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Phytochemical investigation and antioxidant analysis of seeds and aerial parts of coriander (*Coriandrum sativum* L.) cultivated in Ethiopia.

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A thesis submitted to the Chemistry Department of Addis Ababa University in partial fulfillment of the requirements for the Degree of Master of Science in chemistry.

Advisors: Professor B. S. Chandravanshi
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This is to certify that the thesis prepared by Mekides Assefa entitled: **Phytochemical investigation and antioxidant analysis of seeds and aerial parts of coriander (*Coriandrum sativum* L.) cultivated in Ethiopia** and submitted in partial fulfillment of the requirements for the degree of master in chemistry complies with the regulation of the university and meets the accepted standards with respect to originality and quality.

Approved by the examining board:

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Declaration

I declare that this thesis entitled "Phytochemical investigation and antioxidant analysis of seeds and aerial parts of coriander (*Coriandrum sativum* L.) cultivated in Ethiopia" is my original work under the supervision of Prof: B. S. Chandravanshi and Dr. Estifanos Ele, Department of Chemistry, Addis Ababa University and that all sources of materials used for this thesis have been duly acknowledged. I solemnly declare that this thesis is not submitted to any other institution, anywhere for the award of any academic degree, diploma, or certificate.

Name: Mekides Assefa Signature: ________________________

This MSc. Thesis has been submitted for examination with our approval as university advisors.

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Abbreviations and Acronyms

DPPH	1,1-Diphenyl-2-picrylhydrazyl
FDA	Food and Drug Administration
FEMA	Foreign Exchange Management Act
FEMA	Flavor and Extract Manufacturers' Association,
GC-MS	Gas chromatography-mass spectrometry
ITC	International Trade center
L-L	Liquid-liquid extraction
MHEJ	Methanol aerial extract from Jimma
MHES	Methanol aerial extract from Sululta
MHEW	Methanol aerial extract from Wolaita Sodo
MLE	Methanol leaf extract
MSE	Methanol seed extract
MUFA	Monounsaturated fatty acids
NFI	Novel Food Ingredient
NIST	National Institute of Standards and Technology
NMRS	Nuclear magnetic resonance spectrometry
PUFA	Polyunsaturated fatty acids
Rt	Retention time
SFA	Saturated fatty acid
SNNPR	Southern Nations, Nationalities, and People's Region
UAE	United Arab Emirates
UV-VIS	Ultraviolet-visible spectrophotometer
P/S index	The ratio of PUFA to SFA

Abstract

In this study essential oils extracted from coriander seed and aerial parts of the samples collected from Sululta, Jimma and Wolaita Sodo were analyzed using GC-MS. Similarly, fatty acids from the coriander seeds were extracted and analyzed in their methyl ester form. The antioxidant activities of the crude extracts of coriander aerial parts were evaluated using a UV-Vis spectrophotometer. The optimum time for extraction of essential oil was determined to be 5 h. The concentration of each fatty acid component was evaluated based on an external standard prepared from linoleic acid ethyl ester. From the analyzed data, the sample collected from Sululta showed the highest number of compounds and a higher amount of Petroselinic acid (107.53 μg/mL) compared to Wolaita Sodo (41.12 μg/mL) and Jimma (20.41μg/mL). In this study, 18.24-22.37% linoleic acid (omega-6) was determined. The P/S index values were calculated for all oil and found to be between 1.69 and 2.39. The total number of compounds identified in the essential oils extracted from seeds collected from Jimma, Sululta and Wolaita Sodo were 7, 9 and 15 with combined percent areas of 99.64, 75.14 and 96.68, respectively. The essential oils were dominated by linalool, which accounts for 36.72%-88.50% of the total amount. From the aerial parts of the plants collected from Jimma, Wolaita Sodo and Sululta, 45, 21 and 19 different compounds were identified, respectively. Decanal and (E)-2-decenal were the major components of the essential oils. The crude methanol extract of coriander aerial parts from all three sample areas showed good radical scavenging activities with values ranging from 91.091% to 92.295% at a concentration of 500 μg/mL.

Keywords: Coriander (*Coriandrum sativum* L.) seeds and aerial parts; phytochemicals; antioxidant activity; P/S index.

1. Introduction

Coriander (*Coriandrum sativum* L.), locally known as dembilal. It is an annual herbaceous plant that belongs to the Apiaceae family. It originated from the Mediterranean and Western Asian regions and is cultivated worldwide (Parthasarathy et al., 2008). It is the most useful essential oil-bearing plant cultivated throughout the world for its seeds and leaves (Mandal and Mandal., 2015).

Ethiopia is one of the main producers of coriander in Africa, which is a means of income for farmers living in the highlands. Coriander grows at an altitude of 1500-2500 m where the rainfall is between 120 and 400 mm. It can also grow in the lowland where the rainfall is sufficient (Jansen., 1981). Coriander can grow in any type of soil that provides a sufficient amount of organic matter. However, rich and loam soil is the preferred one due to its water retention ability. The plant requires a temperature ranging from 10 to 28 ºC and soil which has a pH range from 5.5 to 6.5 at the vegetative stage, but at the generative stage, it needs a higher amount of sunlight for the synthesis of essential oils and growth (Weirdak et al., 2013). Coriander is highly cultivated in the Amhara, Oromia, Southern Nations, Nationalities, and People's Region (SNNPR) and Gambela regions. It is harvested by uprooting with the hands or cutting with sickles when the seeds change from green to yellow. Harvesting is carried out early in the morning or late afternoon to prevent shattering. Harvested plants are piled up into small stocks in the field in order to dry up for 2-3 days under the shade, which helps to prevent the loss of some volatile compounds. Separation of the crop from the herb is done by beating with a stick (Kifelew et al., 2017; Mhemdi et al., 2011).

All parts of the plants are edible. Especially, leaves are mainly used for their distinctive pungent smell in the form of salads, flavoring soups, meat products, and juice (Eyers et al., 2005). In Ethiopia, coriander seeds are a highly consumable spice that is used for flavoring black pepper, bread, injera and meat dishes. In the 'Kefa region', powdered seeds are added to cheese and porridge made from *Colocasia esculenta* (taro). The seeds of coriander are boiled in water and drunk on an empty stomach to treat stomachaches (Jansen., 1981).

1.1. Statement of the problem

There is a longstanding tradition of cultivation of coriander in Ethiopia. The massive uses of coriander depend on the choice of seeds or green aerial parts, which is related to the most important components such as essential oils and fatty acids (Diederichsen., 1996). The essential oil compositions of coriander seeds collected from Bale, Gonder and two varieties (Indium and Dinqnesh) from the Kulumsa Agricultural Research Centre in Ethiopia were determined (Asfaw and Abegaz., 1989; Hirko and Abera., 2019). Moreover, the percent yield of essential oil and crude oil content of forty-nine accessions of coriander collected from different areas were quantified (Mengesha and Alemawu., 2010). Essential metals such as Ca, Zn and Cr were detected in coriander leaves collected from four different cultivation areas (Gefersa, Mekanisa, Holeta and Sebeta) in Ethiopia (Abdella et al., 2018). However, there is no reported literature on the chemical composition of fatty acids in coriander seeds, essential oil and antioxidant activity of coriander aerial parts from three sampling areas. Hence, this study was undertaken to increase awareness about its nutritional value and to determine the fatty acids and essential oils of coriander seed and aerial parts by using gas chromatography-mass spectrometry (GC-MS) and to evaluate the antioxidant activity of coriander aerial parts from selected areas.

1.2. Objectives of the study

1.2.1. General objective

❖ To determine phytochemicals in coriander samples from Jimma, Sululta and Wolaita Sodo in Ethiopia by using GC-MS and evaluation of the biological activity of the plant extracts using ultraviolet-visible spectrophotometry.

1.2.2. Specific objectives

✓ To determine fatty acids constituents of coriander seeds and essential oil components of seeds and aerial parts by using GC-MS

✓ To evaluate the antioxidant activity of coriander aerial parts by using UV-Visible spectrophotometry

✓ To compare the chemical composition of fatty acids of coriander seeds, essential oils of seeds and aerial parts with other reported values

- ✓ To compare the essential oil composition of coriander at a different stages of maturity level
- ✓ To compare the percent radical scavenging capacity of methanol extract of coriander aerial parts with the data reported in the work of literature

1.3. Significance of the study

Coriander is one of the main spices used for flavoring different kinds of dishes. This study will contribute to scientific knowledge of the chemical composition and variation of chemical constituents in coriander seeds and aerial parts by using the GC-MS technique for qualitative and quantitative analysis. Moreover, the radical scavenging capacity provides natural preservatives and is used to substitute synthetic antioxidants, which have negative impacts on human health. The variation of essential oils, fatty acids and cloudy hydrosol can be used as a baseline for future research.

2. Literature review

Coriander is a spice crop mainly cultivated in the highlands of Ethiopia with many different genotypes. The word "coriander" is derived from Greek, which means bedbug, and the word "sativum" is related to latin "serere", which means to cultivate, plant and sow (Jansen., 1981; Nadeem et al., 2013). Coriander is a storehouse of many bioactive compounds, such as essential oils, fatty acids, minerals and antioxidants. These bioactive components are distributed in all parts of the plant. Due to its flavor and medicinal applications every part of coriander plant is edible.

Ethiopia is a center of primary diversity for coriander seeds. Three different types of coriander basal leaves with their round seeds were identified. Which have deep green flat corresponding to high seed yield and lower oil content, light green erect contain lower seed yield and accumulate higher amount oil and an intermediate value in seed yield and oil content. The highest yield of essential oils was extracted from larger sized coriander seeds (Diederichsen., 1996; Kassahun., 2020). The main components of coriander seeds are fatty oil (16-28%), fiber (23-36%), carbohydrates (20%) and proteins (11-17%) (Mahendra and Bisht., 2011).

The chemical composition of 49 accessions of coriander seeds collected from Ethiopia indicated that 0.25-0.85% essential oils obtained from hydro-distilled coriander seeds and 11.11-16.53% fatty oil were determined by using Nuclear Magnetic Resonance Spectrometry (NMRS) (Mengesha and Alemawu., 2011). Previous literature reported that 0.54% and 0.6% yield of essential oils were achieved in coriander seed collected from Bale and Gonder in Ethiopia, which has a higher percent composition of linalool (70.07-76.61%). Coriander seeds is a rich source of linalool than other spices (Mandal and Mandal., 2015). Essential metals in coriander leaves were found in the range of Zn (33.4–54.8 mg/kg), Ca (2319–3503 mg/kg) and Cr (5.55-9.86 mg/kg), which are free from toxic metals (Abdella et al., 2018). However, the chemical composition and percent yield of commercial essential oils and fatty acids in coriander seeds and leaves are variable due to the effect of climate, differences between species, maturity stage, moisture content of plant material and soil type (Shu and Lawrence., 1997). Since, the chemical composition of fatty acids in coriander seed, essential oils and radical scavenging activity of coriander aerial parts were not studied in the sample from selected areas in Ethiopia.

A previous study by the Ethiopian Export Promotion Agency/Ministry of Trade and Industry (2003) indicated that coriander was estimated to account for 0.266% of spice crop production and was cultivated on 942 hectares. Coriander is mixed with other different spices and used as a basic food item in the diet of Ethiopian people. Coriander seeds and herbs are the main ingredients for the preparation of hot pepper (berbere) flour. Hot pepper flour is used for the preparation of most staple foods 'wot' in many parts of the country (Yimer., 2010). In addition, the leaves and the immature fruits are used as an ingredient for the preparation of ‘‘data’’, a traditional spice that is eaten together with meat and fish (Kassahun et al., 2018). Most Ethiopian people use fresh leaves as a common ingredient in soups and salads. Moreover, fresh leaves of coriander are used for garnishing, flavoring, seasoning and masking the unwanted odor of many dishes. Coriander seeds and leaves are an important spice crop in Ethiopia due to their rich source of essential minerals and oils (Abdella et al., 2018; Hirko and Abera., 2019). Currently, interest is growing in the use of natural products rich in bioactive substances. This has promoted the growing interest of the food industry because dietary antioxidants are safer than synthetic analogues, effective in preventing the growth of cancer and other related diseases (El-Ghorab., 2008).

2.1. Global coriander trade

As shown in **Table 1**, India is the world’s largest producer and leading exporter of coriander seeds, accounting for 35.9% of total global exports in 2008. Bulgaria (27.9%) is the next followed by Morocco (6.8%) and Canada (4.7%). Thus, these four countries accounted for over 75% of global trade quantities (Peter., 2012).

Table 1. Top 10 Exporter of coriander seeds.

Rank	Country	Trade value (USD)	Trade quantity (Kg)	%Total trade quantity
1	India	46309220	35872012	35.86
2	Bulgaria	32491063	27920019	27.91
3	Morocco	10484463	6843476	06.84
4	Canada	6789323	4689118	04.69
5	China	3835034	3175743	03.17
6	Italy	5976060	2990498	02.99
7	Netherland	4625568	2308354	02.31
8	USA	2029376	1661644	02.02
9	Singapore	2755261	9394413	01.66
10	All other exporter	15812694	9394413	09.39
11	Total exports	134376052	100033654	100.00%

Source: Peter., 2012.

2.2. Ethiopian coriander production and trade

Ethiopia's climate and agro-ecology are suitable for growing a wide range of spice and oilseed crops. Spices are mostly produced by smallholder farmers and commercial growers. Smallholder farmers carry out the production of spices largely as a mixed production with other income crops (Yimer., 2010). Among them, coriander is the most important cash crop in Ethiopia. According to the data obtained from the Ethiopian Export Promotion Agency/Ministry of Trade and Industry (2003) showed that coriander is potentially produced in the three main regions of SNNP, Oromia and Amhara Regions. It was estimated to account for a total production of 0.266% compared with that of total spice production and cultivated on 492 hectares. Ethiopia exported 316,340.00 kg coriander for total a price of 203,874.30 US dollars. It is mainly exported to Singapore (36%), Yemen (30%), followed by the UAE (14%) and Djibouti (12%) with a share value of coriander export. Recent data found from the International Trade Centre (ITC., 2020) revealed that coriander seeds are exported in combination with other spices. Ethiopian spice products export data (US dollars) from 2013-2018 is shown in **Table 2.**

Table 2. Ethiopian spice product export value (US Dollar thousand) from 2013-2018.

Product label	2013	2014	2015	2016	2017	2018
Ginger, turmeric, curry, saffron, curcuma, thyme, bay leave and other spices	15858	14926	9121	7182	7426	6732
Pepper of the genus, Piper, dried or crushed of ground fruits of the genus capsicum	8405	9552	8704	15426	10743	1398
Seeds of coriander, anis, fennel and badian	4478	8400	6372	5253	2991	797
Cumin or caraway, juniper berries cardamoms, mace and Nutmeg	355	427	382	164	120	56
Cinnamon and cinnamon tree flowers	126	51	71	46	57	-
Cloves, stems, whole fruit and cloves	0		4	3	0	-

Source: ITC Trade Map, 2019

As a result of reduced spice productions, Ethiopian spice exports have decreased. The main reasons are lack of sufficient training and awareness about harvesting and post harvesting practice leads to low quality products. Lack of government support in terms of inadequate supply of fertilizer and improved variety of spices (Shimelis., 2021).

2.3. Chemical composition of coriander seeds and aerial parts

Coriander contains variable amounts of proteins, fats, carbohydrates, fibers, minerals and vitamins. 100 g of fresh coriander leaves contains 87.9 g of moisture, 3.3 g protein, 6.5 g carbohydrates, 1.7 g total ash, 0.14 g calcium, 0.06 g phosphorus, 0.01 g iron, 60 mg vitamin B_2, 0.8 mg niacin, 135 mg vitamin C and 10,460 I.U. (International Unit) vitamin A (Shahwar et al., 2012). 100 g of coriander seeds contains 11 g of starch, 20 g of fat, 11 g of protein, and 30 g of crude fiber. The aromatic odor and taste of coriander seeds and leaves are largely due to their volatile oils and fatty acids. The odor and flavor of the fresh herb are completely different from those of the matured seeds (Peter, 2012). Coriander seed is a rich source of petroselinic acid in addition to essential fatty acids such as linoleic acid (omega-6). Previously, reported results indicated that the methanol extract of coriander leaves is rich in total phenolic compounds, which contains 30.25 ± 3.42 mg/g, helps to scavenge free radicals (Shahwar et al., 2012).

2.3.1. Minerals in coriander

Minerals are inorganic nutrients present in all the body tissues and fluids and their presence is necessary for the maintenance of certain physicochemical processes which are essential to life. Essential minerals such as calcium are used for the construction and maintenance of bones and the normal function of nerves and muscles. Phosphorus is an important constituent of adenosine triphosphate (ATP) and nucleic acid and is also essential for acid-base balance, bone and tooth formation. Iron is used for the proper function of hemoglobin (Soetan et al., 2010). These important minerals can be obtained from coriander seeds and leaves. It can be absorbed by plants from different sources and accumulated in different parts of the plant's body. Coriander seeds (100 g) contain 1267 mg potassium, followed by 709 mg calcium, 409 mg phosphorus, 330 mg magnesium, 35 mg sodium and 4.70 mg zinc (Bhat et al., 2013). Ethiopian coriander leaves are a rich source of calcium (2319-3503 mg/kg), zinc (33.4-54.8 mg/kg) and chromium (5.55-9.86 mg/kg) (Abdela et al., 2018).

2.3.2. Essential oils in coriander

Essential oil is the aromatic part of a plant that is borne in that plant within distinctive oil cells. The type of essential oil-containing glands is an important characteristic of the plant family. It must be isolated using either steam or hydro-distillation method (Lawrence., 2001). Natural essential oils are a collection of hydrophobic secondary metabolites with unique characteristic, fragrance, volatile, odoriferous oils obtained from plants. They are found in flowers, leaves, roots, seeds and barks with a variable functional group and percent composition. The essential oils obtained from ripe dried seeds are a colorless or pale-yellow liquid with a distinctive characteristic odor, mild, sweet, warm and aromatic. The essential oil extracted from the aerial part is a colorless liquid with an unpleasant odor (Matasyoh et al., 2009). Essential oils of coriander are made up of monoterpene hydrocarbons, oxygenated monoterpenes, monoterpene alcohols, monoterpene esters, sesquiterpenes, aliphatic hydrocarbons, aliphatic alcohols and aliphatic aldehydes (Parthasarathy and Zachariah., 2008). A single compound of essential oil may have a distinct smell. Most essential oils are a combination of many compounds with a characteristic smell associated with a particular plant. Coriander oil is approved for food use by the FDA (Food and Drug Administration), FEMA (Foreign Exchange Management Act) and the Council of Europe (Siliva et al., 2011). This edible plant is non-toxic to humans and its essential oil is used in foods and in pharmaceutical products (therapeutic action) as well as in perfumes (Mandal and Mandal., 2015). Aliphatic aldehyde is the predominant component in coriander leaf oil and green seeds with their unpleasant odor and monoterpene alcohol are the major compounds obtained in matured coriander seeds with a characteristic odor of linalool, a mild, sweet, warm and aromatic flavor. However, the essential oil composition appears to be influenced by biological and geographical factors (Bhuiyan et al., 2009).

2.3.2.1. Chemistry of essential oils

There are special classes of naturally occurring volatile organic compounds in coriander seeds and aerial parts. Among them, terpenoids are the main components. Terpenoids are the hydrocarbons of plant origin of the general formula $(C5H8)n$ as well as their oxygenated, hydrogenated and dehydrogenated derivatives. The isoprene rule states that the terpenoid molecules are constructed from two or more isoprene units in a head-to-tail style, but this is not always true. Carotenoids are joined in a tail to tail at their central carbon. Terpenoids $(C5H8)n$ can be classified based on the number of carbon atoms present in the structure. Each class can be further subdivided into subclasses according to the number of rings present in the structure.
Basic structure of isoprene unit and classification of terpenoids are shown in Figure 1 and Table 3, respectively (Yadav et al., 2014).

