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Quality and Oxidative Stability of Edible Seed Vegetable Oils Assessed via Physicochemical Indices

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Abstract:

The nutritional content, shelf life, and safety of edible seed vegetable oils for human consumption are largely determined by their quality and oxidative stability. To provide a comprehensive evaluation of oil quality, this study investigates key physicochemical indices that influence oil stability, including the refractive index, hydroxide value, acid value, iodine value, and saponification value. The study analyzes the physicochemical properties of nine seed vegetable oil samples obtained from various sources, both local and commercial. Standard titrimetric techniques were employed for the analyses. Results revealed significant variations among the samples. Notably, local oils generally exhibited higher iodine values, with Abyani sesame oil showing a value of 337.554 ± 0.649 g/100 g oil, compared to 240.316 ± 0.743 g/100 g in Ethiopian black seed oil. Additionally, local oils such as Yemeni Almond demonstrated higher saponification numbers 282.20 ± 0.745 mg KOH/g, indicating the presence of shorter-chain fatty acids and suggesting greater unsaturation. Commercial oils, like Somalia sesame, had a mean saponification value of 237.276 ± 0.748 mg KOH/g. The findings highlight how oil content and quality are influenced by factors such as processing conditions, extraction techniques, and geographic origin. Furthermore, seed oils exhibited notable antioxidant properties. Based on these results, this study reaffirms the importance of physicochemical parameters particularly saponification and iodine values as reliable indicators for assessing the nutritional quality and oxidative stability of seed vegetable oils, with implications for quality control, labeling, and consumer health awareness.

Keywords: Physicochemical parameters, sesame oil, saponification number, iodine value, antioxidant.

1. Introduction:

Sesame seeds are rich in fats, proteins, vitamins, minerals, and dietary fiber. Traditional methods of oil extraction produce sesame oil, which is particularly high in fat-soluble vitamins, amino acids, and unsaturated fatty acids. Studies indicate that sesame seeds contain significant levels of minerals such as iron and calcium, with a protein content of approximately 21.9% and a fat content of 61.7% [**1**]. Since humans cannot synthesize essential unsaturated fatty acids like linoleic and linolenic acids, these must be obtained through the diet. Linoleic acid supports growth and development, improves the integrity of vascular epithelial cells, and plays a role in cholesterol metabolism. Linolenic acid boosts acquired external immunity and stimulates lymphatic B-cell differentiation and proliferation [**2**].

Sesame oil is notable for its high content of major unsaturated fatty acids, primarily oleic and linoleic acids, which range from 26.60% to 54.85%. Minor unsaturated fatty acids comprise approximately 0.13% to 0.89%, while saturated fatty acids account for 0 to 10.58%. This composition makes sesame oil a valuable supplement for essential fatty acids [**3**]. The lipid content of sesame seed oil underpins many physiological functions, including energy production, cell membrane integrity, chemical mediators of oxidation, and critical processes such as blood coagulation, anti-inflammatory responses, anti-aging, and renal function. Additionally, sesame oil acts as a carrier for fat-soluble vitamins A, D, E, and K [**4**].

Furthermore, sesame oil contains about 43% polyunsaturated fatty acids, 40% monounsaturated fatty acids, and approximately 40 mg of vitamin E per 100 g [**5**]. The phytochemical content of sesame oil is influenced by various factors, including sesame variety, soil conditions, climate, environmental factors, irrigation, nutrient management, harvest timing, and extraction methods [**6**]. Hulling and oil extraction techniques are particularly important in determining lignan content, which contributes to the oil's health benefits [**7**].

The quality and purity of sesame oil are often assessed through parameters such as saponification value, acid value, and refractive index. The refractive index provides a rapid, non-destructive measure of molecular composition and unsaturation degree. The acid value reflects free fatty acid levels, indicating hydrolysis extent and potential rancidity during processing or storage. The saponification value estimates the average molecular weight of fatty acids, crucial for applications in soap and cosmetic formulations. As interest in sustainable, high-quality oils grows driven by industrial demand and food security reliable characterization techniques are increasingly vital. Comparative analysis based on physicochemical properties can reveal significant variations affecting the oil’s performance, shelf life, and safety.

