Research Article

Received: 2 November 2009 Revised: 28 April 2010 Accepted: 26 July 2010 Published online in Wiley Online Library: 14 October 2010

(wileyonlinelibrary.com) DOI 10.1002/jsfa.4140

Chemical composition, antioxidant and antibacterial properties of the essential oils of *Etlingera elatior* and *Cinnamomum pubescens* Kochummen

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Abstract

BACKGROUND: Plant essential oils are widely used as fragrances and flavours. Therefore, the essential oils from the leaves of *Cinnamomum pubescens* Kochummen (CP) and the whole plant of *Etlingera elatior* (EE) were investigated for their antioxidant, antibacterial and phytochemical properties.

RESULTS: CP and EE were found to contain appreciable levels of total phenolic contents (50.6 and 33.41 g kg^{-1} as gallic acid equivalent) and total flavonoid contents (205.6 and 244.8 g kg^{-1} as rutin equivalent), respectively. DPPH free radical scavenging activity of CP is superior to EE ($P < 0.05$) showing IC_{50} of 77.2 and 995.1 μg mL^{-1}, respectively. Methicillin-resistant *Staphylococcus aureus* (MRSA), *Bacillus subtilis, Pseudomonas aeruginosa* and *Salmonella choleraesuis* were tested against CP and EE. Only MRSA was the most susceptible bacteria to CP. GC/MS studies resulted in the identification of 79 and 73 compounds in CP and EE, respectively. The most abundant components of EE included β-pinene (24.92%) and 1-dodecene (24.31%). While the major compound in CP were 1,6-octadien-3-ol,3,7-dimethyl (11.55%), cinnamaldehyde (56.15%) and 1-phenyl-propane-2,2-diol diethanoate (11.38%).

CONCLUSION: This study suggests that the essential oils from *Cinnamomum pubescens* Kochummen and *Etlingera elatior* could be potentially used as a new source of natural antioxidant and antibacterial in the food and pharmaceutical industries.

Keywords: antibacterial activities; antioxidant; chemical composition; *Cinnamomum pubescens* Kochummen; *Etlingera elatior*

INTRODUCTION

Essential oils from herbal sources are used in food flavours, perfumes and pharmaceutical preparations for their functional properties.[1] The commercial use of essential oils in aromatherapy constitutes little more than 2.0% of the total market.[2] Moreover, the antibacterial properties of these herbal essential oils and their components are exploited in such diverse commercial products as dental root canal sealers, antiseptics and animal feed supplements.[3] Besides the antibacterial properties, some of essential oils were proven to possess antioxidant properties.[4,5]

Williams and Harborne screened 39 species of ginger (Zingiberaceae) for their phytochemical constituents. Leaves of Alpinia and Zingiber were found to contain kaempferol and quercetin glycosides, and myricetin and quercetin glycosides, respectively.[6] Flavonoids in the leaves of *Etlingera elatior* (Zingiberaceae) have been identified as kaempferol 3-glucuronide, quercetin 3-glucuronide, quercetin 3-glucoside, and quercetin 3-rhamnoside. Members of the *Etlingera* genus have various remedial and commercial uses. Young shoots, flowers and fruits are eaten either raw, cooked as a vegetable, or used as a condiment.[7] Inflorescences of *E. elatior* are widely cultivated as spice for curry.[8] Fruits are used to treat ear itching, while leaves are applied for healing wounds.[7] *E. elatior* was also found to have anti-tumour promoting and cytotoxic activities.[9,10]

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Cinnamomum pubescens Kochummen (family: Lauraceae) is a small tree up to 7 m tall. It is indigenous to Peninsular Malaysia; the leaves are opposite to alternate, with a hairy stalk 1–2 cm in length. The blade is leathery, drying greenish yellow, lanceolate, apex pointed, base cuneate, finely pubescent on the under surface, midrib and secondary nerves flattened to sunken on the upper surface, raised on the lower surface.[11,12] As with all cinnamomum species, the whole parts of the tree are aromatic and are used in traditional medicine as *medang*, but this species has not been used commercially.[13] The leaf oil of *C. pubescens* showed significant larvacidal and platelet-activating factor (PAF) receptor-binding antagonist activities.[14]

In this present study, the essential oils obtained from the whole plant of *E. elatior* and leaves of *C. pubescens* Kochummen (referred to as *C. pubescens* for the remainder of this paper) were analysed by GC/MS and their antioxidant activities using diphenylpicrylhydrazyl (DPPH) free-radical scavenging activity, antibacterial properties and their chemical composition were compared. To the best of our knowledge, this study is the first of its kind to report the antioxidant activities and antibacterial effect of essential oils from *E. elatior* and *C. pubescens*.

