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Correlation Between Chemical Composition and Antifungal Activity of the Essential Oils of Eight *Cinnamomum* Species

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Abstract

Fourteen essential oils hydrodistilled from eight *Cinnamomum* (Lauraceae) species (*C. pubescens* Kochummen, *C. impressicostatum* Kosterm, *C. microphyllum* Ridl., *C. scortechinii* Gamb., *C. rhyncophyllum* Miq., *C. cordatum* Kosterm, *C. zeylanicum* Blume, and *C. mollissimum* Hook f.) were examined for their antifungal activity against six dermatophytes (*Trichophyton rubrum, T. mentagrophytes, T. tonsurans, Microsporum canis, M. gypseum*, and *M. audouini),* one filamentous fungi *(Aspergillus fumigatus*), and five strains of yeasts (*Candida albicans, C. glabrata, C. tropicalis, C. parapsilosis*, and *Crytococcus neoformans*) by using the broth microdilution method. The antifungal activities of 13 standard compounds that are prevalent constituents in *Cinnamomum* oils were also investigated in an effort to correlate the effectiveness of the oils with those of the components of the oils. The chemical composition of the oils was analyzed by GC and GC-MS. Most of the oils showed moderate to strong activity against the fungi. Among the oils, the leaf and bark oils of *C. zeylanicum* showed the highest activity against all the fungi with MIC values of 0.04 to 0.63 μg μL^{-1}. Other oils that gave a strong inhibition on fungal growth were the leaf oil of *C. cordatum* and bark and twig oils of *C. pubescens* and *C. impressicostatum.* Cinnamaldehyde, which was the most abundant component of the bark oil of *C. zeylanicum,* showed the strongest activity against all the fungi studied. Based on the results of the assay on standard samples, it may be that the high levels of cinnamaldehyde, eugenol, geraniol, benzyl benzoate, and methyl cinnamate in the oils and in combination with the minor components is responsible for the high antifungal activity of the oils.

Keywords: Antifungal activity, cinnamaldehyde, *Cinnamomum* species, dermatophytes, essential oils, filamentous fungi, yeasts.

Introduction

The genus *Cinnamomum* (Lauraceae) contains about 250 species; 21 species are found in peninsular Malaysia. The species are shrubs and small to medium-sized trees (Jantan et al., 1995). They are found in tropical rain forests where they grow at various altitudes from highland slopes to lowland forests and occur in both marshy places and on well-drained soils. However, in latitudes with seasonal climatic conditions, they become exceedingly rare (Lawrence, 1967). The genus occurs in eastern and southeastern Asia, through Malaysia and into the Pacific (Burkill, 1966). *C. zeylanicum*, *C. loureirii*, *C. burmanni*, and *C. cassia* are the four principal *Cinnamomum* species whose bark enters the trade as cinnamon, the spice that depends on cinnamaldehyde for its characteristic flavor (Lawrence, 1967). Oil from the bark, commercially known as cinnamon oil, is used as flavoring ingredient in foods and drinks, as a perfumery material, and in many pharmaceutical preparations for its carminative and astringent properties. Leaf oil distilled from *C. zeylanicum* is used as a source of eugenol (Reynolds, 1993).

The essential oils of the economically more important species have been thoroughly investigated (Lawrence, 1969; Herisset et al., 1974; Wijesekera et al., 1974). The essential oils of other *Cinnamomum* species have also been the subject of some study. For example, linalool (Fujita & Fujita, 1972), camphor (Yuangzheng et al., 1986),

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cinnamadehyde (Fang et al., 1989), 1,8-cineole, eugenol (Wijesekera & Jayewardene, 1974), terpinen-4-ol, and safrole (Biyao et al., 1986) have been found as major components of leaf, twig, bark, wood, and root oils of various species. Systematic chemical studies on the essential oils of some of the Malaysian species have been carried out, and they were found to contain mainly safrole, eugenol, linalool, camphor, benzyl benzoate, or cinnamaldehyde as major components (Jantan & Goh 1990, 1992; Jantan et al., 1994a, 2002, 2003, 2004). The antimicrobial properties of cinnamon oil have been well investigated (Inouye et al., 2003; Kalemba & Kunicka 2003; Ranasinghe et al., 2002). The antimicrobial activities of the essential oils of several *Cinnamomum* species from peninsular Malaysia have been reported (Jantan et al., 1994b; Mohd Ali et al., 2002; Mohtar et al., 1999).

