AJBCPS African Journal of Biological, Chemical and Physical Sciences
Jozac Publishers
Vol 4, Issue 1, 2025

ISSN: 2790-9522 (Print) | 2790-9530 (Online)
Website: https://journals.jozacpublishers.com/ajbcps/index
https://doi.org/10.5281/zenodo.17260435

OPEN ACCESS

Integrative Nutritional, physicochemical, and bioactive profiling of Sesamum radiatum seeds: A Potential Healthy Food Source

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Received: June 16, 2025 | **Accepted:** September 28, 2025 | **Published:** October 03, 2025

Abstract
Sesamum radiatum, a neglected relative of commercial sesame (S. indicum), holds significant potential as a source of nutritious seeds and oil. This study presents a comprehensive analysis of seeds from Nigeria, revealing a rich nutritional profile featuring high crude lipid (31.9%) and fiber (29.8%) content, alongside substantial mineral levels such as calcium (7.92 mg/g). Oil yield was substantial (32.0%), with favorable physicochemical properties including a high iodine value (192.9) and smoke point (224 °C). The oil demonstrated potent concentration-dependent antioxidant activity (IC_{50} = 6.94 mg/mL). Crucially, GC-MS analysis revealed a unique fatty acid profile dominated by 10,13-octadecadienoic acid (41.77%), alongside linoleic (16.98%) and palmitic (6.17%) acids. Spectroscopic characteristics (UV-Vis and FT-IR) provide a distinct fingerprint for quality control. These findings underscore that S. radiatum is not merely an understudy to its commercial cousin but a valuable resource in its own right, with promising applications for the food, nutritional, and healthcare industries aimed at leveraging novel and sustainable plant oils.

Keywords: Antioxidant activity, FT-IR spectroscopy, GC-MS, Mineral content, Neglected oilseed, 10,13-Octadecadienoic acid, Proximate composition, Sesamum radiatum

1. Introduction
Global food security faces unprecedented challenges from climate change, population growth, and the over-reliance on a narrow range of staple crops (Ebert, 2024). This has intensified the search for resilient and nutritious alternative food sources. Neglected and underutilized species (NUS), often adapted to marginal growing conditions, represent a vital reservoir of genetic diversity and potential for enhancing dietary diversity, nutrition, and sustainable agriculture (Mabhaudhi et al., 2019).

Sesamum radiatum Schum. & Thonn. (Pedaliaceae), a wild relative of the commercially cultivated sesame (*Sesamum indicum* L.), is one such species endemic to West and Central Africa (Bedigian, 2010). Known colloquially as benniseed, black benniseed, or karkashi, it is deeply embedded in indigenous food cultures and traditional medicine systems across its range, particularly in Nigeria and Benin (Dansi et al., 2012; Jimam et al., 2015). While S. indicum has achieved global economic importance, *S. radiatum* remains largely confined to local use and is classified as a neglected species, despite its documented role in food security and income generation for rural communities (Agbankpé et al., 2015; Akanmu et al., 2019).

The full potential of *S. radiatum*, especially its seeds, remains underexplored from a scientific standpoint. Comprehensive data on its nutritional composition, bioactive properties, and seed oil characteristics are fragmented and insufficient to advocate for its broader application. Therefore, this study aims to provide a comprehensive analysis of *S. radiatum* seeds and their oil to scientifically validate their traditional use and unlock their potential for food, nutritional, and industrial applications.

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2. Literature review

2.1. Traditional uses and agronomic potential

Sesamum radiatum is a versatile plant traditionally consumed as a leaf vegetable and whose seeds are eaten whole, ground into paste, or pressed for oil (Bedigian, 2010; Auwalu & Babatunde, 2007). Beyond its nutritional value, it holds a significant place in ethnomedicine. Extracts from its leaves are used as laxatives, antidotes to scorpion venom, and to ease childbirth, while the stem and bark have been noted for antibacterial properties (Konan et al., 2011; Oduntan, 2011; Agbankpé et al., 2015). Agronomically, its resilience suggests potential as a hardy crop for challenging environments, a critical trait for climate-resilient agriculture (Getinet & Sharma, 1996).

2.2. Nutritional and phytochemical studies

Existing research on *S. radiatum* has primarily focused on its leafy vegetables. Studies on leaves from Benin and Nigeria have reported appreciable levels of protein, minerals, and antioxidants (Agbankpé et al., 2015; Jimam et al., 2015; Oduntan, 2011). For instance, Jimam et al. (2015) reported high ash content (indicating mineral richness) in leaves from Plateau State, Nigeria. Phytochemical screening of leaf extracts has confirmed the presence of bioactive compounds like flavonoids, alkaloids, and saponins, which correlate with their observed antimicrobial and antioxidant activities (Akanmu et al., 2019).

