Journal of Bacteriology and Virology 2007. Vol. 37, No. 3 p.129 – 136

Chemical Composition and Antibacterial Activity Against Oral Bacteria by the Essential Oil of *Artemisia iwayomogi*

Jeong-Dan Cha

Institute of Oral Bioscience and Department of Oral Microbiology, School of Dentistry, Chonbuk National University, Republic of Korea

Received : July 4, 2007
Accepted : August 22, 2007

The aerial part of *Artemisia iwayomogi* KITAMURA has traditionally been used for antitumour, immunomodulating, antimutagenic, antioxidant, antibacterial, antifungal, antipyretic, diuretic, liver protective effect, and choleretic purposes in Korea. The chemical composition of the essential oil obtained from *A. iwayomogi* was analyzed by GC/MS. The essential oil and its major compounds were tested for antibacterial activities against 15 different genera of oral bacteria. The essential oil of *A. iwayomogi* was rich in camphor (17.96%), 1,8-cineole (14.79%), terpinen-4-ol (3.28%), α-terpineol (17.60%), and β-caryophyllene (4.05%). The essential oil of *A. iwayomogi* exhibited considerable inhibitory effects against all obligate anaerobic bacteria (MICs, 0.05 to 0.2 mg/ml; MBCs, 0.1 to 0.4 mg/ml) tested, while its major compounds demonstrated various degrees of growth inhibition.

Key Words: *Artemisia iwayomogi*, Essential oil, Antibacterial activity, Minimum inhibitory concentrations/Minimum bactericidal concentrations (MICs/MBCs)

INTRODUCTION

Essential oils of aromatic plant species are used in industries for the production of soaps, perfumes and toiletries (12,14). Essential oils of aromatic plant species have been found to be antibacterial, antifungal, spasmolytic, and antiplasmodial activity and therapeutic effect in cancer treatment (3~6,15,23). Some oils of aromatic plant species have been shown to have applications in food preservation, pharmacological properties, and aromatherapy (7).

Most *Artemisia* plants have been used in traditional biomedicine for intestinal bacteria, as food, and for many other purposes in Korea. The genus *Artemisia*, one of the largest genera belonging to the Compositae family consisting of more than 350 species, is predominantly distributed in the world (21,26). *Artemisia* species are frequently utilized for the treatment of diseases such as inflammation, hepatitis, cancer, and infections by malaria, fungi, bacteria, and viruses (8,10,18,20,22,26). *A. iwayomogi* KITAMURA. (*A. messerschmidtiana* var. *viridis* Besser, Compositae), locally known as Haninjin or Dowijigi, is a perennial herb easily found in Korea (17). The aerial part of *A. iwayomogi* has traditionally been used for antitumour, immunomodulating, antimutagenic, antioxidant, antibacterial, antifungal, and liver protective effect and choleretic purposes in Korea (2,16,19,30). Moreover, two sesquiterpenes isolated from *A. iwayomogi* are identified as inhibitors of iNOS expression in LPS-activated macrophages (1). The polysaccharide fraction AIP1 from *A. iwayomogi* suppresses apoptotic death of the mouse spleen cells in culture (11).

In this study, the essential oil obtained from *A. iwayomogi* was analyzed for its chemical composition, and then we demonstrated that the essential oil of *A. iwayomogi* exhibits

*Corresponding author: Prof. Dr. Jeong-Dan Cha. Department of Oral Microbiology, School of Dentistry, 664-14 Duckjin-Dong, Duckjin-Ku, Jeonju, Chonbuk, 561-756, Republic of Korea.
Phone: +82-63-270-4022, Fax: +82-63-270-4037,
e-mail: joungdan@chonbuk.ac.kr

antibacterial activity against oral bacteria.

MATHERIALS AND METHODS

1. Plant material and isolation of the essential oil

The aerial parts of *A. iwayomogi* were collected in September 2004 from the area of around Pallang Fall of Yanggu-gun in Korea. The identity was confirmed by Dr. Bong-Seop Kil, College of Natural Science, Wonkwang University. The voucher specimen (JD-05-01) was deposited at the College of Dentistry, Chonbuk National University. The crushed materials of *A. iwayomogi* (1 kg) were air dried and then distilled for 3 h, using a modified Clevenger type apparatus in order to obtain essential oil. Anhydrous sodium sulphate was used to absorb the little water that the essential oil contained. The essential oil was stored in a deep freezer (-70℃) to minimize the loss of volatile compounds.

