

Physicochemical Properties, Nutritional Assessment, and Bioactive Composition of *Sesamum indicum* (Sesame Seed) Oil: A Comprehensive Analysis

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Abstract

Sesame (*Sesamum indicum* L.) is a prized oil seed crop due to its versatility and exceptional nutritional value and are used traditionally for treatments of various health conditions, such as respiratory ailments, diarrhea, and dysentery. Despite the seeds are rich in nutrients, antioxidants and secondary metabolites with significant health benefits, but its industrial and pharmacological applications remains limited due to the limited scientific evaluations of the oil's physicochemical, bioactive and nutritional composition. This study investigates the physicochemical properties, nutritional composition, and bioactive components of sesame oil to evaluate its suitability for various industrial or therapeutic applications. The result revealed moisture content of 20%, contributing to a high yield of pure oil. The oil exhibited a specific gravity of 0.73 with proteins and carbohydrates having 22.4% and 22% respectively. Chemical analysis revealed an acid value of 176.6 mg KOH/g, indicating a higher susceptibility to spoilage compared to other seed oils, and a saponification value of 303.9 mg KOH/g, suggesting a higher proportion of short-chain fatty acids. The iodine value of 91.21 g/100g, indicative of the oil's unsaturation, positions it as non-drying oil which might be more suited for food applications. Fatty acid analysis showed a predominance of saturated fatty acids (29.65%). Furthermore, bioactive compounds such as sesamin (1.09%) were detected. FTIR spectroscopy identified key functional groups such as ester carbonyl and alkane groups at different peaks (1742.5 and 1455.5 respectively). Generally, sesame oil exhibits a promising bioactive and nutritional profile for various industrial applications. However, further research is recommended to determine its shelf life and preservation methods.

Keywords: GC-MS, FTIR, Sesame oil, Sesamin.

1.0 Introduction

Sesame (*Sesamum indicum* L.) is a prized oil seed crop because of its versatility and exceptional nutritional value. Africa contributes approximately 40% of the global sesame production, with Nigeria, Ethiopia, and Sudan ranking among the leading producers [1]. Sesame seeds are rich in

essential micronutrients beneficial to human health, which include vitamins and minerals, as well as unique bioactive compounds like sesamin, sesamol, and sesamolol [2]. Sesame oil is widely used in cooking, confectionery, and margarine production. Sesame seeds are nutrient-rich in oil and protein, it have been traditionally utilized for treatments of various health conditions, such as

respiratory ailments, diarrhea, and dysentery [3]. Additionally, sesame seed powder is known to alleviate gynecological and gastrointestinal issues, including amenorrhea and ulcers [4].

Emerging research highlights sesame's potential in improving cholesterol levels and reducing oxidative stress, facilitating cholesterol metabolism by increasing fecal sterol excretion and stimulating bile acid production in the liver [5]. Moreover, it enhances antioxidant defense by boosting hepatic catalase and superoxide dismutase activities while lowering lipid peroxidation [5]. Sesame oil is also utilized in pharmaceutical formulations and health products because of its rich in vitamin E and strong antioxidant properties [6]. The lignans, such as sesamin and sesamol have increase the sesame's value to act as antioxidants and active ingredients for antiseptics, bactericides, viricides, and disinfectants [7]. However, the protein- and calcium-rich meal left after oil extraction is a valuable resource for animal feed [2]. Despite the seeds are rich in nutrients, antioxidants and secondary metabolites with significant health benefits, but its industrial and pharmacological applications remains limited due to the limited scientific evaluations of the oil's physicochemical and nutritional composition. In addition, inconsistent in the findings from few existing researches have created uncertainty about the suitability for various industrial or therapeutic applications. This study is aim to investigate the physicochemical properties, nutritional composition, and bioactive components of sesame (*Sesamum indicum*) oil.

2.0 Materials and Methods

Study Area

The study was conducted at the Centre for Advanced Science Research and Analytical Services (CASRAS), Usmanu Danfodiyo University Sokoto, Sokoto State, Nigeria.

2.1 Plant Material and Authentication

Sesame seeds were procured from Sokoto Central Market. A portion of the purchased sesame seeds was submitted to the Herbarium, Department of Plant Science, Usmanu Danfodiyo University, Sokoto, for taxonomic identification and authentication and the voucher specimen (UDUH/ANS/0084) was deposited.