In contrast, data on the seeds are notably scarce. A comprehensive profile encompassing its precise fatty acid distribution, mineral content (micro and macro elements), spectroscopic fingerprints, and detailed antioxidant capacity is still lacking. This gap is significant given that the nutrient profile of oilseeds can be highly influenced by genotypic and environmental factors (Ghorase et al., 2022; Oboulbiga et al., 2023). Furthermore, the mineral composition of the seeds, which is crucial for assessing their nutritional quality and safety from heavy metal contamination, remains largely uninvestigated.

2.3. Analytical characterization of plant oils

Standard methods for evaluating oil quality, such as iodine value, peroxide value, and saponification value, are well-established (AOAC, 1990) and have been applied to various novel oils, including S. indicum (Oboulbiga et al., 2023). Spectroscopic techniques like Fourier-Transform Infrared (FT-IR) spectroscopy have become indispensable for providing a molecular fingerprint of oils, allowing for quality assessment, authentication, and detection of adulteration (Gbonjubola et al., 2023; Coates, 2000). The application of these rigorous analytical techniques to *S. radiatum* seed oil is necessary to establish its fundamental properties and benchmark its quality against other commercial oils.

This study seeks to bridge these knowledge gaps by conducting a comprehensive analysis of *S. radiatum* seeds from Nigeria, with specific objectives to determine their: (1) proximate and elemental composition, (2) oil yield and physicochemical properties, (3) antioxidant activity, (4) phytochemical profile, (5) fatty acid composition using GC-MS, and (6) spectroscopic characteristics using UV-Vis and FT-IR spectroscopy.

3. Research methodology

3.1. Research design

This study employed an experimental research design to analyze the composition and properties of *S. radiatum* seeds and oil through a series of standardized analytical techniques.

3.2. Sample collection and preparation

Approximately 2.5 kg of seeds of *S. radiatum* were sourced from Langkuk farm in Jwakkom village, Mangu area council, Plateau state, Nigeria (approximately 9.4926° N, 9.1526° E; see Supplementary Figure S1 for a detailed map). In the laboratory, the seeds underwent a cleaning process involving sieving with a 1.18mm sieve using Haver EML digital Plus, Haver & Boeker 59302 OELDE, Germany, to eliminate small impurities. Subsequently, hand-sorting was employed to remove any defective seeds. The cleaned seeds were then blended and stored in a clean glass container for future use.

3.3. Proximate analysis of *S. radiatum* seed

The proximate composition of the seeds was assessed to determine key nutritional components, including moisture content, ash, crude protein, crude fat, crude fiber, and carbohydrates. Standard methods were employed for these analyses. Specifically, the moisture, crude lipid, and crude fiber contents were determined following the protocols outlined by researchers (Udo & Oguwele, 1986). The ash content was determined using the method prescribed by James (1995). For crude protein analysis, the micro-Kjeldahl method as described by AOC (1990) was employed. Additionally, the method outlined by James (1995) was adopted to ascertain the total proportion of carbohydrates. All analyses were performed in triplicate and results are expressed as mean ± standard deviation.

3.4. Elemental analysis of *S. radiatum*seeds

A seed sample weighing 1g underwent digestion with 10 mL of HNO_3 on an electric hot plate. After digestion, the sample was filtered into a 100 mL volumetric flask, and the volume was adjusted to the mark. The analysis was conducted using a Thermos Scientific iCE 3000 series spectrometer. Results from the spectrometer, initially in mg/L, were converted to mg/kg of seed using the formula:

$$\text{Concentration} = \left(\frac{C_s - C_b}{m}\right) \times 100 \qquad 1$$

Here, m is the mass (g) of the seed sample digested, while C_s and C_b denote the concentrations (mg/L) of the seed sample and blank, respectively. The analysis was performed in duplicate and results were expressed as the mean.

3.5. Extraction of *S. radiatum* seed oil

The blended seed (60g) was placed in a cellulose thimble and sealed with cotton to prevent sample transfer. The thimble was then inserted into a Soxhlet apparatus with a condenser, set on a 500-mL flask with 400 mL of n-hexane. Reflux extraction occurred for 9 hours at 6 cycles per hour. After extraction, n-hexane was evaporated using a vacuum rotary evaporator, and the content was transferred to a preweighed beaker. Remaining n-hexane in the oil was dried and weighed until consecutive weights differed by less than 10% (w/w). The extract yield was expressed as a percentage relative to the weight of the dry seed used, following the equation

$$\text{Yield (\%)} = \frac{\text{weight of oil (g)}}{\text{wight of seed(g)}} \times 100 \qquad 2$$

This process was performed three times and result expressed as mean ± standard deviation.

