Bull. Chem. Soc. Ethiop. **2024**, 38(4), 863-876.
ISSN 1011-3924
Printed in Ethiopia
Online ISSN 1726-801X
DOI: https://dx.doi.org/10.4314/bcse.v38i4.4

FATTY ACID AND ESSENTIAL OIL COMPOSITIONS OF SEEDS OF CORIANDER (*CORIANDRUM SATIVUM* L.) CULTIVATED IN DIFFERENT REGIONS OF ETHIOPIA

Mekides Assefa[1], Estifanos Ele Yaya[1], Bhagwan Singh Chandravanshi[1*], and Melaku Assefa[2]

[1]Department of Chemistry, College of Natural and Computational Sciences, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia
[2]Department of Chemistry, College of Natural and Computational Sciences, Wollo University, Ethiopia

(Received January 15, 2024; Revised March 14, 2024; Accepted March 19, 2024)

ABSTRACT. Coriander (*Coriandrum sativum* L.) seeds are used as spices. In this study, fatty acids extracted from the coriander seeds collected from three places (Sululta, Jimma and Wolaita Sodo) in Ethiopia were determined as their methyl ester using GC-MS. The fatty acid components were assessed using linoleic acid ethyl ester as an external standard. Sululta sample showed five fatty acids, while Wolaita Sodo and Jimma three each with highest amount of petroselinic acid: 68.41%, 72.53%, and 64.4%, respectively, of the total fatty acids. Linoleic acid (omega-6) was found in the range of 18.24-22.37%. The polyunsaturated versus saturated (P/S) index values were found to be 1.69-2.39, which indicated that coriander seeds from the three sites have a good capacity to prevent the development of cardiovascular and some chronic diseases. The number of compounds identified in the essential oils of coriander seeds from Jimma, Sululta, and Wolaita Sodo were 7, 9, and 15 with total percent areas of 99.64, 75.14, and 96.68, respectively. The major component in the essential oils was linalool ranging from 36.72-88.50% of the total amount. In general, the chemical constituents of fatty acids and essential oils of coriander seeds indicates its good nutritional quality and usefulness for human health.

KEY WORDS: Coriander seeds, Fatty acids, P/S index, Essential oils, Nutritional quality, Spice

INTRODUCTION

Coriander (*Coriandrum sativum* L.) belongs to the family Apiaceae. It is cultivated throughout the world for its seeds and leaves [1]. In Ethiopia, coriander grows at altitudes of 1500-2500 m, but it can be cultivated in the lowland [2]. It can be cultivated in any type of soil provided sufficient organic matter is available. Coriander herbs require a temperature of 10 to 28 ºC and a soil pH of 5.5 to 6.5 [3].

All parts of coriander are edible. But people mainly use the dried seeds as a spice. Leaves are mainly used in the form of salad and flavoring soup, meat products, and juice [4]. It can be combined with other spices used to flavor black peppers, bread, and injera [5].

Several types of compounds are found in coriander such as essential oils, fatty acids, minerals, and antioxidants. These are distributed in all parts of the plant with variable amounts and variation in the level and chemical composition arise from different genotypes and stages of maturity [6]. Coriander seeds contain significant amounts of several vitamins [7] and minerals [8]. Ethiopian coriander seeds contain essential oils, linalool, α-pinene, and geraniol [9]. Coriander contains about 20% oleic, petroselinic and linolenic fatty acids [10]. The presence of bioactive substances in coriander products has created the great interest in food industries [11]. Volatile oil and oleoresins are new value-added products of coriander seeds and are in great demand in international markets [12]. Recently vegetable oil from coriander has been considered as a novel food ingredient and proved to be safe for consumption as a food supplement for adults [13].

*Corresponding authors. E-mail: bscv2006@yahoo.com

Coriander oil is stable and can retain its chemical and physical characteristics for a longer time than the oil of its class as compared to oils extracted from similar spices which are readily oxidized [14]. The presence of linoleic acids in the diet is very important. They play very significant roles in human health and nutrition and are required for the development of some organs and cardiovascular disease prevention [10]. Coriander seeds possess phenolic compounds, flavonoids, β-carotene, vitamin C, vitamin E, and fatty acids (petroselenic, linoleic, oleic and palmitic acids) [15, 16]. These bioactive compounds are used to scavenge free radicals and help to prevent cancer and related diseases [17] and used as anti-micro-organisms [18]. The existence of a higher percentage of petroselenic acid is used to reduce the level of arachidonic acid in the heart and liver [19].

Ethiopia is a major producer of coriander in Africa. Coriander is cultivated in different regions of Ethiopia. Ethiopia is the land of 81 Ethiopian coriander genotypes [20]. The percent yield of both essential oil and fatty acids depends on the genotype of the seeds [6, 20]. Coriander is an essential spice in the Ethiopian kitchen. The seeds are used as a flavoring ingredient in chili powder, porridge, cheese, and the traditional bread injera. Recently the European Union has authorized the use of coriander oil as a food supplement [21]. The two important products (volatile oil and oleoresins) of coriander seeds are in high demand in international markets [12]. Presently Ethiopia exports coriander seeds and herbs in the form of raw crops and fresh leaves without any value addition. That means they have sold the raw coriander and imported an essential oil and oil resin of coriander at a high price.

Recently some studies have been conducted on the composition of fatty acids in green coffee beans [22, 23], teff grains [24], and pumpkin seeds [25] and essential oil of *Coriandrum sativum* L. [9, 26, 27] cultivated in Ethiopia. Even though, there are some study reported on the essential oils from coriander seeds but not on the fatty acids. Asfaw and Abegaz [9] obtained dried coriander seeds from Bale and Gondar and extracted essential oils and determined its composition. They did not extracted fatty acids and they did not determined fatty acids composition. Mikre, Rohloff, and Hymete [26], purchased the dried seeds of coriander from a local market in Addis Ababa and extracted the essential oils and assayed its antioxidant activity. They did not extracted fatty acids and they did not determined fatty acids composition. Hirko and Abera [27] collected the seeds of coriander varieties from Kulumsa Agricultural Research Centre during January, 2018 and extracted and determined the composition of the essential oil. They did not extracted fatty acids and they did not determined fatty acids composition.