2.2 Quality Assurance and Control

The reagents, chemicals and assay kits used for the determinations of nutritional profiles, saponification, iodine, and specific gravity, ester, and percentage purity were of standard analytical grade. Furthermore, the supplementary reagents used during this experiment were of high quality and prepared in accordance with specifications using distilled water and calibrated measuring flasks except where stated otherwise.

2.3 Sample Pre-treatment and Preparation

To ensure quality and reduce microbial contamination the sesame seed was sorted to remove impurities and extraneous materials such as stones and other foreign debris. Once sorted the seeds was rinsed three times under a running tap water. The sesame seed was oven dried at 40°C to reduce moisture content and stored in clean dry polyethylene bags at room temperature until time of use. To obtain a fine particle, the seed was subsequently crushed using an electric blender (Master Chef Blender, Model MC-BL 1980, China).

2.4 Extraction of Oil from Sesame Seed

The extraction of sesame oil followed the procedure described by Visavadiya et al.[3]. A total of 250 g of powdered sesame seed was processed in a Soxhlet apparatus (EX5/55/100, England) using n-hexane solvent. After the extraction, the solvent was removed under vacuum at 40°C using a rotary vacuum evaporator (Tokyo Rikakikai Co. Ltd., Eylea) with vacuum control. The extracted oil was then stored in at room temperature for further analysis.

2.5 Proximate Composition of Sesame Seeds

2.5.1 Determination of Moisture Contents

Exactly 5 grams of the sample were added into a weighed glass crucible. The crucible and its contents were then placed in a thermostatically controlled oven (FS Tupola Plant, Wageningen) at 105°C for 5 hours. After heating, the sample was cooled in a desiccator, and its final weight was recorded. This process was repeated until a constant weight was obtained [8]. The moisture content was calculated as a percentage of the initial sample weight using equation I:

$$\% \text{ Moisture Content} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (I)$$

Where,

W_2 = Weight of sample + crucible,

W_3 = Weight after drying

W_1 = Weight of the empty crucible.

2.5.2 Determination of Ash Content

A crucible was cleaned, dried in an oven, and cooled in a desiccator. Five grams (5 g) of the sample were placed into the crucible, and its weight along with the sample was recorded. The crucible was heated in a muffle burner (Binder FD 115 model, Germany) until smoke ceased. It was then subjected to further heating in a muffle furnace at 550–570 °C for 2 hours to incinerate all organic matter, leaving only ash. After heating, the crucible was removed, cooled in a desiccator, and its final weight was recorded using equation II [8].

Ash content (%)

$$= \frac{\text{Weight of ash}}{\text{Weight of original sample}} \times 100 \text{ (II)}$$

2.5.3 Determination of Crude Fat

A 250 mL round-bottom flask was dried in an oven (FS Tupola Plant, Wageningen) and weighed. Two gram (2 g) of the sample was placed into a 22 × 80 mm paper thimble, with cotton added to prevent sample loss. The thimble was inserted into a Soxhlet extractor fitted with a condenser and a round-bottom flask. The residual solvent in the fat was evaporated by placing the extract on a water bath. The sample was then dried further in an oven (FS Tupola Plant, Wageningen) at 105°C for 30 minutes, cooled in a desiccator, and weighed [8].

The % crude fat was then obtained using equation III:

$$\text{Crude fat (\%)} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100 \text{ (III)}$$

2.6 Physiochemical Analysis of Sesame oil

2.6.1 Saponification Value

A 2 g of the oil sample was weighed and placed in a 200 mL Erlenmeyer flask and then 25 mL of 0.5 M ethanolic KOH was added to dissolve the oil. The mixture was refluxed on a water bath with a condenser for one hour. After cooling at room temperature, the mixture was titrated with 0.5 M

HCl using 1% phenolphthalein as indicator. A blank titration was also performed without the oil [9]. The saponification index was computed using equation IV:

$$S.V = \frac{(b-a) \times 28.05}{g} \text{ (IV)}$$

Where,

S.V = Saponification value,

b = Titre value of blank

a = Titre value of the sample

g = Weight of oil sample,

28.05 = Constant.

