CHAPTER IV

RESULTS AND DISCUSSION

1. Essential Oil Composition in Each Selected *Cinnamomum* Species

1.1. Essential oil composition of *Cinnamomum bejolghota*

By HS-GC/MS analysis, two samples of *Cinnamomum bejolghota* dried leaves were analyzed. As tabulated in Table 4-1, fifty-eight compounds were identified. These included 27 monoterpenes (59.60-59.86%), 23 sesquiterpenes (37.11-37.62%) and 8 non-terpenes (1.33-2.64%).

From two *C. bejolghota*, the one from Nan province (cin21) contained the monoterpenes *p*-cymene (17.05%) and α-phellandrene (10.91%) as major components followed by α-pinene (7.90%). The major sesquiterpene was viridiflorene (6.98%) followed by (*E*)-caryophyllene (6.06%) and aristolene (5.10%). The sample from Surat-Thani province (cin27) contained the monoterpene 3-carene (16.76%) as major component, followed by β-(*E*)-ocimene (9.30%), linalool (6.77%), 1,8-cineol (5.46%) and geraniol (5.27%). The major sesquiterpene was (*E*)-caryophyllene (20.72%), followed by valencene (5.89%).

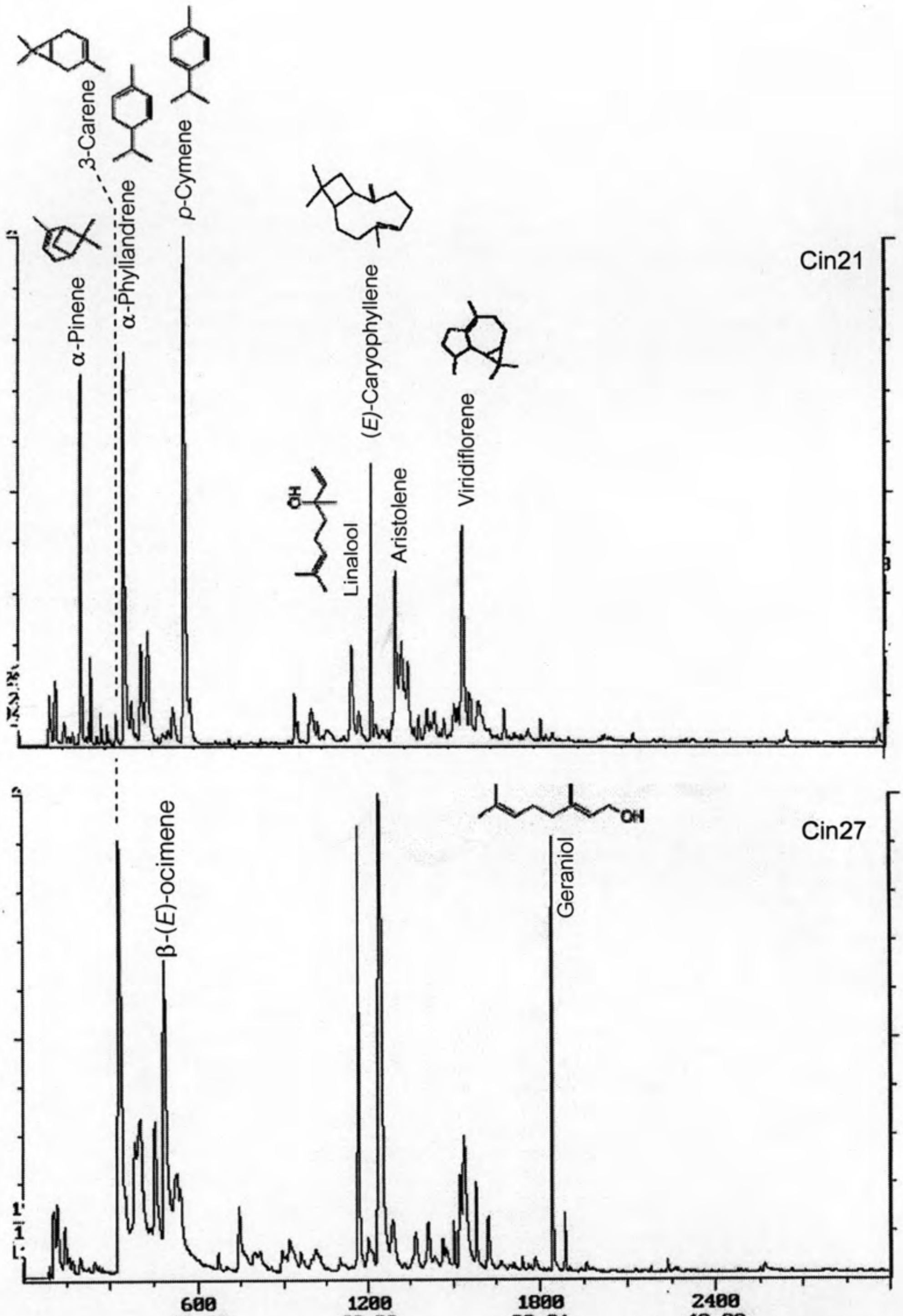

Figure 4-1 GC/MS-chromatograms of leaf oil from *Cinnamomum bejolghota*

Table 4-1 Chemical constituents of leaf oil from *Cinnamomum bejolghota*

Compound	Retention time (RT)	% Peak area		
		cin21	cin27	Average
Monoterpenes				
α-pinene	3.18	7.90	0.20	4.05
camphene	3.68	1.08	0.00	0.54
β-pinene	4.22	0.34	0.00	0.17
sabinene	4.40	0.30	0.00	0.15
3-carene	4.92	0.72	16.76	8.74
α-phyllandrene	5.35	10.91	1.92	6.42
α-terpinene	5.75	1.30	0.00	0.65
limonene	6.27	3.15	3.40	3.27
β-phyllandrene	6.48	0.00	1.94	0.97
1,8-cineol	6.67	4.57	5.46	5.01
β-(Z)-ocimene	7.55	0.21	3.64	1.92
γ-terpinene	7.90	0.21	0.00	0.10
β-(*E*)-ocimene	8.10	1.26	9.30	5.28
p-cymene	8.62	17.05	1.33	9.19
terpinolene	9.05	1.42	0.94	1.18
α-pyronene	12.50	0.00	1.61	0.80
dehydro-p-cymene	14.95	1.35	0.31	0.83
(*Z*)-linalool oxide	15.05	0.40	0.00	0.20
(*E*)-linalool oxide	16.18	0.38	0.00	0.19
linalool	19.45	4.11	6.77	5.44
bornyl acetate	20.30	0.14	0.00	0.07
terpinene-4-ol	21.30	1.47	0.00	0.74
α-terpineol	25.03	1.00	0.60	0.80
nerol	28.98	0.00	0.16	0.08
sabinol	29.10	0.38	0.00	0.19

Table 4-1 (Continued)

Compound	Retention time	% Peak area		
		cin21	cin27	Average
geraniol	30.73	0.00	5.27	2.63
carvacrol	43.03	0.21	0.00	0.10
Sesquiterpenes				
isoledene	15.67	1.76	0.00	0.88
α-cubebene	16.32	0.10	0.00	0.05
α-copaene	16.63	0.78	0.00	0.39
ylangene	18.08	4.41	0.16	2.28
isocaryophyllene	1248	0.56	0.00	0.28
longifolene	19.92	0.32	0.63	0.47
β-gurjuene	20.50	0.58	0.00	0.29
(*E*)-caryophyllene	20.73	6.06	20.72	13.39
aristolene	21.13	5.10	0.00	2.55
alloaromadendrene	21.35	3.44	2.49	2.97
α-guaiene	22.43	0.61	0.00	0.30
β-guaiene	22.70	1.15	0.93	1.04
β-cadinene	23.08	1.17	0.00	0.59
α-humulene	23.52	0.48	1.29	0.88
γ-muurolene	24.28	0.48	0.00	0.24
viridiflorene	24.48	6.98	0.50	3.74
β-selinene	25.45	1.96	2.63	2.30
valencene	25.65	0.00	5.89	2.94
δ-cadinene	26.98	0.85	1.29	1.07
calamenene	29.75	0.26	0.40	0.33
vetivenene	34.17	0.21	0.00	0.11
α-caryophyllene alcohol	37.30	0.07	0.17	0.12
guaiazulene	48.12	0.28	0.00	0.14

Table 4-1 (Continued)

Compound	Retention time	% Peak area		
		cin21	cin27	Average
Non-terpenes				
methylheptenone	11.15	0.10	0.30	0.20
1-hexanol	11.78	0.05	0.00	0.02
2-butoxy ethanol	13.60	0.04	0.00	0.02
2-methylcyclopentanol	13.83	0.03	0.00	0.02
acetic acid	15.98	0.00	0.33	0.17
benzaldehyde	18.92	1.11	0.00	0.56
benzyl acetate	26.30	0.00	1.26	0.63
safrole	31.48	0.00	0.76	0.38
% Identified		98.81	99.35	99.08

1.2. Essential oil composition of *Cinnamomum camphora*

Forty-five components were identified by GC/MS analysis of the *Cinnamomum camphora* leaf oil from six localities. These included 25 monoterpenes (76.35-99.23%), 11 sesquiterpenes (0.61%-11.02%) and 9 non-terpenoid (0.12-8.24%). As shown in Table 4-2, the oxygenated-monoterpene camphor (59.81-95.73%) appeared to be the major component in most samples (cin05, 10, 19, and 47) and linalool (72.13-73.92%) was found to be the major component in two other samples (cin07 and 23).

On average, the leaf oil of *C. camphora* contained camphor (51.35%) as the major component, followed by linalool (24.64%). Other monoterpenoid components present in amount greater than 1% were limonene (3.46%), α-pinene (2.71%), α-phellandrene (2.01%), *p*-cymene (1.38%), and camphene (1.35%). Minor compounds were the sesquiterpene (*E*)-caryophyllene (1.63%), and the phenylpropane eugenol (1.56%).

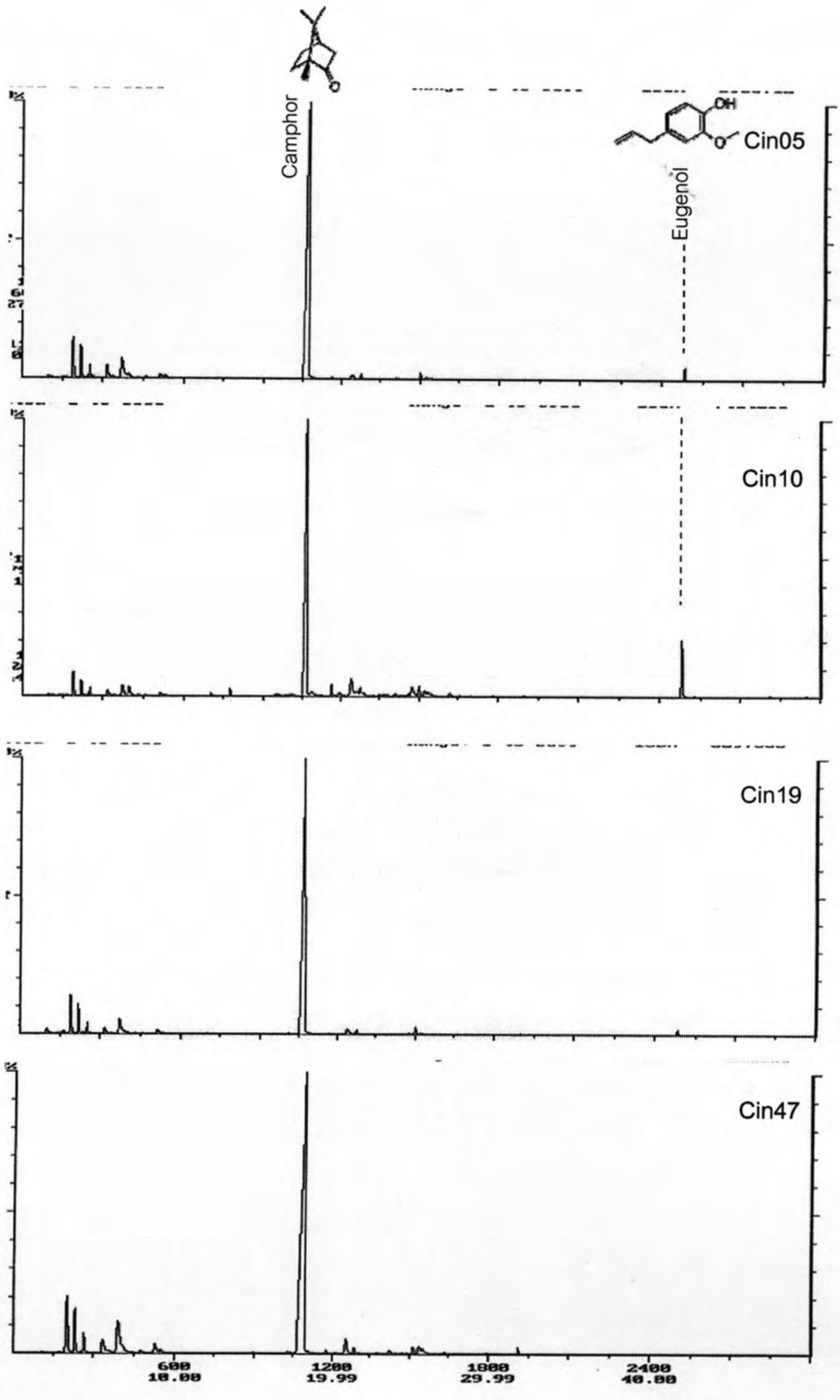

Figure 4-2 GC/MS-chromatograms of essential oil from *C. camphora* leaves, having camphor as the major component.

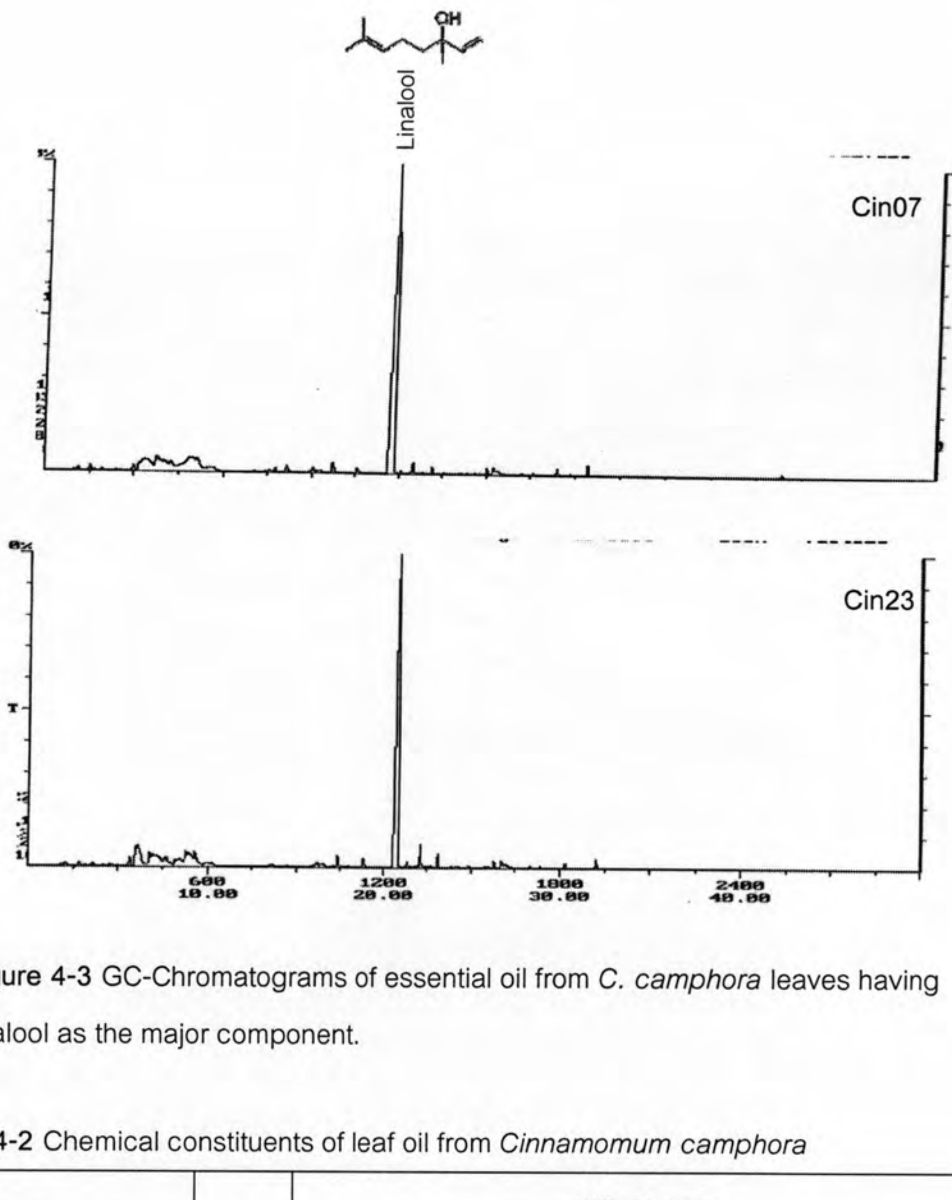

Figure 4-3 GC-Chromatograms of essential oil from *C. camphora* leaves having linalool as the major component.

Table 4-2 Chemical constituents of leaf oil from *Cinnamomum camphora*

Compound	RT	%Peak area						
		cin05	cin07	cin10	cin19	cin23	cin47	Average
Monoterpenes								
α-pinene	3.18	5.80	0.27	3.23	5.70	0.37	0.88	2.71
camphene	3.68	3.09	0.03	1.31	3.07	0.08	0.49	1.35
β-pinene	4.22	1.17	0.12	0.72	1.08	0.11	0.21	0.57
sabinene	4.40	0.13	0.06	0.05	0.11	0.08	0.02	0.07
3-carene	4.92	0.00	0.84	0.00	0.00	1.34	0.01	0.37
α-phyllandrene	5.35	2.45	2.65	1.10	1.31	4.25	0.31	2.01

Table 4-2 (Continued)

Compound	RT	%Peak area						
		cin05	cin07	cin10	cin19	cin23	cin47	Average
α-terpinene	5.75	0.44	0.00	0.38	0.00	0.00	0.08	0.15
limonene	6.27	5.26	4.13	2.29	3.52	4.74	0.82	3.46
1,8-cineol	6.67	1.01	1.32	1.77	0.00	0.79	0.00	0.82
β-(Z)-ocimene	7.55	0.39	0.00	0.16	0.00	0.00	0.00	0.09
γ-terpinene	7.90	0.00	0.00	0.00	0.00	0.00	0.07	0.01
β-(*E*)-ocimene	8.10	0.00	0.00	0.00	0.00	1.42	0.00	0.24
p-cymene	8.62	0.74	4.01	0.73	1.04	1.61	0.19	1.38
terpinolene	9.05	0.36	0.00	0.25	0.00	0.00	0.08	0.11
(*E*)-isolimonene	9.80	0.00	0.23	0.00	0.00	0.26	0.00	0.08
(Z)-linalool oxide	15.05	0.00	1.09	0.00	0.00	0.45	0.00	0.26
(*E*)-linalool oxide	16.18	0.00	1.54	0.00	0.00	1.34	0.00	0.48
camphor	17.60	72.78	0.85	59.81	77.82	1.14	95.73	51.35
linalool	19.45	0.19	72.13	1.46	0.10	73.92	0.04	24.64
bornyl acetate	20.30	0.00	0.28	0.00	0.00	0.36	0.00	0.11
terpinene-4-ol	21.30	0.64	0.00	1.34	0.45	0.00	0.05	0.41
α-terpineol	25.03	0.90	0.58	1.71	1.17	0.55	0.12	0.84
borneol	25.28	0.00	0.00	0.00	0.00	0.00	0.14	0.02
nerol	28.98	0.00	0.47	0.00	0.00	0.44	0.00	0.15
geraniol	30.73	0.00	0.83	0.06	0.00	0.79	0.00	0.28
Sesquiterpenes								
α-copaene	16.63	0.00	0.00	0.00	0.47	0.00	0.07	0.09
longifolene	19.92	0.12	0.00	1.00	0.13	0.00	0.00	0.21
ylangene	18.08	0.00	0.00	0.74	0.00	0.00	0.00	0.12
(*E*)-caryophyllene	20.73	1.01	0.89	4.43	1.38	1.77	0.29	1.63
α-humulene	23.52	0.27	0.00	0.36	0.14	0.00	0.05	0.14
γ-muurolene	24.28	0.04	0.00	0.00	0.05	0.00	0.00	0.02

Table 4-2 (Continued)

Compound	RT	%Peak area						
		cin05	cin07	cin10	cin19	cin23	cin47	Average
viridiflorene	24.48	0.00	0.00	2.61	0.00	0.00	0.00	0.43
β-selinene	25.45	0.50	1.13	1.18	0.19	1.12	0.00	0.69
α-gurjunene	25.65	0.00	0.00	0.00	0.00	0.00	0.14	0.02
δ-cadinene	26.98	0.11	0.32	0.55	0.17	0.25	0.03	0.24
calamenene	29.75	0.08	0.02	0.15	0.11	0.00	0.02	0.06
Non-terpenes								
methylheptenone	11.15	0.00	0.00	0.00	0.04	0.00	0.00	0.01
1-hexanol	11.78	0.00	0.15	0.28	0.12	0.00	0.00	0.09
(Z)-3-hexenol	12.97	0.00	0.29	0.79	0.07	0.00	0.00	0.19
2-methylcyclopentanol	13.83	0.00	0.06	0.00	0.00	0.00	0.00	0.01
acetic acid	15.98	0.00	0.00	0.00	0.09	0.12	0.00	0.04
benzaldehyde	18.33	0.00	0.00	0.00	0.00	0.00	0.06	0.01
benzyl alcohol	31.73	0.06	0.00	0.13	0.15	0.00	0.06	0.07
eugenol	41.43	1.52	0.33	6.92	0.61	0.00	0.00	1.56
eugenyl acetate	46.85	0.00	0.00	0.11	0.00	0.00	0.00	0.02
% Identified		99.07	94.61	95.61	99.09	97.29	99.95	

1.3. Essential oil composition of *Cinnamomum iners*

There are seventy-nine compounds identified in the leaf essential oil from 14 samples of *Cinnamomum iners*. These included 30 monoterpenes (8.91-91.82%), 30 sesquiterpenes (2.73-85.40%) and 19 non-terpenoids (1.77-15.70%).

