CHAPTER IV

RESULTS

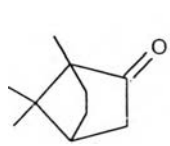
4.1 Chemical Composition of the Essential Oils from Thai Lauraceous Plants

4.1.1. Essential Oil Composition of *Cinnamomum camphora* Th. Fries. collected from Bangkok

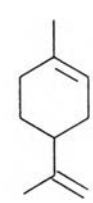
The leaves of *Cinnamomum camphora* collected in Bangkok were found to contain essential oil at 0.38 % (v/w) of the fresh weight. GC/MS analysis showed at least 34 peaks in its GC chromatogram (Fig. 2). These peaks were identified as 14 monoterpenes, 4 oxygenated monoterpenes, 10 sesquiterpenes and 1 phenylpropane and 1 long chain hydrocarbon (Table 3). Among these, the major components were found to be camphor (55.43 %) , limonene (11.58 %) and α-pinene (10.59 %).

In terms of relative amount, the oxygenated monoterpenes appeared to be the major terpenoid group, accounting for 57.75 % of the essential oil. Monoterpenes and sesquiterpenes were present in lesser amount, at 39.98 % and 1.39 %, respectively (Fig. 3).

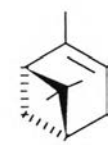
In terms of structure, the major components, camphor belongs to the oxygenated monoterpenoid group of camphane, whereas α-pinene and limonene belong to the monoterpenoid groups of pinane and menthane, respectively.



camphor
(camphane)



limonene
(menthane)



α-pinene
(pinane)

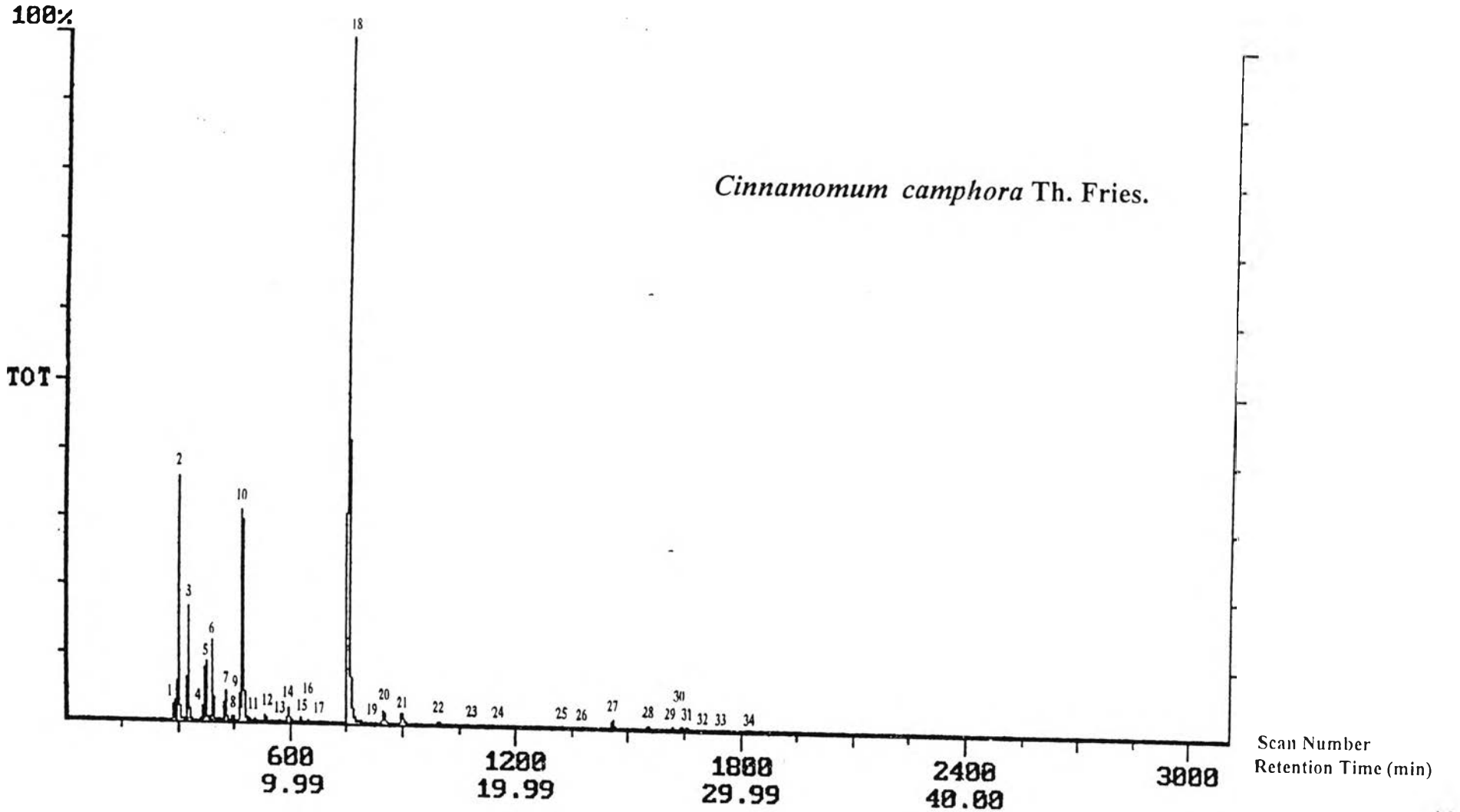


Figure 2 GC chromatogram of the essential oil from *Cinnamomum camphora* Th. Fries. Leaves (Bangkok)

Table 3 Essential oil composition of *Cinnamomum camphora* leaves (Bangkok)

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	0.87
2	α-pinene	5.03	10.59
3	camphene	5.48	5.22
4	sabinene	6.08	0.60
5	β-phellandrene	6.23	2.87
6	β-pinene	6.54	3.72
7	α-phellandrene	7.11	1.62
8	δ-*2*-carene	7.44	0.17
9	verbenene	7.78	1.44
10	limonene	7.88	11.58
11	*(E)*-β-ocimene	8.48	0.04
12	γ-terpinene	8.91	0.37
13	trans-sabinene hydrate	9.61	0.05
14	terpinolene	9.93	0.84
	Oxygenated monoterpene		
18	camphor	12.54	55.43
19	borneol	13.99	0.06
20	terpin-*4-ol*	14.16	1.13
21	α-terpineol	14.98	1.13
	Sesquiterpene		
25	α-copaene	22.38	0.07
26	β-elemene	23.09	0.03
27	*(E)*-caryophyllene	24.33	0.59
28	α-humulene	25.89	0.18
29	γ-muurolene	26.99	0.08
30	β-selinene	27.34	0.22
31	α-selinene	27.63	0.14
32	germacrene A	28.11	0.03
33	*trans*-β-guaiene	28.59	0.02
34	germacerne B	30.19	0.03
	Phenylpropanoid		
24	*(Z)*-isosafrole	18.99	0.07
	Long chain hydrocarbon		
15	*n*-heneicosane	10.44	0.14
	Miscellaneous		
16	unknown	10.83	0.09
17	unknown	11.79	0.30

Table 3 (continued)

Peak No	Compound	Retention time (min)	%Area
22	unknown	16.61	0.15
23	unknown	17.98	0.11

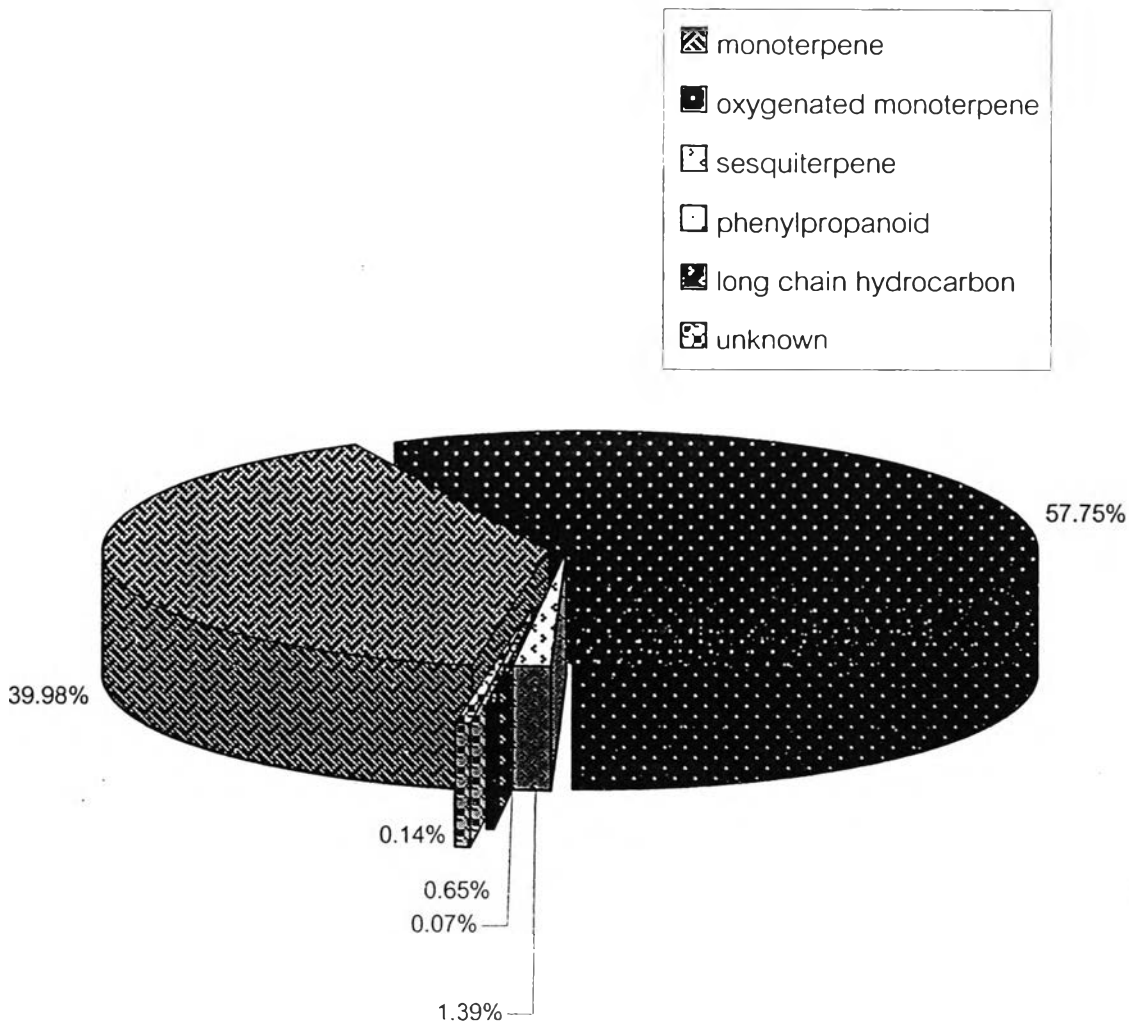


Figure 3 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum camphora* Th. Fries. Leaves (Bangkok)

4.1.2. Essential Oil Composition of *Cinnamomum camphora* Th. Fries. collected from Rayong

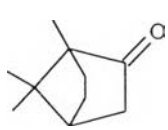
By hydrodistillation, the yield of the essential oil from *Cinnamomum camphora* Th. Fries. collected from Rayong was found to be 0.33% (v/w) of the fresh weight. GC/MS analysis of the essential oil showed 34 peaks (Fig. 4). These peaks were identified as 13 monoterpenes, 7 oxygenated monoterpenes, 10 sesquiterpenes, 3 oxygenated sesquiterpenes and 1 long chain hydrocarbon (Table 4). Among these, camphor (56.06%) appeared to be the major component, followed by limonene (9.03%) and α-pinene (7.92%).

The oxygenated monoterpene appeared to be the major terpenoid group, accounting for 58.61% of the essential oil (Fig. 5). Monoterpenes and sesquiterpenes were present in lesser amount, at 30.35 and 9.67%, respectively.

Structurally, the major components, camphor belongs to the oxygenated monoterpenoid group of camphene, while limonene and α-pinene belong to the monoterpenoid group of menthane and pinane, respectively.

