Chemical Composition and Acetylcholinesterase Inhibitory Activity of Essential Oils from *Piper* Species

Cai-Peng **Xiang**,[†,#] Jia-Xin **Han**,[†,#] Xing-Cong **Li**,[$] Yun-Hui **Li**,[‡] Yi **Zhang**,[‡] Lin **Chen**,[†] Yan **Qu**,[⊥] Chao-Yun **Hao**,[§] Hai-Zhou **Li**,[†] Chong-Ren **Yang**,[†,‡,⊥] San-Jun **Zhao**[*,&], Min **Xu**[*,†]

[†]*Center for Pharmaceutical Sciences, Faculty of Life Science and Technology, Kunming University of Science and Technology, Chenggong Campus, Kunming 650500, P. R. China*

[&]*School of Life Science, Yunnan Normal University, Kunming 650500, P. R. China*

[$]*National Center for Natural Products Research, School of Pharmacy, University of Mississippi, Mississippi 38677, United States*

[‡]*Yunnan Engineering Research Center of Ethnopharmacy, Yunnan Provincial Academy of Science and Technology, Kunming 650101, P. R. China*

[§]*Chinese Academy of Tropical Agricultural Sciences, Hainan 100049, P. R. China*

[⊥] *State Key Laboratory of Phytochemistry and Plant Resources in West China, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming 650201, P. R. China*

[#]*These authors contributed equally to this work.*

Corresponding Author. * Tel: +86-0871-65920570. Fax: +86-0871-65920570.

E-mail: xumin8121@hotmail.com, sanjunzhao@hotmail.com

[‡] Cai-Peng Xiang and Jia-Xin Han contributed equally to this paper

Supporting Information Available

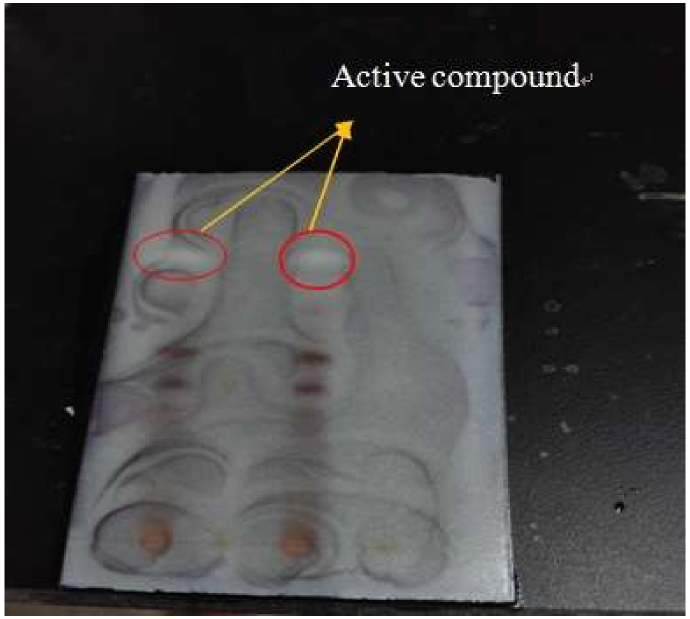


Figure 1. TLC bioautography for acetylcholinesterase inhibitors, active compounds appear as white spots against a purple background

