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Original Research Article

Fatty Acid Profiles of White Sesame Seeds from the Different Cultivation Areas of Ethiopia

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ABSTRACT

Sesame is one of the most important export commodity of Ethiopia. However, the chemical composition of white sesame seeds (*Sesamum indicum* L.) from the major production areas of the country remains underexplored. This study assessed the geographic variations in fatty acid composition of white sesame seeds from Humera, Metema, West Armachiho, Wolkayiet, and Tach Armachiho using gas chromatography coupled with mass spectrometry (GC-MS). The seeds were rich in essential fatty acids, with linoleic acid and oleic acid comprising 35.3–48.3% and 29.8–38.2% of total fatty acids, respectively. Together, they accounted for 72.0–78.8% of the fatty acid content. Palmitic and stearic acids contributed 19.8–22.0%, while minor fatty acids, palmitoleic, margaric, gadoleic, arachidic, and behenic acids, collectively made up 1.34–2.32%. The sesame seed oils exhibited a high unsaturated-to-saturated fatty acid ratio of 2.98–3.70, meeting most dietary recommendations. The oleic-to-linoleic acid ratio ranged from 0.80 to 0.97, with the highest value in seeds from Humera. Among individual fatty acids, significant differences ($p < 0.05$) were observed only for palmitic and palmitoleic acids, which were highest in Humera seeds (14.9 ± 1.5% palmitic acid and 0.25 ± 0.04% palmitoleic acid)

Keywords: Armachiho, Centeral Gondar, indigenous community, respondents, therapeutic species.

INTRODUCTION

Sesame (*Sesamum indicum* L.) is a species within the genus *Sesamum* and the family *Pedaliaceae* (Gebremedhn et al., 2019). It is an important oilseed crop, as its seeds contain approximately 50% oil by weight (Alemu, 2018). According to the Ethiopia Commodity Exchange (http://www.ecx.com.et/Pages/Sesame.aspx#SE), India and China are currently the largest sesame producers globally, followed by Myanmar, Sudan, Mexico, Nigeria, Venezuela, Turkey, Uganda, and Ethiopia.

In Ethiopia, sesame seed ranks as the second most important export commodity after coffee (Kedir et al., 2017). In the country, sesame is typically grown at altitudes ranging from 500 to 1300 m above sea level, predominantly in the northwestern regions (Alemu, 2018). The majority of sesame traded from Ethiopia originates from the Humera and Metema districts, which are widely recognized for producing high-quality seeds. According to the Ethiopia Central Statistical Agency (CSA, 2020), over 2.6 million quintals of sesame were produced during the 2019/20 crop season, with more than 60% of this output coming exclusively from the Humera and Metema districts.

The biochemical composition of plant products depends mainly on environmental factors, genetic traits, and agronomic practices (Mehari *et al.*, 2016). Since one or more of these factors may differ from one region to the other, the identity and concentration of the biochemical constituents can vary depending on the geographical origin of the sesame seeds.

The fatty acid composition of sesame seeds, which includes essential fatty acids such as oleic and linoleic acids, plays a crucial role in determining the quality and health benefits of sesame oil. These fatty acids are not only vital for human health but also influence the stability and shelf-life of the oil. The composition of fatty acids in sesame seeds can vary significantly depending on several factors, including genetic makeup, environmental conditions, and agricultural practices (Smith and Jones, 2020; Lee and Kim, 2019). Among these, the geographical origin of the seeds is a critical determinant, as it encompasses a range of climatic, soil, and ecological variables that can influence the biosynthesis and accumulation of fatty acids. Previous studies have highlighted notable differences in the oil content and fatty acid profiles of coffee beans (Mehari *et al.*, 2019) and teff (Reta *et al.*, 2024) from different regions of Ethiopia, suggesting a strong geographical influence on seed oils. Understanding the geographical variation in fatty acid composition is essential as it can aid in the identification of high-quality sesame varieties.