Thus, no systematic study has been reported on the extraction and composition of fatty acids and essential oils of coriander seeds cultivated in different regions of Ethiopia. Therefore, it was worthwhile to investigate the chemical composition of fatty acids and essential oils in coriander seeds cultivated in three places (Sululta, Jimma and Wolaita Sodo) in Ethiopia.

The main objective of this study was to investigate the chemical constituents (fatty acids and essential oils) of coriander (*Coriandrum sativum* L.) seeds cultivated in Ethiopia by GC-MS. It also compares the functionality of essential oil of coriander found at different maturity stages from Wolaita Sodo with that reported elsewhere.

EXPERIMENTAL

Apparatus and instrumentation

A high-speed multifunctional grinder (Schingi, Yuan, China) was used for grinding and homogenizing the samples. Soxhlet apparatus was used for the extraction of fatty acids. Clevenger apparatus was used for the extraction of essential oils. The rotary evaporator (Heidolph Instruments, Gmbh & Co: KG, Germany) was used for concentrating the sample.

Chemicals and reagents

All the chemicals, reagents, and solvents were analytical/HPLC grade. Methanol (> 99.7%, Sigma-Aldrich, USA), *n*-hexane (99 %, Labachemical Pvt. Ltd, India), dichloromethane (Fisher Scientific, UK), chloroform (Carloerba reagent groups, France), KOH pellets, and NaCl were used as received.

Description of the sampling area

The coriander seeds were collected from three different localities: Wolaita Sodo from Southern Nations, Nationalities, and People's Region, and Sululta and Jimma from Oromia Region of Ethiopia. Jimma is located at a latitude of 7º40´26´´ and longitude of 36º50´8.8´´E with an elevation of 1400-2000 m above sea level. Sululta is located at the latitude of 9º11´0´´ N and longitude of 38º45´0 E´´ at an altitude of 2750 m above sea level. Wolaita Sodo is the administrative center of the Wolaita Zone of Southern Nations, Nationalities, and People's Region. It is located at the latitude of 6º54´ N and 37°45′ E. The selection of these areas was based on their higher production of coriander. The map of sampling area is shown in Figure 1.

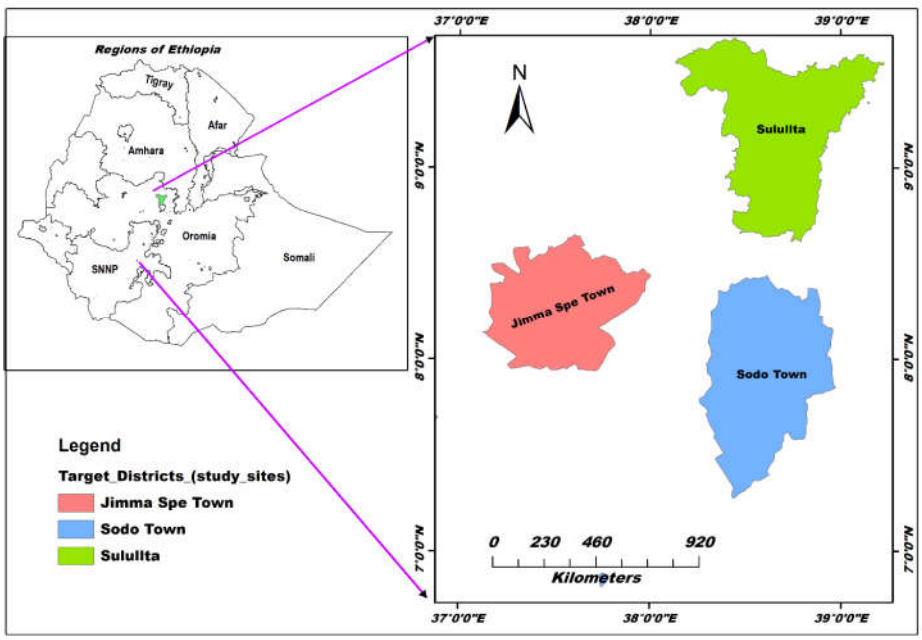

Figure 1. Map of the study area.

Extraction of fatty acid

The powdered coriander seed (80 g) was placed in the Soxhlet apparatus and extracted with 200 mL of *n*-hexane for 8 h 65 ºC. The extract was concentrated by rotary evaporator [28].

Preparation of fatty acid methyl esters

The fatty acid extract (1 g) was esterified with 2% methanolic KOH following the reported method [28, 31].

Extraction of volatile compounds

Essential oils were extracted from 80 g of powdered coriander seeds by hydro-distillation using Clevenger apparatus [29] for 5 h. The essential oil was dried over anhydrous Na_2SO_4 and kept in a refrigerator until GC-MS analysis [30]. The extraction time of essential oil was varied up to 8 h and the amount of essential oil produced within every hour was recorded.