α-pinene
(pinane)

limonene
(menthane)



camphor
(camphane)

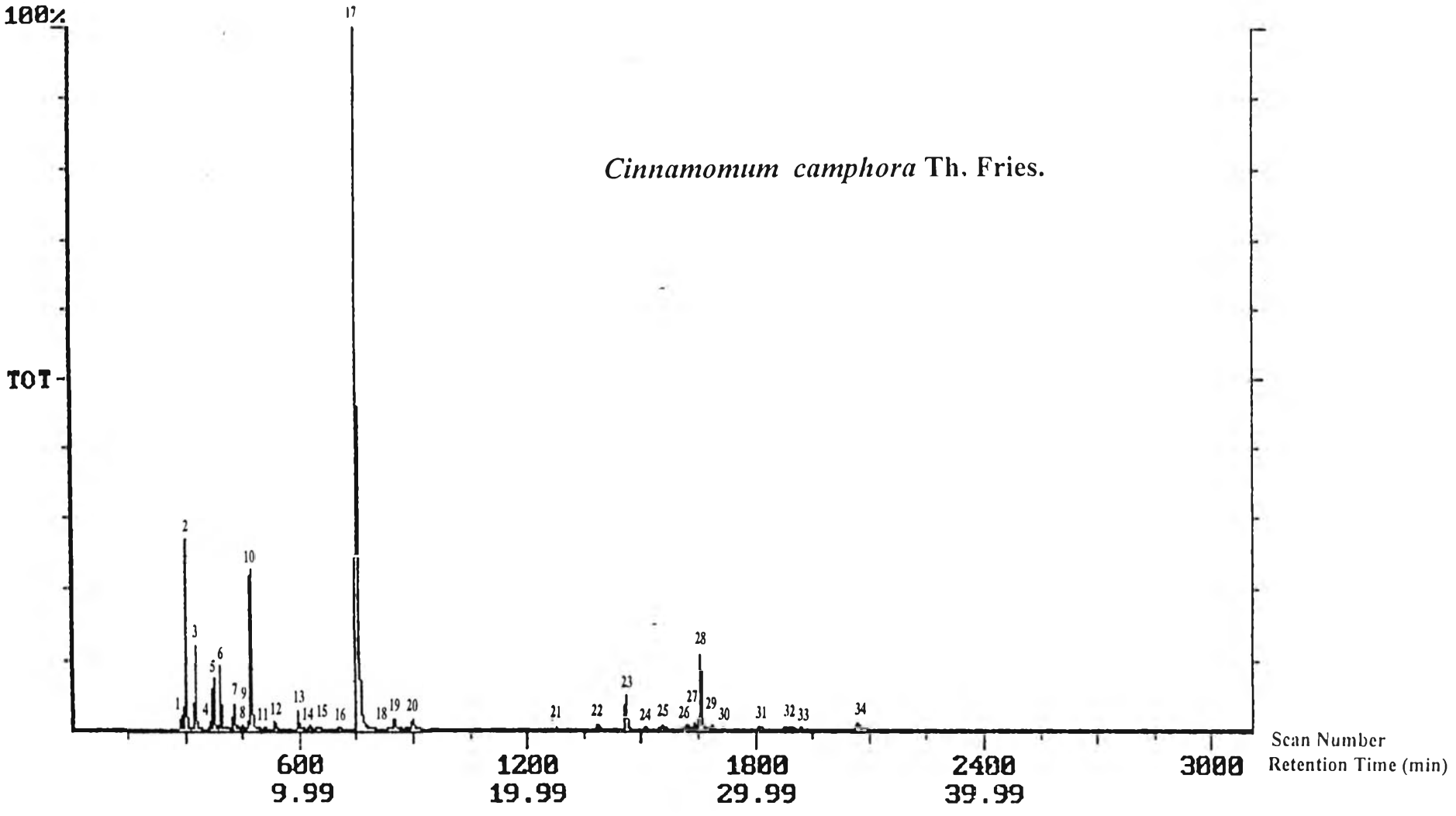


Figure 4 GC chromatogram of the essential oil from *Cinnamomum camphora* Th. Fries. Leaves (Rayong)

Table 4 Essential oil composition of *Cinnamomum camphora* leaves (Rayong)

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	0.53
2	α-pinene	5.03	7.92
3	camphene	5.48	3.79
4	sabinene	6.08	0.37
5	β-phellandrene	6.23	2.40
6	β-pinene	6.54	3.03
7	α-phellandrene	7.11	1.22
8	δ-*2*-carene	7.44	0.15
9	verbenene	7.78	0.45
10	limonene	7.88	9.03
11	*(E)*-β-ocimene	8.48	0.09
12	γ-terpinene	8.91	0.42
13	terpinolene	9.93	0.95
	Oxygenated monoterpene		
15	linalool	10.81	0.32
16	α-campholenal	11.73	0.13
17	camphor	12.54	56.06
18	borneol	13.99	0.12
19	terpin-*4-ol*	14.16	0.95
20	α-terpineol	14.98	0.97
21	α-terpinyl acetate	19.79	0.06
	Sesquiterpene		
22	β-elemene	23.09	0.21
23	*(E)*-caryophyllene	24.33	2.49
24	longifolene	25.11	0.06
25	α-humulene	25.89	0.21
26	γ-muurolene	26.99	0.33
27	β-selinene	27.34	0.36
28	bicyclogermacrene	27.59	5.58
29	germacrene A	28.11	0.17
30	*trans*-β-quaiene	28.59	0.10
31	germacrene B	30.19	0.16
	Oxygenated sesquiterpene		
32	spathulenol	31.29	0.27
33	α-eudesmol acetate	31.59	0.06
34	α-eudesmol	34.48	0.78
	Long chain hydrocarbon		
14	*n*-heneicosane	10.44	0.21

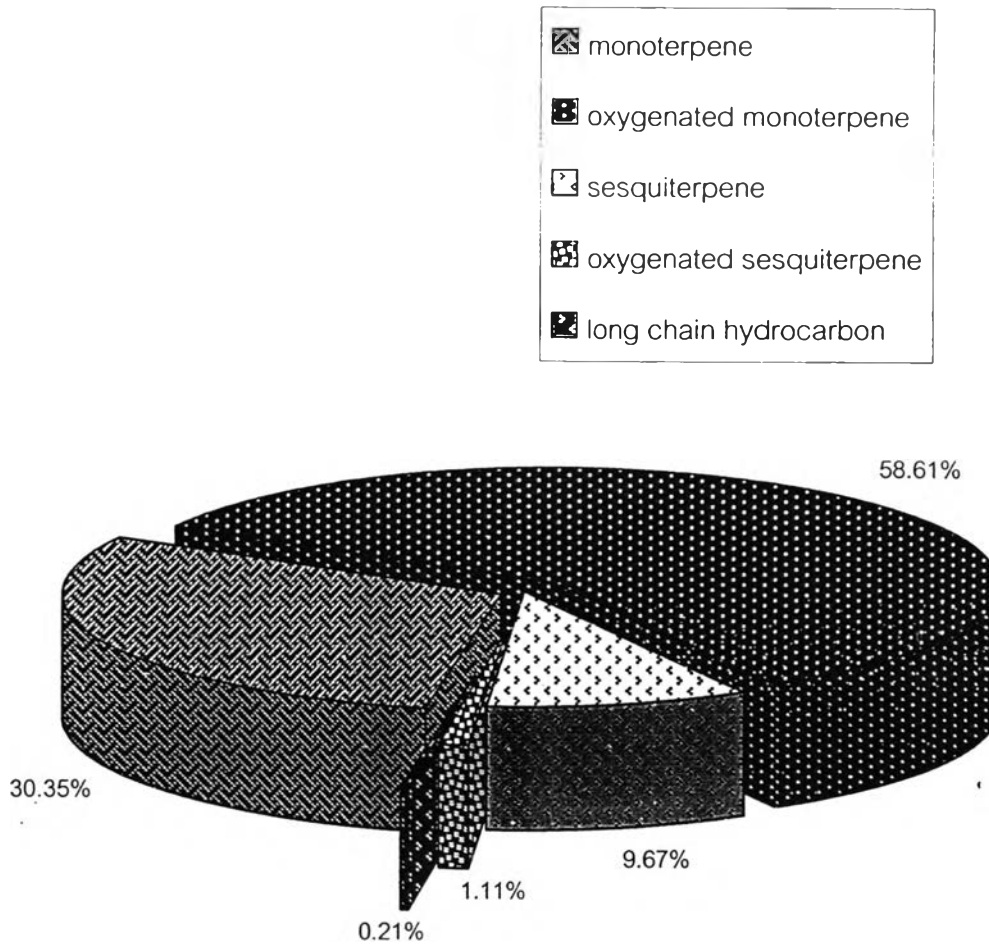
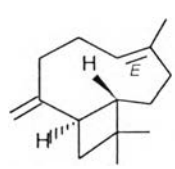


Figure 5 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum camphora* Th. Fries. Leaves (Rayong)

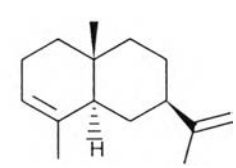
4.1.3. Essential Oil Composition of *Cinnamomum iners* Bl.

The yield of the essential oil isolated from *Cinnamomum inners* leaves was found to be 0.1% (v/w) of the fresh weight. GC/MS analysis of the essential oil showed that there were at least 45 components present in the oil (Fig. 6). These components were identified as 11 monoterpenes, 4 oxygenated monoterpenes, 17 sesquiterpenes, 9 oxygenated sesquiterpenes, 1 phenylpropane and 3 non-terpenoid components (Table 5). Among these, *(E)*-caryophyllene (20.38 %) was found to be the major components followed by spathulenol (19.75%) and α-selinene (10.80%), which contributed greatly to the overall sesquiterpenoids content. This group of terpenoids appeared to be the major one, accounting for 47.92 % of the essential oil (Fig. 7),. followed closely by the oxygenated sesquiterpenes (47.48 %) and monoterpenes (2.42 %).

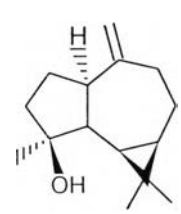
In terms of structure type, the major component, *(E)*-caryophyllene and α-selinene belong to the sesquiterpenoid group of caryophyllane and simple eudesmane, whereas spathulenol belongs to the oxygenated sesquiterpenoid group of aromadendrane.



(E)-caryophyllene
(*caryophyllane*)



α-selinene
(simple eudesmane)



spathulenol
(aromadendrane)