Most previous studies on Ethiopian sesame has primarily focused on comparing the physicochemical characteristics of different sesame varieties (Zerihun and Berhe, 2020; Zebib et al., 2015) or has been limited to a single production area (Seid and Mehari, 2022). However, a comprehensive study examining the geographical variation in the fatty acid composition of white sesame seeds is still lacking. Therefore, this study aimed to investigate the differences in fatty acid profiles of white sesame seeds cultivated in the major commercial production regions of the country.

MATERIALS AND METHODS

Collection of sesame seed samples

Sesame in Ethiopia is primarily grown in the northwestern region (Figure 1). For this study, sesame seed samples were obtained from five major production districts across 19 farmer villages "Kebeles", totaling 53 samples collected from various farmers. Sampling sites were selected randomly. The production districts included Metema (Delelo, Meka, Lencha, Metema 01, Kokit), Humera (Mikadira, Bereket), Wolkayiet (Dansha Anbaba, Soroka Akafay, Tegedie Ergoye, Tegedie Harid, Tegedie Anbagenet, Tegedie Habtom, Tegedie Misgan), West Armachiho (Abrehajera, Abderafie, Terefwork), and Tach Armachiho (Sanja, Asherie). From each Sub-district, two to three samples of 250 g of white sesame seeds were collected from different farmers at the market. Samples from each Sub-district were then pooled to prepare a bulk sample for analysis. All samples were collected during the 2022/23 harvest season.

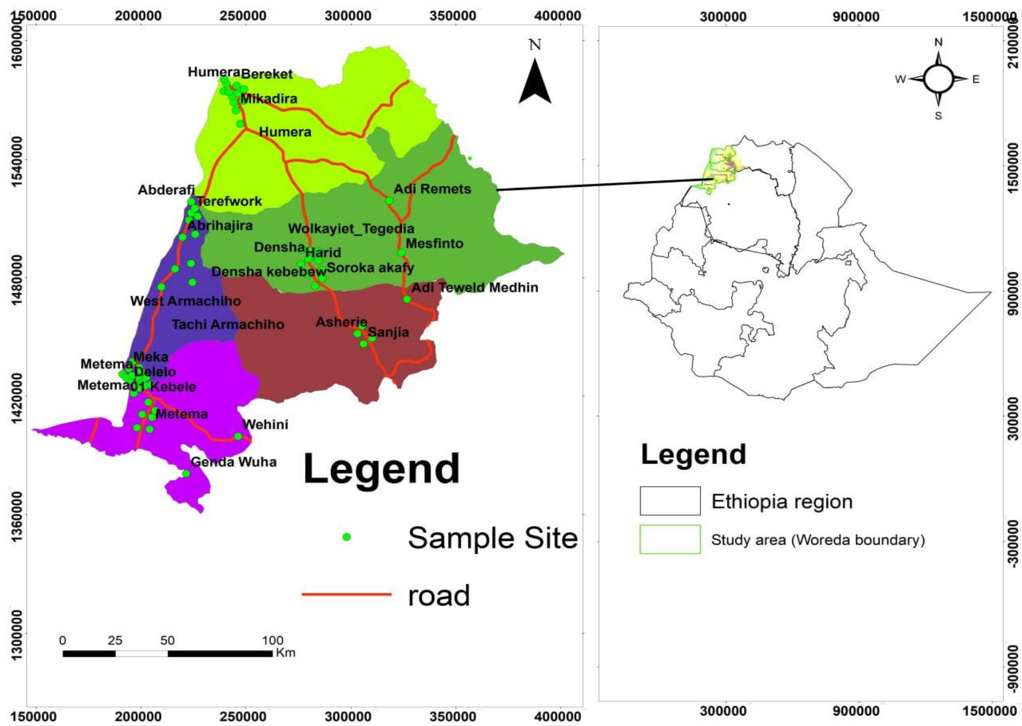

Figure 1. Map of Ethiopia showing the sesame sampling areas.