2.6.2 Determination of Iodine Value

The method described by Ibrahim and Yusuff[9] was adopted for the determination of iodine value with slight modification. Five gram (5.0 g) of oil sample was placed in a clean, dry 250 mL Erlenmeyer flask, followed by the addition of 20 mL of carbon tetrachloride to dissolve the oil. Next, 25 mL of prepared Wijs solution was added, and the flask was sealed with a cork, which were kept in a dark place at room temperature for 30 minutes. Afterward, 20 mL of 10% potassium iodide solution and 100 mL of distilled water were added to the mixture. The resulting solution was titrated with sodium thiosulfate solution, using starch as an indicator. A blank titration was also performed under identical conditions, excluding the oil sample (equation 5).

$$I.V = \frac{(B-S) \times M \times 12.69}{G} \text{ (V)}$$

From equation V, I.V = Iodine value; B = Titre value of blank, S = Titre value of the sample, M = Molarity of sodium thiosulphate; G = Weight of oil sample used, 12.69 = Equivalent of iodine.

2.6.3 Determination of Acid Value

The acid value was determined following the ISO 660:1996 standard (10) by placing 5.0 g of oil sample into a clean, dry 250 mL Erlenmeyer flask, to which 25 mL of ethyl alcohol and 1–3 drops of phenolphthalein indicator were added. The mixture was shaken and heated in a water bath at 60°C for 10 minutes, then allowed to cool for and titrated with 0.1 M KOH until a persistent pink endpoint was observed for 30 seconds. The acid

value was calculated using the formula provided and expressed in milligrams of KOH.

$$A.V = \frac{56.1 \times C \times V}{W} \quad \text{VI}$$

Where,

C= Concentration of KOH,

V= Volume of KOH,

56.1= Molar mass of KOH,

W= Weight of oil (cm³).

2.6.4 Determination of Specific Gravity

The specific gravity of the oil was determined using a density bottle, following the method outlined by Tsado et al.[11]. A clean, dry stoppered bottle with a capacity of 25 cm³ was weighed (W0), then filled with the oil and then reweighed to obtain (W1). Afterward, the bottle was washed, dried, and refilled with distilled water, then weighed again to give (W2). The specific gravity was calculated using the formula provided.

$$\text{Specific gravity} = \frac{W1 - W2}{W2 - W0} \quad \text{VII}$$

Where:

W0 = weight of dry empty bottle;

W1 = weight of bottle + oil;

W2 = weight of bottle + distilled water.

2.7 Determination of Oil Composition using Gas Chromatography-Mass Spectroscopy (GC-MS)

The analysis was conducted using an Agilent Intuvo 9000 GC system coupled with a 5977B mass selective detector (MSD) system and a split/splitless injector. A DB-5 MS fused silica capillary column (30 m, 320 μm i.d., and 0.25 μm film thickness) with 5% phenyldimethylsiloxane was employed, and helium gas (99.99% purity) served as the carrier gas at a flow rate of 1.2 mL/min. The inlet temperature was set at 300 °C, the MS source temperature was at 230 °C, and the MS quadruple was maintained at 150 °C. The oven temperature was programmed at 50 °C for 5 minutes, ramped up to 300 °C at increasing rate of 10 °C/min, and held for 20 minutes. A 1 μL sample extract was injected in split-less mode into

the GC system using the Agilent Automated Liquid Sampler (ALS) G4513A and ran for 50 minutes. Data were acquired using the GCMSD/Enhanced Mass-Hunter Software (version B.07), and the GCMSD data were processed with the 2017 version of the NIST library [12].

2.8 Evaluation by Fourier Transform Spectroscopy (FT-IR)

The FT-IR spectra of the oil samples were obtained using Fourier Transform Spectroscopy. The analysis was performed with an Agilent Cary 630 FTIR spectrometer, coupled with a 5-bounce diamond ATR sampling accessory, utilizing an internal reflection element (IRE) crystal. The analysis was conducted in transmittance mode, and the signal was collected over the wave number range between 4000–650 cm⁻¹. The sample spectra were generated using MicroLab software (version 5.2).

3.0 Results

3.1 Proximate Composition of Sesame Seed

Table 1 present the proximate composition sesame seed oil, which includes percentage moisture content, ash content, total sugar content, protein content, and total lipids, and crude fiber (Table 1). Among these parameters, ash content and crude fiber were observed to be lowest with 10.0% and 12.3%, respectively, while the moisture content of 20.0% and 22.4% of crude protein was detected in the sesame seed. However, carbohydrates and crude fat were found be at 22.0% and 13.3%, respectively.