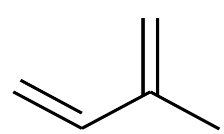


Figure 1. Basic structure of isoprene unit**.**

Table 3. Classification of terpenoid.

Carbon number	n value	Class	Sub class
10	2	Monoterpenoids ($C_{10}H_{16}$)	Acyclic, mono cyclic and bicyclic monoterpenoids
15	3	Sesquiterpenoids ($C_{15}H_{24}$)	Acyclic, mono cyclic and bicyclic sesquiterpenoids
20	4	Diterpenoids ($C_{20}H_{32}$)	Acyclic and mono cyclic diterpenoids

2.3.3. Fatty acids in coriander seeds

A fatty acid made up of a straight chain and a carboxyl group (-COOH) at the different ends. They are naturally found in the form of triglycerides. Basically, fatty acids are classified into saturated and unsaturated. Petroselinic, linoleic, oleic and palmitic acids are the most abundant fatty acids found in coriander seeds (Diederichsen., 1996; Ramadan and Morsel., 2002). This fatty oil is light yellow and distinct odor. The oil is unique because it is a good source of petroselinic acid (C18: 1(n-6)) and a lower concentration of palmitic acid (SFA) (Bhat et al., 2014). The location of unsaturation in this fatty acid is at the 6, 7-position, which is rare in octadecanoic acid and can produce unique derivatives that cannot be achieved with other seeds. Coriander fatty oil contains linoleic acid, which belongs to the ω-6 (n-6) series of polyunsaturated fatty acids (PUFA) (Sahib et al., 2012). Recently, the importance of linoleic acid in the diet has significantly become more recognized due to its contribution to human health and nutrition (Ertas et al., 2005).

2.3.4. Antioxidants in coriander aerial parts

Antioxidants refer to a group of compounds that can delay or inhibit the oxidation of lipids. Bioactive constituents with antioxidant activity are found in herbs and spices (Shahwar et al., 2012). The polyphenol composition of coriander leaves includes kaempherol, quercetin, 3'- o-mesquercetin, 4'-omequercetin and acacetin while the phenolic acids are vanillic acid, *p*-coumaric acid, (E)-ferulic acid and (Z)-ferulic acid are the major phenolic acids identified in coriander leaves (Nambiar et al., 2010). This phenolic compound is used to inhibit free radicals generated in the cellar system, when they are obtained through the diet by donating hydrogen (Siriti et al., 2013). They are used to producing high-quality foods with superior texture, color, flavor, and nutritional values with an extended shelf-life period.

2.4. Consumption of coriander oil

Coriander oils are used as cosmetics, cleaning and food ingredients as flavoring agents for different food products, including alcoholic beverages, tobacco, candy, pickles, meat sauce and seasonings. The recommended amount of essential oil in cosmetics and cleaning products as well as food products are shown in **Table 4** and **Table 5,** respectively.

Table 4. Recommended level of coriander oil in fragrance product by (Opdyke., 1973).

Products	Usual level (%)	Maximum level (%)
Soap	0.02	0.05
Cream, lotion	0.02	0.06
Perfume	0.04	0.60

Table 5. Permitted level of coriander oil by (Burdock and Carabin ., 2003).

Food categories	Use level (µg/mL)		Food categories	Use level (µg/mL)	
	Min	Max		Min	Max
Alcoholic beverage	105.7	121.2	Gelatin pudding	26.18	32.86
Baked goods	53.6	62.06	Hard candy	7.51	7.51
Chewing gums	0.09	6.62	Hard candy	160.25	181.11
Chewing gums	0.06	0.08	Meat product	43.00	68.47
Confectionary frosting	8.9	13.8	Nonalcoholic beverage	2.77	8.94
Frozen diary	39.15	47.35	Soft candy	42.14	46.91

2.5. Medicinal applications of coriander

Coriander has been reported to possess many pharmacological activities due to the presence of essential oils, fatty acids, minerals and polyphenolic compounds within the seeds and leaves. Coriander essential oil is used to inhibit a broad spectrum of micro-organisms (Siliva et al., 2011). Coriander fatty oil such as linoleic acid (omega-6) is required for neonatal retinal and brain development and cardiovascular disease prevention (Ertas et al., 2005). The methanol extract of coriander leaves is rich in total phenolic compounds such as beta carotene, vitamin C, E, ferulic acid, caffeic acid, kaempferol and quercertin. All these compounds are used to prevent cancer and other related diseases by scavenging free radicals found in our body (Abdella et al., 2018). Coriander is a valuable herb for promoting digestion and treating gastro-intestinal disorders such as dyspepsia, flatulence, loss of appetite, griping pain and vomiting (Jabeen et al., 2009).

2.6. Extraction methods

Extraction is the separation of bioactive portions of plants from their inactive or inert components by using selective solvents in standard extraction procedures. This procedure helps to eliminate the inert material by treatment with a selective solvent. There are two main kinds of extraction technique, including solid phase and liquid-liquid extraction. In solid phase extraction, the sample of interest is obtained from a solid sample and in liquid-liquid extraction, the separation of liquid analyte from a liquid sample is based on variation in boiling point. Bioactive compounds were extracted by using, Soxhlet extraction, maceration and hydro-distillation.

2.6.1. Hydro-distillation

It is the analytical method used for extraction of volatile compounds from plant material by using the Clevenger apparatus (Cleavenger., 1928). This method can be classified into water distillation, water and steam distillation and direct steam distillation.

2.6.1.1. Water distillation

It is the extraction of volatile components of plant materials by using water as a solvent. Extraction is achieved by immersing plant materials in water and boiling them at 100 ºC. The combination of water vapor and volatile components is vaporized, condensed and collected in a Clevenger apparatus. Clear separated by a layer formed by essential oil and hydrosol.

2.6.1.2. Water and steam distillation

Water-steam distillation is an improvement to simple water distillation. The charge of plant material is supported on a mesh or grill above boiling water. The water is boiled, either over a fire or by steam from a boiler using a steam coil or jacket. This system greatly reduces local overheating and burning of the charge. It is important that the charge be packed evenly and not too tightly into the still. Over-packing will result in backpressure and the steam finding channels through the charge leaving zones that have not been extracted (Kumar and Tripathi., 2011).

2.6.1.3. Direct steam distillation

Steam distillation is a method used for extracting heat-sensitive volatile compounds. The difference between steam distillation and hydro-distillation is that there is no direct contact between water and plant materials. This process involves steam being used as a stripping gas to extract the oil. The bubbling steam will continuously enter through a heated mixture of the raw material. The influence of water vapor forced the plant material to burst and release essential oils from its glands. The vapor mixture is cooled, condensed and yields a layer of oil and hydrosol (Kumar and Tripathi., 2011).

2.6.2. Soxhlet extraction

Soxhlet extractor is a laboratory apparatus first invented by Franz Ritter von Soxhlet in 1879 (Jensen., 2007). It is designed for the extraction of lipids from solid materials. The extraction can be performed with different types of solvent. Recently, hexane has become a commonly used solvent for extraction of vegetable oils. The extraction is carried out by packing a finely powdered sample in a cotton thimble. The thimble is placed in a Soxhlet extraction chamber. Extractions solvents are heated in the round bottom flask, vaporized, condensed and dripped back into the sample thimble. The bioactive compounds are diffused out and filled the siphon arm. The sample solution is unloaded into the round bottom flask repeatedly. The process continues for 8 h (Azwanida., 2015)

2.6.3. Maceration

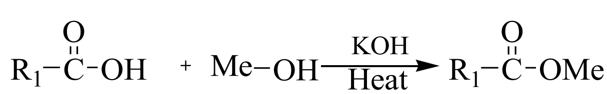
The non-volatile compounds are obtained by a solvent extraction method (El-Ghorab et al., 2008). Freeze dried and homogenized coriander aerial parts are placed in glass bottles and filled with the solvent (methanol) until a layer forms above the sample. The sample is continuously shaken for 48 h at 3 h intervals. Then the sample is filtered and concentrated by a rotary evaporator until a solvent free sample is obtained (Shahwar., 2012).

2.6.4. Liquid-liquid extraction

Liquid-liquid extraction is used for separation or purification of an analyte in a separatory funnel. The separation process is done with the addition of both aqueous and organic solvents. Continuous shaking was applied to increase the solubility of the sample. Finally, the analyte can distribute itself in a certain ratio between two immiscible solvents based on their relative solubility in two different immiscible liquids, usually water and an organic solvent. When a clear separation layer appeared, the aqueous part was rinsed out and the remaining one was taken as the sample of interest.

2.6.5. Trans-esterification of fatty acids

Trans-esterification is the chemical conversion process of triglyceride ester with alcohol to an alkyl ester with the help of basic reagents and heat. Both heat and methanol base reagents are used as catalysts that speed up the reaction. This method is used for converting non-volatile fatty acids into volatile esters. The reaction mechanism of trans-esterification of fatty acids is shown in **Scheme 1.**



Scheme1. Trans-esterfication of fatty acid.

3. Experimental part

3.1. Chemicals, reagents and materials

3.1.1. Plant materials

Coriander seed and aerial parts used in this study were collected from the selected areas and packed in polyethylene bags. Then samples were transported to the AAU Chemistry laboratory and fresh aerial parts were stored in ice boxes. Images of collected coriander seeds and flowering aerial parts are shown in **Figure 2** and **3**, respectively.

Figure 2. Image of dried coriander seeds.

Figure 3. Picture of flowering coriander aerial parts.

The selection of sampling areas was based on a mini survey conducted at Mercato, which is a big open market area in Africa. The researcher interviewed coriander merchants, distributor and retailers about the potential coriander producing areas. Accordingly, they responded that Wolaita Sodo, Jimma and Sululta are the prominent coriander producing areas. Based on this evidence, the researcher was enforced to collect samples from three different sites.

3.1.2. Description of the sampling areas

The coriander seeds and aerial parts were collected from the most coriander crop production areas in three different localities in the Southern Nations, Nationalities, and People's Region and Oromia Region. Specifically, the geographical locations of the sampling sites are described as follows. Sululta is located at a latitude of 9º11´0´´ N and longitude of 38º45´0 E´´ in the Northern hemisphere. Sululta is located approximately 37.2 km north of Addis Ababa, at an altitude of 2750 above sea level. Wolaita Sodo is a town in southern- central Ethiopia. It is the administrative center of the Wolaita zone in the Southern Nations, Nationalities, and People's Region. The town is located at an altitude of 6º54´ N and 37°45′ E. Wolaita Sodo is located at 326 km far from Addis Ababa. Jimma is the largest city in the SouthWestern Oromia region in Ethiopia. This town is located at an altitude of 7º40´26´´ and longitude of 36º50´8.8´´E with an elevation of 1400-2000 meters above sea level. Jimma is located at 347.7 km from Addis Ababa. The selection of these areas is based on their high production and consumption of coriander. Geographical descriptions of sampling sites are shown in **Table 6**.

Table 6. Geographical description of sample collection sites.

	Geographical locations			
Sampling site	Latitude	Longitude	Elevation	Distance from Addis Ababa (km)
Sululta	9º11´0´´ N	38º45´0"E	2750	37.2
Wolaita Sodo	6º54´ N	37º45′ E	1600-2100	326.1
Jimma	7º40´26´´N	36º50´8.8"E	1400-2000	347.7

3.2. Materials

Polyethylene plastic bags were used to pack coriander seeds and aerial parts from the sample site. An ice box was used for storing and transporting coriander aerial parts. Scissors were used to separate the coriander green seeds from the aerial parts. Mortar and pestle and a high-speed multifunctional grinder (Schingi, Yuan, China) were used for grinding and homogenizing the samples. Digital analytical balance with a precision of (0.001 g), measuring cylinder, pipettes and micropipettes (Supertech) were used for measuring samples and solvents. Round-bottomed flasks (JLASSCO, Borosilicate) were used for distillation and concentrating sample solutions.

Erlenmeyer (Pyrex) flask and (INKALABORTECHINK) shaker were used for maceration (solvent extraction from the leaf part). A water bath and an electro thermal hot plate were used as heat sources. A cotton thimble was used to pack the powdered sample. A Soxhlet extraction chamber was used to hold the thimble. The Clevenger apparatus was used for collecting essential oils and hydrosols. Separatory funnel was used for liquid-liquid extraction. The rotary evaporator (Heildolph instruments, Gmbh & Co: KG, Germany) was used for concentrating the sample. Vials were used for storing extracted samples and GC-MS analysis.

3.2.1. Chemicals and reagents

All the chemicals, reagents and solvents used in this study were analytical/HPLC grade. Distilled water, methanol (>99.7%, Sigma-Aldrich, USA), n-hexane (99%, Labachemic Pvt. Ltd, India), dichloromethane (Fisher Scientific, UK), chloroform (CARLOERBA reagent groups, France), DPPH (ALPHA CHEMIKA, India), KOH, and NaCl were used. Liquid nitrogen was used for frizz drying of aerial parts of coriander. The external standard (linoleic acid ethyl ester) of the fatty acid was a product of Aldrich Chemical Company (USA).

3.3. Instrumentation

GC-MS analysis was conducted on an Agilent Technology 7820 A GC system (USA) coupled with an Agilent Technology 5977 E MSD equipped with an auto-sampler (USA). The chromatographic separation was done on a DB-1701 micro column (30 m x 0.25 µm) at a pressure of 8 psi and a flow rate of 0.97989 mL/min. Ultra-high pure helium (99.999%) was used as a carrier gas at a constant flow mode. An Agilent G 4567 A auto sampler was used to inject 1 µL of the sample with a split less injection mode into the inlet heated to 275 ºC with a total run time of 29.33 min for the essential oils analysis and 16.67 min for fatty acids analysis. For the essential oil analysis, the oven temperature was programmed with an initial column temperature of 60 ºC and 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. For the fatty acid analysis, the initial oven temperature was set at 100 ºC with a 2 min hold-time. The oven temperature was increased to 220 with a ramp rate of 15 ºC/min and heated again to 240 with a ramp rate of 3 ºC/min. No mass spectrum was collected during the first 4 min of the solvent delay. The transfer line and the ion source temperatures were 280 ºC and 230 ºC, respectively. The detector voltage was 1600 V and the electron energy was 70 eV. Mass spectral data were collected from 40–650 m/z. The fatty acid methyl esters and the essential oil components were identified by matching their mass spectra with those of reference compounds recorded in the National Institute of Standards and Technology (NIST-14) mass spectral library.

DPPH assay was carried out with a UV–VIS–NIR spectrophotometer. The UV-Visible absorbance of the mixture of methanol extract from coriander aerial and DPPH solution was obtained by using a 1 cm path length with two side transparent quartz cuvette. The light source for the Perkin Elmer UV–VIS–NIR Spectrophotometer was a deuterium discharging lamp for the UV range and a tungsten-halogen lamp for the visible range. Hence, a double beam UV–VIS–NIR Spectrometer, Perkin Elmer Lambda 950 (Perkin Elmer, Llantrisant, CF728YW, and UK) which was operated by Perkin Elmer, UV Win Lab software was used. All the experimental datas were analyzed by using origin software (version 2019).

3.4. Sample preparation

Impurities present in the coriander sample were separated out. Coriander seeds were ground using a mortar and pestle and the aerial parts were chopped off in to pieces. 80 g of coriander seed were powdered by a high-speed multifunctional grinder for extraction of fatty acid. Fresh aerial parts (500 g) were frozen in liquid Nitrogen and ground using a mortar and pestle for extraction of phytochemicals.

3.5. Extraction of volatile compounds

Essential oils were extracted from either crushed coriander seeds (500 g) or small sized coriander aerial parts (500 g) by the Clevenger apparatus using a hydro-distillation method (Clevenger., 1928). The distillation flask was half-filled with distilled water. The round bottomed flak was fitted with Clevenger apparatus, which was in turn fitted with a condenser. The mixture was heated for 5 hours continuously and essential oil was collected. Essential oil was separated from the aqueous phase and dried over anhydrous Na_2SO_4. The samples were stored in a refrigerator at 4 ºC until for GC-MS analysis (Mohamed et al., 2018). The essential oil extraction process by using the hydrodistillation method is shown in **Figure 4**.

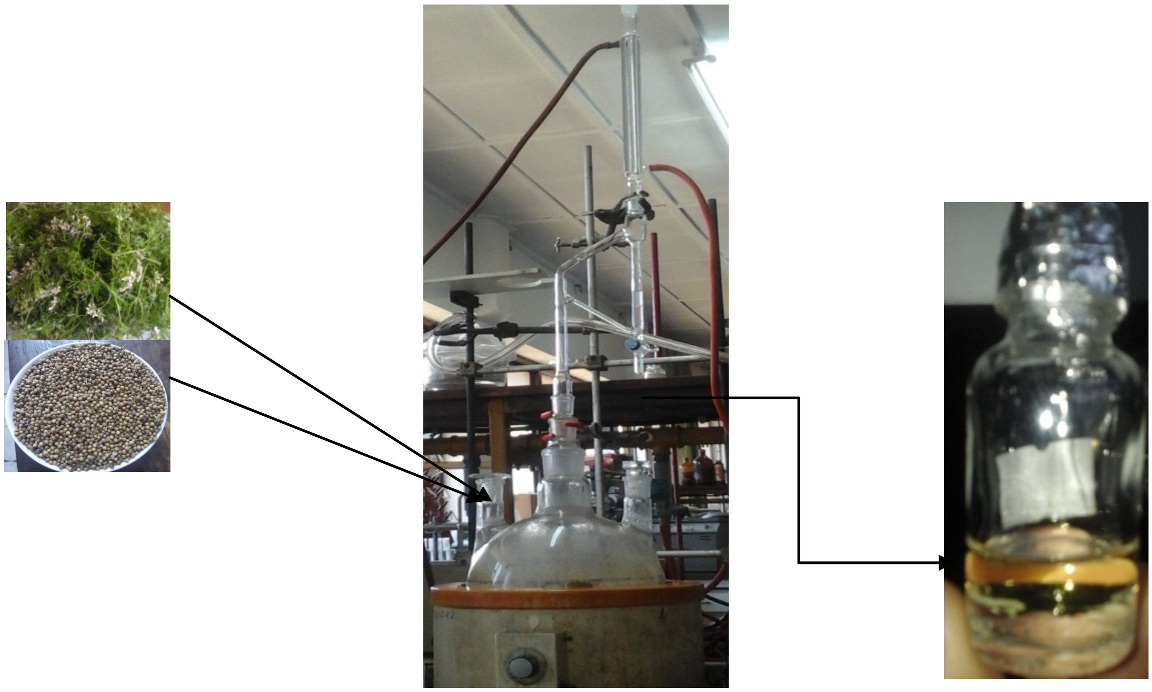


Figure 4. Essential oil extraction process by using hydro-distillation methods.

3.6. Extraction of fatty acid

As shown in **Figure 5,** the powdered coriander seed (80 g) was placed in the thimble and inserted into the Soxhlet chamber. Anti-bumping chips and n-hexane (200 mL) were added to a 500 mL round-bottomed flask into which the Soxhlet chamber and condenser were fitted. Once all the Soxhlet apparatus was assembled, the temperature was adjusted to 80 ºC. Hexane vapor was raised up and returned drop by drop through the thimble. This process continued for 8 hours. Then the heating process was stopped and the mixture was allowed to cool down to room temperature. A dark brownish-green mixture with a similar pleasant odor to the essential oil was finally filtered and the solvent was removed by a rotary evaporator under reduced pressure and temperature.