Chemicals

Methanol, toluene, n-hexane, and chloroform (Loba Chime, Mumbai, India); acetone and nitric acid (Thomas Baker, Mumbai, India); potassium per chromate (Blulux, Faridabad, India); sodium chloride (Arkem, Turkey); and fatty acid standards (Sigma-Aldrich, Germany) were used in the study.

Apparatus

Gas chromatograph equipped with an autosampler, a split spitless injector, and a mass spectrometer (Agilent Technologies 7890B-5977A. China), orbit shaker (VRN 480, Germany).

Extraction of Lipids

Lipids were extracted following a reported procedure (Mehari *et al.*, 2019). Briefly, a 0.5 g powdered sesame was extracted with 10 mL of a chloroform:methanol mixture (2:1 v/v) while shaking for 3 h at 250 rpm. The extraction mixture was then centrifuged at 4000 rpm for 5 min, and the supernatant was taken and adjusted to 10 mL by adding solvent. The extract was treated with 2 mL of 0.73% NaCl solution and the lower chloroform layer was recovered and washed twice with 1.5 mL each of water. The resulting solution was dried with anhydrous sodium sulphate and the solvent was removed under vacuum. The residue was then dissolved in 10 mL of toluene.

Derivatization of Fatty Acids

Fatty acids were converted to their methyl esters prior to GC–MS analysis following the method of Mehari et al. (2019). In brief, 1 mL of lipid extract in toluene was reacted with 2 mL of 1% sulfuric acid in methanol at 50 °C for 12 hours in an incubator. After the reaction, 5 mL of 5% aqueous NaCl solution was added, and the mixture was extracted twice with 5 mL of hexane. The combined hexane layers were dried over anhydrous Na_2SO_4, and the solvent was evaporated under vacuum to a final volume of 5 mL. This extract was then used for gas chromatographic analysis.

Fatty acid analysis was performed using GC-MS under the following conditions (Mehari et al., 2019): 1 µL splitless injection, injector temperature 280 °C, and a DB-5 MS fused silica capillary column (30 m × 250 µm × 0.25 µm). The oven was programmed at 60 °C (3 min hold), increased at 5 °C min^{-1} to 230 °C, and held for 20 min. Helium served as the carrier gas at 1.68 mL min^{-1}. MS settings included a 300 °C transfer line, scan range m/z 60 - 400, 70 eV ionization, and 3000 V electron multiplier voltage.

Statistical analysis

One-way ANOVA was applied to assess the effect of growing area on fatty acid concentrations. Data were analyzed using SPSS version 20, and differences were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Fatty Acid Profiles of the Sesame Seeds

A total of nine fatty acids were identified in all sesame seed samples (Figure 2). Their identities were confirmed using standard fatty acids and the NIST mass spectral library (Table 1).

