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Review Article

Review: Antimicrobial Activity of Coriander (*Coriandrum sativum* Linn.)

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ABSTRACT

Bioactive chemicals are abundant in natural products; some have strong antibacterial properties. Coriander (*Coriandrum sativum*. Linn) is one of the spices with a long history of use in traditional medicine and foods. Apart from its use as a flavouring agent in foods, it also has a wide range of applications in man's healthcare due to its numerous phytoconstituents, with notable antibacterial activities. This review summarizes the findings of scientific studies on the antimicrobial activity of Coriander, highlights the methods used for testing the antimicrobial activity, the part(s) of the plant used, and the compounds of Coriander with antimicrobial activity. This review concludes that Coriander is a source of therapeutic agents for infectious diseases and food-borne pathogens.

Keywords: *Coriandrum sativum*, antimicrobial, diffusion method, dilution method, essential oil

Introduction

Coriander is a well-known medicinal plant native to the Middle East and the Mediterranean. It has significant bioactivity and is utilized as a stomachic, spasmolytic, and carminative. Various parts of the plant, including the seeds, leaves, flowers, and fruit, have antioxidant, diuretic, anti-convulsant, anti-diabetic, sedative, hypnotic, anti-mutagenic, antimicrobial, and anthelmintic properties.[1]

The scoured product of Coriander is often used as a complementary spice in Indonesian cuisine, both for ready-to-eat food and preserved food, because the essential oil produced from Coriander is believed to be able to protect food products traditionally.[2]

The essential oil of Coriander has been reported to possess antibacterial activity against a panel of human pathogenic bacteria, *Staphylococcus aureus, Pseudomonas aeruginosa, Proteus mirabilis, Escherichia coli, Lactobacillus acidophilus*, and *Listeria monocytogenes*.[3] A major constituent of Coriander's essential oil (EO) with established antibacterial and antifungal is linalool, known to act by causing disruption of bacterial cell membranes.[4] Linalool accounts for about 62.2-76.7% of coriander essential oil.[5] In addition, coriander EO has also been shown to be effective against *Candida* species.[6] Antimicrobial activity screening of Coriander is not limited to its essential oil; the extracts, fractions, and isolated compounds have also been investigated. This review aimed to highlight the antimicrobial potency of Coriander phytoconstituents.

Materials and Method

Data for this study were sourced from different journals and online libraries, search engines such as Google Scholar, PubMed, Wiley Online Library, Elsevier, Springer, Science Direct, and ResearchGate.

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Search terms include essential oils, phytoconstituents, GC-MS analysis, antimicrobial properties of coriander, medicinal uses, and major compounds of coriander. Publications investigated are limited to the period between 2010 and 2022.

Antimicrobial Activity of Coriander

Antimicrobial Activity Investigation by Diffusion Method

Two primary methods have been used to investigate the antimicrobial activity of various parts and compounds of Coriander. These are the agar well diffusion and dilution methods. Tables 1 and 2 show the results of the antimicrobial activity of the essential oils and extracts from coriander seeds, fruit, flowers, leaves, stems, and roots using the agar diffusion method. Table 1 shows the results of antimicrobial activity using the disc diffusion method, while Table 2 shows the results using the agar well diffusion method. Our search revealed that the paper disc method was mainly used for investigating the antimicrobial activity compared to the well diffusion method.

The potency of antimicrobial activity of the plant using the agar (disc) diffusion method was categorized based on the diameter of the clear zone of inhibition, where a clear zone diameter of < 7 mm is classified as having no activity, a diameter of 7-11 mm as weak activity, 11-16 mm as moderate activity and > 16 mm strong activity.[21] Based on these categories, Table 1 shows that the leaves EOs exhibited strong antimicrobials activity against *Staphylococcus aureus* (STA 34), *S. aureus* ATCC 2943, *Bacillus cereus*, *Enterococcus faecalis*, *Listeria monocytogenes* BC 8533, *Escherichia coli*, *Pseudomonas aeruginosa*, *Aspergillus parasiticus*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Aspergillus niger* BC 103, *Candida albicans* ATCC 1223, *Candida lypolitica*, *Penicillium digitatum*, *Penicillium roquefortii* BC 111, *Saccaromyces cerevisiae* and *Trichotecium roseum*. The essential oil from the seeds prevents *Staphylococcus aureus, Bacillus cereus, Escherichia coli, Pseudomonas aeruginosa, Aspergillus parasiticus, Aspergillus flavus, aspergillus fumigatus, Aspergillus niger, Candida albicans, Candida lypolitica, Penicillium digitatum*, and *Saccharomyces cerevisiae* from growing. The seed's EO was said to possess significant antimicrobial activity. EOs of the leaf, stem, and flowers have been shown to exhibit potent antimicrobial activity, inhibiting the growth of some fungi, *Alternaria alternata, Mucor racemosus*, and *Penicillium chrysogenum.*

Table 2 shows the results of the antimicrobial activity of the EOs from fruit in the agar well diffusion method. From the results, the EOs of the

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fruit exhibited the highest inhibitory activity against *Microsporum canis* CEMM 01-3-188 with an inhibitory diameter of 32 mm.[20] The EO of the seeds also shows significant and strong antimicrobial activity against *Candida albicans* with an inhibitory diameter of 29 mm.[9]

Antimicrobial Activity Investigation dilution method

Table 3 summarises the antimicrobial activity of Coriander using the dilution method. The table is classified in order of antimicrobial potency. Based on the MIC values, the antimicrobial is categorised into three groups, strong, medium, and weak, with MIC values of <100 µg/mL (< 0.1 mg/mL), > 100-625 µg/mL (< 0.1-0.625 mg /mL), and > 625 µg/mL (> 0.625 mg/mL), respectively.[31] As shown in Tables 1 and 2, the EOs from different plant parts of coriander (seed and leaf) possessed antimicrobial activities and were thus classified as strong antimicrobials.