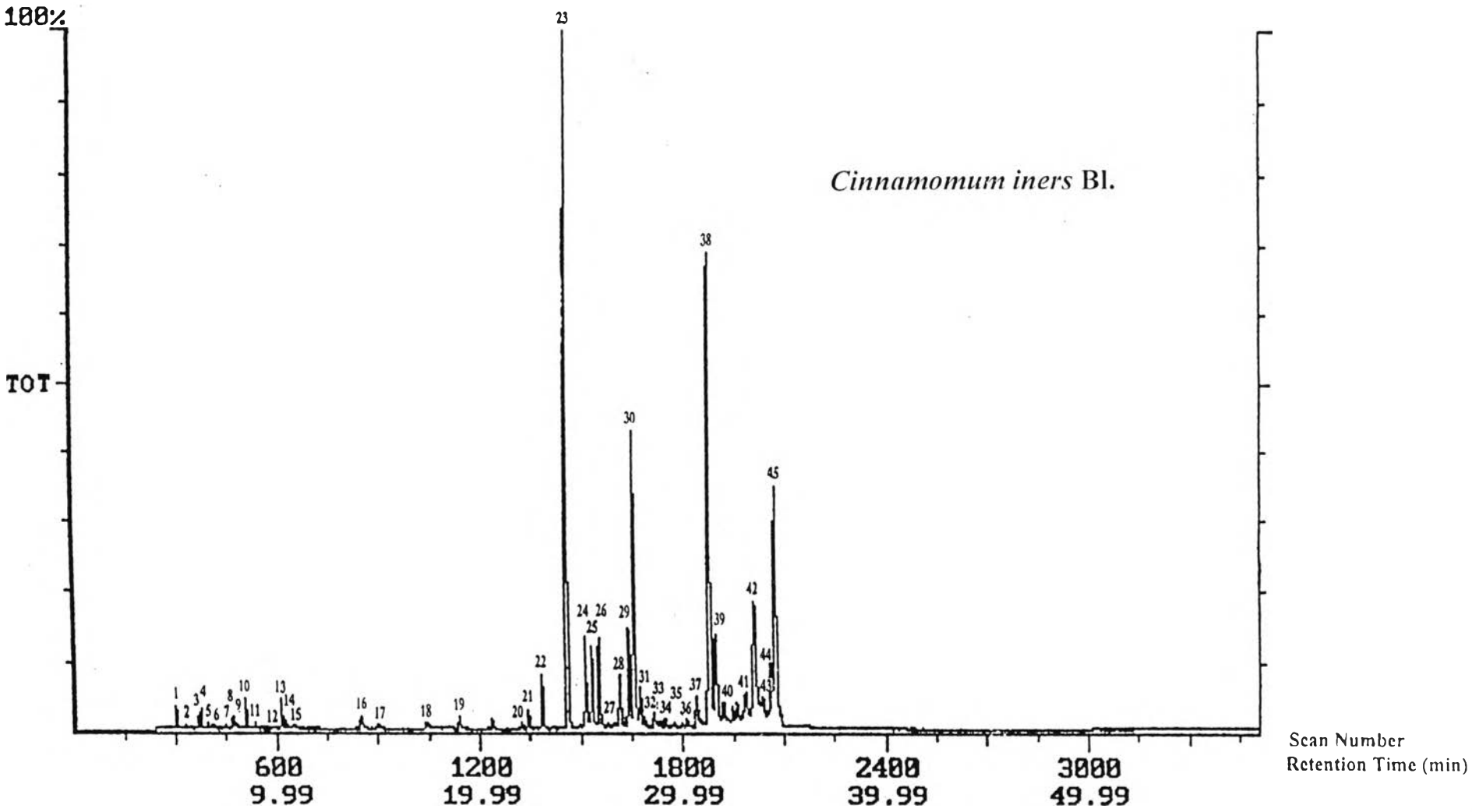


Figure 6 GC chromatogram of the essential oil from *Cinnamomum iners* Bl. leaves

Table 5 Essential oil composition of *Cinnamomum iners* leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-pinene	5.03	0.42
2	camphene	5.48	0.04
3	sabinene	6.08	0.21
4	β-phellandrene	6.23	0.39
5	β-pinene	6.54	0.11
7	δ-*2*-carene	7.44	0.05
8	verbenene	7.78	0.21
9	limonene	7.88	0.23
10	*(E)*-β-ocimene	8.48	0.59
11	γ-terpinene	8.91	0.13
12	terpinolene	9.93	0.04
	Oxygenated monoterpene		
15	linalool	10.81	0.13
16	terpin-*4-ol*	14.16	0.39
17	α-terpineol	14.98	0.17
18	geraniol	17.38	0.24
	Sesquiterpene		
19	δ-elemene	20.63	0.25
21	α-copaene	22.38	0.48
22	β-elemene	23.09	1.45
23	*(E)*-caryophyllene	24.33	20.38
24	α-gerjunene	25.23	2.10
25	cyperene	25.54	2.15
26	α-humulene	25.89	2.58
27	β-patchoulene	26.61	0.25
28	α-muurolene	26.89	1.60
29	β-selinene	27.34	3.35
30	α-selinene	27.63	10.80
31	β-gurjunene	27.88	1.42
32	germacrene A	28.11	0.35
33	*trans*-β-guaiene	28.59	0.28
34	selina-*3,7(11)*-diene	28.91	0.18
35	α-calacorene	29.61	0.11
36	germacrene B	30.19	0.19
	Oxygenated sesquiterpene		
37	*(E)*-nerolidol	30.66	0.88
38	spathulenol	31.29	19.75
39	α-eudesmol acetate	31.59	3.98

Table 5 (continued)

Peak No	Compound	Retention time (min)	%Area
40	hinesol acetate	31.96	0.71
41	juniper camphor acetate	33.08	1.73
42	bicyclovetivenol	33.54	7.32
43	α-muurolol	33.93	1.04
44	himachalol	34.36	2.07
45	selin-*11*-en-*4-alpha*-ol	34.58	10.00
	Phenylpropananoid		
20	*(Z)*-isoeugenol	22.10	0.16
	Long chain hydrocarbon		
6	*n*-decane	6.83	0.07
13	*2*-nonanone	10.23	0.73
14	*n*-heneicosane	10.44	0.16

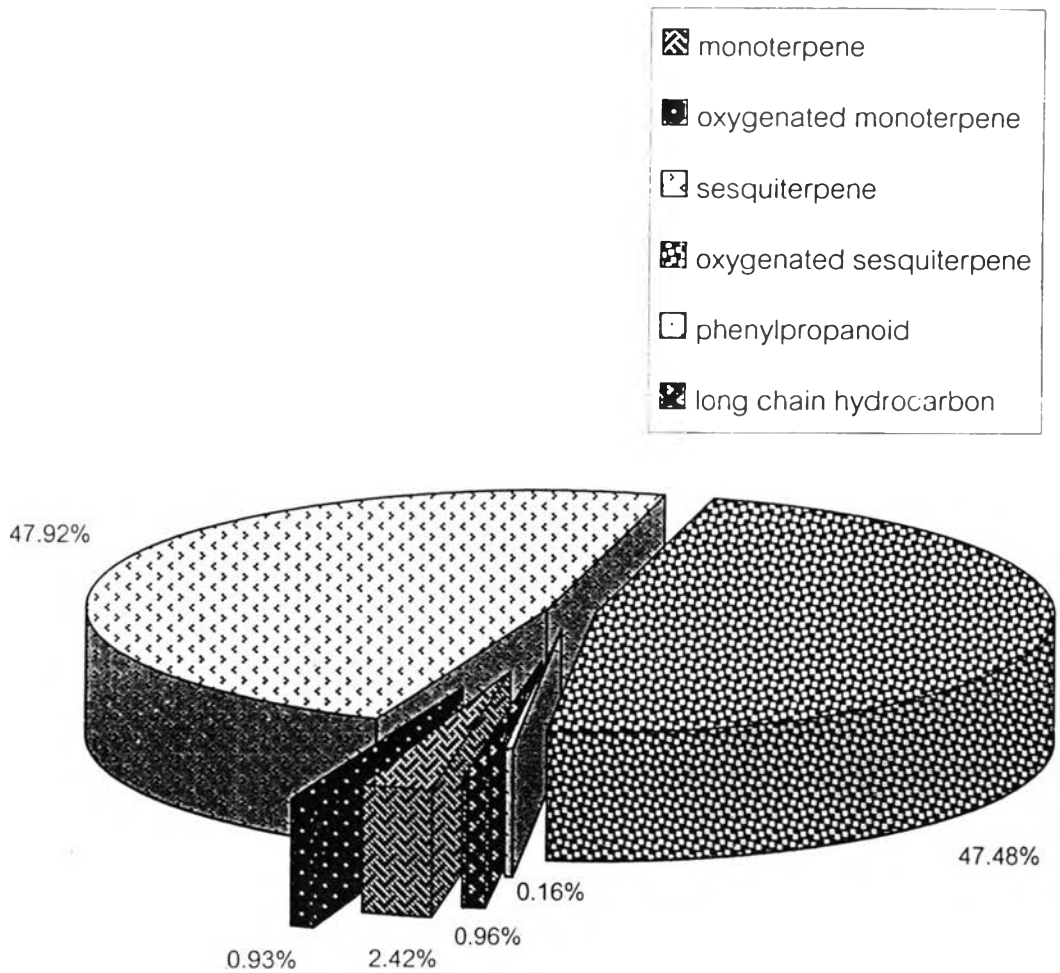
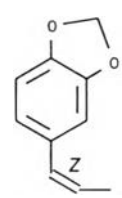


Figure 7 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum iners* Bl. leaves

4.1.4. Essential Oil Composition of *Cinnamomum porrectum* Kosterm leaves

By hydrodistillation, the yield of the essential oil from *Cinnamomum pathenoxylon* leaves was found to be 0.5 % (v/w) of the fresh weight. Analysis of the essential oil by GC/MS showed 15 separated peaks (Fig. 8). These peaks were identified as 4 monoterpenes, 4 sesquiterpenes, 5 phenylpropanes and 2 non-terpenoid components (Table 6). Among these, the phenylpropanoid *(Z)*-isosafrole (97.30 %) appeared to be the major component, followed by *(E)*-caryophyllene (1.51 %).

Thus, the phenylpropanoids appeared to be the major components, accounting for 97.71% of the essential oil. Sesquiterpenes and monoterpenes were present in lesser amount, at 1.71 and 0.41%, respectively (Fig. 9).



(Z)-isosafrole
(phenylpropane)

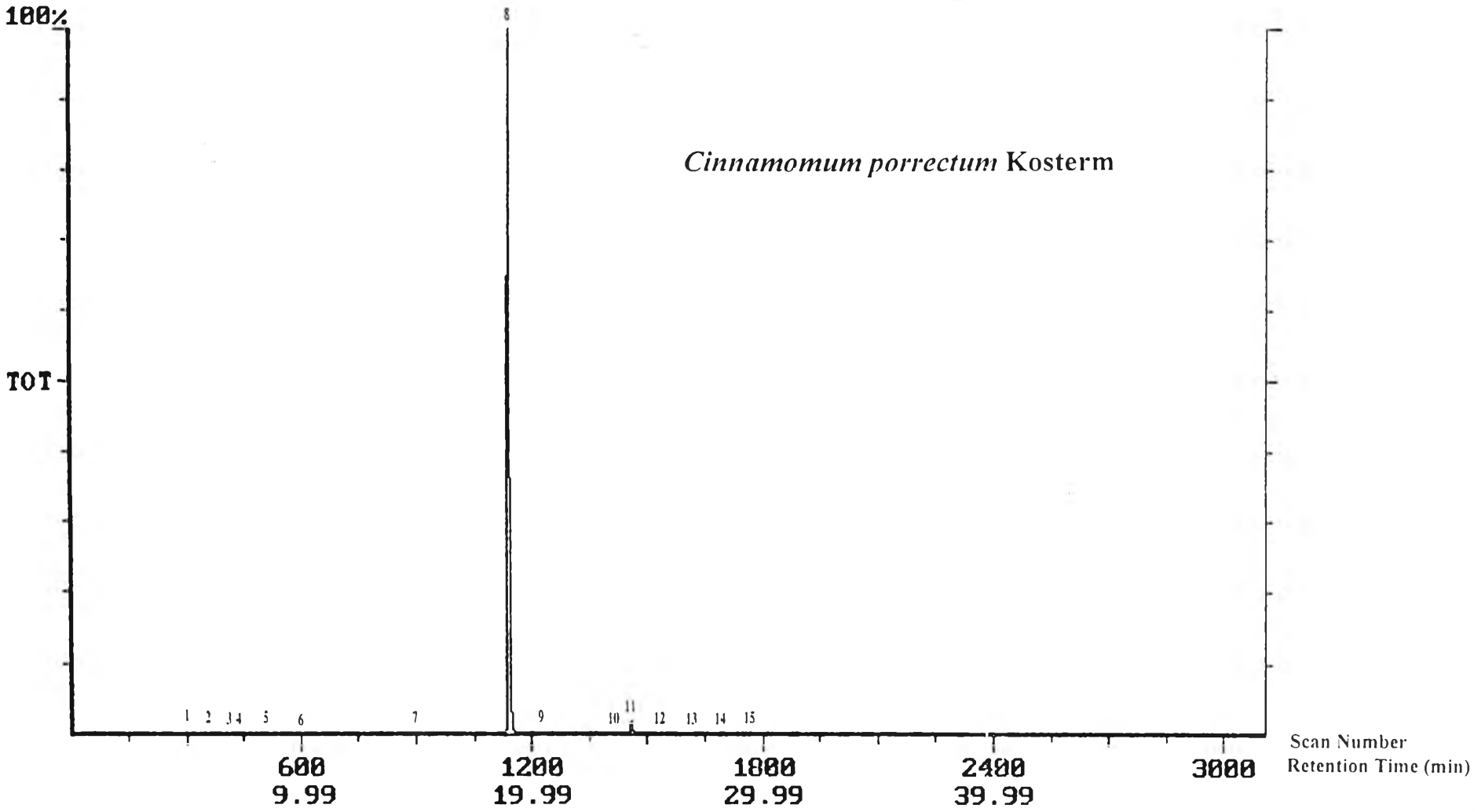


Figure 8 GC chromatogram of the essential oil from *Cinnamomum porrectum* Kosterm leaves

Table 6 Essential oil composition of *Cinnamomum porrectum* leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-pinene	5.03	0.06
2	sabinene	6.08	0.08
3	β-phellandrene	6.23	0.12
5	*(E)*-β-ocimene	8.48	0.15
	Sesquiterpene		
11	*(E)*-caryophyllene	24.33	1.51
12	α-humulene	25.89	0.14
13	γ-muurolene	26.99	0.06
14	*trans*-β-guaiene	28.59	0.02
	Phenylpropananoid		
7	*n*-methyl chavical	14.88	0.19
8	*(Z)*-isosafrole	18.99	97.30
9	*(E)*-isosafrole	23.04	0.03
10	methyl eugenol	23.18	0.16
15	myristicin	30.15	0.03
	Long chain hydrocarbon		
4	*2*-nonanone'	10.23	0.04
6	*n*-heneicosane	10.44	0.09