Although the chemical constituents and the antifungal activity of the essential oils of various Malaysian *Cinnamomum* species have been reported, there was little attempt to correlate their constituents and their antifungal activity. In this study, the essential oils of eight *Cinnamomum* species (*C. rhyncophyllum* Miq., *C. microphyllum* Ridl., *C. pubescens* Kochummen, *C. mollissimum* Hook. f., *C. impressicostatum* Kosterm, *C. cordatum* Kosterm, *C. scortechinii* Gamb, and *C. zeylanicum* Blume) were investigated for their antifungal activity against six dermatophytes (*Trichophyton mentagrophytes, T. tonsurans, T. rubrum, Microsporum canis, M. gypseum*, and *M. audouini*), five isolates of yeast-like fungi (*Candida albicans, C. glabrata, C. parapsilosis, C. tropicalis, and Crytococcus neoformans*), and one filamentous fungi (*Aspergillus fumigatus*). The chemical composition of the essential oils was analyzed by GC and GC-MS. In addition, the antifungal activities of 13 known constituents (methyl cinnamate, linalool, cinnnamaldehyde, benzyl benzoate, 1,8-cineole, benzyl salicylate, methyl eugenol, eugenol, camphor, terpineols, safrole, terpinen-4-ol, geraniol) of the essential oils of the *Cinnamomum* oils were also investigated in an effort to correlate the effectiveness of the oils with those of the components of the oils.

Materials and Methods

The fresh samples of seven *Cinnamomum* species (*C. rhyncophyllum*, *C. microphyllum.*, *C. pubescens*, *C. mollissimum., C. impressicostatum*, *C. scortechinii*, and *C. cordatum*) were collected from Gunung Berembun (altitude 1500 m) in Cameron Highlands, Pahang, Malaysia, in June 2002. *C. zeylanicum* was obtained from the Forest Research Institute of Malaysia (FRIM) in September 2002. The voucher specimens were identified and deposited at the Herbarium of FRIM, Kepong.

The plant materials were air-dried, comminuted, and 150 g of each sample was hydrodistilled in a Clevenger-type apparatus for 8 h. The oily layers obtained were separated and dried over anhydrous magnesium sulfate. The yields were averaged over three experiments and calculated based on dry weight of the plant materials. The yield of oils from each species is given in Table 1.

Table 1. Essential oil yield from different parts of eight Malaysian *Cinnamomum* species.

Species	Voucher number	Part used	Yield* (%)
C. rhyncophyllum	FRI 44095	Leaf	3.5 ± 0.4
		Bark	1.5 ± 0.3
C. microphyllum	FRI 44089	Leaf	3.3 ± 0.2
C. pubescens	FRI 44097	Leaf	5.4 ± 0.3
		Bark	3.6 ± 0.3
		Twig	1.9 ± 0.2
C. mollissimum	FRI 44082	Leaf	2.8 ± 0.1
C. impressicostatum	FRI 44094	Leaf	4.8 ± 0.4
		Bark	3.2 ± 0.2
		Twig	2.4 ± 0.3
C. cordatum	FRI 44083	Leaf	0.8 ± 0.1
C. scortechinii	FRI 44086	Leaf	0.5 ± 0.1
C. zeylanicum	FRI 44102	Leaf	5.5 ± 0.3
		Bark	1.5 ± 0.3

*On a dry weight basis.

