NPC Natural Product Communications

2012
Vol. 7
No. 2
261 - 264

Composition, Antioxidant, Antimicrobial and Anti-wood-decay Fungal Activities of the Twig Essential Oil of *Taiwania cryptomerioides* from Taiwan

Chen-Lung Ho[a], Su- Sing Yang[b], Tsong-Min Chang[b] and Yu-Chang Su[c*]

[a]*Division of Wood Cellulose, Taiwan Forestry Research Institute. 53, Nanhai Rd., Taipei, Taiwan 100*

[b]*Department of Applied Cosmetology and Master Program of Cosmetic Science, Hungkuang University. 34, Chung-Chie Rd., Taichung, Taiwan 443*

[c]*Department of Forestry, National Chung Hsing University, 250 Kuo Kuang Rd., Taichung, Taiwan 402*

ycsu@nchu.edu.tw

Received: December 18th, 2011; Accepted: January 20th, 2012

This study investigated the chemical composition, antioxidant, antimicrobial and anti-wood-decay fungal activities of the essential oil isolated from the twigs of *Taiwania cryptomerioides* from Taiwan. The essential oil was isolated using hydrodistillation in a Clevenger-type apparatus, and characterized by GC–FID and GC–MS. A total of 35 compounds were identified, representing 100% of the oil. The main components identified were α-cadinol (45.9%), ferruginol (18.9%) and β-eudesmol (10.8%). The antioxidant activity of the oil was tested by the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging capability test. The results showed an IC_{50} of 90.8 ± 0.2 μg/mL. The active source compound was ferruginol. The antimicrobial activity of the oil was tested by the disc diffusion and micro-broth dilution methods against ten microbial species. The oil exhibited strong growth suppression against Gram-positive bacteria and yeast with inhibition zones of 45~52 mm and MIC values of 31.25~62.5 μg/mL, respectively. The anti-wood-decay fungal activity of the oil was also evaluated. The oil demonstrated excellent activity against four wood-decay-fungal species. For the antimicrobial and anti-wood-decay fungal activities of the oil, the active source compounds were determined to be α-cadinol, β-eudesmol and ferruginol.

Keywords: *Taiwania cryptomerioides*, Cupressaceae, Essential oil, Antioxidant activity, Antimicrobial activity, Anti-wood-decay fungal activity, α-Cadinol, β-Eudesmol, Ferruginol.

Taiwania cryptomerioides Hayata (Cupressaceae) is one of the five most valuable conifers in Taiwan [1]. Many previous studies have demonstrated that the leaf and heartwood essential oils and extractives of *T. cryptomerioides* have inhibitory effects against mites and fungi, as well as having antioxidant and anticancer properties [2-6]. However, no prior study has investigated the chemical composition and biological activity of the twig essential oil. Thus, this was obtained by hydrodistillation, analyzed for its chemical composition, and evaluated for its antioxidant, antimicrobial and anti-wood-decay fungal activities.

A dark-yellow oil was obtained from the twigs in a yield of 0.98 ± 0.03%. Thirty-five compounds were identified (Table 1), of which oxygenated sesquiterpenes were predominant (75.3%), followed by diterpenes (19.8%), sesquiterpene hydrocarbons (4.3%), and oxygenated monoterpenes (0.5%). Among the oxygenated sesquiterpenes, α-cadinol (45.9%) and β-eudesmol (10.8%) were the major compounds, and of the diterpenes, ferruginol (18.9%) was the chief component.

The essential oil was tested for its DPPH free radical scavenging capability. Ascorbic acid was used as a positive control. The IC_{50} of the DPPH free radical scavenging capability of the twig essential oil was 90.8 ± 0.2 μg/mL. The individual main components of the twig essential oil, α-cadinol, β-eudesmol and ferruginol, were also compared for their DPPH free radical scavenging capability. The results in decreasing order were ferruginol (IC_{50} = 48.0 μg/mL), α-cadinol and β-eudesmol (IC_{50} > 2000 μg/mL). Hence, we deduced that ferruginol was mainly responsible for the radical scavenging. The results are also in congruency with the conclusions of several other reports [3,7,8]. The antioxidant activity (IC_{50} value) of *T. cryptomerioides* twig oil was superior to those of the leaf, heartwood, sapwood, bark and twig essential oils of sugi (*Cryptomeria japonica*) [8], which have IC_{50} values of >2000, 327, 113, 580, and 124 μg/mL, respectively. Furthermore, the IC_{50} values of the twig oil and those of the leaf oils of different *Cinnamomum osmophloeum* clone strains, which ranged from 33.4 to 708.5 μg/mL [9], were within the same range.