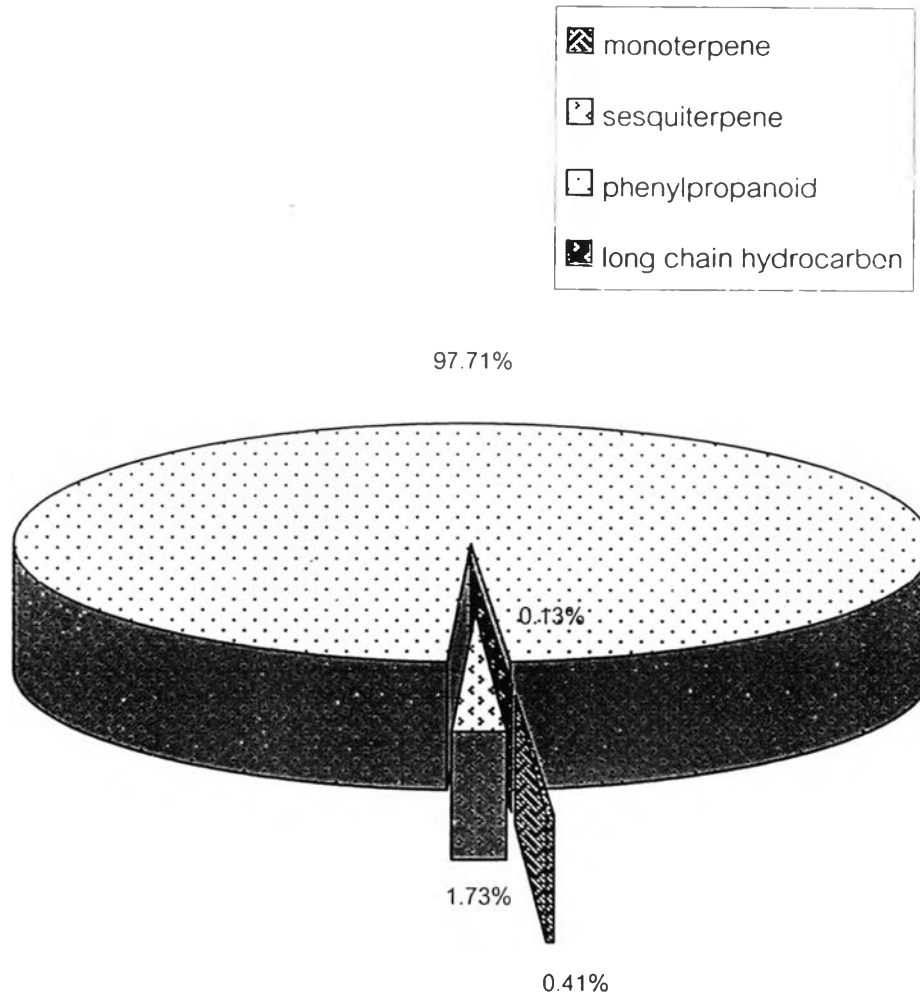
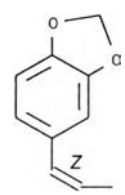


Figure 9 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum porrectum* Kosterm leaves

4.1.5. Essential Oil Composition of *Cinnamomum porrectum* Kosterm bark

The yield of the essential oil isolated from *Cinnamomum pathenoxylon* Nees. bark was found to be 0.1 % (v/w) of the fresh weight. GC/MS analysis of the essential oil showed that there were 15 peaks of the components present in the oil (Fig. 10). These peaks were identified as 3 sesquiterpenes, 2 oxygenated sesquiterpenes, 6 phenylpropanes and 4 non-terpenoid components (Table 7). Among these, *(Z)*- isosafrole (96.89 %) appeared to be the major component belongs to the phenylpropanoid group.

Quantitatively, the phenylpropanoids appeared to be the major group, accounting for 99% of the essential oil (Fig. 11). Aliphatic alcohol, Sesquiterpenoids and oxygenated sesquiterpenoids, both were present in lesser amount, at 0.38, 0.17 and 0.17%, respectively.



(Z)-isosafrole
(phenylpropane)

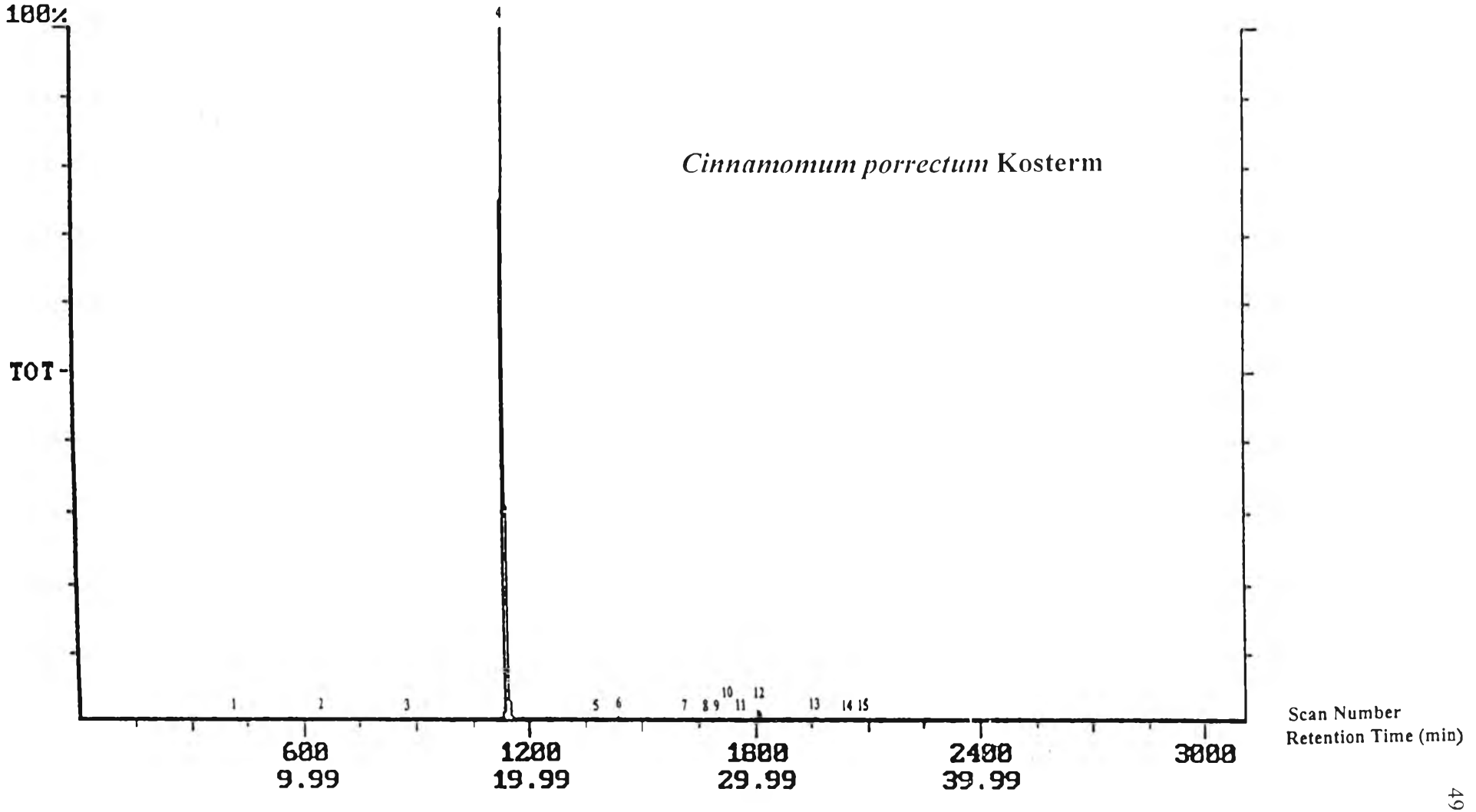


Figure 10 GC chromatogram of the essential oil from *Cinnamomum porrectum* Kosterm bark

Table 7 Essential oil composition of *Cinnamomum porrectum* bark

Peak No	Compound	Retention time (min)	%Area
	Sesquiterpene		
7	γ-cadinene	26.75	0.03
8	*cis*-muurola-*4(14),5*-diene	28.39	0.02
10	*cis*-calamenene	28.78	0.12
	Oxygenated sesquiterpene		
14	*epi*-α-muurolol	33.98	0.05
15	α-cadinol	34.49	0.12
	Phenylpropanoid		
3	methyl chavical	14.88	0.20
4	*(Z)*-isosafrole	18.99	96.85
5	*(E)*-isosafrole	34.04	0.15
6	methyl eugenol	23.18	0.51
11	myristicin	30.15	0.04
12	elemicin	32.64	1.25
	Aliphatic alcohol		
13	dodecanal	32.64	0.38
	Long chain hydrocarbon		
1	*n*-decane	6.83	0.05
2	*n*-heneicosane	10.44	0.11
	Miscellaneous		
9	unknown	28.48	0.08

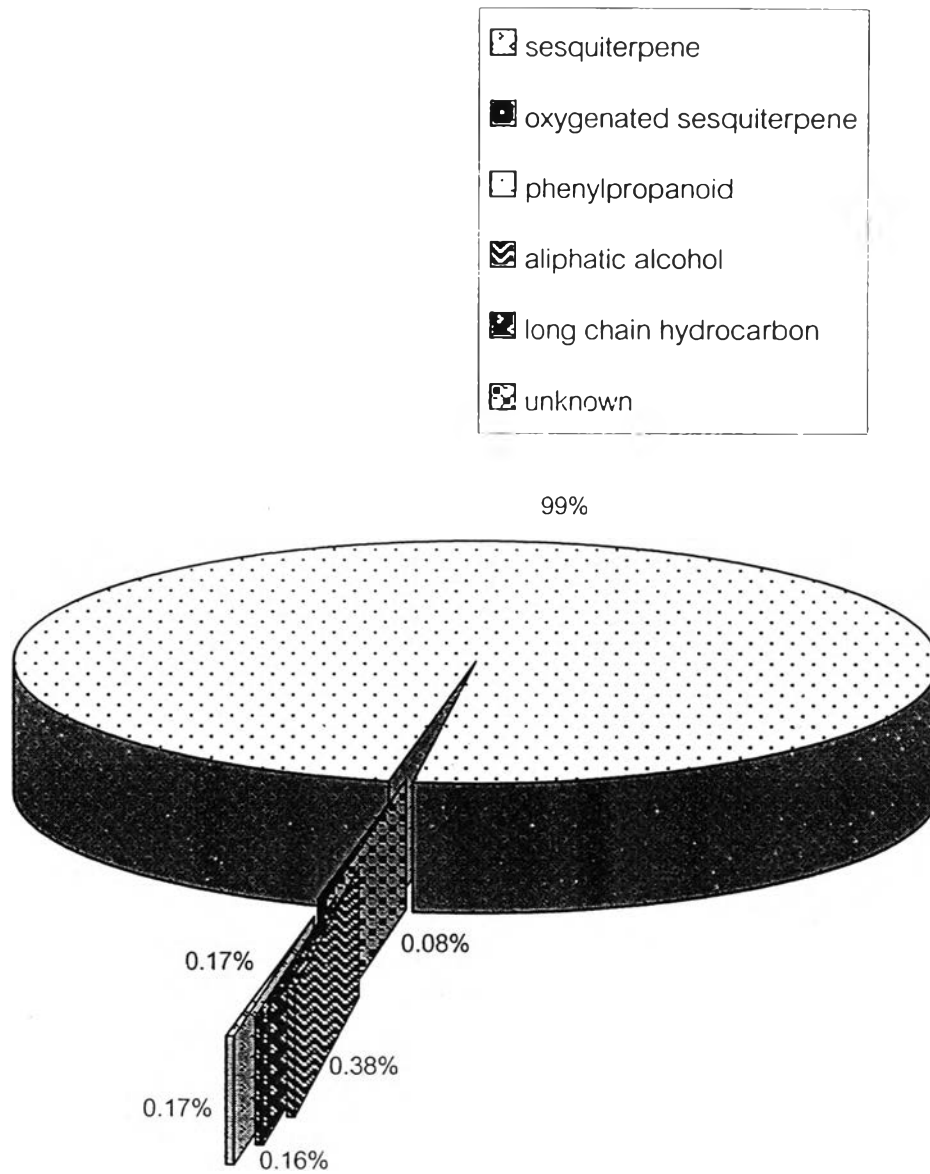


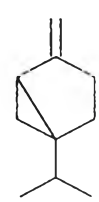
Figure 11 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum porrectum* Kosterm bark

4.1.6. Essential Oil Composition of *Litsea cubeba* Pers.

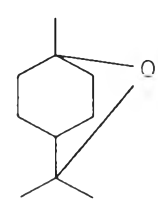
The yield of the essential oil isolated from *Litsea cubeba* leaves was found to be 0.48% (v/w) of the fresh weight. GC-MS analysis of the essential oil showed that there were at least 26 components (Fig. 12). These peaks were identified as 15 monoterpenes, 7 oxygenated monoterpenes, 1 sesquiterpene and 1 oxygenated sesquiterpene (table 8). Among these, sabinene (42.72%) appeared to be the major component, followed by *1,8*-cineole (18.33%) and β-phellandrene (6.16%).

These major components belong to the monoterpenoid group, while accounts for 63.02% of the essential oil. Oxygenated monoterpenes, sesquiterpene and oxygenated sesquiterpene were present in lesser amount, at 36.01, 0.06 and 0.50%, respectively (Fig. 13).