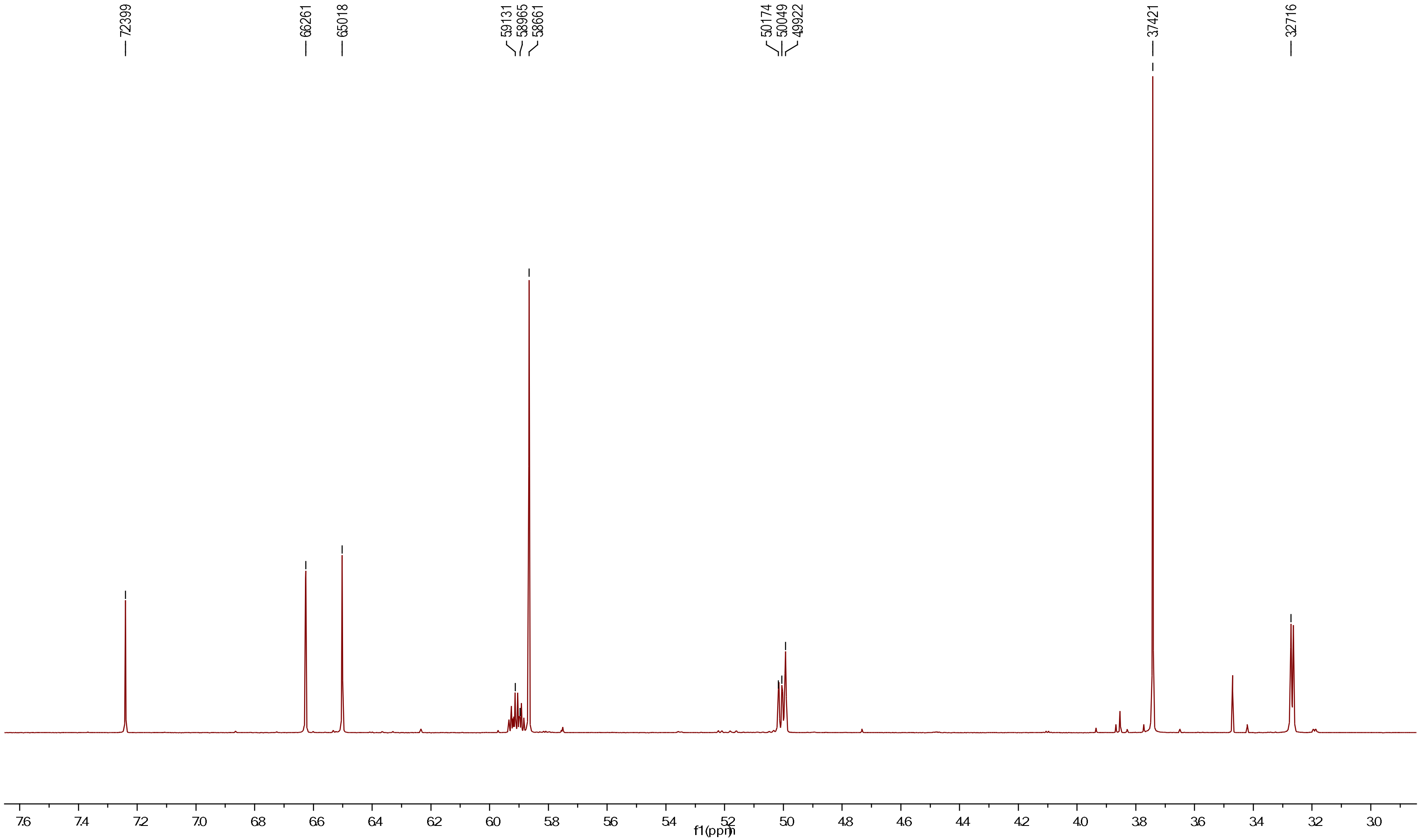


Figure 2. ^{1}H-NMR spectrum of asaricin

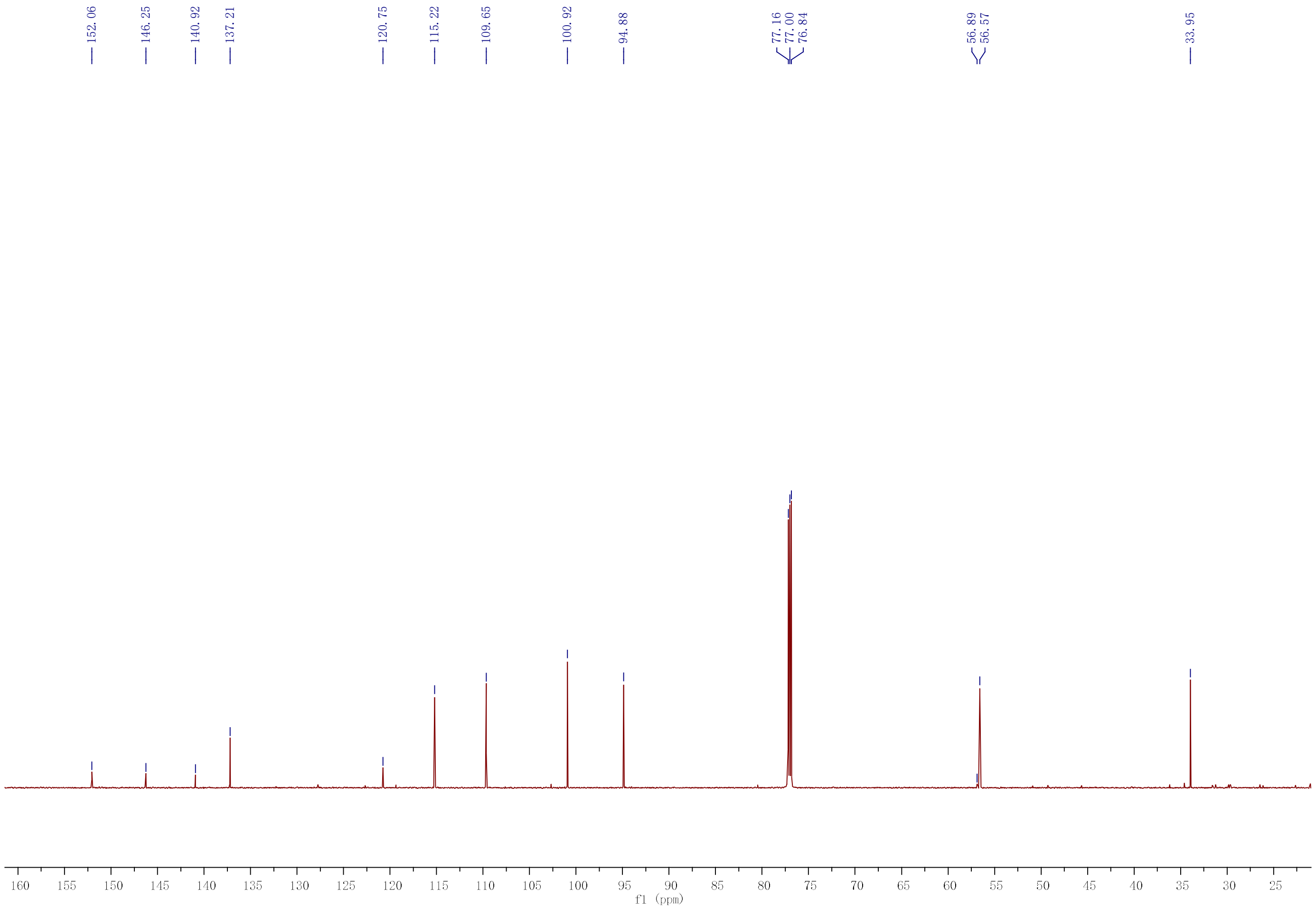


Figure 3. ^{13}C-NMR spectrum of asaricin

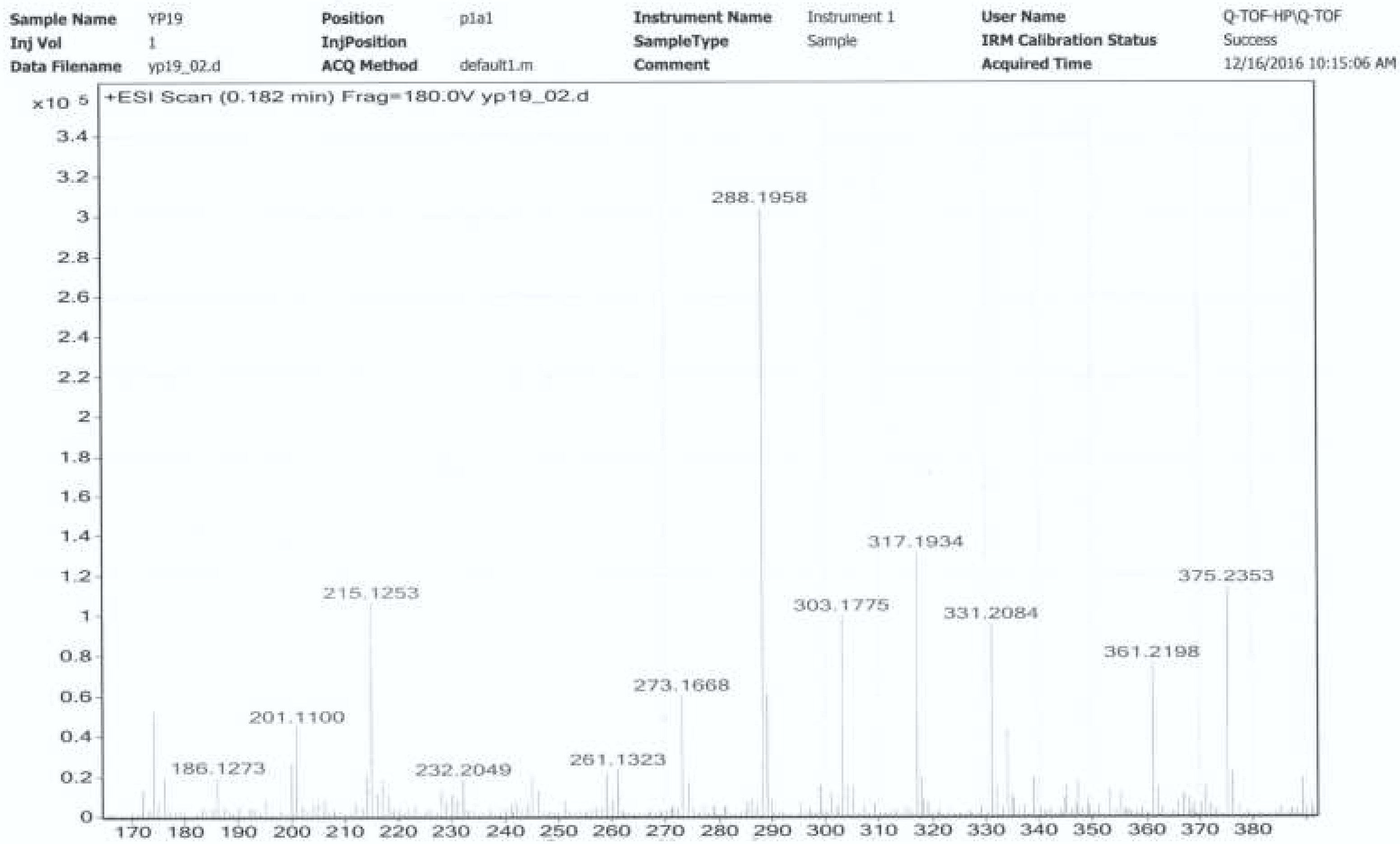


Figure 4. ESI-MS spectrum of asaricin

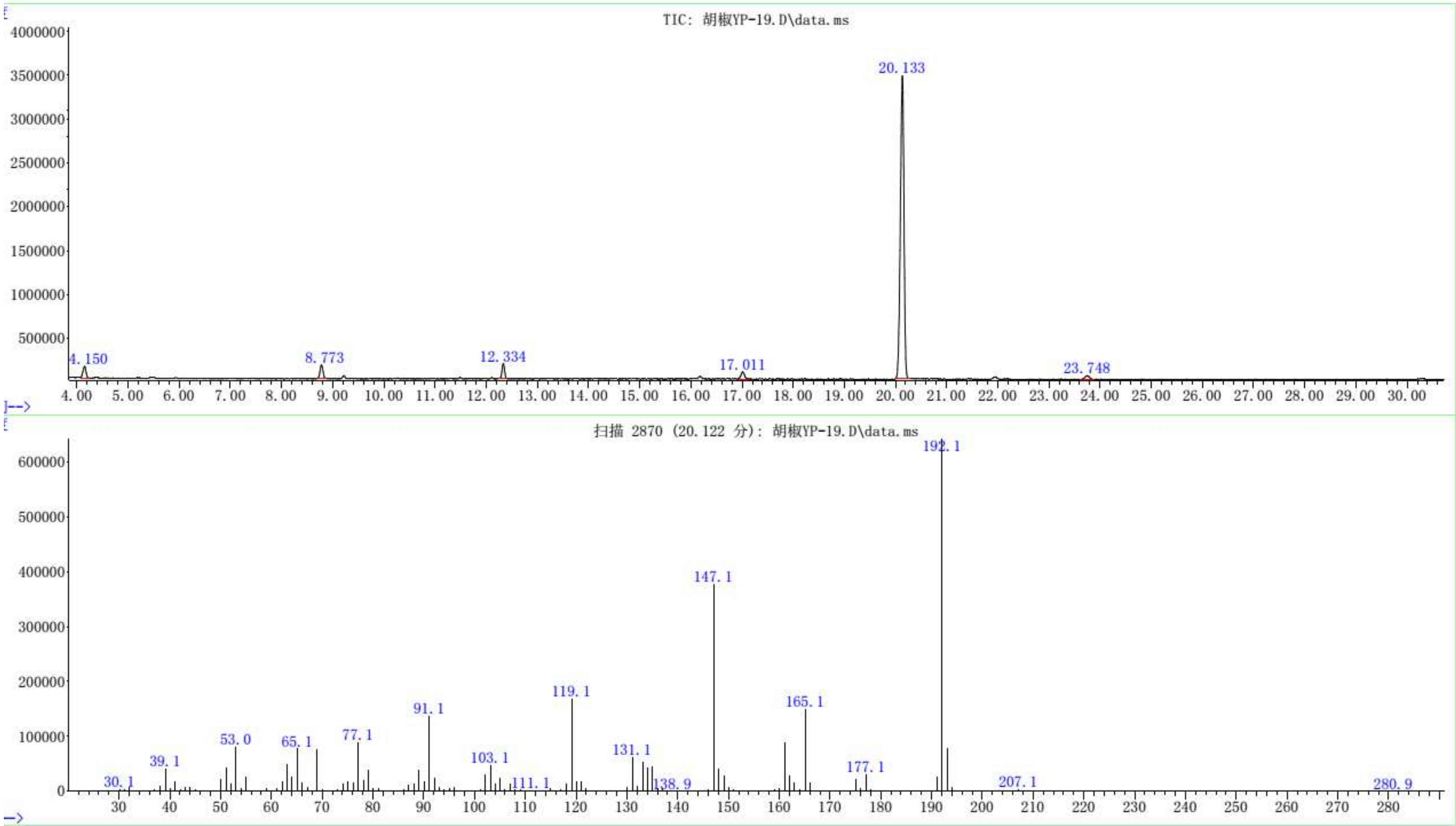
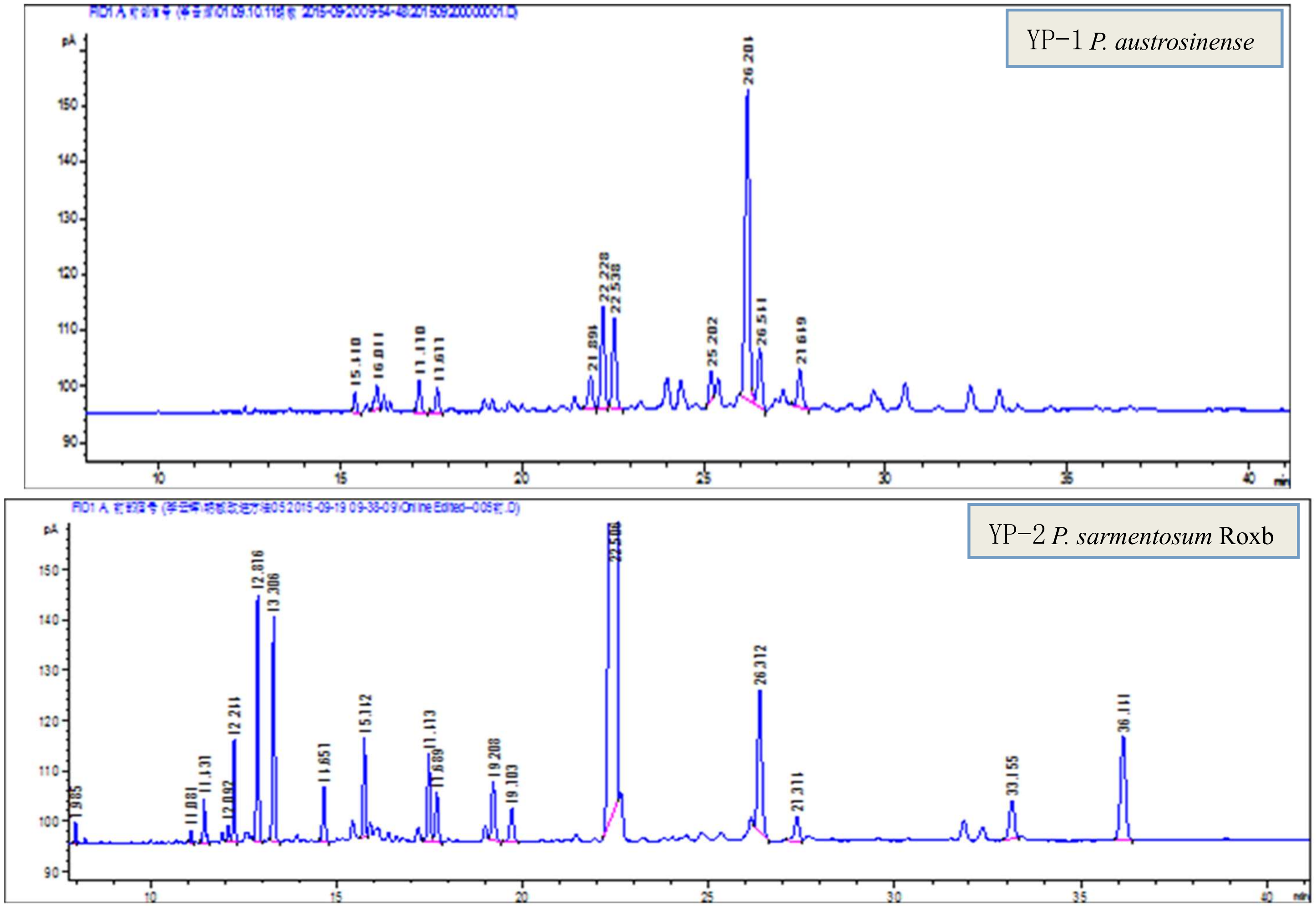
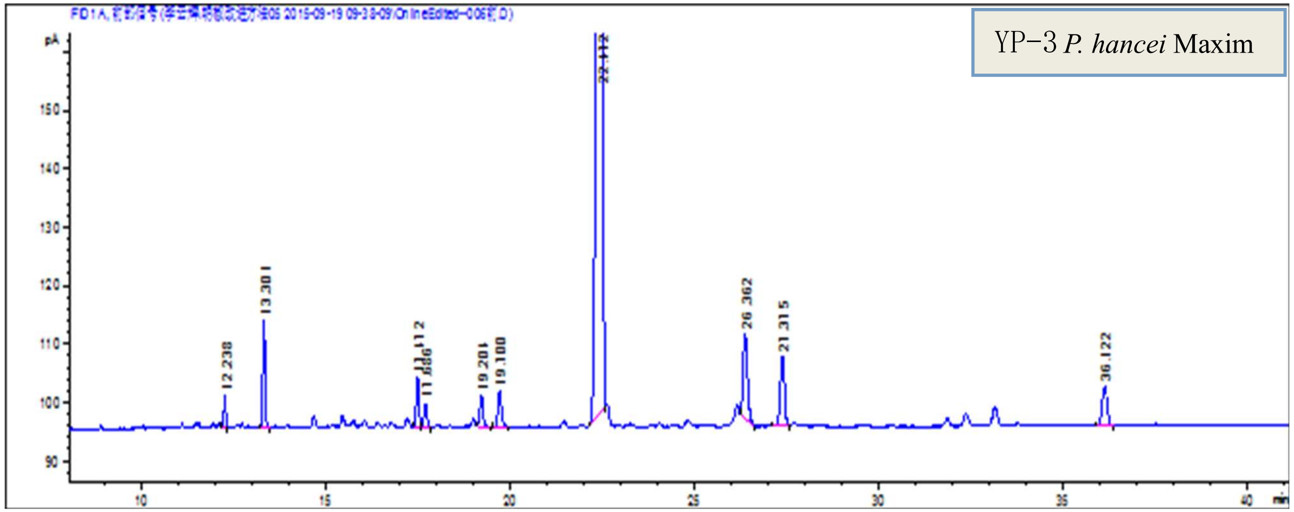