Sesame seed oil also contains bioactive compounds such as phytosterols and lignans, including sesamin, sesamol, and sesamolin. These compounds' antioxidant properties may contribute to the oil's remarkable stability and confer various health benefits [**8**]. The primary lignans, sesamin and sesamolin, exhibit anti-inflammatory, antioxidant, hypocholesterolemic, neuroprotective, and antihypertensive effects [**9**].
This study aims to assess and compare the refractive index, acid value, and saponification value of oils sourced from diverse origins. It is hoped that the findings will enhance understanding of oil quality standards and support their application across various food industries.

2. Materials and Methods

2.1 Samples Collection

Nine seed oil samples were collected: Yemeni almond (YA), Abyani sesame (AS), Yemeni fenugreek (YF), Laheji sesame (LS), Tehama sesame (TS), Saudi black seed (SB), Somalia sesame (SS), Indian linseed (IL), and Ethiopian black seed (EB). These samples were obtained from various manufacturers in markets across Aden, Lahej, and Abyan governorates. Qualitative phytochemical screening was performed on the samples to detect the presence of various constituents, including refractive index, acid value, saponification value, iodine value, hydroxyl value, free fatty acid content, ester value, and other phytochemical parameters relevant to natural oils.

2.2 Refractive Index

The refractive index was measured using an Abbe refractometer. The device was first calibrated with a drop of distilled water. Then, a small amount of the oil sample was placed into the sample chamber, which was closed. The adjustment knob was turned until the light and dark fields intersected at the crossbar, and the reading was recorded.

2.3 Reagents and Standards

Potassium hydroxide (KOH) and sodium hydroxide (NaOH) solutions at 0.1 N concentration were prepared, with standardization performed using oxalic acid.
Phenolphthalein indicator was prepared by dissolving 1 g in 100 mL of 95% ethanol.
Hydrochloric acid (HCl) at 0.5 N was standardized using sodium carbonate (0.5 N).
Methyl orange indicator was prepared by dissolving 0.1 g in 100 mL of ethanol, then diluting to volume with distilled water.
Iodine value and saponification number were determined according to AOAC methods [**10,11**].
For iodine value determination, a Hanus solution was prepared by dissolving 6.6 g of iodine in 50 mL of glacial acetic acid and heating for 15 minutes. After cooling, 2.12 g of bromine was added.
Potassium iodide (KI) solution (15%) was used in titrations.
The liberated iodine was titrated with 0.1 N sodium thiosulphate, using 0.5 mL of starch solution as an indicator. A blank titration was performed for control.

2.4 Antioxidant Activity

The antioxidant activity of the sesame seed oil extracts was assessed using the DPPH radical scavenging assay. Ascorbic acid served as the positive control. The assay was conducted following standard protocols [**12**,**13**].

3. Results and Discussions:

Since The physicochemical characteristics of oils are critical indicators of their quality, stability, and suitability for various industrial applications. Due to their importance, these properties have been extensively studied. The parameters examined in this study, and their corresponding findings, are presented in **Tables** 1 and 2: refractive index, pH, acid value, saponification value, iodine value, hydroxyl value, ester value, and free fatty acid content.

3.1 Physical Properties

3.1.1 Refractive index

The refractive index is a rapid, reliable method for assessing oil purity and the degree of unsaturation, as it reflects molecular composition changes resulting from oxidation or adulteration [**14**]. At room temperature, the measured refractive indices for Somalia sesame and Ethiopian black seed oils ranged from 1.4671 to 1.4775, indicating significant variation in their molecular structures and unsaturation levels. Consistent with previous research, oils with higher refractive indices generally contain a greater proportion of unsaturated fatty acids [**14**, **15**].

Specifically, the refractive index of Somalia sesame oil was 1.4775 (**Table 1**). The elevated refractive index suggests a higher number of carbon atoms in the fatty acids, which correlates with increased unsaturation [**16**]. The average refractive indices observed in this study were 1.4757 for the local oils and 1.4747 for the commercial oils. These values fall within the range reported by Seegeler [**17**], who documented a refractive index of 1.463–1.474 at 25°C. They also align with findings from a study on sesame oil in Saudi Arabia (1.461–1.476) [**9**], and are slightly higher than the value reported in a Brazilian study (1.465) [**18**].