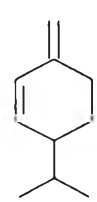
In terms of structure, sabinene belongs to the thujane group of monoterpenoids whereas both *1,8*-cineol and β-phellandrene belong to the menthane group.



sabinene
(thujane)



1,8-cineol
(menthane)



β-phellandrene
(menthane)

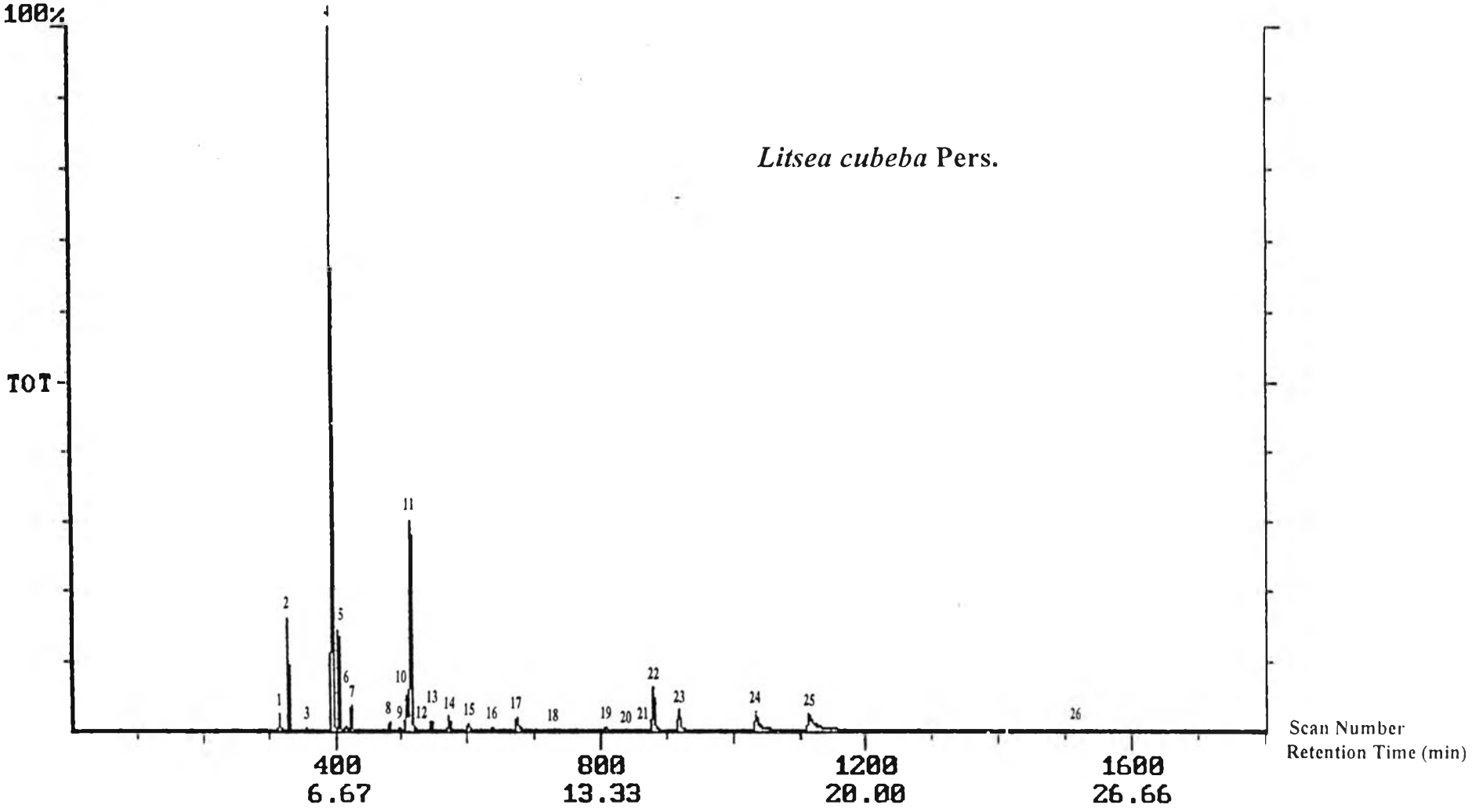


Figure 12 GC chromatogram of the essential oil from *Litsea cubeba* Per. leaves

Table 8 Essential oil composition of *Litsea cubeba* leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	0.82
2	tricyclene	4.98	5.39
3	camphene	5.48	0.11
4	sabinene	6.08	42.72
5	β-phellandrene	6.23	6.16
7	β-pinene	6.54	1.67
8	δ-*2*-carene	7.44	0.53
9	*o*-cymene	7.59	0.21
10	limonene	7.88	2.56
12	*(Z)*-β-ocimene	8.13	0.18
13	*(E)*-β-ocimene	8.48	0.67
14	γ-terpinene	8.91	1.08
15	*trans*-sabinene hydrate	9.61	0.70
16	terpinolene	9.93	0.22
	Oxygenated monoterpene		
11	*1,8*-cineole	7.98	18.33
17	linalool acetate	10.81	1.75
19	citronellal	12.76	0.47
22	terpin-*4-ol*	14.16	4.24
23	α-terpineol	14.98	2.56
24	*cis*-carveol	17.23	3.49
25	geranial	18.77	5.17
	Sesquiterpene		
26	*(E)*-caryophyllene	24.33	0.06
	Oxygenated sesquiterpene		
6	*6*-methyl-*5*-hepten-*2-one*	6.37	0.50
	Miscellaneous		
18	unknown	12.25	0.13
20	unknown	13.84	0.10
21	unknown	14.23	0.17

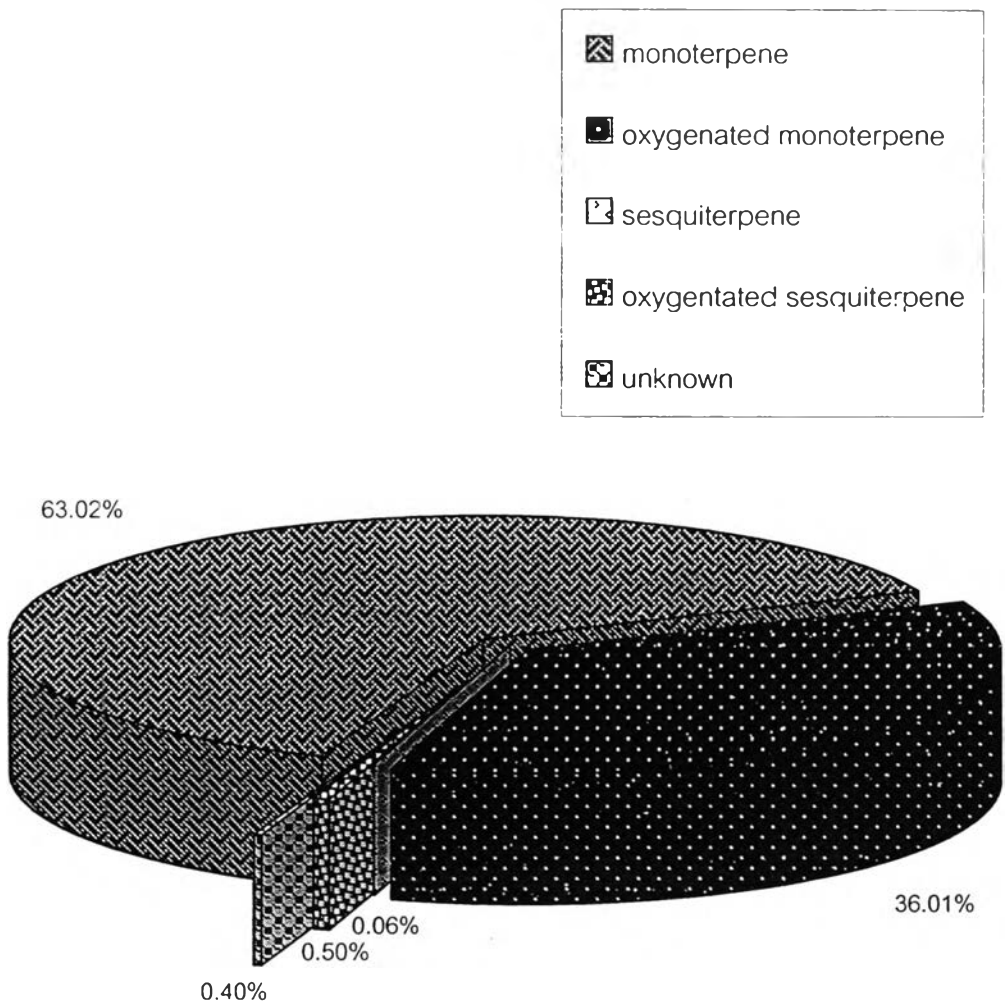


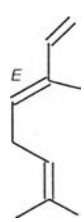
Figure 13 The percentage of various terpenoid groups found in the essential oil of *Litsea cubeba* Pers. leaves

4.1.7. Essential Oil Composition of *Litsea glutinosa* C.B. Robinson.

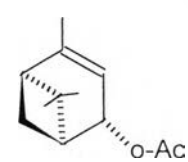
The essential oil from the fruits of *Litsea glutinosa* was isolated by hydrodistillation and examined by GC/MS. The fruits yielded oil at 0.37% (v/w) of the fresh weight. Thirty compounds were identified (Fig. 14), of which *(E)*-β-ocimene (55.18%), *cis*-verbenyl acetate (5.38%) and *9-epi-(E)*-caryophyllene (5.26%), were the major constituents. Ten monoterpenes, seven oxygenated monoterpenes, four sesquiterpene and an oxygenated sesquiterpenes were identified (Table 9).

The monoterpene was found to be the major terpenoid group, accounting for 69.69% of essential oil. Oxygenated monoterpenes, sesquiterpenes and oxygenated sesquiterpene were present in lesser amount, at 10.85, 6.99 and 2.51%, respectively (Fig. 15).

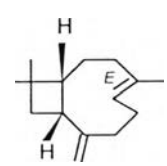
Structurally, the major component, *(E)*-β-ocimene, belongs to the acyclic monoterpenoid group, whereas *cis*-verbenyl acetate belong to the oxygenated monoterpenoid group of pinanes and *9-epi-(E)*-caryophyllene belongs to the sesquiterpenoid group of caryophyllane.



(E)-β-ocimene
(acyclic monoterpenoid)



cis-verbenyl acetate
(pinane)



9-epi-(E)-caryophyllene
(caryophyllane)

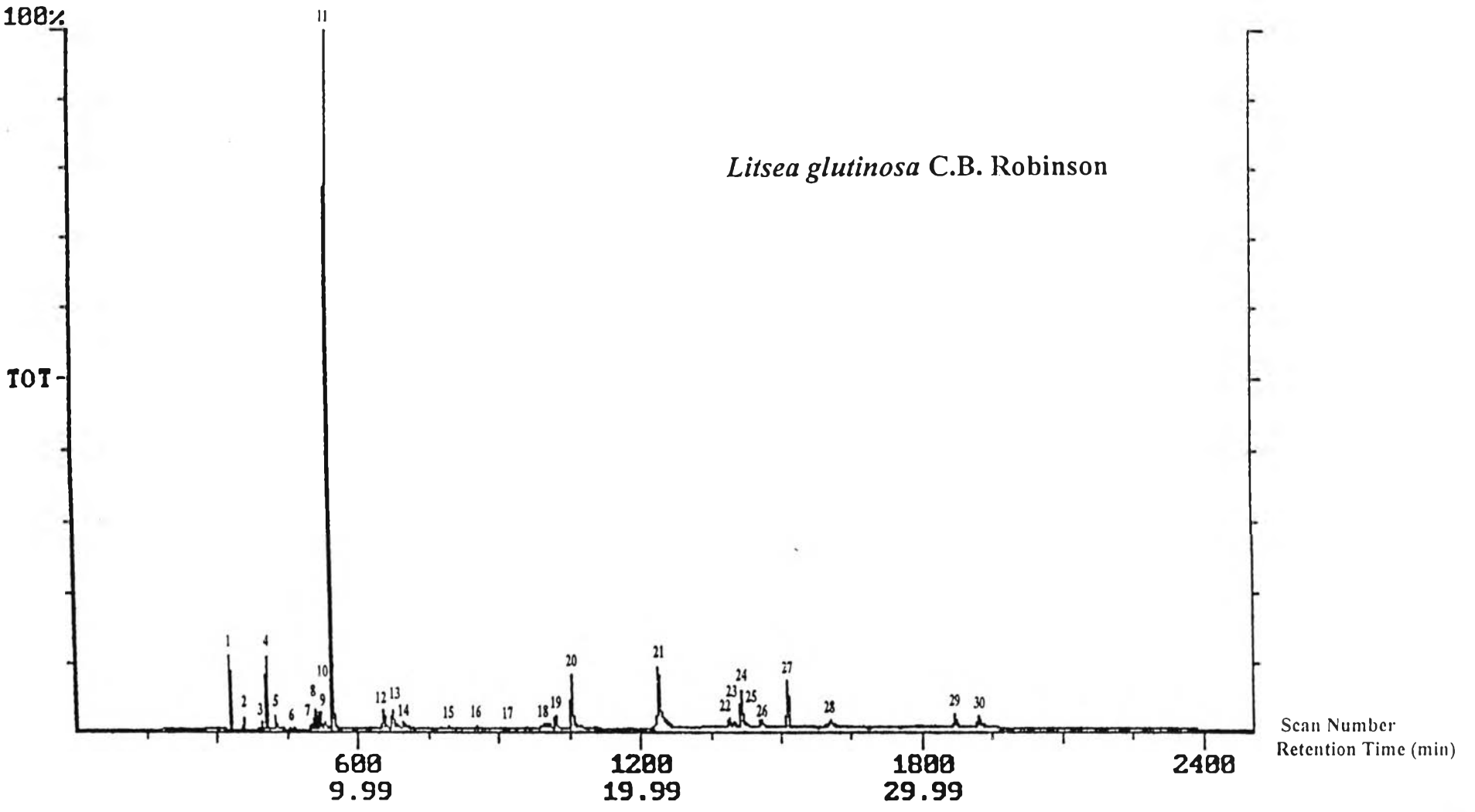


Figure 14 GC chromatogram of the essential oil from *Litsea glutinosa* C.B. Robinson fruits