GC-MS analysis

GC-MS analysis was conducted on an Agilent Technology 7820A GC system coupled with an Agilent Technology 5977E MSD equipped with an autosampler. The chromatographic separation was done on a DB-1701 (14%-cyanopropyl-phenyl-methylpolysiloxane) column (30 m × 0.25 µm) at a flow rate of 1 mL/min. Ultra-high pure helium (99.999%) was used as carrier gas at constant flow mode (1 mL/min). An Agilent G4567A autosampler was used to inject 1 µL of the sample with a splitless injection mode into the inlet heated to 275 ºC with a total run time of 29.33 min. The oven temperature was programmed with the initial column temperature of 60 ºC and a hold time of 2 min. The column temperature was increased to 200 ºC at a rate of 10 ºC/min and then heated again at a rate of 3 ºC/min until the temperature reached 240 ºC. The transfer line and the ion source temperatures were 280 ºC and 230 ºC, respectively. The electron energy was 70 eV. Mass spectral data were collected from 40–650 m/z. The fatty acid methyl esters were identified by matching their mass spectra with those of reference compounds recorded in the National Institute of Standards and Technology (NIST) mass spectral library [24, 25, 28].

Preparation of external standard for GC-MS analysis

Linoleic acid ethyl ester at different concentrations (1, 10, 20, 40 and 80 µg/mL) was prepared. The calibration curve was constructed from average peak area versus concentration. The unknown concentration of analyte fatty acids was calculated from the regression equation of the linoleic acid ethyl ester standard [31, 32].

Sample preparation for GC-MS analysis

A 1000 µg/mL of linoleic acid ethyl ester standard stock solution was prepared in dichloromethane and 20 µg/mL solution was prepared from the stock solution for GC-MS analysis by serial dilution. Similarly, coriander seeds fatty acid methyl ester stock solution of 1000 µg/mL was prepared in dichloromethane and 20 µg/mL solution obtained from serial dilution was used for GC-MS analysis.

Determination of the percentage of individual components in the essential oil

The percentage of individual components of the essential oil was determined from the peak area obtained from the chromatogram. The selection of peaks was based on relative qualitative information obtained from the NIST-14 library. Peak purity and identity checks were done both automatically using the software and also manually by selecting different parts of a peak, subtracting the background and comparing with data stored in the NIST-14 library. The number of individual components in the chromatogram of different samples was compared by considering peak area, retention time, and index.

Retention index

The retention index (RI) was calculated by injecting a mixture of *n*-alkane with the same experimental condition as that of the sample analysis and using the van den Dool and Kratz relationship [33]:

$$RI = [100n+100(Rt(unknown)-Rt)]/[Rt (n+1)-Rt`(n)] \quad (1)$$

where, n = the number of carbon atoms eluting before the analyte, Rt (unknown) = retention time of the analyte, Rt (n+1) = retention time of the reference elute after the analyte, and Rt (n) = retention time of the reference elute before the analyte.

RESULTS AND DISCUSSION

Chemical composition of fatty acids in coriander seeds

The results obtained revealed that petroselinic acid was the major fatty acid constituent observed in all the samples (Table 1). Higher percentages of petroselinic acid were determined in coriander seeds in all the samples (Sululta, 68.41%; Wolaita Sodo, 72.53%; Jimma, 64.4%) of the total fatty acids. While the linoleic acid contents were (Sululta, 20.03%; Wolaita Sodo, 18.24%; Jimma, 22.37%) of the total fatty acids and palmitic acid contents were (Sululta, 6.20%; Wolaita Sodo, 9.22%; Jimma, 13.22%) of the total fatty acids. Oleic acid (3.21% and stearic acid (2.16%) were only observed in the samples from Sululta.

Table 1. Fatty acid constituents and their percentage in coriander seeds from the three selected areas.

Sample sites	Compounds name	Rt	% total fatty acid	Qual.
Sululta	Palmitic acid (C16:0)	11.42	6.20	99
	Petroselinic acid (C 18:1 (n-6))	13.29	68.41	97
	Oleic acid (C18:1(n-9))	13.31	3.21	97
	Linoleic acid (C18:2)	13.37	20.03	99
	Stearic acid (C18:0)	13.43	2.16	98
Wolaita Sodo	Palmitic acid (C16:0)	11.42	9.22	99
	Petroselinic acid (C 18:1(n-6))	13.29	72.53	97
	Linoleic acid (C 18:2)	13.36	18.24	99
Jimma	Palmitic acid (C 16:0)	11.43	13.22	98
	Petroselinic acid (C 18:1)	13.29	64.4	99
	Linoleic acid (C 18:2)	13.36	22.37	99

Rt = retention time, Qual. = NIST matching quality.

As shown in Table 1, a maximum amount of petroselinic acid was observed in coriander seeds harvested from Wolaita Sodo compared to Sululta and Jimma. Lower amounts of stearic and oleic acids was determined in coriander seeds collected from Sululta than in the two sampling areas. A relatively higher percentage of linoleic and palmitic acids was quantified in coriander seeds collected from Jimma than in other sampling sites. A representative gas chromatogram of methyl ester of fatty acids in coriander seeds from sululta and gas chromatogram of mixture of methyl esters of standard fatty acids are shown in Figure 2.

A comparison of fatty acid constituents determined in this study with the reported values is shown in Table 2. The data showed that the percent composition of petroselinic acid is lower than that from Tunisia [34]. Petroselinic acid in coriander seeds from Wolaita Sodo is higher than that from Germany [16], similar to that of Tunisia and Canada [35]. In this study, a higher percentage of palmitic and linoleic acids were determined than that reported from Tunisia, Canada, Germany, the United States, Vietnam, and Turkey. Hence, one may conclude that Ethiopian coriander seeds are a good source of omega-6 which has nutritional value for our body and plays a vital role in the health of a person [16, 35].