3.6. Determination of physicochemical properties of *S. radiatum* seed oil

The analysis of the extracted oil included measuring its density, refractive index, iodine value, peroxide value, acidity, and saponification value, following the procedures outlined in AOAC(AOAC, 1990). Viscosity was determined using an ND-5S viscometer with a size 2 spindle at 30 revolutions per minute. Smoke and melting points were assessed using a mercury-in-glass and infrared thermometer (KM-JT1600 Kaemeasu, county). To determine the oil's ability to allow the passage of light, observations were made against an electric bulb. Color was determined by comparing the oil with a color chart. Density determination was conducted using a 25 mL density bottle. All analyses were performed in triplicate, and results were expressed as mean ± standard deviation.

3.7. Determination of antioxidant property of *S. radiatum* seed oil

DPPH (1, 1-diphenyl-2-picryl hydrazyl) method was used to assess the antioxidant activity of the oil extract. A stock of the oil was prepared by dissolving 200mg of the oil in 20 mL of ethanol to give a 10mg/ml concentration. Serial dilutions were prepared to obtain concentrations of 10, 5, 2.5, 1.25, and 0.625 mg/ml. 3 mL of each oil concentration was mixed with 1 mL of DPPH (40μg/ml) in triplicate. The mixture was allowed to stand in a dark cupboard for 20 minutes, and the absorbance (As) was measured at 517nm using a UV-Visible spectrometer (6850 UV/Vis. Spectrophotometer, JENVA, China). The percentage inhibition of the various oil concentrations was calculated using the following equation:

$$\%\ \text{Inhibition} = \frac{\text{Ao}-\text{As}}{\text{Ao}} \times 100 \qquad 3$$

Where Ao is the absorbance at 517nm of the blank (containing 3 mL of ethanol and 1 mL of DPPH solution). The IC_{50} value, representing the concentration at which the oil reduces the initial DPPH concentration by half, was determined from the linear regression plot of antioxidant activity (%) against concentration (μg/mL) of the oil.

$$\%\ \text{Inhibition} = \text{mC} \pm \text{I} \qquad 4$$

Where m and I denote the slope and intercept, respectively, of the plot.

3.8. Qualitative phytochemical screening of *S. radiatum*seed oil

Qualitative tests were conducted as described by Adedunni *et al*. (2016) to identify the presence or absence of phytochemical compounds, including alkaloids, flavonoids, tannins, saponins, steroids, glycosides, phenols, terpenoids, volatile oils, sterols, phlobatannins, and resin.

3.9. Fatty acid profiling by Gas Chromatography-Mass Spectrometry (GC-MS) of *S. radiatum*seed oil

A sample of oil weighing 400mg was subjected to saponification in a flask using 4 mL of 0.5M methanolic KOH and heated to boiling point for a quarter of an hour. This was followed by the addition of 1.6 mL of methanolic HCl (HCl: MeOH, 4:1) and further heating for 25 minutes. After cooling down, the flask was supplemented with 8 mL of deionized water. The Fatty Acid Methyl Esters (FAMEs) were then extracted using three rounds of n-hexane, each using 6ml, making a total of 15ml. The n-hexane extract was then dried with Sodium sulfate in preparation for GC-MS analysis.

The GC-MS analysis was performed on an Agilent GCMSD system fitted with an HP-5ms Ultra Inert column (30 m x 250 μm x 0.25 μm), and helium was used as the carrier gas at an average speed of 31.147 cm/sec. The oven temperature was initially set at 40 °C for 2 minutes, then ramped up to 180 °C at a rate of 15 °C/min, then slowly increased to 205 °C at a rate of 3 °C/min, and finally ramped up to 300 °C at a rate of 8 °C/min, where it was held for 7 minutes. A 2 μL sample was injected in a split mode (split ratio 5:1) at a temperature of 250 °C. The FAMEs were identified by comparing their retention times with those of FAME standards. The MS analysis was carried out in SIM/Scan mode with a mass range from 46 to 600 amu and a dwell time of 100 ms for 18 specific ions. The data acquisition was managed by the Agilent MassHunter software.