Table 9 Essential oil composition of *Litsea glutinosa* fruits

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	tricyclene	4.98	3.83
2	camphene	5.48	0.62
3	sabinene	6.08	0.56
4	β-pinene	6.54	4.02
5	δ-*3*-carene	7.16	0.45
6	δ-*2*-carene	7.44	0.12
7	*o*-cymene	7.59	0.30
8	limenene	7.88	1.21
10	*(Z)*-β-ocimene	8.13	1.03
11	*(E)*-β-ocimene	8.48	46.13
	Oxygenated monoterpene		
9	*1,8*-cineole	7.98	1.02
12	verbenone	10.35	2.13
15	camphor	12.54	0.19
16	terpin-*4*-ol	14.16	0.12
17	α-terpineol	14.98	0.12
24	*cis*-verbenyl acetate	23.01	4.50
26	cumin aldehyde	24.20	0.98
	Sesquiterpene		
23	α-copaene	22.38	0.47
25	elemene	23.09	0.19
27	*9-epi*-caryophyllene	25.07	4.40
28	*(Z)*-α-bisabolene	25.44	0.79
	Oxygenated sesquiterpene		
29	caryophyllene oxide	31.32	2.10
	Miscellaneous		
13	unknown	11.26	2.24
14	unknown	11.61	1.25
18	unknown	15.54	0.76
19	unknown	17.60	1.30
20	unknown	19.83	6.35
21	unknown	20.02	10.05
22	unknown	21.65	1.09
30	unknown	31.89	1.67

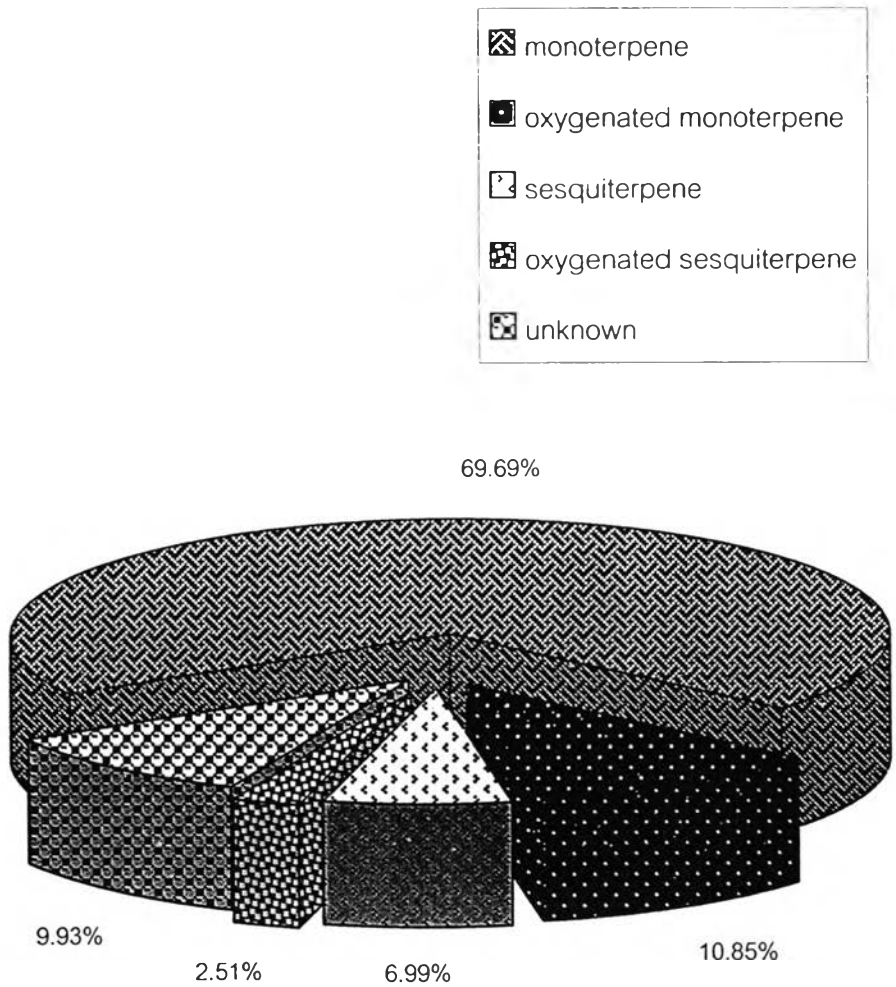


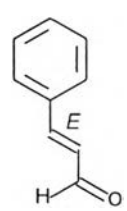
Figure 15 The percentage of various terpenoid groups found in the essential oil of *Litsea glutinosa* C.B.Robinson fruits

4.1.8. Essential Oil Composition of *Litsea petiolata* Hook.f. leaves

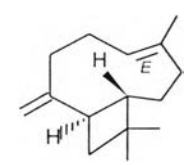
The yield of essential oil hydrodistilled from *Litsea petiolata* leaves was found to be 2.1% (v/w) of the fresh weight. Analysis of the essential oil by GC/MS showed 15 peaks (Fig. 16). These peaks were identified as 3 monoterpenes, 4 sesquiterpenes and 3 non-terpenoid components (Table 10). Among these, the phenylpropanoid *(E)*-cinnamaldehyde (57.77%) appeared to be the major component, followed by *(Z)*-isosafrole (35.36%) and *(E)*-caryophyllene (1.44%).

The phenylpropanes was found to be the major group of components of components, while accounting for 93.13 % of the essential oil, while sesquiterpenes and monoterpenes were present in a lesser amount at 3.04 and 0.46%, respectively (Fig.17).

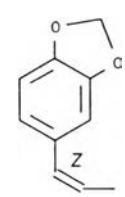
Structurally, the major component, *(E)*-cinnamaldehyde and *(Z)*-isosafrole, belong to the phenylpropanoid compound respectively, while *(E)*-caryophyllene belongs to the sesquiterpenoid group of caryophilane.



(E)-cinnamaldehyde
(phenylpropane)



(E)-caryophyllene
(*caryophilane*)



(Z)-isosafrole
(phenylpropane)

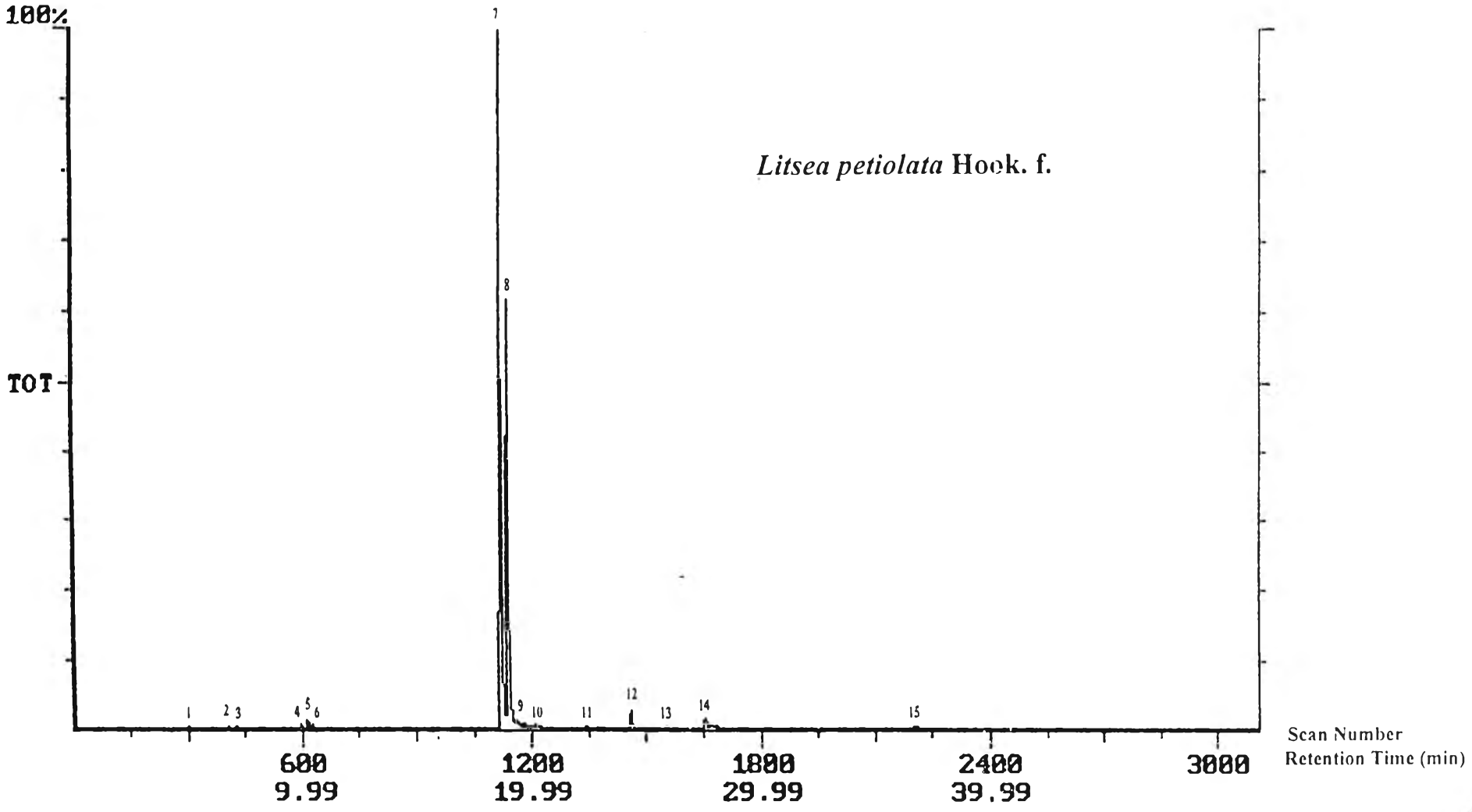


Figure 16 GC chromatogram of the essential oil from *Litsea petiolata* Hook. f. leaves

Table 10 Essential oil composition of *Litsea petiolata* Hook.f. leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-pinene	5.03	0.05
3	phellandrene	6.23	0.18
4	terpinolene	9.93	0.23
	Sesquiterpene		
11	α-copaene	22.38	0.16
12	*(E)*-caryophyllene	24.33	1.44
13	α-humulene	25.89	0.10
14	bicyclogermacrene	27.59	1.34
	Phenylpropanoid		
7	*(E)*-cinnamaldehyde	18.68	57.77
8	*(Z)*-isosafrole	18.99	35.36
	Long chain hydrocarbon		
2	*n*-decane	6.83	0.08
16	*2*-nonanone	10.23	0.63
17	*n*-heneicosane	10.44	0.25
	Miscellaneous		
9	unknown	19.34	1.42
10	unknown	19.66	0.73
15	unknown	36.76	0.21