MATERIALS AND METHODS

All solvents used were of analytical grade. Methanol, ethyl acetate, hexane, chloroform, butylated hydroxytoluene (BHT) and Folin–Ciocalteu reagent were obtained from Merck (Darmstadt, Germany).

Plant materials

Fresh leaves of *C. pubescens* and whole plant of *E. elatior* were collected from Pahang and Selangor states, Malaysia, respectively, in 2009. Plants were identified by Assistant Professor Shamsul Khamis at the Unit of Biodiversity, Institute of Bioscience, Universiti Putra Malaysia, Malaysia. The voucher specimens under the plants' names were deposited in the unit herbarium.

Isolation procedure for the essential oils

The fresh whole plant of *E. elatior* and leaves of *C. pubescens*, were steam distilled, separately, in a hydrodistillation apparatus (Clevenger-type) for 8 h. The essential oils were dried over anhydrous sodium sulfate and stored at 4–6 °C before analysis.

Antioxidant activity

Determination of total phenolic content

Total phenolic content (TPC) in essential oils of *E. elatior* and *C. pubescens* was determined with Folin–Ciocalteu reagent following the method of Kaur *et al*.[15] Stock solutions of oils were prepared in a concentration of 10 mg mL^{-1}, and a 50 µL from this solution was transferred to a test tube ($n = 3$). To this tube, 0.4 mL of Folin–Ciocalteu reagent (1 : 10) was added and the tube was shaken thoroughly. After 1 min, 0.8 mL of sodium bicarbonate solution (0.9 mol L^{-1}) was added and the mixture allowed standing in dark room for 30 min with intermittent shaking. Absorbance was measured at 765 nm using a Shimadzu UV–visible spectrophotometer (Mini 1240; Shimadzu, Columbia, MD, USA). The total phenolic content (TPC) was expressed as gallic acid equivalent (GAE) in mg per g oil from the calibration curve of gallic acid standard solution. For the gallic acid, the curve was established by plotting concentration (mg mL^{-1}) versus absorbance (nm) ($y = 5.145x + 0.014$; $R^2 = 0.9975$), where y is the absorbance and x is the concentration.

Determination of total flavonoid content

Total flavonoid content (TFC) was determined by the $AlCl_3$ method, using rutin as a standard.[16] The test samples were dissolved in dimethyl sulfoxide (DMSO). The sample solution (1.0 mL) was mixed with 1.0 mL of $AlCl_3$ (0.15 mol L^{-1}). After 10 min of incubation at ambient temperature, the absorbance of the supernatant was measured at 435 nm using a Shimadzu UV–visible spectrophotometer (Mini 1240). Three replicates were made for each test sample. The total flavonoid content was expressed as rutin equivalents (RE, mg g^{-1}). For the rutin, the curve was established by plotting concentration (mg mL^{-1}) versus absorbance (nm) ($y = 5.6752x - 0.0312$; $R^2 = 0.994$), where y is the absorbance and x is the concentration.

