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Chemical composition and antimicrobial activity of the essential oil of *Coriandrum sativum*

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ABSTRACT

The essential oil from leaves of *Coriandrum sativum* L. (Apiaceae), obtained by hydro-distillation was analysed by gas chromatography–mass spectrometry (GC–MS) and also evaluated for *in vitro* antimicrobial activity. Out of 27 peaks, 24 components, which constitute 92.7%, were identified in the oil. The oil was dominated by aldehydes and alcohols which accounted for 56.1% and 46.3% of the oil, respectively. The major constituents were 2*E*-decenal (15.9%), decanal (14.3%), 2*E*-decen-1-ol (14.2%) and *n*-decanol (13.6%). Other constituents present in fairly good amounts are 2*E*-tridecen-1-al (6.75%), 2*E*-dodecenal (6.23%), dodecanal (4.36%), undecanol (3.37%), and undecanal (3.23%). The oil was screened for antimicrobial activity against both Gram positive (*Staphylococcus aureus, Bacillus* spp.) and Gram negative (*Escherichia coli, Salmonella typhi, Klebsiella pneumonia, Proteus mirabilis, Pseudomonas aeruginosae*) bacteria and a pathogenic fungus, *Candida albicans*. The oil showed pronounced antibacterial and antifungal activity against all of the microbes tested, except for *P. aeruginosae*, which showed resistance.

1 Introduction

Microorganisms, including Gram positive and Gram negative bacteria, in addition to fungi, have been recognised as the main causers of various human infections. Though effective antimicrobials have been developed over the years, there has been increased development of antimicrobial drug resistance to presently available antimicrobials (Chopra, 2007). This has necessitated the development of new antimicrobial drugs. Medicinal plants and herbs have been preferred sources of active molecules which become lead compounds for the manufacture of various pharmaceutical products. Aromatic and medicinal plants produce a wide variety of volatile aliphatic and cyclic hydrocarbons. Their corresponding oxygenated isoprenoid derivatives and analogues form a mixture called essential oils (Hammer, Carson, & Riley, 1999). The antimicrobial properties of essential oils have been recognised for many years (Deferera, Ziogas, & Polissiou, 2000; Matasyoh, Kiplimo, Karubiu, & Hailstorks, 2007). Indeed, *Coriandrum sativum* has been recommended for dyspeptic complaints, loss of appetite, convulsion, insomnia and anxiety (Emamghoreishi, Khasaki, & Aazam, 2005).

Early cultures have recognised the value of using spices and herbs for preserving foods and for their medicinal value (Jones, 1996). The spice *C. sativum* is among the plants that are known to produce essential oils with antimicrobial activity (Burst, 2004). Although chemical and pharmacological studies of *C. sativum* essential oils have been carried out, most of the studies have used mainly the plant seeds/fruits (Lo Cantore, Iacobellis, De Marco, Capasso, & Senatore, 2004). However, pharmacological studies on *C. sativum* leaves, the part of the plant most consumed by humans, are limited. At the same time, available studies have assessed antimicrobial activity against few microorganisms (Wong & Kitt, 2006) and even fewer have used human clinical isolates.

The main aim of this study was therefore to determine the main constituents of the essential oil of *C. sativum* leaves growing in Kenya and to evaluate its antimicrobial activity against clinical isolates of Gram positive (*Staphylococcus aureus*, *Bacillus* spp.) and Gram negative (*Escherichia coli, Salmonella typhi, Klebsiella pneumoniae, Proteus mirabilis, Pseudomonas aeruginosae*) bacteria, in addition to a pathogenic fungus, *Candida albicans*.

2. Materials and methods

2.1. Plant material

The leaves of *C. sativum* were collected from a plot at Egerton University in Kenya which is at an altitude of 2127 m above sea level. Voucher specimens (sk71) were deposited at the Department of Botany, Egerton University.

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2.2. Test microorganisms

The test microorganisms used for antimicrobial sensitivity testing included *S. aureus* ATCC 25923, *E. coli* ATCC 25922, *P. aeruginosae* 27853 and clinical isolates, *Bacillus* spp., *S. typhi, K. pneumoniae*, *P. mirabilis* and *C. albicans*. The microorganisms were sourced from the Center for Microbiology Research, Kenya Medical Research Institute.

2.3. Isolation of volatile components

Fresh leaves of *C. sativum* were subjected to hydro-distillation in a modified Clevenger-type apparatus for a minimum of 4 h. The essential oil was obtained in a yield of 0.04% w/w after drying over anhydrous Na_2SO_4.