Figure 5. GC-FID and GC-MS spectra of asaricin


YP-1 *P. austrosinense*
YP-2 *P. sarmentosum* Roxb
pA
min


YP-3 P. hancei Maxim
pA
150
140
130
120
110
100
90
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13.301
19.201
26.362
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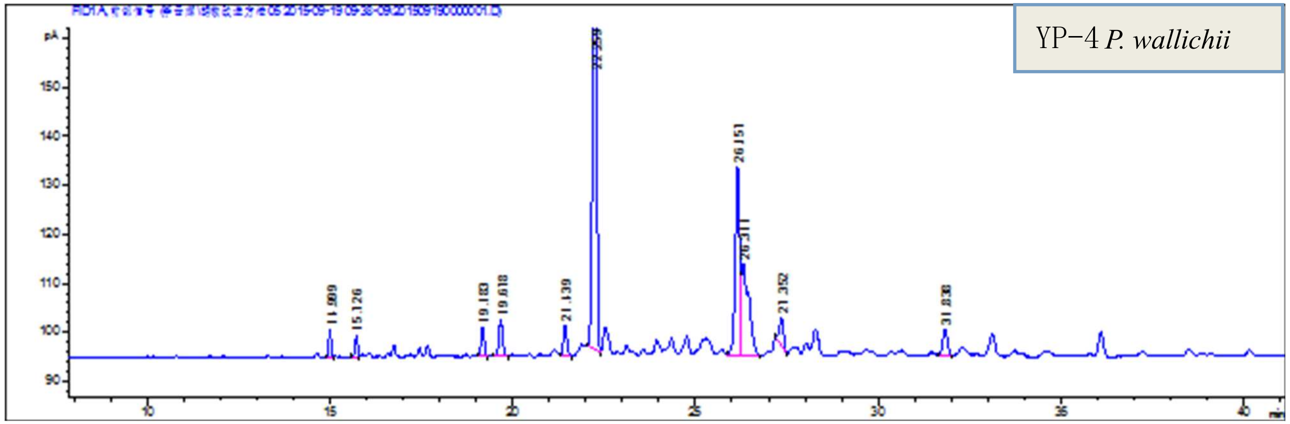
10
15
20
25
30
35
40
min


YP-4 P. wallichii
pA
150
140
130
120
110
100
90
15.126
19.183
19.618
21.139
27.352
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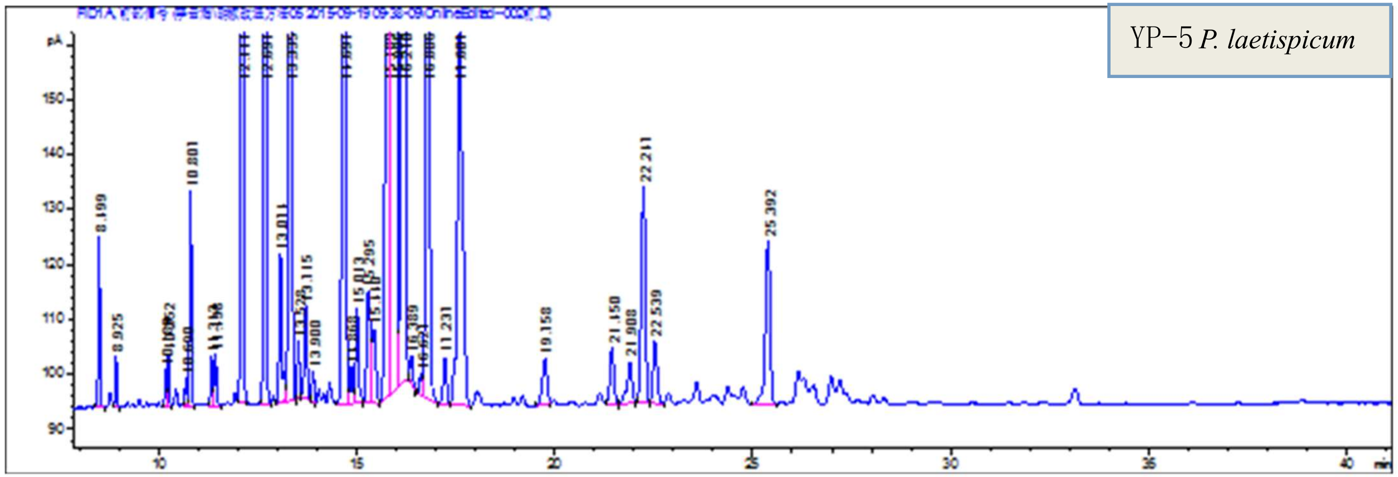
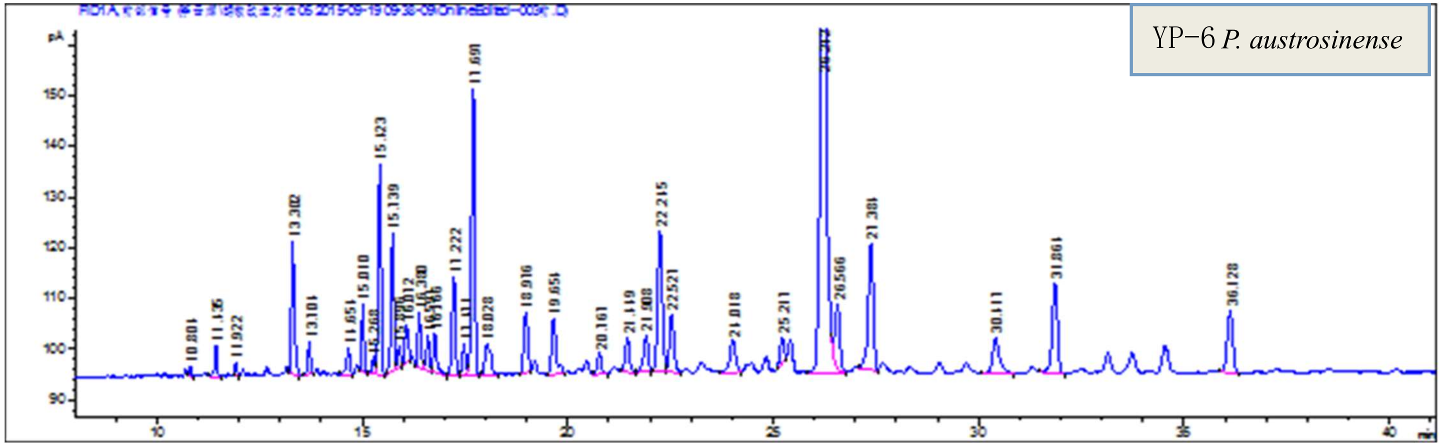
25
30
35
40
min