Table 1: Proximate composition of sesame seed oil from Sokoto

Constituents	Percentage (%)
Ash content	10.0
Crude Fiber	12.3
Moisture content	20.0
Protein content	22.4
Carbohydrate	22.0
Crude fat	13.3

3.2 Physicochemical Properties of Sesame Oil

The physicochemical properties of the sesame oil shown in table 2 indicated highest saponification

value of 303.80 mg KOH/ g, followed by Acid value with 176.28 mg KOH/ g, and ester value of 127.28 mg KOH/ g, while the iodine value were found to be 91.21 g/100 g, a percentage purity of 80% and specific gravity of 0.73 g/cm³ were recorded.

Table 2: Physicochemical properties of sesame oil

Parameters	Composition
Iodine value (g/100g)	91.21
Saponification value (mgKOH/g)	303.80
Specific gravity g/ cm ³	0.73
Acid Value (mg KOH/g)	176.60
Ester Value (mg KOH/g)	127.28
Percentage Purity (%)	80.00
Ester value = Saponification value - Acid value	

Table 3: Composition of Sesame oil using GC-MS

Compound	RT	% Area
Palmitoleic acid	22.265	0.43
N-octanoic acid	22.602	26.89
Hexadecanoic acid	22.751	2.15
Heptadecanoic acid	23.394	0.14
9, 12 – Octadecadienoic acid	23.707	0.53
11 – Octadecenoic acid	23.752	0.40
5 – Decen-1-ol	24.554	17.73
Octadecanoic acid	24.845	0.47
11,14 – Eicosadienoic acid	25.046	0.56
Linoelaidic acid	25.727	1.62
1,8,11 – Heptadecatriene	26.327	1.35
Fumaric acid	26.751	0.24
Stigmasta-3,5- diene	31.683	3.40
(+) – Sesamin	32.152	1.09
1,3 – Benzodioxole	32.204	1.99
UFA		29.65
SFA		3.54
UFA/SFA		0.12

RT = Retention time UFA = unsaturated fatty acid, SFA = saturated fatty acid

3.4 FTIR spectra of sesame oil

The result of the FTIR spectra analysis revealed a series of bands along with % transmittance related to the functional groups in sesame oil. The strong density of 1742.50 cm⁻¹ shows the CO stretching

3.3 Compounds Present in the Sesame Oil

GC-MS analysis of sesame oil reveals the abundance of the identified compounds in the following descending order; n-octanoic acid (26.89%) > 5-decen-1-ol (17.73%) > Stigmasta-3,5-diene (3.40%), > Hexadecanoic acid (2.15%) > 1,3 – Benzodioxole (1.99%)>Linoelaidic acid (1.62%)>1,8,11–Heptadecatriene (1.35%)>(+) – Sesamin (1.09%) > 11, 14–Eicosadienoic acid (0.56%) > 9,12–Octadecadienoic acid (0.53%) > Octadecanoic acid (0.47%) > Palmitoleic acid (0.43%) > Octadecenoic acid (0.40%) > Fumaric acid (0.24%) > Heptadecanoic acid (0.14%) (Table 3)

of esters typical of fatty acid methyl esters spectral (Figure 1). The peak at 1455.50 cm⁻¹ corresponds to the bending of -CH present in the oil, in addition to other groups shown in the Table 4 and Figure 1.

Table 4: Peak Assignment for Different Functional Groups in Sesame oil

No.	Wavelength (cm ⁻¹)	Type of Vibration	Assignment
1	712.2, 937.4	Out-of-plane bending	=C-H Alkenes
2	1094.0 1162.9 1237.5 1284.1		-C-O Alcohols, ethers, anhydrides, esters, carboxylic acids
3	1377.3		C-N Amines
4	1455.5	Bending	C-H Alkanes
5	1709.0	Stretching	C=O Ketone
6	1742.5	Stretching	C=O Ester
7	2851.4	Stretching	C-H Aldehyde
8	2918.5	Stretching	C-H Alkanes
9	3011.7		O-H Carboxylic acid