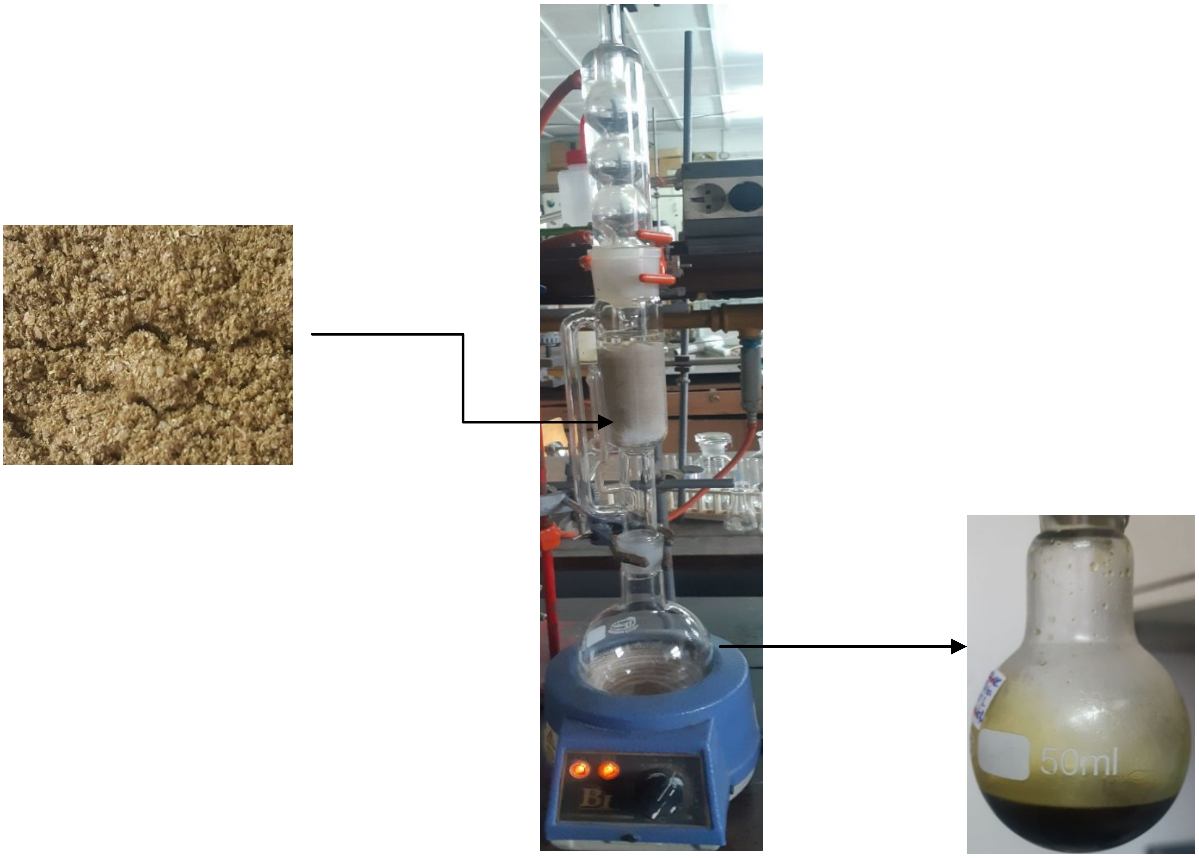


Figure 5. Crude oil extraction process by using Soxhlet extraction method.

3.7. Preparation of fatty acid methyl esters (Trans-esterification)

To a 100 mL round bottom flask, 1 g of hexane extract and 2% methanolic KOH solution (6 mL) were added. After the condenser was connected to the round bottom flask, the mixture was heated at 80 ^{o}C for 1 hour in a water bath with continuous stirring. The reaction mixture was allowed to cool at room temperature and transferred to a separatory funnel. To the cooled reaction mixture, 10 mL of saturated sodium chloride and 30 mL of hexane were added. The sample solution was shaken for 5 min and allowed to settle down so as to initiate phase separation. The aqueous phase was extracted for an additional two times and all the organic phase were combined. The combined organic phase was dried with anhydrous sodium sulphate, filtered and concentrated. The methyl ester was stored at 4 °C till GC-MS analysis. Schematic diagram of trans-esterification is shown in **Figure 6**.

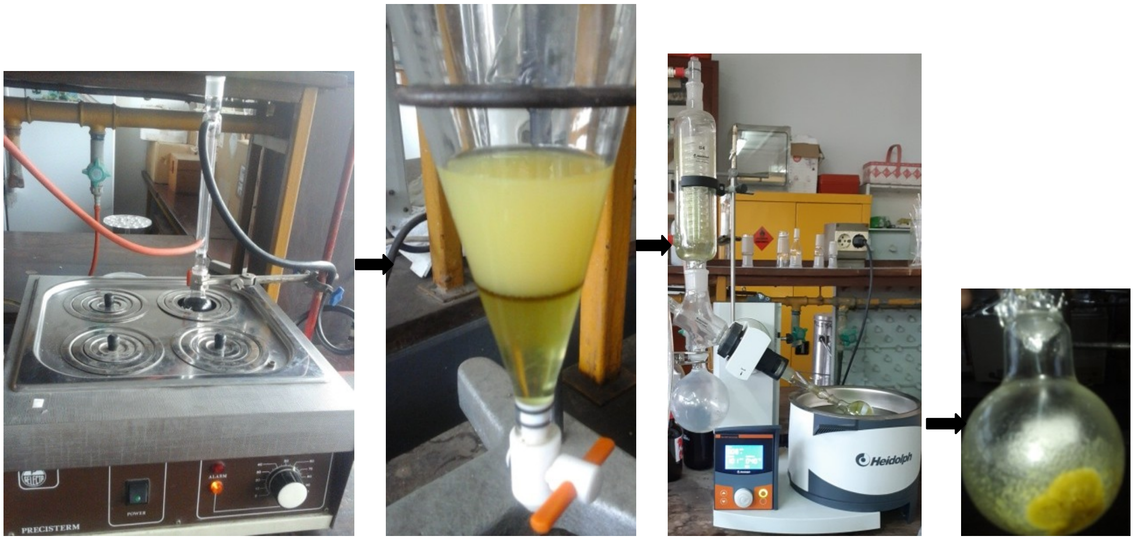


Figure 6. Schematic diagram of trans-esterification.

3.8. Maceration of coriander aerial parts

Powdered coriander aerial parts (500 g) were placed in Erlenmeyer flask (Pyrex) and methanol (1 L) was added. The sample mixture was shaken continuously using a shaker (INKA LABORTECHNIK) for 48 h. The mixture was filtered and concentrated by using a rotary evaporator at 40 °C. The crude product was stored at 4 °C till further analysis. A schematic diagram of solvent extraction method is shown in **Figure 7.**

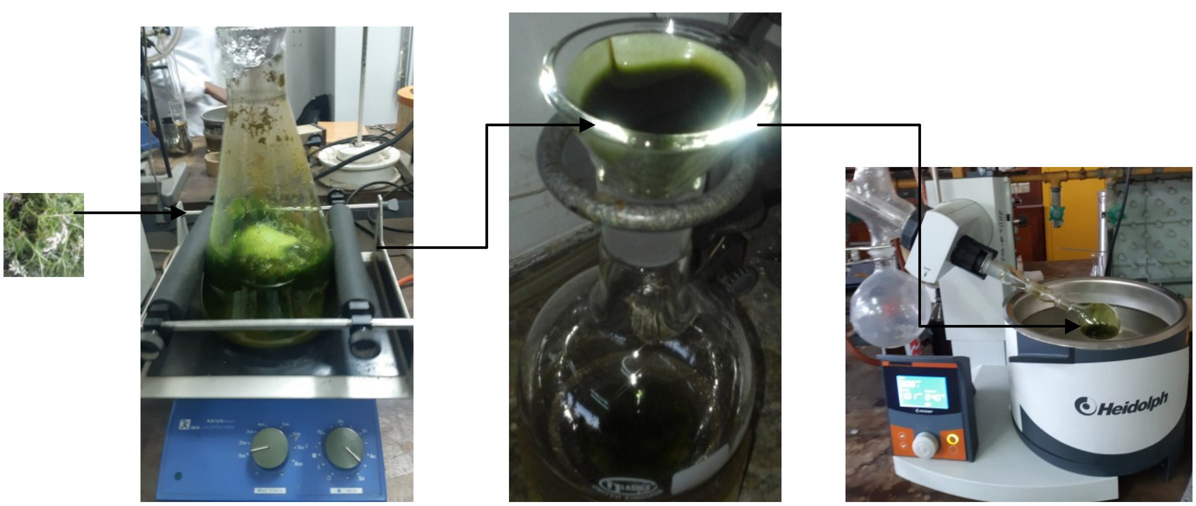


Figure 7. Schematic diagram of solvent extraction method.

3.9. Sample preparation for GC-MS analysis

3.9.1. Preparation of essential oil solution

In this study, a 1000 µg/mL stock solution was prepared from hydro-distilled oil by using the following equation.

$$1000\ \mu g/mL = \frac{X\ \mu L \times 10^6\ \mu g/mL}{\text{Volume of sample solution}} \quad (1)$$

$$X\ \mu L = \frac{1000\ \mu g/mL \times 5000\ \mu L}{10^6\ \mu g/mL} \quad (2)$$

$$X = 5\ \mu L \quad (3)$$

1000 µg/mL stock solution was prepared by adding 5 µL essential oil to 4995 µL dichloromethane. 20 µg/mL solution was prepared from the stock solution for GC-MS analysis by using serial dilution ($C_1V_1 = C_2V_2$).

3.9.2. Preparation of fatty acid solution

15,600 µg/mL fatty acid stock solution was prepared from 0.156 g trans-esterified fatty acid in dichloromethane (10 mL) and a 20 µg/mL solution was prepared from the stock solution by using a serial dilution formula.

3.10. Antioxidant activity determination

The DPPH technique with the stable organic radical, 1, 1-diphenyl-2-picrylhydrazyl, is used for the determination of the free radical scavenging activity of methanolic extracts of coriander aerial parts. When $DPPH^{\bullet}$ reacts with an antioxidant compound, it can be easily reduced by accepting hydrogen. The changes in color (from deep-violet to light-yellow) were measured at 517 nm on a UV-Visible light spectrophotometer (El-Ghrob et al., 2008)

3.10.1. Preparation of stock solution

The stock solution was prepared by dissolving 0.05 g of ascorbic acid in methanol (100 mL) to get a concentration of 500 µg/mL. These 100, 50, 25 and 12.5 µg/mL values were prepared from a combination of 4 mL DPPH and 1 mL ascorbic acid solution by using serial dilution. The reaction mixtures were shaken vigorously and allowed to stand for 30 min at room temperature in a dark place. The absorbance of the samples was measured by spectrophotometer at a 517 nm.

3.10.2. Sample preparation for antioxidant analysis (DPPH assays) of coriander aerial parts

A 5000 µg/mL sample solutions was prepared from methanol extract of coriander aerial parts (0.5 g) in 100 mL methanol and used as a stock solution. 0.004% DPPH reagent was prepared by dissolving 0.01 g of DPPH in 250 mL of methanol and stored in the refrigerator. Different concentrations, 2500, 1250, 500, 250, 125 and 62.5 µg/mL were prepared from the sample solution in 10 mL volumetric flask and used as a stock solution from which 500, 250, 100, 50, 25 and 12.5 µg/mL concentrations were prepared by adding 4 mL of 0.004% DPPH solution to 1 mL of each sample solution, respectively. Each solution was vigorously shaken and incubated in the darkness at room temperature for 30 min. After incubation, the absorbance of the reaction mixture was measured spectrophotometrically at a wavelength of 517 nm. The scavenging effect was derived from the absorbance of 007Athe sample at 517 nm (El-Ghorab et al., 2008). The scavenging effect of DPPH free radical was calculated by using **Equation 4**.

$$\%\ \text{DPPH inhibition} = \frac{\text{Absorbance of blank} - \text{Absorbance of sample}}{\text{Absorbance of blank}} \times 100 \qquad (4)$$

3.11. Construction of calibration curve and determination of concentration of fatty acids

Calibration curve was prepared from a known quantity of pure analyte, which has a retention time different from that of the unknown sample. Then, the curve was constructed from five concentration levels corresponding to 1, 10, 20, 40 and 80 µg/mL. The linear equation was used to calculate the amount of each fatty acid shown in **Table 10**. The calibration curve resulted in good linearity with a squared regression coefficient (R^2) value of 0.9948. The calibration curve of the linoleic acid ethyl ester standard is shown in **Figure 8**. Linoleic acid ethyl ester standard solutions and their corresponding areas are shown in **Table 7**.

Table 7. Linoleic acid ethyl ester standard solution and their corresponding area.

Concentration (µg/mL)	Rt (min)	Average peak area
1	14.129	34183016
10	14.115	491821979
20	14.113	1559837090
40	14.117	3792699683
80	14.129	8188166966

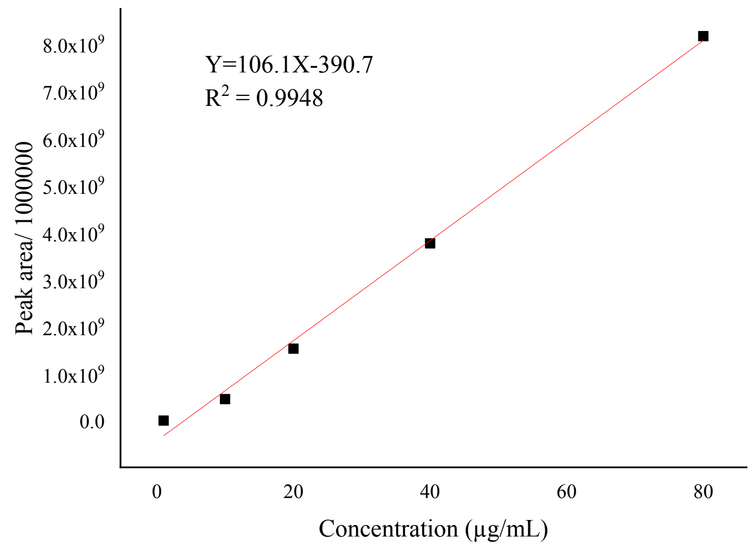


Figure 8. Calibration curve of linoleic acid ethyl ester standard

3.12. Determination of percent yield of essential oil

The percent yield of essential oils in coriander seed or aerial parts were determined by using (**Equation 5**).

$$\text{Percent yield} = \frac{\text{Weight of essential oil (g)}}{\text{Weight of raw sample (g)}} \times 100 \qquad (5)$$

3.13. Determination of the amount of individual components in the essential oil

The amount of each component of the essential oil was determined based on the peak area obtained from the chromatogram. Selection of peaks was based on relative quality information obtained from 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 and subtracting the background and comparing them 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.

3.14. Retention index

The van den Dool and Kratz relationship was used to calculate the retention index after injecting a mixture of n-alkane with the same experimental condition as that of the sample analysis. It is used to convert retention times into system-independent constants and to identify peaks by comparing measured retention indices with those reported in literature.

$$RI = \frac{100n+100(Rt(unknown)-Rt)}{Rt\ (n+1)-Rt`(n)} \quad (6)$$

where, n = Number of carbon atom eluting before the analyte

Rt(unkown) = The retention time of the analyte

Rt (n+1) = Retention time of the reference elute after the analyte

Rt (n) = Retention time of the reference elute before the analyte

4. Results and discussions

4.1. The percent yield of crude oils in coriander seeds

The percent yield of crude oil for the seeds from three selected areas was calculated by using **equation 6**. The percent yield of crude oil obtained in this study was lower than the results reported from France and within the range of the values from Ethiopia and Germany. Comparison of crude oil content in coriander seeds with reported results is shown in **Table 8**.

$$\% \text{ Yield} = \frac{\text{Weight of crude oil (g)}}{\text{Weight of raw coriander powder (g)}} \times 100 \qquad (7)$$

Table 8. Comparison of crude oil content in coriander seeds with reported results.

Sampling area	Crude oil content %	References
France	25.11	Nguyen et al., 2015
Germany	9.9-27.7	Diedrichsen., 1996
Ethiopia	7.23-18.6	Mengesha and Alemaw., 2010
Ethiopia	4.85-11.9	Geremewu et al., 2015
Wolaita Sodo	**14.12**	
Jimma	**3.92**	**This study**
Sululta	**10.73**	

4.2. Chemical composition of fatty acids in coriander seeds collected from the sampling areas

Fatty acid methyl esters that were prepared by trans-esterification of n-hexane extract of coriander seeds were carried out by using GC-MS. The analysis data indicated that a total of five different compounds were identified in the fatty acids obtained by Soxhlet extraction. The concentration of each fatty acid component was determined using an external standard and the identification of individual components was strictly based on the NIST-14 mass spectral library. The calculated data revealed that petroselinic acid was the major fatty acid constituent observed in all selected areas. Higher concentrations of petroselinic, linoleic and palmitic acid were determined in coriander seeds from Sululta than in other selected sites, which account for 107.53, 31.48 and 9.75 µg/mL, respectively. Lower concentrations of petroselinic, linoleic and palmitic acid were determined in coriander seeds from Jimma than in other sampling areas. The percent of each fatty acid constituent in the sample from Wolaita Sodo, Sululta and Jimma are displayed in **Figure 9** (a), (b) and (c), respectively. The chemical composition of fatty acid constituents in coriander seeds from selected areas is listed in **Table 9**.

Table 9. Chemical composition of fatty acid constituents in coriander seeds from selected areas.

S. sites	Compounds name	Rt	Area %	Conc. (µg/mL)	% total fatty acid	Qual.
Sululta	Palmitic acid (C16:0)	11.42	4.29	9.75	6.20	99
	Petroselinicacid (C 18:1 (n-6))	13.29	73.4	**108**	68.4	97
	Oleic acid (C18:1(n-9))	13.31	0.96	5.04	3.21	97
	Linoleic acid (C18:2)	13.37	19.6	**31.5**	20.0	99
	Stearic acid (C18:0)	13.43	1.73	3.39	2.16	98
Wolaita Sodo	Palmitic acid (C16:0)	11.42	3.30	5.23	9.22	99
	Petroselinic acid (C 18:1(n-6))	13.29	82.1	**41.1**	72.5	97
	Linoleic acid (C 18:2)	13.36	14.60	**10.3**	18.2	99
Jimma	Palmitic acid (C 16:0)	11.43	2.53	4.19	13.2	98
	Petroselinic acid (C 18:1)	13.29	81.3	**20.4**	64.4	99
	Linoleic acid (C 18:2)	13.36	16.2	**7.09**	22.4	99

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

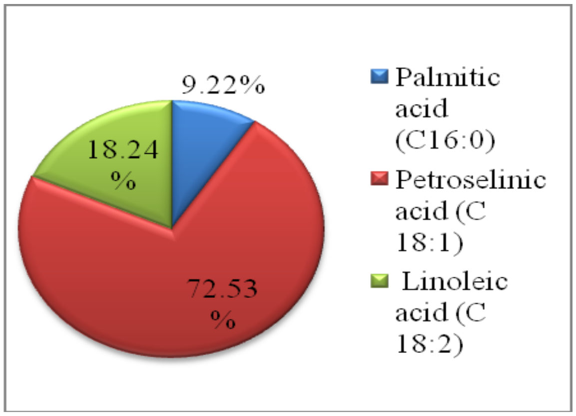
The result shown in **Table 10** indicates, the quantified percent composition of petroselinic acid was lower than in coriander seeds from Tunisia reported by (Msaada et al., 2009). Petroselinic acid in coriander seeds from Wolaita Sodo was higher than reported from Germany (Ramadan and Morsel., 2002) and similar to that of Tunisia and Canada studied by (Sirit et al., 201) and from Jimma was lower than all reported results. In this study, higher percent of palmitic and linoleic acid were determined than in coriander seeds from Tunisia, Canada, Germany, United

States, Vietnam and Turkey. Hence, one may draw a conclusion that Ethiopian coriander seeds are a good source of omeg-6, which has nutritional values for our body and plays a vital role in the health of a person (Sriti et al., 2011; Ramadan and Morsel, 2002). Comparisons of fatty acid constituents determined in this study with other reported values are shown in **Table 10**.