2. Analysis of physicochemical properties of the essential oil

Refractive indices, optical rotation, and specific gravity were determined according to methods recommended in the French norms AFNOR. The refractive index was determined using an Abbe refractometer (Atago-3T, Tokyo, Japan). Optical rotations were recorded in a 0.5 ml cell of 1 cm length using an ADP 220 polarimeter (Bellingham and Stangley, Kent, UK) at 589 nm.

3. Analysis of the chemical composition of the essential oil

GC analysis was performed on a Hewlett Packard model 5890 series II gas chromatograph (HP, Palo Alto, CA, USA) with a flame ionization detector (FID), a split ratio of 1:35 using two different fused silica capillary column, Suplecowax 10 (60 m×0.32 mm. i.d., 0.25 μm film thickness) and SPB-1 (30 m×0.32 mm, i.d., 0.25 μm film thickness). The injector or detector temperature for each analysis was about 250℃. The carrier gas was nitrogen, at a flow rate of 1.86 ml/min for the Suplecowax 10 column, and nitrogen at a flow rate of 1:20 ml/min for the SPB-1 column. Peak areas were measured by electronic integration. The relative amounts of the individual components were based on the peak areas. The GC-MS was carried out on an HP model 5970 mass spectrometer operating in the EI mode at 70 eV, combined with the GC described above, fitted with an innowax column (60 m×0.25 mm, i.d., 0.25 μm film thickness) and SPB-1 column (30 m×0.32 mm, i.d., 0.25 μm film thickness). The temperature of the column was programmed from 40℃ to 230℃ at 2℃/min. The injector and ion source temperatures were the same as above. The carrier gas was helium at a flow rate of 1.25 ml/min for both analyses. The identification of the chemical constituents was based on comparisons of their relative retention times and mass spectra with those obtained from authentic sample and/or the NIST/NBS and Wiley libraries spectra.

4. Microbial strains

Antimicrobial activities of the essential oil and some of its major components against some oral bacteria and reference strains were determined by the broth dilution method (15). The oral bacterial strains used in this study were: *Streptococcus mutans* ATCC 25175, *Streptococcus sanguinis* ATCC 10556, *Streptococcus sobrinus* ATCC 27607, *Streptococcus ratti* KCTC (Korean collection for type cultures) 3294, *Streptococcus criceti* KCTC 3292, *Streptococcus anginosus* ATCC 31412, *Streptococcus gordonii* ATCC 10558, *Actinobacillus actinomycetemcomitans* ATCC 43717, *Fusobacterium nucleatum* ATCC 10953, *Prevotella intermedia* ATCC 25611, and *Porphylomonas gingivalis* ATCC 33277. The reference strains used in this study were: *Escherichia coli* ATCC 25922, *Staphylococcus aureus* ATCC 29213, *Staphylococcus epidermidis* ATCC 12228, and *Streptococcus pyogenes* ATCC 21059. Brain-heart infusion (BHI) broth supplemented with 1% yeast extract (Difco Laboratories, Detroit, MI, USA) was used for all bacterial strains except *P. intermedia* and *P. gingivalis*. For *P. intermedia* and *P. gingivalis*, BHI broth containing hemin 1 μg/ml (Sigma, St. Louis, MO, USA) and menadione 1 μg/ml (Sigma) was used.