The twig essential oil of *T. cryptomerioides* was tested against three Gram-positive and five Gram-negative bacteria, as well as two fungi. The results, presented in Table 2, show strong growth suppression against all ten microbes studied. The most sensitive were *Bacillus cereus*, *Staphylococcus aureus*, *S. epidermidis,* and *Candida albicans,* with inhibition zones of 45~52 mm and MIC values of 31.25~62.5 μg/mL, respectively. The essential oil showed superior suppressive activity toward the Gram-positive bacteria than either the Gram-negative bacteria or the fungi. The probable cause of the susceptibility of Gram-positive bacteria and relative tolerance of Gram-negative bacteria to essential oils has been correlated with the presence of a hydrophilic outer layer [11]. It is presumed that penetration of hydrophobic components in Gram-negative microorganisms is more difficult due to the presence of a second physical barrier formed by the outer membrane [12]. In comparison with the antimicrobial activity of the essential oils from *Metasequioa glyptostroboides* [13], *Litsea kostermansii* [14], *L. akoensis* [15], *Machilus pseudolongifolia* [16], and *M. kusanoi* [17] the antimicrobial activity of the twig essential oil of *T. cryptomerioides* was superior. The results validated the excellent antimicrobial activity of *T. cryptomerioides* twig essential oil.

Table 1: Chemical composition of the twig essential oil of *Taiwania cryptomerioides*.

Consituents	RI [a]	Conc.(%)	Identification [b]
Camphor	1146	0.2	MS, KI, ST
Citronellyl acetate	1353	0.4	MS, KI, ST
α-Cedrene	1412	0.2	MS, KI, ST
γ-Muurolene	1480	0.2	MS, KI
α-Muurolene	1500	0.4	MS, KI
γ-Cadinene	1514	0.9	MS, KI
δ-Cadinene	1523	0.3	MS, KI
trans-Calamenene	1529	0.4	MS, KI
α-Cadinene	1539	0.2	MS, KI
α-Calacorene	1546	0.4	MS, KI, ST
Elemol	1550	4.4	MS, KI, ST
Caryophyllene oxide	1583	0.3	MS, KI, ST
Gleenol	1587	0.3	MS, KI
Cedrol	1601	3.7	MS, KI, ST
1,10-di-*epi*-Cubenol	1619	0.8	MS, KI
1-*epi*-Cubenol	1629	1.7	MS, KI
γ-Eudesmol	1632	3.6	MS, KI, ST
β-Eudesmol	1651	10.8	MS, KI, ST
α-Cadinol	1654	45.9	MS, KI, ST
β-Bisabolol	1675	0.6	MS, KI, ST
Cadalene	1677	1.5	MS, KI
cis-14-nor-Muurol-5-en-4-one	1689	0.3	MS, KI
Acorenone b	1697	0.2	MS, KI
epi-Nootkatol	1699	0.1	MS, KI
10-nor-Calamenen-10-one	1702	0.1	MS, KI
13-Hydroxy-valencene	1768	0.3	MS, KI
14-Hydroxy-α-muurolene	1780	0.3	MS, KI
Hinesol acetate	1784	0.8	MS, KI
β-Eudesmol actate	1792	0.8	MS, KI
α-Eudesmol actate	1795	0.4	MS, KI
Kudtdiol	1912	0.3	MS, KI
Sandaracopimarinal	2184	0.2	MS, KI
Phyllocladanol	2210	0.3	MS, KI
Sandaracopimarinol	2269	0.1	MS, KI
Ferruginol	2332	18.9	MS, KI, ST
Compounds identified			
Monoterpene hydrocarbons (%)		0.0	
Oxygenated monoterpenes (%)		0.5	
Sesquiterpene hydrocarbons (%)		4.3	
Oxygenated sesquiterpenes (%)		75.3	
Diterpenes (%)		19.8	
Oil Yield (ml/100 g)		0.98 ± 0.03	

[a] Retention index on a DB-5 column with reference to *n*-alkanes [10].

[b] MS, NIST and Wiley library spectra and the literature; RI, Retention index; ST, authentic standard compounds.