These results demonstrate that measuring the refractive index is an effective method for distinguishing oils based on their purity and chemical composition.

Table 1: Values of refractive index in vegetable seed local oils and commrical oils

			Local oils					**Commercial oils**			
Parameters	Saudi Arabia [9]	Brazil [18]	Yemeni Almond	Abyani Sesame	Yemeni Fenugreek	Laheji Sesame	Tehama Sesame	Saudi Black	Somalia Sesame	Indian Linseed	Ethiopian Black
Refractive index	1.461–1.476	1.465	1.4772	1.4773	1.4710	1.4772	1.4773	1.4771	1.4775	1.4774	1.4671
Mean ±SD			1.4757± 0.738					1.4747 ±0.737			

3.1.2 pH of oils

The pH values of the sesame seed oil samples ranged from 2.4 in Yemeni almond oil to 5.76 in Laheji sesame oil among the local samples. In the commercial oils, pH values ranged from 4.05 in Ethiopian black seed oil to 6.2 in Somali sesame oil **Figure 1**. The observed differences between local and commercial sources suggest that pH variations partly reflect the accumulation of free fatty acids resulting from hydrolytic degradation. Higher pH values in local samples may be associated with traditional extraction methods and less controlled storage conditions, while the lower pH values in commercial samples likely result from refining and purification processes.

Although the World Health Organization (WHO) and the FAO/WHO Codex Alimentarius do not specify official pH standards for sesame seed oil, measuring pH is an important indirect indicator of oil stability and quality [**19**, **20**]. Typically, the pH range for similar seed oils, such as virgin sesame oil, falls between 6.0 and 6.4. Recent studies support using these ranges as reference values. Despite the absence of official standards, many researchers recommend including pH measurements in quality control protocols, as it provides valuable insights into the oxidative stability and storage behavior of vegetable oils [**21**, **22**].

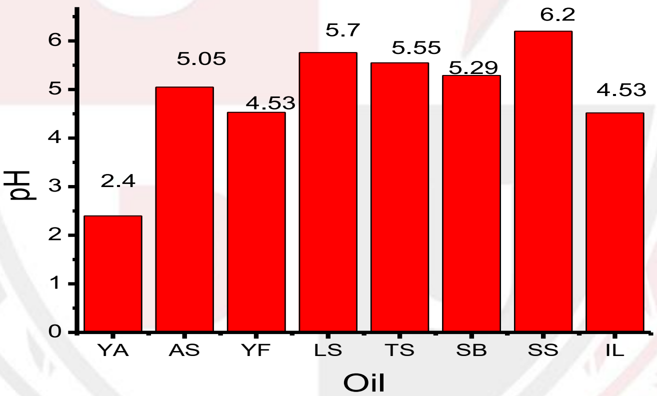

Figure 1: The pH values of the seed vegetable oil samples

3.2.1 Free fatty acid content in seed vegetable oils

The commercial vegetable oil samples exhibited a higher average free fatty acid (FFA) content of 0.2330 ± 0.317%, compared to the local samples, which had an average FFA of 0.8289 ± 0.152% in Saudi black seed oil. This indicates a greater degree of hydrolytic breakdown or less favorable storage and processing conditions in the commercial oils, as the average FFA level in these samples was nearly double that of the local oils. Both sample types fall within the typical range for fresh, high-quality sesame oils, which is between 0.1% and 1.5%, as reported by [**23**].

The notably lower FFA concentration in the local Yemeni almond oil (0.0727 ± 0.165%) aligns with studies showing that low FFA levels can be maintained through minimal processing and shorter storage durations [**24**]. According to Codex Alimentarius guidelines for edible oils, the FFA content expressed as oleic acid should not exceed 3%. Both the commercial and local samples are well within this limit, indicating they are suitable for human consumption.

However, the marked difference between the two sample groups underscores the potential impact of supply chain management and storage conditions on oil quality, emphasizing the importance of proper handling throughout the production and distribution process.

Table 2: Physicochemical properties of seed vegetable oils.