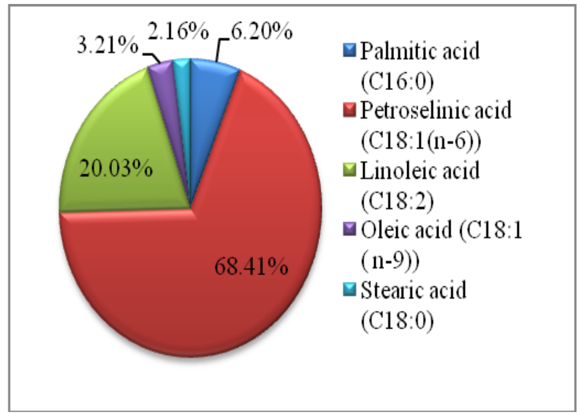
Table 10. Comparisons of fatty acid constituents of coriander seeds with the reported values.

Percent of total fatty acids (%)							
Palmitic acid	Stearic acid	Petroselinic acid	Linoleic acid	Oleic acid	Method	Origion	References
3.60	0.70	80.9	13.6	0.20	GC-FID	Tunisia	Msaada et al., 2009
3.82	0.82	75.7	12.8	6.38	GC-FID	Tunisia	Sirit et al., 2011
3.97	0.95	73.2	14.8	6.48	GC-FID	Canada	Srit et al., 2011
3.96	2.91	65.7	16.7	7.85	GLC-FID	Germany	Ramadan and Morsel., 2002
5.30	3.10	68.5	13.0	7.60	GC-FID	U.S	Moser and Vaughn., 2010
2.91	0.51	78.8	14.2	-	GLC	Vietnam	Matthaus et al., 2003
3.74	0.97	77.1	14.8	2.94	GC-FID	Turkey	Kiralan et al., 2009
6.20	**2.16**	**68.4**	**20.0**	**3.21**	**GC-MS**	**Sululta**	
9.22	**-**	**72.5**	**18.2**	**-**	**GC-MS**	**W.S**	**This study**
13.2	**-**	**64.4**	**22.4**	**-**	**GC-MS**	**Jimma**	

Where W.S = Wolaita Sodo, U.S= United State



a



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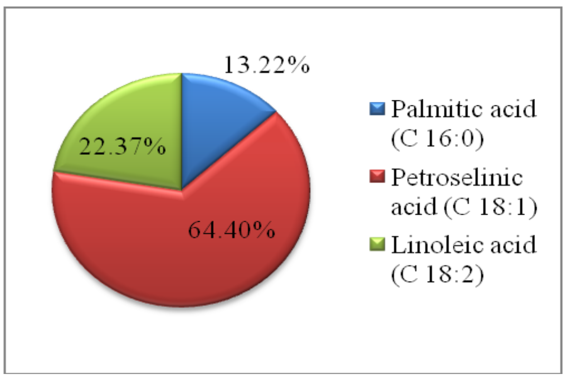


c

Figure 9. Total fatty acids in coriander seeds from a) Wolaita Sodo, b) Sululta and c) Jimma.

As shown in **Figure 9** (a), maximum percent of petroselinic acid was observed in coriander seeds from Wolaita Sodo compared to Sululta and Jimma. Similarly, as depicted in **Figure 9** (b), smaller amount of stearic and oleic acids were determined in coriander seeds from Sululta but not in other sampling areas. As displayed in **Figure 9** (c), relatively higher percent of linoleic and palmitic acids were quantified in coriander seeds collected from Jimma than other selected sites.

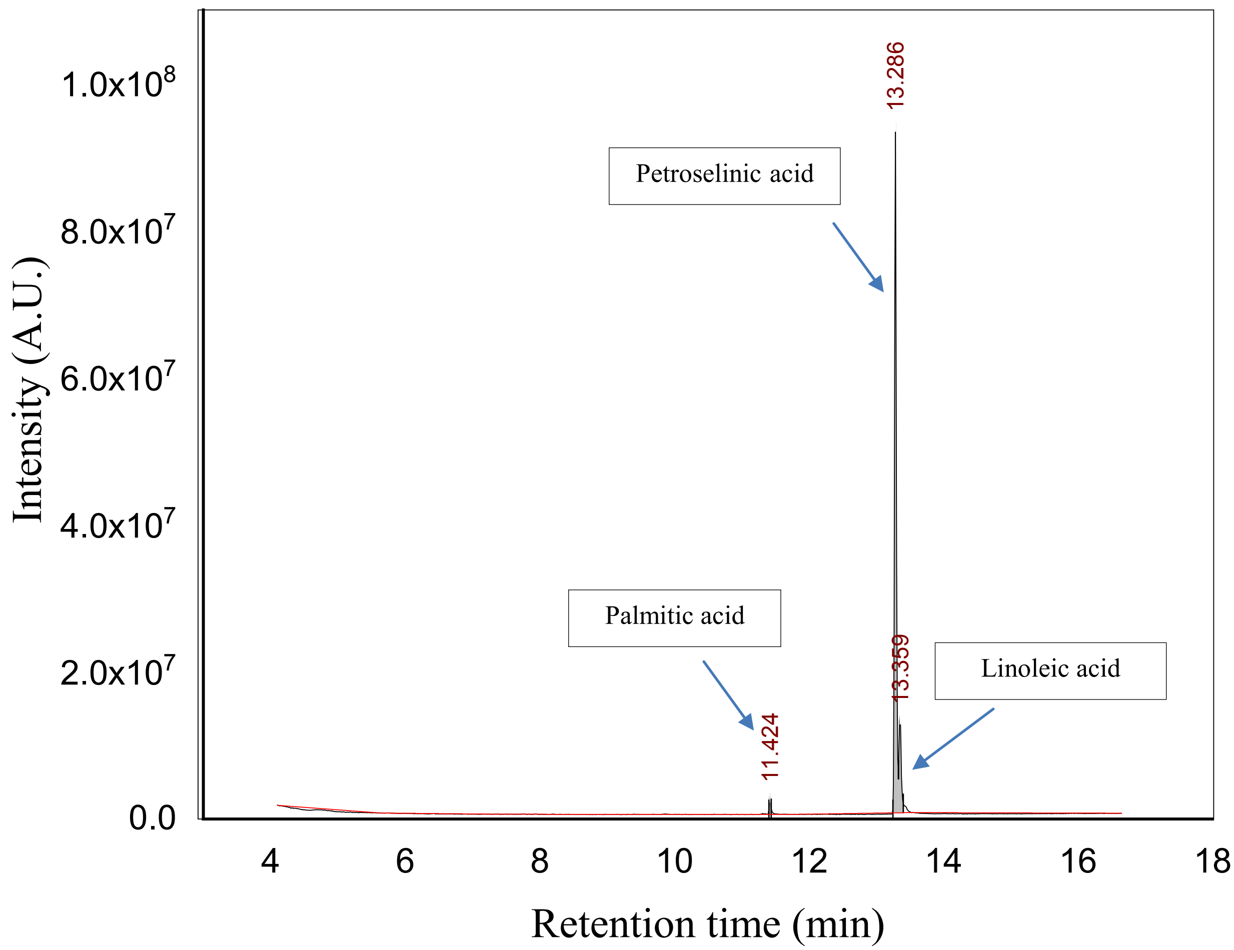


Figure 10. Chromatogram of fatty acids in coriander seeds from Jimma.

As shown in **Figure 10**, three different compounds were determined using GC-MS and variable retention times were obtained due to variation in boiling point or volatility of the fatty acids. Based on the retention time depicted in **Figure 10**, palmitic acid has a lower boiling point than linoleic and petroselinic acid. Higher peak intensity at 13.28 min was related to the presence of a major compound (petroselinic acid) in coriander seed from Jimma. The smaller concentration of palmitic acid was described by a smaller peak intensity. The higher boiling point of linoleic acid was determined by their maximum retention time.

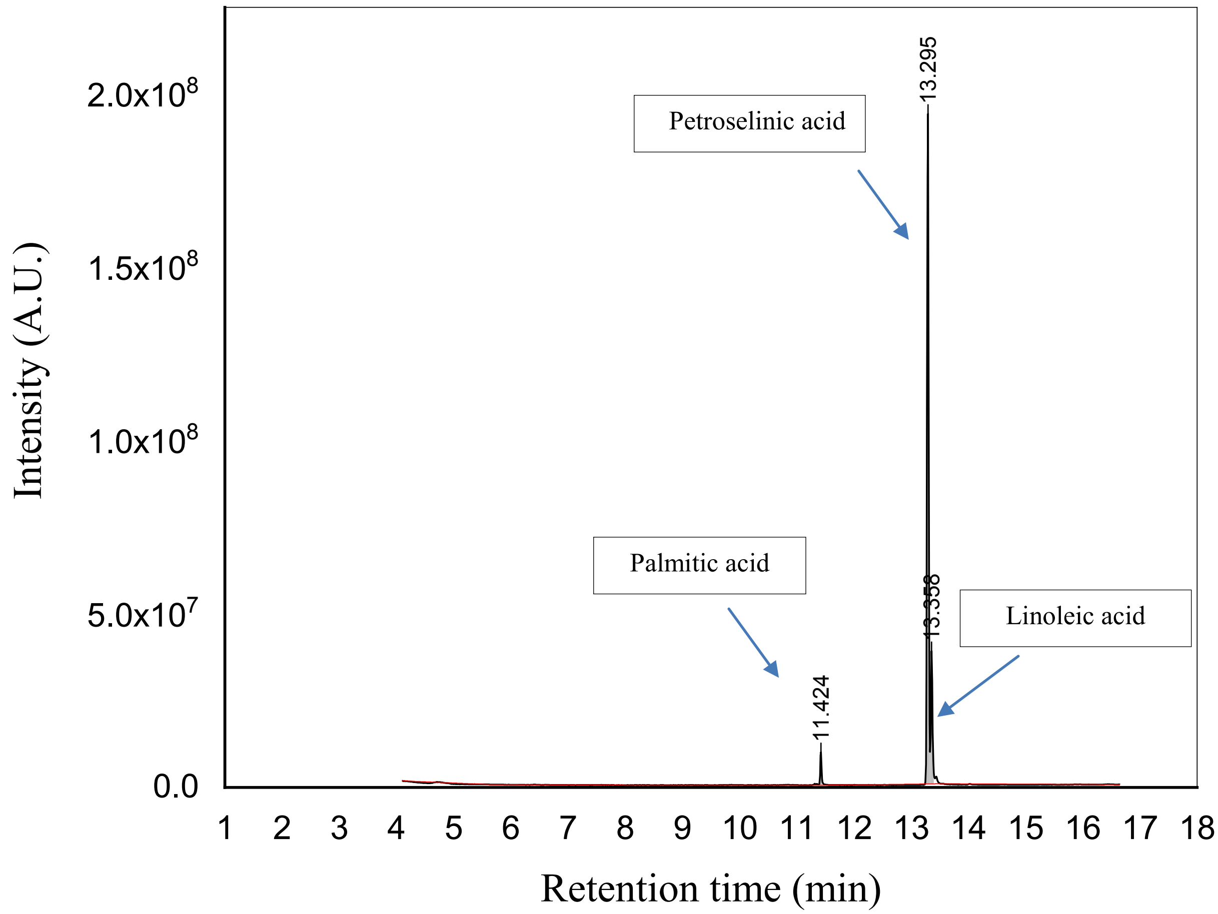


Figure 11. Chromatogram of fatty acids in coriander seeds from Wolaita Sodo.

As shown in **Figure 11**, the presence of three different intensity peaks describes difference in concentration and variation in the Rt indicates the boiling or volatile nature of the compounds.

Higher intensity peak at 13.29 min was related to the presence of dominant monounsaturated fatty acids compared to those of polyunsaturated and saturated fatty acids. A smaller peak observed at 13.35 min resulted from the lower concentration of linoleic acid in the sample from Wolaita Sodo compared to Jimma and Sululta.

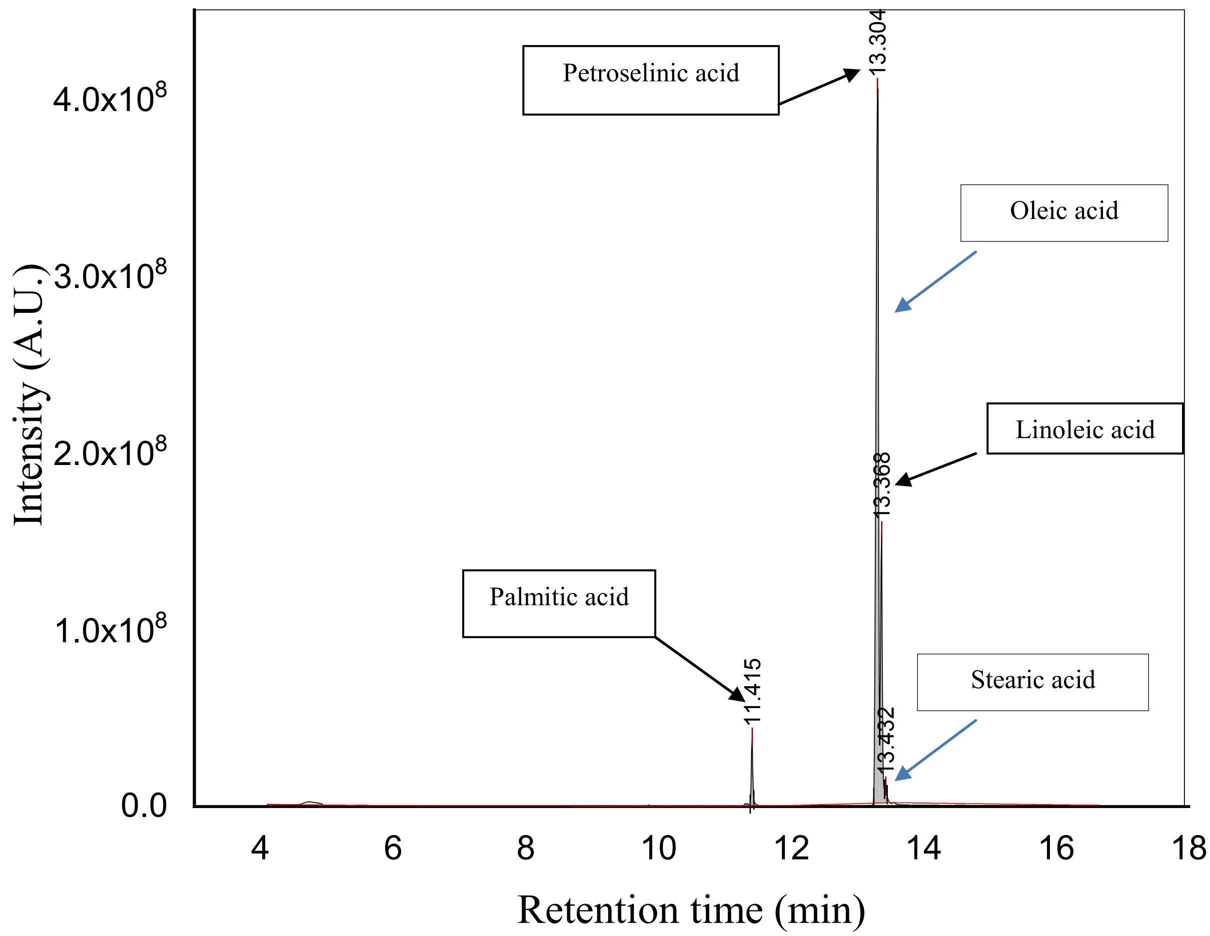


Figure 12. Chromatogram of fatty acids in coriander seeds from sululta.

As can be seen in **Figure 12**, five different intensity peaks were detected from fatty acids of coriander seeds from Sululta. A higher peak intensity at 13.30 min was due to two overlapping peaks corresponding to petroselinic and oleic acids. The overlapped peak was first checked for peak purity, which confirmed the presence of two peaks. Peak separation and ion extraction methods were used to successfully separate. The smallest peak at 13.43 min was displayed due to the smallest amount of stearic acid in the sample mixture.

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

P/S index is an important parameter used for evaluating the nutritional value and healthiness of foods (Wo1oszyn et al., 2019). The P/S index values shown in **Table 11**, were calculated from the ratio of total PUFA to total SFA and the P/S index value of coriander seeds from Sululta was higher than other selected areas. According to WHO, diets which have a P/S index ratio above 1, are recommended for human consumption to prevent the development of cardiovascular and some chronic diseases. The P/S index value of coriander seeds in all selected areas are fulfills the above requirements.

Table 11. The P/S index values for fatty acids in coriander seeds from selected areas.

Sampling areas	SFA	MUFA	PUFA	P/S index
Sululta	8.36	71.6	20.0	2.39
Wolaita Sodo	9.22	72.5	18.2	1.69
Jimma	13.2	64.4	22.4	1.98

4.3. Chemical composition of essential oils in coriander seeds and aerial parts

4.3.1. Essential oil extraction (Selection of optimal time)

Optimal extraction time was selected based on the amount of essential oils obtained at different intervals of time. In order to check the total amount of essential oils from coriander seeds and aerial parts, the amount of essential oil produced within an hour was recorded. The amounts of essential oils were increased until 5 hr but not above. Hence, 5 h was selected as the best time for all essential oil extractions. The effect of extraction time is shown in **Figure 13.**

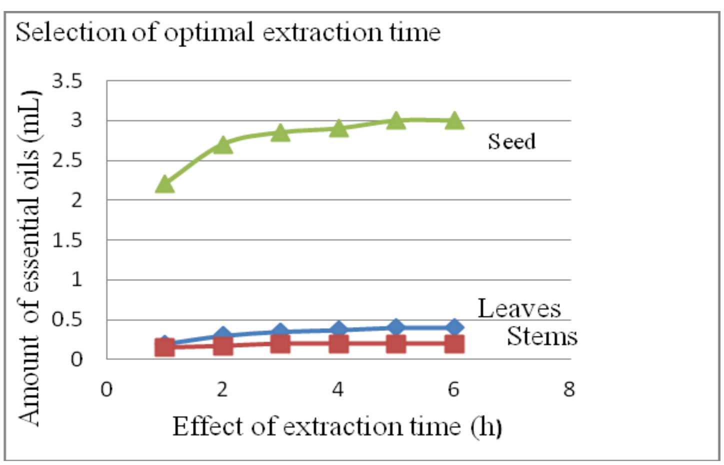


Figure 13. The effect of extraction time.

4.3.2. The percent yield of essential oils in coriander seeds and aerial parts

The percent yield of essential oils of both the seed and aerial parts was calculated from weight of essential oil/weight of raw material multiplied by a hundred (**Equation 5**). Relatively higher amount of essential oil was quantified from fresh green coriander seeds (0.60%) compared to dried seeds and aerial parts. The oil content results showed that the percent yields of the essential oil of the aerial parts of Jimma, Sululta and Wolaita Sodo were 0.17, 0.31 and 0.18, respectively, and the percent yields of seeds, sequentially, were found to be 0.31, 0.40, and 0.38. As shown in **Table 12,** percent yield of essential oil of aerial parts from three sampling areas were lower than the leaves reported in the United Kingdom and Bangladesh and also comparable with the results from Egypt. The percent yields of essential oils of the seed obtained in this study were lower than the values reported from United Kingdom and consistent with other literature values.