For this study, the 14 samples representing *C. iners* appear to contain highly variable composition in their leaf essential oil. As shown in Table 4-3, most samples (cin03, 06, 18, 22, 37, 39, 41, 43, 49 and 50) contained (*E*)-caryophyllene (17.56-51.87%) as their major component, while the major component in other 3 samples was linalool (33.55-52.75%). Only one sample (cin51) contained *p*-cymene (16.92%) and α-pinene (12.14%) as major components, followed by (*Z*)-3-hexenol (8.06%). Other components that were present in the amount of more than 10% were α-pinene (20.97%, in cin18), β-(*E*)-ocimene (12.25%, in cin46), β-phellandrene (17.54%, in cin43) and α-phellandrene (18.94%, in cin46).

On average, the leaf oil of *C. iners* contained (*E*)-caryophyllene (23.48%) and linalool (11.25%) as major component, followed by α-pinene (7.91%).

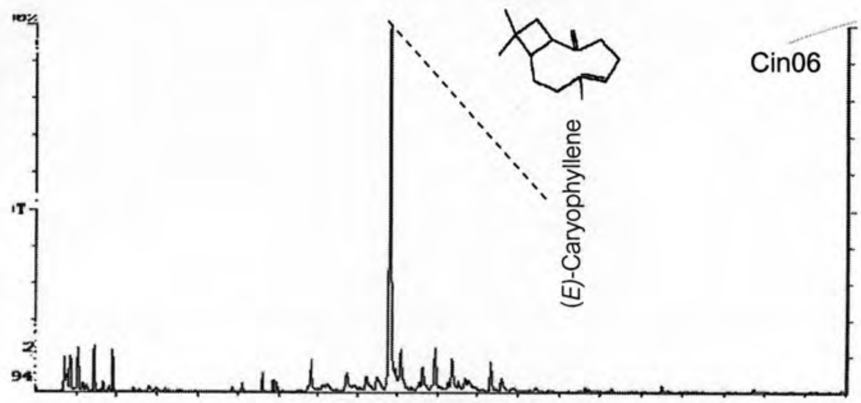

Figure 4-4 GC-Chromatogram of essential oil from *C. iners* leaves which have (*E*)-caryophyllene as major component.

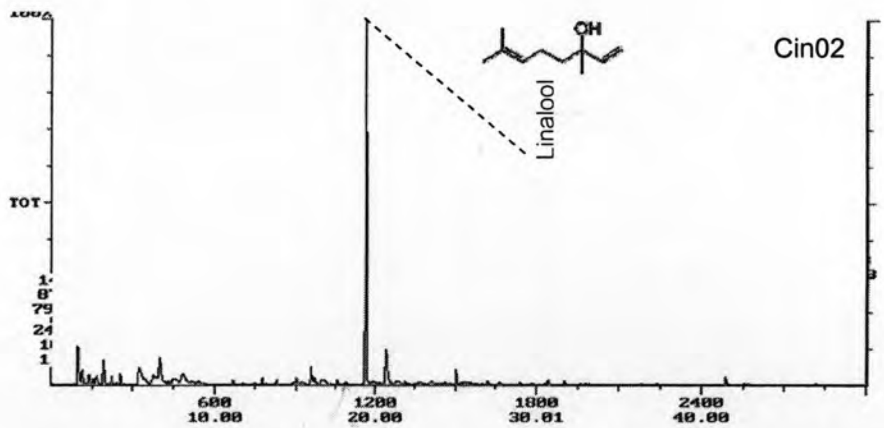

Figure 4-5 GC-Chromatogram of essential oil from *C. iners* leaves which have linalool as major component.

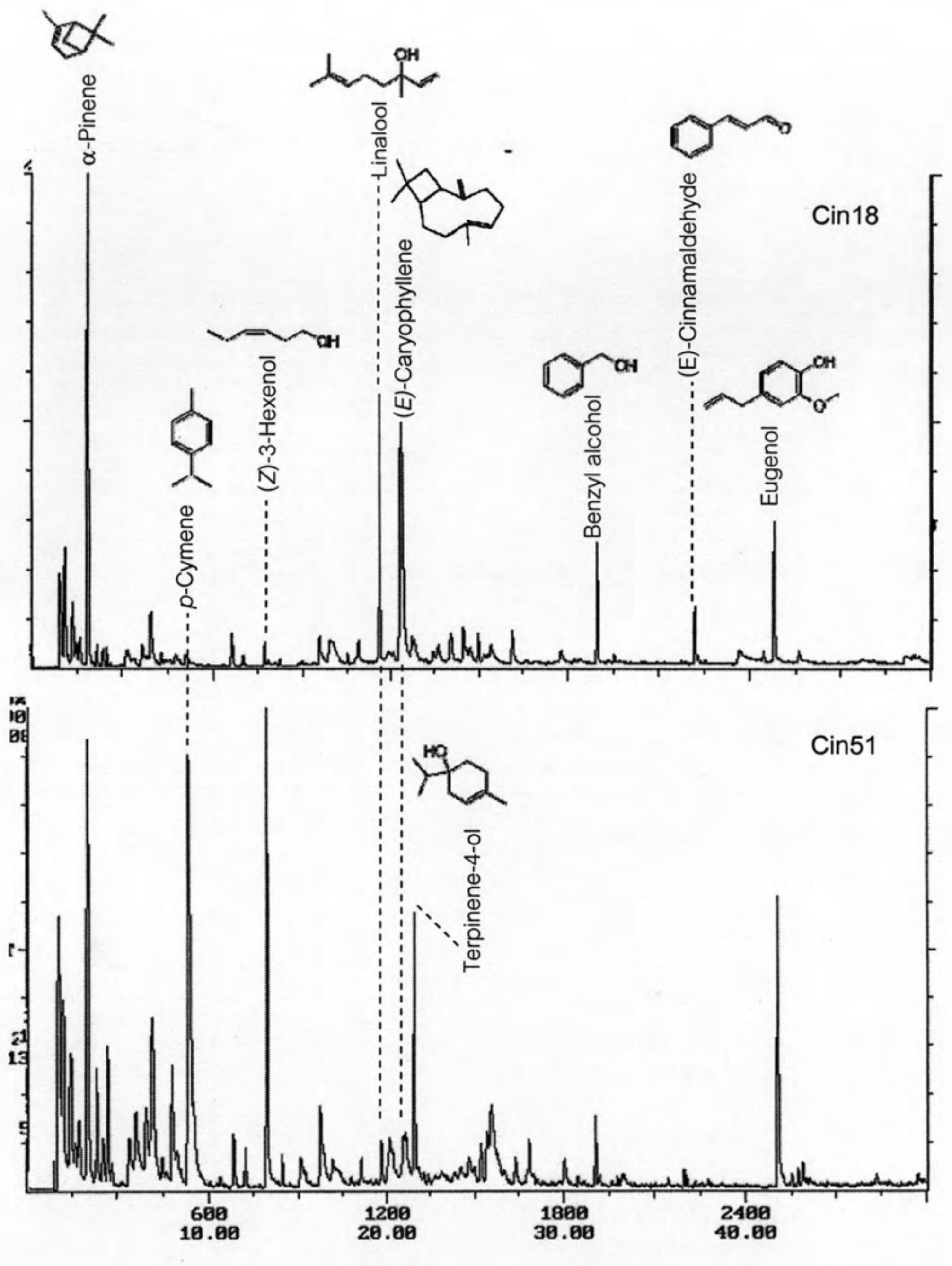

Figure 4-6 GC-Chromatogram of essential oil from *C. iners* leaves which have mixed-compounds as major components.

Table 4-3 Chemical constituents of leaf oil from *Cinnamomum iners*

Compound	RT	%Peak area														
		cin02	cin03	cin06	cin13	cin18	cin22	cin37	cin39	cin41	cin43	cin46	cin49	cin50	cin51	Average
Monoterpenes																
α-pinene	3.18	4.15	6.46	4.24	4.27	20.97	2.51	5.08	15.46	8.84	8.50	2.45	10.57	5.98	12.28	7.98
camphene	3.68	0.98	0.13	0.58	0.97	0.67	0.26	0.91	0.85	0.35	0.21	0.00	2.22	0.25	2.41	0.77
β-pinene	4.22	1.11	0.37	2.23	0.72	0.00	0.52	1.16	1.28	2.05	1.26	0.90	2.36	1.69	2.87	1.32
sabinene	4.40	0.00	0.00	0.00	4.11	0.51	0.16	0.00	1.09	2.30	1.78	0.22	2.32	2.37	0.37	1.09
3-carene	4.92	0.00	0.00	0.00	0.00	1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.16	0.17
α-phyllandrene	5.35	5.66	0.21	0.34	0.00	0.47	1.67	0.00	1.38	2.02	5.72	18.94	2.06	1.22	1.17	2.92
α-terpinene	5.75	1.88	0.00	0.00	0.00	0.00	2.31	0.64	2.67	3.75	4.51	0.00	3.25	2.02	2.23	1.66
limonene	6.27	0.83	0.35	0.79	2.30	1.29	0.98	1.23	1.84	1.59	3.62	8.09	2.08	1.15	2.13	2.02
β-phyllandrene	6.48	0.00	0.00	0.00	0.00	0.00	0.91	0.00	0.00	0.00	17.54	0.00	0.00	0.00	0.00	1.32
1,8-cineol	6.67	4.96	0.09	0.45	5.37	4.00	1.98	6.22	4.24	5.22	0.00	0.00	4.59	4.40	6.50	3.43
β-(Z)-ocimene	7.55	2.36	0.00	0.00	4.75	0.00	0.53	0.34	0.00	0.57	0.00	7.04	4.09	2.73	0.00	1.60
γ-terpinene	7.90	0.00	0.00	0.00	0.00	0.00	3.05	0.39	3.06	4.83	3.98	0.00	0.00	0.00	3.55	1.35
β-(*E*)-ocimene	8.10	4.14	0.00	0.00	7.35	0.99	1.49	0.78	0.00	2.16	0.00	12.25	0.47	0.00	1.08	2.19
p-cymene	8.62	0.45	0.52	0.00	0.00	0.92	2.93	0.52	2.51	8.22	6.14	1.68	5.75	3.59	17.12	3.60
terpinolene	9.05	0.63	0.00	0.00	1.12	0.00	1.06	0.26	1.08	2.29	1.99	3.14	1.91	1.31	3.21	1.29

Table 4-3 (Continued)

Compound	RT	%Peak area														
		cin02	cin03	cin06	cin13	cin18	cin22	cin37	cin39	cin41	cin43	cin46	cin49	cin50	cin51	Average
dehydro-p-cymene	14.95	0.00	0.00	0.00	0.49	0.00	0.21	0.00	0.32	0.00	0.00	1.22	0.00	0.00	1.00	0.23
(*Z*)-linalool oxide	15.05	0.77	0.00	0.00	0.80	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.20
(*E*)-linalool oxide	16.18	1.38	0.00	0.00	0.58	0.00	0.00	1.11	0.00	0.00	0.00	0.57	0.42	0.54	0.00	0.33
camphor	17.60	0.67	0.18	0.00	0.10	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
linalool	19.45	45.16	0.00	0.00	52.75	8.83	1.67	7.92	2.34	0.97	1.33	33.55	0.99	1.11	0.85	11.25
bornyl acetate	20.30	0.00	0.00	0.00	0.35	0.27	0.00	0.21	0.00	0.00	0.00	0.00	0.05	0.00	1.38	0.16
terpinene-4-ol	21.30	0.00	0.00	0.00	0.00	1.01	3.57	0.95	2.68	2.53	5.35	0.30	2.66	3.87	4.42	1.95
α-terpineol	25.03	2.13	1.12	0.30	0.00	1.11	1.00	0.00	1.07	0.43	0.76	0.84	0.76	0.45	0.92	0.78
borneol	25.28	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
cumin aldehyde	27.68	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
nerol	28.98	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.04	0.00	0.05
sabinol	29.10	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
geraniol	30.73	0.51	0.00	0.00	0.67	0.00	0.00	0.00	0.28	0.27	0.05	0.36	0.12	0.00	0.00	0.16
cuminic alcohol	39.71	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
carvacrol	43.03	0.52	0.39	0.00	0.00	0.00	0.00	0.00	0.23	0.36	0.00	0.00	0.00	0.00	0.00	0.11

Table 4-3 (Continued)

Compound	RT	%Peak area														
		cin02	cin03	cin06	cin13	cin18	cin22	cin37	cin39	cin41	cin43	cin46	cin49	cin50	cin51	Average
Sesquiterpenes																
isoledene	15.67	0.00	0.00	0.00	0.00	0.00	0.49	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
α-cubebene	16.32	0.00	1.82	0.00	0.66	0.00	1.41	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.29
α-copaene	16.63	2.89	0.84	0.44	1.01	3.94	6.69	13.28	0.00	0.00	0.00	0.58	0.00	1.74	0.33	2.27
β-pachoulene	17.10	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.20	0.63	0.00	0.13
ylangene	18.08	0.00	1.66	2.72	0.00	0.00	2.14	1.00	0.06	0.82	0.11	0.00	0.00	0.54	0.00	0.65
isocaryophyllene	22.87	0.00	2.80	1.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
longifolene	19.92	0.00	2.32	1.93	0.00	0.00	1.90	0.26	0.00	0.00	1.58	0.00	0.00	0.00	0.00	0.57
(E)-caryophyllene	20.73	9.73	34.17	51.87	3.58	21.77	29.93	29.66	40.52	29.59	21.97	1.76	30.82	17.56	2.78	23.26
aristolene	21.13	0.00	7.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.43	0.00	0.73
alloaromadendrene	21.35	0.00	7.34	5.06	0.00	2.18	3.51	3.74	4.93	3.14	3.48	0.00	2.66	0.00	0.00	2.57
aromadendrene	21.70	0.00	3.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
α-guaiene	22.43	0.00	0.00	0.00	0.00	0.45	0.00	0.41	0.00	0.00	0.00	0.00	0.00	4.27	0.00	0.37
β-guaiene	22.70	0.00	1.74	0.00	0.00	0.76	0.00	0.00	3.04	1.53	1.77	0.00	1.93	1.45	0.00	0.87
α-humulene	23.52	0.87	3.74	4.51	0.00	2.23	2.42	2.56	4.52	2.36	2.51	0.00	2.73	2.17	0.00	2.19
γ-muurolene	24.28	0.00	1.36	0.00	0.00	0.84	1.97	1.06	0.00	0.93	0.18	0.00	1.27	2.63	0.00	0.73
viridiflorene	24.48	0.00	3.14	4.88	1.08	0.00	4.63	3.41	0.00	0.00	1.09	0.00	0.00	3.24	0.00	1.53

Table 4-3 (Continued)

Compound	RT	%Peak area														
		cin02	cin03	cin06	cin13	cin18	cin22	cin37	cin39	cin41	cin43	cin46	cin49	cin50	cin51	Average
β-selinene	25.45	0.00	2.80	0.86	0.00	0.00	1.34	0.00	0.00	0.00	0.19	0.00	0.00	1.91	0.00	0.51
α-selinene	25.52	0.00	7.06	0.00	0.00	0.00	2.28	0.00	0.00	0.00	0.27	0.00	0.00	0.92	0.00	0.75
valencene	25.65	0.00	0.00	0.00	0.00	1.18	0.00	0.00	0.57	0.00	0.00	0.00	0.00	3.17	4.51	0.67
α-muurolene	25.75	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.65	0.00	0.20	0.00	0.00	0.00	0.00	0.17
δ-cadinene	26.98	0.75	1.05	3.48	0.00	1.97	4.19	1.81	0.44	1.00	0.89	0.00	0.60	9.39	0.73	1.88
α-curcumene	27.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.66	0.08
calamenene	29.75	0.00	0.00	0.00	0.00	0.92	1.62	1.12	0.00	0.00	0.00	0.39	0.00	5.31	0.85	0.73
β-calacorene	32.32	0.00	0.00	0.00	0.00	0.00	0.23	0.31	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.06
α-calacorene	32.68	0.00	0.76	0.50	0.00	0.33	0.71	0.39	0.00	0.00	0.07	0.00	0.00	1.61	0.22	0.33
caryophyllene oxide	35.45	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.06	0.00	0.00	0.00	0.00	0.23	0.00	0.04
α-dehydro-himachalene	37.77	0.00	0.00	0.00	0.00	0.15	0.36	0.14	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.10
spathulenol	39.68	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
cadalene	42.80	0.27	0.24	0.00	0.00	0.56	0.72	0.43	0.00	0.31	0.00	0.00	0.21	1.87	0.52	0.37
guaiazulene	48.12	0.00	1.11	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
Non-terpenes																
methylheptenone	11.15	0.65	0.20	0.38	0.27	1.49	0.38	0.30	0.09	1.57	0.11	0.00	1.81	0.44	1.12	0.63
1-hexanol	11.78	0.00	0.00	0.55	0.00	0.45	0.15	0.46	0.43	0.78	0.42	0.83	0.36	0.11	0.71	0.37

Table 4-3 (Continued)

Compound	RT	%Peak area														
		cin02	cin03	cin06	cin13	cin18	cin22	cin37	cin39	cin41	cin43	cin46	cin49	cin50	cin51	Average
(Z)-3-hexenol	12.97	0.81	1.46	1.27	0.09	0.82	0.39	3.60	1.27	0.90	0.76	1.88	0.96	0.18	8.06	1.60
2-butoxy ethanol	13.60	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.15	0.00	0.06
2-methylcyclopentanol	13.83	0.55	0.07	0.62	0.04	0.23	0.28	1.79	0.19	1.01	0.25	1.54	0.10	0.13	0.48	0.52
furfural	14.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.40	0.00	0.45	0.42	0.00	0.13
acetic acid	15.98	3.20	0.46	2.29	0.65	1.53	0.57	0.46	0.29	1.63	0.24	0.79	1.56	0.80	3.04	1.25
benzaldehyde	18.33	0.00	0.00	0.00	0.75	1.52	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.49	0.24
methyl benzoate	22.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.02
ethyl benzoate	23.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.01
pentyl benzoate	30.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.17	0.00	0.03
safrole	31.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.34	0.00	0.04
benzyl alcohol	31.73	0.50	0.52	0.00	0.19	4.12	0.00	0.22	0.00	0.11	0.00	0.00	0.08	0.10	1.23	0.50
butylated hydroxytoluene	32.98	0.00	0.00	0.00	0.17	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
o-methyleugenol	36.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.02
(*E*)-cinnamaldehyde	37.12	0.00	0.00	0.00	0.00	2.24	0.00	0.00	0.00	2.65	0.00	0.00	4.19	0.00	0.18	0.66
cinnamyl acetate	40.95	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.03

Table 4-3 (Continued)

Compound	RT	%Peak area														
		cin02	cin03	cin06	cin13	cin18	cin22	cin37	cin39	cin41	cin43	cin46	cin49	cin50	cin51	Average
eugenol	41.43	1.04	1.32	0.00	0.36	5.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.32	0.95
o-eugenol	42.22	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.02
%Identified		99.85	99.36	93.61	97.93	98.29	96.08	96.29	99.43	98.29	99.42	99.58	97.88	97.92	97.39	97.95

1.4. Essential oil composition of *Cinnamomum pachyphyllum*

Forty-eight compounds were separated and identified by GC/MS analysis of *Cinnamomum pachyphyllum* leaf oil. These included 24 monoterpenes (67.54-79.29%), 20 sesquiterpenes (10.48-30.18%) and only 4 non-terpenoids (0.34-1.09%). Two samples of *C. pachyphyllum* were collected from the same location, but they showed some differences in their chemical composition.