The MBC/MFC, the smallest value of an antimicrobial compound that can kill microbes, equals the MIC or several times the MIC value obtained. However, not all test samples exhibit bactericidal activity, so they do not have an MBC/MFC value. Essential oils from leaves, seeds, and fruit have potent antibacterial activity and have MBC/MFC values. The peptide isolated from the leaves also exhibits potent antimicrobial activity. The peptide was isolated by 400 µL aliquots of leaf extract separated by a reverse phase C18 semipreparative column using 1% acetonitrile as an eluent with a flow rate of 2 mL/mm. The absorbance was monitored at a wavelength of 220 nm. Splitting resulted in 11 peaks. The active fraction (C6) was then purified using a C18 column to obtain a peptide, Plantaricin CS. Plantaricin CS is hydrophobic and consists of 26 amino acids. Most peptides that have antimicrobial activity have 10-50 amino acids.[23]

According to Furletti[6], column fractions of EO obtained from fresh aerial parts of Coriander showed strong anticandidal activity. Ten (F1-F10) fractions were obtained and pooled into F1-F2, F3-F4, F5, F6, F7, and F8-F10 based on the TLC profile. The amounts of the fractions were F8-10 (155.20 mg/g), F7 (120.40 mg/g), F5 (25.90 mg/g), F6 (22.60 mg/g), and F3-4(8.74 mg/g), respectively. Each group was tested for anticandidal activity. F8-10 exhibited the highest antifungal activity against Candida spp. The results of the GC-MS analysis of the EO content of the aerial parts of the plant revealed the presence of volatile alcohols and aldehyde derivatives, such as decene, decanal, decenol, decenal, decanol, dodecanal, dodecanol, tetradecenal, tetradecanol, tridecanol, hexenol and cyclodecane. Copious amounts of 3-hexen-1-ol (16.08%), 2-hexen-1-ol (14.52%), and 1-decanol (44.16%) were found in F 8- 10.[6]

In another study, the EO fraction of the leaf was investigated against *Candida spp.* The GC-MS analysis of this EO also revealed that fractions F8-F10 exhibited the most potent anticandidal activity. The major components of the leaf oil were decanal (19.09%), trans-2-decenal (17.54%), 2-decen-1-ol (12.33%), and cyclodecane (12.15%). All of these components have similarities with those contained in the active fraction F8-10.[27]

Table 1: Antimicrobial activities of Coriander using agar diffusion method

Microbe	Part of plant	Sample	Concentration	Inhibitory zone(mm)	Reference
Gram-positive bacteria					
Staphylococcus aureus	Seeds	Ethanol extract	200 mg/ml	14	[7]
	Seeds	Water-ethanol extract	200 mg/ml	9	[7]
	Leaves	Essential oil	10 µl	13.3	[8]
	Seeds	Essential oil	10 µl	12.5	[8]
	Seeds	Essential oil	300 mg/ml	10a 11b	[9]
Staphylococcus aureus (STA39)	Leaves	Essential oil	0.3;0.6;0.9;10;50;100%	6,10,14,19,30,38	[10]
	Seeds	Essential oil	0.3;0.6;0.9;10;50;100%	7,12,17,25,32,47	[10]
Staphylococcus aureus ATCC 6538	Fruits	Essential oil	6 µl	10	[11]
	Fruits	Extract	6 µl	9	[11]
Staphylococcus aureus ATCC 2943	Leaves	Essential oil	10 µl	21	[12]
Bacillus cereus	Leaves	Essential oil	0.3;0.6;0,9;10;50;100%	4,9,14,22,27, 34	[10]
	Seeds	Essential oil	0.3;0.6;0,9;10;50;100%	5,8,12,23,30,38	[10]
Bacillus cereus BC 6830	Leaves	Essential oil	300 µg	9	[12]
Bacillus cereus ATCC 11778	Fruits	Essential oil	6 µl	9	[11]
	Fruits	Extract	6 µl	10	[11]
Bacillus subtilis	Seeds	Water-ethanol extract	200 mg/ml	10	[7]
	Seeds	Ethanol extract	200 mg/ml	14	[7]
Bacillus subtilis BC5211	Leaves	Essential oil	10 µl	11	[12]
Enterococcus faecalis	Leaves	Ethanol extract	300 µg	10	[12]