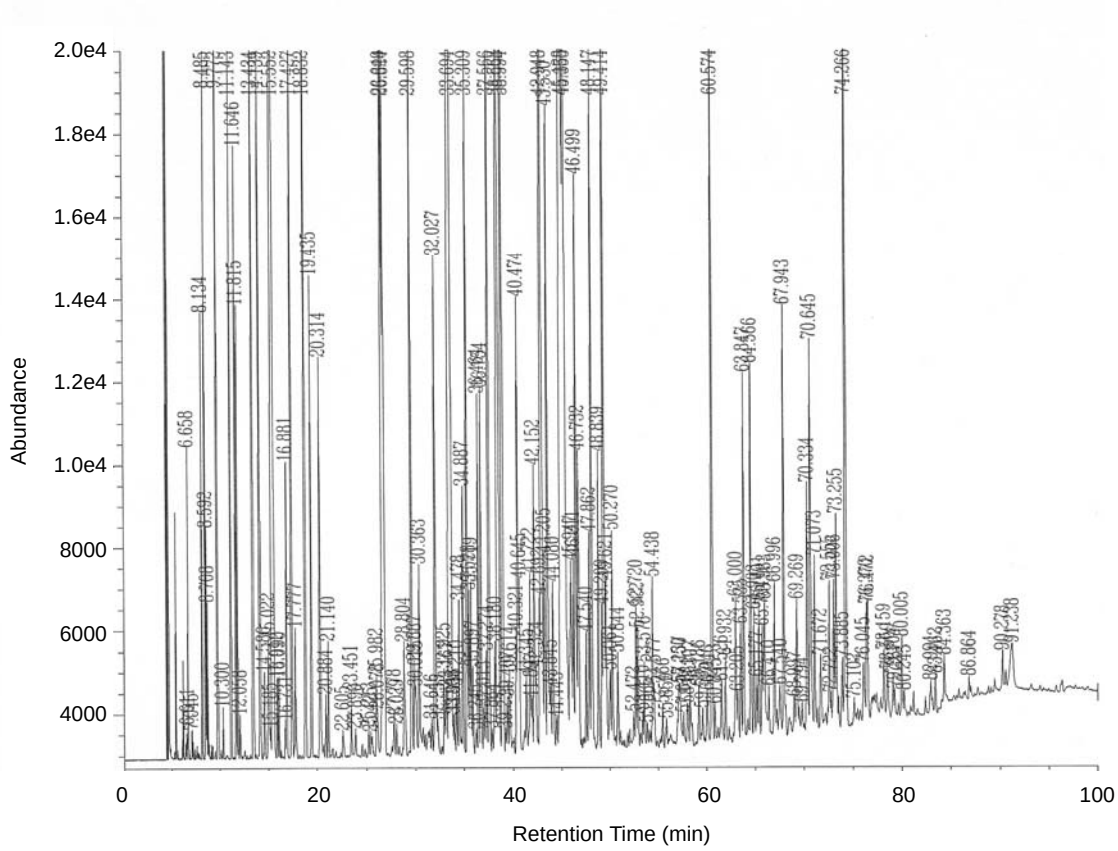

Figure 1. Gas chromatography/mass spectrometric analysis of the essential oil obtained from *Artemisia iwayomogi*

5. Minimum inhibitory concentrations/minimum bactericidal concentrations assay

The minimum inhibitory concentrations (MICs) were determined for the essential oil and some of its major components by the broth dilution method, and were carried out in triplicate. The antibacterial activities were examined after incubation at 37℃ for 18 h ~ 3 days under anaerobic conditions. MICs were determined as the lowest concentration of test samples that resulted in a complete inhibition of visible growth in the broth. Following anaerobic incubation of MICs plates, the minimum bactericidal concentrations (MBCs) were determined on the basis of the lowest concentration of the essential oils that kills 99.9% of the test bacteria by plating out onto each appropriate agar plate. Ampicillin (Sigma) and gentamicin (Sigma) were used as standard antibiotics in order to compare the sensitivity of the oil and its components against test bacteria.

RESULTS

1. Chemical composition of *A. iwayomogi* essential oil

A light green essential oil of *A. iwayomogi* was obtained in a yield of 0.8% fresh weight. The physiochemical properties of the essential oil were $d^{25} = 0.9312$ $n_D^{25} = 1.4751$, $[\alpha]_D^{25} = -17.3$($CHCl_3$, *c* 1.2). In the essential oil of *A. iwayomogi* 102 compounds were identified by GC/MS representing 95.50% (area per cent) of the total oil (Fig. 1 and Table 1). Fourteen monoterpene hydrocarbons (10.74%), thirty-seven oxygenated monoterpenes (66.73%), twenty sesquiterpen hydrocarbons (9.40%), nineteen oxygenated sesquiterpenes (3.95%), and twelve others (5.83%) were identified in the oil. The main compounds with concentrations higher than 3% as percentage peak area of GC analysis were camphor (17.96%), 1,8-cineole (14.79%), terpinen-4-ol (3.28%), α-terpineol (17.60%), and β-caryophyllene (4.05%).