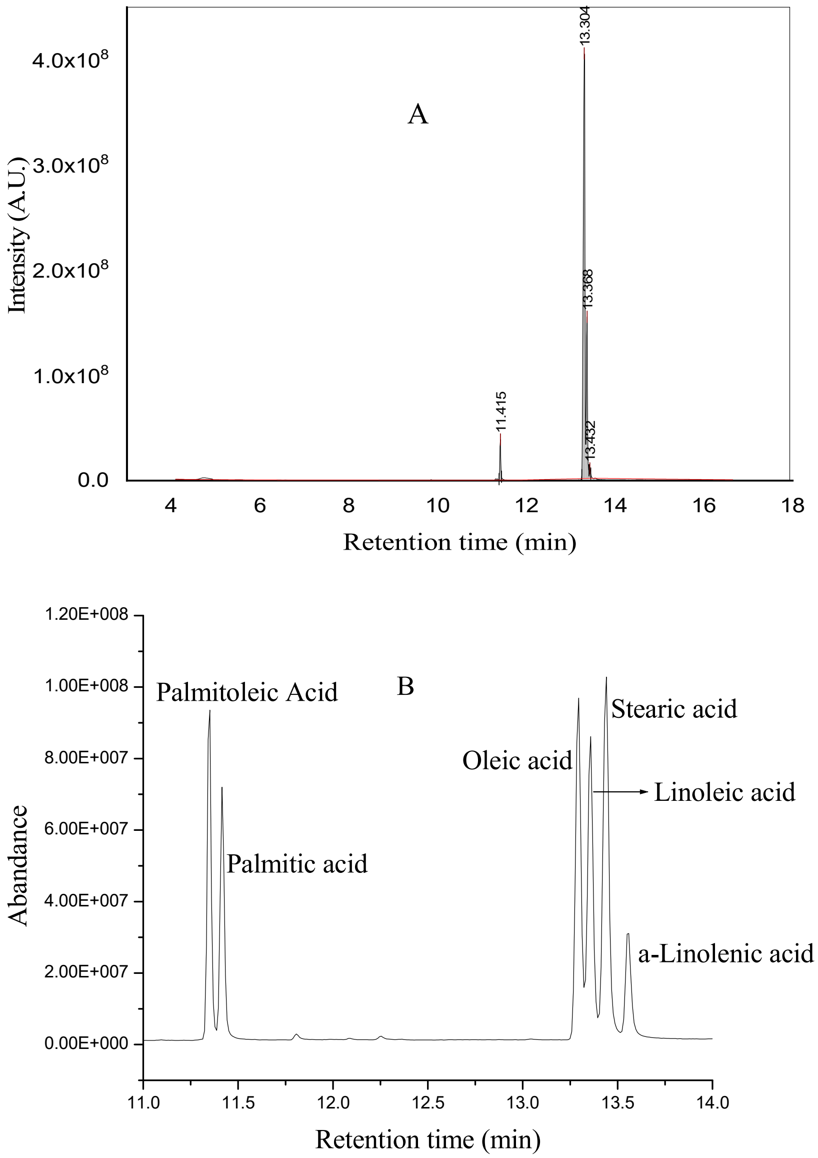

Figure 2. Gas chromatogram of (A) methyl ester of fatty acids in coriander seeds from Sululta and (B) mixture of methyl esters of standard fatty acids.

Table 2. Comparisons of fatty acid constituents of coriander seeds with reported values.

	Percent of total fatty acids (%)						
Palmitic acid	Stearic acid	Petroselinic acid	Linoleic acid	Oleic acid	Method	Origin	Ref.
3.60	0.70	80.90	13.60	0.20	GC-FID	Tunisia	[34]
3.82	0.82	75.66	12.79	6.38	GC-FID	Tunisia	[35]
3.97	0.95	73.23	14.80	6.48	GC-FID	Canada	[35]
3.96	2.91	65.7	16.70	7.85	GLC-FID	Germany	[16]
5.30	3.10	68.50	13.00	7.60	GC-FID	USA	[36]
2.91	0.51	78.76	14.23	-	GLC	Vietnam	[43]
3.74	0.97	77.10	14.76	2.94	GC-FID	Turkey	[38]
6.20	2.16	68.41	20.03	3.21	GC-MS	Sululta, Ethiopia	This study
9.22	-	72.53	18.24	-	GC-MS	Wolaita Sodo, Ethiopia	
13.22	-	64.4	22.37	-	GC-MS	Jimma, Ethiopia	

P/S index values of fatty acids in coriander seeds from selected sampling areas

The P/S index is an important parameter used for evaluating the nutritional value and healthiness of foods [39]. P/S index values were calculated from the ratio of total polyunsaturated fatty acid (PUFA) to total saturated fatty acid (SFA) (Table 3). The diets that have a P/S index ratio above 0.45 were recommended for human consumption to prevent the development of cardiovascular and some chronic diseases such as cancer. The P/S index value of coriander seeds fatty acids in all the selected areas fulfilled the above requirements and is consistent with the previously reported results [40].

Table 3. The p/s index values for fatty acids in coriander seeds from the selected areas.

Sampling areas	SFA	MUFA	PUFA	P/S index
Sululta	8.36	71.62	20.03	2.39
Wolaita Sodo	9.22	72.53	18.24	1.69
Jimma	13.22	64.4	22.37	1.98

MUFA = mono unsaturated fatty acid, PUFA = poly unsaturated fatty acid.

Optimum time of extraction of essential oils from coriander seeds

To determine the optimum time of extraction of the essential oils, separate experiments were conducted which limited the extraction time of seeds from Wolaita Sodo at 3 h and 5 h. The GC-MS analysis revealed that eight compounds were extracted in the first 3 h while ten compounds were extracted in the second phase that covers from 3-5 h. The 3 h extraction gave only part of the compounds and full extraction was only achieved at longer extraction hours. Hence, to get the total constituents of the essential oil, distillation for 5 h was preferred.