The following fungi were obtained from the Institute for Medical Research, Kuala Lumpur; seven dermatophytes, i.e., *Trichophyton mentagrophytes* (clinical isolation), *T. tonsurans* (T14 -Australian QC), *T. rubrum* (T28 -Australian QC), *Microsporum canis* (M17), *M. gypseum* (M141) *M. audouini* (M142) and *Aspergillus fumigatus* (A31); five isolates of yeast-like fungi, i.e., *Candida albicans* (ATCC 10231), *C. glabrata* (ATCC 1300), *C. parapsilosis* (ATCC 200219), *C. tropicalis* (ATCC 7110), and *Crytococcus neoformans* (C6185). The fungi were maintained on potato dextrose agar (PDA) plates (Merck, Darmstadt, Germany) at 30°C. The fungi were subcultured in antibiotic medium 3 agar (M-3) (Sigma, St. Louis, MO, USA) and incubated at 37°C overnight. Each fungal culture was diluted with sterile 0.85% sodium chloride solution to produce a cell suspension containing 1×10^6 to 5×10^6 organisms per milliliter and to obtain a turbidity comparable with that of McFarland standard tube No. 0.5. The inoculum size was determined spectrophotometrically at 530 nm and further confirmed by using a Neubauer counting chamber.

The antifungal activity of the essential oils and the essential oil standards (methyl cinnamate, linalool, cinnamaldehyde, benzyl benzoate, benzyl salicylate, 1,8-cineole, methyl eugenol, eugenol, geraniol, camphor, terpineols, safrole, terpinen-4-ol) were analyzed by the broth microdilution method according to NCCLS (1998) with a slight modification. The experiments were carried out in a class 2 laminar flow cabinet. Sterility conditions were maintained throughout the experiments. Serial dilutions of the essential oil solutions and 13 essential oil standards were placed in Eppendorf tubes labeled A to H. Tube A was filled with 100 μL of essential oil stock solution (500 μg μL^{-1}, DMSO). Only 50 μL of the stock solution in tube A was

transferred to tube B and diluted with 50 μL of DMSO. The procedure was repeated for solutions in tubes B to H. Each well was diluted with M-3 broth to obtain concentrations ranging from 10.0 to 0.08 μg μL^{-1}; 100 μL from each tube was then transferred to 96-well microtiter plates. Each well was then filled with 100 μL fungal suspension to obtain serial dilution of the test materials (5, 2.5, 1.25, 0.63, 0.31, 0.16, 0.08, and 0.04 μg μL^{-1}), and the mixtures were stirred thoroughly and incubated at 35°C overnight for the yeasts and *Aspergillus fumigatus* and for 4 days at 30°C for the dermatophytes. Amphotericin B (50 μg mL^{-1}) was used as a positive control, and 1% DMSO served as a negative control. Turbidity was taken as an indication of growth, and the lowest concentration that remained clear after macroscopic evaluation was recorded as the minimum inhibitory concentration (MIC). The MIC value was recorded as the mean concentration of duplicates. MIC value of <1.0 μg μL^{-1}was considered as strong, and values between 1.0 and 4.9 μg μL^{-1} and those ≥5 μg μl^{-1} were categorized as moderate and weak, respectively.

The oils were analyzed on a Shimadzu GC 2000 chromatograph (Asia Pacific, Singapore) equipped with a flame ionization detector (FID) detector using a DB-5 capillary column (25 m × 0.25 mm, 0.25-μm film thickness). The operation parameters were nitrogen as carrier gas at 50 cm/s, injector and detector temperatures maintained at 250°C. The column was programmed initially at 75°C for 10 min, then 3°C min^{-1} to 210°C and held for 1 min. The oils were also examined using a DB-1 stationary phase column (25 m × 0.25 mm, 0.25-μm film thickness) programmed from 60°C for 10 min, then 3°C min^{-1} to 180°C and held for 10 min. Peak areas and retention times were measured by electronic integration. The relative amounts of individual components are based on peak areas obtained, without FID response factor correction. Temperature program linear retention indices of the compounds were also determined relative to *n*-alkanes (Kovats, 1965). The oils were also analyzed by GC-MS with a Hewlett-Packard GC-MSD 5890 series 2 mass spectrometer (70 eV direct inlet) on a BPX5 column (30 m × 0.25 mm, 0.25-μm film thickness) initially at 75°C for 10 min, then 3°C min^{-1} to 210°C and held for 1 min with helium as carrier gas. The constituents were identified by comparison of their retention indices with literature values and their mass spectral data with those from the Wiley mass spectral database and in some cases by co-chromatography on the different columns with authentic samples (Adams, 2001; McLafferty & Staufer, 1989).