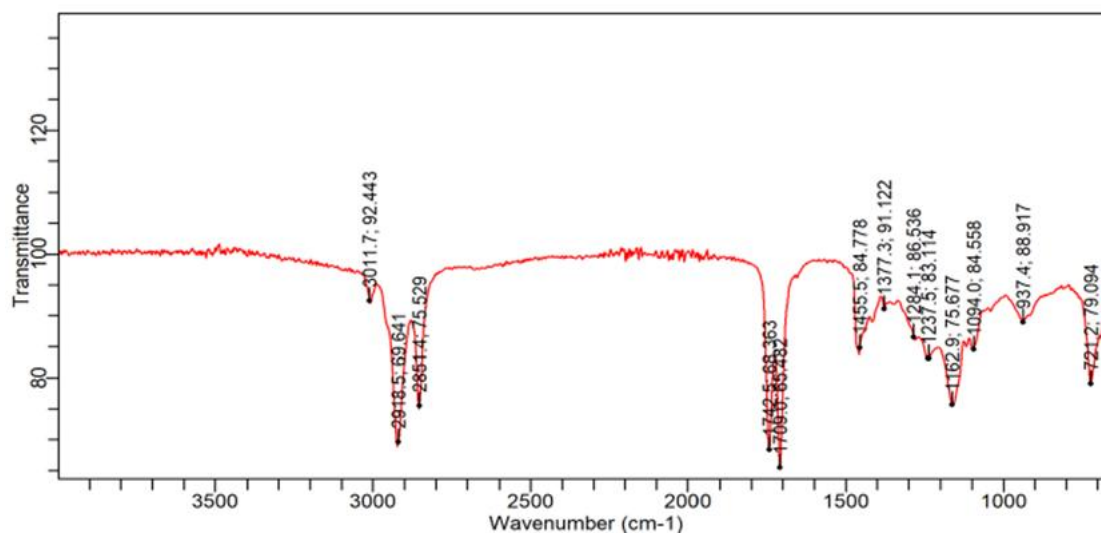


Figure 1: FTR results showing functional groups present in sesame oil

4.0 Discussions

Moisture content have reported to affects different nutritional as well as organoleptic properties of food and the texture of product [13]. The proximate compositions of sesame seeds reveals moderate moisture content which is in line with the findings of [13]. Low moisture content indicate a higher shelf life and reduced the risk of

microbial activities and may also contribute to the higher yield of pure oil [13].

The ash content found in this study is align with the studies of Ibrahim and Yusuf [9] who found 5% of ash content in *Citrus sinensis* seeds. The presence of significant amount of ash content in the sesame seeds suggest a high amount of mineral content [9]. The carbohydrate and protein contents are found to be higher than ANSES's

benchmarks of 20.8% and 9.85%, respectively, while the fiber content was found within the recommended range of 11.8–18% [14]. However, the fat content fell below the 49.7% standard value set by ANSES [14]. The differences observed could be attributed to regional variations, potentially influencing the seed's nutritional composition and edibility. Despite the discrepancies observed, the extracted oil demonstrated nutritional benefits, affirming its suitability for consumption based on the nutritional composition. However, the presence of fibers and lipids in significant amount suggests that sesame seed can aid in digestion and have higher energy density [13].

The sesame oil had a specific gravity of 0.73, typical of oils with lower densities than water, making it ideal for use in creams due to its ease of spread on the skin [15]. The oil also exhibited an 80% purity level, enhancing its potential for applications in food, cosmetics, and therapeutic products [16].

The acid value of the sesame oil was found to be 176.6 mg KOH/g, which is higher than the values reported for *Cucurbita pepo* (37.03 mg KOH/g), *Cucume ropsismannii* (27.95 mg KOH/g), and *Lagenaria breviflora* (33.10 mg KOH/g) [17]. A lower acid value generally indicates better stability and a lower risk of rancidity [13]. However, the elevated acid value in this sample suggested an increasing susceptibility to spoilage, which could affect its shelf life.

The saponification value (SV) of 303.9 mg KOH/g in the sesame seed oil is higher than the values for *Citrus sinensis* (190.32 mg KOH/g) [9], and watermelon oil (163 mg/g) [18]. A higher SV indicates a larger proportion of short-chain fatty acids, which is favorable for culinary uses [19].