Table 1. Constituents of essential oil of *Artemisia iwayomogi*

Peak no[a]	Compounds	RI[b]	RI[c]	Peak Area (%)[d]
Monoterpene hydrocarbons				**(10.74)**
1	Tricyclene	1006	919	0.18
2	α-Pinene	1012	930	0.33
3	α-Thujene	1029	924	0.09
4	Camphene	1071	943	2.77
5	β-Pinene	1111	966	0.61
6	Sabinene	1124	965	0.32
9	α-Phellandren	1167	994	2.01
10	α-Terpinene	1184	1007	0.86
12	Limonene	1196	1021	0.13
14	*cis*-β-Ocimene	1240	1029	0.19
15	γ-Terpinene	1247	1050	1.24
16	*trans*-β-Ocimene	1257	1035	0.10
17	*p*-Cymene	1273	1011	1.59
18	Terpinolene	1283	1078	0.32
Oxygenated monoterpenes				**(66.73)**
11	2,3-Dehydro-1,8-cineole	1193	978	0.06
13	1,8-Cineole	1215	1023	14.79
21	3-Octanol	1394	979	0.06
22	Yomogi alcohol	1403	984	2.30
23	*trans*-3-Hexen-1-ol	1409	852	1.53
24	α-Thujone	1423	1080	t
25	β-Thujone	1440	1091	0.15
27	*trans*-Sabinene hydrate	1465	1052	0.16
29	Chrysanthenone	1508	1096	0.09
30	Camphor	1517	1124	17.96
33	*iso*-Pinocamphone	1536	1118	0.67
34	Linalool	1546	1106	0.15
35	*cis*-Sabinene hydrate	1550	1130	0.14
36	β-Terpinyl acetate	1561	−	t
37	Pinocarvone	1562	1134	0.30
38	*cis*-*p*-Menth-2-en-1-ol	1566	1104	0.34
39	*cis*-Chrysanthenyl acetate	1570	1243	0.06
40	Bornyl acetate	1578	1265	1.02
43	Terpinen-4-ol	1601	1158	3.28
45	Lavandulyl acetate	1612	1275	0.09
46	Myrtenal	1627	1167	0.44
48	Umbellulone	1639	1165	0.07
49	*trans*-Pinocarvyl acetate	1648	−	0.18
50	*trans*-Pinocarveol	1653	1119	0.30
53	*trans*-Verbenol	1672	1123	0.22
54	*trans*-Piperitol	1676	1205	0.68
57	α-Terpineol	1701	1169	17.60
58	Borneol	1703	1150	2.36
62	Carvone	1732	1210	0.37
63	*cis*-Chrysanthenol	1754	1150	0.20
69	Myrtenol	1793	1177	0.20
71	*trans*-Carveol	1832	1181	0.11
74	*cis*-Myrtanol	1859	1280	0.14
75	*cis*-Carveol	1862	1196	0.14
76	β-Phenylethyl alcohol	1903	1081	0.08
79	Perillyl alcohol	1997	1277	0.07
93	Thymol	2187	1263	0.42
Sesquiterpene hydrocarbons				**(9.40)**
28	δ-Copaene	1490	1369	0.57
31	α-Gurjunene	1525	1389	t
32	Berkheyaradulen	1531	1377	0.14
41	β-Elemene	1589	1381	0.13
42	β-Caryophyllene	1594	1418	4.05
44	Aromadendrene	1609	1447	0.05
47	γ-Elemene	1629	−	0.15
51	γ-Gurjunene	1663	1463	0.11
52	*trans*-β-Farnesene	1668	1454	1.48
55	γ-Muurolene	1686	1464	0.20
56	γ-Cadinene	1690	1497	t
59	β-Selinene	1717	1471	0.34
60	Piperitone	1721	1220	0.16
61	*cis, trans*-α-Farnesene	1726	1447	0.60
64	α-Cadinene	1762	1505	0.10
65	β-Sesquiphellandrene	1770	1515	0.25
66	*ar*-Curcumene	1773	1472	0.12
68	δ-Cadinene	1785	1524	0.77
72	*p*-Cymen-8-ol	1835	1165	0.11
73	*trans*-Myrtanol	1845	−	0.07

Table 1. Continued

Table 1. Continued

Peak no[a]	Compounds	RI[b]	RI[c]	Peak Area (%)[d]
Oxygenated sesquiterpenes				**(3.95)**
77	*iso*-Caryophyllene oxide	1967	1524	0.07
78	Caryophyllene oxide	1979	1556	1.07
80	Eicosane	2000	2000	0.08
82	α-Humulene oxide	2038	1586	0.12
83	*trans*-Nerolidol	2043	1555	0.32
84	Globulol	2058	1568	0.32
85	Viridiflorol	2070	1569	0.05
86	Elemol	2073	1527	0.12
87	Cubenol	2086	1619	0.19
88	Guaiol	2105	1576	0.14
89	Spathulenol	2125	1551	0.35
90	Eugenol	2146	1323	t
91	α-Cedrol	2150	1575	0.15
92	α-Cadinol	2173	1628	0.27
94	α-Eudesmol	2221	1622	0.13
95	Carvacrol	2229	1273	0.17
96	T-Muurolol	2234	1615	0.23
98	*cis, trans*-Farnesol	2298	1695	0.10
100	Caryophyllene alcohol	2357	1607	0.07
Others				**(4.68)**
7	1,4-Dimethylbenzene	1129	936	0.23
8	1,3-Dimethylbenzene	1135	946	t
19	6-Methyl-5-hepten-2-one	1341	−	t
20	*n*-Hexanol	1355	851	t
26	1-Octen-3-ol	1453	969	0.81
67	Methyl salicylate	1782	1173	1.50
70	*p*-Mentha-1(7),8-dien-2-ol	1801	−	0.08
81	Elemyl acetate	2027	−	0.15
97	Ethyl hexadecanoate	2253	1984	1.72
99	Tricosane	2300	2300	0.11
101	Diethyl phthalate	2361	−	t
102	Hexadecanol	2368	1864	0.08
Total identified				**(95.50%)**