However, to ascertain the source compounds of the antimicrobial activity of *T. cryptomerioides* twig essential oil, the main components were individually tested for antimicrobial activity. Results indicated that the active compounds were α-cadinol, β-eudesmol and ferruginol. Various studies support the argument that these compounds are highly active in suppressing microbial growth [18-21].

The twig essential oil was also tested against two white rot fungi (*Trametes versicolor* and *Phanerochaete chrysosporium*) and two brown rot fungi (*Phaeolus schweinitzii* and *Lenzites sulphureus*). The anti-wood-decay fungal indices presented in Table 3 clearly demonstrate the excellent anti-wood-decay fungal activity of the twig essential oil. Growth of *T. versicolor, Phane. chrysosporium*, *Phaeo. schweintizii* and *L. sulphureus* were completely inhibited at concentrations of 12.5, 12.5, 6.25, and 6.25 μg/mL, respectively. The anti-wood-decay fungal activity of the twig essential oil was superior to those of the essential oils of *Cunninghamia konishii* [22], *Chamaecyparis formosensis* [23] and *C. japonica* [24].

In order to ascertain the active compounds of the *T. cryptomerioides* twig essential oil, we also tested the anti-wood-decay fungal activities of its major components. The results indicated that the sources of activity were also α-cadinol, β-eudesmol and ferruginol. At a 50 μg/mL concentration, α-cadinol showed total growth inhibition against all the white-rot and brown-rot fungi tested, while β-eudesmol and ferruginol at 50 μg/mL could partially inhibit white-rot and brown-rot fungi. The results agree with those of Rudman [25], Kondo and Imamura [21], and Mori *et al.* [26]. Thus, the excellent wood-decay-fungi inhibition activities exhibited by *T. cryptomerioides* twig essential oil could be attributed to the presence of compounds such as α-cadinol, β-eudesmol and ferruginol.

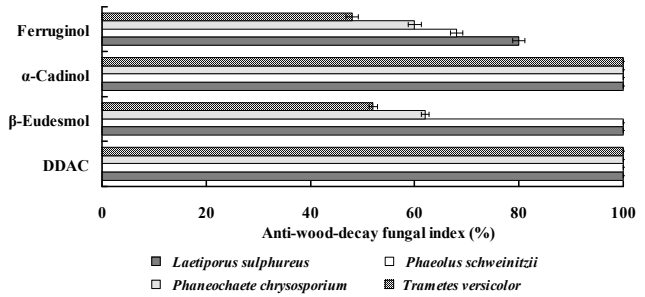

Figure 1: Anti-wood-decay fungal indices of the three main compounds (50 μg/mL) of the twig essential oil of *T. cryptomerioides*.
Note: DDAC (didecyl dimethyl ammonium chloride) (50 μg/mL) is a wood preservative for wood decay fungi and is used as a positive control. Anti-wood-decay-fungal index see Experimental section. Data are expressed as the means ± SD of three independent experiments.

Experimental

Plant materials: Fresh twigs of *T. cryptomerioides* were collected in June 2011 from Chilan Mt in northeast Taiwan (Yilan County, elevation 850 m, N 24º 40′ 50″, 121º 39′ 10″). The samples were compared with specimen no. ou 5996 from the Herbarium of the National Chung-Hsing University and positively identified by Prof. Yen-Hsueh Tseng of NCHU. The voucher specimen (CLH-017) was deposited in the NCHU herbarium. Leaves of the species were collected for subsequent extraction and analysis.

Isolation of the twig essential oil: Twigs of *T. cryptomerioides* (1 Kg) were placed in a round-bottom flask and hydrodistilled for 8 h with 3 L of distilled water. The essential oil obtained was dried

Table 2: Antimicrobial activity of the twig essential oil of *T. cryptomerioides*

Microbial species	*T. cryptomerioides* Twig		Compounds [c]			Antibiotics		
			1	2	3	Tetracycline (30 μg/disk)	Gentamicin (10 μg/disk)	Nystatin (30 μg/disk)
	IZ [a]	MIC [b]	MIC	MIC	MIC	IZ	IZ	IZ
Bacillus cereus	52 ± 0.6	31.25	125	125	15.625	22 ± 0.8	-	nt
Staphylococcus aureus	50 ± 0.4	31.25	62.5	62.5	62.5	21 ± 0.4	-	nt
Staphylococcus epidermidis	50 ± 0.4	31.25	62.5	62.5	15.625	34 ± 0.4	-	nt
Escherichia coli	38 ± 0.8	125	500	750	250	-	22 ± 0.8	nt
Enterobacter aerogenes	32 ± 0.8	250	125	250	250	10 ± 0.4	-	nt
Klebsiella pneumoniae	30 ± 0.4	250	125	250	375	-	21 ± 0.8	nt
Pseudomonas aeruginosa	32 ± 0.8	250	500	750	250	-	12 ± 0.8	nt
Vibrio parahaemolyticus	29 ± 0.4	375	1000	1000	375	-	13 ± 0.8	nt
Aspergillus niger	28 ± 0.4	375	1000	>1000	375	nt	nt	17 ± 0.8
Candida albicans	45 ± 0.4	62.5	125	125	62.5	nt	nt	19 ± 0.8