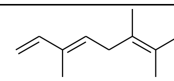
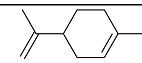
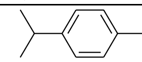
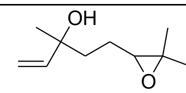
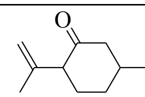
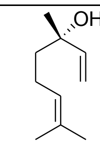
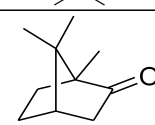
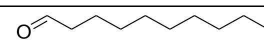
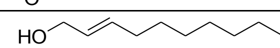
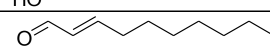
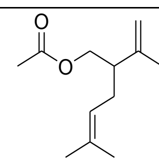
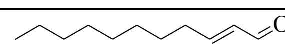
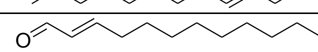
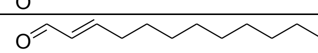
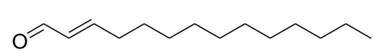
Table 12. Comparison of percent yield of hydro-distilled volatile compounds in coriander seeds and aerial parts with previously reported values.

Sampling area	Yield coriander aerial (%)	Yield coriander seeds (%)	Reference
Egypt	0.27	0.31	(Mohamed et al., 2018)
Bangladesh	0.10 (leaf)	0.40	(Bhuiyan et al., 2009)
UK	0.10 (leaf)	1.10	(Shahwar et al., 2012)
Jimma	**0.17**	**0.31**	
Sululta	**0.31**	**0.40**	**This study**
Wolaita Sodo	**0.18**	**0.38**	

4.3.3. The chemical composition of essential oils extracted from coriander seeds

The GC-MS analysis of the essential oils of green coriander seeds from Wolaita Sodo revealed 15 different compounds with a total area of 96.7%. Aliphatic aldehydes were the predominant compounds in the mixture, which accounted for 52.5% and other determined compounds were monoterpene alcohol (31.13%), monoterpene hydrocarbon (7.61%), monoterpene oxide (5.09%) and aliphatic alcohol (3.63%). From the analysis data, the number of compounds in the green coriander seeds is a bit higher compared to the dried seeds. However, the concentration of linalool measured in the green seeds of Wolaita Sodo was relatively smaller compared to the dried seeds of Jimma and Wolaita Sodo. This could possibly be due to seed maturation, which has a relationship with the biosynthesis of individual components. Hence, it is advisable to keep the seeds till maturation to extract if the objective of the work is to get a good amount of linalool. The chemical composition of essential constituents found in green coriander seed from Wolaita Sodo is listed in **Table 13**.

Table 13. Chemical composition of essential oil constituents detected in green coriander seed from Wolaita Sodo.

Pk	Rt	RI	Area (%)	Compound names	Qual.	Structures
1	5.08	637.30	3.32	(E)-β-Ocimene	95	
2	6.72	708.86	0.83	d-Limonene	62	
3	6.98	725.70	3.46	*p*-Cymene	95	
4	8.26	851.30	0.62	(Z)-Linalool oxide	80	
5	8.55	870.23	0.84	Isopulegon	50	
6	8.80	886.57	**30.6**	Linalool	70	
7	9.84	564.83	2.94	(+)-2-Bornanone	98	
8	10.27	653.77	**9.19**	Decanal	91	
9	11.39	664.71	3.63	(E)-2-Decen-1-ol	70	
10	11.45	668.82	**34.5**	(E)-2-Decenal	94	
11	12.54	685.86	0.51	(R)- Lavandulyl acetate	78	
12	12.83	708.61	0.69	2-Undecenal	83	
13	13.01	919.06	0.62	Dodecenal	92	
14	14.13	1012.38	**6.18**	2-Dodecenal	91	
15	16.54	1252.13	1.39	(E-)Tetradec-2-enal	86	

Pk = peak number, Rt = retention time, RI = retention index, Qual = NIST matching quality

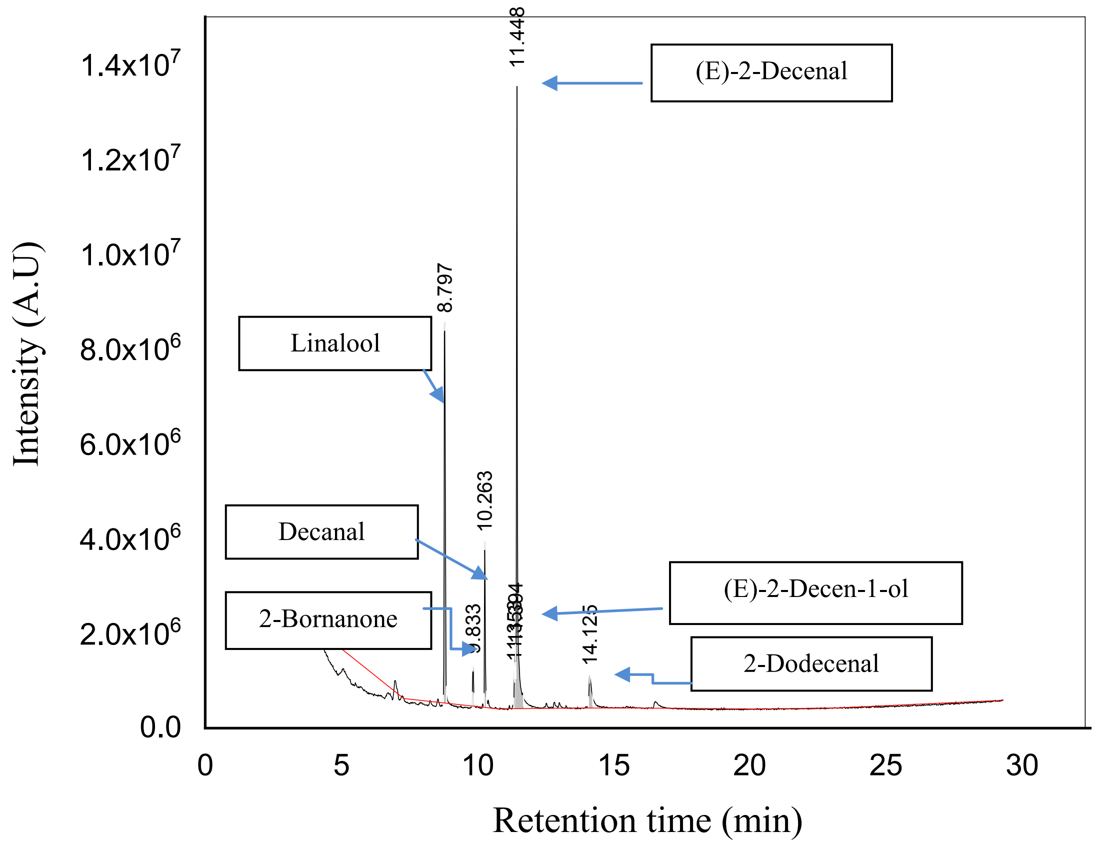
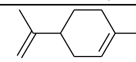
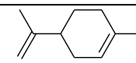
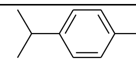
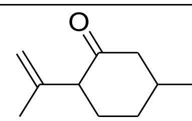
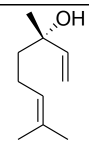
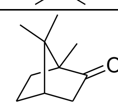
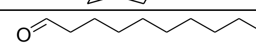
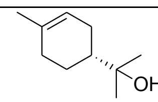
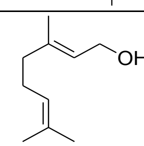
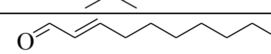
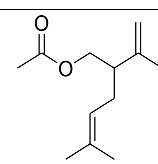


Figure 14. Chromatogram showing the essential oil components of green coriander seeds from Wolaita Sodo.

Two major peaks with retention times of 8.80 and 11.45 min are displayed in the chromatogram of essential oil (**Figure 14**), which describes the major compounds identified in green coriander seeds. These can be used as finger prints to identify the source of the essential oil and perhaps the localities from which it was obtained. The retention time observed at 8.80 and 9.83 min indicates the higher volatility of linalool and 2-bornanone.

Results obtained from dried seeds of the Wolaita Sodo species showed 12 different compounds with a combined percent area of 99.99%. Higher concentration of monoterpene alcohol was measured in the dried coriander seeds essential oil mixture compared to the green one. The amount of decanal at (10.27 min) and (E)-2-decenal (11.45 min) quantified from dried seeds is relatively lower compared to the green seeds. This could most likely be due to the high volatility and low boiling points of the compounds, which make them escape at high temperatures required for drying. Chemical composition of essential oil extracted from coriander seeds from Wolaita Sodo is shown in **Table 14.**

Table 14. Chemical composition of essential oils extracted from coriander seeds from Wolaita Sodo.

Pk	Rt	RI	Area (%)	Compounds name	Qual.	Structures
1	4.97	630.27	0.26	α-Pinene	91	
2	5.07	636.30	**2.07**	(E)-β-Ocimene	72	
3	6.72	708.40	**1.41**	D-Limonene	98	
4	6.97	725.17	0.65	*p*-Cymene	87	
5	8.53	868.97	0.32	Isopulegon	74	
6	8.79	560.74	**86.2**	Linalool	93	
7	9.84	623.26	**6.17**	(+)-2-Bornanone	98	
8	10.27	653.56	0.68	Decanal	91	
9	10.34	587.53	0.54	α-Terpineol	87	
10	11.31	658.2	0.45	Geraniol	85	
11	11.45	669.04	0.34	(E)-2-Decenal	85	
12	12.53	685.24	0.93	(R)-Lavandulyl acetate	84	

Pk = peak number, Rt = retention time, RI = retention index, Qual = NIST matching quality.

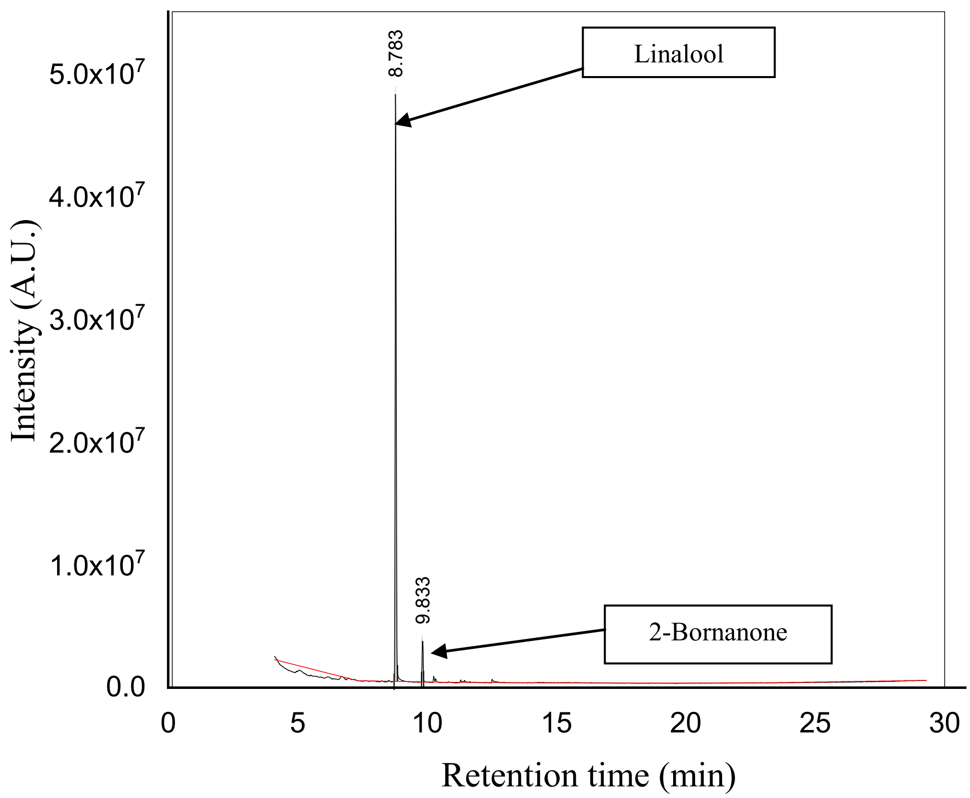
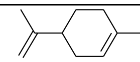
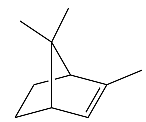
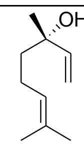
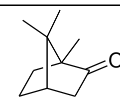
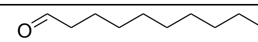
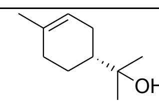
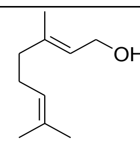


Figure 15. Chromatogram of essential oil constituents in coriander seeds from Wolaita Sodo.

As shown in **Figure 15**, two intense peaks at 8.783 and 9.833 min are displayed in the chromatogram of essential oils associated with higher percent composition of monoterpene alcohol and monoterpene oxide in the sample mixture.

From GC-MS analysis data shown in **Table 15**, seven compounds were determined in coriander seeds from Jimma with a combined percent area of 99.64. Higher amounts of linalool (88.5%) and 2-bornanone (7.19%) were determined compared to the green one, but the number of essential oil constituents was lower than all analyzed essential oils of coriander seeds.

Table 15. Chemical composition of essential oil constituents extracted from coriander seeds from Jimma.

Pk	Rt	RI	Area (%)	Compounds name	Qual.	Structures
1	6.71	707.75	**1.35**	D-Limonene	96	
2	7.20	739.79	0.92	2, 2, 7-Trimethyl bicycle [2. 2. 1] hept-2-ene	80	
3	8.79	886.10	**88.5**	Linalool	93	
4	9.83	623.07	**7.19**	(+)-2-Bornanone	98	
5	10.27	653.21	0.53	Decanal	86	
6	10.34	587.49	0.54	α-Terpineol	93	
7	11.31	658.25	0.61	Geraniol	87	

Pk = peak number, Rt = retention time, RI = retention index, Qual = NIST matching quality.

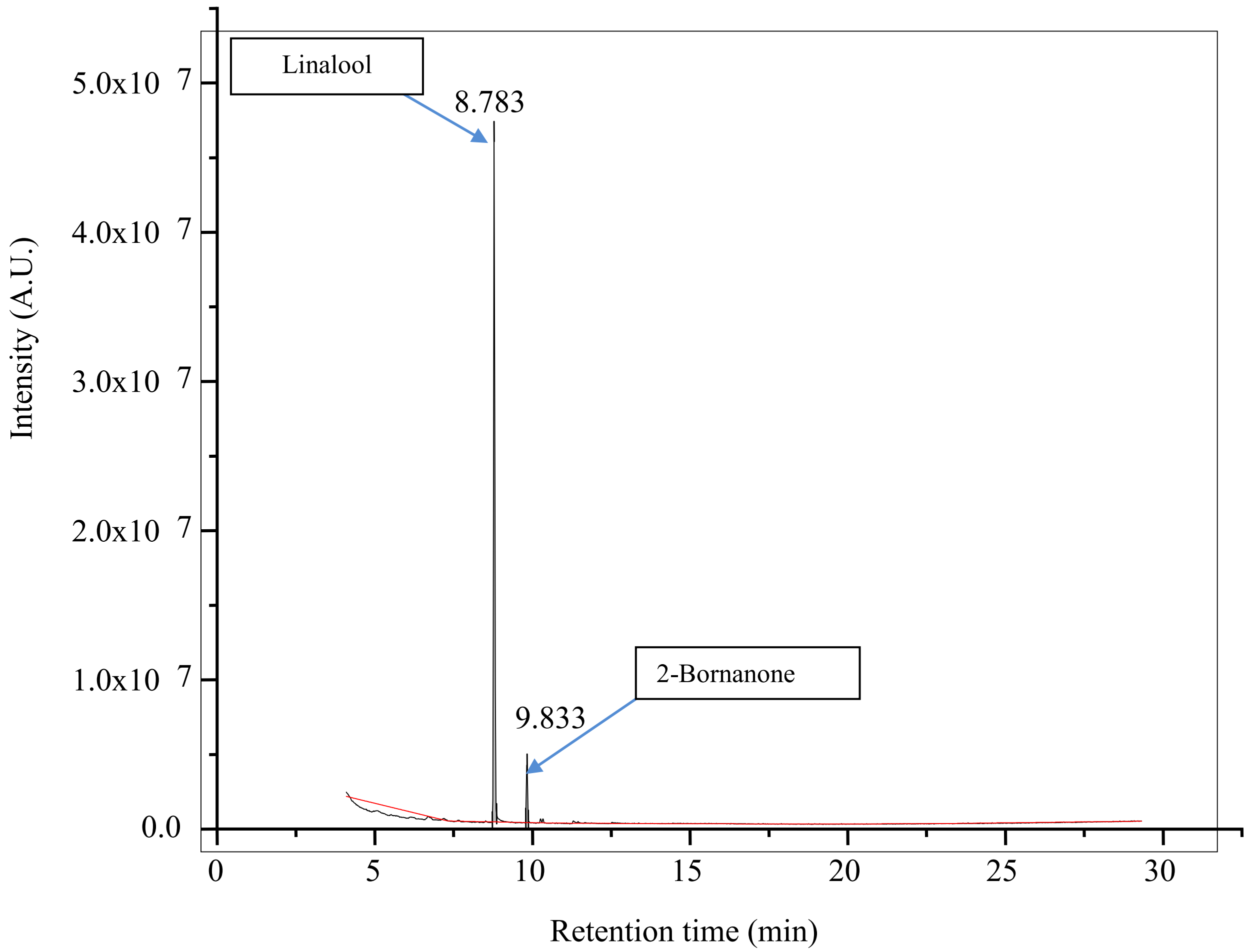
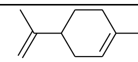
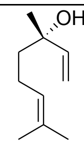
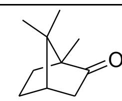
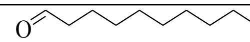
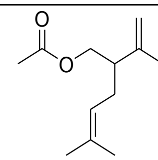
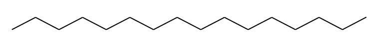
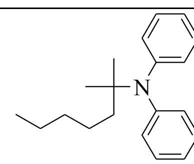
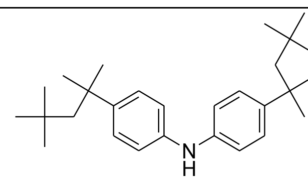


Figure 16. Chromatogram of essential oils of coriander seeds from Jimma.

As displayed in **Figure 16,** highest intensity peak at 8.78 min describes the maximum percent composition of linalool in the sample mixture. A relatively medium intensity peak at 9.83 min indicates the presence of the second major compound of essential oils of coriander seeds. The dominance of these peaks could be due to the stage of maturity and type of species.

GC-MS analysis data revealed that coriander seed oil from Sululta composed of nine compounds with a total percent area of 75.14 (**Table 16)**. Relatively similar concentrations of linalool and 2-bornanone were quantified compared with green seeds from Wolaita Sodo. This could be due to environmental, growth conditions and stage of maturity.

Table 16. Chemical composition of essential oils extracted from coriander seeds from Sululta.