	Oil	pH	Acid Value mg NaOH/g	Iodine Value g/100g oil	Free Fatty Acid %	Saponification Value mg KOH/g	Hydroxyl Value	Ester Value mg/g
Local oils	Yemeni Almond	2.4	1.763±0.231	108.975±0.469	0.0727±0.165	282.20±0.745	83.026±0.475	280.440±0.836
	Abyani Sesame	5.05	3.876±0.158	337.554±0.649	0.1927±0.212	220.42±0.826	152.54±0.469	216.551±1.436
	Yemeni Fenugreek	4.53	8.594±0.354	194.632±0.362	0.3562±0.126	176.61±0.538	11.399±0.647	168.015±0.719
	Laheji Sesame	5.76	3.474±0.276	159.735±0.413	0.0932±0.318	217.62±0.749	17.492±0.249	214.145±0.579
	Tehama Sesame	5.55	6.8161±0.378	154.976±0.316	0.2330±0.317	169.884±0.467	48.891±0.563	163.067±0.578
Commercial oils	Saudi Black	5.29	16.759±0.451	215.73±0.469	0.8289±0.152	133.38±0.624	123.349±0.762	116.621±0.473
	Somalia Sesame	6.2	12.139±0.157	128.327±0.714	0.1463±0.541	237.276±0.748	26.089±0.271	225.136±0.848
	Indian Linseed	4.52	5.624±0.241	214.936±0.703	0.2247±0.470	- -	98.189±0.538	- -
	Ethiopian Black	4.05	7.292±0.438	240.316±0.743	0.2726±0.198	119.34±0.637	130.712±0.541	112.047±0.608

3.2.2 Estimation of saponification values

The current results (**Table 3**) show that the average saponification value of the local vegetable oil samples is 282.20 ± 0.745 mg KOH/g, with Yemeni almond oil exhibiting a notably high value. This is substantially above the widely accepted Codex Alimentarius standard range of 187–196 mg KOH/g [**23**]. The high mean and considerable variability suggest possible differences in fatty acid chain length distribution, extraction methods, or heterogeneity of raw materials.

In contrast, the commercial Somalia sesame oil sample had a mean saponification value of 237.276 ± 0.748 mg KOH/g, which is significantly lower than the recognized standards for authentic sesame oil. This discrepancy could indicate adulteration, over-refining, or the presence of substantial amounts of unsaponifiable components. While the commercial sample levels are notably atypical, some local samples approach or slightly exceed the standard saponification range of 187–196 mg KOH/g reported in the literature [**25**].

Only the local samples partially meet the saponification value range specified by the Codex Alimentarius (187–196 mg KOH/g) for sesame oil, as defined by the joint FAO/WHO standards [**23**]. Conversely, the commercial samples fall outside these quality benchmarks, highlighting the need for further investigation into potential adulteration, compositional authenticity, or processing techniques influencing these values.

Table 3: Typical fatty acid composition and Codex ranges of some parameters of seed vegetable oil

Sample	Mean saponification value (mg KOH/g)	Comparison to Standard (187–196 mg KOH/g)
Local sesame oil	282.20±0.745	Higher than upper limit; variability large
Local sesame oil	169.884±0.467	Significantly lower than standard; markedly off
Commercial sesame oil	237.276±0.748	Higher than upper limit; variability large
Commercial sesame oil	-	Significantly lower than standard; markedly off
Codex / USP /	187–196	Within accepted standard ranges

When compared to other research carried out in Saudi Arabia, Congo, and Brazil, the average values of the current study varied (**Table 4**), exhibiting both rises and declines [**13**, **16**, **17**]. In a study conducted by Dudi, et al. [**26**] on the saponification number of various types of seed vegetable oils, the values ranged between 55.93 and 114.33 mg KOH/g. These results are much lower than those reported in this study.