The concentrations (%, w/w) of the fatty acid derivatives obtained from the GCMS results were converted to their equivalent fatty acid concentrations (%, w/w) and normalized. Similarly, the concentrations of the non-fatty acid components were normalized.

3.10. Spectroscopic characterization (UV-Vis and FT-IR) of *S. radiatum seed* oil

The FT-IR spectrum of *S. radiatum* seeds was obtained in neat mode using Thermoscientific Nicolet iS5 FT-IR equipped with iD7 ATR accessory. UV-Visible spectrometry of the oil, both with and without a solvent, was conducted using a UV-Visible spectrometer (6850 UV/Vis. Spectrophotometer, JENVA, China). The analysis followed rigorous conditions: Scan Range, 190.0-1100.0nm; Scan Step, 1.0nm; Scan Filter, 10. The resulting spectrum was recorded as a plot of absorbance against wavelength, followed by a meticulous data re-plotting process.

4. Data analysis

This study is a compositional analysis, wherein each parameter measured is a unique property of the *S. radiatum* seeds and oil. As such, the data are presented descriptively and not subjected to comparative inferential statistical testing between parameters. Proximate analysis, Extraction of *S. radiatum* seed oil, Physicochemical properties determination, and antioxidant activity were performed in triplicate (n=3). elemental analysis, was performed in duplicate (n=2). Fatty acid profiling and and spectroscopic characterization were conducted in singlet. Data are presented as mean ± standard deviation for triplicate experiments and as mean for duplicate experiments. All graphing was performed using Microsoft Excel 2021.

5. Results and discussion

5.1. Proximate composition of *S. radiatum* seeds

The proximate composition of S. seeds presented in Table 1 exhibits a well-rounded nutritional profile. The seeds display a moderate moisture content (4.132±0.1%), suggesting potential for long–term storage stability. The ash content (2.791 ± 0.1 %), indicative of the mineral composition, implies the presence of essential minerals. The seeds possess a high crude fiber content (29.803 ± 1%), underscoring their potential as a dietary fiber source for digestive health (Deme et al., 2017). Substantial crude lipid content of 31.903 ± 0.4% positions the seeds as a rich source of lipids, a finding that is significant for applications in oil extraction or as a potential ingredient in lipid-based products. The seeds have a moderate crude protein content of 5.9407±0.3%, contributing to their overall nutritional value. The carbohydrate content of 25.4303 ± 0.2% indicates a significant energy source, complementing the lipid and protein content. The nutritional profile of the seeds obtained in this study contrasts with results reported for leaves by Jimam êt al. (Jimam et al., 2015).

Collectively, these findings underscore the potential of *S. radiatum* seeds as a versatile and nutritionally valuable food source.

Table 1: Proximate composition of *S. radiatum* seeds

Property (%)	value
Moisture content	4.132 ± 0.1
Ash content	2.791 ± 0.1
Crude fiber	29.803 ± 1.0
Crude lipid	31.903 ± 0.2
Crude protein	5.9407 ± 0.3
Carbohydrates	25.4303 ± 0.2

5.2. Elemental composition of *S. radiatum* seeds

The elemental composition of *S. radiatum* seeds, displayed in Table 2, highlights their nutritional value by demonstrating the presence of essential minerals. These seeds are a rich source of vital elements, containing significant amounts of zinc (0.0225mg/g), manganese (0.094mg/g), magnesium (1.378mg/g), iron (0.026mg/g), and calcium (7.922mg/g). Zinc and manganese, crucial for various physiological functions such as immune response and antioxidant activity (Mezzaroba *et al*., 2019), are present in substantial quantities. The seeds' nutritional profile is further enriched by the presence of magnesium and potassium, known for their beneficial effects on cardiovascular health and muscle function (Kibiti & Afolayan, 2015). The considerable iron content emphasizes the seeds' potential as a dietary source to address iron deficiency anemia. The elemental composition results for *S. radiatum* seeds from this study are lower than those reported for the leaf of *S. radiatum* cultivated in the Benin Republic (Agbankpé *et al*., 2015) and are generally higher than results reported for leaves cultivated in the Plateau state of Nigeria (Jimam *et al*., 2015). The seeds also display low levels of potentially harmful elements such as cadmium (0.026mg/g) and lead (0.567mg/g), indicating their safety for consumption.

This elemental profile supports the traditional use of *S. radiatum* seeds as a nutritional and medicinal resource. Future research could explore the bioavailability of these minerals and their potential health benefits, contributing to the development of functional foods or nutraceuticals.

