crude lecithin obtained from the previous processes was calculated as a percentage using the equation reported by [12] as follows:

lecithin % = Weight of extracted gum after drying / Weight of crude oil × 100%

2.3 Chemical analysis of crude lecithin extracted from sesame oil

Moisture content determination

The moisture content of the extracted crude lecithin was determined in accordance with the standard method approved by [13] and expressed as a percentage.

Ash content determination

The ash content of the crude lecithin extract was determined according to the standard method approved by [13].

Free Fatty Acids in the Lecithin

The percentage of free fatty acids in the extracted lecithin was determined in accordance with the [14].

2.4 DETERMINATION OF QUALITY INDICATORS FOR THE EXTRACTED LECITHIN

Acid Value of Lecithin

The acidity of the extracted lecithin was determined according to the standard method adopted by [14].

Peroxide value of lecithin

The peroxide value of the lecithin was determined in accordance with the standard method approved by [15].

Assessment of antioxidant activity

Antioxidant activity was assessed using the DPPH assay to determine the ability of lecithin to scavenge free radicals. The method of [16] was followed with some modifications different concentrations of the extracted lecithin (0.8, 0.6, 0.4, 0.2) mg/ml were prepared and added to the DPPH solution; the tubes were incubated in the dark for 30 minutes at room temperature, A control sample was prepared by replacing the lecithin solution with the solvent (methanol), Absorbance was then measured at a wavelength of 517 nm, and the percentage of inhibition was calculated using the following equation:

inhibition % = (Absorbance of control – Absorbance of sample) / Absorbance of control × 100

Statistical Analysis

The results were statistically analyzed using a 2×5 factorial design with a completely randomized design (CRD) to determine the effect of oil type and extraction method on lecithin yield. Differences between the means of the groups studied were compared using Duncan's multiple range test at a significance level of 5%, and the data were analyzed using the statistical analysis software Genstat v.12.1 (Genstat, 2009).

3 Results And Discussion

3.1 Effect of oil type and extraction method on lecithin yield

The results in table (1) showed significant differences in lecithin yield depending on the extraction method and the type of oil used. The 10-minute ultrasonic extraction method recorded the highest yield of 3.912%, followed by the 20-minute and 30-minute treatments, while the aqueous method recorded the lowest yield, Furthermore,

unroasted oil yielded a higher average yield than roasted oil, indicating that phospholipids are affected by roasting and thermal treatments. This can be explained by the fact that the roasting of sesame seeds leads to changes in the chemical composition of the components, including phospholipids, as the roasting process causes partial degradation of the phospholipids. This was confirmed by a study [17], which found that roasting leads to changes in the components of sesame oil, including phospholipids, which affects their separation efficiency during the degumming process.

The lower yield of the aqueous method can be explained by the fact that this method relies primarily on the hydration of hydrophilic phospholipids only, while a proportion of the hydrophobic phospholipids remain bound to the oil and are not completely separated, [4] noted that the aqueous extraction of gums relies on the hydration of phospholipids followed by their separation by centrifugation; however, the efficiency of this process may be limited in extracting all the phospholipids present in the oil.

The acid method, on the other hand, yielded a higher yield compared to the aqueous method. This is because acids such as phosphoric acid or citric acid convert the insoluble phospholipids into a form that is more readily separable, a principle known in acid-based gum removal processes used in vegetable oil refining [18], however, this method remained less efficient than the ultrasonic-assisted extraction method. The clear superiority of the ultrasonic-assisted extraction method is attributed to the phenomenon of acoustic cavitation, where ultrasound causes the formation of microscopic bubbles in the liquid medium; when these bubbles collapse, high mechanical forces are generated that increase mass transfer and break the bonds between phospholipids and other components in the oil, thereby facilitating the extraction process [19].

A study by [11] reported that the use of ultrasonic gum extraction from sunflower oil led to a 2–2.5% increase in gum yield compared to gum removal by the aqueous method, with maximum yield achieved at an ultrasonic treatment time of 5–10 minutes.

Table (1) Effect of oil type and extraction method on the yield of extracted lecithin (%)

Oil type / Extraction method	**Aqueous**	**Acidic**	**Ultrasonic 10 m**	**Ultrasonic 20 m**	**Ultrasonic 30 m**	**Average of oil type**
roasted	**0.443 a**	**1.025 c**	**3.715 h**	**2.885 f**	**1.900 d**	**1.994**
unroasted	**0.578 b**	**1.028 c**	**4.110 i**	**3.105 g**	**2.148 e**	**2.194**
Average of extraction method	**0.510**	**1.026**	**3.912**	**2.995**	**2.024**	
L.S.D type×method=0.1122		**L.S.Dmethod=0.0793**		**L.S.Dtype=0.0502**		

The values are expressed as the arithmetic mean of five replicates.

Different letters indicate a statistically significant difference between the means of the treatments at the 0.05 significance level.