Table 4: Physicochemical characteristics of seed vegetable oil compare with seed vegetable oil in different countries

Parameters	Saudi Arabia [**16**]	Congo [**13**]	Brazil [**17**]	Yemeni Almond	Ethiopian Black	Saudi Black	Yemeni Fenugreek	Indian Linseed	Abyani Sesame	Laheji Sesame	Somalia Sesame	Tehama Sesame
Iodine value (g/100 g oil)	103.17–113.11	111	90.17	108.975	240.316	215.73	194.6329	214.9369	337.554	159.735	128.327	154.9766
Saponification mg KOH/100 g	185.45–200.05	186	416.78	282.20	119.34	133.38	176.61	--	220.42	217.62	237.276	169.884

3.2.3 Iodine values

A high iodine value typically indicates a high content of unsaturated fatty acids (USFA). In this study, the iodine value for Abyani sesame oil was 337.554 ± 0.649 g/100 g, while all roasting methods showed decreased values, with the lowest being 108.975 ± 0.469 g/100 g for Yemeni almond oil (**Table 2**). The iodine value is an important indicator of the oil's stability and degree of unsaturation; higher values reflect greater unsaturation and are preferred by oil processors, whereas lower values suggest reduced quality. When compared to literature values, which range from approximately 103 to 130 g/100 g for sesame oil in various studies, and regulatory standards such as the Indian sesame oil standard 103–120 g/100 g, the values obtained here are markedly elevated [**27**, **28**]. The mean iodine values for local and commercial sesame oils were lower, aligning with previous studies by [**28**] and [**29**], reporting values of 102–105 g I_2/100 g oil and 103–116 g I_2/100 g oil, respectively.

3.2.4 Estimation of hydroxyl values

The hydroxyl values of the oils studied ranged from 11.399 to 152.541. The lowest hydroxyl values were observed in Yemeni fenugreek oil, while Ethiopian black seed and Saudi black seed oils showed similar, slightly higher results. Abyani sesame oil recorded the highest hydroxyl value among all samples (**Table 2**). Notably, commercial sesame oil in this study exhibited an average hydroxyl value of 130.712 ± 0.541 in Ethiopian black seed oil, whereas local Abyani sesame oil had an average hydroxyl value of 152.54 ± 0.469. This significant variation suggests a higher presence of hydroxyl-containing compounds in the commercial samples, which could result from differences in processing, storage conditions, or refining levels. Elevated hydroxyl values are often associated with secondary oxidation products or partial oxidation, potentially impacting oil stability and quality. These results are substantially higher than the hydroxyl values reported in previous literature, such as those by Seegeler [**17**] and Weiss [**25**], who documented values between 1.0 and 10.0 for sesame seed oil. Such variations imply that, compared to fresh, high-quality sesame oils, the oils examined here may have undergone notable compositional changes. These findings underscore the importance of strict regulation of extraction, harvesting, and storage processes to maintain oil quality.

3.2.5 Ester values

The ester value was calculated based on the saponification and acid values. Results (**Table 2**) showed that Saudi black seed oil and Ethiopian black seed oil had the lowest ester values, while Yemeni almond oil exhibited the highest. Moderate values were observed for Yemeni fenugreek and sesame oils. The ester value reflects the integrity of ester bonds between glycerol and fatty acids; higher ester values indicate more intact ester linkages and reduced susceptibility to oxidation. A low ester value, as seen in Yemeni almond oil, suggests high ester bond stability, making it more suitable for consumption and storage. According to El-Beltagi et al. [**29**], unroasted seed oils tend to have high ester content, correlating with high acidity. In their study, ester values increased from 188.8 mg/g in unroasted seeds to a maximum of 193.7 mg/g after oven roasting, with this study's values being slightly lower (mean of 208.444 mg/g in local oils and 151.268 mg/g in commercial oils).

3.3 Antioxidant activity

In this study, the antioxidant activity of various seed vegetable oils Yemeni almond, Abyani sesame, Yemeni fenugreek, Laheji sesame, Tehama sesame, Somali sesame, and Indian linseed was evaluated

using the DPPH radical scavenging assay, with ascorbic acid serving as the standard reference.