Results and Discussion

Results obtained from the broth microdilution assay of the controls indicated that the solvents had no effect on the fungi after 48 and 96 h of incubation, and the organisms grew well during incubation. Sterility conditions were also maintained throughout the experiments. Most of the 14 essential oils studied were strongly to moderately effective against the fungi, with MIC values ranging from 0.04 to 2.50 μg μL^{-1}(Table 2). Among the oils, the leaf and bark oils of *C. zeylanicum* showed the highest activity against all the fungi with relatively low MIC values of 0.04 to 0.63 μg μL^{-1}. Other oils that showed strong inhibition on a wide spectrum of fungal growth were the leaf oil of *C. cordatum* and bark and twig oils of *C. pubescens* and *C. impressicostatum*. The remaining oils showed selective toxicity against the dermatophytes but weaker activity against the yeasts. In fact, the dermatophytes were more susceptible to all the essential oils than were the yeasts, with all oils

Table 2. The minimum inhibitory concentrations (μg μL^{-1}) of the essential oils of *Cinnamomum* species.

Species	Parts	Ca	Cp	Ct	Cg	Cr	Af	Tr	Tm	Tt	Mg	Ma	Mc
C. pubescens	Leaf	>5.00	2.50	3.75	>5.00	0.63	3.75	<0.04	0.16	<0.04	0.08	0.08	0.16
	Bark	0.63	0.63	0.63	1.25	0.63	0.31	0.31	0.31	0.16	0.08	<0.04	0.16
	Twig	0.63	0.63	0.63	0.63	0.63	0.31	0.08	0.16	0.16	0.16	0.08	0.16
C. impressicostatum	Leaf	2.50	2.50	3.75	>5.00	0.63	3.75	0.08	0.16	<0.04	0.16	<0.04	0.16
	Bark	0.63	1.25	1.25	1.25	1.25	0.63	0.31	0.31	0.16	0.08	<0.04	0.16
	Twig	0.63	0.63	1.25	1.25	0.63	0.63	0.08	0.31	<0.04	<0.04	<0.04	0.16
C. rhyncophyllum	Leaf	>5.00	2.50	3.75	>5.00	0.63	3.75	0.16	0.16	0.08	0.16	0.16	0.16
	Bark	0.63	1.25	2.50	1.25	1.25	0.63	0.16	0.31	0.16	0.16	< 0.04	0.08
C. cordatum	Leaf	0.63	0.31	1.25	0.63	1.25	0.63	0.31	0.16	0.16	0.08	<0.04	0.78
C. zeylanicum	Leaf	0.63	0.31	0.31	0.31	0.31	0.31	0.08	0.08	0.08	0.08	<0.04	0.16
	Bark	0.16	0.08	0.16	0.16	0.16	0.16	0.08	0.08	<0.04	0.08	<0.04	0.08
C. microphyllum	Leaf	>5.00	2.50	3.75	>5.00	0.63	3.75	0.16	0.16	0.08	0.31	0.08	0.16
C. mollissimum	Leaf	>2.50	>2.50	>2.50	>2.50	>2.50	>2.50	0.16	0.16	0.08	0.31	0.08	0.16
C. scortechini	Leaf	1.25	0.63	2.50	1.25	2.50	0.93	0.08	0.16	0.08	0.08	0.08	0.16
Amphotericin		—	—	—	—	—	—	—	—	—	—	—	—

Ca, *Candida albicans*; Cp, C. *parapsilosis*; Ct, C. *tropicalis*; Cg, C. *glabrata*; Cr, *Cryptococcus neoformans*; Af, *Aspergillus fumigatus*; Tr, *Trichophyton rubrum*; Tm, *T. mentagrophytes*; Tt, *T. tonsurans*; Mg, *Microsporum gypseum*; Ma, *M. audouini*; Mc, *M. canis*, –, no growth.

Table 3. The minimum inhibitory concentrations ($\mu g\ \mu L^{-1}$) of the essential oil standards.