YP−5 *P. laetispicum*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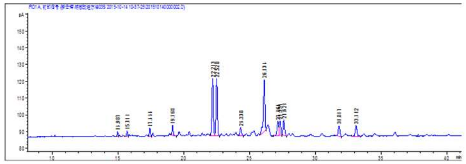
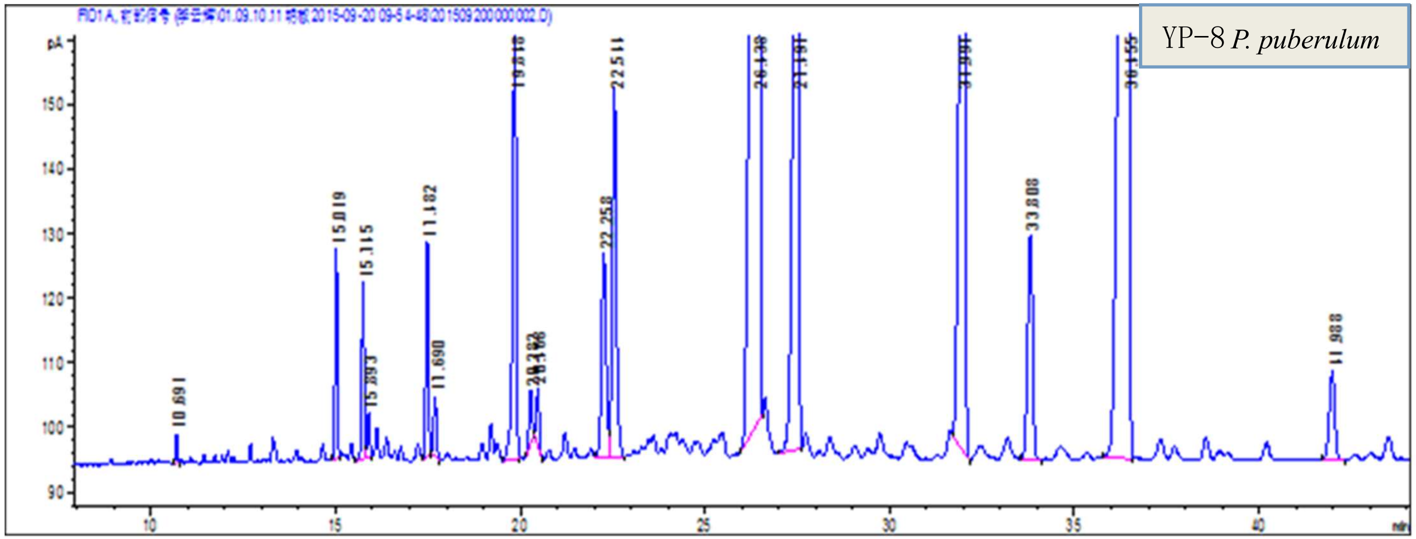
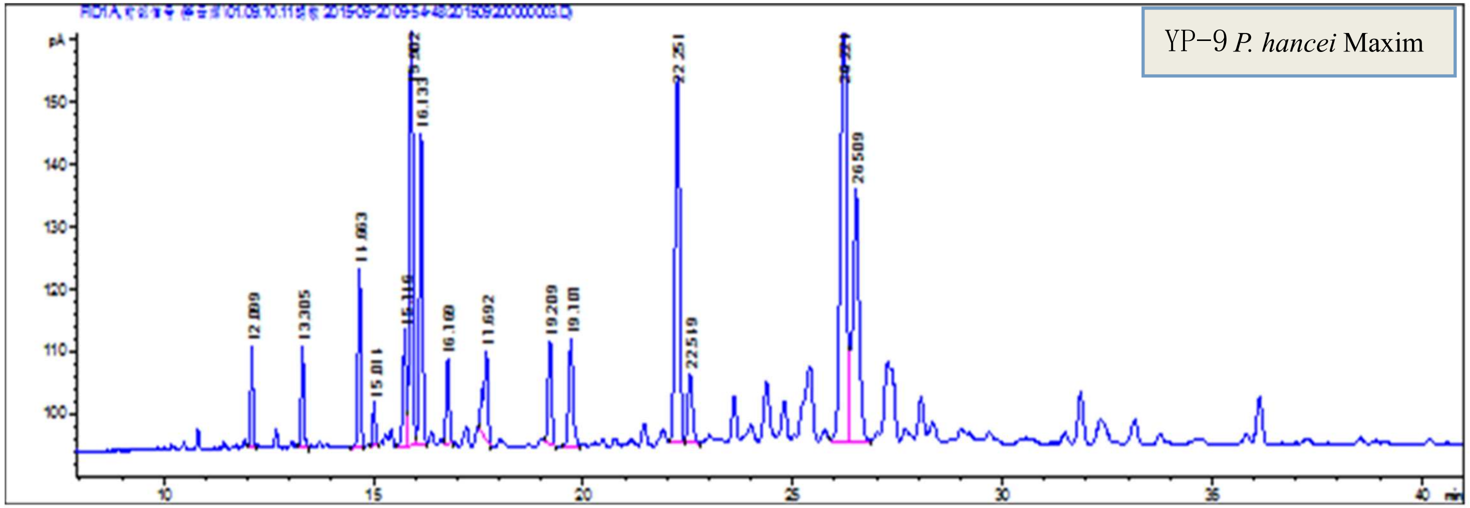


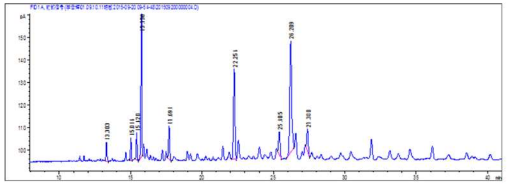
YP-7 *P. bavinnum*



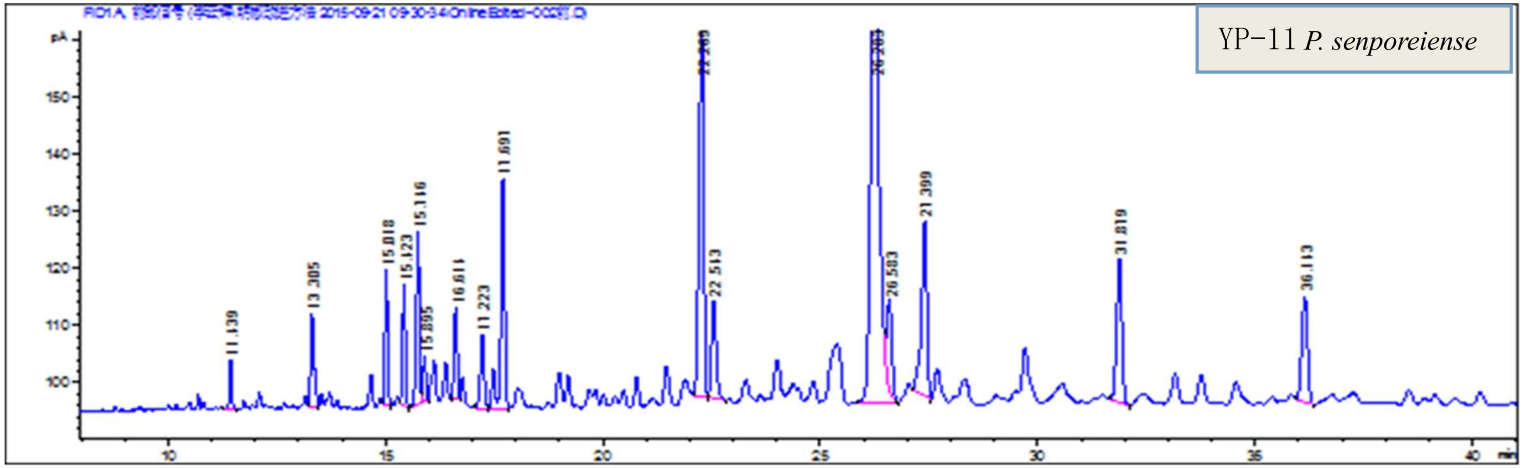
YP-8 *P. puberulum*



YP-9 *P. hancei* Maxim



YP-10 *P. betle*



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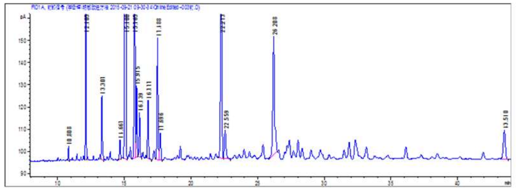
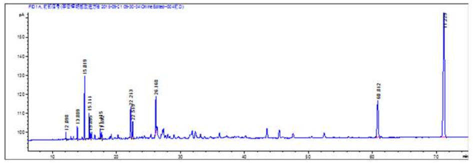