2.4. Gas chromatography–mass spectroscopy (GC–MS) analysis

Samples of essential oils were diluted in methyl tertbutylether (MTBE) (1:100) and analysed in an Agilent GC–MSD apparatus equipped with an Rtx-5 SIL fused-silica capillary column ('Resets') (30 m × 0.25 mm internal diameter, 0.25 μm film thickness). Helium (0.8 ml/min) was used as a carrier gas. Samples were injected in the split mode at a ratio of 1:10–1:100. The injector was kept at 250 °C and the transfer line at 280 °C. The column was maintained at 50 °C for 2 min and then programmed to 260 °C at 5 °C/min and held for 10 min at 260 °C. The MS was operated in the EI mode at 70 eV, in the *m/z* range 42–350. The identification of the compounds was performed by comparing their retention indices and mass spectra with those found in the literature (Adams, 1995) and supplemented by the Wiley & QuadLib 1607 GC–MS libraries. The relative proportions of the essential oil constituents were expressed as percentages obtained by peak area normalization, all relative response factors being taken as one. The Kovat indices were determined from the retention times after co-injection with *n*-alkanes.

2.5. Pharmacological screening

The antimicrobial activity of the essential oil was evaluated against the test organisms according to the National Committee of Clinical Laboratory Standards (CLSI, 2007). Freshly cultured microbial suspensions in Mueller Hinton Broth were standardised to a cell density of 1.5×10^8/ml (McFarland No. 0.5). The essential oil extract was serially-diluted, using 10% Tween 80 in distilled sterile water. The diluent was also used as the negative control. The oil was diluted to concentrations of 20%, 25%, 33% and 50%. Neat undiluted oil was also used, giving a corresponding concentration of 65×10^2 μg per sensitivity disc. The experiments were done in duplicate and positive antimicrobial activities were established by measuring the zones of inhibition after 24 h of incubation at 37 °C. Minimum inhibitory concentration (MIC) was defined as the lowest concentration that inhibited growth of the microorganism detected visually. Chloramphenicol and nystatin were used as positive controls for bacteria and fungus, respectively. The positive controls were obtained from Cypress Diagnostics Company, Belgium.

3. Results and discussion

The essential oil of *C. sativum* obtained on hydro-distillation was analysed by gas chromatography–mass spectroscopy (GC–MS). Twenty-four components, representing 92.7% of the total oil, were identified. The constituents identified by GC–MS analysis, their retention indices and area percentages (concentrations) are summarised in Table 1. The oil was dominated by aldehydes and alcohols which accounted for 55.5% and 36.3% of the oil, respectively. The major aldehydes were 2*E*-decenal (15.9%) and decanal (14.3%) while the alcohols consisted mainly of 2*E*-decen-1-ol (14.2%) and *n*-decanol (13.6%). Other aldehydes present in appreciable amounts are 2*E*-tridecen-1-al (6.75%), 2*E*-dodecenal (6.23%), dodecanal (4.36%) and undecanal (3.23%). The alcohol undecanol (3.37%) was also present in fairly good amounts. The monoterpenes α-pinene (0.04%) and linalool (0.32%) were present in trace amounts. The chemical composition of the essential oil was, however, different from that observed from Tunisian plant materials (Msaada, Hosni, Ben Taarit, Chahed, & Marzouk, 2007). Indeed, in the Tunisia study, the predominant aldehyde was 2*E*-dodecenal while, in the current study, it was 2*E*-decenal.

The essential oil was evaluated for antimicrobial activity against pathogenic strains of Gram positive (*S. aureus, Bacillus* spp.) and Gram negative (*E. coli, P. aeruginosae, S. typhi, K. pneumoniae, P. mirabilis*) bacteria. It was found to be active against all of the bacterial strains except *P. aeruginasae*. It also showed a marked antifungal activity against *C. albicans. P. aeruginosae* has also been observed to be resistant to the essential oils from other plants, such as *Salvia verbeneca* (Tawfeq, 2002), *Achillea holosericea* (Magiatis, Meliou, Skaltsounis, Chinou, & Mitaku, 1999) and *Stachys* species (Skaltsa, Demetzos, Lazari, & Sokovic, 2003). This bacterium is less susceptible to the antimicrobial properties of essential oils than are many bacteria and its tolerance is considered to be due to its outer membrane (Cox et al., 2001). The activity of the oil varies with its concentration and kind of bacteria. These differences in the susceptibility of the test organisms to essential oil could be attributed to variation in the rate of essential oil constituent's penetration through the cell wall and cell membrane structures. The

Table 1
The chemical composition of *Coriandrum sativum* leaves essential oil

Compound	KI	Concentration %
Monoterpenes		
α-Pinene	920	0.04
Linalool	1096	0.32
	Sub-total	0.36
Aldehydes		
n-Octanal	996	0.8
Nonanal	1101	0.54
2*E*-Hexanal	1195	0.12
Decanal	1204	14.3
2*E*-Decenal	1261	15.9
Undecanal	1305	3.23
Dodecanal	1406	4.36
2*E*-Dodecenal	1464	6.23
Tridecanal	1507	0.63
2*E*-Tridececen-1-al	1567	0.56
Tridecanal	1609	1.16
2*E*-Tridecen-1-al	1669	6.75
3-Dodecen-1-al	1774	0.91
	Sub-total	55.5
Alcohols		
Octanol	1067	0.15
Nonanol	1170	0.38
2*E*-Decen-1-ol	1268	14.2
n-Decanol	1272	13.6
Undecanol	1362	3.37
Trans-2-Undecen-1-ol	1368	2.12
n-Undecanol	1372	2.38
	Sub-total	36.30
Alkanes		
Nonane	860	1.21
n-Decane	992	0.25
	Sub-total	1.46
	Total	92.7

KI-Kovat index.