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	Leaves	Essential oil	10 µl	16	[12]
Flavobacterium indologenes BC 1520	Leaves	Ethanol extract	300 µg	8	[12]
Listeria monocytogenes	Seeds	Ethanol extract	200 mg/ml	14	[7]
	Seeds	Water-ethanol extract	200 mg/ml	10	[7]
Listeria monocytogenes BC 8533	Leaves	Essential oil	10 µl	25	[12]
Gram-negative bacteria					
Escherichia coli	Leaves	Essential oil	0.3;0.6;0.9;10;50;100%	5,8,13,18,26	[10]
	Seeds	Essential oil	0.3;0.6;0.9;10;50;100%	6,12,18,21,26,30	[10]
	Seeds	Water- ethanol extract	200 mg/ml	8	[7]
	Seeds	Ethanol extract	200 mg/ml	14	[7]
	Leaves	Essential oil	10 µl	11	[8]
	Seeds	Essential oil	10 µl	8.5	[8]
	Seeds	Essential oil	10 mg/ml	16	[13]
Escherichia coli ATCC8739	Fruits	Essential oil	6 µl	8	[11]
	Fruits	Extract	6 µl	10	[11]
	Seeds	Essential oil	50 µl	14,2	[14]
Escherichia coli ATCC 25922	Fruits	Essential oil	6 µl	12.5	[11]
	Fruits	Extract	6 µl	8.5	[11]
Klebsiella pneumonia	Seeds	Ethanol extract	200 mg/ml	14	[7]
	Seeds	Water-ethanol extract	200 mg/ml	7	[7]
Klebsiella pneumoniae BC 32	Leaves	Essential oil	10 µl	18	[12]
	Leaves	Ethanol extract	300 µg	10	[12]
Klebsiella pneumoniae BC 1749	Leaves	Essential oil	10 µl	16	[12]
	Leaves	Ethanol extract	300 µg	10	[12]
Pseudomonas aeruginosa	Leaves	Essential oil	0.3;0.6;0.9;10;50;100%	4,5,16,20,33,44	[10]
	Seeds	Essential oil	0.3;0.6;0.9;10;50;100%	4,7,14,23,35,49	[10]
	Seeds	Ethanol extract	200 mg/ml	12	[7]
	Seeds	Water-ethanol extract	200 mg/ml	6	[7]
	Seeds	Essential oil	300 mg/ml	10a 10b	[9]
Pseudomonas aeruginosa BC 4372	Leaves	Essential oil	10 µl	7	[12]
Pseudomonas pseudoalcaligenes BC 3445	Leaves	Essential oil	10 µl	15	[12]
	Leaves	Ethanol extract	300 µg	10	[12]
Pseudomonas fluorescens BC 7324	Leaves	Essential oil	10 µl	9	[12]
Proteus mirabilis BC 2644	Leaves	Ethanol extract	300 µg	12	[12]
	Leaves	Ethanol extract	10 µl	19	[12]
Proteus vulgaris	Fruits	Essential oil	6 µl	9	[11]
	Fruits	Extract	6 µl	9	[11]
Providencia alcalifaciens	Leaves	Ethanol extract	300 µg	10	[12]

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	Leaves	Essential oil	10 µl	14	[12]
Salmonella typhimurium RSSK 95091	Leaves	Essential oil	10 µl	9	[12]
Salmonella sp	Leaves	Essential oil	10 µl	10.6	[8]
	Seeds	Essential oil	10 µl	8.16	[8]
Shigella dysenteriae	Seeds	Ethanol extract	50; 75;100%	3.27; 4.57;8.7	[15]
Vibrio cholerae	Leaves	Essential oil	10 µl	12.17	[8]
	Seeds	Essential oil	10 µ	10.16	[8]
Fungi					
Alternaria alternata	Stems, leaves, flowers	Essential oil	50, 100%	15.6; 21.8	[16]
Aspergillus parasiticus	Leaves	Essential oil	0.3; 0.6; 0.9; 10;50;100%	1,5,9, 20,29,36	[10]
	Seeds	Essential oil	10, 50, 100%	25,37,42	
Aspergillus flavus	Leaves	Essential oil	0.3; 0.6; 0.9; 10;50;100%	1,4,7,10,15,25	
	Seeds	Essential oil	0.3; 0.6; 0.9; 10;50;100%	4,7,11,15,20,28	
Aspergillus fumigatus	Leaves	Essential oil	0.3; 0.6; 0.9; 10;50;100%	2,5,9,13,15,26	
	Seeds	Essential oil	0.3; 0.6; 0.9; 10;50;100%	3,6,10,18,22,30	
Aspergillus niger	Leaves	Essential oil	0.3; 0.6; 0.9; 10;50;100%	2,5,6,11,19,28	
	Seeds	Essential oil	0.3; 0.6; 0.9; 10;50;100%	2,5,8,18,30,35	
	Fruits	Essential oil	6 µl	6	[11]
	Fruits	Extract	6 µl	8	[11]
	Seeds	Essential oil	150,300 mg/ml	10,14a 12,14b	[9]
Aspergillus niger BC 103	Leaves	Essential oil	10 µl	17	[12]
Candida albicans	Seeds		15 µl	29	[17]
	Seeds	Ethanol extract	200 mg/ml	16	[7]
	Seeds	Water-ethanol extract	200 mg/ml	8	[7]
	Seeds	Essential oil	150,300 mg/ml	15,24a 20,24b	[9]
Candida albicans ATCC 1223	Leaves	Essential oil	10 µl	18	[12]
Candida lipolytica	Leaves	Essential oil	0.3; 0.6; 0.9; 10;50;100%	3,7,13,18,22,27	[10]
	Seeds	Essential oil	0.3; 0.6; 0.9; 10;50;100%	5,12,16,20,27,32	[12]
Cladosporium herbarum BC 106	Leaves	Essential oil	10 µl	22	[12]

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Mucor recemosus	Stems, leaves, flowers	Essential oil	50%, 100%	14.3;24.6	[16]
Penicillium chrysogenum	Stems, leaves, flowers	Essential oil	50%, 100%	24.2;38.5	[16]
Penicillium brevi compactum BC 109	Leaves	Essential oil	10 µl	19	[12]
Penicillium digitatum	Leaves	Essential oil	0.3; 0.6; 0.9; 10;50;100%	3,9,14,26,32,37	[10]
	Seeds	Essential oil	0.3; 0.6; 0.9; 10;50;100%	5,12,18,30,38,42	[10]
Penicillium roquefortii BC 111	Leaves	Essential oil	10 µl	21	[12]
Saccharomyces cerevisiae	Leaves	Essential oil	0.3; 0.6; 0.9; 10;50;100%	5,8,11,16,21,30	[10]
	Seeds	Essential oil	0.3; 0.6; 0.9; 10;50;100%	3,7,10,18,25,36	
Trichotecium roseum BC 116	Leaves	Essential oil	10 µl	26	[12]
Yersinia enterocolitica BC 0184	Leaves	Ethanol extract	10 µl	10	[12]
Yersinia enterocolitica	Leaves	Essential oil	10 µl	11.33	[8]
	Seeds	Essential oil	10 µl	10.33	[8]