Species	Ca	Cp	Ct	Cg	Cr	Af	Tr	Tm	Tt	Mg	Ma	Mc
Methyl (*E*)-cinnamate	0.63	0.63	0.63	1.25	0.63	1.56	0.16	0.31	0.31	0.08	0.08	0.16
Linalool	0.63	0.31	0.63	1.25	0.31	1.56	0.16	0.31	0.31	0.16	0.16	0.63
Cinnamaldehyde	0.08	0.08	0.08	0.16	<0.04	<0.04	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Benzyl benzoate	0.31	0.31	0.63	0.31	0.63	1.56	<0.04	<0.04	0.16	0.08	0.08	0.16
Benzyl salicylate	>5.00	>5.00	>5.00	3.70	0.63	0.63	<0.04	<0.04	0.16	<0.04	<0.04	0.08
1,8-Cineole	>5.00	>5.00	>5.00	2.50	2.50	0.31	0.31	0.63	0.16	0.63	0.31	1.25
Methyl eugenol	1.25	0.63	1.25	1.25	1.25	0.63	0.16	0.16	0.31	0.16	0.16	0.31
Eugenol	0.63	0.31	0.63	0.63	0.63	0.16	0.16	0.08	0.08	0.08	<0.04	0.16
Geraniol	0.31	0.31	0.31	0.31	0.31	0.31	<0.04	0.16	0.08	0.08	<0.04	0.16
Camphor	3.75	3.75	2.50	1.25	2.50	0.31	0.31	0.31	0.31	0.31	0.08	0.31
α-Terpineol	1.25	1.25	1.25	1.25	1.25	1.87	0.63	0.31	0.31	0.63	0.31	0.31
Safrole	1.25	1.25	1.25	1.25	1.25	1.25	0.31	0.63	0.16	0.31	0.31	0.31
Terpinen-4-ol	1.25	1.25	1.25	0.93	0.63	1.25	0.63	1.25	0.31	0.63	0.31	0.31
Amphotericin	—	—	—	—	—	—	—	—	—	—	—	—

Ca, *Candida albicans*; Cp, C. *parapsilosis*; Ct, C. *tropicalis*; Cg, C. *glabrata*; Cr, *Cryptococcus neoformans*; Af, *Aspergillus fumigatus*; Tr, *Trichophyton rubrum*; Tm, *T. mentagrophytes*; Tt, *T. tonsurans*; Mg, *Microsporum gypseum*; Ma, *M. audouini*; Mc, *M. canis*, –, no growth.

exhibiting MIC values of $<0.31\ \mu g\ \mu L^{-1}$. *Microsporum audouini* appeared to be the most susceptible dermatophyte with all oils displaying MIC values of $<0.08\ \mu g\ \mu L^{-1}$. The most resistant yeast was *Candida glabrata*, with most oils exhibiting MIC values $>1.25\ \mu g\ \mu L^{-1}$, and four oils showed values $>5.0\ \mu g\ \mu L^{-1}$ (Table 2).

The antifungal activity of 13 standard compounds (methyl cinnamate, linalool, cinnamaldehyde, benzyl benzoate, benzyl salicylate, 1,8-cineole, methyl eugenol, eugenol, geraniol, camphor, terpineols, safrole, terpinen-4-ol) that are commonly found as major components in *Cinnamomum* oils were also investigated. All the standard samples tested were effective against the fungi, exhibiting MIC values of $<1.25\ \mu g\ \mu L^{-1}$, with the exception of benzyl salicylate, 1,8-cineole, and camphor and which showed relatively weak to moderate activity against the yeasts but strong activity against the dermatophytes (Table 3). As the essential oils, the activity of the standard samples towards the fungi was selective as they were more effective against the dermatophytes (MIC values $<0.63\ \mu g\ \mu L^{-1}$). Cinnamaldehyde was found to be the most active compound, with MIC values of $0.16\ \mu g\ \mu L^{-1}$ against the resistant *C. glabrata* and $<0.08\ \mu g\ \mu L^{-1}$ against the rest. Geraniol and eugenol were the other standards that exhibited comparably strong effects against all the fungi with MIC values of $<0.63\ \mu g\ \mu L^{-1}$.