The first sample (cin28) contained the monoterpenes *p*-cymene (19.45%) and limonene (15.48%) as major components, followed by α-pinene (6.85%), 1,8-cineol (6.70%) and linalool (5.36%). The sesquiterpenoids comprised 10.48% of the total leaf oil. Comparing to the first one, the second sample contained more sesquiterpenoid compounds (30.18%), of which (*E*)-caryophyllene (13.13%) as major components. Other components that were found in quantity of more than 10% were β-phellandrene (20.40%) and 1,8-cineol (13.47%).

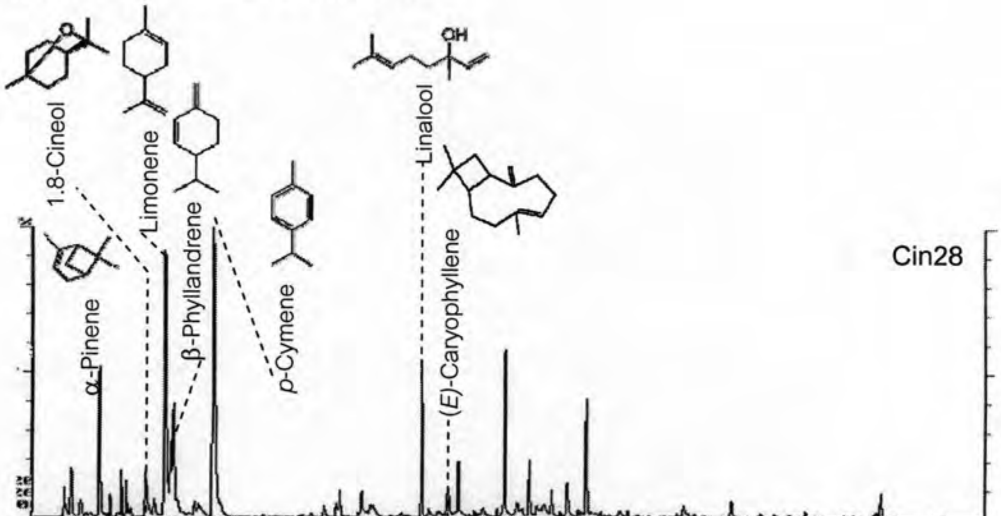

Figure 4-7: GC-Chromatograms of essential oil from *C. pachyphyllum*

Table 4-4 Chemical constituents of leaf oil from *Cinnamomum pachyphyllum*

Compound	Retention time	%Peak area		
		cin28	cin29	Average
Monoterpenes				
α-pinene	3.18	6.85	2.81	4.83
camphene	3.68	0.58	0.28	0.43
β-pinene	4.22	1.13	0.54	0.84
sabinene	4.40	1.34	0.56	0.95
3-carene	4.92	0.30	0.00	0.15
α-phyllandrene	5.35	2.70	8.92	5.81
α-terpinene	5.75	0.84	1.60	1.22
limonene	6.27	15.48	7.41	11.44
β-phyllandrene	6.48	3.84	20.40	12.12
1,8-cineol	6.67	6.70	13.47	10.09
γ-terpinene	7.90	0.65	0.52	0.59
β-(*E*)-ocimene	8.10	0.77	0.00	0.38
p-cymene	8.62	19.45	3.97	11.71
dehydro-p-cymene	14.95	0.85	0.25	0.55
(Z)-linalool oxide	15.05	1.10	0.00	0.55
1,3,8-p-menthatriene	15.40	0.00	0.29	0.14
(*E*)-linalool oxide	16.18	0.99	0.00	0.49
linalool	19.45	5.36	1.60	3.48
terpinene-4-ol	21.30	1.97	1.23	1.60
α-terpineol	25.03	2.07	2.90	2.48
cumin aldehyde	27.68	4.75	0.62	2.69
geraniol	30.73	0.19	0.00	0.09
cuminic alcohol	39.71	0.24	0.00	0.12
carvacrol	43.03	1.15	0.16	0.65

Table 4-4 (Continued)

Compound	Retention time	%Peak area		
		cin28	cin29	Average
Sesquiterpenes				
α-cubebene	16.32	0.00	2.79	1.40
α-copaene	16.63	0.00	1.30	0.65
isocaryophyllene	22.87	0.36	0.00	0.18
(*E*)-caryophyllene	20.73	1.89	13.13	7.51
alloaromadendrene	21.35	0.00	2.69	1.35
α-guaiene	22.43	0.29	0.27	0.28
α-humulene	23.52	0.26	1.28	0.77
γ-muurolene	24.28	0.63	0.78	0.71
viridiflorene	24.48	0.41	1.72	1.06
β-selinene	25.45	0.61	1.22	0.91
valencene	25.65	0.73	0.78	0.76
α-muuro	25.75	0.96	0.85	0.90
δ-cadinene	26.98	2.11	1.41	1.76
calamenene	29.75	0.57	0.84	0.71
α-calacorene	32.68	0.16	0.31	0.23
vetivenene	34.17	0.00	0.13	0.06
caryophyllene oxide	35.45	0.87	0.17	0.52
α-caryophyllene alcohol	37.30	0.26	0.17	0.21
α-dehydro-himachalene	37.77	0.20	0.14	0.17
cadalene	42.80	0.19	0.20	0.19
Non-terpenes				
methylheptenone	11.15	0.11	0.00	0.06
2-butoxy ethanol	13.60	0.20	0.00	0.10
acetic acid	15.98	0.07	0.19	0.13
ionol	32.98	0.70	0.15	0.43
% Identified		**90.87**	**98.06**	**94.47**

1.5. Essential oil composition of *Cinnamomum porrectum*

Forty-nine components were characterized in the leaf essential oil from two samples of *Cinnamomum porrectum*. These included 11 monoterpenes (12.18-24.00%), 22 sesquiterpenes (47.06-69.33%) and 16 non-terpenes (13.61-21.25%).

In Figure 4-8, the chromatograms showed different chromatographic profiles of leaf essential oil of *C. porrectum* from 2 locations. However, as tabulated in Table 4-5, both samples contained the sesquiterpene (*E*)-caryophyllene (15.17-37.18%) as their major component. Other major components in the sample from Surat Thani province (cin25) were safrole (9.93%), 2-methyl-3-butan-2-ol (9.16%), α-selinene (6.17%) and β-selinene (5.32%). The *C. porrectum* sample from Prathum Thani (cin44) also contained appreciable amount of 2-methyl-3-butan-2-ol (6.36%).

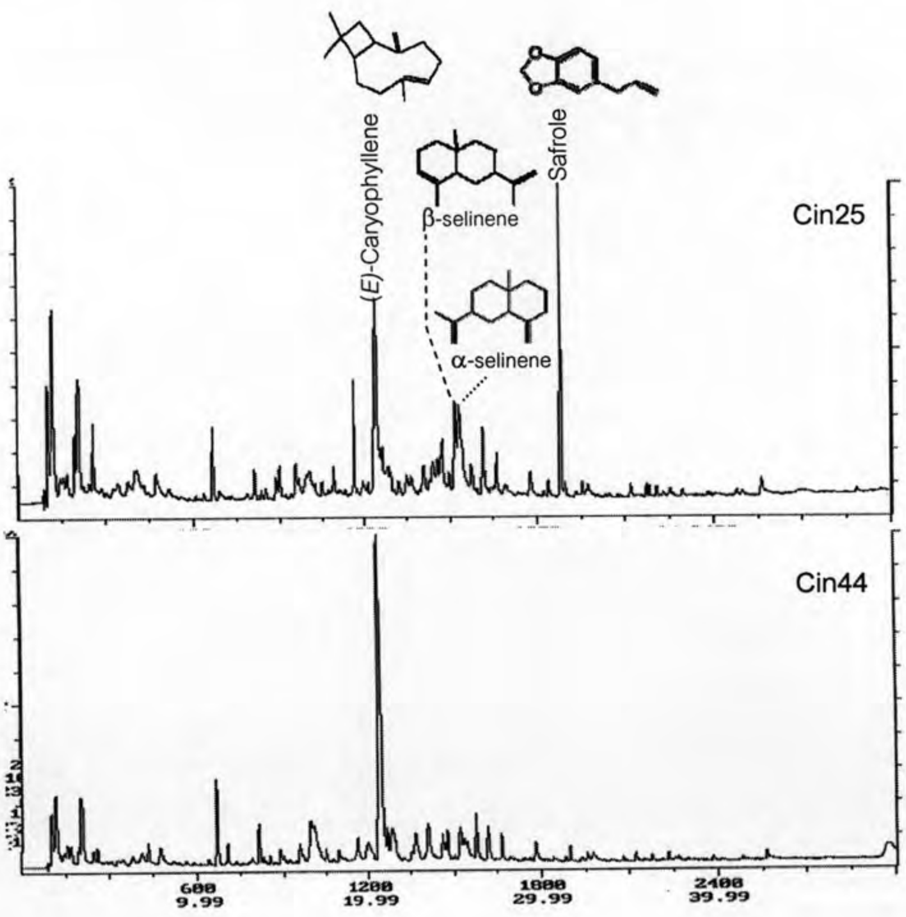

Figure 4-8: GC-Chromatograms of essential oil from *C. porrectum*

Table 4-5 Chemical constituents of leaf oil from *Cinnamomum porrectum*

Compound	Retention time	%Peak area		
		cin25	cin44	Average
Monoterpenes				
α-pinene	3.18	2.48	0.88	1.68
2-methyl-3-butan-2-ol	3.38	9.16	6.36	7.76
β-pinene	4.22	2.13	0.00	1.06
sabinene	4.40	0.00	0.60	0.30
γ-terpinene	7.90	1.91	1.37	1.64
(Z)-linalool oxide	15.05	1.30	0.39	0.85
(*E*)-linalool oxide	16.18	1.14	0.00	0.57
camphor	17.60	0.57	0.63	0.60
linalool	19.45	4.01	1.78	2.89
bornyl acetate	20.30	0.23	0.00	0.12
α-terpineol	25.03	0.63	0.00	0.31
geraniol	30.73	0.46	0.17	0.32
Sesquiterpenes				
α-copaene	16.63	0.00	3.02	1.51
ylangene	18.08	0.95	0.00	0.47
longifolene	19.92	0.69	2.47	1.58
(E)-caryophyllene	20.73	15.17	37.18	26.18
alloaromadendrene	21.35	0.00	3.51	1.76
aromadendrene	21.70	0.20	0.83	0.52
α-guaiene	22.43	1.31	0.49	0.90
β-guaiene	22.70	0.00	3.05	1.53
α-humulene	23.52	1.44	3.63	2.54
γ-muurolene	24.28	1.68	1.40	1.54
viridiflorene	24.48	1.26	0.88	1.07

Table 4-5 (Continued)

Compound	Retention time	%Peak area		
		cin25	cin44	Average
β-selinene	25.45	5.32	2.80	4.06
α-selinene	25.52	6.17	1.61	3.89
aristolene	25.65	2.32	0.00	1.16
δ-cadinene	26.98	3.78	2.45	3.12
α-curcumene	27.75	1.05	1.24	1.15
calamenene	29.75	1.76	1.62	1.69
α-calacorene	32.68	0.50	0.35	0.43
caryophyllene oxide	35.45	0.55	0.50	0.52
spathulenol	39.68	0.00	0.22	0.11
cadalene	42.80	0.73	0.45	0.59
Non-terpenes				
methylheptenone	11.15	2.92	4.46	3.69
1-hexanol	11.78	0.41	0.74	0.58
2-butoxy ethanol	13.60	1.22	2.20	1.71
2-methylcyclopentanol	13.83	0.38	0.26	0.32
furfural	14.82	1.24	1.04	1.14
acetic acid	15.98	1.88	1.08	1.48
benzaldehyde	18.33	0.00	0.54	0.27
ethyl benzoate	23.82	0.37	0.00	0.19
benzyl acetate	26.30	1.33	2.56	1.94
hydrocinnamaldehyde	28.15	0.34	0.00	0.17
safrole	31.48	9.93	0.16	5.04
benzyl alcohol	31.73	0.32	0.59	0.45
O-methyleugenol	36.52	0.35	0.00	0.17
3-benzene propanol	37.50	0.40	0.00	0.20

Table 4-5 (Continued)

Compound	Retention time	%Peak area		
		cin25	cin44	Average
eugenol	41.43	0.16	0.00	0.08
%Identified		92.32	95.13	93.72

1.6. Essential oil composition of *Cinnamomum sintoc*

It was found that the leaf oil of *C. sintoc* was dominated by the sesquiterpene (*E*)-caryophyllene (26.19%), with lesser amounts of δ-cadinene (5.46%). The major monoterpene was α-pinene (13.47%), followed by γ-terpinene (5.99%), *p*-cymene (5.91%) and 1,8-cineol (5.72%). Fifteen monoterpenes, thirteen sesquiterpenes, and one aliphatic compound were identified in this oil. The chemical composition of the leaf oil is summarized in Table 4-6.

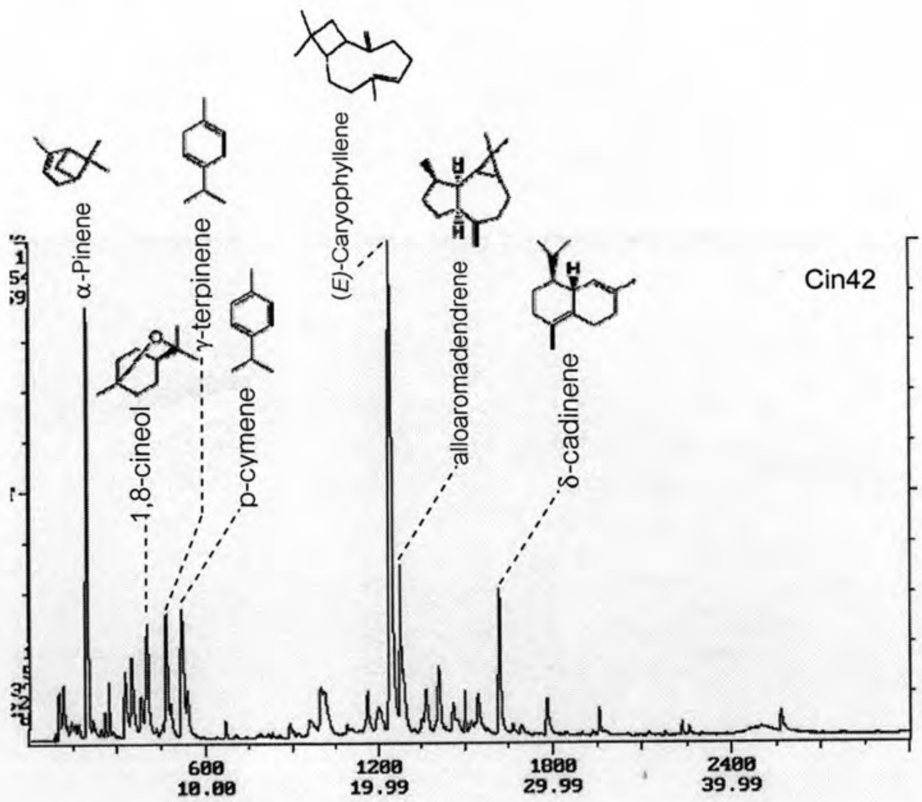

Figure 4-9: GC-Chromatogram of essential oil from *C. sintoc*

Table 4-6 Chemical constituents of leaf oil from *Cinnamomum sintoc*

Compound	Retention time	%Peak area
Monoterpenes		
α-pinene	3.18	13.47
β-pinene	4.22	0.50
sabinene	4.40	1.07
α-phyllandrene	5.35	2.85
α-terpinene	5.75	4.03
limonene	6.27	1.75
1,8-cineol	6.67	5.72
β-(Z)-ocimene	7.55	0.40
γ-terpinene	7.90	5.99
β-(*E*)-ocimene	8.10	1.41
p-cymene	8.62	5.91
terpinolene	9.05	1.84
linalool	19.45	1.57
terpinene-4-ol	21.30	1.42
α-terpineol	25.03	0.76
Sesquiterpenes		
α-copaene	16.63	2.09
(E)-caryophyllene	20.73	26.19
allo aromadendrene	21.35	3.45
β-guaiene	22.70	2.26
α-humulene	23.52	3.18
γ-muurolene	24.28	0.65
δ-cadinene	26.98	5.46
α-curcumene	27.75	0.18
calamenene	29.75	1.74

Table 4-6 (Continued)

Compound	Retention time	%Peak area
α-calacorene	32.68	0.82
α-caryophyllene alcohol	37.30	0.27
α-dehydro-himachalene	37.77	0.27
cadalene	42.80	0.71
Non-terpene		
Methylheptenone	11.15	0.39

1.7. Essential oil composition of *Cinnamomum subavenium*

Five samples of *C. subavenium* were collected from two provinces: one from Phitsanulok (cin20) and the other four from Nakorn Ratchasima (cin33-cin36). There were sixty components identified, including 20 monoterpenes (4.82%-67.96%), 29 sesquiterpenes (13.93-86.21%) and 11 non-terpenes (0.97-13.43%).

As shown in Figures 4-10 and 4-11, the sample from Phitsanulok (cin20) contained leaf oil rich in α-pinene (22.84%) and linalool (22.07%). On the other hand, the four samples from Nakorn Ratchasima province contained less than 10% of these substances, but their leaf oils had (*E*)-caryophyllene (22.26-58.69%) as the major compound.

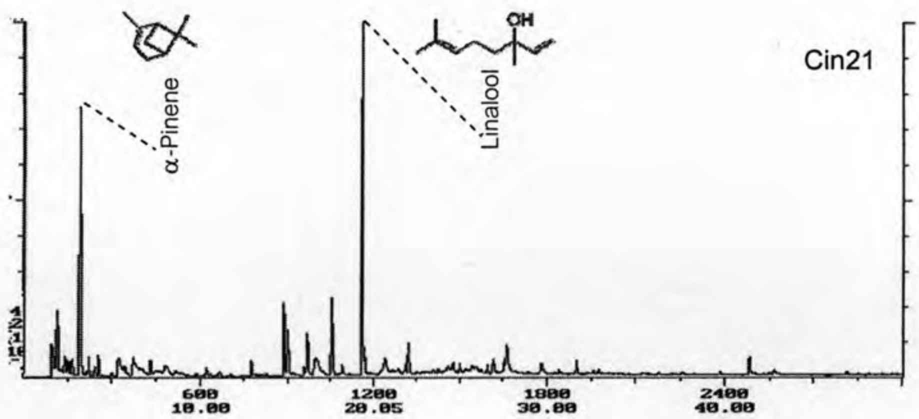

Figure 4-10: GC-Chromatogram of essential oil from *C. subavenium* collected from Phitsanulok province.

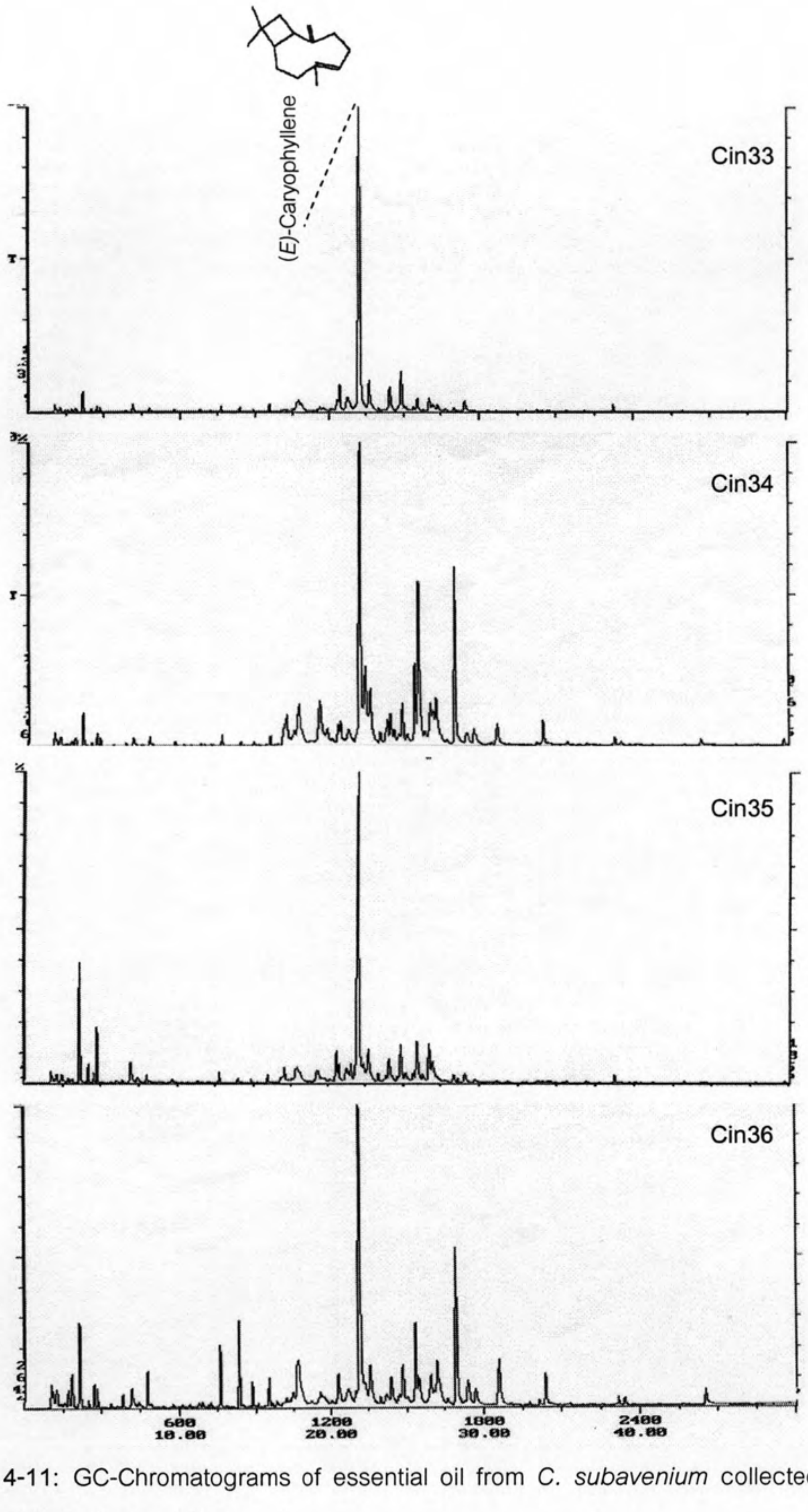

Figure 4-11: GC-Chromatograms of essential oil from *C. subavenium* collected from Nakorn Ratchasima province.