Chemical composition of essential oils extracted from coriander seeds

The chemical composition of essential from green and dried coriander seed from Wolaita Sodo is listed in Table 4. The GC-MS analysis of the essential oils of green and dried coriander seeds from Wolaita Sodo revealed 15 and 12 different compounds, respectively with a total area of 99.31% and 99.99% in that order. For the green coriander, aliphatic aldehydes were the predominant compounds in the mixture accounting for 52.54% and other determined compounds were monoterpene alcohol (31.13%), monoterpene hydrocarbon (7.61%), monoterpene oxide (5.09%) and aliphatic alcohol (3.63%). The highest concentration of linalool was measured in dried coriander seeds' essential oil compared to the green one. The amount of decanal at (10.27 min) and (*E*)-2-decenal (11.45 min) quantified from dried seeds are relatively lower compared to the green seeds. This could most likely be due to high volatility and low boiling points of the compounds which make them escape at the high temperature required for drying. The relative concentrations of linalool, 2-bornanone and D-limonene were higher in dried coriander seeds compared to green seeds while the amounts of isopulegon, decanal and (*E*)-2-decenal were decreased in dried seeds than in the green seeds.

Table 4. Chemical composition of essential oil identified in green and dried coriander seed from Wolaita Sodo.

Name of compounds	Green seeds peak area (%)	Dried seeds peak area (%)
α-Pinene	–	0.26
(E)-β-Ocimene	3.32	2.07
D-Limonene	0.83	1.41
p-Cymene	3.46	0.65
Z-linalool oxide	0.62	–
Isopulegon	0.84	0.32
Linalool	30.62	86.17
(+)-2-Bornanone	2.94	6.17
Decanal	9.19	0.68
α-Terpineol	–	0.54
Geraniol	–	0.45
(*E*)-2-Decen-1-ol	3.63	–
(*E*)-2-Decenal	34.47	0.34
(*R*)-Lavandulyl acetate	0.51	0.93
2-Undecenal	0.69	–
Dodecenal	0.62	–
2-Dodecenal	6.18	–
(*E*)-Tetradec-2-enal	1.39	–

The chemical composition of essential oil extracted from the dried coriander seeds from Wolaita Sodo, Jimma, and Sululta is given in Table 5. GC-MS analysis data revealed that the dried coriander seeds from Wolaita Sodo, Jimma, and Sululta are composed of 12, 7, and 9 compounds with a total percent area of 99.99 %, 99.64 %, and 99.94 %, respectively. As can be seen in Table 5, a larger number of essential oil constituents were detected in coriander seeds from Wolaita Sodo than in other selected areas. Coriander seeds from Jimma were a potential source of linalool and 2-bornanone, followed by Wolaita Sodo. However, the relative concentration of these dominant compounds were lower and two different compounds were found (*tert*-octyldiphenylamine and bis(4-(2,4,4-trimethylpentan-2-yl)phenyl) amine) that were not detected in all the other samples. The lower amount of α-pinene was quantified only in the seeds from Wolaita Sodo. A gas chromatogram of essential oils of coriander seeds from Sululta is shown in Figure 3. A gas chromatogram of mixture of n-alkanes is shown in Figure 4.

Table 5. Comparision of essential oil constituents extracted from coriander seeds from the three areas.

Compounds name	Wolaita Sodo (%)	Sululta (%)	Jimma (%)
α-Pinene	0.26	-	-
(E)-β-Ocimene	2.07	2.70	-
D-Limonene	1.14	-	1.35
p-Cymene	0.65	-	-
Isopulegon	0.32	-	-
2,2,7-trimethyl bicyclo(2.2.1) hept-2-ene	-	-	0.92
Linalool	86.17	48.86	88.5
(+)-2-Bornanone	6.17	3.23	7.19
Decanal	0.68	0.81	0.53
α-Terpineol	0.54		0.54
(R)-Lavandulyl acetate	0.93	0.98	-
(E)-2-Decenal,	0.34	-	-
Geraniol	0.45	-	0.61
Hexadecane	-	2.34	-
Octadecane	-	3.52	-
Tert-octyldiphenylamine	-	4.47	-
Bis(4-(2,4,4-trimethylpentan-2-yl)phenyl) amine	-	33.03	-

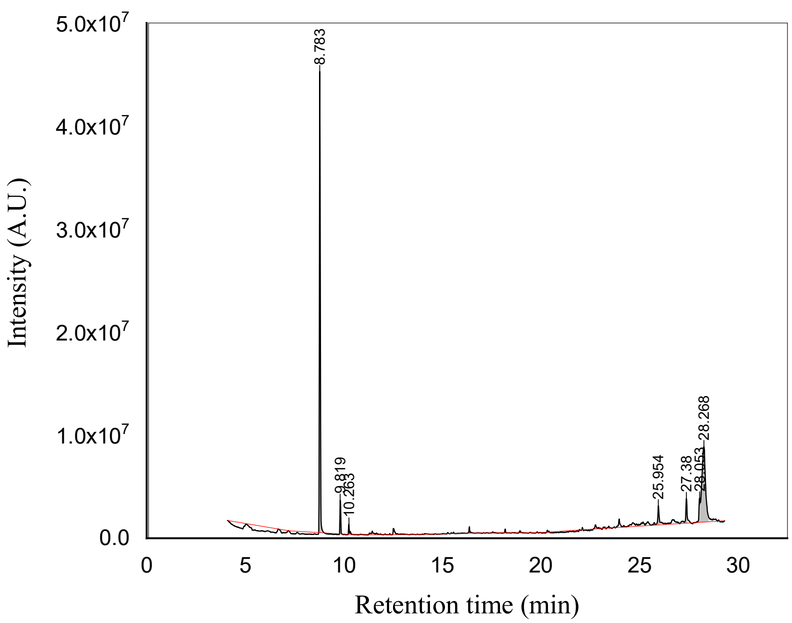

Figure 3. Gas chromatogram of essential oils of coriander seeds from Sululta.