Notes: a: Hidro distillation (HD), b: microwave-assisted hydrodistillation (MAHD

A comparative antimicrobial activity study by Ali[10] (Table 1) showed that the seed EO exhibited better antimicrobial activity than the leaves. These results were supported by the findings of Anwesa[13] (Table 2). However, another study[8] employing the disc dilution method reported that the EO extracted from the leaves exhibited better antimicrobial activity than the seed. This study's results are shown in Table 3.

Tables 1, 2, and 3 compare the activity of essential oils from seeds using the hydrodistillation (HD) and microwave-assisted hydrodistillation (MAHD) methods. HD is one of the conventional essential oil isolation methods. The disadvantages of this method are long duration, low efficiency, loss of volatile compounds and decomposition of unsaturated compounds due to heat. MAHD is a newer method of extracting plants' EOs. In MAHD, microwave waves replace heat energy. It has a faster processing time, more efficiency, less solvent, higher quality, and environmentally friendly results. Compared to HD, the MAHD method produces essential oils with better antimicrobial activity.[9] Both extraction methods were compared in a study by Jilali *et al*. HD and MAHD were separately used to extract the EOs of *Lavendula dentata* and their antimicrobial activities were compared. The result of the study revealed that MAHD-extracted oils exhibit a more potent antibacterial activity than HD-extracted EOs. The study result may be attributed to the high concentration of certain chemicals in MAHD-derived essential oils.[32]

In the antimicrobial screening of Coriander EOs, microorganisms pathogenic to both humans and cause food spoilage were used. In a study conducted by Pellegrini *et al.*, *Staphylococcus aureus* STA 32, *S.aureus* STA 47, *S. aureus* STA 39, *Pseudomonas fluorescens* (derived from dairy products), *Brochothrix thermospacta* B2, *B. thermospacta* B1 (derived from poultry), *Salmonella enteritidis* S2, *Salmonella typhymurium* S4 (derived from meat), *Listeria monocytogrnes* LM4 (derived from processed meat) were employed[24]. Table 3 shows that the essential oil from the seeds exhibits strong antibacterial activity against the above bacteria. Suggesting that Coriander seed essential oil has the potential as a preservative in food.

Major Components of Coriander Essential Oil

The analysis of coriander EO components has been widely carried out. Content analysis of Coriander essential oil was carried out by GC-MS (Gas Chromatography-Mass Spectrophotometry). Differences in the composition of essential oils can be influenced by various factors starting from the part of the plant, the environment in which the plant grows, the type of fertilizer used in cultivation, the length of harvest, and the soil conditions.[33] Table 4 summarises the major components from several studies.

Coriander essential oil contains linalool (3,7-dimethyl-octa-1,6-diene-3-ol) as the main antimicrobial component.[37] Percentage linalool composition of the EO in the different parts of the plant as reported are seed (78.20%), leaves (13.9%) and fruits (71.90%). Coriander flower essential oil does not contain linalool but contains dodecanoic acid (5%), 7-n-pentadecylaminomethyl-6-hydroxy-5,8-quinilidione (0.29%) and 2,3,5,6-tetrafluroanisole (8.62). %), which has been shown to possess antimicrobial activity.[36] The potent antimicrobial activity of seed, leaf and fruit essential oils (Tables 1, 2 and 3) could be attributed to linalool, a known terpene in most medicinal herbs.

Conclusion

This review highlighted the antimicrobial properties of Coriander essential oil. Essential oils from various parts of Coriander (leaves, seeds, stems, flowers, and fruit) and peptides isolated from the leaves have been shown to possess potent antimicrobial activity against a panel of pathogenic microorganisms implicated in various human diseases and food spoilage. The review also revealed that linalool is the main component of the EOs of Coriander, which is responsible for its potent

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antimicrobial activity. This research suggests Coriander as a source of therapeutic agents for infectious diseases and food-borne pathogens.