YP-12 *P. aduncum*



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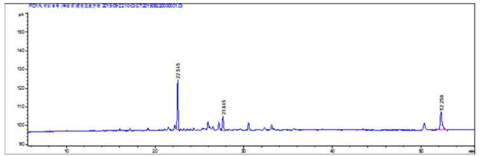
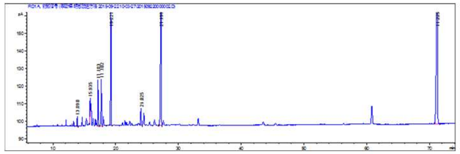
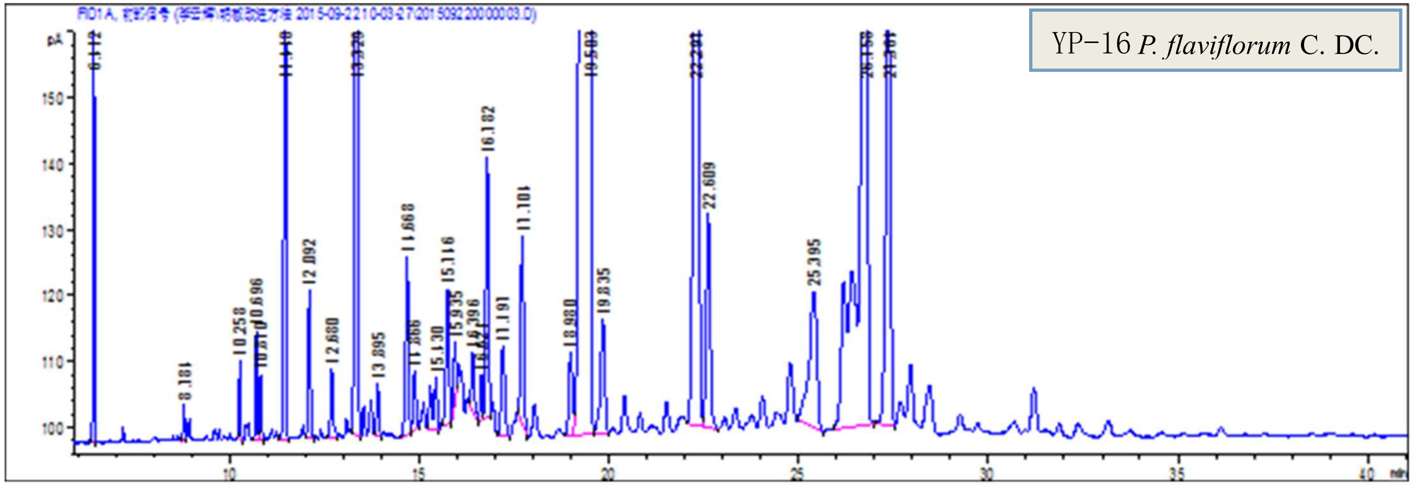


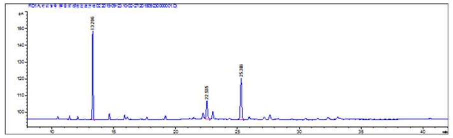
YP-14 *P. thomsonii* (C. DC.) Hook.f.



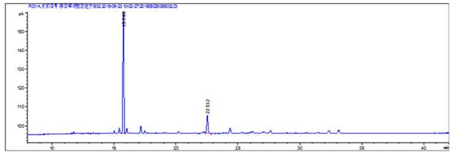
YP-15 *P. boehmeriaefolium* (Miq.) C.



YP-16 *P. flaviflorum* C. DC.

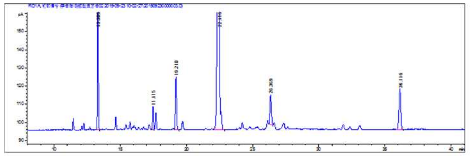


YP-17 *P. nigrum* L.

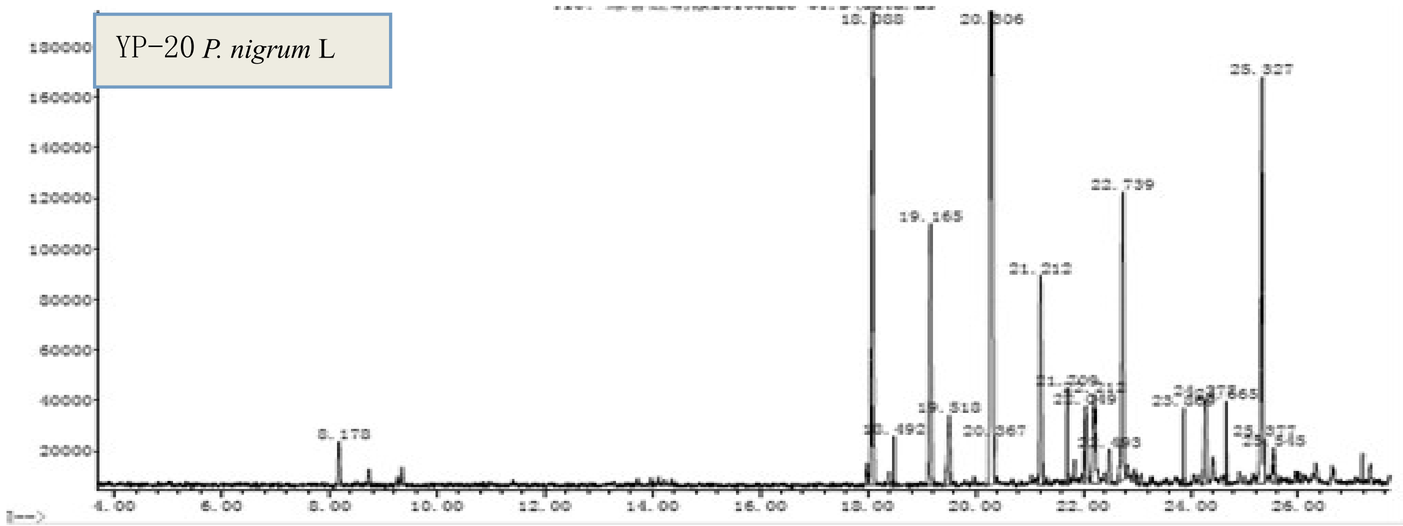


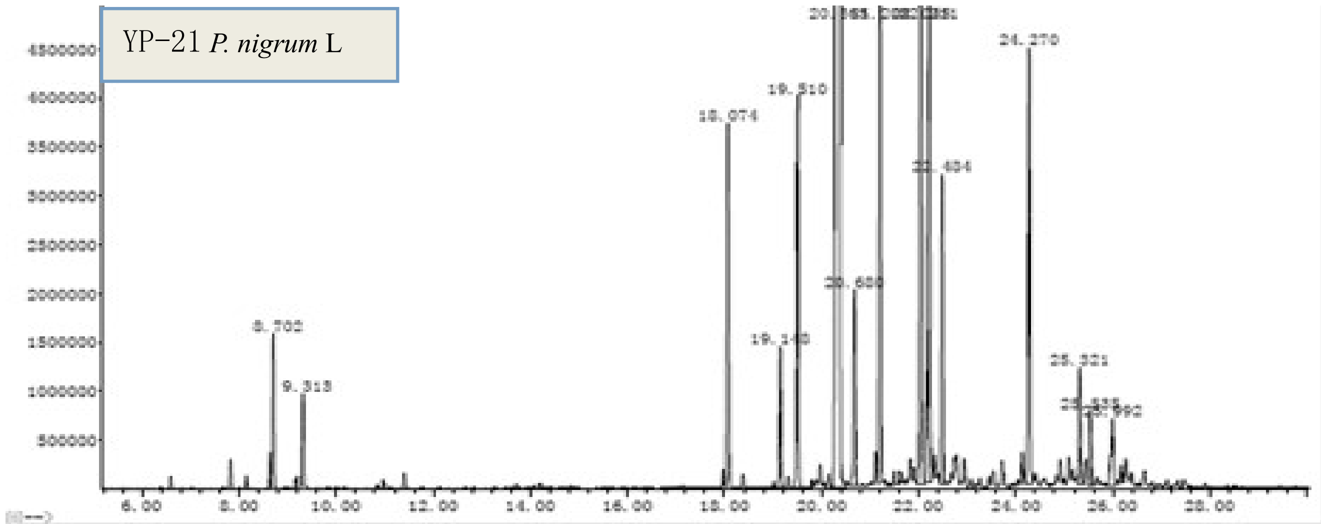
YP-18 *P. betle*

YP-19 *P. hispidimervium* C. DC.



YP-20 *P. nigrum* L




YP-21 *P. nigrum* L
4500000
4000000
3500000
3000000
2500000
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1500000
1000000
500000
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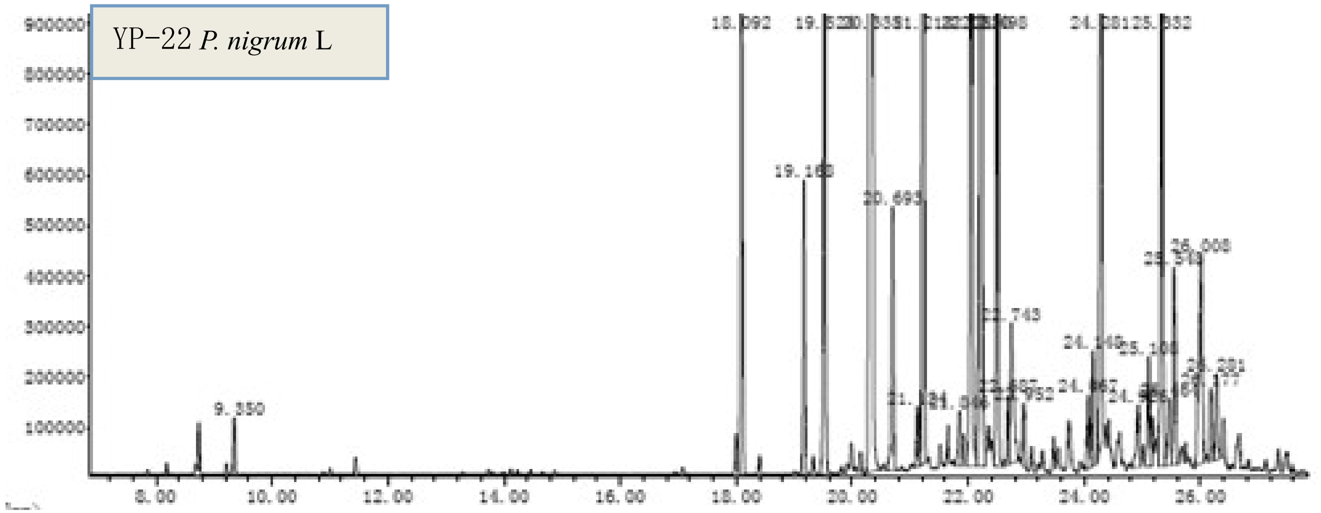
19.510
24.270
8.702
9.318
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
26.00
28.00