Table 2: Metallic composition (mg/g) of *S. radiatum* seeds

Zn	Mn	Mg	Cd	Pb	Cr	Co	K	Fe	Ca	Cu	Ni	Na
0.24	0.094	1.378	0.026	0.567	0.034	0.015	2.645	0.026	7.922	0.044	0.040	0.182

5.3. Physicochemical properties of *S. radiatum* seed oil

The physicochemical properties of Radiatum seed oil, as detailed in Table 3, offer valuable insights into its quality and potential applications. The oil yield of 32.024 ± 0.5% suggests a substantial quantity of oil can be extracted from the seeds, thereby contributing to the economic viability of *S. radiatum* cultivation.

Key indicators of oil stability and quality, such as the acid value, iodine value, and peroxide value, provide further insights. The observed acid value of 8.415 ± 0.1 mg KOH/g indicates a moderate level of free fatty acids, consistent with the findings by Gbonjubola *et al*. (2023). The iodine value of 192.888 ± 0.4 wijs reflects the degree of unsaturation in the oil, suggesting a high content of unsaturated fatty acids, a characteristic also reported by researchers (Gbonjubola et al.,2023). The peroxide value of 29.000 ± 0.3 mEq/Kg, indicative of the extent of primary oxidation products, provides insights into the oil's oxidative stability. The saponification value of 190.740 ± 0.2 mg KOH/g, a measure of the average molecular weight of all fatty acids in the oil, is in line with Awolola *et al*.'s (2023) report. The free fatty acid content (4.208 ± 0.1 mg KOH/g) is favorable for the oil's quality, as higher free fatty acid can contribute to undesirable flavors and aromas. The viscosity (83.5 ± 1.8 mPa.S), smoke point (224.0±3.9°C), and boiling point (297.6±2.1°C) further characterize the thermal stability and application of versatility of *S. radiatum* seed oil. The yellow color and transparent nature of the oil align with the visual appeal of *S. radiatum* oil reported by researchers (Gbonjubola et al., 2023).

The physicochemical properties suggest that *S. radiatum* seed oil possesses desirable characteristics for various applications, including culinary and industrial uses. These findings contribute to our understanding of the oil's potential in the food and manufacturing sectors.

Table 3: Physicochemical properties of *S. radiatum* seeds

Property (%)	value
Acid value (mg KOH/g)	8.415 ± 0.1
Iodine value (wijs)	192.888 ± 0.4
Peroxide value (mEq/Kg)	29.000 ± 0.3
Saponification value (mg KOH/g)	190.740 ± 0.2
Free fatty acid (mg KOH/g)	4.208 ± 0.1
Viscosity (mPa.S)	83.5 ± 1.8
Smoke point (^{0}C)	224.0 ± 3.9
Boiling point (^{0}C)	297.6 ± 2.1
Relative density	0.915 ± 0.1
Color	Yellow
Transparency	Transparent

5.4. Antioxidant property of *S. radiatum* seed oil

The evaluation of the antioxidant properties of *S. radiatum* seed oil provides a good picture of its potential health benefits. The oil's capacity to inhibit free radicals, quantified as IC_{50} value, is a key metric in assessing its antioxidant potential. The inhibition of free radicals by the oil is concentration-dependent, as depicted in Figure 1. At a concentration of 10.00 mg/ml, the oil exhibits substantial inhibition of 65.680%, demonstrating its effective neutralization of free radicals. As concentration decreases, a corresponding decrease in inhibition is observed, with the lowest concentration of 0.625 mg/ml still showing a notable inhibitory effect of 9.763%. These values align with results reported on the effect of plant maturity on the antioxidant properties of *S. radiatum* leaves by Oduntan *et al*. (2011). The calculated IC_{50} of 6.943 mg/ml, representing the concentration at which the oil inhibits 50% of free radicals, is a crucial measure of the oil's antioxidant potency (Lima *et al*., 2021). A low IC_{50} value indicates a stronger antioxidant capacity.

These results suggest that *S. radiatum* seed oil has significant antioxidant potential, positioning it as a promising natural source of antioxidants. Antioxidants are essential in protecting cells from oxidative stress and are associated with various health benefits. The incorporation of this oil into dietary or cosmetic formulations could enhance antioxidant intake and confer potential health-promoting effects. Future studies could investigate the specific antioxidants present in the oil and their mechanisms of action, contributing to a more comprehensive understanding of its health-related properties.