DPPH radical scavenging antioxidant assay

Radical scavenging activity of plant essential oils against stable DPPH (2, 2-diphenyl-2-picrylhydrazyl hydrate) (Sigma–Aldrich Chemie, Steinheim, Germany) was determined spectrophotometrically. When DPPH reacts with an antioxidant compound, which can donate hydrogen and is reduced, the changes in colour (from deep-violet to light-yellow) were measured at 517 nm wavelength.[17] Radical scavenging activity of essential oils was measured by a slight modification of the method by Ao *et al*.[18] Stock solutions were prepared in 10 mg mL^{-1} in methanol. The working solution was prepared using methanol in a concentration of 2.0 mg mL^{-1} (Labsystems iEMS Reader MF; Eichenweg, Aumühle, Germany). The solution of DPPH in methanol (1 mmol L^{-1}) was freshly prepared, before UV measurements. Five microlitres of this solution were mixed with 100 µL of serial dilutions of samples (15.625–2000 µg mL^{-1}) in a 96-well plate. The samples were kept in the dark for 30 min at ambient temperature and then the decrease in absorption was measured each 30 min for 2 h. Absorption of a blank sample containing the same amount of methanol and DPPH solution was prepared and measured daily. The experiment was carried out in triplicate. Radical scavenging activity was calculated by the following % inhibition $= [(A_B - A_A)/A_B] \times 100$, where A_B is the absorption of blank sample ($t = 0$ min); and A_A is the absorption of tested samples ($t = 30$ min). The inhibitory concentration 50% was determined as well as the kinetics of DPPH scavenging reaction. Commercial standard antioxidant butylated hydroxytoluene (BHT) was also tested against DPPH and used as a reference.

Antibacterial assay

Microbial strains

The antibacterial activity of essential oil samples was evaluated using two Gram-positive bacteria, methicillin resistant *Staphylococcus aureus* (MRSA) and *Bacillus subtilis* B29, and two Gram-negative bacteria, *Pseudomonas aeruginosa* 60 690 and *Salmonella choleraesuis*. All bacterial strains were obtained from the Laboratory of Molecular Biomedicine, Institute of Bioscience, Universiti Putra Malaysia, Serdang, Malaysia.

Disc diffusion method

Screening for the antibacterial effect of the essential oils was carried out by determining the zone of inhibition using paper disc (6 mm in diameter, Whatman No. 1) diffusion method.[19] The microorganism strains obtained were inoculated in a Petri dish containing nutrient broth at 37 °C for 24 h and were referred as seeded broth. The density of the bacterial suspension was standardised and the concentrations of the cultures were adjusted turbidometrically at

wavelength of 600 nm to 5×10^5 to 10^6 colony forming units per mL. The essential oils were dissolved in DMSO which was previously tested for antibacterial activity against all test bacteria and found to have no activity. Essential oils were diluted to a concentration of 100 mg mL^{-1} and finally sterilised by filtration using 0.45 µm Millipore filters. The sterile discs were impregnated with oil solution (0.05 mL from 100 mg mL^{-1}) to achieve desired concentration and placed in inoculated agar. Streptomycin (10 µg mL^{-1}) susceptibility discs and methanol-impregnated discs were used as positive and negative controls, respectively. After incubation overnight at 37 °C, inhibition zones were measured and recorded as mean diameter (mm). Antibacterial activity was also expressed as inhibition percentage of streptomycin.

Minimum inhibitory concentration

The least possible inhibitory concentrations of essential oils against MRSA were estimated using the agar disc method (ADM). Inoculation of 1.0 mL of MRSA was poured into each Petri dish and the agar was later dispensed and permitted to set. Wells were bored using a sterile 3.0 mm cork borer. Serial dilutions of the essential oil were added into the wells. The plates were incubated at 37 °C for 24 h. The growth was observed to determine the sensitivity of MRSA using clear zones of no microbial growth. The least concentration of the essential oil that had inhibitory effect was taken as the minimum inhibitory concentration (MIC).

Gas chromatography mass spectrometry

The essential oils of *E. elatior* and *C. pubescens* were analysed by Shimadzu GC-MS (Model GC-17A). A FT-DB-5 capillary column (30 m × 0.25 mm × i.d. 0.25 µm) was used for gas chromatographic separation of the analytes.[20] The injection volume was 1.0 µL with a split ratio of 13 : 1; the injector temperature was held constant at 230 °C. Helium was used as the carrier gas with an inlet pressure of 21.0 kPa, corresponding to a flow rate of 1.0 mL min^{-1}. The column oven temperature was set at 30 °C (held for 3 min), raised at 8 °C min^{-1} to 230 °C (held for 5 min), and finally held at 245 °C for 10 min. The mass spectrometer was operated in the electron impact (EI) mode with ionisation energy of 70 eV. The transfer line was set at 290 °C. The chemical constituents of the analytes were identified by comparing the MS fragmentation patterns with those of NIST/EPA/NIH mass special database library of the GC/MS system.