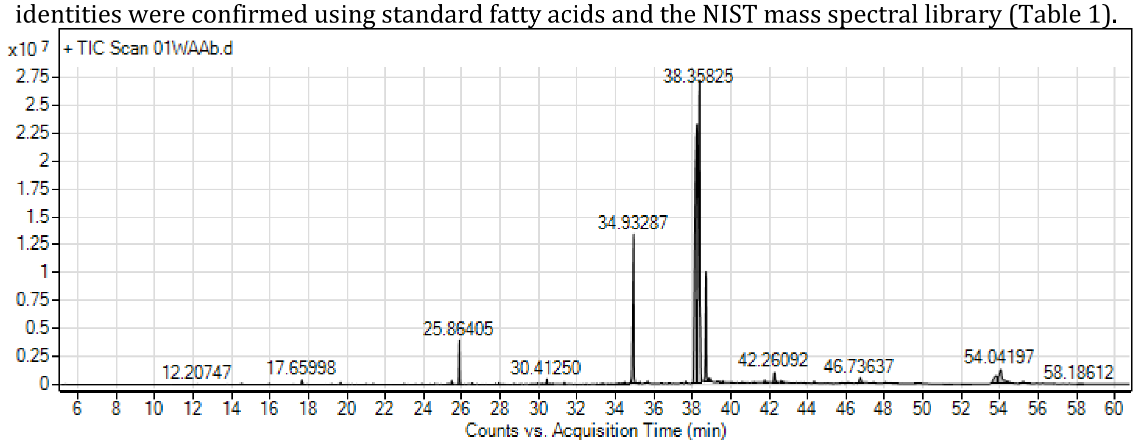

Figure 2. Typical GC-MS chromatogram of the fatty acid extract of sesame seed.

Table 1. The chemical name, common name, symbol, means of identification, and retention times of the fatty acids determined in the sesame seed samples.

Chemical name	Common name	Symbol	Means of Identification*	RT
9-Hexadecanoic acid (Z)	Palmitoleic acid	C16:1(n-7)	NIST	34.48
Hexadecanoic acid	Palmitic acid	C16:0	standard	34.92
Heptadecanoic acid	Margaric acid	C17:0	NIST	36.81
9,12-Octadecadienoic acid (Z,Z)	Linoleic acid	C18:2(n-6)	standard	38.21
9-Octadecenoic acid (Z)	Oleic acid	C18:1(n-9)	standard	38.34
Octadecanoic acid	Stearic acid	C18:0	standard	38.71
9-Eicosenoic acid	Gadoleic acid	C20:1(n-11)	NIST	41.77
Eicosanoic acid	Arachidic acid	C20:0	standard	42.27
Docosanoic acid	Behenic acid	C22:0	standard	47.47

*NIST is the National Institute of Standards and Technology of USA.

Concentrations of Fatty Acids

The concentrations of the determined fatty acids ranged from the lowest margaric acid (4.46–27.7 mg/kg) to the highest oleic acid (20,284–76,804 mg/kg) (Table 2).

Table 2. The average concentration (mg/kg) of fatty acids in the sesame seeds (n =3).

Production Area	Sample Site	Palmitoleic acid	Palmitic acid	Margaric acid	Linoleic acid	Oleic acid	Stearic acid
Mirab-Armachiho	Abrehajera	52.1	2340	9.44	11345	47235	27429
	Abderafie	100	4345	25.8	23116	70831	51640
	Terefwork	33.9	2143	8.24	10162	41701	28344
Wolkayiet	Dansha Anbaba	35.4	1844	7.18	9625	40344	24089
	Soroka Akafay	42.5	2248	8.69	11082	43062	28180
	Tegedie Ergoye	12.2	1059	4.46	5431	20284	13796
	Tegedie Harid	47.7	2686	13.7	13594	50415	34034
	Tegedie Anbagenet	89.1	4628	26.8	27987	76804	57312
	Tegedie Habtom	90.2	3770	19.7	20551	70162	45442
	Tegedie Misgan	25.6	1868	8.61	10035	34633	22975
Metema	Delelo	45.0	2688	13.6	13323	48230	30826
	Meka	42.6	2542	12.2	11776	46297	31874
	Lencha	18.8	1260	6.59	6540	23947	15505
	Metema 01	40.7	2026	9.66	9947	36640	23998
	Kokit	41.8	2491	10.9	13330	47823	28464
Humera	Mikadira	122	4586	27.7	15817	73289	55595
	Bereket	67.5	2698	13.5	12209	49068	30622

Tach-Armachiho	Sanja	50.7	2358	12.1	12528	47855	29726
	sherie	78.2	2745	14. 9	15408	52600	34336

Relative Compositions of Fatty Acids

Linoleic and oleic acids were the predominant fatty acids in the sesame seed samples, comprising 35.3–48.3% and 29.8–38.2%, respectively (Table 3). Together, they represented 72.0–78.8% of total fatty acids. Palmitic and stearic acids contributed 19.8–22.0%, while minor components, palmitoleic, margaric, gadoleic, arachidic, and behenic acids, accounted for 1.34–2.32% collectively.