YP-22 *P. nigrum* L
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800000
700000
600000
500000
400000
300000
200000
100000
9.350
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
26.00

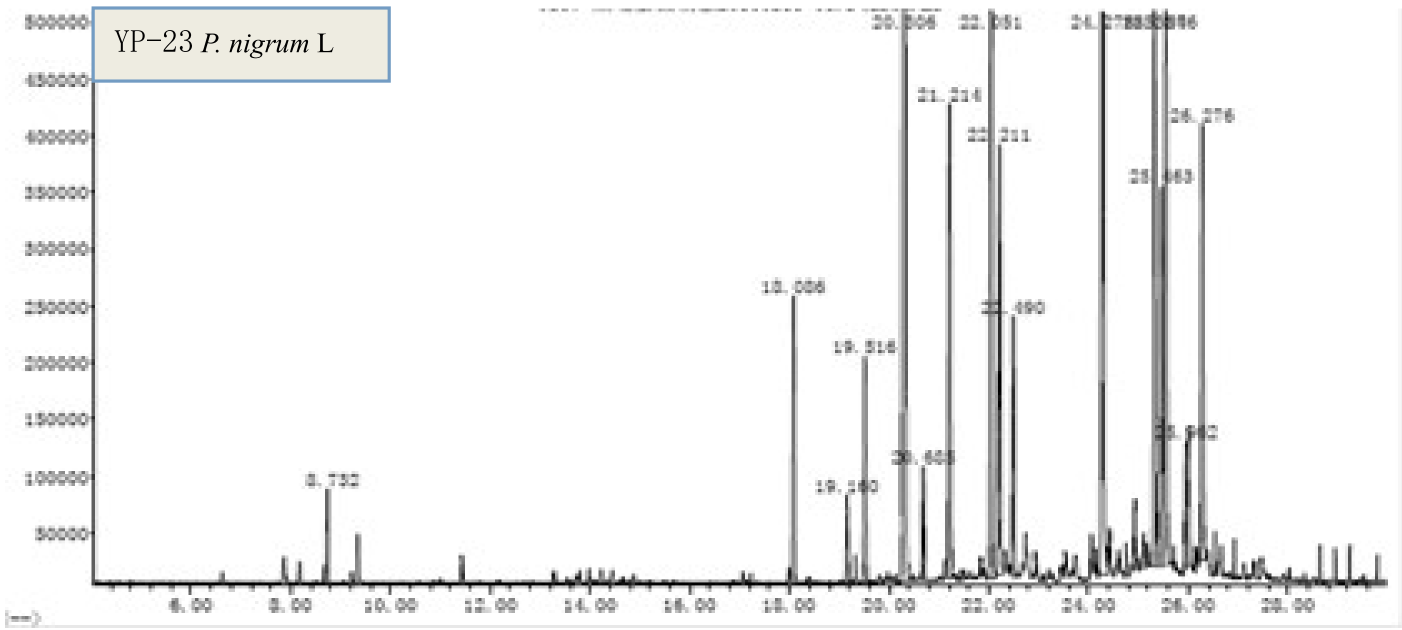

Figure 6. GC spectra of essential oils of *Piper* spp.

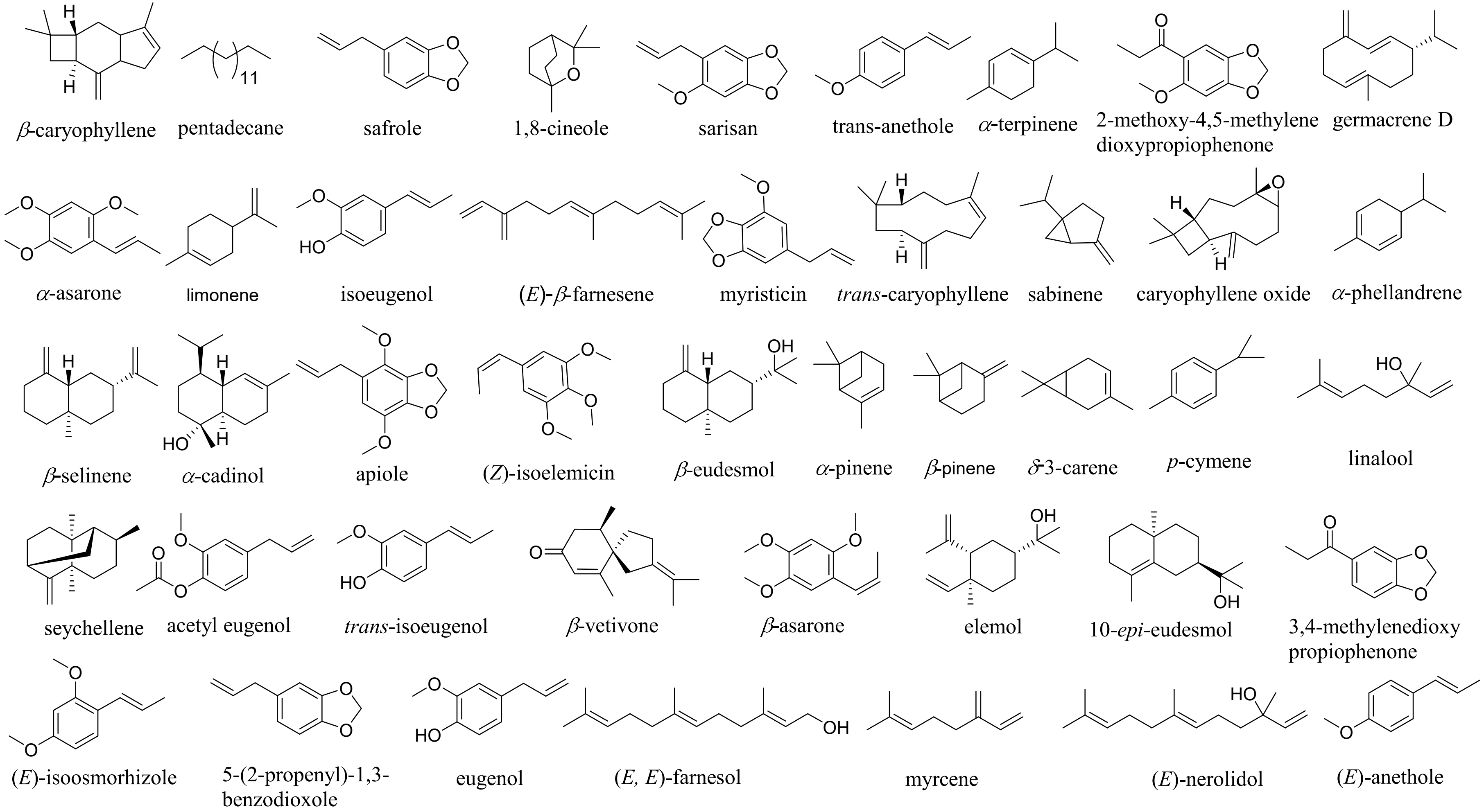

Figure 7. Chemical structures of compounds from *Piper* EOs.

Table 1 Chemical constituents from *Piper* EOs.

No.	Major constituents of the EOs	Sources	Ref.
1	*β*-caryophyllene (17%), pentadecane (17.8%), *β*-bisabolene (11.16%)	*P. longum.*	1
2	Safrole (64.5%)	*P. auritum*	2
3	*δ*-cadinene, *α*-copaene and *β*-pinene	*P. arboreum*	3
4	*β*-caryophyllene, the oxygenated monoterpenes linalol and its acetate	*P. fimbriulatum*	3
5	*β*-caryophyllene, spathulenol and caryophyllene oxide	*P. obliquum*	3
6	*α*-methylbenzyl cinnamate (28.0%), isomeric methylbenzyl cinnamate (18.1%)	*P. pierrei.*	4
7	*β*-caryophyllene (26.1-30.9%), bornyl acetate (10.0%)	*P. lolot*	5
8	*β*-caryophyllene (17.4%) and aromadendrene (13.4%)	*P. aduncum* from Panama	6
9	1,8-cineole (40.5%). Sarisan (1-allyl-2-methoxy-4,5-methylene-dioxybenzene; 12.9%)	*P. aduncum* from Bolivia	6
10	*α*-pinene, camphene, *β*-phellandrene, limonene and menthane derivs.	*P. friedrichsthalii* from Costa Rica	7
11	11-selinen-4*α*-ol, *α*-selinene, germacrene D, *β*-selinene	*P. friedrichsthalii* from Panama	7
12	*β*-elemene, *β*-caryophyllene, germacrene D, *α*-humulene	*P. pseudolindenii* from Costa Rica	7
13	trans-anethole (26.4%) , ishwarane (12.1%)	*P. fulvescens*	8
14	*α*-terpinene (12.1%), p-cymene (10.9%), 1,8-cineole (13.0%), safrole (14.9%), spatulenol (9.8%) *α*-terpinene (9.8%), p-cymene (7.7%), 1,8-cineole (30.2%) and safrole (32.0%)	*P. capunya*	9
15	2-methoxy-4,5-methylenedioxypropiophenone (29.5%), *α*-asarone (14.1%), apiole (8.9%), *β*-asarone (9.4%), methoxy-4,5-methylenedioxypropiophenone isomer (10.9%), and (Z)-isoelemicin (9.5%)	*P. barbatum*	10
16	eugenyl Me ether (9.7%) and (*E*)-asarone (7.8%)	*P. callosum*	11
17	isoeugenol (72.0%), isoeugenyl acetate (12.2%)	*P. betel L.*	12
18	(*E*)-*β*-farnesene (22.8%), myristicin (19.2%), germacrene D (11.8%)	*P. mullesua*	13
19	*trans*-caryophyllene (25.0%), caryophyllene oxide (17.0%) and *β*-selinene (15.0%)	*P. amapense*	14
20	*trans*-caryophyllene (23.5%), caryophyllene oxide (18.4%), *β*-eudesmol (9.4%) and *α*-eudesmol (9.1%)	*P. duckei*	14