The chemical composition of the essential oils was investigated in an effort to correlate the constituents of the oils and their antifungal activities. The list of constituents identified in the oils is shown in order of elution on a DB-5 type column (Table 4). A comparison between the chemical composition of the oils in this study and those previously reported by us indicated that there was little compositional differences but slight variation in amounts of individual component in some oils (Jantan & Goh, 1990, 1992; Jantan et al., 1994a, 2002, 2003, 2004). The nature of the twig oils of *C. pubescens* and *C. impressicostatum* is described for the first time as they have not been reported elsewhere. They were found to possess some compositional similarity in that the major constituents were methyl (*E*)-cinnamate and benzyl benzoate. Methyl (*E*)-cinnamate constituted 84.0% and 67.6% of the twig oils of *C. pubescens* and *C. impressicostatum*, respectively, and benzyl benzoate made up 11.1% and 8.2% of the oils, respectively. The twig oil of *C. impressicostatum* can be differentiated from that of *C. pubescens* in that it contains a greater number and higher amounts of monoterpenoids and sesquiterpenoids. Monoterpenoids in the former were represented by 10 compounds where α-terpinene (7.8%) and β-phellandrene (2.4%) were the major representatives, and seven sesquiterpenoids accounted for 1.5% of the oil. The oil also contained safrole (1.5%), eugenol (1.5%), and methyl (*Z*)-cinnamate (0.4%), which were absent in the twig oils of *C. pubescens*.

Based on the results of the antifungal assays on the essential oils and standard samples, a chemical composition-antifungal relationship analysis was determined. The results demonstrate that the strong antifungal activity of the bark and leaf oils of *C. zeylanicum* is related to the high levels of cinnamaldehyde (44.2%) and eugenol (90.2%), respectively, although other constituents may also contribute to the activity of the oils (Tables 2, 3, and 4). Previous studies have also indicated that cinnamaldehyde present as major component was responsible for the high antifungal activity of cinnamon oil (Ferhout et al., 1999; Simic et al., 2004). The presence of high levels of methyl (*E*)-cinnamate in the bark and twig oils of *C. pubescens* (95.2% and 84.0%, respectively) and *C. impressicostatum* (85.9% and 67.6%, respectively) could explain their strong inhibition on a wide spectrum of fungal growth. The presence of high amounts of benzyl benzoate (>50%) in the leaf oils of *C. rhynchophyllum, C. microphyllum, C. pubescens, C. impressicostatum,* and *C. mollissimum* could explain the selective toxicity of

Table 4. Percentage composition of the essential oils of *Cinnamomum rhyncophyllum*, *C. cordatum*, *C. microphyllum*, *C. scortechinii*, *C. pubescens, C. impressicostatum, C. mollissimum,* and *C. zeylanicum*.