[a] Inhibition zone diameter (mm), including diameter of sterile disk 6 mm; values are given as mean ± SD.[b] Minimum inhibitory concentration values as μg/mL. [c] 1. β-eudesmol (≥ 99.5%), 2. α-cadinol (100%), 3. Ferruginol (100%). Compound 1 was purchased from the Fluka Co. (Milwaukee, USA), whereas compound 2 was from an isolate of Ho *et al*'s study on *Machilus philippinenesis* essential oil [27]; compound 3 was from an isolate of Ho *et al.*'s study of *Cryptomeria japonica* essential oil [8]. Essential oil tested at 15 μL/disc for bacteria and 30 μL/disc for fungi.(-), Inactive; nt, not tested.

Table 3: Anti-wood-decay fungal indices of twig essential oil of *T. cryptomerioides.*

Dosage (μg/mL)	Antifungal index [a] (%)			
	Trametes versicolor	*Phaneochaete chrysosporium*	*Phaeolus schweinitzii*	*Lenzites sulphureus*
6.25	81 ± 6.6	82 ± 3.3	100 ± 0 [b]	100 ± 0
12.5	100 ± 0	100 ± 0	100 ± 0	100 ± 0
25	100 ± 0	100 ± 0	100 ± 0	100 ± 0
50	100 ± 0	100 ± 0	100 ± 0	100 ± 0
75	100 ± 0	100 ± 0	100 ± 0	100 ± 0
100	100 ± 0	100 ± 0	100 ± 0	100 ± 0

[a] Antifungal index see Experimental section. [b] 100 ± 0 % = complete growth inhibition of mycelium. Data are expressed as the means ± SD of three independent experiments.

with anhydrous sodium sulfate. The oil yield and all test data are expressed as the means ± SD of 3 independent experiments.

Essential oil analysis and component identification: The experimental conditions for GC analysis of the essential oil were similar to those reported earlier [16]. Identification of the oil constituents was based on comparisons of retention index (RI) [10], retention times (RT), and mass spectra with those obtained from authentic standards and/or the NIST and Wiley libraries spectra, and literature [10,28], respectively.

DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging capability test: The method of Ho *et al*. [8] was used. Fifty μL of various dilutions of the oils were mixed with 5 mL of a 0.004% methanol solution of DPPH. After an incubation period of 30 min, the absorbance of the samples was determined at 517 nm using a Jasco 7800 spectrophotometer. Ascorbic acid was used as a positive control. Data are expressed as the means ± SD of 3 independent experiments.

Antimicrobial activity* [29]*: Discs containing 15 μL and 30 μL of the oil dissolved in dimethylsulfoxide (DMSO) were placed on the inoculated plates with test microorganisms. Growth inhibition zones (including disc diameter of 6 mm) were measured after 24 h and 48 h of incubation at 37°C and 24°C for bacteria and fungi, respectively. Gentamicin and tetracycline for bacteria, and nystatin for fungi were used as positive controls. Microbial strains were obtained from the Culture Collection and Research Center of the Food Industry Research and Development Institute, Hsinchu City, Taiwan. The microbial strains included 5 Gram-negative bacteria: *Escherichia coli* (IFO 3301), *Enterobacter aerogenes* (ATCC 13048), *Klebsiella pneumoniae* (ATCC 4352), *Pseudomonas aeruginosa* (IFO 3080), and *Vibrio parahaemolyticus* (ATCC 17803); 3 Gram-positive bacteria: *B. cereus* (ATCC 11778), *S. aureus* (ATCC 6538P), and *S. epidermidis* (ATCC 12228); 1 fungus: *Aspergillus niger* (ATCC 16404) and 1 yeast: *Candida albicans* (ATCC 10231). Minimum inhibitory concentration (MIC) values were measured by the microdilution broth susceptibility assay recommended by NCCLS [30] and as reported earlier [16]. Data are expressed as the means ± SD of 3 independent experiments.