Pk	Rt	RI	Area (%)	Compound names	Qual.	Structures
1	5.08	636.92	2.03	(E)-β-ocimene	95	
2	8.90	886.01	**36.7**	Linalool	94	
3	9.83	622.96	**2.43**	(+)-2-Bornanone	98	
4	10.27	653.23	0.61	Decanal	91	
5	12.53	685.32	0.74	(R)-Lavandulyl acetate	90	
6	23.97	-	1.76	Hexadecane	95	
7	25.97	-	2.65	Octadecane	98	
8	27.39	-	**3.36**	Tert-octyldiphenylamine	94	
9	28.27	-	**24.8**	Bis(4- (2, 4, 4-trimethylpentan-2-yl)phenyl)amine]	98	

Pk = peak number, Rt = retention time, RI = retention index, Qual = NIST matching quality.

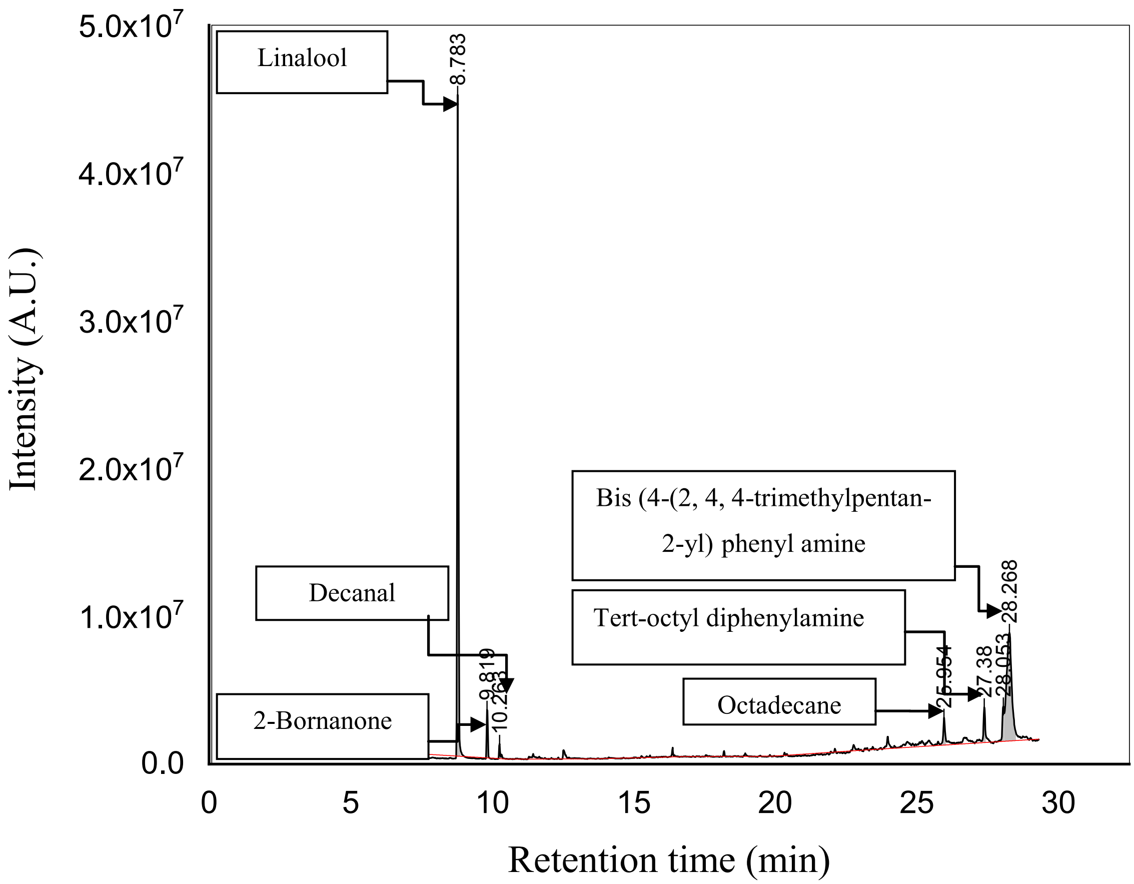


Figure 17. Chromatogram of essential oils of coriander seeds from Sululta.

The intense peak at 8.78 min indicates the presence of a higher amount of linalool (**Figure 17**), than the other compounds listed in **Table 16**. As we have seen, peak intensity at 9.81, 10.26, 25.95, 27.38 and 28.27 min shows the volatility and amount of 2-bornanone, decanal, (R)-lavanduly acetate, hexadecane, octadecane, tert-octyldiphenylamine and bis (4-(2, 4, 4-trimethylpentan-2-yl)phenyl) amine, respectively. The medium intensity peaks of tert-octyldiphenylamine and bis (4- (2, 4, 4-trimethylpentan-2-yl)phenyl) amine were exceptional in this sample mixture.

In order to check the optimum time of extraction of the essential oils, separate experiments were conducted which limited the extraction time of seeds from Wolaita Sodo to 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 covered 3-5 h. A compound (1R)-2, 6, 6-trimethyl bicycle [3.1.1] hept-2-ene was fully extracted in the first 3 h and missing in the last phase of the extract (**Table 17**). However, three compounds (2-n-octyl furan, (E)-2-decenal and octadecanal) that were extracted during the last extraction time were missing in the first extraction phase. All these processes show that different compounds are extracted at different times based on their nature of volatility and boiling temperature. As can be seen from the table below, a higher amount of most of the compounds were extracted at 3 h. The three hour extraction gave only part of the compounds and full extraction was only achieved at a longer extraction hour. Hence, in order to get the total constituents of the essential oil, distillation for 5 h was preferred.

Table 17. Chemical composition of essential oils in coriander seeds hydro-distilled at 3 and 3-5 h from Wolaita Sodo.

Compounds name	Area (%) at 3 h	Area (%) from 3-5 h
(1R)-2, 6, 6-Trimethyl bicyclo[3.1.1]hept-2-ene	1.98	-
D-Limonone	1.32	1.38
Linalool	**88.9**	87.83
(+)-2-Bornanone	**9.84**	5.14
Decanal	**10.3**	0.72
α-Terpineol	**10.3**	0.55
2-n-Octyl furan	-	0.15
Geraniol	0.34	1.32
(E)-2-Decenal	-	1.10
(R)-Lavandulyl acetae	0.39	1.55
Octadecanal	-	0.25

As can be seen from the GC-MS analysis data of all essential oils from the selected areas (**Table 18**), higher number of essential oil constituents detected in coriander seeds from Wolaita Sodo than 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 dominat compounds were lower and two different compounds were determined (tert-octyldiphenylamine and bis(4-(2, 4, 4-trimethylpentan-2-yl)phenyl)amine) that were not included in all the analyzed sample. Lower amount of α-pinene was quantified only in the seeds of Wolaita Sodo.

Table 18. Comparision of essential oil constituents in coriander seeds from the selected areas.

Compounds name	Wolaita Sodo Area (%)	Sululta Area (%)	Jimma Area (%)
α-Pinene	0.26	-	-
(E)-β-Ocimene	2.07	2.03	-
D-Limonene	1.14	-	1.35
p-Cymene	0.65	-	-
Isopulegon	0.32	-	-
2, 2, 7-Trimethyl bicycle [2. 2. 1] hept-2-ene	-	-	0.92
Linalool	**86.2**	**36.7**	**88.5**
(+)-2-Bornanone	**6.17**	**2.43**	**7.19**
Decanal	**0.68**	**0.61**	**0.53**
α-Terpineol	0.54		0.54
(R)- Lavandulyl acetate	0.93	0.74	-
(E)-2-Decenal,	0.34	-	-
Geraniol	0.45	-	0.61
Hexadecane	-	**1.76**	-
Octadecane	-	**2.65**	-
Tert-octyldiphenylamine	-	**3.36**	-
bis(4-(2, 4, 4-Trimethylpentan-2-yl)phenyl) amine	-	**24.8**	-

The percent composition of linalool in the sample from Wolaita Sodo and Jimma was higher than those reported in Ethiopia, Egypt, Iran and India (Asfaw and Abegaz., 1998; Hirko and Abera., 2019; Mohamed et al., 2018; Sourmaghi., 2014; Padalia et al., 2011), but the sample form Sululta contained the lowest amount of linalool than all reported values except from Egypt (Mohamed et al., 2018). Relatively higher amount of β-ocimene were determined in the seed from Wolaita Sodo and Sululta than other reported values shown in **Table 19**. However, a relatively small amounts 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 of Wolaita Sodo, 2, 2, 7-Trimethyl bicycle [2. 2. 1] hept-2-ene from Jimma and the other 4 compounds from Sululta were not included in those literature values.

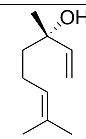
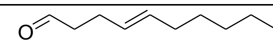
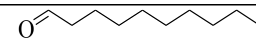
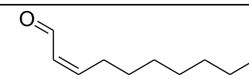
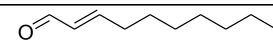
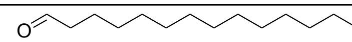
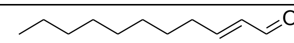
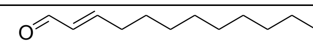
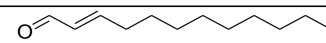
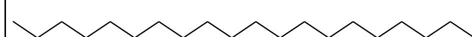
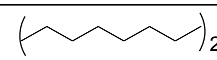
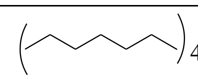
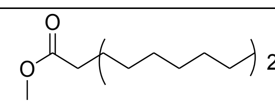
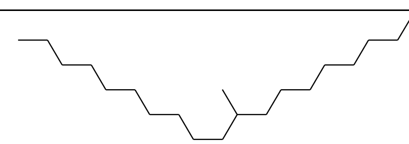
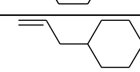
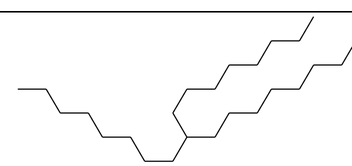
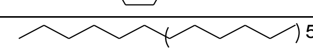
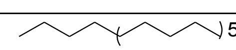
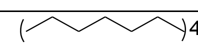
Table 19. Comparison of essential components in coriander seeds with other reported values.

Essential oil constituents (% Area)								
α-Pinene	β-Ocimene	D-Limonene	*p*-Cymene	Isopulegon	Linalool	Origin	Methods	Reference
4.54	0.94	2.23	0.96	-	70.7	Gonder	GC/GC-MS	Asfaw and Abegaz., 1998
1.54	0.02	2.15	0.12	-	76.6	Bale		
6.15	0.03	3.03	-	-	58.9	Arsi	GC-MS	Hirko and Abera., 2019
4.90	0.03	0.72	-	-	76.5			
3.23	0.31	3.30	4.08	-	18.3	Egypt	GC-MS	Mohamed et al., 2018
3.46	-	-	2.94	-	66.3	Iran	GC-MS	Sourmaghi.,2014
2.87	-	2.55	0.83	-	55.4	India	GC/GC-MS	Padalia et al., 2011
0.26	**2.07**	**1.14**	**0.65**	**0.32**	**86.2**	**W.S**	**GC-MS**	**This study**
-	**2.03**	**-**	**-**	**-**	**36.7**	**Sululta**		
-	**-**	**1.35**	**-**	**-**	**88.5**	**Jimma**		
2-Bornanone	Decanal	α-Terpineol	(R)-Lavandulyl acetate	(E)-2-Decenal	Geraniol	Origin	Methods	References
4.79		0.40	-	-	2.58	Gonder	GC/GC-MS	Asfaw and Abegaz., 1998
5.98		0.33	-	-	2.74	Bale		
6.54	-	0.07	-	-	4.02	Arsi	GC-MS	Hirko and Abera., 2019
-	-	-	-	-	1.19			
2.70	2.85	7.71	-	5.10	1.90	Egypt	GC-MS	Mohamed et al., 2018
0.56	0.25	0.53	-	-	1.55	-	GC/GC-MS	Sourmaghi., 2014
0.79	1.44	0.12	-	1.30	1.11	India	GC/GC-MS	Padalia et al., 2011
6.17	**0.68**	**0.54**	**0.93**	**0.34**	**0.45**	**W.S**	**GC-MS**	**This study**
2.43	**0.61**	**-**	**0.74**	**-**	**-**	**Sululta**		
7.19	**0.53**	**0.54**	**-**	**-**	**0.61**	**Jimma**		

4.3.4. The chemical composition of essential oils extracted from coriander's aerial parts

Essential oils of coriander aerial parts from Sululta are composed of 19 essential oil constituents with a total percent area of 88.11 (**Table 20**). The major volatile compounds were (E)-2-decenal (42.92%), decanal (15.01%), 2-dodecenal (5.67%), 2-undecanal (5.32%), octacosane (3.71%) and tetracosane (3.38%). This sample mixture was a rich source of (E)-2-decenal, 2-undecenal, heptadecane, tetracosane and octacosane compared to other selected areas. The chemical composition of essential oil constituents from Sululta is presented in **Table 20**.

Table 20. Chemical composition of essential oils extracted from coriander aerial parts from Sululta.

Pk	Rt	RI	Area (%)	Compound names	Qual.	Structure
1	8.80	886.63	1.69	Linalool	86	
2	10.20	648.45	1.07	(E)-4-decenal	81	
3	10.27	653.64	**15.0**	Decanal	98	
4	11.17	648.40	0.72	(Z)-2-Decenal	86	
5	11.45	668.75	**42.9**	(E)-2-Decenal	53	
6	11.67	618.77	2.86	Tetra decanal	92	
7	12.81	707.29	**5.32**	2-Undecanal	83	
8	13.00	918.39	1.28	Dodecenal	91	
9	14.11	1010.55	**5.67**	2-Dodecenal	95	
10	16.38	1274.17	0.40	2-methyltricosane	87	
11	17.57	1337.53	0.34	Hexadecane	86	
12	18.91	1063.22	0.18	Octacosane	78	
13	18.97	1067.73	0.67	Hexadecanoic acid methyl ester	91	
14	20.43	943.90	0.26	9-methyl nonadecane	89	
15	21.99	847.02	0.18	allylcyclohexane	80	
16	22.13	855.09	0.75	9-octylheptadecane	93	
17	23.99	-	1.7	Heptadecane	95	
18	25.98	-	3.38	Tetracosane	97	
19	28.07	-	3.71	Octacosane	90	

Pk = peak number, Rt = retention time, RI = retention index, Qual = NIST matching quality.

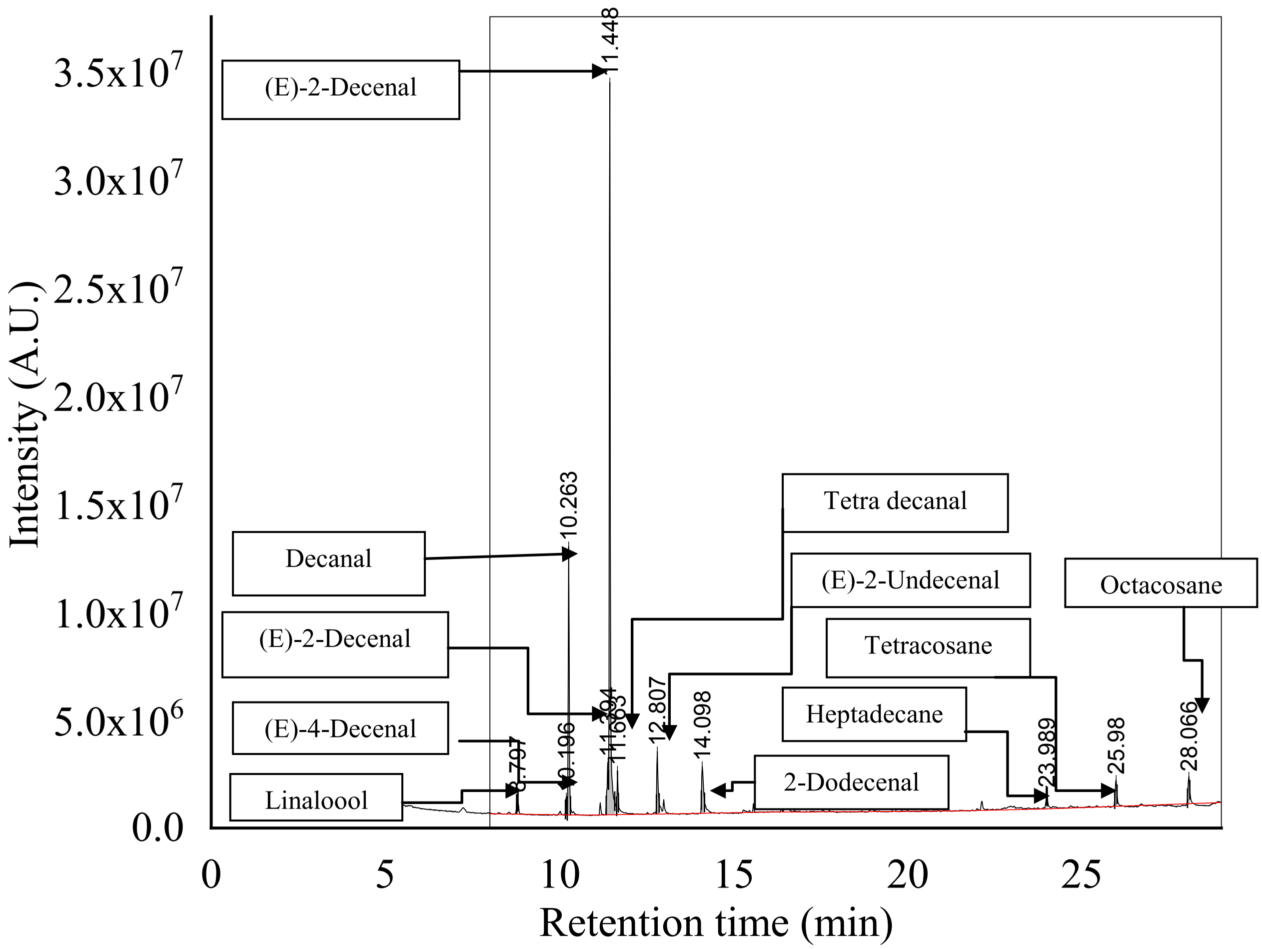
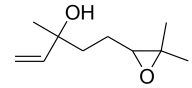
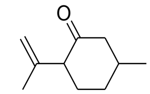
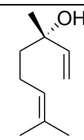
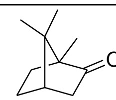
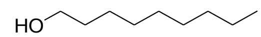
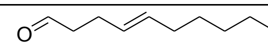
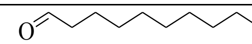
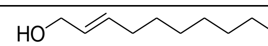
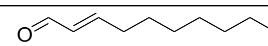
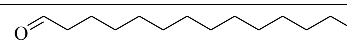
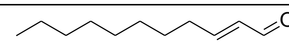
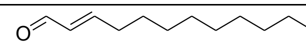
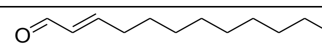
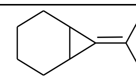
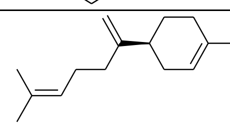
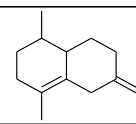
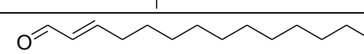
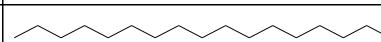
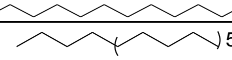
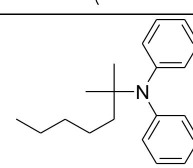
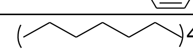


Figure 18. Chromatogram of essential oils of coriander aerial parts from Sululta.

11 different intensity peaks were observed from the chromatogram of essential oils of coriander aerial parts (**Figure 18**). The predominance of (E)-2-decenal was described by maximum intensity peaks at 11.45 min compared to other constituents. Higher retention time of heptadecane, tetracosane and octacosane were caused by their lower volatility.