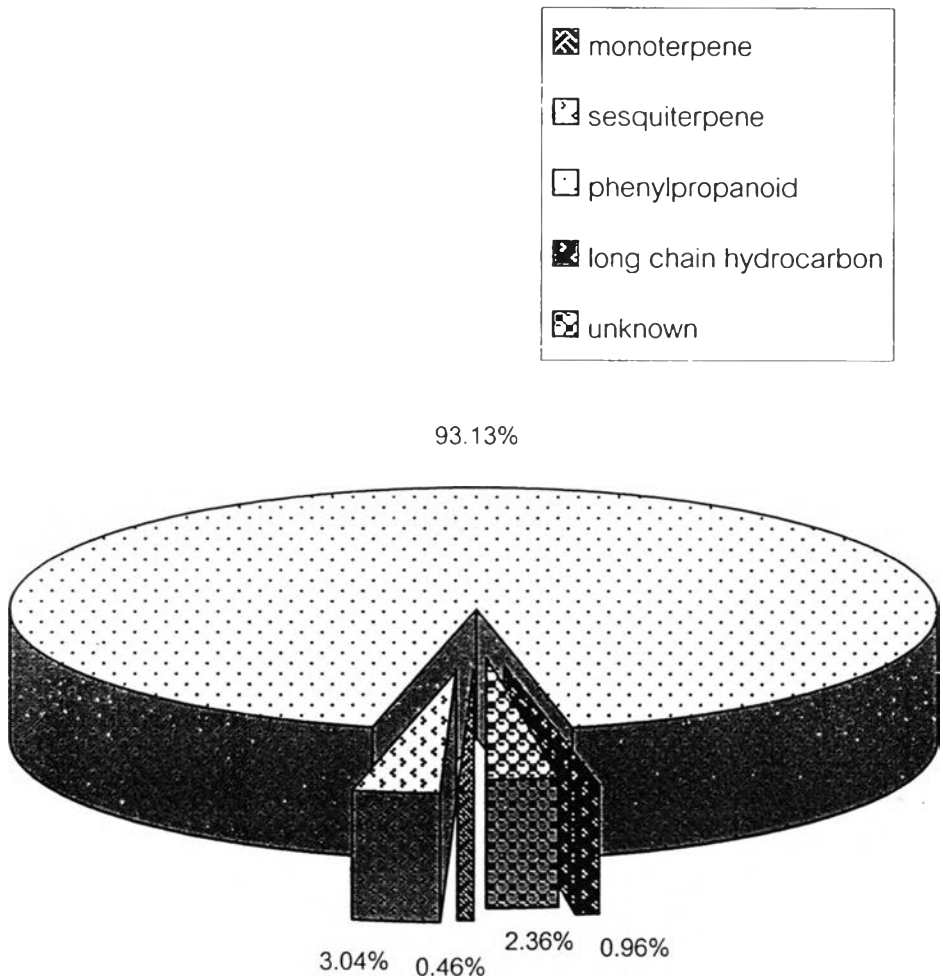


Figure 17 The percentage of various terpenoid groups found in the essential oil of *Litsea petiolata* Hook.f. leaves

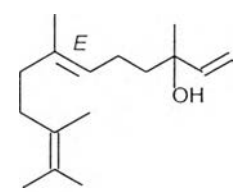
4.1.9. Essential Oil Composition of *Litsea petiolata* Hook.f. bark

The bark of *Litsea petiolata* was found to contain essental oil at 0.17% (v/w) of the fresh weight. GC/MS analysis of its essential oil, showed that the essential oil has at least 26 peaks in the GC chromatogram (Fig. 18). These peaks were identified as 6 monoterpenes, 2 oxygenated monoterpenes, 7 sesquiterpenes, 5 oxygenated sesquiterpenes and 3 non-terpenoid components (Table 11). Among these, *2*-methyl-undecanal (39.62%) appeared to be the major component, followed by *(E)*-nerolidol (22.67%) and *1,4*-cineole (10.28%).

In terms of relative amount, the aliphatic alcohol was found to be the major group, accounting for 39.62% of the essential oil. Oxygenated sesquiterpenes and oxygenated monoterpenes were present in lesser amount, at 24.86 and 11.51%, respectively (Fig. 19).

In terms of structure type, the major component, *2*-methyl-undacanal, is an aliphatic alcohol, while *(E)*-nerolidol belongs to the oxygenated sesquiterpene group of simple farnesane and *1,4*-cineole belongs to the oxygenated monoterpene group of menthane, respectively.

1,4-cineole
(menthane)



(E)-nerolidol
(simple farnesane)

$CH_3(CH_2)_8CHCH_3COH$

2-methyl-undacanal
(aliphatic alcohol)

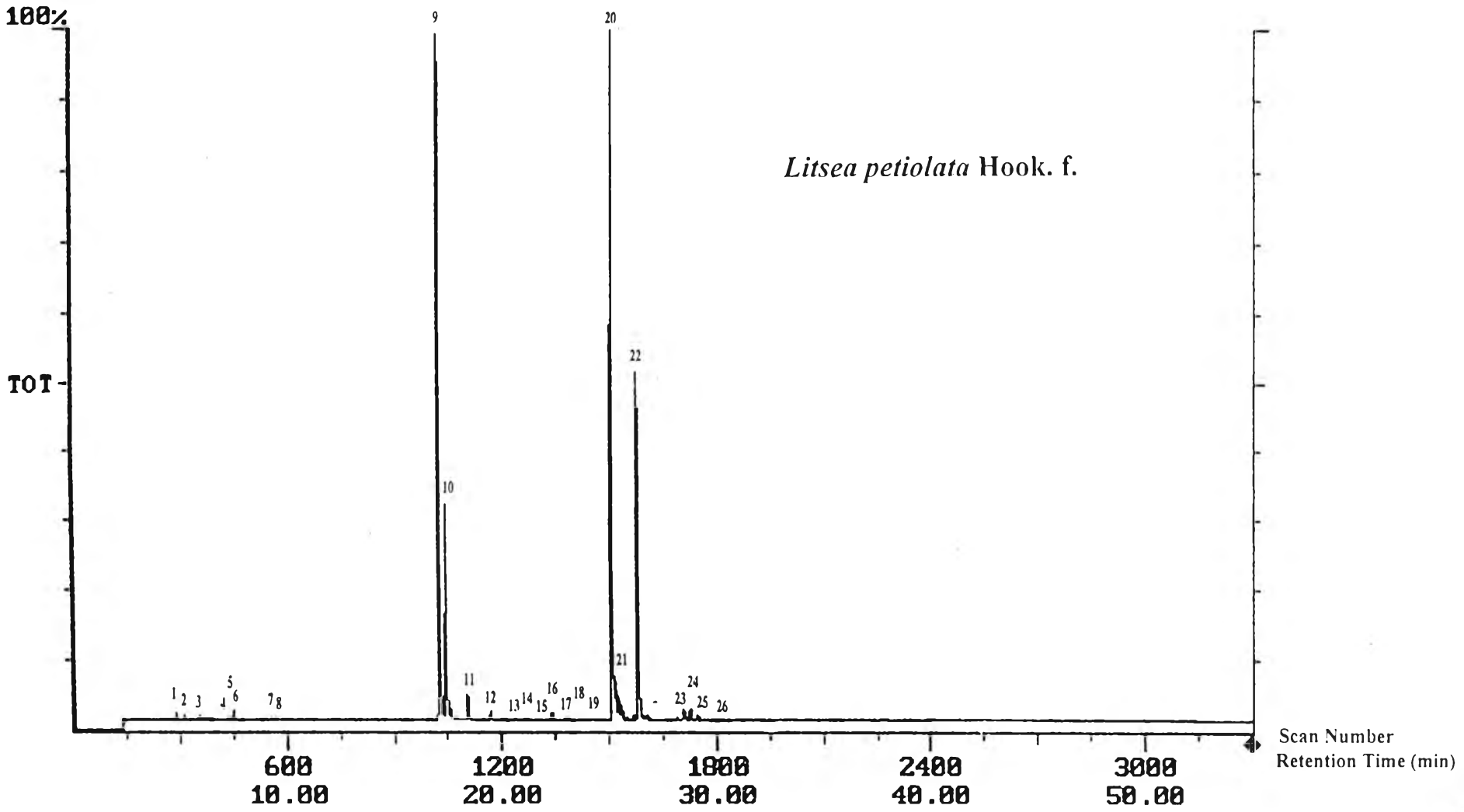


Figure 18 GC chromatogram of the essential oil from *Litsea petiolata* Hook. f. bark

Table 11 Essential oil composition of *Litsea petiolata* Hook.f. bark

Number of peak	Compound	Retention time (min)	%Area
	Monoterpene		
1	tricyclene	4.98	1.09
2	camphene	5.48	1.37
3	β-phellandrene	6.23	0.86
4	*o*-cymene	7.59	0.80
5	limonene	7.88	0.67
7	α-terpinene	9.76	0.06
	Oxygenated monoterpene		
6	*1,8*-cineole	7.98	1.23
9	*1,4*-cineole	10.27	10.28
	Sesquiterpene		
12	α-copaene	22.38	0.12
14	germacrene D	22.93	0.17
15	*cis*-β-guaiene	23.71	0.07
16	*9-epi-(E)*-caryophyllene	25.07	0.53
18	longifolene	25.11	0.25
19	α-humulene	25.89	0.73
21	bicyclogermacrene	27.59	3.06
	Oxygenated sesquiterpene		
22	*(E)*-nerolidol	30.66	22.67
23	spathulenol	31.29	1.03
24	globulol	31.47	0.84
25	β-eudesmol acetate	31.63	0.23
26	cubenol	33.38	0.09
	Aliphatic alcohol		
20	*2*-methyl-undecanal	26.92	39.62
	Long chain hydrocarbon		
8	*2*-nonanone	10.23	0.09
10	*2*-undecanone	18.50	11.84
	Miscellaneous		
11	unknown	18.80	1.97
13	unknown	22.56	0.17
17	unknown	25.09	0.14

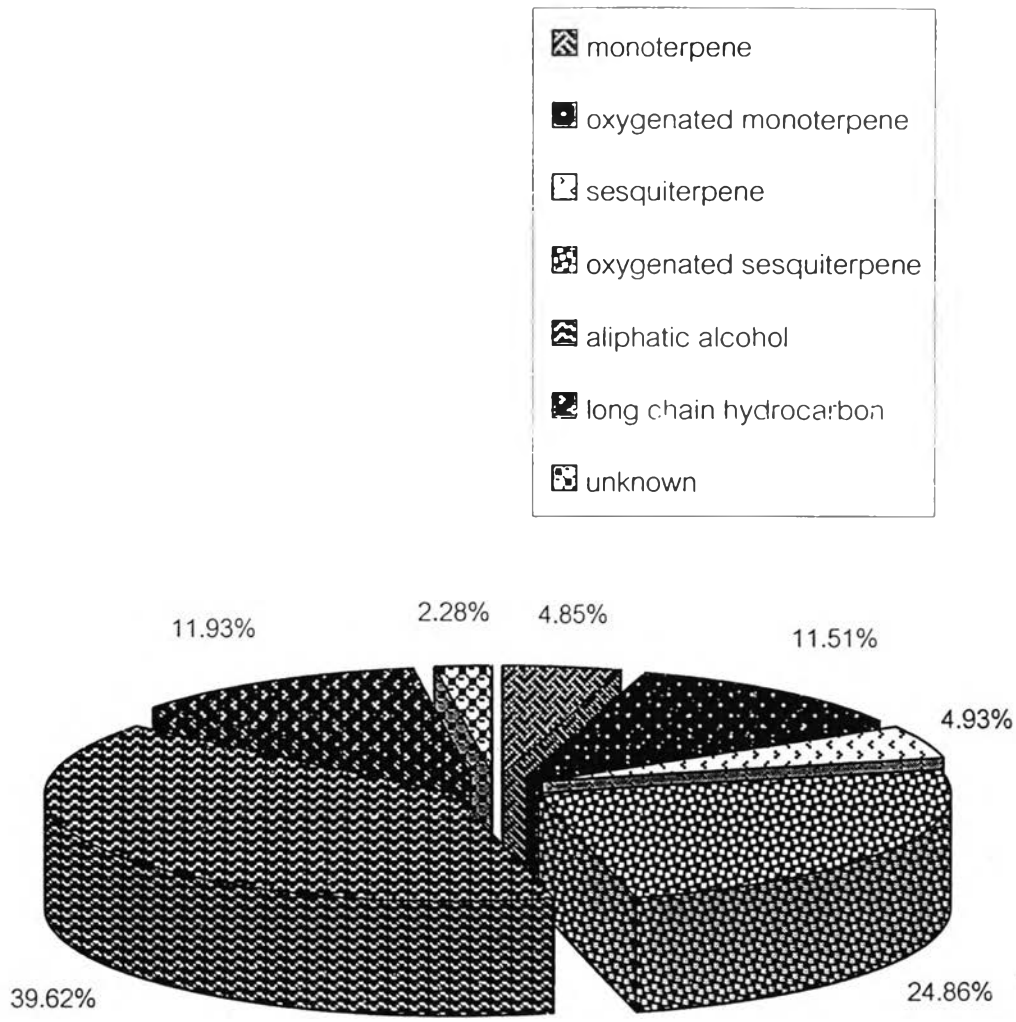


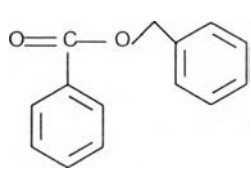
Figure 19 The percentage of various terpenoid groups found in the essential oil of *Litsea petiolata* Hook.f. bark

4.1.10. Essential Oil Composition of *Cinnamomum* sp.1

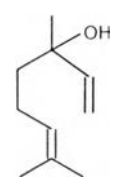
The yield of essential oil hydrodistilled from *Cinnamomum* sp1. leaves was found to be have 0.19 % (v/w) of the fresh weight. Analysis of the essential oil by GC/MS showed 50 peaks separated (Fig. 20) identified as 11 monoterpenes, 8 oxygenated monoterpenes, 8 sesquiterpenes, 9 oxygenated sesquiterpenes and 14 non-terpenoid components (Table 12). Among these, benzyl benzoate (27.38 %) was found to be the major component, followed by linalool (19.63 %) and α-pinene (7.95 %).