[a] Numbering refers to the elution order on a Supelcowax 10 column.
[b] Retention index on a polar Supelcowax 10 column.
[c] Retention index on an apolar SPB-1 column.
[d] Peak area percentage is based on a polar Supelcowax 10 column, and values represent average of three determinations.
t; Trace (<0.05%)

2. Antimicrobial activity

The results of the antibacterial activity (Table 2) showed that the essential oil of *A. iwayomogi* exhibited various activity against all the tested bacteria (MICs 0.05~3.2 mg/ml and MBCs 0.1~3.2 mg/ml). The essential oil showed strong antibacterial activity against *S. mutans*, *S. pyogenes*, *S. sanguinis*, *S. sobrinus*, and *S. gordonii* (MICs 0.1~0.4 mg/ml and MBCs 0.4~0.8 mg/ml) and *F. nucleatum*, *P. intermedia*, and *P. gingivalis* (MICs 0.05~0.2 mg/ml and MBCs 0.1~0.4 mg/ml), while *E. coli*, and *S. epidermidis* appeared to be resistant. The borneol, α-terpineol, and terpinen-4-ol showed strong antibacterial activity against all tested bacteria (MICs 0.05~3.2 mg/ml and MBCs 1~3.2 mg/ml), but the camphor, 1,8-cineole, and β-caryophyllene (MICs 0.4~12.8 mg/ml and MBCs 0.8~12.8 mg/ml) were indicated as low antibacterial activity. *S. gordonii* appeared to be most sensitive by all compounds tested than any other bacteria tested.

DISCUSSION

The main compounds of the *A. iwayomogi* essential oil with concentrations higher than 3% as percentage peak area of GC analysis were camphor (17.96%), 1,8-cineole (14.79%), terpinen-4-ol (3.28%), α-terpineol (17.60%), and β-caryophyllene (4.05%). The analysis of the *A. iwayomogi* essential oil showed that the major components were in agreement with literature reports on the essential oils of other *Artemisia* species (4,5,7,13,18). *Artemisia* species generally contain 1,8-cineole and borneol derivatives, which are widely used in the liqueur-making industry in many countries of the world. The essential oils contained the high proportion of oxygenated monoterpenes have a strong antigal and antioxidant activity (5,7,13,18).

In this study, the *A. iwayomogi* essential oil showed strong antibacterial activity against *S. mutans*, *S. pyogenes*, *S. sanguinis*, *S. sobrinus*, and *S. gordonii* (MICs 0.1~0.4 mg/ml and MBCs 0.4~0.8 mg/ml) and *F. nucleatum*, *P. intermedia*, and *P. gingivalis* (MICs 0.05~0.2 mg/ml and MBCs 0.1~0.4 mg/ml). *Especially*, the *A. iwayomogi* essen-

Table 2. MICs and MBCs (mg/ml) of essential oil and some of its major components of *Artemisia iwayomogi* for some oral bacteria with a few reference strains