21	α-cadinol (11.2%), β-elemene (10.5%), α-muurolol (9.4%), (*E*)-nerolidol (9.0%)	*P. bartlingianum*	[14]
22	caryophyllene oxide (22.9%), spathulenol (9.0%), traps-calamenene (5.4%), α-copaene (5.2%)	*P. peltatum*	[15]
23	dillapiole (82.2%)	*P. aduncum*	[15]
24	β-eudesmol (17.5%)	*P. hispidum Sw.*	[16]
25	globulol, α-pinene, β-caryophyllene and α-terpinene	*P. nigrum L.*	[17]
26	β-caryophyllene, germacrene D, elemicin and parsley apiole	*P. lanceaefolium*	[18]
27	α- and β-pinene	*P. lanceaefolium*	[18]
28	α-pinene (2.4-11.4%), β-pinene (2.0-15.27%), δ-3-carene (0.1-21.0%), limonene (9.4-21.9%) and β-caryophyllene (19.8-45.3%)	*P. nigrum L.*	[19]
29	sabinene (11.2-22.6%), β-pinene (7.5-15.4%), limonene (12.7-23.8%) and β-caryophyllene (8.9-24.1%),	black pepper from Kerala viz Kottanadan,	[20]
30	sabinene (0.1-26.8%), β-pinene (3.8-11.7%), myrcene (0-18.6%), limonene (15.5-21.7%) and β-caryophyllene(15.5-21.7%)	black pepper from Ottaplackal	[20]
31	β-pinene (3.8-10.9%), limonene (9.0-16.9%) and β-caryophyllene (29.0-46.0%),	black pepper from Kuthiravally	[20]
32	sabinene (9.7-22.3%), β-pinene (7.7-11.2%), limonene (14.7-17.8%) and β-caryophyllene	black pepper from Cheriakania kadan	[20]
33	sabinene (4.5-16.2%), β-pinene (3.7-8.7%), limonene (8.3-18.0%) and β-caryophyllene (20.3-34.7%)	black pepper from Kerala viz. Thevanmundi	[21]
34	β-pinene (6.0-11.7%) limonene (14.9-15.8%), β-ocimene (< 0.1-12.0 %), β-caryophyllene (24.4-30.8%) and elemol (1.2-6.8%)	black pepper from Poonjaranmunda	[21]
35	α-pinene (2.9-6.3%), sabinene (12.9-17.1%),α-3-carene (0-10.5%), limonene (12.9-18.6%) and β-caryophyllene (23.0-38.4%).	black pepper from Valiakaniakadan	[21]
36	α-pinene (3.2-7.0%), β-pinene (7.6-9.6%),α-3-carene (19.0-23.4%), limonene (18.3-22.7 %), β-caryophyllene (7.6-21.3%) and caryophyllene oxide (0.4-6 %).	black pepper from Karimunda	[21]
37	β-pinene (32.5%) and β-caryophyllene (12.6%)	*P. capense*	[22]
38	dillapiole (44.8%), and myristicin (9.8%)	*P. guineense*	[22]

39	limonene (18.8%), *β*-caryophyllene (15.4%), sabinene (16.5%) and *β*-pinene (10.7%)	*P. nigrum*	22
40	*β*-pinene (26.8%), α-pinene (17.6%) and (*E*)-nerolidol (12.4%)	*P. umbellatum*	22
41	dillapiole (31.5-97.3%)	*P. aduncum.*	23
42	*α*-cadinol (21.7%)	*P. dactylostigmum*	24
43	1,8-cineole (31.6%)	*P. plurinervosum*	24
44	limonene (33.2%), *p*-cymene (12.8%) and (*E*)-nerolidol (20.6%)	*P. vitaceum Yuncker*	24
47	acetyl eugenol (31.768%), *trans*-isoeugenol (28.322%), 4-allyl pheny acetate (8.053%), *β*-caryophyllene (3.063%), germacrene-d (2.917%), *α*-amorphense (2.520%),*α*-cadinol (2.436%), and chavicol (1.994%)	*P. betel.*	25
48	*β*-vetivone (33.0%), (*Z*)-isoelemicin (21.5%) and (*E*)-asarone (11.6%)	*P. mikanianum*	26
49	eugenyl acetate or isoeugenyl acetate, allylpyrocatechol diacetate, eugenol or isoeugenol, and caryophyllene	*P. betel*	27
50	D-limonene, *β*-pinene, D3-carene and *α*-pinene	*P. nigrum*	27
51	*β*-caryophyllene (26.3%) and *α*-cadinol (13.7%)	*Piper tuberculatum var. tuberculatum*	28
52	*α*-asarone (21.84%), D-nerolidol (8.62%) and anisylacetone (7.11%)	*P. lolot*	29
53	*α*-asarone (52.75%) and phenylpropanoic acid (31.44%)	*P. lolot*	29
54	*β*-asarone (37.62%) and phenylpropanoic acid (25.64%)	*P. lolot*	29
55	safrole (82%)	*P. mikanianum* (Kunth) Steudel	30
56	*α*-pinene (2.5%), *β*-elemene (2.6%), *β*-caryophyllene (4.4%), germacrene D (2.7%), *β*-dihydroagarofuran (31.0%), elemol (12.0%), 10-epi-*γ*-eudesmol (13.0%) and *β*-eudesmol (2.6%).	*P. cernuum*	31
57	bicyclogermacrene (21.88%)/β-caryophyllene (20.69%) and myrcene (52.60%)/linalool (15.89%)	*P. cernuum* and *P. regnellii*	32
58	*α*-eudesmol (9.8%), *α*-caryophyllene (9.6%), globulol (6.9%) and (*Z*)-nerolidol (6.5%).	*P. arborescens*	33
59	*β*-guaiene (8.4%), seychellene (8.3%) and *α*-cadinene (6.9%)	*P. porphyrophyllum.*	33
60	10-epi-*γ*-eudesmol (21.0%), *α*-cadinene (18.8%), seychellene (12.6%) and (*E*, *E*)-farnesol (10.5%)	*P. sarmentosum.*	33

61	Me eugenol (>31.4%)	*P. nigrum*	33
62	*β*-caryophyllene (>26.5%)	*P. betle*	33
63	sarisan (1-allyl-2-methoxy-4,5-methylenedioxybenzene)	*P. affinis hispidinervum*	34
64	*β*-caryophyllene (11.2%), *α*-pinene (9.3%), sabinene (7.6%), *β*-selinene (5.3%) and limonene (4.6%),	*Piper officinarum*	35
65	*β*-caryophyllene (10.9%), *α*-phellandrene (9.3%), linalool (6.9%), limonene (6.7%) and *α*-pinene (5.0%)	*Piper officinarum*	35
66	dillapiole (64.4%), 1,8-cineole	*P. aduncum*	36 37
67	*p*-mentha-1(7),8-diene (39.0%), 3,4-methylenedioxypropiophenone (19.0%), and (*E*)-*β*-ocimene (9.8%)	*P. marginatum*	36
68	(*E*)-isoosmorhizole (32.2%), (*E*)-anethole (26.4%), isoosmorhizole (11.2%), and (*Z*)-anethole (6.0%)	*P. divaricatum*	36
69	safrole (69.2%), methyleugenol (8.6%), and β-pinene (6.2%)	*P. callosum*	36
70	safrole	*P. hispidinervum*	38
71	limonene (19.3%), *β*-elemene (33.1%)	*P. demeraranum*	39
72	germacrene D (14.7%), *trans*-caryophyllene (27.1%).	*P. duckei*	39
73	caryophyllene oxide (11.5%), *β*-pinene (9%), spathulenol (6.7%), camphene (5.2%), *β*-elemene (4.7%), myrtenal (4.2%), verbenone (3.3%) and pinocarvone (3.1%)	*P. aleyreanum*	40

Reference

(1) Shankaracharya, N. B.; Rao, L. J.; Naik, J. P.; Nagalakshmi, S. Characterization of chemical constituents of Indian long pepper (*Piper longum* L.). *Journal of Food Science and Technology* **1997,** *34* (1), 73-75.

(2) Pino, J. A.; Rosado, A.; Rodriguez, M.; Garcia, D. Composition of leaf oil of *Piper auritum* H.B.K. grown in Cuba. *Journal of Essential Oil Research* **1998,** *10* (3), 333-334.

(3) Mundina, M.; Vila, R.; Tomi, F.; Gupta, M. P.; Adzet, T.; Casanova, J.; Canigueral, S. Leaf essential oils of three Panamanian *Piper* species. *Phytochemistry* **1998,** *47* (7), 1277-1282.

(4) Leclercq, P. A.; Van Genderen, M. H. P.; Thanh, L.; Van Khien, P.; Dung, N. X. Composition of the essential oil from the aerial parts of *Piper pierrei* C.DC. from Vietnam. *Journal of Essential Oil Research* **1997,** *9* (6), 721-724.

(5) Dung, N. X.; Thanh, L.; Khoi, T. T. Compositional analysis of the leaf, stem and rhizome oils of *Piper lolot* C. DC. from Vietnam. *Journal of Essential Oil Research* **1996,** *8* (6), 649-652.

(6) Vila, R.; Tomi, F.; Mundina, M.; Santana, A. I.; Solis, P. N.; Arce, J. B. L.; Iclina, J. L. B.; Iglesias, J.; Gupta, M. P.; Casanova, J.; Canigueral, S. Unusual composition of the essential oils from the leaves of *Piper aduncum*. *Flavour and Fragrance Journal* **2005,** *20* (1), 67-69.

(7) Vila, R.; Mundina, M.; Tomi, F.; Ciccio, J. F.; Gupta, M. P.; Iglesias, J.; Casanova, J.; Canigueral, S. Constituents of the essential oils from *Piper friedrichsthalii* C.DC. and *P. pseudolindenii* C.DC. from Central America. *Flavour and Fragrance Journal* **2003,** *18* (3), 198-201.