Table 2: Antimicrobial activities of Coriander using well dilution method

	Part of plant	Sample	Concentration	Inhibitory zone (mm)	Reference
Gram-positive bacteria					
Staphylococcus aureus	Seeds	Essential oil	150, 300 mg/ml	11,15a 12,15b	[9]
	Seeds	Ethanol extract	50 µl	14	[18]
	Green part	Ethanol extract	50 µl	9	[18]
	Leaves	Essential oil	10 mg/ml	9.33	[13]
	Seeds	Essential oil	10 mg/ml	23.24	[13]
Bacillus cereus	Leaves	Essential oil	10 mg/ml	6.94	[13]
	Seed	Essential oil	10 mg/ml	25	[13]
	Roots	Ethanol extract	0.05 mg/ml	19	[19]
Bacillus cereus MTCC 1272	Leaves	Essential oil	10 mg/ml	9.66	[13]
	Seeds	Essential oil	10 mg/ml	26.33	[13]
Bacillus subtilis ATCC 6633	Seeds	Essential oil	50 µl	16.5	[14]
Listeria monocytogenes	Leaves	Essential oil	10 mg/ml	6.04	[13]
	Seeds	Essential oil	10 mg/ml	17.92	[13]
Micrococcus luteus	Leaves	Essential oil	10 mg/ml	9	[13]
	Seeds	Essential oil	10 mg/ml	20.14	[13]
Gram-negative bacteria					[13]
Escherichia coli	Leaves	Essential oil	10 mg/ml	5	[13]
	Seeds	Essential oil	10 mg/ml	16	[13]
Escherichia coli ATCC8739	Seeds	Essential oil	50 µl	14,2	[14]
Klebsiella pneumoniae	Roots	Essential oil	50 µg/ml	20	[19]
Pseudomonas aeruginosa	Seeds	Essential oil	300 mg/ml	15a 14b	[9]
	Seeds	Essential oil	50 µl	16.7	[14]
Pseudomonas aeruginsa ATCC9027	Seeds	Essential oil	50 µl	12.3	[14]
Salmonella typhimurium	Leaves	Essential oil	10 mg/ml	4.89	[13]
	Seeds	Essential oil	10 mg/ml	11.61	[13]
	Roots	Ethanol extract	0.05 mg/ml	11	[19]
	Seeds	Ethanol extract	50 µl	16	[18]
	Green part	Ethanol extract	50 µl	12	[18]
Salmonella typhimurium MTCC 3224	Leaves	Essential oil	10 mg/ml	8	[13]
	Seeds	Essential oil	10 mg/ml	15.33	[13]
Salmonella abony NTCC 6017	Seeds	Essential oil	50 µl	16.7	[14]
Fungi					
Aspergillus brasiliensis ATCC 16404	Seeds	Essential oil	50 µl	24.8	[14]
Aspergillus niger	Seeds	Essential oil	150,300 mg/ml	11,13a 12,16b	[9]
Aspergillus flavus	Seeds	Ethanol extract	50 µl	12	[18]
	Green part	Ethanol extract	50 µl	10	[18]
Candida albicans	Seeds	Essential oil	25 µl	26.35	[17]

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	Seeds	Essential oil	150,300	26,29a 27,29b	[9]
Candida albicans ATCC 10231	Seeds	Essential oil	50 µl	20.3	[14]
Candida tropicalis	Seeds	Ethanol extract	50 µl	19	[18]
	Green part	Ethanol extract	50 µl	16	[18]
Candida spp.CEMM 01-3-077	Fruits	Essential oil	10 mg/ml	9	[20]
Candida spp.CEMM 01-3-069	Fruits	Essential oil	10 m/ml	9	[20]
Candida spp.CEMM 01-3-078	Fruits	Essential oil	10 mg/ml	10	[20]
Candida spp.CEMM 01-3-081	Fruits	Essential oil	10 mg/ml	9	[20]
Emericella nidulans	Seeds	Ethanol extract	50 µl	12	[18}
	Green parts	Ethanol extract	50 µl	14	[18]
Microsporum canis CEMM 01-5-190	Fruits	Essential oil	10 mg/ml	30	[20]
Microsporum canis CEMN 01-3-188	Fruits	Essential oil	10 mg/ml	32	[20]
Microsporum canis CEMM 01-3-186	Fruits	Essential oil	10 mg/ml	30	[20]
Mucor sp	Seeds	Ethanol extract	50 µl	14	[18]
	Green parts	Ethanol extract	50 µl	12	[18]

Notes: a: Hidro distillation (HD), b: microwave-assisted hydrodistillation (MAHD)

Table 3: Antimicrobial activities of Coriander using dilution method

Microbe	Part of plant	Sample	Concentration	MIC (mg/mL)	MBC (mg/mL)	Reference
Strong activities (<0.1mg/mL)						
Gram-positive bacteria						
Staphylococcus aureus	Leaves	Essential oil	2.5-320 µgl/ml	0.005	0.005	[8]
	Seeds	Essential oil	2.5-320 µl/ml	0.02	0.04	
	Seeds	Essential oil	0.195-100 µg/ml	0.0125		[22]
	Leaves	Peptide	0.01-1 mg/ml	0.0352		[23]
	Seeds	Essential oil	0.03-0.45%(v/v)	0.0028*	0.0227*	[17]
Staphylococcus aureus ATCC 6538	Fruits	Essential oil		0.06		[11]
Staphylococcus aureus STA 32	Seeds	Essential oil		0.000625*		[24]
Staphylococcus aureus STA 47	Seeds	Essential oil		0.00125*		[24]
Staphylococcus aureus STA 39	Seeds	Essential oil		0.00125*		[24]
Staphylococcus aureus ATCC 25923	Seeds	Essential oil	0.03-0.45%(v/v)	0.0028*	0.0114*	[17]
Staphylococcus aureus ATCC 6538	Seeds	Essential oil	0.03-0.45%(v/v)	0.0045*	0.0227*	[17]
Staphylococcus epidermidis	Seeds	Essential oil	0.195-100 µg/ml	0.003125		[22]
Bacillus cereus	Seeds	Essential oil	15.6-1000 µg/ml	0.05		[13]
Bacillus subtilis	Seeds	Essential oil	0.195-100 µg/ml	<0.000195		[22]