Anti-wood-decay fungal assays: The method of Su *et al.* [31] was adopted. The fungi used were *Trametes versicolor* (BCRC 35253), *Phaneochaete chrysosporium* (BCRC 36200), *Phaeolus schweinitzii* (BCRC 35365) and *Lenzites sulphureus* (BCRC 35305). Microbial strains were obtained from the Culture Collection and Research Center of the Food Industry Research and Development Institute, Hsinchu City, Taiwan. Anti-wood-decay fungal assays were carried out in triplicate and the data were averaged. Different concentrations of the essential oil (6.25~100 μg/mL) were added to sterilized potato dextrose agar (PDA). The test plates were incubated at 27ºC. When the mycelium of the fungi reached the edge of the control plate, the anti-wood-decay fungal index was calculated as follows: Anti-wood-decay fungal index (%)= (1–Da/Db) X 100, where Da is the diameter of the growth zone in the experimental dish (cm) and Db is the diameter of the growth zone in the control dish (cm). DDAC (didecyl dimethyl ammonium chloride) was used as a positive control. Data are expressed as the means ± SD of 3 independent experiments.

References

[1] Kuo PC. (**1995**) *The Precious 5 Conifers of Taiwan*. Chinese Forestry Association, Taipei, Taiwan.

[2] Su YC, Ho CL, Wang EIC. (**2006**) Analysis of leaf essential oils from the indigenous five conifers of Taiwan. *Flavour and Fragrance Journal*, ***21***, 447-452.

[3] Wang SY, Wu JH, Shyur LF, Kuo YH, Chang ST. (**2002**) Antioxidant activity of abietane-type diterpenes from heartwood of *Taiwania cryptomerioides* Hayata. *Holzforschung*, ***56***, 487-492.

[4] Chang ST, Wang SY, Wu CL, Chen PF, Kuo YH. (**2000**) Comparison of the antifungal activity of cadinane skeletal sesquiterpenoids from Taiwania (*Taiwania cryptomerioides* Hayata) heartwood. *Holzforschung*, ***54,*** 241-245.

[5] Chang ST, Wang DS, Wu CL, Shiah SG, Kuo YH, Chang CJ. (**2000**) Cytotoxicity of extractives from *Taiwania cryptomerioides* heartwood. *Phytochemistry*, ***55***, 227-232.

[6] Chang ST, Chen PF, Wang SY, Wu HH. (**2001**) Antimite activity of essential oils and their constituents from *Taiwania cryptomerioides*. *Journal of Medical Entomology*, ***38***, 455-457.

[7] Haraguchi H, Ishikawa H, Kubo I. (**1997**) Antioxidative action of diterpenoids from *Podocarpus nagi*. *Planta Medica*, ***63***, 213-215.

[8] Ho CL, Wang EIC, Yu HT, Yu HM, Su YC. (2010) Compositions and antioxidant activities of essential oils of different tissues from *Cryptomeria japonica* D. Don. *Quarterly Journal of Chinese Forestry*, ***32***, 63-76.

[9] Chen IY. (**2003**) The antioxidative properties of leaf essential oils of *Cinnamomum osmophloeum*. MS Thesis, Dept. of Food Tech., Natl. Taiwan Univ., Taipei, Taiwan.

[10] Adams RP. (**2001**) *Identification of Essential Oil Components by Gas Chromatography/Quadruple Mass Spectroscopy*, Allured, Carol Stream, IL.

[11] Kalemba D, Kunicka A. (**2003**) Antibacterial and antifungal properties of essential oils. *Current Medicinal Chemistry*, ***10,*** 813-829.

[12] Mann CM, Cox SD, Markham JL. (**2000**) The outer membrane of *Pseudomonas aeruginosa* NCTC6749 contributes to its tolerance to the essential oil of *Melaleuca alternifolia* (tea tree oil). *Letters in Applied Microbiology*, ***30***, 294-297.

[13] Bajpai VK, Sharif MA, Choi UK, Lee JH, Kang SC. (**2009**) Chemical composition, antibacterial and antioxidant activities of leaf essential oil and extracts of *Metasequioa glyptostroboides* Miki ex Hu. *Food and Chemical Toxicology*, ***47***, 1876-1883

[14] Ho CL, Wang EIC, Hsu KP, Lee PY, Su YC. (**2009**) Composition and antimicrobial activities of the leaf essential oil of *Litsea kostermansii* from Taiwan. *Natural Product Communications*, ***4***, 1123-1126.