Table 4-7 Chemical constituents of leaf oil from *Cinnamomum subavenium*

Compound	Retention time	%Peak area					
		cin20	cin33	cin34	cin35	cin36	Average
Monoterpenes							
α-pinene	3.18	22.84	2.14	1.35	7.83	3.84	7.60
camphene	3.68	1.14	0.20	0.08	0.76	0.24	0.48
β-pinene	4.22	1.13	0.32	0.19	2.19	0.51	0.87
3-carene	4.92	0.37	0.00	0.00	0.00	0.21	0.12
α-phyllandrene	5.35	2.42	0.00	0.00	0.00	0.00	0.48
α-terpinene	5.75	1.54	0.14	0.12	0.16	0.47	0.49
limonene	6.27	1.25	0.95	0.51	1.89	1.64	1.25
1,8-cineol	6.67	0.00	0.00	0.00	0.50	0.52	0.20
β-(Z)-ocimene	7.55	0.00	0.15	0.00	0.00	0.24	0.08
p-cymene	8.62	0.49	0.00	0.00	0.00	0.00	0.10
terpinolene	9.05	0.00	0.30	0.19	0.16	0.13	0.16
(*E*)-isolimonene	9.80	0.29	0.00	0.00	0.00	0.13	0.08
dehydro-p-cymene	14.95	0.00	0.62	0.32	0.52	1.04	0.50
(Z)-linalool oxide	15.05	3.96	0.00	0.00	0.00	0.15	0.82
(*E*)-linalool oxide	16.18	3.42	0.00	0.00	0.00	0.00	0.68
camphor	17.60	6.25	0.00	0.00	0.00	0.00	1.25
linalool	19.45	22.07	0.00	1.28	2.46	2.29	5.62
bornyl acetate	20.30	0.00	0.00	0.00	1.40	0.00	0.28
α-terpineol	25.03	0.79	0.00	0.31	0.65	0.00	0.35
cumin aldehyde	27.68	0.00	0.00	1.26	0.00	1.31	0.51
Sesquiterpenes							
α-cubebene	16.32	0.00	0.00	0.47	0.26	1.00	0.35
α-copaene	16.63	4.00	2.10	4.26	2.19	7.10	3.93
β-pachoulene	17.10	0.00	2.09	0.00	0.00	0.00	0.42
ylangene	18.08	0.00	0.68	5.11	2.35	0.30	1.69

Table 4-7 (Continued)

Compound	Retention time	%Peak area					
		cin20	cin33	cin34	cin35	cin36	Average
a-gurjunene	18.92	0.00	0.00	1.27	0.00	0.00	0.25
isocaryophyllene	22.87	0.00	1.38	0.93	1.26	0.00	0.71
longifolene	19.92	0.00	3.80	1.26	2.24	1.79	1.82
(E)-caryophyllene	20.73	1.88	58.69	22.26	38.10	23.47	28.88
aristolene	21.13	0.00	0.00	7.71	2.35	0.00	2.01
alloaromadendrene	21.35	0.00	5.11	5.74	4.99	2.82	3.73
α-guaiene	22.43	0.00	0.00	0.50	0.57	0.40	0.30
β-guaiene	22.70	0.00	0.00	1.94	0.30	1.01	0.65
β-cadinene	23.08	0.00	0.00	0.77	0.00	0.00	0.15
α-humulene	23.52	0.00	5.38	2.30	4.03	2.82	2.91
γ-muurolene	24.28	0.00	0.42	3.28	0.68	4.94	1.86
viridiflorene	24.48	0.00	1.47	11.72	5.04	2.20	4.09
β-selinene	25.45	0.00	2.05	0.65	4.31	2.39	1.88
a-selinene	25.52	0.00	1.50	0.34	2.75	5.05	1.93
α-muurolene	25.75	0.00	1.00	1.48	0.00	0.00	0.50
δ-cadinene	26.98	1.69	0.00	10.34	0.81	9.97	4.56
α-curcumene	27.75	3.76	0.00	0.00	0.00	0.00	0.75
calamenene	29.75	1.61	0.00	1.70	0.00	4.12	1.49
β-calacolene	32.32	0.00	0.38	0.00	0.21	0.28	0.17
α-calacorene	32.68	0.00	0.00	1.49	0.11	1.84	0.69
caryophyllene oxide	35.45	0.00	0.16	0.00	0.17	0.00	0.06
α-dehydro-himachalene	37.77	0.15	0.00	0.14	0.00	0.38	0.13
spathulenol	39.68	0.23	0.00	0.00	0.00	0.00	0.05
cadalene	42.80	0.61	0.00	0.31	0.00	1.10	0.40
guaiazulene	48.12	0.00	0.00	0.30	0.11	0.00	0.08

Table 4-7 (Continued)

Compound	Retention time	%Peak area					
		cin20	cin33	cin34	cin35	cin36	Average
Non-terpenes							
methylheptenone	11.15	0.46	0.00	0.00	0.00	0.21	0.13
1-hexanol	11.78	0.18	0.42	0.33	0.57	2.05	0.71
(Z)-3-hexenol	12.97	0.87	0.37	0.13	0.26	2.69	0.87
2-methylcyclopentanol	13.83	0.00	0.18	0.10	0.15	0.85	0.26
furfural	14.82	4.82	0.00	0.00	0.00	0.00	0.96
acetic acid	15.98	0.79	0.00	3.04	1.38	0.34	1.11
benzaldehyde	18.33	1.02	0.00	0.00	0.00	0.00	0.20
methyl benzoate	22.10	2.44	0.00	0.00	0.00	0.00	0.49
benzyl alcohol	31.73	1.05	0.00	0.00	0.00	0.00	0.21
eugenol	41.43	1.48	0.00	0.00	0.00	0.00	0.30
eugenyl acetate	46.85	0.31	0.00	0.00	0.00	0.00	0.06
% Identified		95.32	92.01	95.50	93.69	91.85	93.67

1.8. Essential oil composition of *Cinnamomum tamala*

C. tamala was collected at two locations: Bangkok (cin04) and Prathum Thani (cin48). The major components of the Bangkok sample were found to be limonene (23.68%) and 1,8-cineol (22.42%), with lesser amount of (*E*)-cinnamaldehyde (10.27%), while the oil of the Prathum Thani sample was dominated by (*E*)-cinnamaldehyde (22.58%) and limonene (20.91%) with lesser amount of 1,8-cineol (15.40%). Other compounds present in amount of more than 5% were α-pinene (7.60-8.73%) and p-cymene (6.33-8.58%). From both samples, thirty-six compounds representing about 98% of the leaf oil were identified. The chemical of the leaf oil are summarized in Table 4-8.

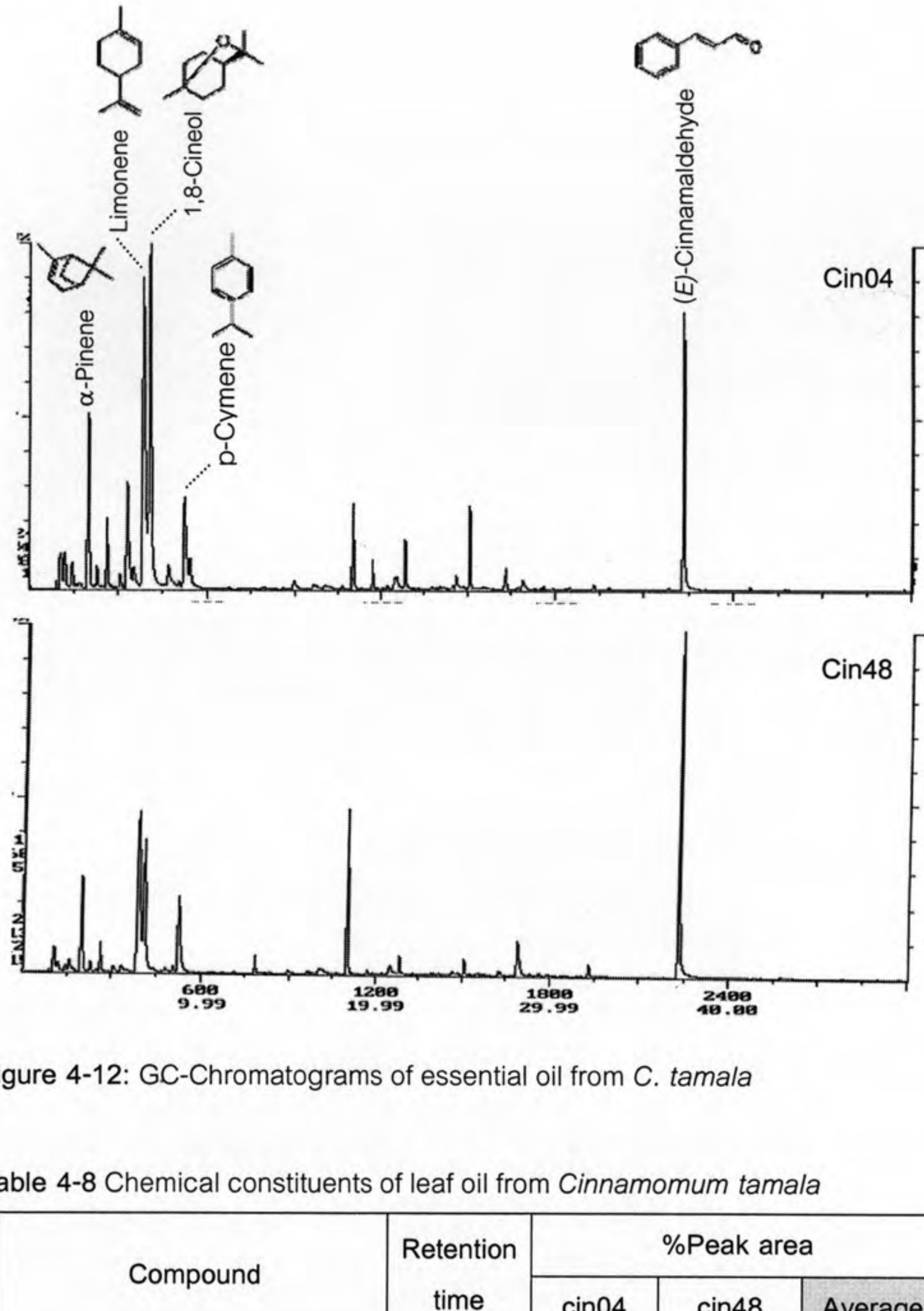

Figure 4-12: GC-Chromatograms of essential oil from *C. tamala*

Table 4-8 Chemical constituents of leaf oil from *Cinnamomum tamala*

Compound	Retention time	%Peak area		
		cin04	cin48	Average
Monoterpenes				
α-pinene	3.18	8.73	7.60	8.17
camphene	3.68	0.71	0.56	0.64
β-pinene	4.22	2.42	1.62	2.02
3-carene	4.92	0.67	0.56	0.62
α-phyllandrene	5.35	7.07	0.79	3.93

Table 4-8 (Continued)

Compound	Retention time	%Peak area		
		cin04	cin48	Average
α-terpinene	5.75	1.46	0.00	0.73
limonene	6.27	23.86	20.91	22.38
1,8-cineol	6.67	22.42	15.40	18.91
β-(Z)-ocimene	7.55	1.05	0.00	0.52
γ-terpinene	7.90	0.00	0.25	0.13
p-cymene	8.62	6.33	8.58	7.45
terpinolene	9.05	1.86	0.00	0.93
camphor	17.60	0.12	0.00	0.06
linalool	19.45	0.83	0.24	0.53
bornyl acetate	20.30	0.12	0.10	0.11
terpinene-4-ol	21.30	1.58	0.87	1.22
α-terpineol	25.03	2.61	0.82	1.72
sabinol	29.10	0.00	0.15	0.07
geraniol	30.73	0.08	0.04	0.06
Sesquiterpenes				
α-copaene	16.63	0.00	0.12	0.06
(*E*)-caryophyllene	20.73	1.18	0.92	1.05
α-muurolene	28.52	0.00	0.10	0.05
cadalene	42.80	0.07	0.10	0.09
Non-terpenes				
1-hexanol	11.78	0.00	0.11	0.05
(*Z*)-3-hexenol	12.97	0.00	0.79	0.39
2-methylcyclopentanol	13.83	0.00	0.11	0.06
furfural	14.82	0.00	0.47	0.23
acetic acid	15.98	0.00	0.17	0.08
benzaldehyde	18.33	2.96	9.79	6.38

Table 4-8 (Continued)

Compound	Retention time	%Peak area		
		cin04	cin48	Average
2-hydroxybenzaldehyde	24.23	0.62	0.22	0.42
hydrocinnamaldehyde	28.15	0.69	3.91	2.30
benzalmalonic dialdehyde	32.22	0.22	0.86	0.54
ionol	32.98	0.12	0.00	0.06
(*E*)-cinnamaldehyde	37.12	10.27	22.58	16.42
cinnamyl acetate	40.95	0.12	0.00	0.06
coumarin	49.50	0.10	0.00	0.05
%Identified		98.27	98.74	98.50

1.9. Essential oil composition of *Cinnamomum verum*

By HS-GC/MS analysis, eight samples of *C. verum* dried leaves were analyzed. As tabulated in Table 4-9, sixty-four compounds were identified.

Of the eight *C. verum* samples, five samples (cin12, 16, 17, 38 and 40) contained eugenol as the major component (19.83-69.21%) while the rest (cin1, 24 and 45) contained linalool (11.20-16.45%) and α-phellandrene (14.05-15.29%) as major components.

On average, the phenylpropanoid eugenol (24.58%) was the major component detected among 24 monoterpenes, 17 sesquiterpenes and 23 non-terpenes identified. The major monoterpene was linalool (9.81%), followed by α-pinene (8.04%), α-phellandrene (7.82%) and *p*-cymene (4.57%). The major sesquiterpene was (*E*)-caryophyllene (10.68%).

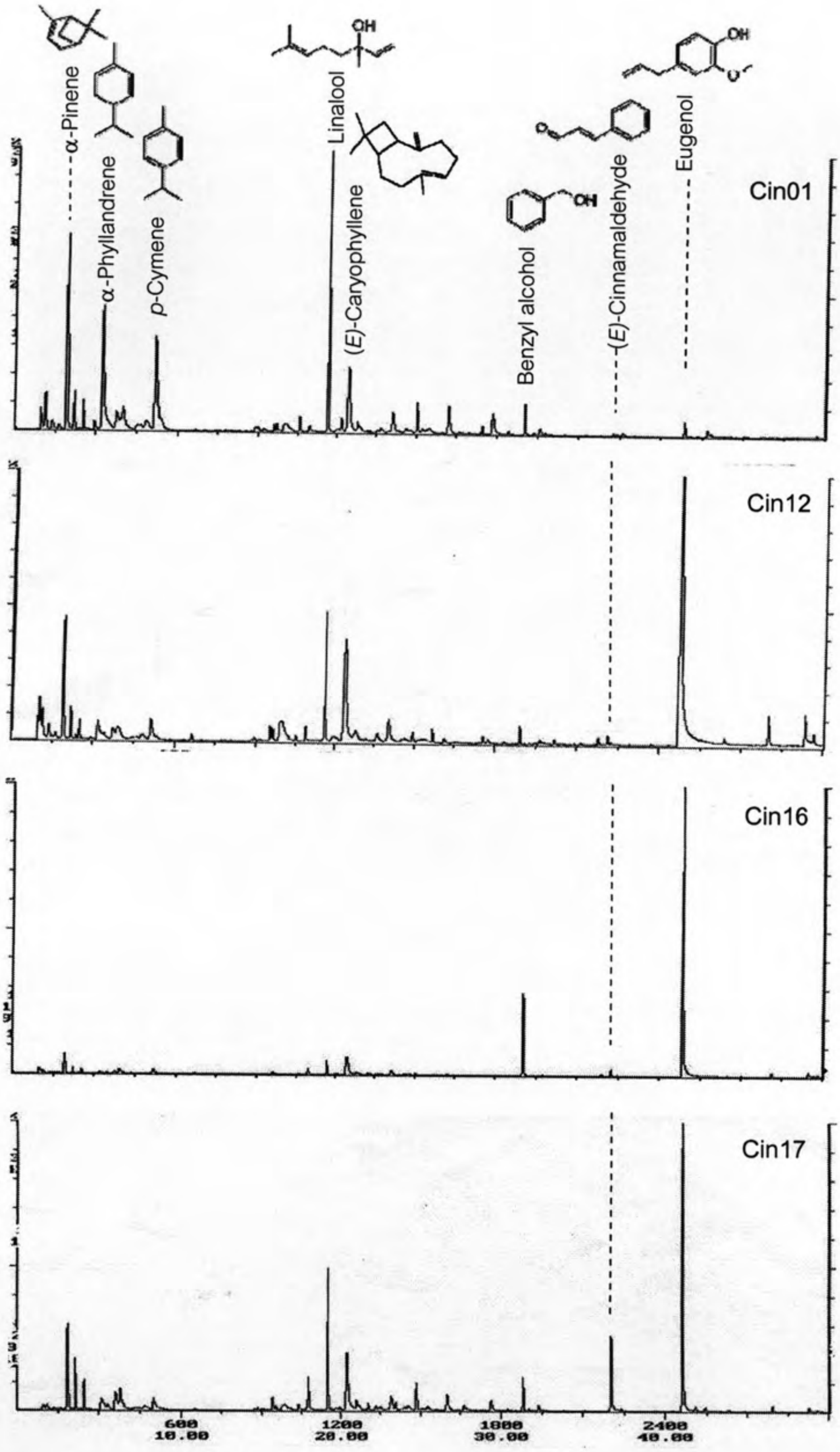

Figure 4-13: GC Chromatograms of essential oil from *C. verum*

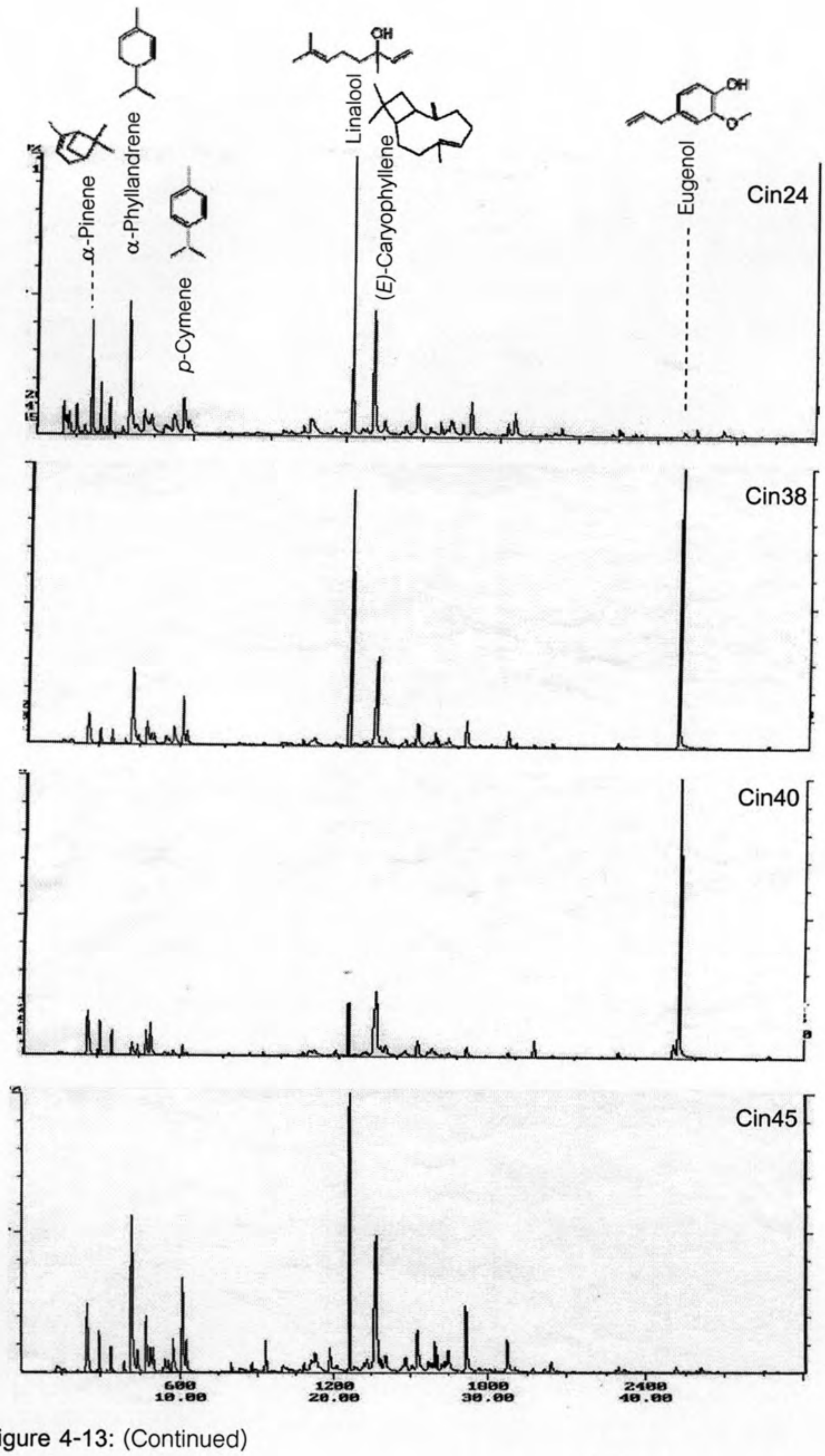

Figure 4-13: (Continued)