Palmitoleic acid ranged from 0.09 to 0.28%. The highest concentration was found in sesame from Mikadira, Humera. This fatty acid is linked to several health benefits, including anti-inflammatory, metabolic, cardiovascular, liver, skin, and potential anti-cancer effects (Friedman, 2014; Cohen and Spiegelman, 2016; Kris-Etherton and Innis, 2007; Jang et al., 2020; Chen et al., 2019), highlighting the nutritional value of Mikadira sesame seeds.

Palmitic acid content ranged from 12.2 to 16.0%, with the highest observed in sesame from Mikadira. As a saturated fatty acid, it is mainly associated with adverse health effects, including elevated LDL cholesterol and increased risk of insulin resistance (Mensink & Katan, 1990; Nolan et al., 2017).

The concentration of margaric acid ranged from 0.04 to 0.09% across samples. As a saturated fatty acid, it can adversely affect cardiovascular and metabolic health (Mensink & Katan, 1990; Kris-Etherton & Innis, 2007). Although present in low amounts, moderation in saturated fat intake is recommended to support overall health (Astrup & Dyerberg, 2011).

Table 3: The average percentage composition of fatty acids determined in the white sesame seeds.

Production Area	Sample Site	Palmitoleic acid	Palmitic acid	Margaric acid	Linoleic acid	Oleic acid	Stearic acid	Gadoleic acid	Arachidic acid	Behenic acid
West	Abrehajera	0.19	13.0	0.05	40.4	37.8	7.42	0.27	0.75	0.11
Armachiho	Abderafie	0.20	13.4	0.07	45.6	31.4	7.74	0.40	0.98	0.15
	Terefwork	0.13	13.2	0.05	40.0	36.8	8.46	0.32	0.94	0.17
Wolkayiet	Dansha Anbaba	0.15	12.2	0.04	40.6	38.2	7.71	0.22	0.85	0.08
	Soroka Akafay	0.16	13.1	0.04	41.3	36.0	7.97	0.29	0.89	0.15
	T*. Ergoye	0.09	12.9	0.05	42.2	35.4	8.14	0.30	0.79	0.13
	T. Harid	0.15	13.0	0.06	42.2	35.1	8.01	0.31	0.96	0.16
	T. Anbagenet	0.15	12.5	0.07	48.3	29.8	7.51	0.38	1.11	0.15
	T. Habtom	0.20	12.7	0.06	44.2	33.9	7.42	0.29	1.07	0.15
	T. Misgan	0.11	12.8	0.06	44.0	34.1	7.65	0.25	0.94	0.12
Metema	Delelo	0.15	13.5	0.06	42.7	34.7	7.50	0.23	0.98	0.17

	Meka	0.15	13.7	0.06	42.7	35.8	8.34	0.27	0.98	0.14
	Lencha	0.12	12.8	0.06	42.4	34.9	7.63	0.25	1.78	0.11
	Metema 01	0.17	13.5	0.06	42.3	34.9	7.73	0.34	0.89	0.13
	Kokit	0.14	12.7	0.05	43.5	35.0	7.05	0.31	1.06	0.13
Humera	Mikadira	0.28	16.0	0.09	35.3	36.7	9.42	0.64	1.27	0.31
	Bereket	0.22	13.8	0.06	40.1	36.2	7.63	0.24	1.53	0.13
Tach	Sanja	0.17	12.4	0.05	42.1	36.1	7.58	0.32	1.07	0.15
Armachiho	Asherie	0.23	12.3	0.06	44.2	33.9	7.48	0.32	1.31	0.13

T* = Tegedie

Linoleic acid was the most abundant fatty acid, ranging from 35.3 to 48.3%, with the highest level in sesame from Tegedie Anbagenet in Wolkayiet. As an essential omega-6 polyunsaturated fatty acid, it supports cardiovascular and metabolic health and contributes to skin maintenance (Siri-Tarino et al., 2010; Mozaffarian and Willett, 2009; Schwab and Vessby, 2005; Madison, 2003).