Strains	Essential oil	Borneol	α-Terpineol	Camphor	1,8-Cineole	β-Caryophyllene	Terpinen-4-ol	Ampicillin	Gentamicin
Escherichia coli ATCC 25922	3.2/3.2	0.4/0.8	1.6/3.2	12.8/12.8<	3.2/6.4	12.8/12.8<	1.6/1.6	256/256×10^{-3}	8/16×10^{-3}
Staphylococcus aureus ATCC 29213	0.8/0.8	1.6/3.2	1.6/3.2	12.8/12.8<	12.8/12.8	12.8/12.8<	1.6/3.2	16/16×10^{-3}	2/4×10^{-3}
Staphylococcus epidermidis ATCC 12228	3.2/3.2	0.8/1.6	1.6/3.2	12.8/12.8<	0.8/1.6	12.8/12.8<	1.6/3.2	32/64×10^{-3}	1/2×10^{-3}
Streptococcus pyogenes ATCC 21059	0.4/0.8	0.8/0.8	1.6/1.6	12.8/12.8<	12.8/12.8	12.8/12.8	1.6/1.6	4/8×10^{-3}	8/16×10^{-3}
Streptococcus mutans ATCC 25175	0.2/0.8	0.8/1.6	1.6/3.2	6.4/12.8	12.8/12.8	1.6/3.2	1.6/3.2	4/4×10^{-3}	8/8×10^{-3}
Streptococcus sanguinis ATCC 10556	0.4/0.8	1.6/3.2	1.6/3.2	12.8/12.8	12.8/12.8	1.6/3.2	1.6/3.2	32/32×10^{-3}	8/16×10^{-3}
Streptococcus sobrinus ATCC 27607	0.4/0.8	0.4/0.8	1.6/1.6	12.8/12.8	12.8/12.8	12.8/12.8	1.6/3.2	2/2×10^{-3}	4/8×10^{-3}
Streptococcus ratti KCTC 3294	1.6/1.6	3.2/6.4	1.6/3.2	12.8/12.8<	12.8/12.8	12.8/12.8<	1.6/3.2	4/4×10^{-3}	4/8×10^{-3}
Streptococcus criceti KCTC 3292	0.8/1.6	3.2/6.4	3.2/3.2	12.8/12.8	12.8/12.8	12.8/12.8<	3.2/3.2	4/4×10^{-3}	8/8×10^{-3}
Streptococcus anginosus ATCC 31412	0.8/0.8	0.8/0.8	1.6/3.2	12.8/12.8	3.2/6.4	12.8/12.8<	1.6/3.2	4/4×10^{-3}	16/16×10^{-3}
Streptococcus gordonii ATCC 10558	0.1/0.4	0.8/0.8	0.05/0.1	12.8/12.8	6.4/6.4	1.6/3.2	0.05/0.1	1/2×10^{-3}	2/4×10^{-3}
Actinobacillus actinomycetemcomitans ATCC 43717	0.8/0.8	0.8/1.6	1.6/3.2	6.4/12.8	6.4/12.8	1.6/1.6	1.6/3.2	64/64×10^{-3}	2/2×10^{-3}
Fusobacterium nucleatum ATCC 10953	0.2/0.4	0.2/0.4	0.4/0.8	6.4/6.4	3.2/6.4	12.8/12.8	0.2/0.4	0.25/0.25×10^{-3}	16/32×10^{-3}
Prevotella intermedia ATCC 25611	0.2/0.4	0.2/0.4	0.2 /0.4	1.6/3.2	1.6/3.2	0.8/1.6	0.2/0.4	32/32×10^{-3}	0.5/1×10^{-3}
Porphylomonas gingivalis ATCC 33277	0.05/0.1	0.8/0.8	0.2/0.8	6.4/12.8	6.4/6.4	0.4/0.8	0.4/0.8	0.5/1×10^{-3}	256/512×10^{-3}

tial oil showed the strongest antibacterial activity against *P. gingivalis* (MICs 0.05 mg/ml and MBCs 0.1 mg/ml). The antibacterial activity was shown that its major compounds of *A. iwayomogi* exhibited moderate activities against all the tested bacteria (MICs 0.05~12.8 mg/ml and MBCs 0.1~12.8 mg/ml). Cariogenic and periodontopathic bacterial strains tested are killed completely by exposure for 30s to 0.2% manuka oil, tea tree oil or eucalyptus oil (9,13). The antibacterial property of mostly essential oils is suspected to be associated with the high percentage of caryophyllene oxide, α-pinene, and β-pinene and α-pinene and 1,8-cineole, which are known to possess strong antibacterial activity (4,18,27,28). The α-terpineol, and terpinen-4-ol, chemical compositions of *A. iwayomogi* showed the strongest antibacterial activity against *S. gordonii* (MICs 0.05 mg/ml and MBCs 0.1 mg/ml). In this study, these results were consistent with previous reports that borneol, α-terpineol, and terpinen-4-ol have moderate antibacterial activity (5,22,24, 25,28). Camphor, 1,8-cineole, borneol, α-terpineol, terpinen-4-ol, bornyl acetate, and chrysanthenol as the major constituents of the oils of *Artemisia* have been previously reported to exhibit antibacterial against *S. aureus*, *Bacillus megaterium*, *Enterobacter cloaceae*, *Klebsiella planticola*, *Bacillus subtilis*, *E. coli*, *Pseudomonas aeruginosa*, *Candida albicans*, *Helicobacter pylori*, and oral bacteria, *S. mutans*, *S. pyogenes*, *S. sanguinis*, *S. sobrinus*, and *S. gordonii*, *A. actinomycetemcomitans*, *F. nucleatum*, *P. intermedia*, and *P. gingivalis*, antifungal against *Sclerotinia* sp, and antioxidant activity (5,16~18,30). The essential oil of *A. iwayomogi* exhibited stronger antibacterial activity than any other of its major compounds.