The quantified iodine value (IV) of 91.21 g/100g in the sesame oil employed in this study is higher than the IV of *Citrus sinensis* oil of 54.19 g/100g [9]. High IV values indicate a greater degree of unsaturation that makes oils more prone to oxidation [20]. Therefore, the sesame oil of this study is found to be more prone to oxidation, which were also classified as non-drying oil due to its IV below 100 g/100g [9], making it more suitable for food applications than for drying purposes.

The oil contains essential fatty acids, which are important energy sources and can support various

bodily functions [7]. Saturated fatty acids (29.65%) were higher than unsaturated fatty acids (3.54%), which might likely due to the presence of n-octanoic acid. The higher saturation level contributes to the oil's stability, reducing oxidation risks and extending its shelf life. In contrast, Tsado et al.[11] reported a high level of unsaturated fatty acids (98.7%) and low saturated fat in *Blighia sapida* oil, which was considered safe for consumption. Additionally, the sesame oil contains bioactive sesamin, known for antioxidant, anti-inflammatory, and antimicrobial properties [21]. However, the sesamin levels in this study were lower than the values reported by Dar et al.[22], where the range fall between 2.10 and 5.98, indicating a lower lignin content, which could impact the oil's nutritional value.

From this study, a total of 15 compounds were identified in the sesame oil, including n-octanoic acid, hexadecanoic acid, 5-decen-1-ol, 1,8,11-heptadecatriene, sesamin, and stigmasta-3,5-diene. In comparison, Karaye et al.[17] identified four primary compounds in *Cucurbita pepo* oil, such as oleic acid and 9,12-octadecanoic acid, five compounds in *Cucume ropsismannii*, including 1,8,11-heptadecatriene and linoelaidic acid, and eight in *Lagenaria breviflora*, including n-hexadecanoic acid and conjugated linoelaidic acid.

In the present study, the major functional groups identified include a frequency at 3011.70 cm^{-1} , which indicates the presence of alcohols or phenols with carboxylic acid (medium intensity), followed by saturated aliphatic groups (alkanes) at 2918.50 cm^{-1} (strong intensity) and 2851.57 cm^{-1} (symmetrical stretching with strong intensity). The strong stretching intensity at 1742.50 cm^{-1} corresponds to the ester carbonyl functional group of triglycerides [19], while the stretching at 1709.0 cm^{-1} suggests the presence of ketones. The CH bending vibration at 1455.5 cm^{-1} is attributed to the -CH group of alkanes. A weaker intensity at 1377.30 cm^{-1} corresponds to amines, similar to the peak value at 1377.41 cm^{-1} observed in the FTIR analysis of *Opuntia ficus indica* seed oil, which was linked to the glycerol group (mono-, di-, and triglycerides) [19]. The frequency range of 1284.10 cm^{-1} to 1094.0 cm^{-1} was assigned to the C-O ester carbonyl group with varying intensities, while the peaks values at 937.4 cm^{-1} and 712.20 cm^{-1} were associated with the =C-H trans or cis-disubstituted alkene group. These findings suggest the presence of saturated aliphatic compounds (CH_2 and CH_3), the dimerized carboxylic acid

group (C=O), ester carbonyl groups, and trans/cis-disubstituted alkenes.

5.0 Conclusion

The sesame seeds analyzed in the present study exhibited a higher moisture content, which is likely contributed to a higher oil yield. However, the nutritional composition of the seeds differed from ANSES benchmarks, but the extracted oil maintained considerable nutritional value, making it suitable for consumption. The sesame oil demonstrated favorable physical and chemical properties, such as a specific gravity, which is ideal for cosmetic applications, and 80% purity, enhancing its versatility in food, cosmetic, and therapeutic industries. However, the oil's relatively high acid value suggests a higher susceptibility to spoilage, which may affect its shelf life. Despite this, the oil's high saponification and iodine values indicate its suitability for culinary uses, with the high iodine value pointing to a greater degree of unsaturation. The oil's composition also includes bioactive compounds like sesamin, known for its antioxidant properties, though its lower concentration in this sample might impact its overall health benefits. FTIR analysis further confirmed the presence of key functional groups, highlighting the complex chemical structure of the sesame oil. Generally, while the sesame oil exhibits a promising profile for various applications, its stability and shelf life may be influenced by factors such as acid value and oxidation risk. Further research on its preservation techniques and long-term stability could enhance its potential for broader industrial use.

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