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Bacillus thermospacta B2	Seeds	Essential oil		0.005*		[24]
Bacillus themospacta B1	Seeds	Essential oil		0.005*		[24]
Enterococcus aerogenes	Seeds	Essential oil	0.195-100 µg/ml	0.003125		[22]
Enterococcus faecalis	Seeds	Essential oil	0.195-100 µg/ml	0.001562		[22]
Enterococcus faecium	Seeds	Essential oil	0.195-100 µg/ml	<0.000195		[22]
Enterococcus faecium P14	Seeds	Essential oil		0.005*		[24]
Enterococcus faecium ATCC 19434	Seeds	Essential oil		0.0025*		[24]
Enterococcus durans	Seeds	Essential oil	0.195-100 µg/ml	0.1		[22]
Listeria monocytogenes	Seeds	Essential oil	0.195-100 µg/ml	0.00625		[22]
Listeria monocytogenes LM4	Seeds	Essential oil		0.000625*		[24]
Listeria monocytogenes ATCC 19144	Seeds	Essential oil		0.000625*		[24]
Listeria monocytogenes ATCC 7644	Seeds	Essential oil		0.000625*		[24]
Listeria innocua	Seeds	Essential oil	0.195-100 µg/ml	0.00039		[22]
Gram-negative bacteria						
Achromobacter denitrificans	Aerial parts	Essential oil	0.004-40 µl/ml	0.010*		[16]
Aeromonas hydrophila	Aerial parts	Essential oil	0.004-40 µl/ml	0.005*		[16]
Alcaligenes faecalis	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.005*		[16]
Enterobacter amnigenus	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.005*		[16]
Enterobacter gergoviae	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.005*		[16]
Escherichia coli ATCC 8739	Fruits	Extract		0.006		[11]
Escherichia coli ATCC 25922	Fruits	Extract		0.006		[11]
Escherichia coli ATCC 25922	Seeds	Essential oil	0.03-0.45%(v/v)	0.0028*	0.0028*	[17]
Escherichia coli	Seeds	Essential oil	0.195-100 µg/ml	0.05		[22]
	Seeds	Essential oil	0.03-0.45%(v/v)	0.0004*	0.0008*	[17]
Escherichia coli	Leaves	Essential oil	2.5-320	0.04	0.08	[8]
Listeria innocua	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.010*		[16]
Klebsiella pneumonia	Seeds	Essential oil	0.01-5.12 mg/ml	0.04	0.16	[25]
	Seeds	Essential oil	0.195-100 µg/ml	0.00039		[22]
	Leaves	Peptide	0.01-1 mg/ml	0.07155		[23]
Proteus vulgaris	Fruit	Extract		0.006		[11]

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Proteus vulgaris	Fruit	Essential oil		0.06		[11]
Proteus mirabilis	Biji	Essential oil	0.03-0.45%(v/v)	0.0114*	0.0454*	[17]
Pseudomonas aeruginosa	Leaves	Peptide	0.01-1 mg/ml	0.0864		[23]
Pseudomonas aeruginosa	Seeds	Essential oil	0.195-100 µg/ml	0.00039		[22]
Pseudomonas fluorescens	Seeds	Essential oil	0.195-100 µg/ml	0.0003125		[22]
Pseudomonas fluorescens P34	Seeds	Essential oil		0.005*		[24]
Pseudomonas fragi	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.010*		[16]
Pseudomonas lilacinum	Leaves	Peptide	0.01-1 mg/ml	0.0621		[23]
Salmonella typhimurium	Leaves	Essential oil	2.5-320	0.08	0.08	[8]
	Seeds	Essential oil	0.195-100 µg/ml	<0.000195		[22]
Salmonella typhymurium S4	Seeds	Essential oil		0.005*		[24]
Salmonella enteriditis	Seeds	Essential oil	0.195-100 µg/ml	<0.000195		[22]
Salmonella enteriditis S2	Seeds	Essential oil		0.005*		[24]
Salmonella kentucky	Seeds	Essential oil	0.195-100 µg/ml	<0.000195		[22]
Salmonella infantis	Seeds	Essential oil	0.195-100 µg/ml	<0.000195		[22]
Salmonella sp	Fruits	Essential oil		0.006		[11]
	Fruits	Essential oil		0.006		[11]
Serratia marcescens	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.010*		[16]
Shewanella putrefaciens	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.010*		[16]
Vibrio cholerae	Fruit	Essential oil	2.5-320 µl/ml	0.02	0.08	[8]
	Leaves	Essential oil	2.5-320 µl/ml	0.005	0.01	
Aspergillus niger	Leaves	Peptide	0.01-1 mg/ml	0.0621		[23]
Aspergillus niger	Fruits	Extract		0.06		[11]
Aspergillus niger	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Aspergillus fumigatus	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Aspergillus sydowii	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Aspergillus repens	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Aspergillus versicolor	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Aspergillus luchuensis	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Alternaria alternata	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Candida albicans	Seeds	Essential oil	0.01-5.12 mg/ml	0.02	0.04	[25]
	Seeds	Essential oil	0.03-0.45%(v/v)	>0.00045*	>0.00045*	[16]
Candida albicans ATCC 10231	Seeds	Essential oil	0.03-0.45%(v/v)	>0.00045*	>0.00045*	[16]
Candida albicans CBS 562	Leaves	Essential oil	0.48-1µg/ml	0.0156	0.0312	[27]
	Aerial parts	Essential oil	0.03-1 mg/ml	0.015		[6]
	Aerial parts	Active fraction	0.03-1 mg/ml	0.015		[6]