Statistical analyses

In order to determine whether there is a statistically significant difference between the obtained results for the different assays the independent *t*-test was carried out using the SPSS 17.0 software package.

RESULTS AND DISCUSSION

Antioxidant capacity

Hydro-distillation of fresh leaves of *C. pubescens* and the whole plant of *E. elatior*, afforded colourless pleasant-smelling essential oils. The total phenolic content (TPC) of these essential oils was determined using the Folin–Ciocalteu method and expressed in mg GAE g^{-1}. Results presented in Table 1 showed that *C. pubescens* (50.6 ± 0.58 g GAE kg^{-1}) had higher TPC when compared to *E. elatior* (33.41 ± 0.92 g GAE kg^{-1}). Independent *t*-test statistical analysis showed the mean TPC of *C. pubescens* is significantly different ($n = 3$) at the 0.05 level of significance. Total flavonoid content (TFC) was determined by the $AlCl_3$ method. Results were expressed as milligrams of rutin equivalent (RE) in one gram of oil (Table 1). The TFC for *E. elatior* was observed to be 244.83 ± 15.5 g RE kg^{-1}, which is not statistically different from the TFC for *C. pubescens* (205.65 ± 30.4 g RE kg^{-1}) (Table 1). The current study shows that the essential oil from *E. elatior* has high TPC and TFC. However, it was reported earlier that a methanolic extract (not the essential oil) from fresh leaves of *E. elatior* has also shown high TPC.[7] Antioxidant activity of essential oils from *E. elatior* and *C. pubescens* was also evaluated using the DPPH assay, which was conducted for 240 min (Fig. 1). Samples were able to reduce violet DPPH to the yellow DPPH-H, with an IC_{50} of 995.1 ± 123 and 77.2 ± 8.5 µg mL^{-1} for *C. pubescens* and *E. elatior*, respectively (Table 1). No earlier reports are available regarding the DPPH radical scavenging activity of the essential oils of *E. elatior* and *C. pubescens* with which to compare the results of our present analysis. However, Chan *et al.*, reported the IC_{50} for a methanolic extract of fresh leaves of *E. elatior* to be 37.5 mg kg^{-1}.[7]

Table 1. Total phenolic content, total flavonoid content and DPPH IC_{50} (µg mL^{-1}) of *Etlingera elatior* and *Cinnamomum pubescens* Kochummen

Sample	Total flavonoid content (RE g kg^{-1})	Total phenolic content (GAE g kg^{-1})	DPPH IC_{50} (µg mL^{-1})
E. elatior	244.83 ± 15.5	3341.2 ± 92.1	995.1 ± 123
C. pubescens	205.65 ± 30.4	5060.5 ± 58.6	77.2 ± 8.5

Results are expressed as average ± SD ($n = 3$).
RE, rutin equivalent; GAE, gallic acid equivalent.

The higher TPC of *C. pubescens* may explain its superiority compared to *E. elatior*. In addition, DPPH protection by *C. pubescens* may be due to the antioxidative action of eugenol (7.27%), which has been detected by GC-MS. This phenolic compound has been detected earlier in the essential oils of eight *Cinnamomum* species.[21]

Despite the fact that *E. elatior* essential oil has a higher flavonoid content (Table 1), significant contributors to the high antiradical effect, it did not show a scavenging effect compared to *C. pubescens*. These surprising results might be explained by the existence of β-pinene (monoterpene hydrocarbons). Some isolated terpenes have been previously tested individually in order to determine the antioxidant nature of the oils, such as β-pinene, but none has exhibited antioxidant activity.[22] To the best of our knowledge, no data have been published on antioxidant activity, using the DPPH method, on *E. elatior* and *C. pubescens* essential oils.