The GC-MS analysis data revealed that 21 compounds were determined from essential oils of coriander aerial parts from Wolaita Sodo with total peak area of 97.97% **(Table 21)** and among them, (E)-2-decenal, decanal, (E)-2-decen-1-ol, 2-dodecenal and tetradecanal were the dominant constituents with values of 29.1%, 24.8%, 8.16%, 7.66% and 4.44%, respectively. N-(2-methylheptan-2-yl)-N-phenylbenzenamine was detected only in coriander aerial parts from Wolaita Sodo and in seeds from Sululta. Higher amount of linalool and decanal were quantified in this sample mixture than in other analyzed coriander aerial parts. The essential oil quality obtained in this study was determined by the ratios of decanal/(E)-2-decanal and linalool/(E)-2-dodecenal corresponding to 1.17 and 1.83. These values were comparable with the previously published results (Shu and Lawerence, 1997). Essential oil constituents identified in coriander aerial parts collected from Wolaita Sodo are shown in **Table 21**.

Table 21. Chemical composition of essential oils in coriander aerial parts from Wolaita Sodo.

Pk	Rt	RI	Area (%)	Compounds name	Qual.	Structure
1	8.26	851.05	1.26	(E)-Linalool oxide	83	
2	8.55	870.10	1.78	Isopulegon	72	
3	8.79	886.57	4.17	Linalool	87	
4	9.84	623.39	0.73	(+)-2-Bornanone	95	
5	9.99	634.11	0.71	1-Nonanol	52	
6	10.19	648.24	0.41	(E)-4-Decenal	64	
7	10.27	653.62	**29.1**	Decanal	99	
8	11.36	662.44	8.16	(E)-2-Decen-1-ol	94	
9	11.45	707.38	**24.8**	(E)-2-Decenal	91	
10	11.67	685.00	4.44	Tetra decanal	87	
11	12.82	344.05	2.06	2-Undecenal	91	
12	13.00	918.72	1.98	Dodecenal	91	
13	14.12	1011.55	7.66	2-Dodecenal	86	
14	14.4	455.19	0.93	7-(Propan-2-ylidene)bicyclo[4.1.0]heptanes	74	
15	15.58	558.5	1.25	*β* –Bisabolene	86	
16	15.99	1239.05	0.62	2-Isopropyl-5-methyl-9-methylene-bicyclo[4.4.0]dec-1-ene	90	
17	16.50	1249.06	2.28	(E)-Tetra dec-2-enal	93	
18	23.99	-	0.59	Heptadecane	58	
19	25.98	-	1.77	Tetracosane	91	
20	27.41	-	2.38	N-(2-Methylheptan-2-yl)-N-phenylbenzenamine	87	
21	28.06	-	0.89	Octacosane	95	

Pk = peak number, Rt = Retention time, RI = retention index, Qual = NIST matching quality.

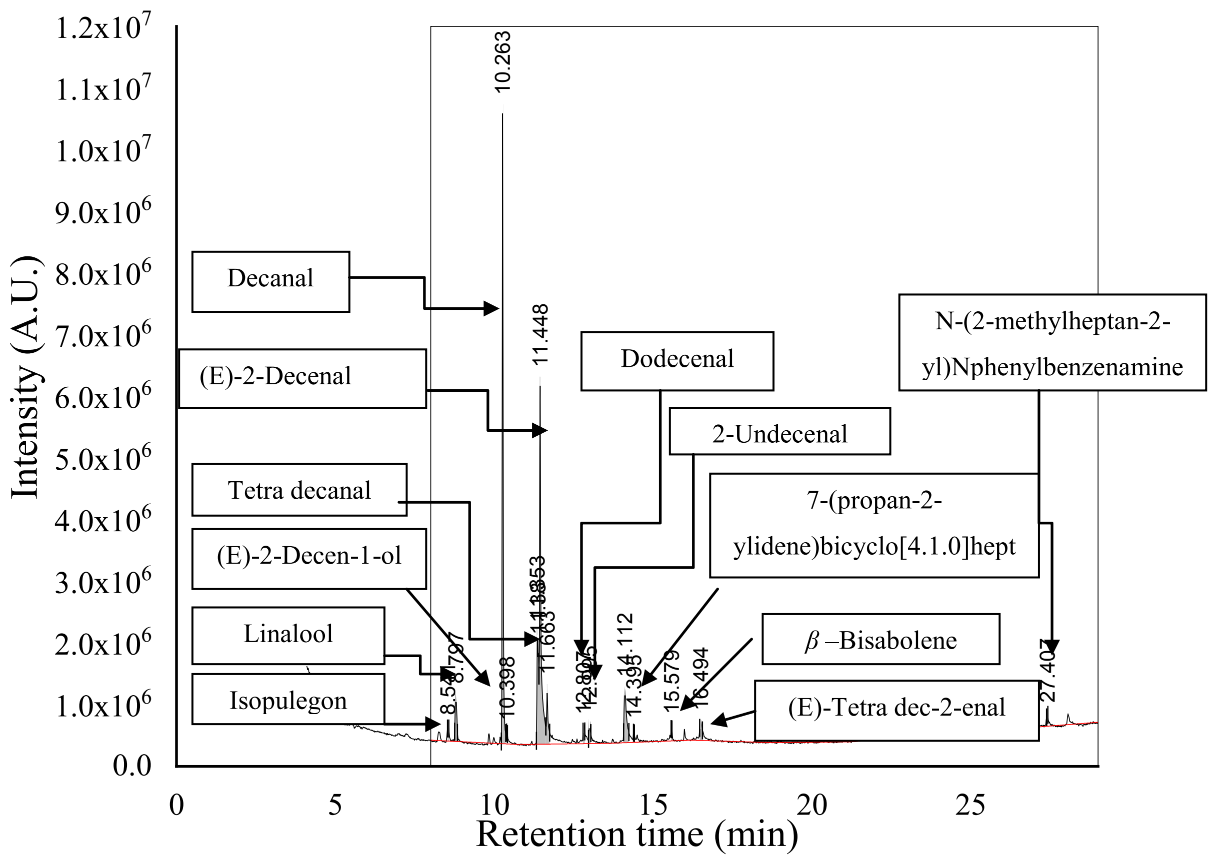
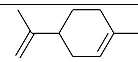
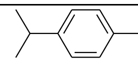
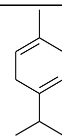
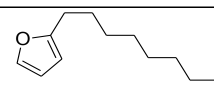
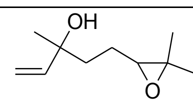
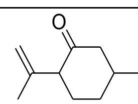
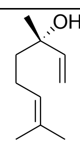
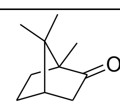
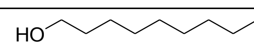
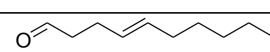
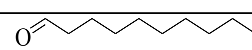
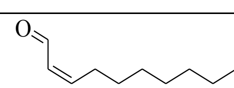
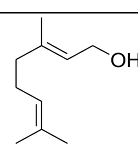
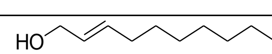


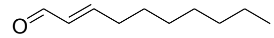
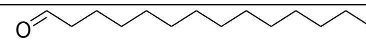
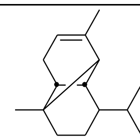
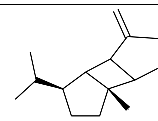
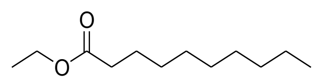
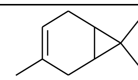
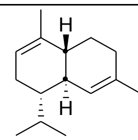
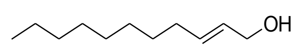
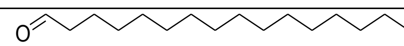
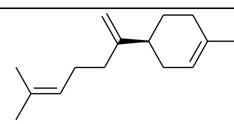
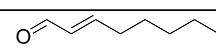
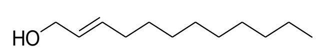
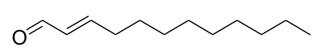
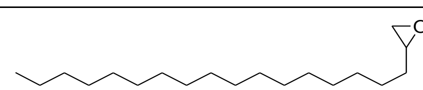
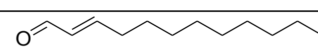
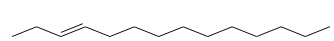
Figure 19. Chromatogram of essential oils in coriander aerial parts from Wolaita Sodo.

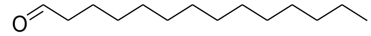
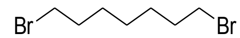
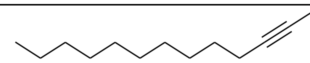
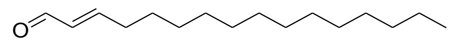
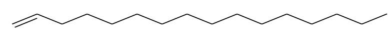
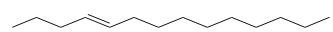
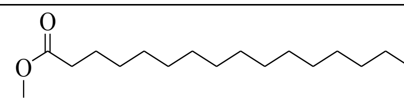
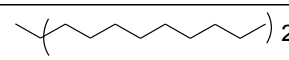
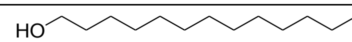
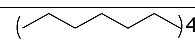
As shown in **Figure 19**, twelve different peaks were observed in the chromatogram of essential oils in coriander aerial parts from Wolaita Sodo. The highest intensity peak at 10.26 min indicated the predominance and volatility of decanal compared to other constituents of the sample mixture. Based on volatility, linalool was detected first than decanal, (E)-2-decenal, tetradecenal, 2-undecenal and 2-dodecenal to the corresponding values of 10.26, 11.45, 11.66, 12.99 and 14.11 min, respectively.

According to the GC-MS data shown in **Table 22**, 45 compounds were determined from essential oils of coriander aerial parts from Jimma with a combined percent area of 99.49. (E)-2-decenal, decanal, (E)-2-decen-1-ol and (E)-2-Dodecenal were the main constituents with a values of 29.7%, 20.2%, 11.7% and 8.88%, respectively. Higher numbers of essential oil constituents were obtained in this sample mixture than all analyzed oil samples. However, the percent composition of each constituent, except 2-dodecenal, was smaller than that of wolaita Sodo and Jimma. Chemical compositions of essential oils in coriander aerial parts from Jimma are shown in **Table 22**.

Table 22. Chemical composition of essential oils in coriander aerial parts from Jimma.

Pk	Rt	RI	Area (%)	Compounds name	Qual.	Structure
1	5.06	636.12	0.76	α-Pinene	97	
2	6.70	707.49	0.34	D-Limonene	98	
3	6.98	725.43	0.50	*p*-Cymene	97	
4	7.23	741.88	0.79	γ-Terpinene	83	
5	7.91	827.57	0.09	2-n-Octaylfuran	72	
6	8.26	850.92	0.10	(E)-Linalool oxide	95	
7	8.54	869.31	0.21	Isopulegon	78	
8	8.79	886.3	**10.6**	Linalool	94	
9	9.83	623.13	0.98	(+)-2-Bornanone	98	
10	9.98	633.39	0.07	1-Nonanol	83	
11	10.19	648.05	1.36	(E)-4-Decenal	83	
12	10.27	653.28	**20.2**	Decanal	99	
13	11.17	648.05	0.17	(Z)-2-Decenal	72	
14	11.3	657.44	0.43	(E)-Geraniol	78	
15	11.39	664.20	**11.7**	(E)-2-Decen-1-	95	

				ol		
16	11.45	668.75	**29.7**	(E)-2-Decenal	95	
17	11.67	684.60	2.87	Tetradecanal	94	
18	11.74	623.91	0.25	α-Copaene	99	
19	11.96	641.30	0.06	β-Bourbonene	96	
20	12.44	678.80	0.22	Decanoic acid, ethyl ester	98	
21	12.51	683.92	0.49	3-Carene	95	
22	12.61	691.69	0.11	α-Cadinene	91	
23	12.70	698.36	0.63	(Z)-2-Undecen-1-ol	96	
24	12.99	720.88	2.03	Hexadecanal	87	
25	13.51	960.85	0.39	β-Bisabolene	98	
26	13.8	984.86	0.05	(E)-2-Octenal	80	
27	13.94	480.48	0.65	(Z)-2-dodecen-1-ol	96	
28	14.08	1008.05	**8.88**	(E)-2-Dodecenal	91	
29	14.24	215.36	0.11	2-heptadecyl oxirane	93	
30	15.29	532.74	0.08	2-Dodecenal	89	
31	15.37	1182.27	0.06	(E)-3-Tetradecen	55	

32	15.42	1187.44	0.26	Tetradecanal	99	
33	15.56	1171.37	0.07	Heptane,1,7-dibromo	47	
34	16.26	1262.91	0.07	2-Tridecyne	91	
35	16.36	1272.71	0.05	Octadecane	91	
36	16.45	1244.50	3.20	(E)-Hexadec-2-enal	91	
37	17.55	1336.20	0.04	Hexadecene	94	
38	17.72	974.80	0.05	(E)-4-Tetradecene	76	
39	18.94	1065.63	0.10	Methyl palmitate	97	
40	20.42	943.07	0.04	Heneicosane	97	
41	22.12	854.22	0.08	Hexadecane	96	
42	23.41	-	0.14	n-Tridecan-1-ol	68	
43	23.98	-	0.12	Heptadecane	91	
44	25.97	-	0.19	Tetracosane	97	
45	28.06	-	0.20	Octacosane	93	

Pk = peak number, Rt = Retention time, RI = retention index, Qual = NIST matching quality.

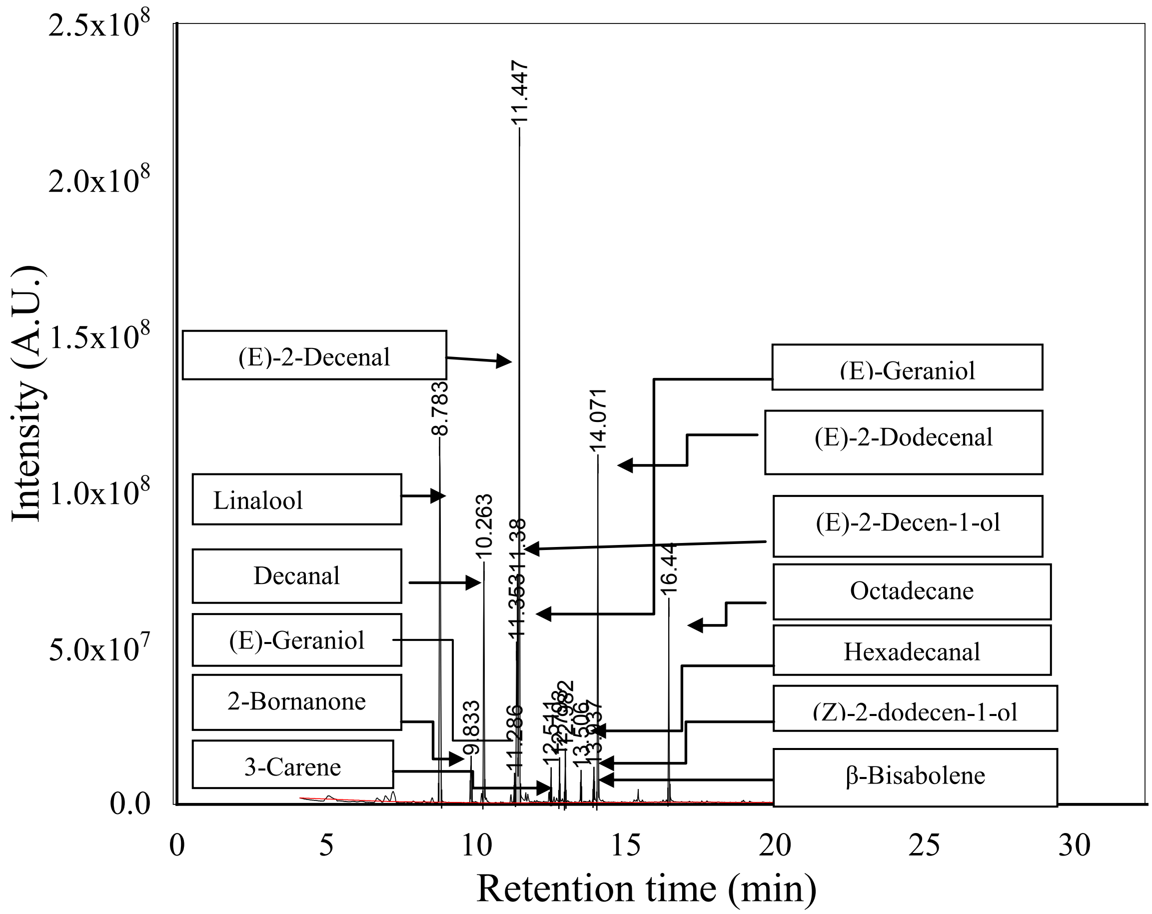


Figure 20. Chromatogram of essential oils in coriander aerial parts from Jimma.

As shown in **Figure 20**, thirteen different peaks were observed. The peak intensity at 11.45 min describes the presence of highly concentrated 2-decen-1-ol and intensity peak at 8.78, 9.83, 10.26, 11.28, 11.35, 11.38, 12.54, 13.50, 14.07 and 16.44 min resulted due to the presence of relatively higher concentration of linalool, 2-bornanone, decanal, (E)-geraniol, decanoic acid ethyl ester, β-bisabolene, trans-2-dodecenal, (E)-2-dodecenal and octadeane, respectively.

In order to obtain the optimum time of extraction of the essential oils, separate experiments were carried out which limit the extraction times of aerial parts from Jimma at 2 h and 5 h. The GC-MS analysis result showed that seven compounds were extracted in the first 2 h while forty five compounds were extracted in the second part that covers from 2-5 h. All the compounds that were not fully extracted in the first 2 h, were fully detected in the last phase of the extract at 5 h (**Table 23**). All these processes showed that different compounds were extracted at different times based on their nature of volatility and boiling temperature. As can be seen from **Table 23**, smaller amount and number of compounds were extracted at 2 h compared to 5 h of extraction time. The optimization of extraction time result indicated that full extraction was only achieved at a longer time than that of a shorter time. Hence, in order to get the total constituents of the essential oil, Hydro-distillation of 5 h was preferred.

Table 23. Chemical composition of essential oils extracted at 2 and 5 h for coriander aerial parts from Jimma.