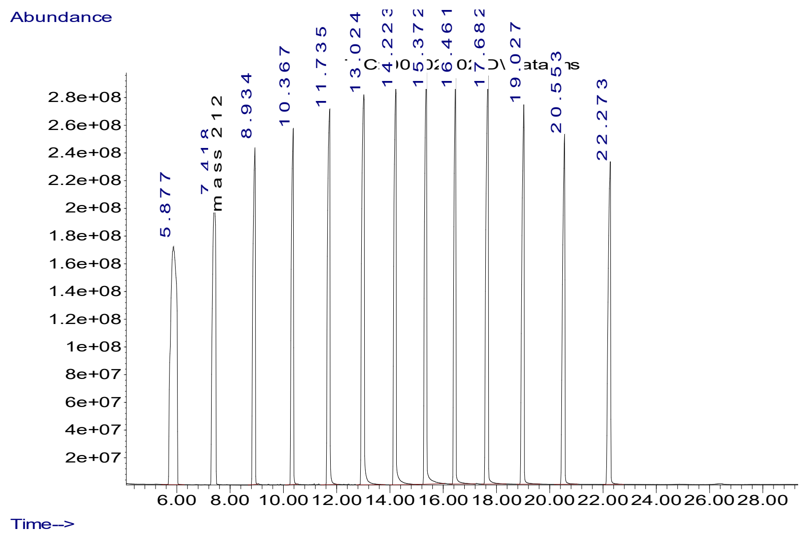

Figure 4. Gas chromatogram of mixture of n-alkane.

Table 6. Comparison of the chemical composition of essential oils of coriander seeds with the reported results.

Essential oil constituents (% area)								
α-Pinene	β-Ocimene	D-Limonene	*p*-Cymene	Isopulegon	Linalool	Origin	Methods	Ref.
4.54	0.94	2.23	0.96	-	70.70	Gonder, Ethiopia	GC-MS	[9]
1.54	0.02	2.15	0.12	-	76.61	Bale, Ethiopia		
6.15	0.03	3.03	-	-	58.86	Arsi, Ethiopia	GC-MS	[27]
4.90	0.03	0.72	-	-	76.45			
3.23	0.31	3.3	4.08	-	18.34	Egypt	GC-MS	[30]
3.46	-	-	2.94	-	66.29	Iran	GC-MS	[41]
2.87	-	2.55	0.83	-	55.42	India	GC-MS	[42]
0.26	2.07	1.14	0.65	0.32	86.17	Wolaita Sodo, Ethiopia	GC-MS	This study
-	2.03	-	-	-	36.72	Sululta, Ethiopia		
-	-	1.35	-	-	88.5	Jimma, Ethiopia		
2-Bornanone	Decanal	α-Terpineol	(R)- lavan dulyl acetate	(E)-2-Decenal	Geraniol	Origin	Methods	Ref.
4.79		0.40	-	-	2.58	Gonder, Ethiopia	GC-MS	[9]
5.98	-	0.33	-	-	2.74	Bale, Ethiopia		
6.54	-	0.07	-	-	4.02	Arsi, Ethiopia	GC-MS	[27]
-	-	-	-	-	1.19			
2.7	2.85	7.71	-	5.1	1.9	Egypt	GC-MS	[30]
0.56	0.25	0.53	-	-	1.55	-	GC-MS	[41]
0.79	1.44	0.12	-	1.30	1.11	India	GC-MS	[42]
6.17	0.68	0.54	0.93	0.34	0.45	Wolaita Sodo, Ethiopia	GC-MS	This study
2.43	0.61	-	0.74	-	-	Sululta, Ethiopia		
7.19	0.53	0.54	-	-	0.61	Jimma, Ethiopia		

A comparison of the chemical composition of essential oils of coriander seeds of the present study with the reported results in the literature is given in Table 6. The percent composition of linalool in the sample from Wolaita Sodo and Jimma was higher than those reported in previous studies from Ethiopia [9, 27], Egypt [30], Iran [41], and India [42] but the sample from Sululta contains lower than all the reported values except from Egypt [30]. Relatively higher amounts of β-ocimene were determined in the seed from Wolaita Sodo and Sululta than other reported values shown in Table 6. However, relatively smaller amounts of α-pinene, (*E*)-2-decenal, and garaniol were quantified in the sample mixture of the seeds from Wolaita Sodo than other reported data. Both (*R*)-lavenduly acetate and iso-pulegon identified in the seeds from Wolaita Sodo, 2,2,7-trimethyl bicycle[2.2.1]hept-2-ene from Jimma and other 4 compounds from Sululta were not reported in the literature. Thus wide variations in the major constituents in the coriander essential oils were in the present study. It should be noted that similar variations were also observed in the other reported studies as can be seen in Table 6. The variations in the composition of essential oils depends on several factors such as geographical location, environmental and climatic conditions, maturity of plants at the time of sampling and so on.

CONCLUSION

Five fatty acids (petroselinic, linoleic, oleic, palmitic, and stearic) were detected in the coriander seeds from Sululta, while three fatty acids each from Wolaita Sodo and Jimma (Ethiopia). Higher concentrations of petroselinic, linoleic, and palmitic acid were found in the samples from the Sululta site than in other selected sites. Lower concentrations of petroselinic, linoleic, and palmitic acid were found in the sample from Jimma than in other sampling areas. The P/S index was found in the range of 1.69-2.39, which indicated that coriander seeds from the selected areas have a good capacity to prevent the development of cardiovascular and some chronic diseases. Variable number of compounds (7, 9, and 12) were identified in the essential oils extracted from coriander seeds from Jimma, Sululta, and Wolaita Sodo with combined percent areas of 99.64, 99.94, and 99.99, respectively. These variations were due to differences in geographical locations as well due to differences in the maturity stages at the time of sampling. Similar variations are common in the essential oil composition of other spices and herbs. In general, the chemical constituents of fatty acids and essential oils of coriander seeds indicates its good nutritional quality and usefulness for human health.