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Candida parapsilosis CBS 604	Aerial parts	n-hexane extract	0.03-1 mg/ml	0.031		[6]
	Aerial parts	Active fraction	0.03-1 mg/ml	0.063		[6]
Candida tropicalis CBS 94	Aerial parts	Active fraction	0.03-1 mg/ml	0.063		[6]
	Leaves	Essential oil	0.48-1µg/ml	0.0312	0.0625	[27]
Candida dubliniensis CBS 7987	Leaves	Essential oil	0.48-1µg/ml	0.0312	0.0625	[27]
	Leaves	Active fraction	0.48-1µg/ml	0.0312	0.125	[27]
	Aerial parts	n-hexane extract	0.03-1 mg/ml	0.031		[6]
	Aerial parts	Essential oil	0.03-1 mg/ml	0.007		[6]
	Aerial parts	Active fraction	0.03-1 mg/ml	0.031		[6]
Candida krusei CBS 573	Aerial parts	Essential oil	0.03-1 mg/ml	0.015		[6]
	Aerial parts	Active fraction	0.03-1 mg/ml	0.063		[6]
	Leaves	Essential oil	0.48-1µg/ml	0.0156	0.0312	[27]
Candida rugosa CBS 12	Leaves	Fraction active	0.48-1µg/ml	0.0625	0.125	[27]
	Leaves	Essential oil	0.48-1µg/ml	0.0156	0.0312	
Candida zeylanoides	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.00125*		[16]
Cladosporium herbarum	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Debaryomyces hansenii	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.00031*		[16]
Fusarium poae	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Fusarium oxysporum	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Microsporum canis CEMM 01-5-190	Fruits	Essential oil	4-5 µg/ml	0.078	0.15	[20]
Mycelia sterilia	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Penicillium sp	Fruits	Essential oil		0.06		[11]
Penicillium italicum	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Penicillium chrysogenum	Seeds	Essential oil	0.1-0.9 µL/mL	0.0009*		[26]
Pichia carsonii	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.005*		[16]
Saccharomyces cerevisae	Fruits	Essential oil		0.06		[11]
Saccharomyces cerevisiae	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.0025*		[16]
Yarrowia lipolytica	Stems, leaves, flowers	Essential oil	0.004-40 µl/ml	0.0025*		[16]
Yersinia enterocolitica	Leaves	Essential oil	2.5-320 µl/ml	0.0025	0.01	[8]

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	Seeds	Essential oil	2.5-320 µl/ml	0.08	0.32	
Medium activities (>0.1-0.625mg/mL)						
Gram-positive bacteria						
Staphylococcuc aureus	Seeds	Essential oil	15.6-1000 µg/ml	0.16		[13]
Staphylococcus aureus ATCC 6538	Fruits	Essential oil		0.6		[11]
Bacillus cereus ATCC 11778	Fruits	Essential oil		0.6		[11]
	Fruits	Essential oil		0.6		[11]
Listeria monocytogenes	Seeds	Essential oil	15.6-1000 µg/ml	0.2		[13]
Micrococcus luteus	Seeds	Essential oil	15.6-1000 µg/ml	0.33		[13]
Enterobacter aerogenes	Seeds	Essential oil	0.01-5.12 mg/ml	0.16	0.16	[27]
Streptococcus pyogenes	Fruits	Essential oil	0.03 -8 %v/v	0.3	1.1	[28]
Gram-negative bacteria						
Escherichia coli ATCC 8739	Fruits	Essential oil		0.6		[11]
Escherichia coli ATCC 25922	Fruits	Essential oil		0.6		[11]
Escherichia coli	Seeds	Essential oil		0.4	0.8	[17]
	Seeds	Essential oil	15.6-1000 µg/ml	0.14		[13]
	Seeds	Essential oil	2.5-320 µl/ml	0.16	0.16	[8]
Salmonella enterica	Seeds	Essential oil	2.5-320 µl/ml	0.16	0.32	[8]
Salmonella typhimurium	Seeds	Essential oil	15.6-1000 µg/ml	0.19		[13]
Fungi						
Aspergillus niger	Fruits	Essential oil		0.6		[11]
Candida spp.CEMM 01-3-077	Fruits	Essential oil	4-5 µg/ml	0.62	1.25	[20]
Candida spp.CEMM 01-3-069	Fruits	Essential oil	4-5 µg/ml	0.31	0.62	
Candida spp.CEMM 01-3-078	Fruits	Essential oil	4-5 µg/ml	0.31	0.62	
Candida spp.CEMM 01-3-081	Fruits	Essential oil	4-5 µg/ml	0.62	1.25	
Candida spp.CEMM 01-3-068	Fruits		4-5 µg/ml	0.31	0.62	
Candida albicans CBS 562	Leaves	Active fraction	0.48-1µg/ml	0.25	1	[27]
	Aerial parts	n-hexane extract	0.03-1 mg/ml	0.125		[6]
Candida parapsilosis CBS 604	Aerial parts	Essential oil	0.03-1 mg/ml	0.125		[6]
Candida tropicalis CBS 94	Aerial parts	n-hexane extract	0.03-1 mg/ml	0.5		[6]
	Leaves	Active fraction	0.48-1µg/ml	0.25	0.5	[27]
Candida kursei CBS 573	Aerial parts	n-hexane extract	0.03-1 mg/ml	0.125		[6]