Table 4-9 Chemical constituents of leaf oil from *Cinnamomum verum*

Compound	Retention time	%Peak area								
		cin01	cin12	cin16	cin17	cin24	cin38	cin40	cin45	Average
Monoterpenes										
α-pinene	3.18	16.04	4.36	4.20	8.27	8.45	5.40	10.19	7.38	8.04
camphene	3.68	2.16	0.83	0.93	3.35	2.29	1.25	3.82	2.16	2.10
β-pinene	4.22	1.47	0.45	0.58	1.94	1.58	0.88	2.42	1.34	1.33
3-carene	4.92	0.71	0.00	0.00	0.00	0.50	0.36	0.00	0.63	0.27
α-phyllandrene	5.35	14.85	1.38	0.66	2.26	14.05	11.42	2.65	15.29	7.82
α-terpinene	5.75	0.00	0.43	0.24	0.95	1.34	1.34	1.39	1.75	0.93
limonene	6.27	2.44	0.45	0.81	2.75	2.20	3.34	3.63	4.94	2.57
β-phyllandrene	6.48	3.28	0.03	1.71	3.79	1.95	1.36	4.67	2.16	2.37
1,8-cineol	6.67	0.00	0.00	0.00	0.00	0.00	1.41	0.00	1.91	0.42
β-(*Z*)-ocimene	7.55	0.00	0.00	0.00	0.00	0.00	1.18	0.58	1.28	0.38
γ-terpinene	7.90	0.00	0.00	0.00	0.00	0.00	0.68	0.34	0.91	0.24
β-(*E*)-ocimene	8.10	0.00	0.00	0.00	0.00	3.28	3.13	0.84	3.07	1.29
p-cymene	8.62	13.12	1.13	1.41	1.55	5.04	5.11	1.48	7.73	4.57
terpinolene	9.05	0.00	0.00	0.00	0.00	1.70	1.34	0.42	2.13	0.70

Table 4-9 (Continued)

Compound	Retention time	%Peak area								
		cin01	cin12	cin16	cin17	cin24	cin38	cin40	cin45	Average
dehydro-p-cymene	14.95	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.48	0.10
(*Z*)-Linalool oxide	15.05	0.00	0.17	0.12	0.32	0.24	0.26	0.00	0.00	0.14
(*E*)-Linalool oxide	16.18	0.54	0.46	0.15	0.37	0.60	0.40	0.34	0.35	0.40
camphor	17.60	1.04	0.17	0.11	0.58	0.00	0.00	0.00	0.00	0.24
linalool	19.45	16.45	3.51	2.16	9.78	14.87	16.34	4.20	11.20	9.81
bornyl acetate	20.30	0.95	0.00	0.00	0.00	0.29	0.38	0.52	0.69	0.36
terpinene-4-ol	21.30	0.58	0.21	0.19	0.67	0.00	0.26	1.48	0.57	0.50
α-terpineol	25.03	2.13	0.29	0.39	0.00	0.71	0.82	0.00	1.14	0.69
borneol	25.28	0.00	0.00	0.00	2.59	0.00	0.55	0.00	0.67	0.48
geraniol	30.73	0.17	0.05	0.00	0.11	0.15	0.22	0.00	0.12	0.10
Sesquiterpenes										
α-cubebene	16.32	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.85	0.19
α-copaene	16.63	0.00	0.02	0.00	1.76	3.68	1.11	0.69	1.36	1.08
β-pachoulene	17.10	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.10
longifolene	19.92	0.00	0.00	0.00	0.00	0.00	0.34	0.55	0.63	0.19

Table 4-9 (Continued)

Compound	Retention time	%Peak area								
		cin01	cin12	cin16	cin17	cin24	cin38	cin40	cin45	Average
(*E*)-caryophyllene	20.73	9.44	7.23	7.65	10.35	14.43	9.52	14.56	12.29	10.68
guaiene	22.70	0.00	0.51	0.43	0.58	1.33	0.34	1.11	0.53	0.60
β-cadinene	23.08	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.03
α-humulene	23.52	2.29	1.30	1.40	2.11	3.29	1.93	2.49	2.59	2.17
γ-muurolene	24.28	0.00	0.00	0.23	0.40	0.79	0.38	1.50	0.66	0.50
viridiflorene	24.48	0.00	0.00	0.31	0.78	0.00	0.00	0.00	0.00	0.14
β-selinene	25.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.04
α-gurjunene	25.65	0.00	0.00	0.00	0.56	3.12	0.00	0.00	0.00	0.46
δ-cadinene	26.98	3.31	0.23	0.25	2.41	3.41	2.30	1.18	3.88	2.12
calamenene	29.75	2.81	0.18	0.00	1.53	3.02	1.48	0.57	2.14	1.47
α-calacorene	32.68	0.53	0.05	0.00	0.53	0.61	0.36	0.27	0.56	0.36
caryophyllene oxide	35.45	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.02
cadalene	42.80	0.61	0.00	0.00	0.40	0.80	0.00	0.00	0.31	0.27

Table 4-9 (Continued)

Compound	Retention time	%Peak area								
		cin01	cin12	cin16	cin17	cin24	cin38	cin40	cin45	Average
Non-terpenes										
methylheptenone	11.15	0.00	0.24	0.18	0.22	0.12	0.00	0.00	0.00	0.10
1-hexanol	11.78	0.00	0.00	0.07	0.00	0.00	0.00	0.15	0.35	0.07
(Z)-3-hexenol	12.97	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.33	0.06
2-methylcyclopentanol	13.83	0.00	0.00	0.00	0.00	0.00	0.00	0.28	1.16	0.18
acetic acid	15.98	0.48	0.55	0.50	1.11	0.10	0.00	0.12	0.00	0.36
benzaldehyde	18.33	0.00	0.45	1.20	3.12	0.21	0.16	0.44	0.00	0.70
methyl benzoate	22.10	0.00	0.00	0.34	0.62	0.00	0.00	0.00	0.00	0.12
ethyl benzoate	23.82	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.09
2-hydroxybenzaldehyde	24.23	0.00	0.00	0.00	0.00	0.00	0.53	0.73	0.68	0.24
benzyl acetate	26.30	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.05
hydrocinnamaldehyde	28.15	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.08
isosafrole	29.63	0.00	0.00	0.00	0.00	1.06	0.00	0.00	0.00	0.13
benzyl alcohol	31.73	1.86	0.49	12.64	2.31	0.14	0.19	1.54	0.17	2.42
o-methyleugenol	36.52	0.00	0.26	0.41	0.00	0.00	0.00	0.00	0.00	0.08

Table 4-9 (Continued)

Compound	Retention time	%Peak area								
		cin01	cin12	cin16	cin17	cin24	cin38	cin40	cin45	Average
(*E*)-cinnamaldehyde	37.12	0.13	0.28	1.30	5.69	0.60	0.26	0.49	0.24	1.12
hydrocinnamic alcohol	37.50	0.00	0.00	0.17	0.07	0.00	0.00	0.00	0.00	0.03
cinnamyl acetate	40.95	0.00	0.00	0.00	0.05	0.00	0.00	2.27	0.00	0.29
eugenol	41.43	0.98	69.21	56.19	22.31	0.65	19.83	27.10	0.33	24.58
o-eugenol	42.22	0.03	0.00	0.00	0.28	0.61	0.00	0.00	0.00	0.12
isoeugenol	43.97	0.00	0.20	0.00	0.14	0.00	0.00	0.00	0.00	0.04
cinnamyl alcohol	45.03	0.06	0.00	0.00	0.00	0.00	0.28	0.43	0.00	0.10
eugenyl acetate	46.85	0.00	1.04	0.76	0.50	0.00	0.00	0.00	0.00	0.29
coumarin	49.50	0.00	0.00	0.66	0.00	0.00	0.16	0.07	0.00	0.11
%Identified		98.44	96.52	98.51	98.46	97.20	97.84	96.52	97.29	

1.10. **Essential oil composition of *Cinnamomum* spp.**

In the present study, five unidentified species were collected from Udon Thani (cin09 = sp.1), Yasothon (cin11 = sp.2, cin14 and 15 = sp.3) and Surat Thani (cin26 = sp.4 and cin30 = sp.5). The composition of their essential leaf oil was shown in Table 4-10. The major components were indicated in the GC-chromatogram of each species shown below.

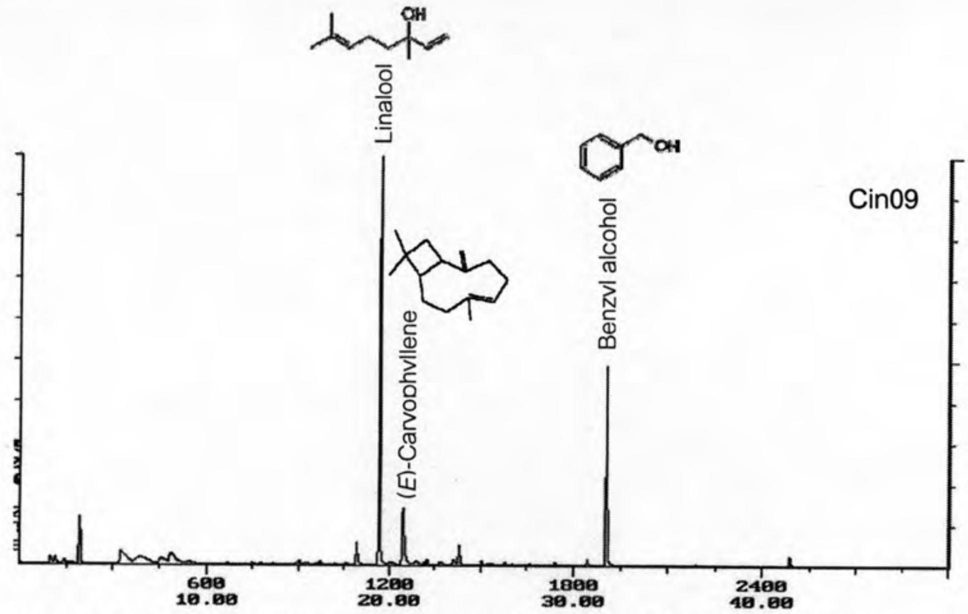

Figure 4-14: GC Chromatogram of essential oil from *Cinnamomum* sp.1

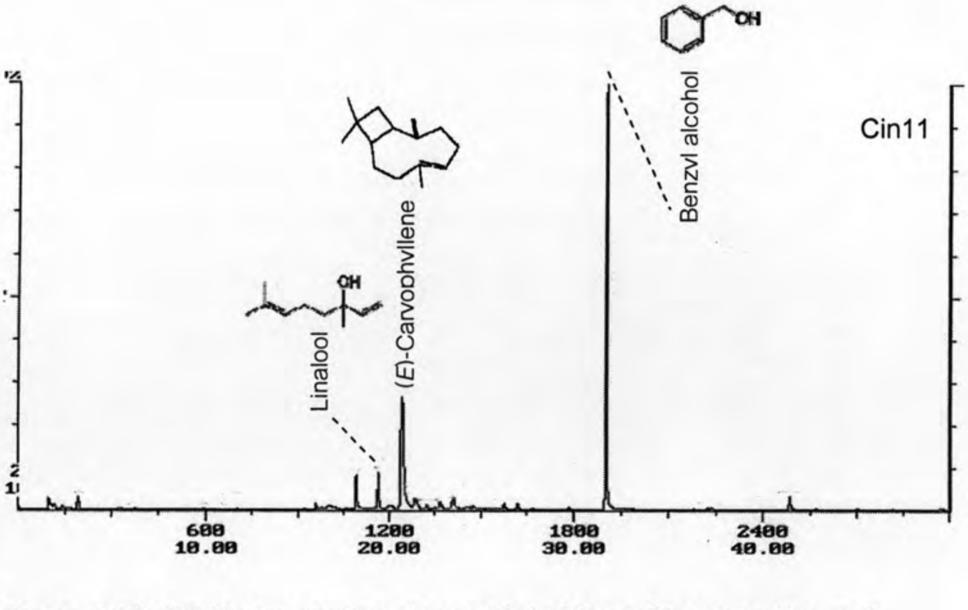

Figure 4-15: GC Chromatogram of essential oil from *Cinnamomum* sp.2

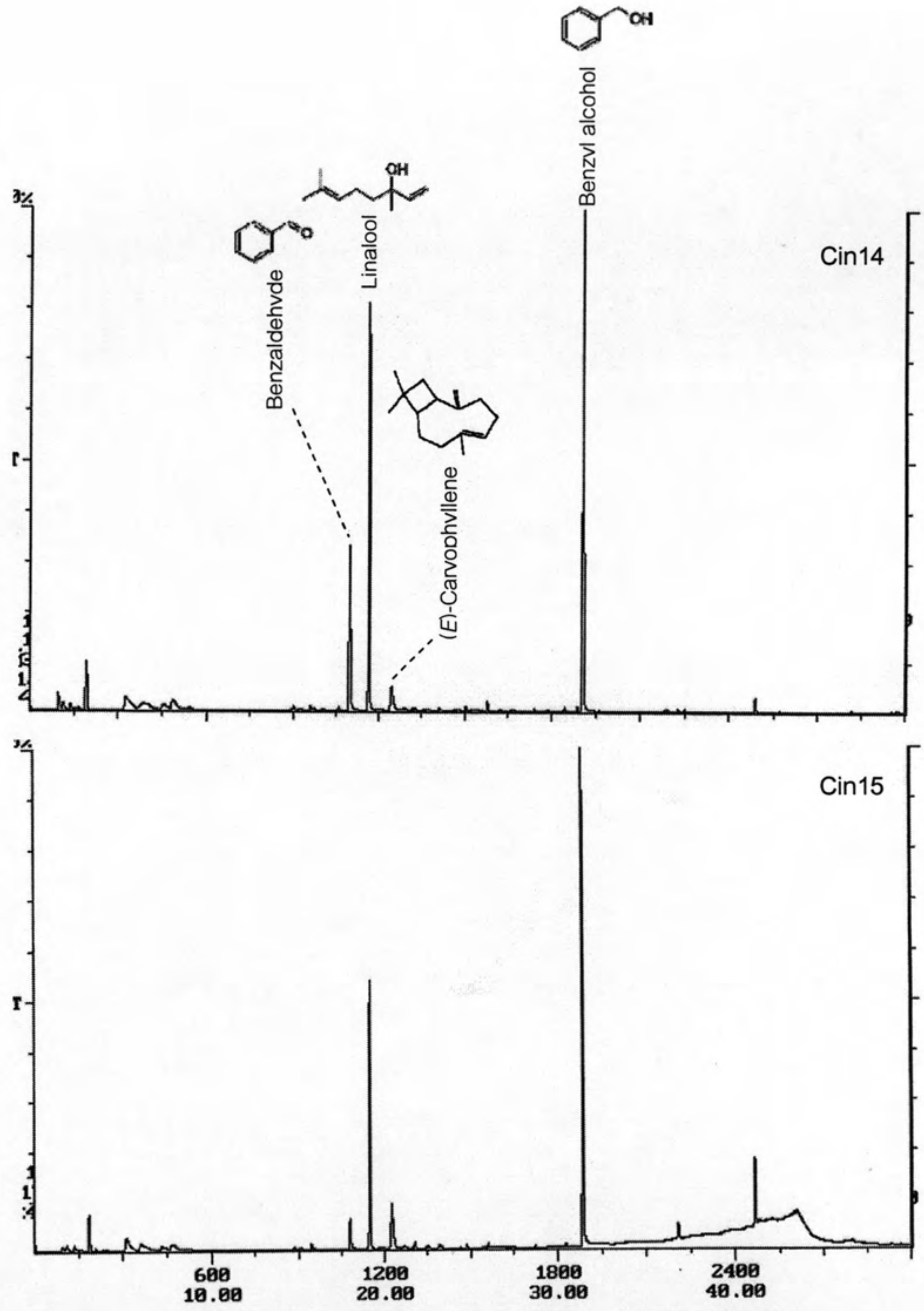

Figure 4-16: GC Chromatograms of essential oil from *Cinnamomum* sp.3

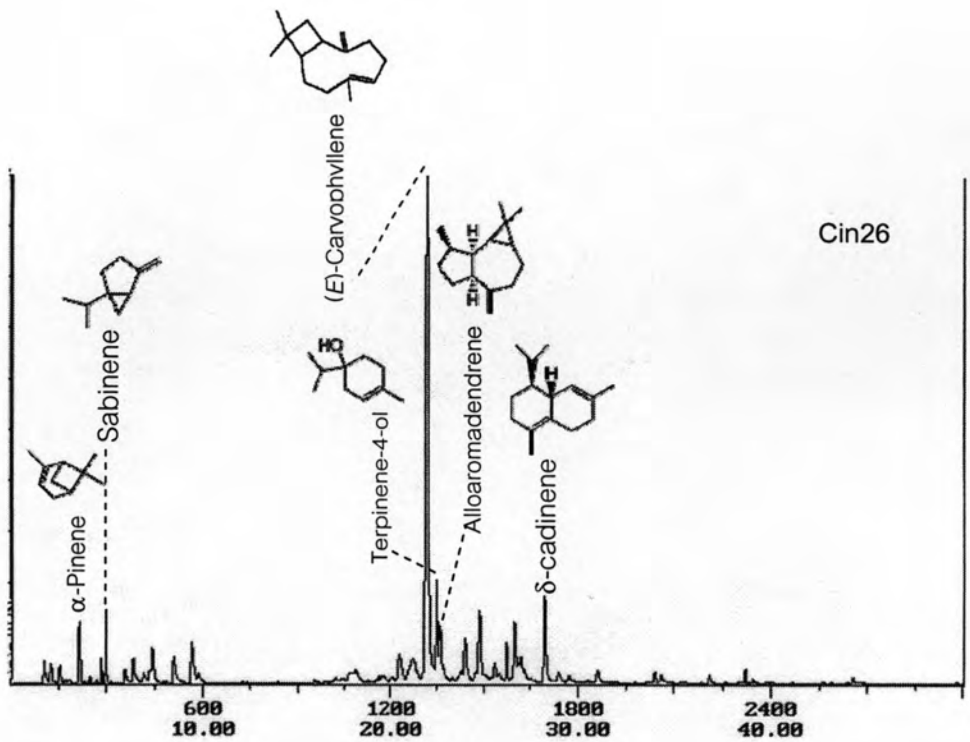

Figure 4-17: GC Chromatogram of essential oil from *Cinnamomum* sp.4

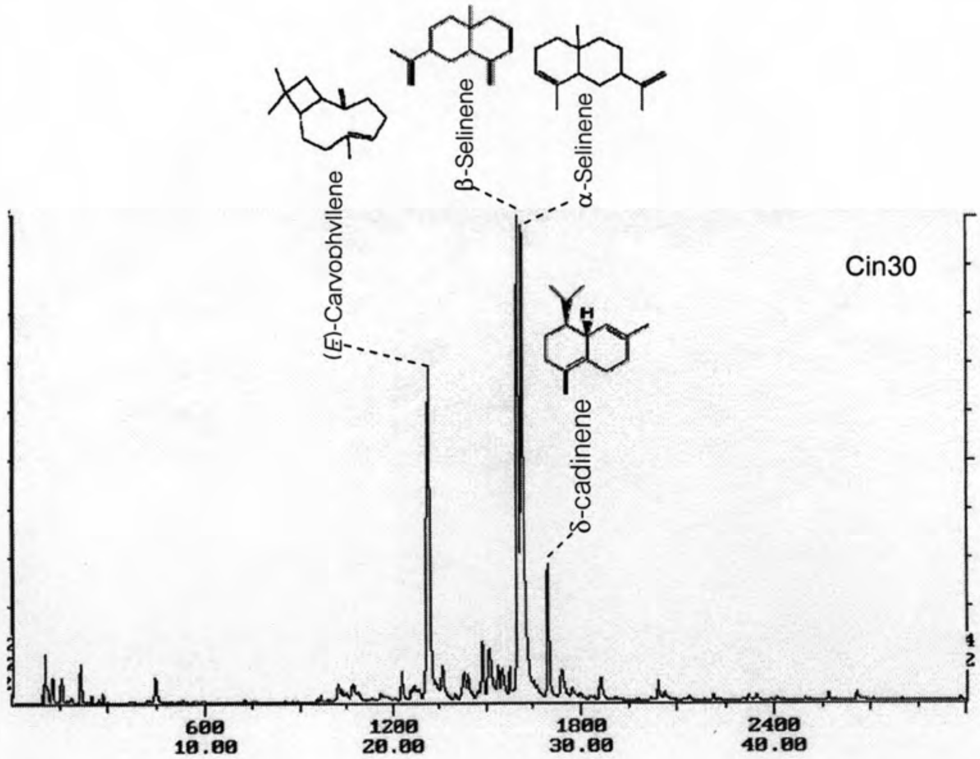

Figure 4-18: GC Chromatogram of essential oil from *Cinnamomum* sp.5

Table 4-10 Chemical constituents of leaf oil from *Cinnamomum* spp.