(8) Vila, R.; Milo, B.; Tomi, F.; Casanova, J.; Ferro, E. A.; Canigueral, S. Chemical composition of the essential oil from the leaves of *Piper fulvescens*, a plant traditionally used in Paraguay. *Journal of Ethnopharmacology* **2001,** *76* (1), 105-107.

(9) Vargas, L.; Velasco-Negueruela, A.; Perez-Alonso, M. J.; Pala-Paul, J.; Vallejo, M. C. G. Essential oil composition of the leaves and spikes of *Piper carpunya* Ruiz et Pavon (Piperaceae) from Peru. *Journal of Essential Oil Research* **2004,** *16* (2), 122-123.

(10) Vargas, L.; Perez-Alonso, M. J.; Velasco-Negueruela, A.; Pala-Paul, J.; Vallejo, M. C. G. Leaf essential oil of *Piper barbatum* H.B.K. (Piperaceae) from Peru. *Journal of Essential Oil Research* **2003,** *15* (3), 163-164.

(11) Van Genderen, M. H. P.; Leclercq, P. A.; Delgado, H. S.; Kanjilal, P. B.; Singh, R. S. Compositional analysis of the leaf oils of *Piper callosum* Ruiz & Pav. from Peru and Michelia montana Blume from India. *Spectroscopy (Amsterdam)* **1999,** *14* (2), 51-59.

(12) Thanh, L.; Dung, N. X.; Van Luu, H.; Leclercq, P. A. Chemical composition of the leaf oil from *Piper betel* L. cultivated in Vietnam. *Journal of Essential Oil-Bearing Plants* **2002,** *5* (1), 38-42.

(13) Srivastava, S.; Gupta, M. M.; Kumar, S. Volatile constituents of the essential oil of *Piper mullesua* from Manipur (India). *Journal of Essential Oil Research* **1999,** *11* (5), 563-564.

(14) Santos, A. S.; Andrade, E. H. A.; Zoghbi, M. d. G. B.; Luz, A. I. R.; Maia, J. G. S. Sesquiterpenes of Amazonian *Piper* species. *Acta Amazonica* **1998,** *28* (2), 127-130.

(15) Pino, J. A.; Marbot, R.; Bello, A.; Urquiola, A. Essential oils of Piper peltatum (L.) Miq. and *Piper aduncum* L. from Cuba. *Journal of Essential Oil Research* **2004,** *16* (2), 124-126.

(16) Pino, J. A.; Marbot, R.; Bello, A.; Urquiola, A. Composition of the essential oil of *Piper hispidum* Sw. from Cuba. *Journal of Essential Oil Research* **2004,** *16* (5), 459-460.

(17) Pino, J. A.; Aguero, J.; Fuentes, V. Chemical composition of the aerial parts of *Piper nigrum* L. from Cuba. *Journal of Essential Oil Research* **2003,** *15* (3), 209-210.

(18) Mundina, M.; Vila, R.; Tomi, F.; Tomas, X.; Ciccio, J. F.; Adzet, T.; Casanova, J.; Canigueral, S. Composition and chemical polymorphism of the essential oils from *Piper lanceaefolium*. *Biochemical Systematics and Ecology* **2001,** *29* (7), 739-748.

(19) Menon, A. N.; Padmakumari, K. P.; Jayalekshmy, A.; Gopalakrishnan, M.; Narayanan, C. S. Essential oil composition of four popular Indian cultivars of black pepper (*Piper nigrum* L.). *Journal of Essential Oil Research* **2000,** *12* (4), 431-434.

(20) Menon, A. N.; Padmakumari, K. P.; Jayalekshmy, A. J. Essential oil composition of four major cultivars of black pepper (*Piper nigrum* L.). *Journal of Essential Oil Research* **2002,** *14* (2), 84-86.

(21) Menon, A. N.; Padmakumari, K. P.; Jayalekshmy, A. Essential oil composition of four major cultivars of black pepper (*Piper nigrum* L.) III. *Journal of Essential Oil Research* **2003,** *15* (3), 155-157.

(22) Martins, A. P.; Salgueiro, L.; Vila, R.; Tomi, F.; Canigueral, S.; Casanova, J.; Da Cunha, A. P.; Adzet, T. Essential oils from four *Piper* species. *Phytochemistry* **1998,** *49* (7), 2019-2023.

(23) Maia, J. G. S.; Zohhbi, M. d. G. B.; Andrade, E. H. A.; Santos, A. S.; Silva, M. H. L. D.; Luz, A. I. R.; Bastos, C. N. Constituents of the essential oil of *Piper aduncum* L. growing wild in the Amazon region. *Flavour and Fragrance Journal* **1998,** *13* (4), 269-272.

(24) Luz, A. I. R.; Da Silva, J. D.; Zoghbi, M. G. B.; Andrade, E. H. A.; Da Silva, M. H. L.; Maia, J. G. S. Volatile constituents of Brazilian Piperaceae. Part 4. Essential oil composition of *Piper dactylostigmum*, *P. plurinervosum* and *P. vitaceum*. *Journal of Essential Oil Research* **2000,** *12* (1), 94-96.

(25) Liao, C. Chemical constituents of oil betel vine from Thailand. *Xiangliao Xiangjing Huazhuangpin* **2000,** (2), 3-6.

(26) Leal, L. F.; Miguel, O. G.; Silva, R. Z.; Yunes, R. A.; Santos, A. S.; Cechinel-Filho, V. Chemical composition of *Piper mikanianum* essential oil. *Journal of Essential Oil Research* **2005,** *17* (3), 316-317.

(27) Hoang, V. L. Chemical components of essential oil of *Piper nigrum* L. and the essential oil of *Piper betel* L. in Nghe An province. *Tap Chi Duoc Hoc* **2003,** (11), 15-17.

(28) Facundo, V. A.; de Morais, S. M. Essential oil of *Piper tuberculatum* var. *tuberculatum (*Micq.) CDC leaves. *Journal of Essential Oil Research* **2005,** *17* (3), 304-305.

(29) Do, D. R.; Doan, T. T.; Vu, T. L. Constituents of the leaf oil and leaf extract of *Piper lolot*. *Hoa Hoc Va Cong Nghiep Hoa Chat* **2001,** (5), 25-29.

(30) de Abreu, A. M.; Sevegnani, L.; Machicado, A. R.; Zimermann, D.; Rebelo, R. A. *Piper mikanianum* (Kunth) Steudel from Santa Catarina, Brazil: A new source of safrole. *Journal of Essential Oil Research* **2002,** *14* (5), 361-363.

(31) de Abreu, A. M.; Brighente, I. M. C.; de Aguiar, E. M.; Rebelo, R. A. Volatile constituents of Piperaceae from Santa Catarina, Brazil - essential oil composition of *Piper cernuum* Vell. and Peperomia emarginella (Sw.) C. DC. *Journal of Essential Oil Research* **2005,** *17* (3), 286-288.

(32) Costantin, M. B.; Sartorelli, P.; Limberger, R.; Henriques, A. T.; Steppe, M.; Ferreira, M. J. P.; Ohara, M. T.; Emerenciano, V. P.; Kato, M. J. Essential oils from *Piper cernuum* and *Piper regnellii*: antimicrobial activities and analysis by GC/MS and 13C-NMR. *Planta Medica* **2001,** *67* (8), 771-773.

(33) Chieng, T. C.; Assim, Z. B.; Fasihuddin, B. A. The essential oil composition of the leaves of five *Piper* species for taxonomic purposes. *ACGC Chemical Research Communications* **2005,** *19*, 6-12.

(34) Bizzo, H. R.; Lopes, D.; Abdala, R. V.; Pimentel, F. A.; De Souza, J. A.; Pereira, M. V. G.; Bergter, L.; Guimaraes, E. F. Sarisan from leaves of *Piper affinis hispidinervum* C. DC (long pepper). *Flavour and Fragrance Journal* **2001,** *16* (2), 113-115.

(35) Wan Salleh, W. M. N. H.; Ahmad, F.; Yen, K. H.; Sirat, H. M. Chemical compositions, antioxidant and antimicrobial activity of the essential oils of *Piper officinarum* (Piperaceae). *Natural Product Communications* **2012,** *7* (12), 1659-1662.

(36) Souto, R. N. P.; Harada, A. Y.; Andrade, E. H. A.; Maia, J. G. S. Insecticidal Activity of Piper Essential Oils from the Amazon Against the Fire Ant Solenopsis saevissima (Smith) (Hymenoptera: Formicidae). *Neotropical Entomology* **2012,** *41* (6), 510-517.

(37) Lara, C. R., Jr.; Lopes de Oliveira, G.; Mota, B. C. F.; Fernandes, M. d. F. G.; Figueiredo, L. S.; Martins, E. R.; Moreira, D. d. L.; Kaplan, M. A. C. Antimicrobial activity of essential oil of *Piper aduncum* L. (Piperaceae). *Journal of Medicinal Plants Research* **2012,** *6* (21), 3800-3805.

(38) Sauter, I. P.; Rossa, G. E.; Lucas, A. M.; Cibulski, S. P.; Roehe, P. M.; Alves da Silva, L. A.; Rott, M. B.; Vargas, R. M. F.; Cassel, E.; von Poser, G. L. Chemical composition and amoebicidal activity of *Piper hispidinervum* (Piperaceae) essential oil. *Industrial Crops and Products* **2012,** *40*, 292-295.

(39) Moura do Carmo, D. F.; Amaral, A. C. F.; Machado, G. M. C.; Leon, L. L.; Silva, J. R. d. A. Chemical and biological analyses of the essential oils and main constituents of *Piper* species. *Molecules* **2012,** *17*, 1819-1829.

(40) Lima, D. K. S.; Ballico, L. J.; Rocha Lapa, F.; Goncalves, H. P.; Mera de Souza, L.; Iacomini, M.; Werner, M. F. d. P.; Baggio, C. H.; Pereira, I. T.; Mota da Silva, L.; Facundo, V. A.; Santos, A. R. S. Evaluation of the antinociceptive, anti-inflammatory and gastric antiulcer activities of the essential oil from *Piper aleyreanum* C.DC in rodents. *Journal of Ethnopharmacology* **2012,** *142* (1), 274-282.