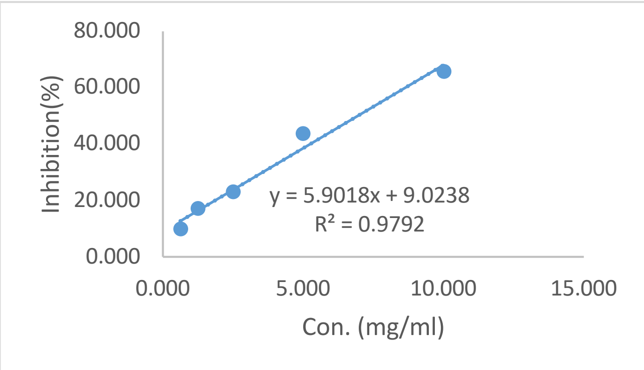

Figure 1: Graph of inhibition (%) against concentration (mg/g) of *S. radiatum* seed oil

5.5. Phytochemical composition of *S. radiatum* seed oil

The qualitative phytochemical analysis of *S. radiatum* seed oil, as detailed in Table 4, reveals the bioactive constituents present, thereby highlighting its potential health-promoting properties. The seed oil contains saponins, alkaloids, phenols, glycosides, cardiac glycosides, steroids, terpenoids, volatile oil, and sterols, showcasing a rich phytochemical profile. Akanmu et al. (2019) and Kalaivani et al. (2023) reported the presence of similar bioactive compounds in *S. radiatum* leaf extract. These compounds are known for their diverse biological activities, including antioxidant, anti-inflammatory, and antimicrobial properties. Saponins, recognized for their characteristic foaming properties, have been associated with various health benefits, such as cholesterol reduction and immune system modulation (Gbonjubola *et* al., 2023). Alkaloids, known for their pharmacological significance, may contribute to the oil's therapeutic potential. Phenols, acting as antioxidants, play a crucial role in scavenging free radicals and preventing oxidative stress. The presence of glycosides and cardiac glycosides suggests potential cardiovascular benefits, while steroids and terpenoids are often associated with anti-inflammatory and anticancer properties. Volatile oils contribute to the oil's aroma and may have antimicrobial effects. Sterols, essential components of cell membranes, can contribute to the oil's nutritional value. The absence of tannins and flavonoids in the oil may limit certain bioactivities, but does not diminish the overall potential health benefits. This is in contrast to the findings of Akanmu *et al* (2019), who reported the presence of flavonoids in the leaf extract.

The qualitative identification of these phytochemicals provides a foundation for further research into the specific compounds present and their individual or synergistic contributions to the oil's bioactivity. Future studies could explore the isolation and characterization of these phytochemicals, allowing for a more detailed understanding of *S. radiatum* seed oil's therapeutic potential.

Table 4: Qualitative phytochemical composition of *S. radiatum* seed oil

Phytochemical	Presence
Saponins	+
Alkaloids	+
Phenols	+
Tannins	-
Flavonoids	-
Glycosides	+
Quinone	-
Cardiac glycosides	+
Steroids	+
Terpenoids	+
Volatile oil	+
Sterols	+
Resin	-
Phlobatanins	-

5.6. Spectroscopic characteristics of *S. radiatum* seed oil

The spectroscopic analysis of *S. radiatum* seed oil (depicted in Figures 2, 3, and 4) offers valuable insights into its molecular composition. The UV-Visible absorbance spectrum of the oil shows distinct peaks, notably at 340 nm (absorbance: 4.1264). This suggests $\pi \rightarrow \pi^*$ electronic transition, common in molecules with conjugated systems (Vogt *et al*., 2023), indicating the presence of unsaturated fatty acids. These fatty acids, often found in vegetable oils, have one or more double bonds (Jadhav & Annapure, 2023) that could lead to such systems. The oil solution, a mixture of oil and hexane (1:2 ml/ml), displays an adsorption peak at 232 nm (absorbance of 3.3058). This shift in absorption suggests potential interactions or changes in the molecular environment upon dilution with hexane. These findings align with the observation of Alarfaj et al. (Nawal *et al*., 2021), who reported similar UV absorption characteristics for *S. indicum* seed oil. The FTIR spectrum of *S. radiatum* seed oil provides further insights into its molecular composition. Characteristic peaks at various wavenumber indicate the presence of specific functional groups. Peaks at 416.76, 430.11, and 457.73 cm^{-1} suggest the presence of aliphatic C-H stretching vibrations (Coates, 2000; Gbonjubola *et al*., 2023; Smith, 2018).