Pk	Rt	RI	Compounds name	Area at (%) 2 h	Area (%) from 2-5 h
1	5.06	636.12	α-Pinene	-	1.48
2	6.70	707.49	D-Limonene	-	0.67
3	6.98	725.43	p-Cymene	-	0.97
4	7.23	741.88	γ-Terpinene	-	1.54
5	7.91	827.57	2-n-Octaylfuran	-	0.18
6	8.26	850.92	(E)-Linalool oxide	-	0.20
7	8.54	869.31	Isopulegon	-	0.40
8	8.79	886.30	Linalool	-	20.6
9	9.83	623.13	(+)-2-Bornanone	-	1.92
10	9.98	633.39	1-Nonanol	-	0.14
11	10.19	648.05	(E)-4-Decenal	**2.26**	**2.65**
12	10.27	653.28	Decanal	**31.0**	**39.4**
13	11.17	648.05	(Z)-2-Decenal	-	0.33
14	11.30	657.44	(E)-Geraniol	-	0.84
15	11.39	664.20	(E)-2-Decen-1-ol	**12.3**	**22.8**
16	11.45	668.75	(E)-2-Decenal	**34.2**	**57.8**
17	11.67	684.60	Tetradecanal	**5.17**	**5.6**
18	11.74	623.91	α-Copaene	-	0.49
19	11.96	641.30	β-Bourbonene	-	0.11
20	12.44	678.80	Decanoic acid, ethyl	-	0.42

			ester		
21	12.51	683.92	3-Carene	-	0.95
22	12.61	691.69	α-Cadinene	-	0.21
23	12.7	698.36	(Z)-2-Undecen-1-ol	-	1.22
24	12.99	720.88	Hexadecanal	**2.65**	**3.95**
25	13.51	960.85	β-Bisabolene	-	0.76
26	13.80	984.86	(E)-2-Octenal	-	0.10
27	13.94	480.48	(Z)-2-dodecen-1-ol	-	1.27
28	14.08	1008.05	(E)-2-Dodecenal	**7.41**	**17.3**
29	14.24	215.36	2-heptadecyl oxirane	-	0.21
30	15.29	532.74	2-Dodecenal	-	0.16
31	15.37	1182.27	(E)-3-Tetradecen	-	0.11
32	15.42	1187.44	Tetradecanal	-	0.51
33	15.56	1171.37	Heptane,1,7-dibromo	-	0.14
34	16.26	1262.91	2-Tridecyne	-	0.13
35	16.36	1272.71	Octadecane	-	0.09
36	16.45	1244.50	(E)-Hexadec-2-enal	-	6.23
37	17.55	1336.20	Hexadecene	-	0.07
38	17.72	974.80	(E)-4-Tetradecene	-	0.10
39	18.94	1065.63	Methyl palmitate	-	0.19
40	20.42	943.07	Heneicosane	-	0.07
41	22.12	854.22	Hexadecane	-	0.16
42	23.41	-	n-Tridecan-1-ol	-	0.27
43	23.98	-	Heptadecane	-	0.24
44	25.97	-	Tetracosane	-	0.38
45	28.06	-	Octacosane	-	0.39

Pk = peak number, Rt = Retention time, RI = retention index, Qual = NIST matching quality.

According to the results obtained from all analyzed essential oils of coriander aerial parts from the selected areas, the percent composition of decanal determined in this study (15.01-29.07%) was higher than the reported values from Egypt, Fiji, Poland and Pakistan reported by (Mohamed., 2018; Eyres et al., 2005; Weirdak et al., 2013; Shahwar et al., 2012) and similar to coriander leaves from Saudi Arabia reported by (Foudah et al., 2021). The relative concentration of (E)-2-decenal` was higher than those reported from Egypt (Mohamed., 2018), Fiji (Eyres et al., 2005) and consistent with the reported data from Pakistan (Shahwar et al., 2012). A relatively lower amount of 2-n-octaylfuran was quantified than the aerial parts from Poland reported by (Weirdak et al., 2013) and a smaller percent composition of (E)-4-tetra decenal was identified, which was not included in others reported result (Table 24). The relative concentration of (Z)-2-undecen-1-ol and (Z)-2-dodecen-1-ol were higher in the coriander leaves from Saudi Arabia reported by (Foudah et al., 2021) than all analyzed samples. The essential oils analyzed in this study were composed of 28 different essential oil constituents (2-heptadecyl oxirane, 1,7-dibromoheptane, 2-Tridecyne, octadecane, hexadecanal, dodecenal, β-bisabolene, 7-(propan-2-ylidene)bicycle [4.1.0] heptan, (E)-2-octenal, 2-methyltricosane, isopulegon, α-cadinene, α-copaene, β-bourbonene, decanoic acid ethyl ester, hexadecane, (E)-4-tetradecene, octacosane, hexadecanoic acid methyl ester, heneicosane, hexadecane, n-tridecan-1-ol, heptadecane, tetracosane, octacosane, tert-octadiphenyl amine, 2-methyltricosane and 2-propylcyclohexane) which were not identified in the samples from Egypt, Fiji, Poland, Pakistan and Saudi Arabia reported by (Mohamed., 2018; Eyres et al., 2005; Weirdak et al., 2013; Shahwar et al., 2012; Foudah et al., 2021). Comparison of essential oil constituents in coriander aerial parts with other reported values is shown in **Table 24.**

Table 24. Comparison of essential oil constituents in coriander aerial parts with other reported values.

Compounds name	Mohamed., 2018	Eyres et al., 2005	Weirdak et al., 2013	Shahwar et al., 2012	Foudah et al., 2021	This study
	Egypt	Fiji	Poland	Pakistan	Saudi Arabia	Ethiopia
α-Pinene	3.23	0.07	-	1.90	-	**0.78**
D-Limonene	3.30	0.10	-	-	-	**0.35**
p-Cymene	4.08	0.70	-	-	-	**0.51**
γ-Terpinene	2.21	0.32	0.10	-	0.28	**0.81**
2-n-Octaylfuran	-	-	0.30	-	-	**0.09**
(E)-Linalool oxide	0.36	0.04	-	-	-	**0.11-1.26**
Linalool	18.3	0.17	1.00	13.97	0.23	**1.69-10.6**
(+)-2-Bornanone	2.70	0.02	0.10	-	-	**0.73-1.01**
1-Nonanol	0.53	0.12	0.20	-	-	**0.07-0.53**
(E)-4-Decenal	-	-	0.80	-	-	**0.41-1.39**
Decanal	2.85	6.56	17.2	1.73	11.04	**15.0-29.1**
(Z)-2-Decenal	-	0.16	-	-	1.42	**0.17-0.72**
(E)-Geraniol	1.90	-	-	-	-	**0.44-1.90**
(E)-2-Decen-1-ol	-	26.0	-	5.45	-	**8.16-12.0**
(E)-2-Decenal	5.10	9.12	-	32.2	-	**24.8-42.9**
Tetradecanal	0.52	0.96	-	1.09	1.08	**0.42-2.94**
3-Carene	-	0.02	-	-	-	**0.50**
(Z)-2-Undecen-1-ol	-	-	-	-	0.78	**0.15**
2-Undecenal	-	1.20	-	-	-	**5.32**
(E)-2-Dodecenal	-	5.37	-	-	-	**1.98-9.11**
(Z)-2-dodecen-1-ol	-	-	-	-	7.87	**0.67**
(E)-Hexadec-2-enal	-	0.39	-	2.94	-	**3.28**
(E)-4-Tetra decenal	-	-	-	-	-	**0.10**
2-Dodecenal	-	-	-	7.51	-	**0.16-7.66**
Method	GC-MS	GC-GC/MS	GC-MS/MS	GC-MS	GC-MS	**GC-MS**

As can be seen from the analyzed results of essential oils in coriander edible parts at different maturity stages from Wolaita Sodo, many essential oil constituents were quantified in coriander aerial parts than in green seeds and dried one (**Table 25**). The relative concentrations of linalool, 2-bornanone and d-limonene were higher in dried coriander seeds compared to green seeds and aerial parts, while the amounts of isopulegon, decanal and (E)-2-decenal were decreased in dried seeds compared to green seeds and aerial parts.

Table 25. Comparison of essential oil constituents in coriander edible parts at different maturity stages.

Name of compounds	Coriander aerials Area (%)	Green seeds Area (%)	Dried seeds Area (%)
α-Pinene	-	-	0.26
(E)-β-Ocimene	2.07	3.32	-
D-Limonene	-	0.83	1.41
p-Cymene	-	-	0.65
Isopulegon	1.78	0.84	0.32
Linalool	**4.17**	**30.6**	**86.2**
(+)-2-Bornanone	**0.73**	**2.94**	**6.17**
1-Nonanol	0.71	-	-
(E)-4-Decenal	0.41	-	-
Decanal	**29.1**	**9.19**	**0.68**
α-Terpineol	-	-	0.54
(E)-2-Decen-1-ol	8.16	3.63	-
(E)-2-Decenal	**24.8**	**34.5**	**0.34**
Tetradecanal	4.44	-	-
(R)-Lavandulyl acetate	-	0.51	0.93
2-Undecenal	2.06	0.69	-
Dodecenal	1.98	0.62	-
2-Dodecenal	7.66	6.18	-
Bicyclo[4.1.0] heptanes,7-(1-methylethylidene)-	0.93	-	-
β-Bisabolene	1.25	-	-
Bicyclo[4.4.0]dec-1-ene,2-isopropyl-5-methyl-9-methylene	0.62	-	
(E)-Tetradec-2-enal	2.28	-	-
Hepta decane	0.59	-	-
Tetracosane	1.77	-	-
Tert-octyldiphenylamine	2.38	-	
Octacosane	0.89	-	-

4.4. Solvent (Methanol) extracts of the coriander aerial parts

The percent of crude oil of aerial parts obtained from Wolaita Sodo was higher than that of Jimma and Sululta, with percent yields of 3.59%, 2.30% and 2.05% respectively.

4.5. Antioxidant tests (DPPH assay)

In this study, the antioxidant test was done by mixing macerated coriander aerial parts and 1, 1-diphenyl-2-picrylhydrazyl (DPPH) with a maximum absorption at 517 nm in methanol. This assay was based on hydrogen atom transfer from the sample solution to the DPPH free radical. The advantage of the DPPH assay is that it is an easy, economical and rapid method to evaluate the radical scavenging activity of non-enzymatic antioxidants.

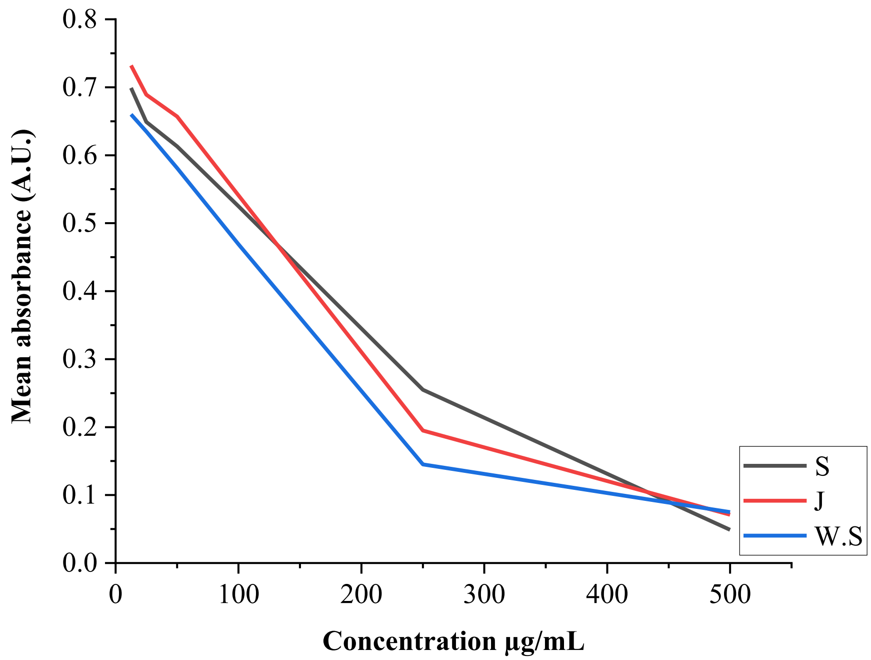
4.5.1. Concentration of anti-oxidants in coriander aerial parts

As can be seen in **Table 26,** sample from Sululta gave the maximum absorbance value (0.075 A.U.) compared to Jimma (0.071A.U.) and Wolaita Sodo (0.049 A.U.) at 500 µg/mL. This absorbance value could be due to higher concentration of antioxidants in coriander aerials from Sululta, followed by Jimma and Wolaita Sodo. However, the absorbance value of the coriander aerial part from Jimma was higher at 12.5 µg/mL than others.

Table 26. Average absorbance of coriander aerial parts extracts.

Concentration µg/mL	Mean absorbance of sample at 517 nm collected from		
	Wolaita Sodo	Jimma	Sululta
12.5	0.699±0.00	**0.732±0.02**	0.660±0.00
25	0.654±0.00	**0.689±0.00**	0.635±0.00
50	0.613±0.00	**0.657±0.00**	0.581±0.01
100	0.525±0.00	**0.541±0.01**	0.469±0.01
250	0.252±0.02	**0.195±0.00**	0.158±0.00
500	**0.049±0.00**	0.071±0.00	**0.075±0.00**

Mean ±SD



Where the letter represents sampling areas from S = Sululta, J = Jimma, W.S = Wolaita Sodo

Figure 21. Mean absorbance versus mean concentration of mixture macerated sample solution from selected sites.

As displayed in **Figure 21,** higher absorbance values were observed in coriander aerial parts from Jimma, Wolaita Sodo and Sululta at 12.50, 250 and 500 µg/mL, respectively. When the mean concentration of antioxidants found from selected areas increased its absorbance values were decreased until they were reached to 500 µg/mL. Beyond 500 µg/mL its absorbance values were constant due to the same amount of antioxidants.

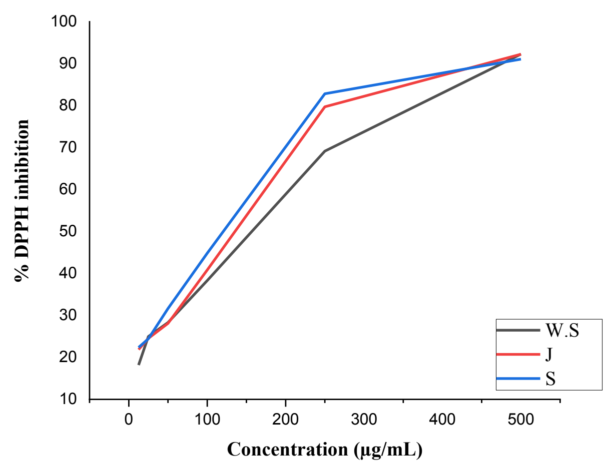
4.5.2. Radical scavenging activities of methanol crude extract in coriander aerial parts from selected areas.

According to UV-Visible spectroscopy data shown in **Table 27**, the percent radical scavenging activities were done in triplicate and percent DPPH inhibition was calculated by using **equation 8**. The methanol extract of coriander aerial parts was able to reduce the stable DPPH radical indicating its potential as a radical scavenger. 44.83%, 40.85% and 38.318% DPPH inhibition values were obtained in coriander aerial parts from Sululta, Jimma and Wolaita Sodo, respectively, at 100 µg/mL. However, the radical scavenging activity of standard ascorbic acid (96.09%) was higher than all methanol extracted samples. Sample solution from Wolaita Sodo was a powerful radical scavenger compared with that of Jimma and Sululta. Its inhibition values were found to be 92.295%, 92.266% and 91.091%, respectively. These inhibition values were caused by the amount of total phenolic compounds extracted by using methanol. The radical scavenging activities of the methanol crude extract of coriander aerial parts from selected areas are shown in **Table 27**.

Table 27. Radical scavenging activity of methanol extract of the samples from three different selected sites.

Concentration µg/mL	% DPPH inhibition			
	Wolaita Sodo	Jimma	Sululta	Ascorbic acid
12.5	18.180±0.41	21.878±0.36	**22.371±0.33**	96.090±0.16
25	23.796±0.00	**24.552±0.06**	24.443±1.81	96.290±0.06
50	28.318±0.50	28.095±0.51	**31.639±1.63**	96.260±0.06
100	38.318±0.50	40.851±0.01	**44.827±0.01**	96.060±0.12
250	70.625±0.275	79.728 ±0.39	**82.419±0.84**	-
500	92.295±0.33	**92.266±0.06**	91.091±0.42	-

The results are reported as mean±SD



Where letter S, J and W.S represents Sululta, Jimma and Wolaita Sodo, respectively.

Figure 22. Determination of DPPH radical scavenging activities of methanol extract in coriander aerial parts from selected sites.

This graph displayed the radical scavenging capacity of coriander aerial parts from Sululta were higher than others within a concentration range between 12.5-250 µg/mL. As can be observed, maximum percent inhibition was calculated from Wolaita Sodo at 500 µg/mL compared to three sampling areas.

As outlined in **Table 28**, the radical scavenging activity in this study was higher than reported value from Pakistan (Shahwar et al., 2012). Coriander aerial part was higher radical scavenging capacity than the leaves and seeds, with values of 92.3%, 72.0% and 64.4%, respectively. This scavenging capacity was associated with the amount of bioactive components present in different edible parts used for food preservation. Hence, coriander aerial parts were better to keep the nutritional quality of food in comparison with the leaves and seeds.

Table 28. Comparison of DPPH scavenging activity of methanol extract in coriander aerial, leaves and seeds.

Concentration (µg/mL)	% DPPH inhibition, Pakistan. (Shahwar et al., 2012)		% DPPH inhibition, Ethiopia (This study)		
	MLE	MSE	MEAW	MEAJ	MEAS
100	29.7±0.73	20.98±0.66	**38.6±0.00**	**40.9±0.01**	**44.8±0.01**
250	44.3±1.19	40.36±0.51	**70.1±0.00**	**78.7±0.00**	**82.8±0.07**
500	72.0±0.64	64.4±0.81	**92.3±0.00**	**92.3±0.00**	**91.1±0.00**

MLE= methanol leave extract, MSE= methanol seed extract, MEAW= methanol extract of aerial part from Wolaita Sodo, MEAS= methanol extact of aerial part from Sululta and MEAJ=methanol extract of aerial part from Jimma.

5. Conclusion

From this study, it is shown to conclude that the essential oils were extracted using hydro-distillation from coriander seeds and aerial parts. The optimum time used for the extraction of essential oils was 5h. Crude oils were extracted using Soxhlet apparatus from the seeds and trans-esterified for the determination of fatty acids by the GC-MS method. The antioxidant activity of the crude extracts of coriander aerial parts was evaluated using a UV-Vis spectrophotometer. The total number of compounds identified in the essential oils extracted from the coriander seeds of Jimma, Sululta and Wolaita Sodo were 7, 9 and 15, with a combined percent area of 99.64, 75.14 and 96.68, respectively. Coriander seeds from Jimma accumulated the highest concentration of linalool and 2-bornanone (88.50% and 7.19%) followed by Wolaita Sodo (86.19% and 6.17%) and Sululta (36.72% and 2.43%). From the aerial parts of the plant collected from Jimma, Wolaita Sodo and Sululta, 45, 21 and 19 different compounds were identified, respectively. Decanal and (E)-2-decenal were the major components of the essential oils of the aerial parts. Moreover, two interferences were detected only in coriander seeds from Sululta. The observed variation in essential oil components and fatty acid constituents might be due to the effects of climate, type of species, stage of plant maturity and soil type.

Five fatty acids (petroselinic, linoleic, oleic, palmitic and stearic) were determined from the seed part of the coriander sample. The content of each fatty constituent was calculated from the linear equation of an external standard. Higher concentrations of petroselinic, linoleic and palmitic acid were determined from Sululta site than other selected sites, which accounted for 107.53, 31.48 and 9.75 μg/mL, respectively. The lowest concentration of petroselinic, linoleic and palmitic acid were determined in coriander seed from Jimma than in other sampling areas. The P/S index values obtained from all analyzed oils were found to be within a range of 1.69-2.39. These values indicate that coriander seeds from the selected areas have a good capacity to prevent the development of cardiovascular and some chronic diseases. Methanol extract of aerial parts and 1, 1-diphenyl-2-picrylhydrazyl showed a powerful radical scavenging activity at 500 μg/mL than other sampling areas. This scavenging property indicated that coriander aerial parts can be used for food preservatives for a long period of time and clean free radicals found in our bodies that help to prevent the development of cancer and other age-related diseases.

6. Recommendations

- The researcher recommended that the antioxidant activity of coriander seeds and leaves, fatty acids in the aerial parts have to be done in further research.
- In this study samples were taken only from three sites, so phytochemicals and anti-oxidant activity of the samples should be studied all over the country.
- To increase the productivity and yield of coriander, different stake holders such as the ministry of agriculture, agricultural research center and farmers, must follow the recommended production packages.

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