Antibacterial activities

Among the tested bacteria, only MRSA was the most sensitive organism to the essential oils of *C. pubescens*. The mean diameter of the zone of inhibition of *C. pubescens* was 15 mm for MRSA which represents 75% inhibition compared to streptomycin MRSA (Table 2). The essential oil of *C. pubescens* was reported earlier to be antifungal.[21] Cinnamaldehyde (the major constituent of *C. pubescens*, 56.15%) is known to be antibacterial against *Escherichia coli* and *Salmonella typhimurium*; it did not disintegrate the outer membrane or deplete the intracellular ATP pool.[23] The carbonyl group of some kind of potential antibacterial agents is thought to bind to proteins, preventing the action

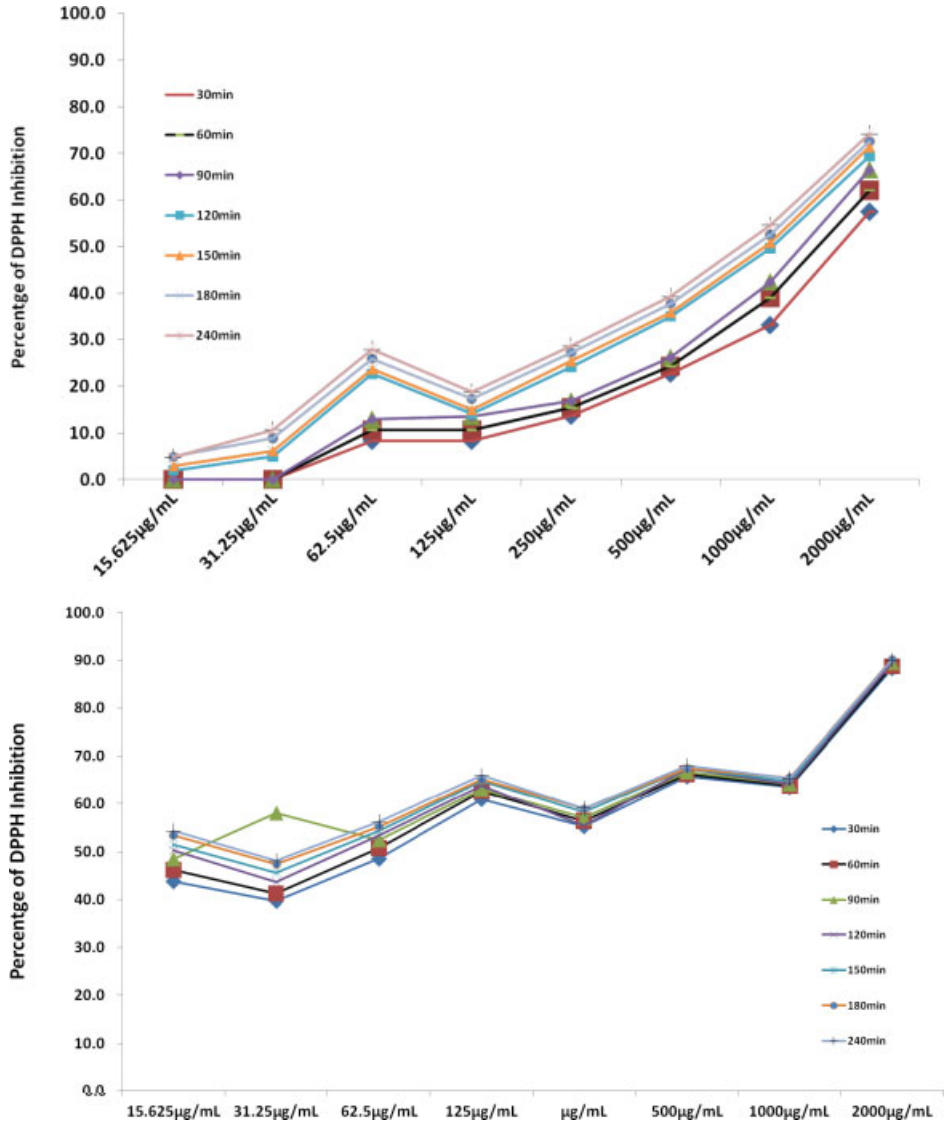

Figure 1. Antioxidant activity of *Etlingera elatior* (upper photo), *Cinnamomum pubescens* (lower photo).