Oleic acid was the second most abundant, ranging from 29.8 to 38.2%, with the highest concentration in sesame from Dansha Anbaba in Wolkayiet. This monounsaturated fatty acid is linked to improved cardiovascular health, better insulin sensitivity, and reduced inflammation (Kris-Etherton and Innis, 2007; Patterson and Roberts, 2014; Schwab and Vessby, 2005; Calder, 2013).

Stearic acid, a saturated fatty acid, is considered relatively neutral regarding cardiovascular, metabolic, and liver health, as well as inflammation, compared to other saturated fats (Mensink and Katan, 1990; Siri-Tarino et al., 2010; Lichtenstein and Appel, 2007). Gadoleic acid, a monounsaturated fatty acid, ranged from 0.22 to 0.64% in the sesame seeds, with the highest in sesame from Mikadira in Humera. It shares the health benefits of monounsaturated fats, including potential improvements in cardiovascular and metabolic health and anti-inflammatory effects (Siri-Tarino et al., 2010; Mozaffarian et al., 2009).

Arachidic acid, a minor saturated fatty acid in the sesame seeds, ranged from 0.75 to 1.53%, with the highest level in seeds from Bereket (Humera). Research has suggested that it may raise LDL cholesterol similar to other saturated fats (Siri-Tarino et al., 2010). Behenic acid, another minor saturated fatty acid, varied from 0.08 to 0.31%, peaking in sesame from Mikadira (Humera). Behenic acid has been associated with potential negative effects on cardiovascular health (Mensink and Katan, 1992). Given the low concentrations, the impacts of arachidic and behenic acids are likely less significant than those of the more abundant saturated fatty acids, palmitic and stearic acids.

Comparison with literature reports

The fatty acid composition of the sesame seeds was compared with literature values from various countries (Table 4). The results were generally consistent with reported data, although the analyzed seeds had higher palmitic and stearic acid levels than those from other regions. Conversely, oleic acid content was lower than in seeds from Niger, India, Turkey, and Egypt, but comparable to sesame from China, the USA, and Japan

Table 4. Comparison of the concentrations (%total fatty acids) of fatty acids in sesame seeds from different countries.

Fatty Acid	Referred Countries						
	Niger	India	Turkey and Egypt	China	USA	Japan	Ethiopia
Palmitoleic acid	0.1-0.2	0.1-0.13	-	-	-	-	0.097-0.276
Palmitic acid	9.0-10.6	8.0-10.0	8.47-8.9	7.5	7.4	8.0	12.16-16.00
Margaric acid	-	-	-	-	-	-	0.05-0.09
Linoleic acid	35.9-44.3	-	42.70-42.77	43.2	44.0	40.6	40.0-48.0
Oleic acid	38.4-47.3	40.0-49.0	41.5-41.6	36.5	35.8	38.3	29.79- 38.2
Stearic acid	5.0-6.9	3.6-4.7	5.43-5.53	4.4	4.3	3.9	7.05- 9.40
Gadoleic acid	-	-	-	-	-	-	0.22- 0.64
Arachidic acid	0.6-0.7	-	-	-	-	-	0.75-1.78
Behenic acid	0.1-0.2	-	-	-	-	-	0.08-0.31
Reference	(Zangui *et al.*, 2023)	(Agidew *et al.*, 2021)	(Gharby *et al.*, 2017)	Zhou *et al.*, 2015	Bashir *et al.*, 2012	Kawakami *et al.*, 1999	This study

Variations among Production Districts

The results of one-way ANOVA showed no significant differences ($p > 0.05$) in the fatty acid compositions of the white sesame seeds across different cultivation areas of Ethiopia (Table 5). Exceptions were palmitoleic and palmitic acids, which were higher in seeds from Humera, which is the major sesame-producing region in the country known for high-quality seeds. These fatty acids may serve as distinguishing markers for Humera sesame.