In conclusion, these results indicate the possibility of exploitation of the essential oil of *A. iwayomogi* as an effective inhibitor of oral bacteria, for example, a component of tooth paste and/or gargling solution. However, for medicinal purposes, the safety and toxicity of this essential oil need to be addressed.

REFERENCES

1) **Ahn H, Kim JY, Lee HJ, Kim YK, Ryu JH:** Inhibitors of inducible nitric oxide synthase expression from *Artemisia iwayomogi*. *Arch Pharm Res* **26:** 301-305, 2003.

2) **Bae JM, Kim MS, Park HJ, Chung HY, Young H, Park KY, Moon SH, Choi JS:** Antimutagenic principle of *Artemisia iwayomogi* and its action mechanism. *J Kor Cancer Assoc* **24:** 352-358, 1992.

3) **Beldjoudi N, Mambu L, Labaied M, Grellier P, Ramanitrahasimbola D, Rasoanaivo P, Martin MT, Frappier F:** Flavonoids from *Dalbergia louvelii* and their antiplasmodial activity. *J Nat Prod* **66:** 1447-1450, 2003.

4) **Cha JD, Jeong MR, Choi HJ, Jeong SI, Moon SE, Yun SI, Kim YH, Kil BS, Song YH:** Chemical composition and antimicrobial activity of the essential oil of *Artemisia lavandulaefolia*. *Planta Med* **71:** 575-577, 2005.

5) **Cha JD, Jeong MR, Jeong SI, Moon SE, Kim JY, Kil BS, Song YG:** Chemical composition and antimicrobial activity of the essential oils of *Artemisia scoparia* and *A. capillaris*. *Planta Med* **71:** 186-190, 2005.

6) **Crowell PL:** Prevention and therapy of cancer by dietary monoterpenes. *Nutrition* **129:** 775-778, 1999.

7) **Faid M, Bakhy K, Anchad M, Tantaoui-Elaraki A:** Almond paste: Physicochemical and microbiological characterizations and preservations with sorbic acid and cinnamon. *J Food Prot* **58:** 547-550, 1995.

8) **Guardia T, Juarez AO, Guerreiro E, Guzman JA, Pelzer L:** Antiinflammatory activity and effect on gastric acid secretion of dehydroleucodine isolated from *Artemisia douglasiana*. *J Ethnopharmacol* **88:** 195-198, 2003.

9) **Hammer KA, Dry L, Johnson M, Michalak EM, Carson CF, Riley TV:** Susceptibility of oral bacteria to *Melaleuca alternifolia* (tea tree) oil in vitro. Oral *Microbiol Immunol* **18:** 389-392, 2003.

10) **Huang W, Zhang J, Moore DD:** A traditional herbal medicine enhances bilirubin clearance by activating the nuclear receptor CAR. *J Clin Invest* **113:**137-143, 2004.

11) **Hwang JS, Chung HK, Bae EK, Lee AY, Ji HJ, Park DW, Jung HJ, Cho CW, Choi HJ, Lee DS, Lee KR, Youn HJ:** The polysaccharide fraction AIP1 from *Artemisia iwayomogi* suppresses apoptotic death

of the mouse spleen cells in culture. *Arch Parm Res* **26:** 294-300, 2003.

12) **Jain SK, Agrawal SC:** Fungistatic activity of some perfumes against otomycotic pathogens. *Mycoses* **45:** 88-90, 2002.

13) **Juteau F, Jerkovic I, Masotti V:** Composition and antimicrobial activity of the essential oil of *Artemisia absinthium* from Croatia and France. *Planta Med* **69:** 158-161, 2003.

14) **Katz N, dos Santos Filho D, Sarti SJ, Mendes NM, Rocha Filho PA, Araujo N:** Chemoprophylactic activity on *Schistosomiasis mansoni* of soaps containing essential oil from the fruits of *Pterodon pubescens*. *Rev Inst Med Trop Sao Paulo* **35:** 183-191, 1993.