Compound	RT	%Peak area					
		sp.1	sp.2	sp.3		sp.4	sp.5
		cin09	cin11	cin14	cin15	cin26	cin30
Monoterpenes							
α-pinene	3.18	5.55	1.78	4.37	3.93	3.10	1.21
camphene	3.68	0.00	0.00	0.00	0.13	0.19	0.13
β-pinene	4.22	0.00	0.00	0.00	0.00	0.62	0.16
sabinene	4.40	0.00	0.00	0.00	0.00	1.64	0.00
α-phyllandrene	5.35	6.17	0.42	4.33	3.89	0.84	0.00
α-terpinene	5.75	0.00	0.18	0.00	0.00	1.62	0.00
limonene	6.27	0.00	0.00	0.00	0.00	0.68	0.00
β-phyllandrene	6.48	0.00	0.00	0.00	0.00	0.65	0.00
1,8-cineol	6.67	0.00	0.00	0.00	0.00	2.41	1.06
β-(Z)-ocimene	7.55	0.00	0.00	1.94	0.00	0.00	0.00
γ-terpinene	7.90	0.00	0.00	0.00	0.00	2.09	0.00
β-(*E*)-ocimene	8.10	3.25	0.00	2.25	1.73	0.00	0.00
p-cymene	8.62	0.00	0.00	0.00	0.00	3.18	0.00
terpinolene	9.05	0.00	0.00	0.00	0.00	0.79	0.00
(Z)-linalool oxide	15.05	0.64	0.00	0.41	0.50	0.00	0.16
(*E*)-linalool oxide	16.18	0.45	0.00	0.35	0.26	0.00	0.47
camphor	17.60	0.00	0.00	0.41	0.09	0.00	0.00
linalool	19.45	42.49	4.28	26.33	22.64	2.40	1.21
terpinene-4-ol	21.30	0.00	0.00	0.00	0.00	4.13	1.25
α-terpineol	25.03	0.33	0.00	0.40	0.33	1.34	0.58
cumin aldehyde	27.68	0.00	0.00	0.00	0.00	0.00	1.95
nerol	28.98	0.28	0.00	0.16	0.15	0.00	0.00
geraniol	30.73	0.55	0.00	0.33	0.29	0.00	0.00
Sesquiterpenes							
α-cubebene	16.32	0.00	0.00	0.00	0.00	0.00	0.57
α-copaene	16.63	0.00	0.00	0.00	0.00	0.00	1.21

Table 4-10 (Continued)

Compound	RT	%Peak area					
		sp.1	sp.2	sp.3		sp.4	sp.5
		cin09	cin11	cin14	cin15	cin26	cin30
β-pachoulene	17.10	0.00	0.00	0.00	0.00	0.50	0.00
α-gurjunene	18.33	0.00	0.00	0.00	0.00	0.33	0.00
longifolene	19.92	0.00	0.00	0.00	0.00	3.52	0.00
(*E*)-caryophyllene	20.73	10.16	29.66	4.04	8.33	42.28	20.07
allo aromadendrene	21.35	0.82	2.43	0.54	0.00	5.16	0.00
β-guaiene	22.70	0.66	1.57	0.26	0.50	0.00	1.58
α-humulene	23.52	0.98	2.68	0.33	0.62	4.35	1.96
γ-muurolene	24.28	0.00	0.00	0.00	0.00	1.00	0.83
viridiflorene	24.48	0.00	0.00	0.00	0.00	0.00	1.29
β-selinene	25.45	0.00	0.00	0.00	0.00	3.49	20.83
α-selinene	25.52	0.00	0.00	0.00	0.00	0.00	29.27
valencene	25.65	0.00	0.00	0.00	0.00	0.96	0.00
δ-cadinene	26.98	0.00	0.81	0.21	0.00	5.24	5.43
α-curcumene	27.75	0.00	0.00	0.16	0.00	0.00	0.00
calamenene	29.75	0.00	0.00	0.15	0.00	1.08	1.22
α-calacorene	32.68	0.00	0.00	0.00	0.00	0.56	0.53
vetivenene	34.17	0.00	0.00	0.00	0.00	0.00	0.15
caryophyllene oxide	35.45	0.00	0.00	0.00	0.00	0.38	0.19
α-caryophyllene alcohol	37.30	0.00	0.35	0.00	0.00	0.52	0.16
α-dehydro-himachalene	37.77	0.00	0.00	0.00	0.00	0.10	0.16
cadalene	42.80	0.00	0.00	0.00	0.00	0.37	0.35
Non-terpenes							
methylheptenone	11.15	0.17	0.11	0.00	0.00	0.00	0.07
1-hexanol	11.78	0.00	0.14	0.00	0.00	0.00	0.00
(Z)-3-hexenol	12.97	0.14	0.00	0.00	0.00	0.00	0.00
2-butoxy ethanol	13.60	0.17	0.00	0.00	0.00	0.00	0.00
acetic acid	15.98	0.19	0.61	0.42	0.58	0.00	1.11

Table 4-10 (Continued)

Compound	RT	%Peak area					
		sp.1	sp.2	sp.3		sp.4	sp.5
		cin09	cin11	cin14	cin15	cin26	cin30
benzaldehyde	18.33	2.73	4.82	13.50	3.50	0.00	0.00
methyl benzoate	22.10	0.49	0.55	0.23	0.66	0.00	0.00
ethyl benzoate	23.82	2.30	0.00	0.00	0.00	0.00	0.00
benzyl acetate	26.30	0.25	0.70	0.70	0.47	0.00	0.00
safrole	31.48	0.00	0.00	0.32	0.00	0.00	0.00
benzyl alcohol	31.73	19.30	46.73	34.69	43.22	0.00	0.00
butylated hydroxytoluene	32.98	0.00	0.00	0.00	0.00	0.32	0.19
o-methyleugenol	36.52	0.00	0.00	0.20	0.00	0.00	0.00
(*E*)-cinnamaldehyde	37.12	0.00	0.32	0.16	1.57	0.00	0.00
3-benzene propanol	37.50	0.00	0.00	0.23	0.00	0.00	0.00
eugenol	41.43	1.00	1.59	1.03	6.13	0.00	0.00
% Identified		99.05	99.74	98.46	99.50	95.82	95.36

2. Distribution of Essential Oil Components in the Selected *Cinnamomum* Species

In this study, data analysis of various leaf essential oil components found in 48 samples of *Cinnamomum species* showed at least 128 peaks in their chromatograms, of which 103 peaks were identified (about 98% of total average %peak area). As shown in Figure 4-19, these included 34 monoterpenes (49%), 35 sesquiterpenes (35%) 14 phenylpropanoids (7%) and 20 miscellaneous (7%).

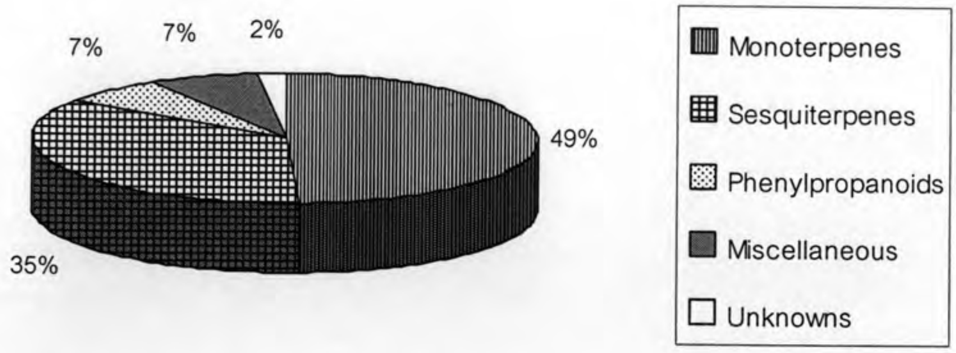

Figure 4-19: The percentage of different chemical groups present in the leaf essential oils of *Cinnamomum* species (48 samples)

The components present in high quantity (more than 10%) are shown in the Table 4-11.

Table 4-11 Major components found in selected *Cinnamomum* species

Compound	Percentage of total peak area	Plant species	Sample code
camphor	95.73	*C. camphora*	cin47
linalool	73.92	*C.* cf. *iners*	cin23
Eugenol	69.21	*C. verum*	cin12
(E)-caryophyllene	58.69	*C. subavenium*	cin33
benzyl alcohol	46.73	*C.* sp.2	cin11
α-selinene	29.27	*C.* sp.5	cin30
limonene	23.86	*C. tamala*	cin04
α-pinene	22.84	*C.* cf. *subavenium*	cin20
(*E*)-cinnamaldehyde	22.58	*C. tamala*	cin48
1,8-cineol	22.42	*C. tamala*	cin04
β-selinene	20.83	*C.* sp.5	cin30
β-phyllandrene	20.40	*C.* cf. *pachyphyllum*	cin29
p-cymene	19.45	*C.* cf. *pachyphyllum*	cin28

Table 4-11 (Continued)

Compound	Percentage in total peak area	Plant species	Sample code
α-phyllandrene	18.94	*C. iners*	cin46
3-carene	16.76	*C.* cf. *bejolghota*	cin27
a-gurjunene	13.50	*C.* sp.3	cin14
α-copaene	13.28	*C.* cf. *iners*	cin37
β-(*E*)-ocimene	12.25	*C. iners*	cin46
viridiflorene	11.72	*C. subavenium*	cin34
δ-cadinene	10.34	*C. subavenium*	cin34

3. Chemometric Analysis

3.1. Hierarchical cluster analysis (HCA)

To gain some indication of the similarity of various *Cinnamomum* species collected in this study, hierarchical cluster analysis was applied to the 128 volatile compounds found in all 48 samples.

To reduce the effect of natural variation within species caused by environmental factors, the relative peak areas of chemical compounds from each chromatogram were normalized and scored before clustering. The between group linkage dendrogram using Pearson correlation is shown in Figure 4-20.

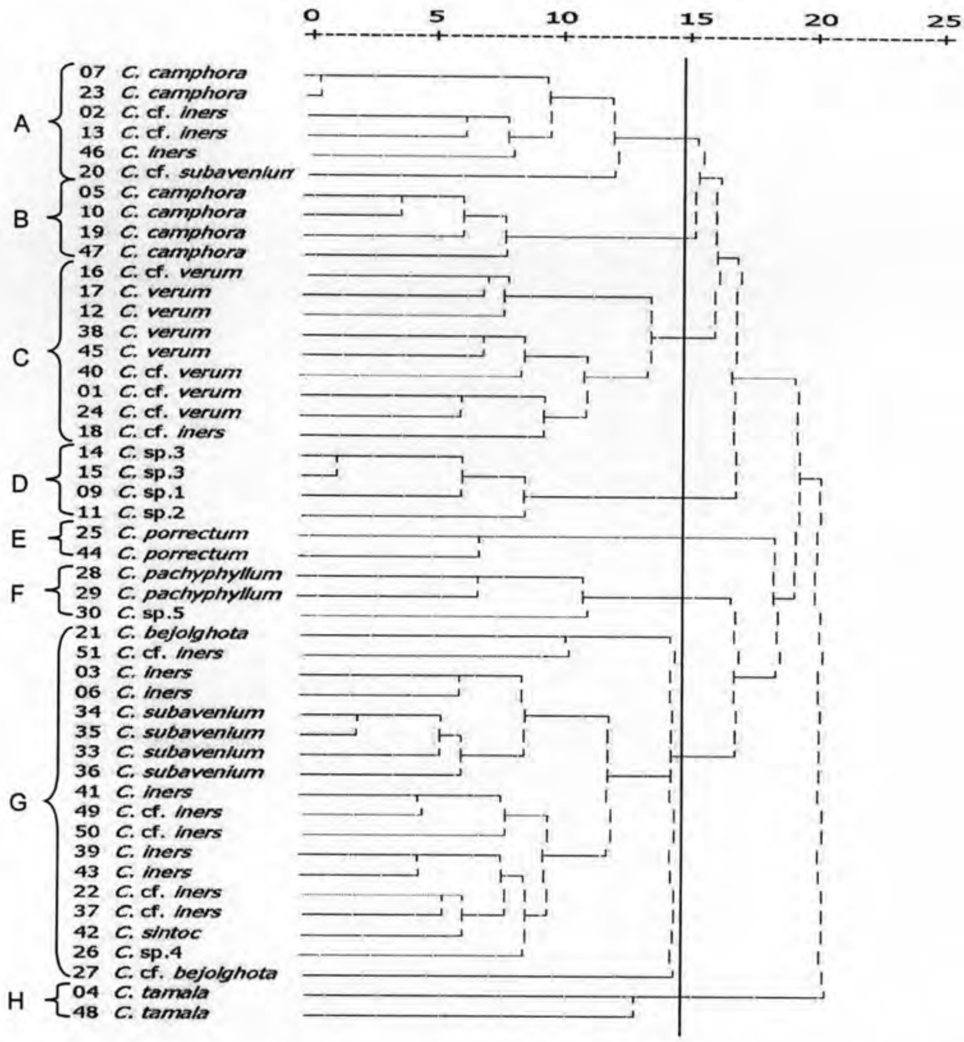

Figure 4-20 Between-group linkage dendrogram using Pearson correlation of 48 *Cinnamomum* samples, showing 8 clusters (A-H)

The dendrogram identifies eight clusters at the level of about 15 of the dissimilarity scale. Cluster A contains the species: *C. camphora*, *C. iners*, and *C. subavenium*. Cluster B is the group of *C. camphora*, while cluster C consists of all *C. verum* and one of *C. iners*. Clusters E, F, and H are groups of *C. porrectum*, *C. pachyphyllum* and *C. tamala*, respectively. Cluster G contains the most variety of species; *C. iners* samples are spreaded out between 2 samples of *C. bejolghota*, while *C. subavenium* sample are grouped together as sub-cluster. Some clusters are further divided into sub-groups with varying major components. A line-chart of some major components is compared to the dendrogram (Figure 4-21) for easier interpretation.

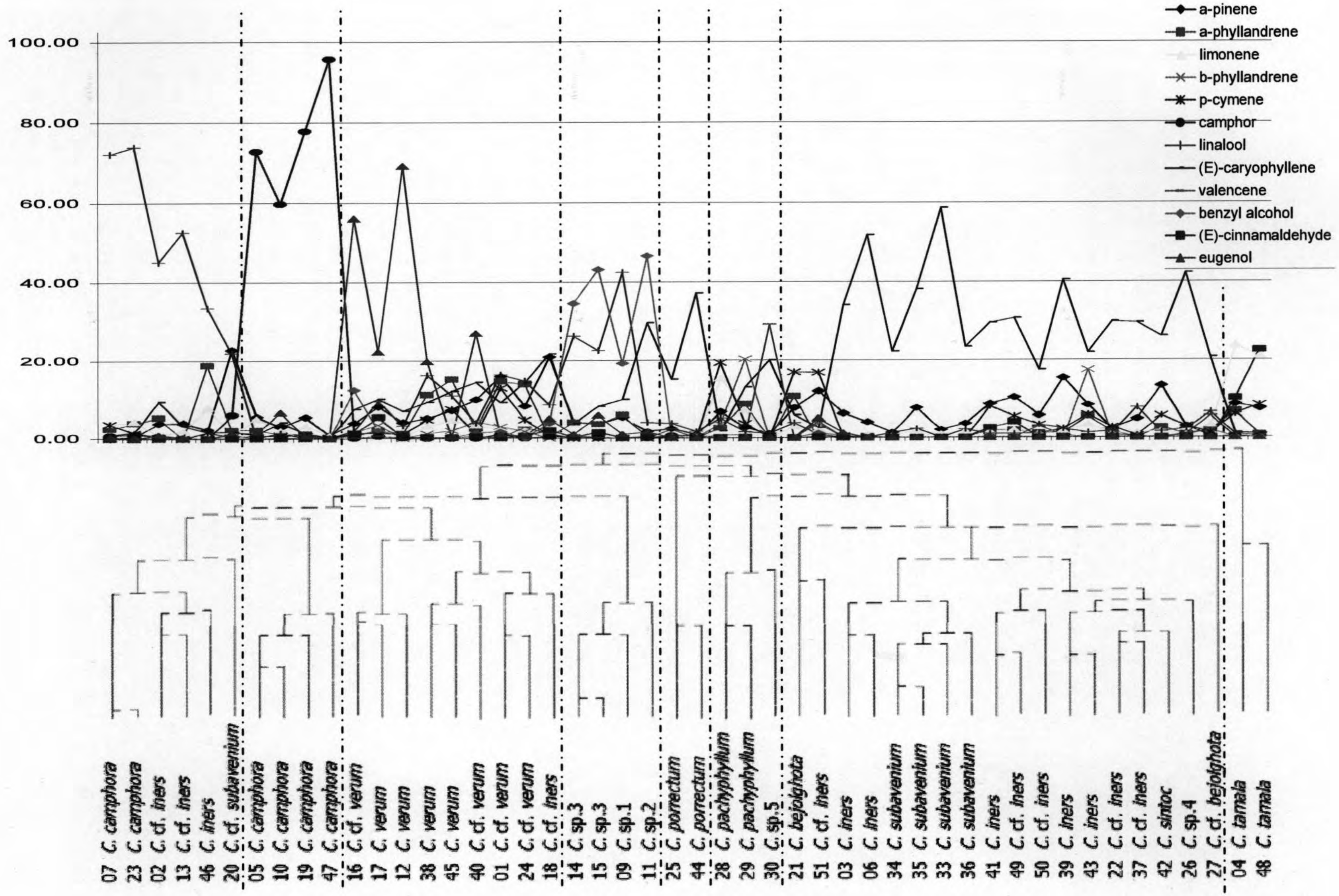

Figure 4-21 A line-chart of %peak area of some major components compare with 48 samples cluster dendrogram

The leaf essential oils of 48 samples representing 9 *Cinnamomum* species (*C. bejolghota*, *C. camphora*, *C. iners*, *C. pachyphyllum*, *C. porrectum*, *C. sintoc*, *C. subavenium*, *C. tamala* and *C. verum*) and 6 unidentified samples were mixtures of terpenoids, benzenoids and phenylpropanoids. Based on differences in the percent composition of the leaf essential oils, the species have been classified into eight main chemical types: linalool type, camphor type, eugenol type, benzyl alcohol type, caryophyllene type, cinnamaldehyde type and mixed type.