Table 2 Moisture and ash content of crude lecithin extracted from sesame oil

Lecithin	**Moisture**	**Ash**
	28.14±0.9384	**7.010±0.1562**

* Values are expressed as the arithmetic mean of three replicates ± standard deviation

Table (3) Quality indicators for extracted lecithin

Indicators	**Value**
Acid Value AV	**1.597**±0.411 (KOH/g)
Peroxid Value PV	**2.610**±0.260 (meq O2/kg)
Free Fatty Acid FFA%	**2.173**±0.295

*Values are expressed as the arithmetic mean of three replicates ± standard deviation

3.2 CHEMICAL COMPOSITION OF LECITHIN

Table (2) shows the moisture and ash content of ultrasonically extracted crude sesame lecithin; the moisture content of the crude lecithin was 28.14%, The high moisture content is attributed to the Amphipathic Nature of phospholipids and their ability to retain water, in addition to the fact that the crude lecithin did not undergo complete drying processes, as noted by [20] that it is difficult to control the drying process of lecithin because

prolonged exposure to high temperatures leads to undesirable changes, such as non-enzymatic browning and oxidation.
The ash content was 7.01%. When compared with previous studies, this value is similar to that reported in the study by [21], which indicated that a type of sunflower lecithin contains 8% ash, representing the inorganic components associated with phospholipids.

3.3 EVALUATION OF LECITHIN QUALITY INDICATORS

The results of the quality assessment of lecithin extracted from sesame oil using ultrasound, as shown in Table (3), indicated that the acid value (AV) was 1.597 mg KOH/g, while the peroxide value (PV) was 2.610 meq O_2/kg, and the free fatty acid (FFA) content was 2.173%, indicating that the extracted lecithin possesses a good degree of oxidative stability and low lipid degradation.
Acidity is an important indicator for assessing the extent of lipid and phospholipid degradation, as it reflects the amount of free fatty acids resulting from hydrolysis. The current value was within the recommended limits for dietary lecithin, which is ≤36, as mentioned in the study by [22], and was also similar to that reported by [12] when extracting sesame lecithin by hydrolysis from Nigerian sesame varieties, where the acidity value ranged between 0.68–2.42 mg KOH/g, indicating the quality of the extracted lecithin and a low level of lipid degradation.
The peroxide value, which is an indicator of the formation of primary oxidation products in fats, was recorded at a low level of 2.610 meq O_2/kg, which is lower than the values reported by [12], which ranged from 6.96–12.57 meq O_2/kg, and falls within the acceptable limits for dietary lecithin (<10 meq O_2/kg), indicating a low degree of oxidation and that the lecithin was not subjected to rancidity during the extraction process.
Meanwhile, the free fatty acid content in the extracted lecithin was 2.173%, which was higher than the value obtained by [12], which ranged from 0.34–1.21% for Nigerian sesame varieties, and lower than the FAO/WHO recommendation of <18%. The same source noted that the lower the free fatty acid content, the higher the quality.

3.4 ANTIOXIDANT ACTIVITY OF RAW LECITHIN

The results of the DPPH antioxidant activity assay showed that the ultrasonic-extracted sesame oil lecithin depicted in table (4) possesses a clear ability to inhibit free radicals, with the 0.8 mg/mL concentration recording the highest inhibition rate of 81.79%, followed by a concentration of 0.6 mg/mL with 77.18%, and then a concentration of 0.4 mg/mL with 73.07%, while the 0.2 mg/mL concentration recorded the lowest inhibition rate of 62.68%, with significant differences between all means, indicating a direct relationship between lecithin concentration and the ability to scavenge free radicals.
This antioxidant activity is attributed to the chemical nature of phospholipids and the content of fatty acids and associated compounds with antioxidant activity in lecithin, which may contribute to the inhibition of oxidative reactions and the reduction of free radical formation. These results are consistent with those reported by [23], which demonstrated improved antioxidant activity in the pinocembrin–lecithin complex, with an inhibition rate of 40.07% at a concentration of 0.1 mg/mL compared to the compound alone. The current results also align with the findings of [24], who reported that soy lecithin was able to inhibit approximately 41% of free DPPH radicals, supporting the antioxidant role of phospholipids.

Table (4) Effect of Sesame Lecithin Concentration on Free Radical Scavenging Capacity

Licethin concentraction mg/ml	Inhibition%
0.8	81.79±0.41a
0.6	77.18±0.57b
0.4	73.07±0.58c
0.2	62.68±0.82d

Values are expressed as the arithmetic mean of three replicates ± standard deviation. Different letters indicate a statistically significant difference at the $P \leq 0.05$ level.

3.5 FTIR ANALYSIS

The results indicate that sesame lecithin has an absorption pattern that is nearly identical to the characteristic absorption regions of lecithin, with a broad band observed at 3315 cm^{-1}. This is attributed to vibrations of polar groups such as O–H or N–H [25] noted the appearance of a peak close to this one at 3319.49 cm^{-1} in the infrared spectrum of soybean lecithin, which may indicate moisture associated with the sample or weak interference from polar groups. A peak appeared at 2926.01 and 2856.58 cm^{-1}) due to CH_2 vibrations, which are among the most characteristic peaks of phospholipids. A strong peak also appeared at 1743.65 cm^{-1} due to the carbonyl group vibrations of esters, specifically the stretching of the C=O bond, while the peaks at 1236.37 cm^{-1} and 2810.76 cm^{-1} are attributed to phosphate groups and the P–O–C and $^{-}PO_2$ bonds specific to phospholipids, confirming the phospholipidic nature of the extracted lecithin [4].

4 Conclusions

The study results indicate that the ultrasonic extraction method was the most efficient for extracting sesame lecithin compared to traditional methods, unroasted oil also yielded a higher lecithin yield than roasted oil, and FTIR results confirmed that the extracted lecithin contained phospholipids responsible for its functional and

emulsifying properties. The lecithin also exhibited antioxidant activity and good emulsifying properties, suggesting its potential for use as a natural emulsifier in food applications.

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