ACKNOWLEDGMENTS

The authors express their gratitude to the Department of Chemistry, Addis Ababa University, Ethiopia for providing laboratory facilities.

REFERENCES

1. Mandal, S.; Mandal, M. Coriander (*Coriandrum sativum* L.) essential oil: Chemistry and biological activity. *Asian Pac. J. Trop. Biomed.* **2015**, 5, 421–428.
2. Jansen, P.C.M. *Spices, Condiments and Medicinal Plants of Ethiopia, Their Taxonomy and Agricultural Significance*, Center for Agricultural Publishing and Documentation: Wageningen, **1981**.
3. Wierdak, R.N. Essential oil composition of the coriander (*Coriandrum sativum* L.) herb depending on the development stage. *Acta Argobot.* **2013**, 66, 53–60.
4. Eyres, G.; Dufour, J.P.; Hallifax, G.; Otheeswaran, S.; Marriott, P.J. Identification of character-impact odorants in coriander and wild coriander leaves using gas chromatography-olfactometry (GCO) and comprehensive two-dimensional gas chromatography-time-of-flight mass-spectrometry (GC6GC–TOFMS). *J. Sep. Sci.* **2005**, 28, 1061–1074.

5. Engels, J.M.M.; Hawkes, J.G.; Worede, M. *Plant Genetic Resources of Ethiopia*, Cambridge University Press: New York; **1991**.
6. Awas, G.; Mekbib, F.; Ayana, A. Genetic diversity analysis of Ethiopian coriander (*Coriandrum sativum* L.) genotypes for seed yield and oil content. *J. Plant Breed. Genet.* **2017**, 5, 7–14.
7. Rizwani, G.H.; Abbas, K.; Zahid, H. Prevention and treatment of different health problems by common people's diet (Haleem). *Afr. J. Food Sci.* **2018**, 11, 82–94.
8. Abdella, A.; Chandravanshi, B.S.; Yohannes, W. Levels of selected metals in coriander (*Coriandrum sativum* L.) leaves cultivated in four different areas of Ethiopia. *Chem. Int.* **2018**, 4, 189–197.
9. Asfaw, N.; Abegaz, B. The essential oils of *Coriandrum sativum* L. grown in Ethiopia. *SINET: Ethiop. J. Sci.* **2007**, 21, 279–285.
10. Ertas, O.N.; Guler, T.; Ciftci, M.; Dalkilic, B.; Yilmaz, O. The effect of a dietary supplement coriander seeds on the fatty acid composition of breast muscle in Japanese Quail. *Rev. Med. Vet.* **2007**, 156, 514–518.
11. El-Ghorab, A.; Shaaban, H.A.; El-Massry, K.F.; Shibamoto, T. Chemical composition of volatile extract and biological activities of volatile and less-volatile extracts in juniper berry (*Juniperus drupacea* L.) fruit. *J. Agric. Food Chem.* **2008**, 56, 5021–5025.
12. Sharma, M.M.; Sharma, R.K. *Coriander In Handbook Of Herbs And Spices*, Peter, K.V. (Ed.), 2nd ed., Woodhead Publishing Series in Food Science, Technology, and Nutrition: Woodhead Publishing Limited, Cambridge, U.K.; **2012**; pp. 216–249.
13. Burdock, G.A.; Carabin, I.G. Safety assessment of coriander (*Coriandrum sativum* L.) essential oil as food ingredient. *Food Chem. Toxicol.* **2009**, 47, 22–34.
14. Purseglove, J.W.; Brown, E.G.; Green, C.L.; Robbins, S.R.J. *Spices*, Vol. 2, Longman: New York; **1981**; pp. 736–788.
15. Diederichsen, A. *Coriander (Coriandrum sativum L.) Promoting the Conservation and Use of Underutilized and Neglected Crops*, 3rd ed., International Plant Genetic Resources Institute: Rome; **1996**.
16. Hossanien, M.F.R.; Morsel, J.T. Oil composition of coriander (*Coriandrum sativum* L.) fruit-seeds. *Eur. Food Res. Technol.* **2002**, 215, 204–209.
17. Rajeshwari, U.; Andallu, B. Medicinal benefits of coriander (*Coriandrum Sativum* L.), *Spatula DD* **2011**, 1, 51.
18. Silva, F.; Ferreira, S.; Queiroz, J.A.; Fernanda, C.D. Coriander (*Coriandrum sativum* L.) essential oil its antibacterial activity and mode of action evaluated by flow cytometry. *J. Med. Microbiol.* **2011**, 60, 1479–1486.
19. Shahwar, M.K.; El-Ghorab, A.H.; Anjum, F.M.; Butt, M.S.; Hussain, S.; Nadeem, M. Characterization of coriander (*Coriandrum sativum* L.) seeds and leaves: volatile and non-volatile extracts. *Int. J. Food Prod.* **2012**, 15, 736–747.
20. Geremew, A.; Firew, M.; Amsalu, A. Genetic diversity analysis of Ethiopian coriander (*Coriandrum sativum* L.) genotypes for seed yield and oil content. *J. Plant Breed. Genet.* **2017**, 05, 07–14.
21. European Food Safety Authority, Scientific opinion on the safety of "coriander seed oil" as a novel food ingredient. *EFSA J.* **2013**, 11, 3422.
22. Mehari, B.; Redi-Abshiro, M.; Chandravanshi, B.S.; Combrinck, S.; McCrindle, R.; Atlabachew, M. GC-MS profiling of fatty acids in green coffee (*Coffea arabica* L.) beans and chemometric modelling for tracing geographical origins from Ethiopia. *J. Sci. Food Agric.* **2019**, 99, 3811–3823.
23. Tsegay, G.; Redi-Abshiro, M.; Chandravanshi, B.S.; Ele, E.; Mohammed, A.M.; Mamo, H. Effect of altitude of coffee plants on the composition of fatty acids of green coffee beans. *BMC Chem.* **2020**, 14, 36.