As shown in Figure 4-21, six samples of *C. camphora* can be classified into two chemical types: linalool and camphor types. Eight samples of *C. verum* also fall into two chemical types, based on their eugenol content. The unidentified *Cinnamomum* species sp.1-sp.3 are grouped together in the benzyl alcohol group. Most *C. iners* which are rich in (*E*)-caryophyllene are placed in the same cluster. Four samples of *C. subavenium* which also contain (*E*)-caryophyllene as their major component are placed as a sub-group in the cluster of *C. iners*. A prominent compound in another group of *C. iners* appears to be linalool. They are, therefore, placed in the same cluster as the two *C. camphora* with high linalool content. Two samples representing *C. tamala* are in a unique cluster due to their high amount of (*E*)-cinnamaldehyde and limonene.

3.2. Principal component analysis (PCA)

Principal component analysis of 48 *Cinnamomum* samples using the scored-peak area of 128 chemical compounds, as in HCA method, was performed on MINITAB 13.0 for Windows. The score plot of principal component 1 against component 2 which accounts for 19% of the variance, is shown in Figure 4-22. Alhough a clear distinction between species is not indicated, the grouping of some species can be observed. It can be seen that *C. verum, C. camphora, C. tamala, C. pachyphyllum* and *C. subavenium* are clumped together but not clearly separated, while *C. iners* are spreaded out. Only the 2 samples of *C. porrectum* are clearly separated from other species.

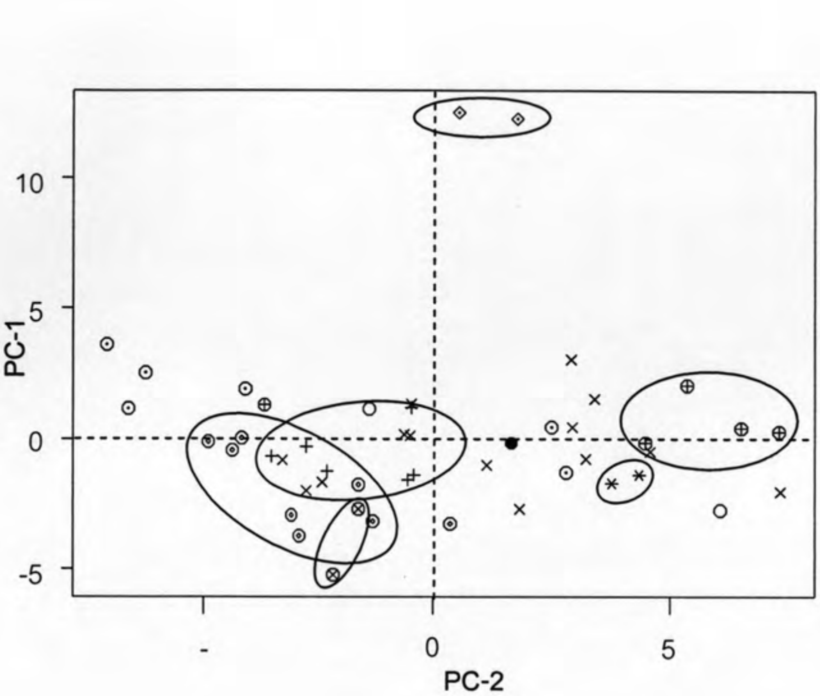

Figure 4-22 Principal component score plot for 48 *Cinnamomum* samples; o = *C. bejolghota*, + = *C. camphora*, x = *C. iners*, ⋇ = *C. pachyphyllum*, ◇= *C. porrectum*, ● = *C. sintoc*, ⊙= unknown *Cinnamomum* sp., ⊕ = *C. subavenium*, ⊗ = *C. tamala*, and ◎ = *C. verum*.

Based on the results of both chemometric methods, HCA (Figure 4-21) and PCA (Figure 4-22), good agreement in the chemical classification of 48 leaf oils is observed. However, the dendrogram is easier to interprete and the relationship between each cluster is better explained than the score plot. In addition, it can be seen from the PCA result that the first 2 principal components could described only 19% of the sample variation. As indicated in Table 4-12, even though 5 principal components were analyzed, the variation was described up to only 35.3%.

Table 4-12 Results from principal component analysis of 48 Cinnamomum samples using 128 compounds for the classification.

Principal component	Percent variance	Cumulative variance
1	11.1	11.1
2	7.9	19.0
3	6.0	25.0
4	5.5	30.5
5	4.8	35.3

From the result shown above, the principal component analysis of 48 *Cinnamomum* samples using 128 compounds was not appropriate for the study of the variation of this sample set. So, it can be concluded that the dendrogram of the between group linkage using Pearson correlation appears to be the effective way in making chemical classification analysis for this study.

4. The Use of *Cinnamomum* Leaf Essential Oil Analysis for Taxonomic Purpose

4.1. Classification of chemotype: The case of *C. camphora*

Intraspecific chemical variability exists in many species of *Cinnamomum*. A previous research has attempted to make a sub-specific classification of a number of species based on volatile oil composition (Fujita, 1967). Such intraspecific variability might have evolved as a result of inter-breeding, and forces such as segregation, chance mutations, and isolation mechanisms acting on the populations. This aspect is well studied in *C. camphora*. It was confirmed on the basis of leaf oil analysis that *C. camphora* exists in at least five chemotypic forms: camphor type, linalool type, cineol type, isonerolidol type and borneol type (Shu *et al.*, 1989.). In the present study, camphor type and linalool type were found. As shown in Figure 4-23, it is quite difficult to distinguish between each chemical type of this *Cinnamomum* species by leaf morphology alone.

Figure 4-23 Herbarium specimens of *C. camphora* camphor type (cin05) and linalool type (cin07 and 23).

There have been previous reports indicating that linalool-rich leaf oil, also called Ho-oil, was obtained from *Cinnamomum camphora* Nees and Eberm var. *linaloolifera* Fujita, so the 2 samples collected in this study which have linalool type-leaf oil might be identified as that variety.

4.2. Confirmation of the conformity species

In this study, many *Cinnamomum* samples were collected from various provinces of Thailand, and then kept as herbarium specimens for species identification. Most of these specimens consist of only branches with leaves, which present difficulty in morphological identification. Only afew specimens of some species contain flowers and fruits, which are necessary for the identification. Therefore, some specimens were identified as "comform to species" represented by the abbreviation "cf." in front of its specific name. For example, *Cinnamomum* cf. *iners* means that this specimen resembles the species "*C. iners*".

Comparison of the chromatographic profiles could help taxonomist classify an unknown sample into the right species. As the aim of this study, chemometric cluster analysis is used for classifying 48 *Cinnamomum* samples in terms of their chemical profiles.

Following the results obtained from the cluster analysis based on the normalized and scored peak area of the oil composition, it can be seen that most samples of the same species, including the "conform" species, were grouped into one cluster (Figures 4-20 and 4-21). This method could support the morphological identification and taxonomic judgment can be made with greater confidence.

4.2.1. *Cinnamomum* cf. *verum* (cin40, 16, 24, 01)

From Figures 4-24 and 4-25, it can be seen that the morphology of all 8 specimens are quite similar. Comparison of these specimens with those in the Forest Herbarium (BKF) identified them as *C. verum*. However, without flowering branches and fruits, even expert cannot be certain of their identify.

With the results of chemometric cluster analysis of the essential leaf oil, four samples that appeared to conform to *C. verum* were grouped together in one cluster with the samples identified as *C. verum*.

Based on the major composition of the essential leaf oil, eight samples of *C. verum* in this study can be classified into 2 chemical groups: eugenol and linalool group. The samples with similar chemical pattern were grouped together first, then linked to the others and finally formed a main cluster.

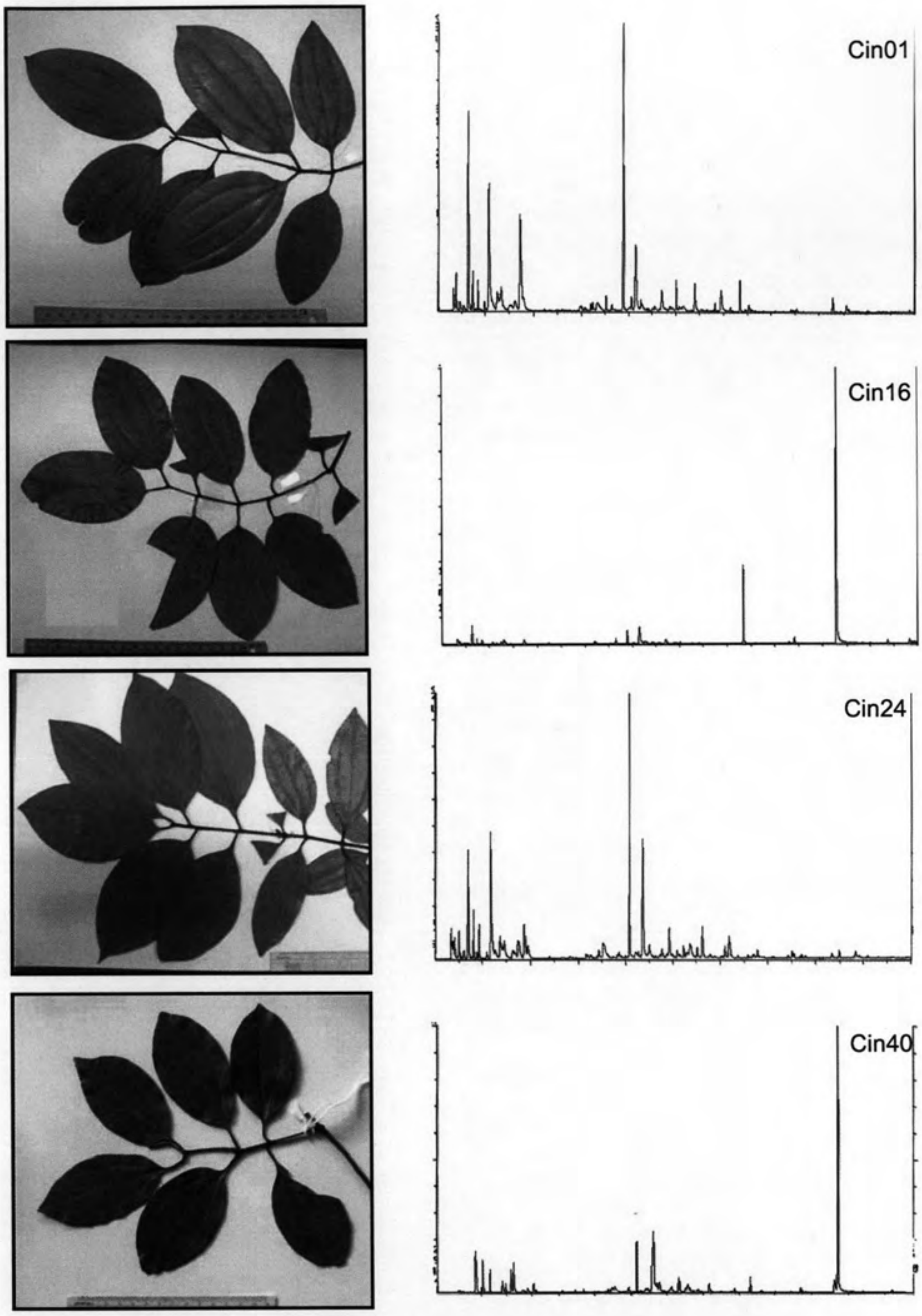

Figure 4-24 Specimens of 4 *Cinnamomum.* cf. *verum* samples and their GC-chromatograms

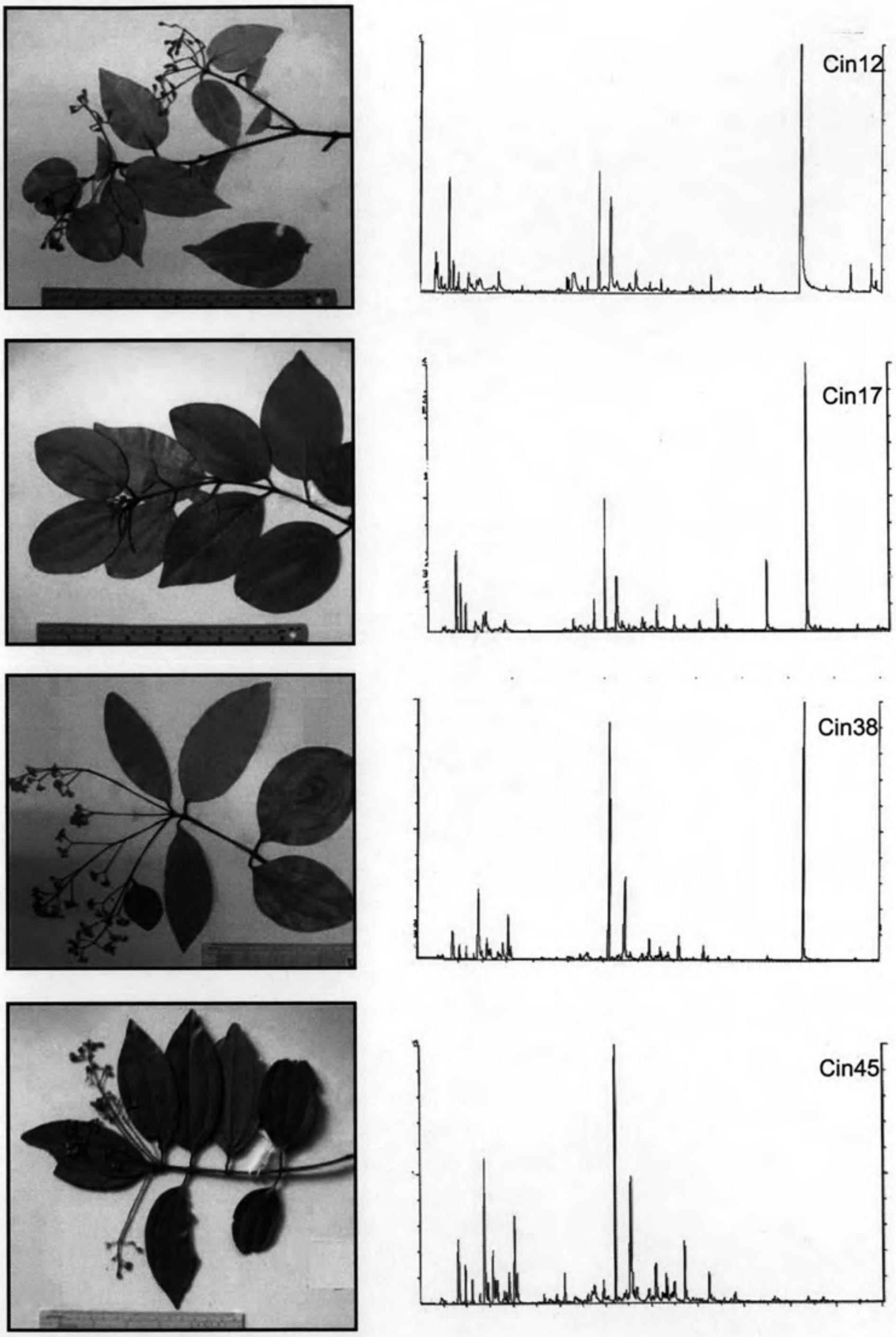

Figure 4-25 Flowering specimens of 4 *C. verum* samples and their GC-chromatograms

4.2.2. *Cinnamomum* cf. *iners* (cin02, 13, 18, 22, 37, 49, 50,)

Unlike *C. verum*, the essential leaf oils of 12 *C. iners* samples were clearly separated into 2 clusters. One is the linalool-rich group and an other is the caryophyllene-rich group. Most samples, including cin22, 37, 49, and 50, are in the cayophyllene group. The linalool group contained 3 samples: cin02, 13 and 46. The cin46 sample was confirmed to be *C. iners*, it can therefore be the reference for the other two samples. Base on these data, it can be concluded that at least 2 chemotypes exist for *C. iners*.

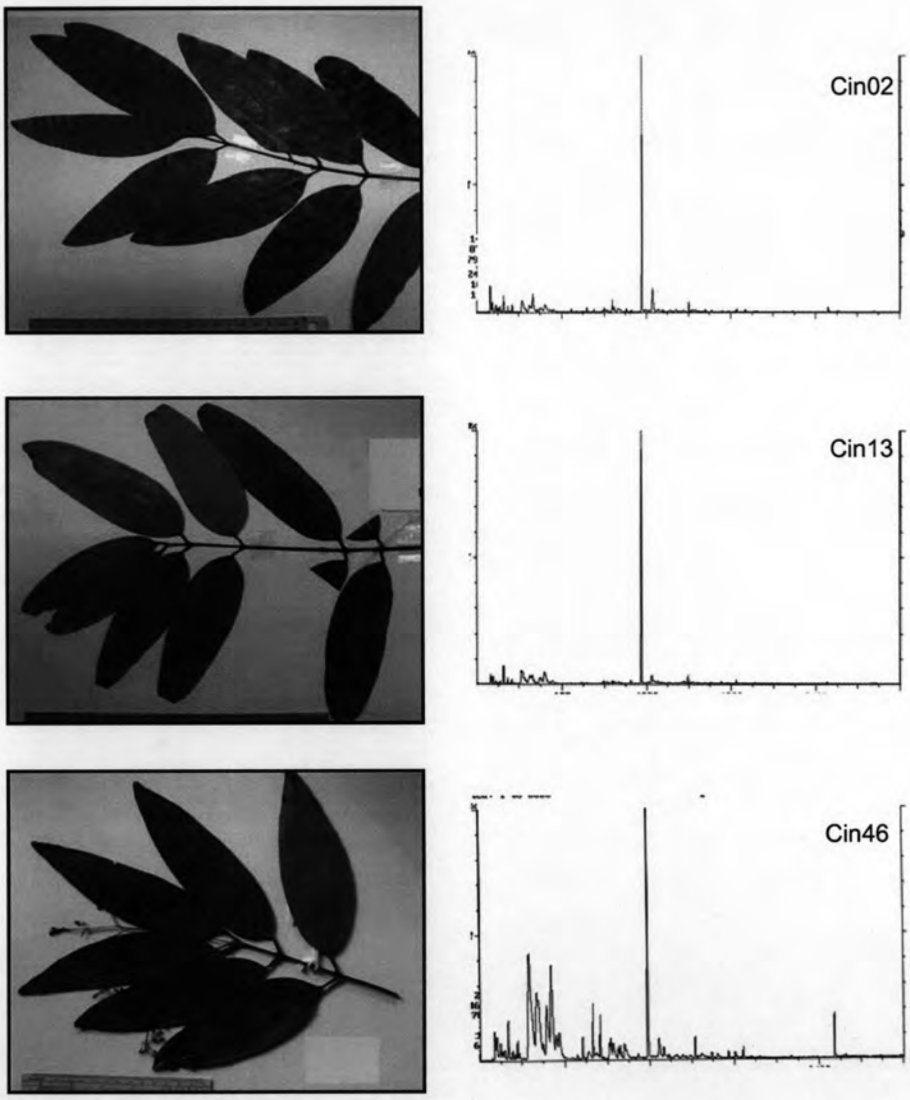

Figure 4-26 Three specimens of the linalool group of *C. iners* and their GC-chromatograms