The peaks at 1096.ion72, 1159.58, and 1237.96 cm⁻¹ correspond to the bending vibration of C-H in-plane deformation. Peaks at 1096.72, 1159.58, and 1237.96 cm⁻¹ are associated with C-O stretching vibrations, indicating the presence of ester groups (Coates, 2000; Smith, 2018). The peaks observed at 1742.50 cm⁻¹ and 2359.61 cm⁻¹ are characteristic of carbonyl (C=O) stretching vibrations and C-H stretching in alkanes, respectively (Smith, 2018). These findings are consistent with the identified fatty acids in the GC-MS results and align with the FTIR analysis reported by researchers (Gbonjubola et al., 2023; Nawal et al.2024).

These spectroscopic characteristics provide an understanding of *S. radiatum* seeds oil's molecular composition. This information is important for establishing reference spectra for future quality assessments and detection of potential adulterations or contaminations.

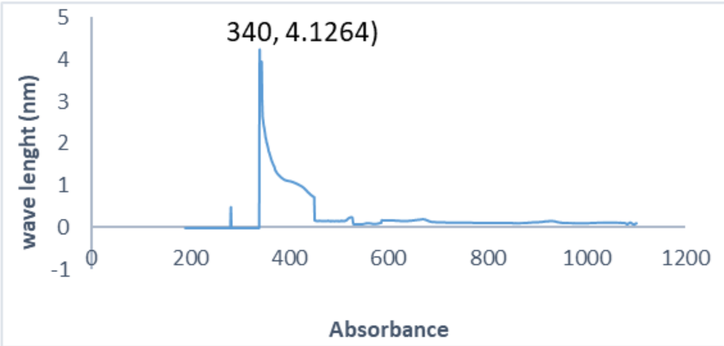

Figure 2: Absorbance spectrum of *S. radiatum* seed oil in the absence of solvent, showing λ_{max} and Absorbance (nm) at λ_{max}

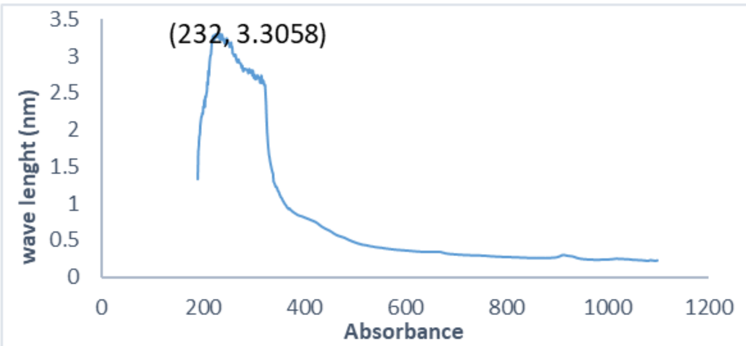

Figure 3: Absorbance spectrum of *S. radiatum* seeds oil-hexane mixture (1 ml: 2 ml) showing λ_{max} and Absorbance (nm) at λ_{max}

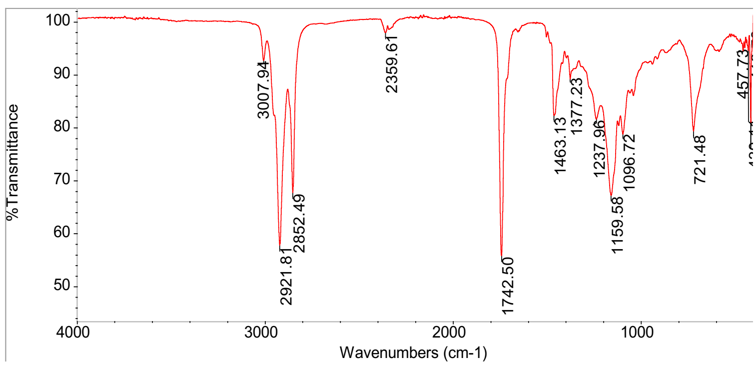

Figure 4: FTIR spectrum of *S. radiatum* seed oil

5.7. Fatty acid profile of *S. radiatum* seed oil

The fatty acid profile of *S. radiatum* seed oil is presented in Table 5. The GC-MS analysis identified the presence of significant fatty acids, including 10, 13-Octadecadienoic acid (41.766%), Linoleic acid

(16.981%), cis-11, 14-Eicosadieoic acid (8.655%), Mead acid (8.873%), and Palmitic acid (6.165%). Additional fatty acids detected are Erucic acid, Azelaaldehydic acid, Stearic acid, Arachidic acid, and trans-3-pentyl-Oxiraneundecanoic acid. Notably, Oleic acid did not appear in the GC-MS result. These findings offer a contrast to the observations made by some researchers (Awolola et al.,.2023), who reported 41% linoleic acid, 39% oleic acid, 8% palmitic acid, and 5% stearic acid in *S. radiatum*. Seed oil. The high proportion of polyunsaturated fatty acids (PUFA) in *S. radiatum* seed oil correlates with the high iodine value obtained, highlighting its potential health benefits. PUFAs are renowned for their health-promoting properties, such as reducing inflammation and lowering the risk of heart disease (Oboulbiga et al., 2023).