Table 2. Antibacterial activity of essential oils of *Etlingera elatior* and *Cinnamomum pubescens* Kochummen against bacteria using the disc-diffusion method and minimum inhibitory concentration

	Methicillin resistant *Staphylococcus aureus*		*Pseudomonas aeruginosa*		*Salmonella choleraesuis*		*Bacillus subtilis*	
Sample	Inhibition zone (mm)	MIC (mg mL^{-1})	Inhibition zone (mm)	MIC (mg mL^{-1})	Inhibition zone (mm)	MIC (mg mL^{-1})	Inhibition zone (mm)	MIC (mg mL^{-1})
Etlingera elatior	15 (75)	10	–	–	–	–	–	–
Cinnamomum pubescens Kochummen	–	–	–	–	–	–	–	–
Control (streptomycin)	20	–	20	–	23	–	23	–
Methanol	–	–	–	–	–	–	–	–

[a] The screening of the essential oils antibacterial effect was carried out by determining the zone of inhibition using paper disc (6 mm in diameter, Whatman No. 1) diffusion method (n = 2). Figures in parentheses are inhibition percentages compared to streptomycin.
MIC: Minimum inhibitory concentration.

of amino acid decarboxylases in *Enterobacter aerogenes*.[24] Gram-positive *Bacillus subtilis* was observed to be resistant for both *E. elatior* and *C. pubescens*. Previous studies on the antimicrobial activity of essential oils obtained from ginger species also showed weak inhibition of bacteria.[25] The mean diameter of the zone of inhibition of streptomycin was 20 mm for MRSA and *Pseudomonas aeruginosa* and 23 mm for *Salmonella choleraesuis* and *B. subtilis* (Table 2). The solvent used to prepare the reference and test samples showed no inhibitory effect on the bacteria used.

Essential oils of *E. elatior* and *C. pubescens* failed to inhibit Gram-negative *S. choleraesuis* and *P. aeruginosa* (Table 2). Selective permeability of the outer membrane of Gram-negative bacteria makes it generally less susceptible to volatile oils than the Gram-positive bacteria. Gram-negative *P. aeruginosa* is known to have a high level of intrinsic resistance to virtually almost all known antimicrobials and antibiotics, due to a very restricted outer membrane barrier, highly resistant even to synthetic drugs.[26] To the best of our knowledge, this is the first study reporting antibacterial activities of the essential oils of *E. elatior* and *C. pubescens*.

Table 3. Compounds tentatively identified in the essential oil of *Cinnamomum pubescens* Kochummen

Compound no.	RT[a]	RC[b] (%)	Compound[c]	Molecular weight	Similarity (%)
1	14.132	0.94	Bicyclo[3.1.1]hept-2-ene, 2,6,6-trimethyl	136	95
2	15.019	0.71	Camphene	136	94
3	16.377	0.77	Benzaldehyde	106	94
4	16.475	0.51	β-Pinene	136	88
5	19.408	0.72	Eucalyptol	154	85
6	23.132	11.55	1,6-Octadien-3-ol,3,7-dimethyl	154	95
7	26.547	1.40	Benzene propanal	134	95
8	26.731	1.13	Borneol	154	94
9	27.870	0.82	(−)-α-Terpineol (*p*-menth-1-en-8-ol)	154	94
10	32.470	56.15	Cinnamaldehyde	132	98
11	35.476	7.27	Phenol, 2-methoxy-4-(2-propenyl)-, acetate (eugenol)	206	76
12	39.822	11.38	1-Phenyl-propane-2,2-diol diethanoate	236	77
12 out of 79	Total	93.35			

[a] RT, Retention time (min).
[b] Relative area percentage (peak area relative to the total peak area percentage).
[c] Compounds are listed in order of their relative area percentage.