Table 5. The concentrations (% total fatty acid) of fatty acids in the sesame seeds from the main production areas of Ethiopia.

Fatty acid	Production area					*P-Value*
	Humera	Metema	West Armachiho	Wolkayiet	Tache Armachiho	
Palmitoleic acid	0.25±0.04	0.15±0.02	0.17±0.04	0.14±0.03	0.20±0.04	0.01
Palmitic acid	14.9±1.5	13.2±0.4	13.2±0.2	12.7±0.4	12.4±0.05	0.001
Margaric acid	0.075±0.02	0.058±0.001	0.057±0.01	0.054±0.01	0.055±0.007	0.269
Linoleic acid	37.7±3.4	42.7±0.5	42±3.2	43.3±2.6	43.2±1.5	0.098

Saturated and Unsaturated Fatty Acids

Total saturated fatty acids in the sesame seeds ranged from 21.3 to 25.1%, while unsaturated fatty acids from 74.8 to 78.7% (Table 5). The unsaturated-to-saturated fatty acid ratio varied between 3.0 and 3.7, with the lowest in seeds from Humera. All samples meet dietary guidelines favoring higher unsaturated and lower saturated fat content. The WHO (2020) and European Food Safety Authority (EFSA, 2010) recommend a minimum unsaturated-to-saturated ratio of 1.5, while the American Heart Association (AHA, 2021) has advised a ratio greater than 2.

The sesame seed oils exhibited a lower saturated-to-unsaturated fatty acid ratio than olive, canola, sunflower, and soybean oils, but a higher ratio than coconut oil (Table 6). The ratio was comparable to that of cottonseed oil. This indicates that sesame oil is a healthy oil option with a favorable balance of unsaturated to saturated fats.

The oleic-to-linoleic acid ratio in the sesame seeds ranged from 0.80:1 to 0.97:1, lower than that reported for olive, canola, and coconut oils (Table 6), but higher than in sunflower, soybean, and cottonseed oils. An optimal edible oil is recommended to have a higher proportion of monounsaturated oleic acid relative to polyunsaturated linoleic acid (WHO, 2020; AHA, 2021).

Table 6. The total saturated and unsaturated fatty acid contents (%total fatty acid) and the relative amounts of oleic and linoleic acids in the sesame seeds.

Production area	SFA	UFA	UFA/SFA	Oleic/Linoleic
Humera	25.1	74.8	3.0	0.97
Metema	22.2	78.2	3.5	0.82
Wolkayiet	21.6	78.3	3.6	0.80
West Armachiho	22.2	77.8	3.5	0.84
Tache Armachiho	21.3	78.7	3.7	0.81
Common edible oils**				
Olive oil	14.5	85.5	5.9	6.6
Canola oil	13.5	86.5	6.4	2.2
Sunflower oil	9	91	10.0	0.3
Coconut oil	90.5	9.5	0.1	3.0
Soybean oil	13.5	86.5	6.4	0.4
Cottonseed	22.4	77.6	3.5	0.4

*SFA is total saturated fatty acids, UFA is total unsaturated fatty acids, and SFA/UFA is the ratio of total saturated fatty acids to total unsaturated fatty acids.

**Sources: Kostik *et al.* (2013) and USDA (2021).

CONCLUSION

Nine fatty acids were identified and quantified in white sesame seeds from the major cultivation areas of Ethiopia. The seeds were rich in linoleic and oleic acids and exhibited a high unsaturated-to-saturated fatty acid ratio, providing healthful lipids for human consumption. Fatty acid profiles were generally consistent across regions, except that seeds from Humera contained higher levels of palmitic and palmitoleic acids.

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CONFLICT OF INTEREST

The authors do not have a conflict of interest in the publication of this article.

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