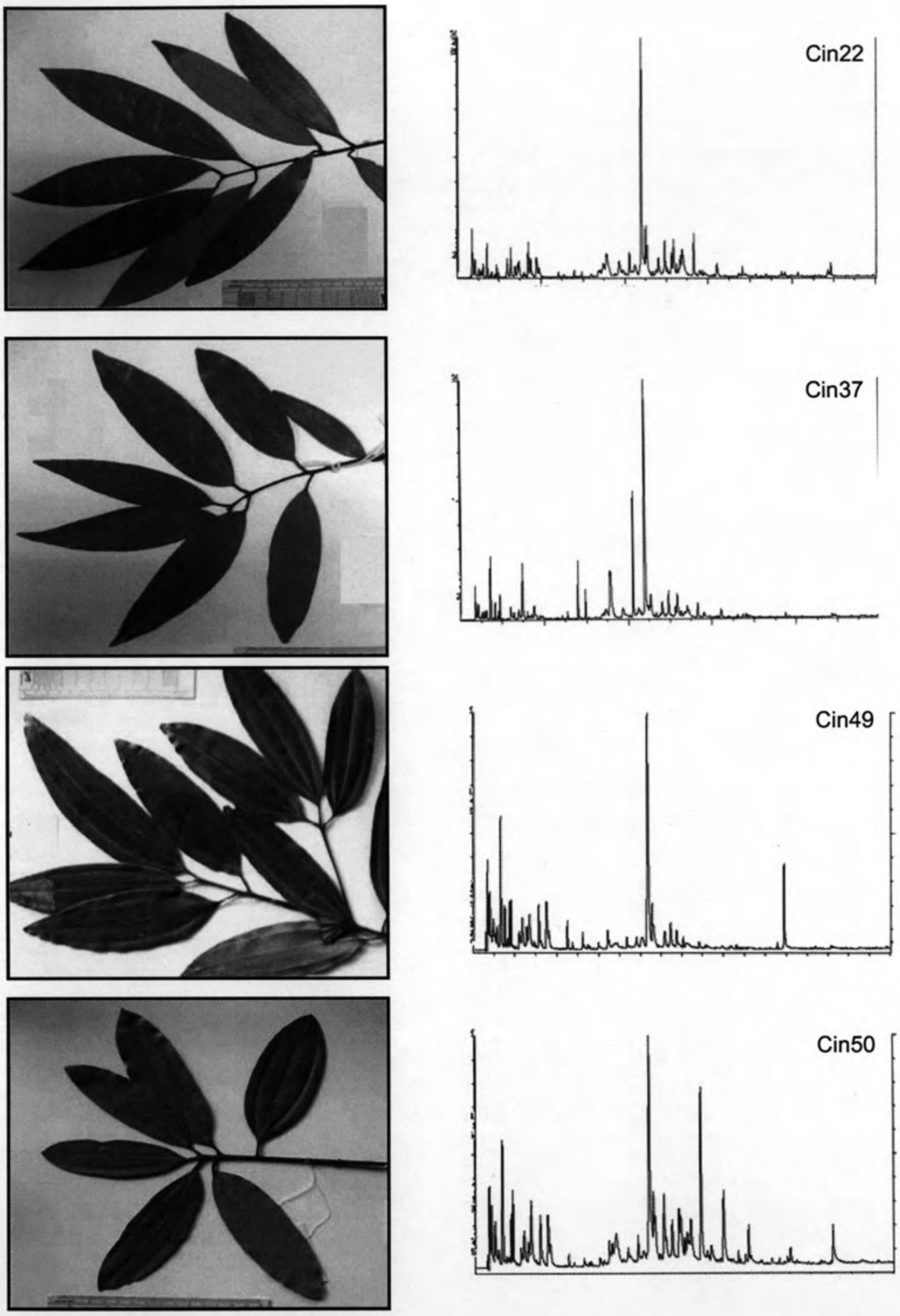

Figure 4-27 Four specimens of the caryophyllene group of *Cinnmomum*. cf. *iners* and their GC-chromatograms

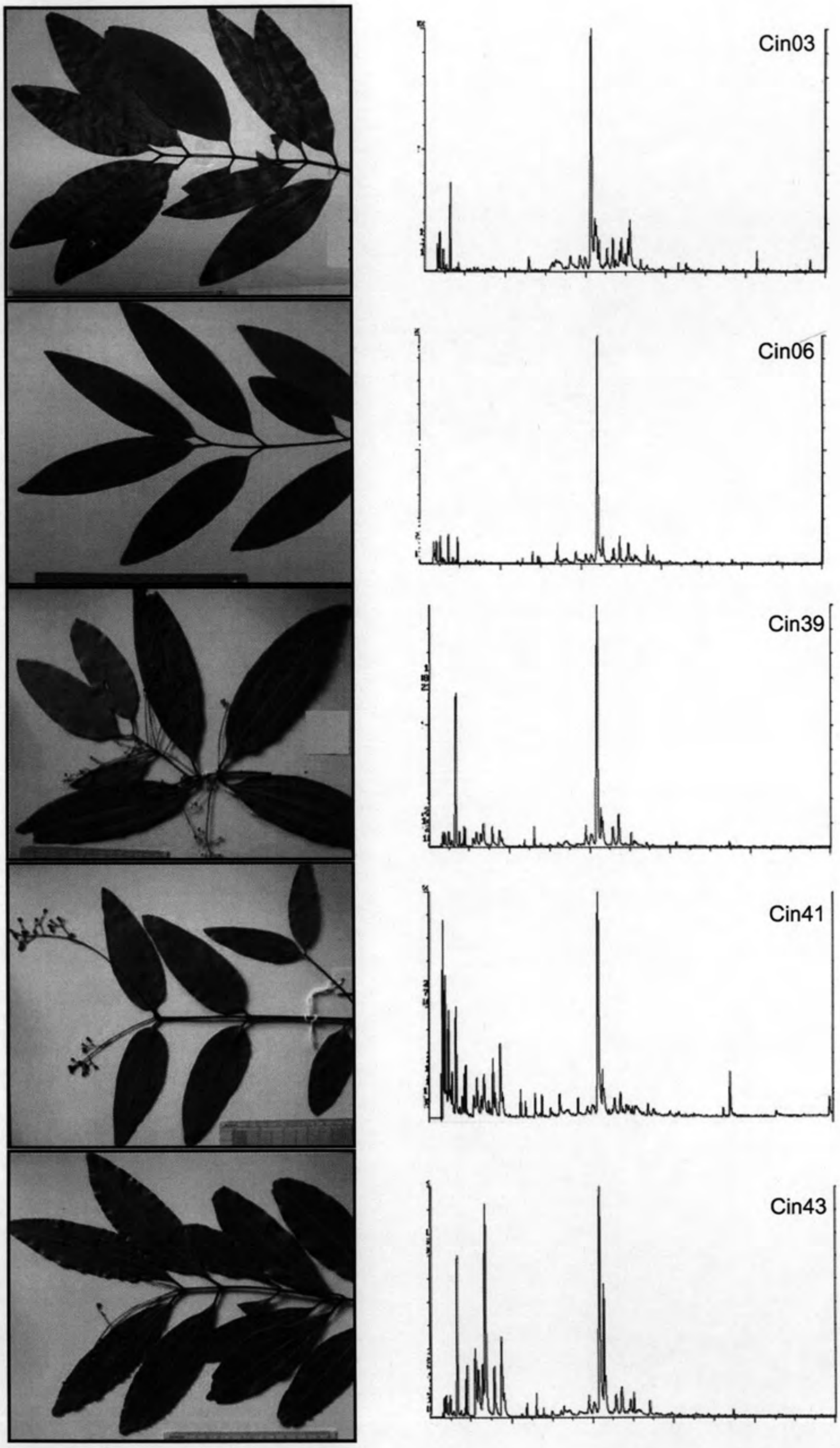

Figure 4-28 Specimens of the caryophyllene group of *C. iners* and their GC-chromatograms

However, there are 2 samples of *Cinnamomum* cf. *iners* that could not be properly placed into the main group. The sample cin18 was grouped together with *C. verum* according to its high content of α-pinene (20.97%), linalool (8.83%) and eugenol (5.30%) in the oil.

The sample cin51 has similar chemical pattern to cin21 (*C. bejolghota*) with high p-cymene (16.92%) content and low caryophyllene content (2.78%) compared to other caryophyllene-rich samples. Therefore, cin51 was clustered into the same group as cin21, but still in the main cluster of *C. iners*.

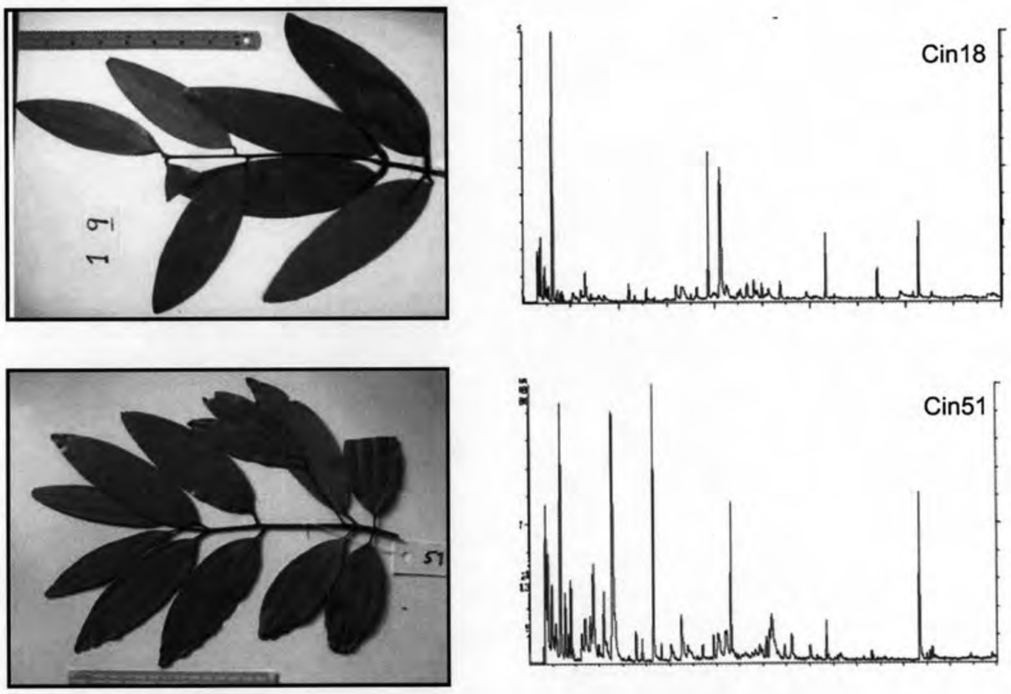

Figure 4-29 Specimens of the separated *C.* cf. *iners* and their GC-chromatogram

4.2.3. *Cinnamomum* cf. *bejolghota* (cin27)

Although cin27 was assigned into the same main cluster with the correctly identified *C. bejolghota* (cin21), they were linked by large dissimilarity value. Because of the difference between their chemical content and lack of complete specimen, identify confirmation for this sample cannot be made.

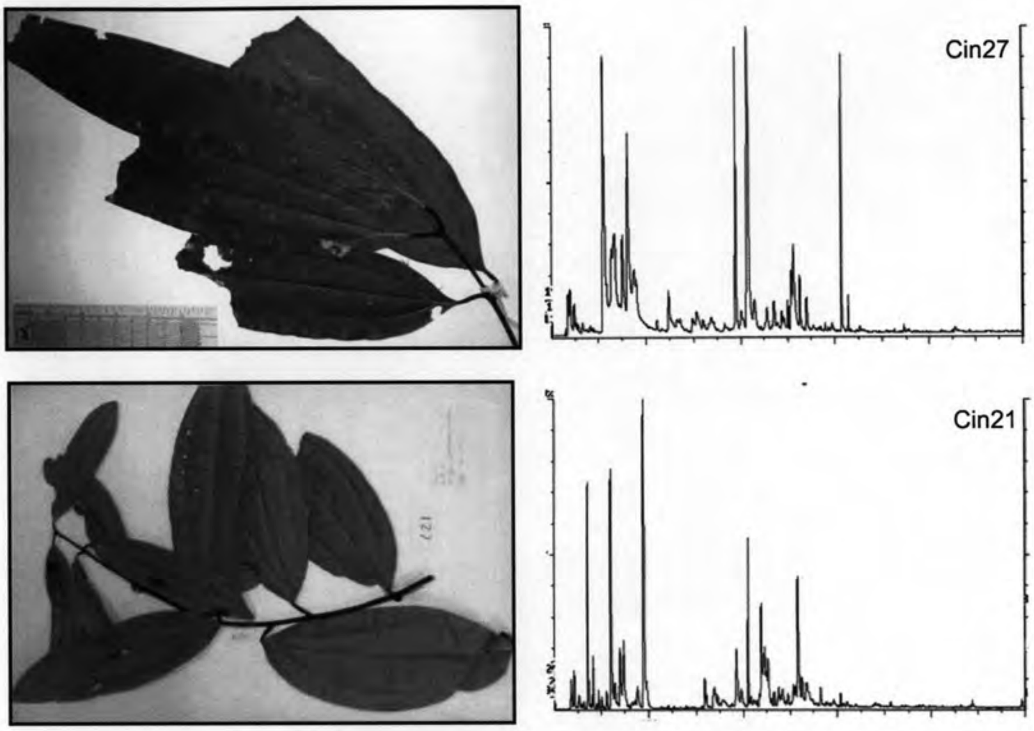

Figure 4-30 Specimens of *Cinnamomum* cf. *bejolghota* (cin27) and *C. bejolghota* (cin21) and their GC-chromatograms

4.2.4. *C.* cf. *subavenium* (cin20)

The sample cin20 has very similar morphology to *C. subavenium* collected from Nakhon Ratchasima, but they are very different in their chemical compositon of their leaf oil. The four samples from Nakhon Ratchasima contained caryophyllene as the major component makinge them closely related to *C. iners*. Therefore, they were grouped as sub-cluster in the *C. iners.* Cluster. Cin20 contained linalool as the major component and was clustered into the same high linalool group of content species, *C. camphora* and *C. iners*.

It can possibly be assumed from the result that there was a geographical variation in the composition of *C. subavenium* leaf oil and more than one chemotype of this species existed. To prove this hypothesis, more samples of *C. subavenium* from other locations should be collected and analyzed.

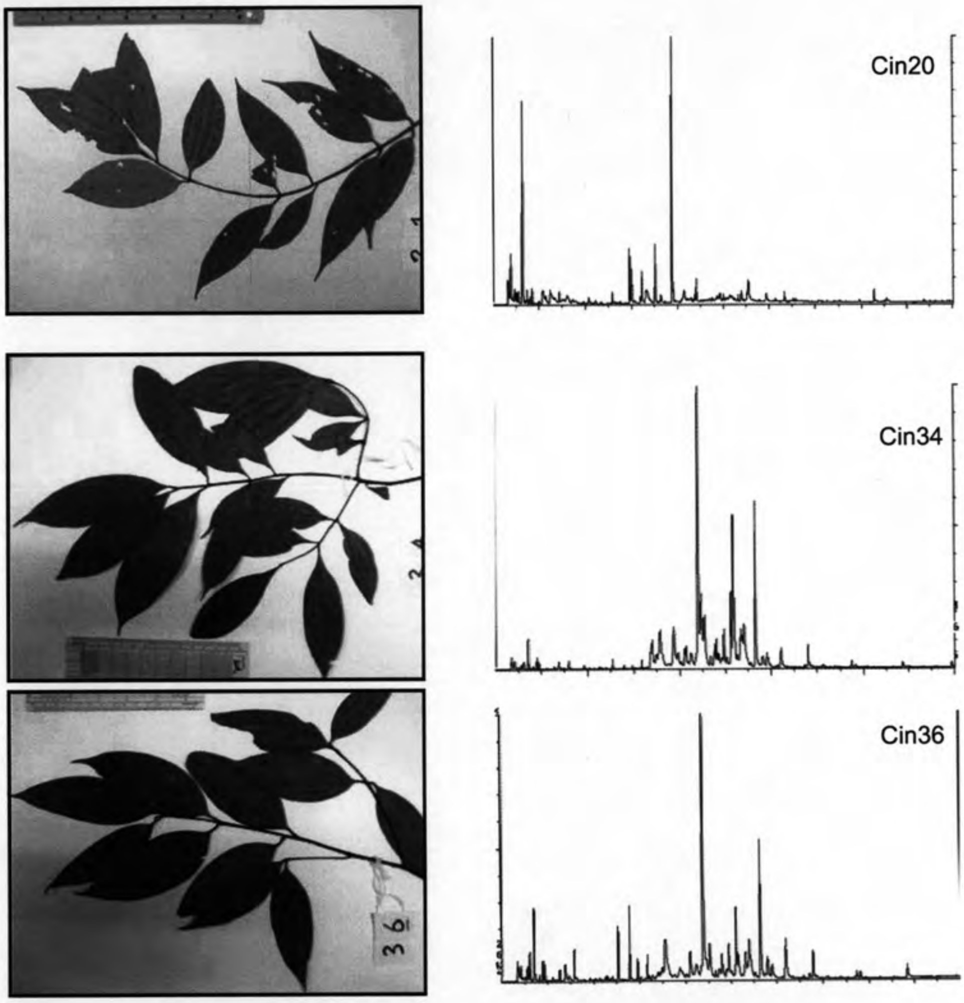

Figure 4-31 Specimens of *Cinnamomum*. cf. *subavenium* (cin20) and *C. subavenium* from Nakhon Ratchasima (cin34 and 36) and their GC-chromatograms.

4.3. Classification of unidentified species

4.3.1. Species 01-03

The species 01 (cin09) was collected from Udon Thani. Other 3 samples, one of species 02 (cin11) and 2 samples of species 03 (cin14 and 15), were collected from Yasothon province. Cin14 and cin15 are very similar morphologically and were classified as the same species (species 03). When only leaf morphology was considered, the cin11 is less different from the other two samples, so it was classified as another species (species 02). From the result of HCA using Pearson correlation and between group linkage, the dendrogram showed distinct cluster of the unknown species 01-03. The essential leaf oil of this cluster contained high amount of benzyl alcohol (19.30-46.76%) and linalool (22.64-42.49%) except that of cin11 which contained only 4.28% of linalool.

Combination of morphological identification and the result from chemometric analysis indicate the possibility that all 3 samples from Yasothon province are the same species.

4.3.2. Species 04-05

The samples of species 04 and 05 (cin26 and cin30) were collected from Surat Thani in Peninsular Thailand, together with *C. pachyphyllum* (cin28 and 29). The herbarium specimen of these 2 samples could not be made because of limited plant materials. However, the dendrogram of cluster analysis revealed that one of them (cin30) was *C. pachyphyllum*.

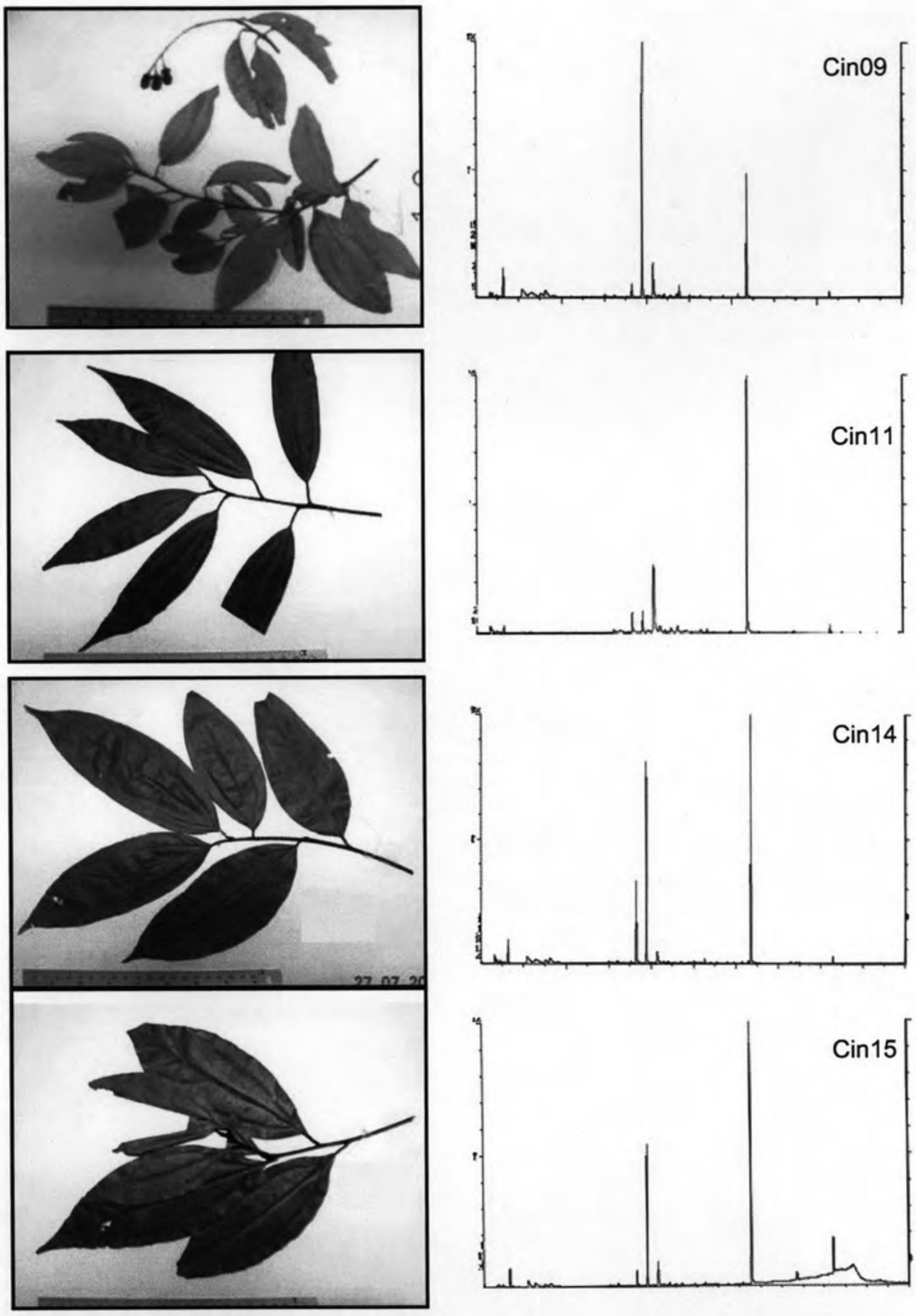

Figure 4-32 Specimens of the unidentified species and their chromatograms; cin09 = sp.01, cin11 = sp02, cin14 and cin15 = sp.03