Table 4. Compounds tentatively identified in the essential oil of *Etlingera elatior*

Compound no.	RT[a]	RC[b] (%)	Compound[c]	Molecular weight	Similarity (%)
1	14.151	11.59	Bicyclo[3.1.1]hept-2-ene, 2,6,6-trimethyl	136	97
2	16.528	24.92	β-Pinene	136	96
3	17.206	0.60	β-Myrcene	136	91
4	26.919	0.86	Bicyclo[3.1.1]heptan-3-one, 2,6,6-trimethyl	152	92
5	27.908	0.66	(−)-α-Terpineol (*p*-menth-1-en-8-ol)	154	86
6	27.917	0.74	7-Methylene-9-oxabicyclo[6.1.0]non-2-ene	136	78
7	28.325	0.69	Decanal	156	94
8	32.448	0.74	2-Undecanone	170	95
9	32.639	1.38	3-Bromo-7-methyl-1-adamantane carboxylic acid	272	78
10	37.937	8.15	Dodecanal	184	97
11	38.074	2.49	β-Farnesene	204	87
12	39.554	2.41	1,6,10-Dodecatriene, 7,11-dimethyl-3-methylene	204	91
13	39.744	1.99	α-Caryophyllene	204	94
14	40.935	24.31	1-Dodecene	168	96
15	41.675	0.90	2-Tridecanone	198	96
16	45.447	2.56	*trans*-(*Z*)-α-Bisabolene epoxide	220	86
17	46.405	3.49	Acetic acid	228	87
18	46.663	1.22	2-Pentadecyn-1-ol	224	83
19	48.837	0.63	(*E*)-10-Pentadecenol	226	92
20	49.334	2.27	1,3-Propanediol, 2-dodecyl	244	93
20 out of 73	Total	92.6%			

[a] RT, Retention time (min).
[b] Relative area percentage (peak area relative to the total peak area percentage).
[c] Compounds are listed in order of their relative area percentage.