[15] Ho CL, Lin CY, Wang EIC, Su YC. (**2011**) Composition, antioxidant and antimicrobial activities of leaf and twig essential oils of *Litsea akoensis* from Taiwan. *Natural Product Communications*, ***6***, 901-904.

[16] Ho CL, Liao PC, Wang EIC, Dong WZ, Su YC. (**2010**) Composition and antimicrobial and anti-wood-decay fungal activities of the leaf essential oils of *Machilus pseudolongifolia* from Taiwan. *Natural Product Communications*, ***5***, 1143-1146.

[17] Ho CL, Hsu KP, Tseng YH, Wang EIC, Liao PC, Chou JC, Lin CN, Su YC. (**2011**) Composition and antimicrobial activities of the leaf essential oil of *Machilus kusanoi* from Taiwan. *Natural Product Communications*, ***6***, 267-270.
[18] Becerra J, Flores C, Mena J, Aqueveque P, Alarcón J, Bittner M, Hernández V, Hoeneisen M, Ruiz E, Silva M. (**2002**) Antifungal and antibacterial activity of diterpenes isolated from wood extractables of Chilean Podocarpaceae. *Boletín de la Sociedad Chilena de Química*, ***47***, 151-157.
[19] Solís C, Becerra J, Flores C, Robledo J, Silva M. (**2004**) Antibacterial and antifungal terpenes from *Pilgerodendron uviferum* (D. Don) Florin. *Journal of the Chilean Chemical Society*, ***49***, 157-161.
[20] Kalemba D, Kunicka A. (**2003**) Antibacterial and antifungal properties of essential oils. *Current Medical Chemistry*, ***10***, 813-829.
[21] Kondo R, Imamura H. (**1986**) Antifungal compounds in heartwood extractives of hinoki (*Chamaecyparis obtuse* Endl.). *Journal of the Japan Wood Research Society*, ***32***, 213-217.
[22] Cheng SS, Lin CY, Gu HJ, Chang ST (**2011**) Antifungal activities and chemical composition of wood and leaf essential oils from *Cunninghamia konishii*. *Journal of Wood Chemistry and Technology*, ***31***, 204-217.
[23] Wang SY, Wu CL, Chu FH, Chien SC, Kuo YH, Shyur LF, Chang ST. (**2005**) Chemical composition and antifungal activities of essential oil isolated from *Chamaecyparis formosensis* Matsum. wood. *Holzforschung*, ***59***, 295-299.
[24] Cheng SS, Lin HY, Chang ST. (**2005**) Chemical composition and antifungal activity of essential oils from different tissues of Japanese cedar (*Cryptomeria japonica*). *Journal of Agricultural and Food Chemistry*, ***53***, 614-619.
[25] Rudman, P. (**1965**) The causes of natural durability in timber. Pt. XVII. The causes of decay and termite resistance in *Callitris columellaris* F. Muell. *Holzforschung*, ***19***, 52-57.
[26] Mori M, Aoyama M, Doi S. (**2000**) Antifungal constituents in the bark of *Magnolia obovata* Thunb. *Journal of Hokkaido Forest Product Research Institute*, ***14***, 1-5.
[27] Ho CL, Hsu KP, Wang EIC, Lin CY, Su YC. (**2010**) Composition and anti-wood-decay fungal activities of the leaf essential oil of *Machilus philippinensis* from Taiwan. *Natural Product Communications*, ***5***, 337-340.
[28] Massada Y. (**1976**) *Analysis of Essential Oil by Gas Chromatography and Spectrometry*, Wiley, New York.
[29] Baron EJ, Finegold SM. (**1990**) Methods for testing antimicrobial effectiveness. In *Diagnostic Microbiology*. Stephanie M. (Ed.). Baltimore, Mosby. 171-194.
[30] NCCLS (**1999**) *National Committee for Clinical Laboratory Standards*. Performance standards for antimicrobial susceptibility testing. 9th International Supplement, Wayne PA., M100-S9.
[31] Su YC, Ho CL, Wang EIC, Chang ST. (**2006**) Antifungal activities and chemical compositions of essential oils from leaves of four Eucalypts. *Taiwan Journal of Forest Science*, ***21***, 49-61.

Review/Account

Natural Product Communications
2012
Volume 7, Number 2

Contents

Continued inside backcover