For the assay, 0.3 mL of each oil sample was dissolved in 3 mL of chloroform and then added to 3 mL of DPPH solution. The mixtures were incubated in the dark at room temperature for 30 minutes. After incubation, the absorbance was measured against a blank solution at λ = 517 nm. DPPH exhibits a strong absorption band at this wavelength due to its unpaired electron, and the solution appears deep violet in color. Ascorbic acid has two adjacent internally connected sites of hydrogen abstraction this leads to a 2:1 stoichiometry for DPPH and ascorbic acid, that is, two molecules of DPPH reduced by one molecule of ascorbic acid. The solution of ascorbic acid was differenced concentrations (5, 10, 20, 30, 40, 50 µg/L) as represented in **Table 5 and Figure 2.** The percentage of DPPH scavenging activity was calculated using the formula:

$$\% \text{ inhibition} = (A_0 - A_1) / A_0 \times 100$$

where: A_0 = absorbance of control, A_1 = absorbance of sample.
where A_0 s the absorbance of the control (DPPH solution without sample), and A_1 is the absorbance of the sample mixture.

Table 5: Standard ascorbic acid solutions, absorbance, and % inhibition of DPPH

Concentration of ascorbic acid µg/L	Absorbance	Inhibition (%)
5	0.1285	50.6149
10	0.1098	57.8016
20	0.085	67.3328
30	0.0685	73.6741
40	0.0441	83.0515
50	0.0253	90.2767
Control	0.2606	--

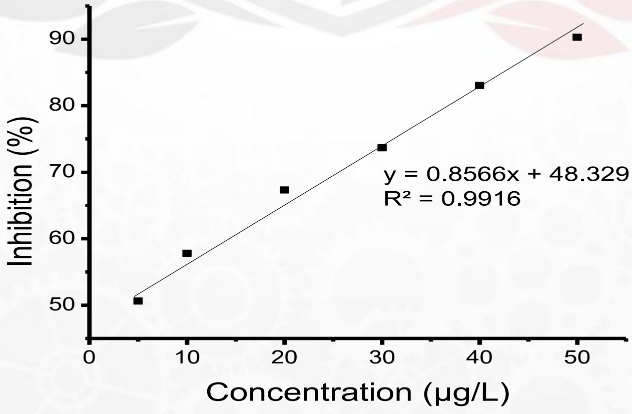

Figure 2: Free radical scavenging effect of standard ascorbic acid solutions by DPPH assay

Table 6 presents the results of the DPPH radical scavenging assay used to evaluate the antioxidant activity of the seed sesame oils. The antioxidant capacity of the oils was determined by calculating the percentage of DPPH radical inhibition. The results indicated that Indian linseed exhibited the highest scavenging activity, with a percentage inhibition of 86.34%, followed by Abyani sesame with 76.48%. Conversely, the lowest inhibition percentages were observed in Somali sesame (45.93%) and Yemeni fenugreek (48.96%). Notably, Laheji and Tehama sesame oils showed similar inhibition values.

Previous literature has explored the chemical composition and antimicrobial properties of Yemeni plants and their oils, with limited research on their antioxidant activities [**29**, **30**]. The DPPH assay in some studies has demonstrated only weak antioxidant activity, around 28% inhibition [**31**]. While all tested oils exhibited notable antimicrobial properties, their antioxidant activity was generally weak. The results reported by Ramzi et al. [**31**] are significantly lower than those obtained in this study.

Ghasemzadeh and Ghasemzadeh [**33**] reviewed the roles of flavonoids and phenolic acids in plant antioxidant systems and highlighted their potential health benefits, emphasizing the importance of these compounds in contributing to antioxidant activity.

Table 6: Percentage of inhibition of oils using DPPH assay

Oil	Absorbance	Inhibition (%)
Yemeni almond	0.1154	55.7175
Abyani sesame	0.0613	76.4773
Yemeni fenugreek	0.133	48.9639
Laheji sesame	0.0997	61.7421
Tehama sesame	0.0845	67.5748
Somalia sesame	0.1409	45.9324
Indian linseed	0.0356	86.3392

Conclusion:

The quality and oxidative stability of edible seed vegetable oils are vital for ensuring safety, health, and market integrity. Physicochemical indices such as hydroxide, acid, iodine, and saponification values are essential tools for assessing oil quality and predicting its behavior during processing and storage. This study highlights the balance between the nutritional benefits of polyunsaturated oils and their increased susceptibility to oxidation. While only 45% of the samples met the FAO/WHO standards, these analyses underscore the importance of standardized testing to preserve nutritional content, extend shelf life, and inform consumer choices. Strengthening these analytical techniques will support a more sustainable, transparent, and health-focused edible oil industry.

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