Compound	Rhy (L)	Rhy (B)	Cor (L)	Mic (L)	Sco (L)	Pub (L)	Pub (B)	Pub (T)	Imp (L)	Imp (B)	Imp (T)	Mol (L)	Zey (L)	Zey (B)
Styrene	—	—	—	—	—	—	—	—	—	—	—	—	—	0.6
α-Thujene	0.2	0.1	0.2	—	0.7	0.2	—	—	0.2	—	—	—	0.1	0.3
α-Pinene	3.5	0.1	1.7	0.1	1.7	1.8			3.9		0.4		0.4	2.0
Benzaldehyde	—	—	—	1.0	—	—	—	—	—	—	—	0.2	0.1	0.2
Sabinene	1.5	0.1	1.3	0.1	2.4	1.7	t	—	—	—	0.2	—	—	t
β-Pinene	2.7	—	1.1	0.1	1.6	1.2	—	—	3.4	—	0.4	0.1	0.1	0.3
Myrcene	1.1	—	1.2	t	2.4	0.8	—	—	1.4	—	0.4	—	0.1	t
α-Phellandrene	0.5	—	2.6	—	0.8	1.7	—	—	12.3	—	0.4	—	0.3	2.8
α-Terpinene	0.1	—	0.6	—	—	—	—	—	0.2	—	7.8	—	—	—
p-Cymene	0.7	0.2	1.5	—	—	11.7	t	0.4	7.0	0.1	—	1.9	0.3	4.0
Limonene	0.3	—	2.4	0.1	6.8	—	—	—	4.8	—	—	—	—	—
β-Phellandrene	10.0	—	9.0	—	17.3	1.1	—	0.3	2.2	—	2.6	—	0.5	8.0
1,8-Cineole		—	0.3	t	—	—	0.1	—	—	—	—	1.0	—	—
δ-3-Carene	t	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzyl alcohol	—	—	—	2.1	—	—	—	—	—	—	—	—	—	—
(*Z*)-β-Ocimene	—	—	—	—	—	0.1	—	—	0.2	—	—	—	—	—
(*E*)-β-Ocimene	—	—	—	—	—	—	—	—	0.2	—	—	—	—	—
γ−Terpinene	0.3	0.1	1.5	—	0.3	—	—	—	0.3	0.1	—	—	—	0.2
trans-Linalool oxide	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—
cis-Linalool oxide	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—
Terpinolene	t	—	0.5	—	0.2	—	—	—	0.1	—	—	—	t	0.4
Linalool	0.4	t	17.3	1.4	16.4	—	t	0.2	0.1	—	0.4	0.6	0.2	4.8
Camphor	—	0.1	0.4	0.2	—	—	—	—	—	—	—	—	—	—
Isopulegol	—	—	—	—	0.3	—	—	—	—	—	—	—	—	—
Citronellal	—	—	0.3	—	—	—	—	—	—	—	—	—	—	—
Borneol	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—
Terpinen-4-ol	1.1	0.5	7.0	t	6.6	0.6	0.3	0.5	0.8	0.3	0.9	0.4	t	0.9
α-Terpineol	0.4	0.2	3.6	0.1	2.3	0.2	0.5	0.7	0.4	1.0	0.6	0.3	t	1.6
Cinnamaldehyde	—	—	—	—	—	—	—	—	—	—	—	—	—	44.2
cis-Piperitol	—	—	0.2	—	0.3	—	—	0.1	—	—	—	—	—	—
Nerol	—	—	0.2	—	0.3	—	—	—	—	—	—	—	—	—
Geraniol	—	—	0.8	0.3	0.6	—	—	—	—	—	—	—	—	—
Safrole	0.7	41.5	0.1	—	0.2	—	3.0	—	0.2	7.5	1.5	—	—	—
Methyl(*Z*)-cinnamate	—	—	—	—	—	—	—	—	—	—	0.4	—	—	—
Eugenol	0.1		0.1	0.1	—	—	—	—	—	—	—	1.5	90.2	1.6
Methyl(*E*)-cinnamate	4.3	41.7	17.1	—	—	1.8	95.2	84.0	1.0	85.9	67.6	—	—	0.6
β-Bourbonene	—	—	—	—	0.3	—	—	—	—	—	—	—	—	—
Neryl acetate	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—
α-Copaene	—	—	—	—	—	—	—	—	—	—	—	—	—	4.8
β-Elemene	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—
Methyl eugenol	0.2	1.8	4.4	t	—	—	—	—	—	—	—	0.4	0.1	—
cis-α-Bergamotene	—	—	—	—	—	—	—	—	0.3	—	—	0.6	—	—
β−Caryophyllene	0.4	0.1	0.3	1.2	0.2	—	—	—	0.3	—	—	—	2.0	6.9
trans-α-Bergamotene	—	—	—	—	—	—	—	—	0.1	—	—	0.1	—	0.2
Aromadendrene	—	—	0.3	0.1	0.4	—	—	—	—	—	—	—	—	0.1
β-(Z)-Farnesene	—	—	—	—	—	—	—	—	—	—	0.3	—	—	—
α-Humulene	1.1	0.1	0.2	0.6	0.1	0.4	—	—	1.0	—	0.1	1.5	—	1.5
β-(E)-Farnesene	—	—	—	0.2	0.2	0.1	—	—	—	0.1	0.2	—	—	—
Curcumene	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—
γ-Muurolene	—	—	0.2	—	—	—	—	—	—	—	—	—	—	0.3
β-Selinene	0.1	—	—	0.6	—	—	—	—	—	—	—	—	0.4	—
cis-β-Guaiene	0.1	—	t	—	—	—	—	—	—	—	—	—	—	—
α-(E,E)-Farnesene	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—
β-Bisabolene	—	—	—	—	—	—	—	0.1	—	—	0.2	0.2	—	—
γ-Cadinene	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—
δ-Cadinene	0.1	—	0.9	—	0.3	—	—	—	—	—	0.1	—	t	0.7