The total concentration of unsaturated fatty acids (TUFAs) was significantly higher than that of saturated fatty acids (SFAs), underscoring the oil’s potential health advantages. This aligns with the study of Nawal *et al*. (2021), who reported a high TUFAs content in the ethanol extract of sesame seeds. Table 6 outlines the normalized composition of non-fatty acid components of the transesterified *S. radiatum* seed oil, including D-Lemonene, 2-Methyl-Z, Z-3,13-Octadecadienol, and 1,15-Pentadecanediol. These compounds add to the seed oil's chemical complexity and enhance our understanding of its composition.

The fatty acid profile is a critical factor in determining the nutritional and functional properties of the oil. The dominance of polyunsaturated fatty acids in *S. radiatum* seed oil underscores its potential as a health-promoting ingredient. This analysis provides valuable insights for applications in the food and pharmaceutical industries, where specific fatty acid compositions are sought after.

Table 5: Fatty acid composition (%, w/w) of trans-esterified *S. radiatum* seeds oil

Concentration (%, w/w)	Fatty acid	Common name	Type
1.016	13-Docosenoic acid	Erucic acid	MUFA
0.372	Nonanoic aci, 9-oxo-	Azelaaldehydic acid	SFA
6.165	Hexadecanoic acid	Plamitic acid	SFA
41.766	10,13-Octadecadienoic acid	—	PUFA
5.014	Octadecanoic acid	Stearic acid	SFA
3.712	Eicosanoic acid	Arachidic acid	SFA
16.981	9,12-Octadecadienoic acid (Z,Z)	Linoleic acid	MUFA
8.873	11,13-Eicosadienoic acid	Mead acid	PUFA
7.446	trans-3-pentyl-Oxiraneundecanoic acid	—	MUFA
8.655	cis-11,14-Eicosadienoic acid	—	PUFA
100			
15.2693			TSFA
25.813			TMUFA
59.294			TPUFA
84.737			TUFA

Note: Values for TSFA, TMUFA, TPUFA, and TUFA represent the sum of the normalized concentrations (%) of all individual fatty acids identified within each category. TUFA is the sum of TMUFA and TPUFA.

Table 6: Non-fatty acid composition (%, w/w) of trans-esterified *S. radiatum* seeds oil

Name	Concentration (%)
Cyclohexane, methyl	3.197
D- Limonoene	2.628
1, 15-Pentadecanediol	20.149
2-Methyl-Z,Z-3,13-octadecadienol	74.026
Total	100

6. Conclusion

This study has provided a comprehensive analysis of the spectroscopic, nutritional, physicochemical, and phytochemical properties of *S. radiatum* seeds and their oil. The seeds demonstrated a balanced nutritional profile, rich in essential minerals and dietary fiber. The seed oil exhibited a high yield and a favorable fatty acid profile, with a high proportion of polyunsaturated fatty acids. The oil's antioxidant property, coupled with its rich phytochemical composition, underscores its potential health-promoting attributes. The spectroscopic characteristics provide insights into the oil's molecular composition, contributing to its potential applications in various industries. These findings collectively highlight the potential of *S. radiatum* seeds as a versatile and nutritionally valuable resource, warranting further exploration and utilization in food and pharmaceutical industries. This study lays the foundation for leveraging the diverse potential of *S. radiatum* seeds and contributes to the growing body of knowledge on underutilized crops and their potential role in enhancing food security and promoting health.

7. Limitations and Future Research

This study is based on a single geographical source of *S. radiatum* seeds, and thus the reported profile may be influenced by local growing conditions. The phytochemical analysis was qualitative, and the antioxidant activity was assessed via a single (DPPH) in vitro assay. Future work should focus on quantitative phytochemical identification, bioavailability of the identified nutrients and their potential health benefits-contributing to the development of functional foods or nutraceuticals, corroboration with other antioxidant assays, and agronomic studies across different regions to confirm the robustness of these findings.

8. Funding

This research paper received no internal or external funding.

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