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	Leaves	Active fraction	0.48-1µg/ml	0.125	0.25	[27]
M.canis CEMM 01-4-104	Fruits	Essential oil	4-5 µg/ml	0.31	0.62	[20]
M.canis CEMM 01-3-188	Fruits	Essential oil	4-5 µg/ml	0.62	1.25	
M.canis CEMM 01-3-186	Fruits	Essential oil	4-5 µg/ml	0.62	1.25	
M.canis CEMM 01-3-165	Fruits	Essential oil	4-5 µg/ml	0.62	1.25	
Penicillium sp	Fruits	Extract		0.6		[11]
Rhizopus sp	Fruits	Extract		0.6		[11]
	Fruits	Essential oil		0.6		[11]
Saccharomyces cerevisae	Fruits	Extract		0.6		[11]
Weak activities (>0.625mg/mL)						
Gram-positive bacteria						
Streptococcus viridans	Fruits	Essential oil	0.03 -8 %v/v	0.7	0.7	[28]
Staphylococcus aureus	Seeds	Ethanol extract		32		[7]
	Seeds	Water-ethanol extract		62		
Staphylococcus aureus	Seeds	Essential oil	0.25-128 mg/ml	16 a 32b	32a 64b	[9]
Staphylococcus aureusATCC6538	Fruits	Essential oil		>0.6		[11]
Bacillus cereus ATCC11778	Seeds	Essential oil		8	32	[29]
Bacillus subtilis	Seeds	Ethanol extract		32		[7]
	Seeds	Water-ethanol extract		64		
Listeria monocytogenes	Seeds	Ethanol extract		32		[7]
	Seeds	Water-ethanol extract		64		
Enterococcus faecalis	Fruits	Essential oil	0.03 -8 %v/v	4.4	27.9	[28]
Enterococcus faecalisATCC29212	Seeds	Essential oil		8	32	[29]
Enterococcus faecium	Fruits	Essential oil	0.03 -8 %v/v	2.3	101.3	[28]
Enterococcus faecium ATCC29212	Seeds	Essential oil		8	32	[29]
MSSA	Fruits	Essential oil	0.03 -8 %v/v	2.2	9.0	[28]
MRSA	Fruits	Essential oil	0.03 -8 %v/v	2.2	6.5	[28]
MRSA 10/08	Seeds	Essential oil		2	16	[29]
Methicillin RSA 12/08	Seeds	Essential oil		8	32	[29]
Vancomycin-resist Enterococcus	Fruits	Essential oil	0.03 -8 %v/v	2.2	73	[28]
Gram-negative bacteria						
Escherichia coli	Seeds	Essential oil	0.01-5.12 mg/ml	0.64	1.28	[27]
	Fruits	Essential oil	0.03 -8 %v/v	2.3	2.3	[28]

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	Seeds	Ethanol extract		32		[7]
	Seeds	Water-ethanol extract		32		
	Seeds	Essential oil	2.5-320 µl/ml	0.16	0.16	[8]
Salmonella enterica	Seeds	Essential oil	2.5-320 µl/ml	0.16	0.32	[8]
Salmonella typhimurium	Seeds	Essential oil	15.6-1000 µg/ml	0.19		[13]
Salmonella typhimurium ATCC13311	Seeds	Essential oil		4	8	[29]
Pseudomonas aeruginosa	Seeds	Ethanol extract		64		[7]
	Seeds	Water-ethanol extract		125		
	Seeds	Essential oil	0.25-128 mg/ml	128a 64b	128a 128b	[9]
Peudomonas aeruginosa ATCC27853	Seeds	Essential oil		16	16	[29]
Klebsiella pneumonia	Fruits	Essential oil	0.03 -8 %v/v	2.4	6.3	[28]
Klebsiella pneumoniae ATCC13883	Seeds	Essential oil		2	2	[29]
Proteus vulgaris	Seeds	Ethanol extract		16		[7]
Proteus vulgaris	Seeds	Water-ethanol extract		32		[7]
Fungi						
Aspergillus niger	Seeds	Essential oil	0.25-128 mg/ml	16a 8b	324a 16b	[9]
Candida albicans	Seeds	Essential oil	0.25-128 mg/ml	2a 4b	14a 8b	[9]
Candida albicans ATCC90028	Fruits	Phenol extract	1.25;2.5;5 mg/ml	1.25		[30]
Saccharomyces cerevisiae	Stems, leaves, flowers	Essential oil	40	2.5		[17]
Microsporum canis CECT20190	Fruits	Phenol extract	1.25;2.5;5 mg/ml	5		[30]
Microsporum gypseum CECT2098	Fruits	Phenol extract	1.25;2.5;5 mg/ml	1.25		[30]
Tricophyton mentagrophytes ATCC 36107	Fruits	Phenol extract	1.25;2.5;5 mg/ml	1.25		[30]
Tricophyton rubrum	Fruits	Phenol extract	1.25;2.5;5 mg/ml	1.25		[30]

Notes: *: v/v, a: hydrodistillation (HD), b: microwave-assisted hydrodistillation (MAHD)

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Table 4: Major component of coriander essential oil

Essential oil of coriander seeds [34]	Essential oil of coriander leaves [35]	Essential oil of coriander fruits [5]	Essential oil of coriander flowers [36]
Linalool (72.34%)	(*E*)-2-Decenal (32.23%)	Linalool (71.90%)	benzofuran,2,3-dihydro (15.4%)
Carvacrol (6.41%)	Linalool (13.97%)	α-Pinene (5.4%)	hexadecanoic acid, methyl ester (10.32%)
γ-Terpinene (5.67%)	(*E*)-2-Dodecenal (7.51%)	γ-Terpinene (4.4%)	2-methoxy-4-vinyl phenol (8.8%)
Camphor (3.04%)	(*E*)-2-Tetradecenal (6.56%)	Camphor (4.0%)	2,3,5,6-tetrafluroanisole (8.62%)
α-pinene (2.47%)	2-Decen-l-ol (5.45%)	Geranyl acetate (3.90%)	2,6-dimethyl-3-aminobenzoquinone (6.81%)
p-Cymene (1.21%)	(E)-2-Undecenal (4.31%)	Limonene (2.1%)	dodecanoic acid (5%)
Geranyl acetate (0.64%)	Dodecanal (4.07%)	Geraniol (1.40%)	9-octadedeconic acid(z)-,2-dihydroxy-1-(hydroxy methyl)ethyl ester (4.49%)
D-Carvone (0.38%)	(*E*)-2-Tridecenal (3.00%)		7-n-pentadecylaminomethyl-6-hydroxy-5,8-quinilidione(0.29%)
4-Terpineol (0.36%)	Undecanal (2.43%)		proponic acid,3-(bicyclo(2.2.1)hept-1-yl,methyl ester (0.048%)

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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