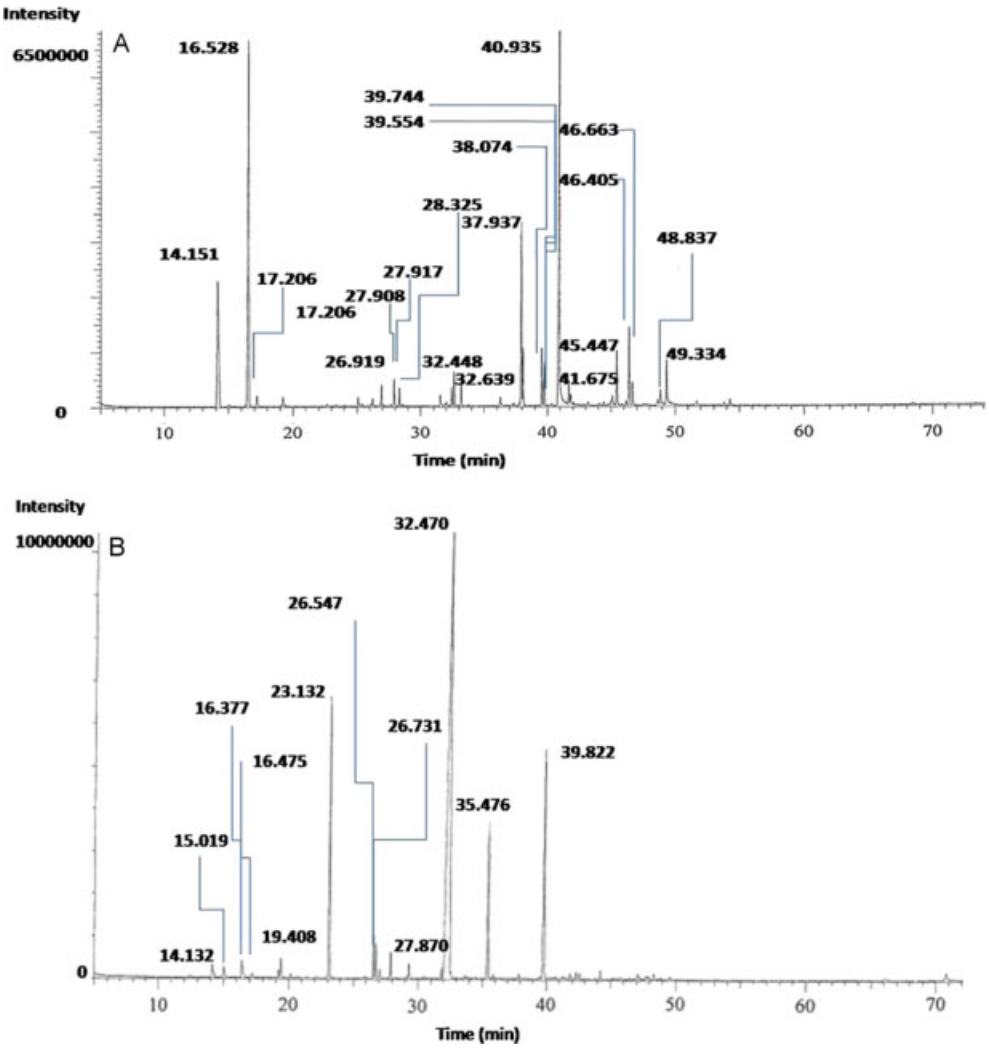

Figure 2. Total ionic chromatogram (GC-MS) of essential oils of *Etlingera elatior* (A) and *Cinnamomum pubescens* Kochummen (B) obtained with 70 eV using a A FT-DB-5 capillary column (30 m × 0.25 mm × i.d. 0.25 μm). Helium was used as the carrier gas with an inlet pressure of 21.0 kPa, corresponding to a flow rate of 1.0 mL min^{-1}.

Chemical composition

The chemical composition of *E. elatior* and *C. pubescens* essential oils studied by GC-MS is presented in Tables 3 and 4. Total ionic chromatograms of both *E. elatior* and *C. pubescens* are presented in Fig. 2. A total of 79 compounds were characterised in *C. pubescens* while the essential oil of *E. elatior* consists of 73 compounds. The most abundant components in the leaf essential oil of *E. elatior* included bicyclo[3.1.1] hept-2-ene, 2,6,6-trimethyl (11.59%), β-pinene (24.92%), 3-bromo-7-methyl-1-adamantanecarboxylic acid (1.38%), dodecanal (8.15%), β-farnesene (2.49%), 1,6,10,-dodecatriene, 7,11-dimethyl-3-methylene (2.41%), α-caryophyllene (1.99%), 1-dodecene (24.31%), *trans*-(*Z*)-α-bisabolene epoxide (2.56%), acetic acid (3.49%) and 1,3-propanediol, 2-dodecyl (2.27%) (Table 3). 1,6-Octadien-3-ol,3,7-dimethyl (11.55%), borneol (1.13%), cinnamaldehyde (56.15%), phenol, 2-methoxy-4-(2-propenyl)-, acetate (7.27%) and 1-phenyl-propane-2,2-diol diethanoate (11.38%) were the major compounds in *C. pubescens* (Table 3).

Bicyclo [3.1.1] hept-2-ene, 2,6,6-trimethyl was found to be more abundant in the essential oil of *E. elatior* (11.59%) compared to *C. pubescens* (0.94%), while β-pinene is abundant in the latter (24.92%) compared to *C. pubescens* (0.51%) (Tables 3 and 4). Caryophyllene was reported previously in *E. elatior* and *C. pubescens*; however, the current study revealed the absence of this sesquiterpene hydrocarbon in *C. pubescens*.[25]

Previously, Jaafar *et al*. analysed the essential oils isolated from different parts (leaves, stems, flowers and rhizomes) of Malaysian *E. elatior* using GC-MS.[9] The leaf essential oil was found to contain β-pinene (19.7%), β-caryophyllene (15.4%) and *trans*-β-farnesene (27.1%) as the major compounds whereas the stem essential oil was largely dominated by 1,1-dodecanediol diacetate (34.3%) and *trans*-5-dodecene (27.0%). The essential oils of the flowers and rhizomes contained 1,1-dodecanediol diacetate (24.4% and 40.4%, respectively) and cyclododecane (47.3% and 34.5%, respectively) as the major compounds. The current study demonstrated a higher percentage of β-pinene and lower for α-caryophyllene and *trans*-β-farnesene.

CONCLUSIONS

Essential oils of *C. pubescens* and *E. elatior* have significant differences in their chemical composition and antibacterial

activities. *C. pubesecens* essential oil showed an interesting antibacterial effect against methicillin resistant *Staphylococcus aureus*, a bacterium responsible for difficult-to-treat infections in humans. In view of the antioxidant properties of these two essential oils they might be considered for inclusion as natural antioxidants in nutraceutical and pharmaceutical preparations.

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