(Continued on next page)

Table 4. Percentage composition of the essential oils of *Cinnamomum rhyncophyllum*, *C. cordatum*, *C. microphyllum*, *C. scortechinii*, *C. pubescens, C. impressicostatum, C. mollissimum,* and *C. zeylanicum. (Continued)*

Compound	Rhy (L)	Rhy (B)	Cor (L)	Mic (L)	Sco (L)	Pub (L)	Pub (B)	Pub (T)	Imp (L)	Imp (B)	Imp (T)	Mol (L)	Zey (L)	Zey (B)
(*Z*)-Nerolidol	—	—	0.7	—	—	—	—	—	—	—	—	—	—	—
(*E*)-Nerolidol	—	—	—	0.2	—	—	—	—	—	—	—	—	—	—
Spathulenol	0.1	0.1	1.6	0.8	1.7	—	—	—	—	—	—	—	—	—
Caryophyllne oxide	—	—	—	—	—	—	—	—	—	—	—	0.5	—	—
Globulol —		—	1.6	1.7	1.2	—	—	—	—	—	0.5	—	t	—
Viridiflorol	—	—	1.4	—	—	—	—	—	—	—	—	—	—	—
β-Eudesmol	—	—	0.5	0.4	0.6	—	—	—	—	—	—	—	—	—
α- Eudesmol	—	—	0.3	—	0.3	—	—	—	—	—	—	—	—	—
(*E*, *Z*)-Farnesol	—	—	—	0.1	0.3	—	—	—	—	—	—	—	—	—
(*E*)-Asarone	—	0.1	0.1	—	—	—	—	—	—	—	—	—	—	—
Benzyl benzoote	70.0	13.0	7.6	87.8	13.5	50.2	—	11.1	50.9	2.0	8.2	87.6	—	—
Benzyl salicylate	—	—	4.7	—	9.4	23.4	—	—	7.5	0.3	—	0.2	—	—

Percentages were obtained by peak-area normalization on column DB-5, all relative response factors being taken as one.
t,trace; Rhy , *C. rhyncophyllum*; Cor, *C. cordatum*; Mic, *C. microphyllum*; Sco, *C. scortechinii;* Pub, *C. pubescens*; Imp, *C. impressicostatum;* Mol, *C. mollissimum;* Zey, *C. zeylanicum*; L, leaf; B, bark; T, twig.

the oils against the dermatophytes and *Crytococcus neoformans* but weak to moderate activity toward all the *Candida* spp. and *Aspergillus fumigatus* (Tables 2, 3, and 4).

The high antifungal activity of the leaf oil of *C. cordatum* could be possibly due to synergy between methyl (*E*)-cinnamate (17.1%), linalool (17.3%), terpinen-4-ol (7.0%), methyl eugenol (4.4%), and α-terpineol (3.6%). The presence of linalool (16.4%), benzyl benzoate (13.5%), benzyl salicylate (9.4%), terpinen-4-ol (6.6%) and α-terpineol (2.3%) could possibly produce a synergistic effect on the overall antifungal activity of the oil of *C. scortechinii* (Tables 2, 3 and 4). The less abundant constituents of the oils especially the monoterpenoids could also be involved in the overall antifungal activity of the oils. Pattnaik and co-workers (1997) reported that the nature and proportion of individual constituents of an essential oil and their synergistic effects have strong influence on the antimicrobial activity of the oil. The inhibitory activity may be due to the different modes of action of the total components of the oils toward the fungi.

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