24. Yisak, H.; Yaya, E.E.; Chandravanshi, B.S. Redi-Abshiro, M. GC-MS profiling of fatty acids and nutritional properties of the white and brown teff [Eragrostis tef (Zuccagni) Trotter] varieties cultivated in different parts of Ethiopia. *J. Food Compos. Anal.* **2022**, 107, 104–405.
25. Hagos, M.; Yaya, E.E.; Chandravanshi, B.S. Redi-Abshiro, M. Determination of fatty acids composition by GC-MS and most important physiochemical parameters of pumpkin (*Cucurbita maxima*) seed oil cultivated in Ethiopia. *Bull. Chem. Soc. Ethiop*. **2023**, 37, 565–577.
26. Mikre, W., Rohloff, J.; Hymete, A. Volatile constituents and antioxidant activity of essential oils obtained from important aromatic plants of Ethiopia. *J. Essent. Oil-Bear. Plants* **2007**, 10, 465–474.
27. Hirko, B.; Abera, S. Chemical composition of essential oils from released coriander variety (*Coriandrum sativum* L.) grown in Ethiopia. *Chem. Mater. Res.* **2019**, 11, 1–5.
28. Sisay, M.A.; Mammo, W.; Yaya, E.E. Phytochemical studies of *Melilotus officinalis*. *Bull. Chem. Soc. Ethiop*. **2021**, 35, 141–150.
29. Clevenger, J.F. Apparatus for determination of volatile oil. *J. Am. Pharm. Assoc.* **1928**, 17, 346–349.
30. Mohamed, M.A.; Ibrahim, M.E.; Wahba, H.E. Flavoring compounds of essential oil isolated from agriculture waste of coriander (*Coriandrum sativum*) plant. *J. Mater. Environ. Sci.* **2018**, 9, 77–82.
31. Tesfamicael, F.; Ele, E. Assessment of fatty acids composition in commercially available and widely consumed edible oils in Ethiopia: their relevance and health implications. *Sinet: Ethiop. J. Sci.* **2016**, 39, 21–33.
32. Ramadan, M.F., Kinni, S.G., Seghagiri, M. and Morsel, J.T. Fat soluble bio actives, fatty acids profiles and radical scavenging activity of Seme carpus anacardium seed oil. *J. Am. Oil Chem. Soc.* **2010**, 87, 885–894.
33. van Den Dool, H.; Kratz, P.Dec. A generalization of the retention index system including linear temperature programmed gas-liquid partition chromatography. *J. Chromatogr. A* 1963, 11, 463–471.
34. Msaada, K.; Taarit, M.B.; Hosin, K.; Hammami, M. Effect of growing region and maturity stage on oil yield and fatty acid composition of coriander (*Coriandrum sativum* L.) fruit. *Sci. Hortic.* **2009**, 120, 525–531.
35. Siriti, J.; Wannes, W.A.; Talou, T.; Vilarem, G.; Marzouk, B. Chemical composition and antioxidant activities of Tunisian and Canadian coriander (*Coriandrum sativum* L.) fruit. *J. Essent. Oil Res.* **2013**, 23, 7–15.
36. Moser, B.; Vaughn, S.F. Coriander seed oil methyl esters as biodiesel fuel: Unique fatty acid composition and excellent oxidative stability. *Biomass Bioenerg.* **2010**, 34, 550–558.
37. Matthaus, B.; Vosmann, K.; Pham, L.Q.; Kurt, A. FA and tocopherol composition of Vietnamese oilseeds. *J. Am. Oil Chem. Soc.* **2003**, 80, 1013–1020.
38. Kiralan, M.; Calikoglu, E.; Ipek, A.; Bayrak, A.; Gurbuz, G. Fatty acid and volatile oil composition of different coriander (*Coriandrum sativum* L) registered varieties cultivated in Turkey. *Chem. Nat. Comp.* **2009**, 45, 100–102.
39. Wo1oszyn, J.; Haraf, J.; Okruszek, A.; Werenska, M.; Goluch, Z.; Teleszko, M. Fatty acid profiles and health lipid indices in the breast muscles of local Polish goose varieties. *Poultry Sci.* **2019**, 99, 1216–1224.
40. Sani, R.K.; Assefa, A.D.; Keum, Y.S. Spices in the Apiaceae family represent the healthiest fatty acid profile: A systematic comparison of 34 widely used spices and herbs. *Foods* **2021**, 10, 854–866.
41. Sourmaghi, M.H.S.; Kiaee, G.; Golfakhrabadi, F.; Jamalifar, H.; Khanavi, M. Comparison of essential oil composition and antimicrobial activity of *Coriandrum sativum* L. extracted by

hydrodistillation and microwave-assisted hydrodistillation. *J. Food Sci. Technol.* **2015**, 52, 2452–2457.
42. Padalia, R.C.; Karki, N.; Sah, A.N.; Verma, R.S. Volatile constituents of leaf and seed essential oil of *Coriandrum sativum* L. *J. Essent. Oil-Bearing Plants* **2011**, 14, 610–616.
43. Bhuiyan, M.A.; Ibrahim, M.E.; Wahba, H. Chemical composition of leaf and seed essential oil of *Coriandrum sativum* L. from Bangladesh. *Bangladesh J. Pharmacol.* **2009**, 4, 150–153.