15) **Kim KJ, Kim YH, Yu YH, Jeong SI, Cha JD, Kil BS, You YO:** Antibacterial activity and chemical composition of essential oil of *Chrysnathemum boreale*. *Planta Med* **69:** 274-277, 2003.

16) **Kim SS, Lee CK, Kang SS, Jung HA, Choi JS:** Chlorogenic acid an antioxidant principle from the aerial parts of *Artemisia iwayomogi* that acts on 1,1-diphenyl-2-picrylhydrazyl radical. *Arch Pharm Res* **20:** 148-154, 1997.

17) **Koo KA, Kwak JH, Lee KR, Zee OP, Woo ER, Park HK, Youn HJ:** Antitumor and immunomodulating activities of the polysaccharide fractions from *Artemisia slengenesis* and *Artemisia iwayomogi*. *Arch Pharm Res* **17:** 371-374, 1994.

18) **Kordali S, Kotan R, Mavi A, Cakir A, Ala A, Yildirim A:** Determination of the chemical composition and antioxidant activity of the essential oil of *Artemisia dracunculus* and of the antifungal and antibacterial activities of Turkish *Artemisia absinthium*, *A. dracunculus*, *Artemisia santonicum*, and *Artemisia spicigera* essential oils. *J Agric Food Chem* **53:** 9452 -9458.

19) **Lee SB, Cho TS, Yoon KW, Lee JC, Lee SM, Shim SB:** Astudy on the hepatoprotective effect of PS-1 from *Artemisia iwayomogi*. *J Appl Pharmacol* **6:** 119-129, 1998.

20) **Lee SH, Lee MY, Kang HM, Han DC, Son KH, Yang DC, Sung ND, Lee CW, Kim HM, Kwon BM:** Antitumor activity of the farnesyl-protein transferase inhibitors arteminolides, isolated from *Artemisia*. Bioorg. *Med Chem* **11:** 4545-4549, 2003.

21) **Li H, Madden JL, Potts BM:** Variation in volatile leaf oils of the *Tasmanian Eucalyptus* species. 1. Subgenus Monocalyptus. *Biochem Syst Ecol* **23:** 299-318, 1995.

22) **Mangena T, Muyima NY:** Comparative evaluation of the antimicrobial activities of essential oils of *Artemisia afra*, *Pteronia incana*, and *Rosmarinus officinalis* on selected bacteria and yeast strains. *Lett Appl Microbiol* **28:** 291-296, 1999.

23) **Sadraei H, Asghari GR, Hajhashemi V, Kolagar A, Ebrahimi M:** Spasmolytic activity of essential oil and various extracts of *Ferula gummosa* Boiss. on ileum contractions. *Phytomedicine* **8:** 370-376, 2001.

24) **Santoyo S, Cavero S, Jaime L, Ibanez E, Senorans FJ, Reglero G:** Chemical composition and antimicrobial activity of *Rosmarinus officinalis* L. essential oil obtained via supercritical fluid extraction. *J Food Prot* **68:** 790-795, 2005.

25) **Shunying Z, Yang Y, Huaidong Y, Yue Y, Guolin Z:** Chemical composition and antimicrobial activity of the essential oils of *Chrysanthemum indicum*. *J Ethnopharmacol* **96:** 151-158, 2005.

26) **Tan RX, Zheng WF, Tang HQ:** Biologically active substances from the genus *Artemisia*. *Planta Med* **64:** 295-302, 1998.

27) **Uluelen A, Toqcu G, Eris C:** Terpenoids from *Salva sclarea*. *Phytochemistry* **36:** 971-974, 1994.

28) **Viljoen A, van Vuuren S, Ernst E, Klepser M, Demirci B, Baser H, van Wyk BE:** *Osmitopsis asteriscoides* (Asteraceae)-the antimicrobial activity and essential oil composition of a Cape-Dutch remedy. *J Ethnopharmacol* **88:** 137-143, 2003.

29) **Wang YC, Huang TL:** Screening of anti-*Helicobacter pylori* herbs deriving from Taiwanese folk medicinal plants. *FEMS Immunol Med Microbiol* **43:** 295-300, 2005.

30) **Yu HH, Kim YH, Kil BS, Kim KJ, Jeong SI, You YO:** Chemical composition and antibacterial activity of essential oil of *Artemisia iwayomogi*. *Planta Med* **69:** 1159-1162, 2003.