Table 2
Antimicrobial activity of the essential oil of *Coriandrum sativum* leaves

Microorganism	Source	Inhibition (mm)								MIC mg/ml	
		Essential oil ($\mu g \times 10^2$)								EO[b]	STD[a]
		65	32.5	21.7	16.3	13	10.8	STD[a] (30 μg)	STD[d]		
Gram negative											
E. coli	ATCC 25922	13.0 ± 1.4	10.5 ± 0.7	8.0 ± 0.0	0	0	0	31.7 ± 1.5	0	163	25
S. typhi[c]	KEMRI	13.0 ± 1.4	11.0 ± 1.4	9.5 ± 0.7	7.5 ± 0.7	0	0	32.0 ± 2.0	0	130	25
K. pneumoniae[c]	KEMRI	21.0 ± 1.4	13.0 ± 1.4	11.0 ± 1.4	0	0	0	40.3 ± 1.5	0	163	22.5
P. mirabilis[c]	KEMRI	18.5 ± 0.7	11.0 ± 1.4	0	0	0	0	21.5 ± 1.9	0	217	–
P. aeruginosa	ATCC 27853	0	0	0	0	0	0	31.6 ± 2.0	0	0	–
Gram positive											
S. aureus	ATCC 25923	31.0 ± 1.4	19.0 ± 1.4	13.0 ± 1.4	9.5 ± 0.7	7.5 ± 0.7	0	30.0 ± 1.0	0	108	31.3
Bacillus spp.[c]	KEMRI	33.0 ± 1.4	21.0 ± 1.4	18.5 ± 0.7	13.0 ± 1.4	8.0 ± 0.0	0	39.6 ± 1.5	0	108	26.3
Fungus											
C. albicans[c]	KEMRI	18.5 ± 0.7	11.0 ± 1.4	8.0 ± 0.0	0	0	0	21.7 ± 2.1	0	163	–

[a] Chloramphenicol.
[b] Essential oil.
[c] Clinical isolates from Kenya Medical Research Institute (KEMRI).
[d] Control.

ability of essential oil to disrupt the permeability barrier of cell membrane structures and the accompanying loss of chemiosmotic control are the mostly likely reasons for its lethal action (Cox et al., 2000). This antimicrobial activity against bacteria and fungi has also been demonstrated in essential oils extracted from *C. sativum* seed (Lo Cantore et al., 2004).

Although the concentrations of the oil were generally about 100 times more than those of the standard antibiotic (chloramphenicol), they showed marked antibacterial and antifungal activities, as evidenced by their zones of inhibition (Table 2). This difference between concentrations of the essential oil and the standard antibiotic can be explained in terms of the fact that the active components in the oil comprise only a fraction of the oil used. Therefore, the concentration of the active components could be much lower than the standard antibiotics used. It is important to note that, if the active components were isolated and purified, they would probably show higher antimicrobial activities than those observed here.

Among the Gram negative bacteria, the oil was very active against *K. pneumoniae* and *P. mirabilis*. The best activity was observed for the Gram positive bacteria. The activity responses to *S. aureus* and *Bacillus* spp. were similar (at 65×10^2 μg) to that of chloramphenicol (30 μg). The oil showed similar activity, across the concentration range, to *E. coli* and *S. typhi*.

The minimum inhibiting concentration (MIC) of oil for Gram negative bacteria ranged from 130 to 217 mg/ml and 108 mg/ml for both Gram positive bacteria. The MIC for the fungus *C. albicans* is 163 mg/ml. The MIC values for chloramphenicol range from 22.5 to 31.3 mg/ml. In general, the oil showed greater antibacterial activity than antifungal activity (see Table 2).

Aldehydes and alcohols have been known to be active but with differing specificity and levels of activity, which is related not only to the functional group present but also to hydrogen bonding parameters (Skaltsa et al., 2003). Linalool, though a minor component in this study, has been found to have antimicrobial activity against various microbes, except for *P. aeruginosae* (Carson & Riley, 1995). Linalool is also known to inhibit spore germination and fungal growth. The inhibition of sporelation appeared to arise from respiratory suppression of aerial mycelia (Lahlou & Berrada, 2001).

4. Conclusions

The essential oil of *C. sativum* showed antimicrobial activity against both Gram positive and Gram negative bacteria and therefore it can be used as a herbal medicine. The plant is not known to be toxic because it has been consumed by mankind for centuries without showing any signs of toxicity.

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