Quantitatively, the benzyl benzoated appeared to be the major group, accounting for 27.38 % of the essential oil. Oxygenated monoterpene, monoterpenne, phenyl propane, oxygenated sesquiterpene and sesquiterpene was present in a lesser amount, at 29.22 %, 19.66%, 8.08%, 8% and 4.03%, respectively (Fig. 21).

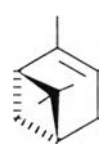
Structurally, the major component, benzyl benzoate, belongs to the benzenoid group of compounds, whereas linalool belongs to the oxygenated acyclic monoterpenoid group and α-pinene belongs to the monoterpenoid group of pinane.



benzyl benzoate
(benzoid)



linalool
(acyclic monoterpenoid)



α-pinene
(pinane)

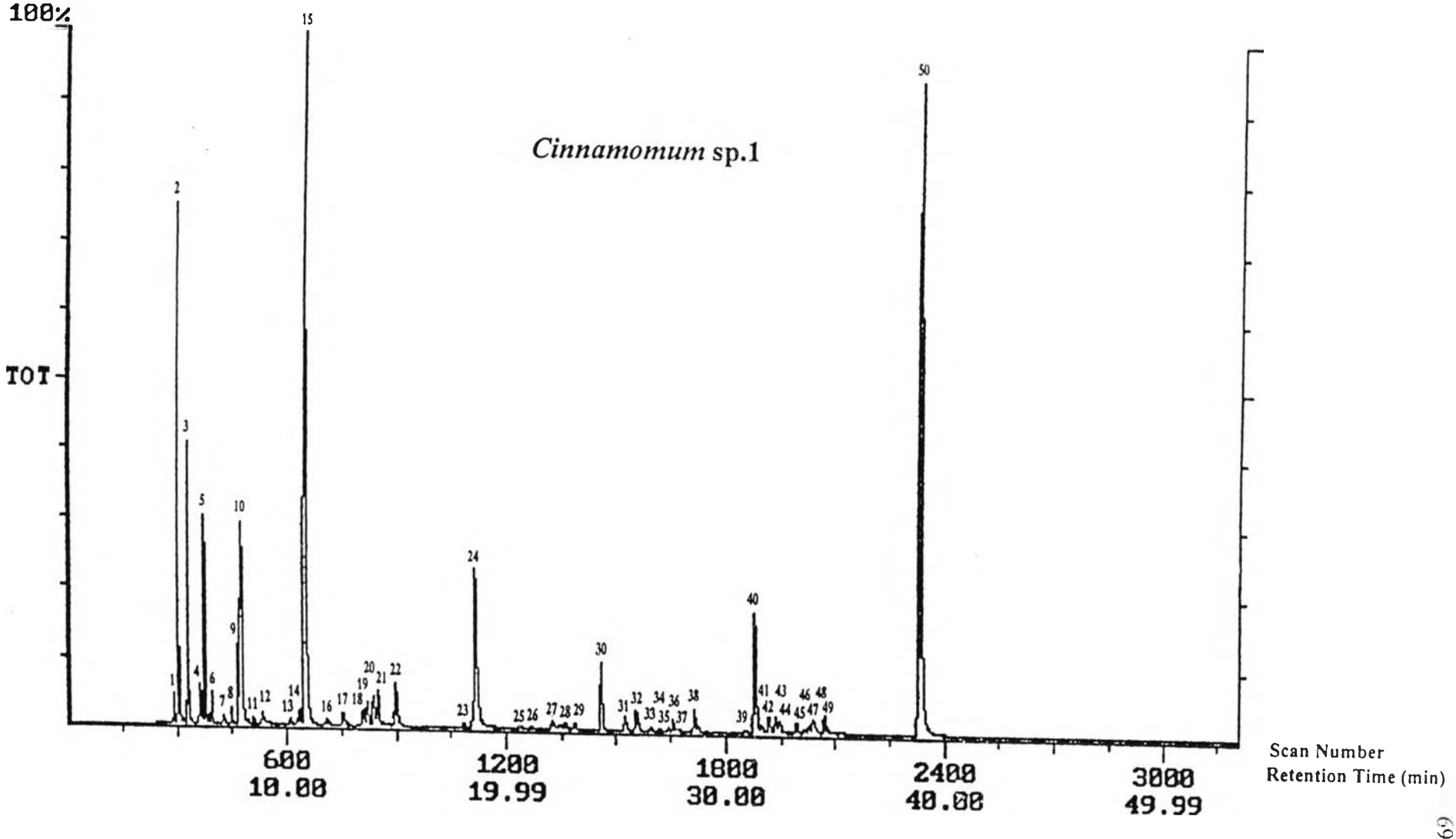


Figure 20 GC chromatogram of the essential oil from *Cinnamomum* sp.1 leaves

Table 12 Essential oil composition of *Cinnamomum* sp.1 leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	0.47
2	α-pinene	5.03	7.95
3	camphene	5.48	4.59
5	β-phellandrene	6.23	3.54
6	β-pinene	6.54	0.55
7	α-phellandrene	7.11	0.21
8	δ-2-carene	7.44	0.26
9	verbenene	7.78	1.45
11	*(E)*-β-ocimene	8.48	0.13
12	γ-terpinene	8.91	0.44
13	terpinolene	9.93	0.07
	Oxygenated monoterpene		
10	*trans*-sabinene hydrate acetate	7.94	4.83
14	*trans*-linalool oxide	10.13	0.15
15	linalool	10.81	19.63
16	*trans-para*-menth-*2*-en-*1*-ol	11.81	0.18
17	camphor	12.54	0.44
20	isoborneol	13.93	1.17
21	terpin-*4*-ol	14.16	1.21
22	α-terpineol	14.98	1.61
	Sesquiterpene		
26	β-cubebene	21.13	0.03
28	α-copaene	22.38	0.24
30	*(E)*-caryophyllene	24.33	1.87
32	α-humulene	25.89	0.79
33	δ-cadinene	26.58	0.09
34	γ-muurolene	26.99	0.04
36	bicyclogermacrene	27.59	0.38
38	trans-β-guaiene	28.59	0.59
	Oxygenated sesquiterpene		
37	*epi*-cubebol	27.84	0.10
40	spathulenol	31.29	4.29
41	α-eudesmol acetate	31.59	0.39
42	hinesol acetate	31.96	0.55
43	longiborneol acetate	32.26	0.46
44	humulene epoxide II	32.44	0.35
45	*1-epi*-cubebol	33.19	0.33
48	*epi*-α-muurolol	33.96	0.85

Table 12 (continued)

Peak No	Compound	Retention time (min)	%Area
49	α-cadinol	34.49	0.68
	Phenylpropanoid		
18	*(Z)*-cinnamyl alcohol	13.46	0.51
24	*(E)*-cinnamaldehyde	18.61	7.16
27	*(Z)*-isoeugenol	22.10	0.41
	Benzenoid		
4	bebzaldehyde	6.01	1.28
19	ethyl benzoate	13.66	0.75
23	*n*-pentyl benzoate	18.04	0.11
29	*n*-hexyl benzoate	22.66	0.27
31	*(Z)*-methyl butyl benzoate	25.41	0.40
50	benzyl benzoate	38.86	27.38
	Miscellaneous		
25	unknown	20.63	0.07
35	unknown	27.41	0.08
39	unknown	30.88	0.11
46	unknown	33.59	0.17
47	unknown	33.78	0.26

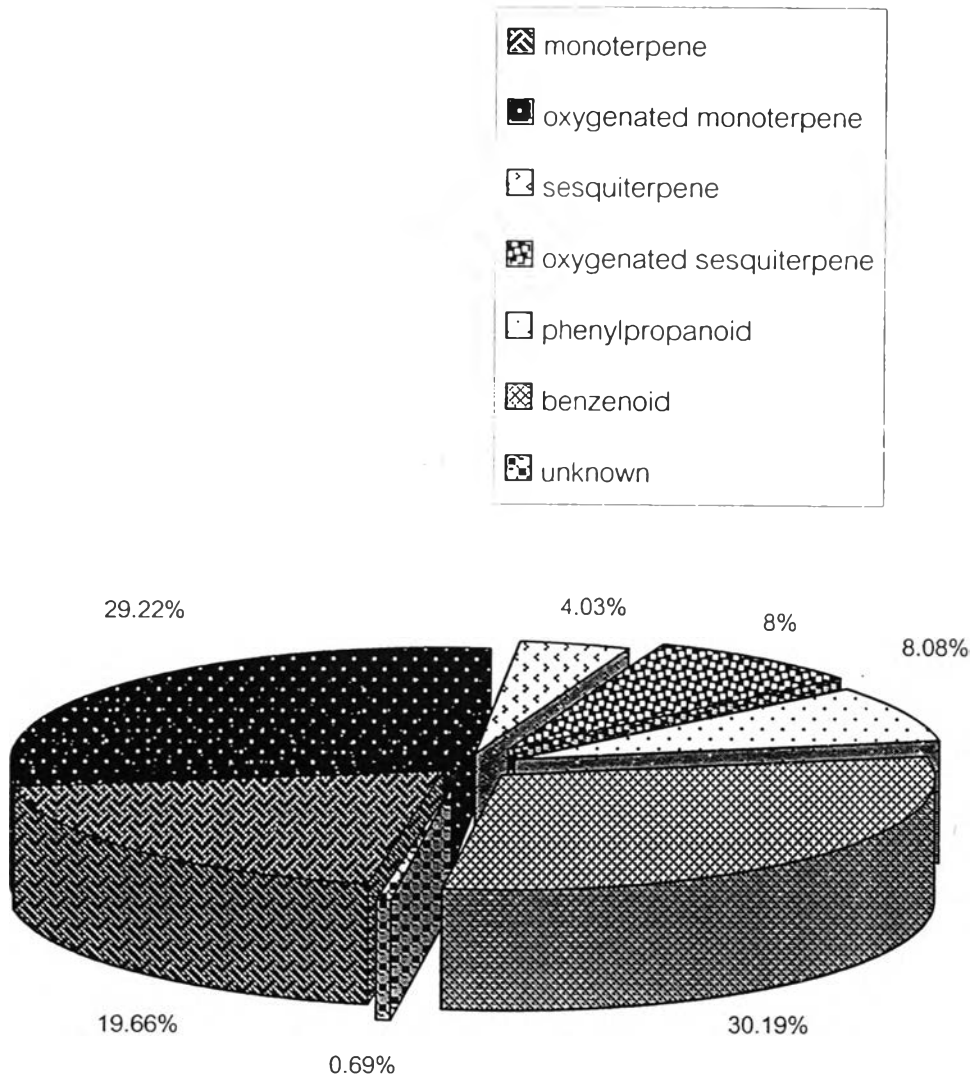


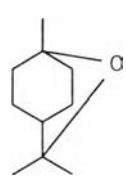
Figure 21 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum* sp.1 leaves

4.1.11. Essential Oil Composition of *Cinnamomum* sp. 2

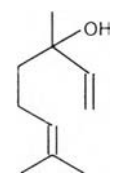
The yield of essential oil from *Cinnamomum* sp. 2 leaves was found to be 0.32% (v/w) of the fresh weight. Analysis of the essential oil by GC/MS showed that there were at least 28 components (Fig. 22). These components were identified as 11 monoterpenes, 5 oxygenated monoterpenes, 3 sesquiterpenes, 1 oxygenated sesquiterpene, 3 phenylpropanes and 2 non-terpenoid components. (Table 13). Among these *(Z)*-isoeugenol (89.59%) appeared to be the major component.

The phenylpropanes was found to be the major group, accounting for 90.29% of the essential oil (Fig. 23). Monoterpenes and oxygenated monoterpenes were present in lesser amount at 4.03 and 3.65%, respectively.

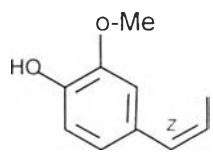
Structurally, the major components, *(Z)*-isoeugenol belong to the phenylpropanoid group, while linalool and *1,8*-cineole belong to the oxygenated monoterpene group of acyclic monoterpenoid and menthane, respectively.



1,8-cineole
(menthane)



linalool
(acyclic monoterpenoid)



(Z)-isoeugenol
(phenylpropanoid)

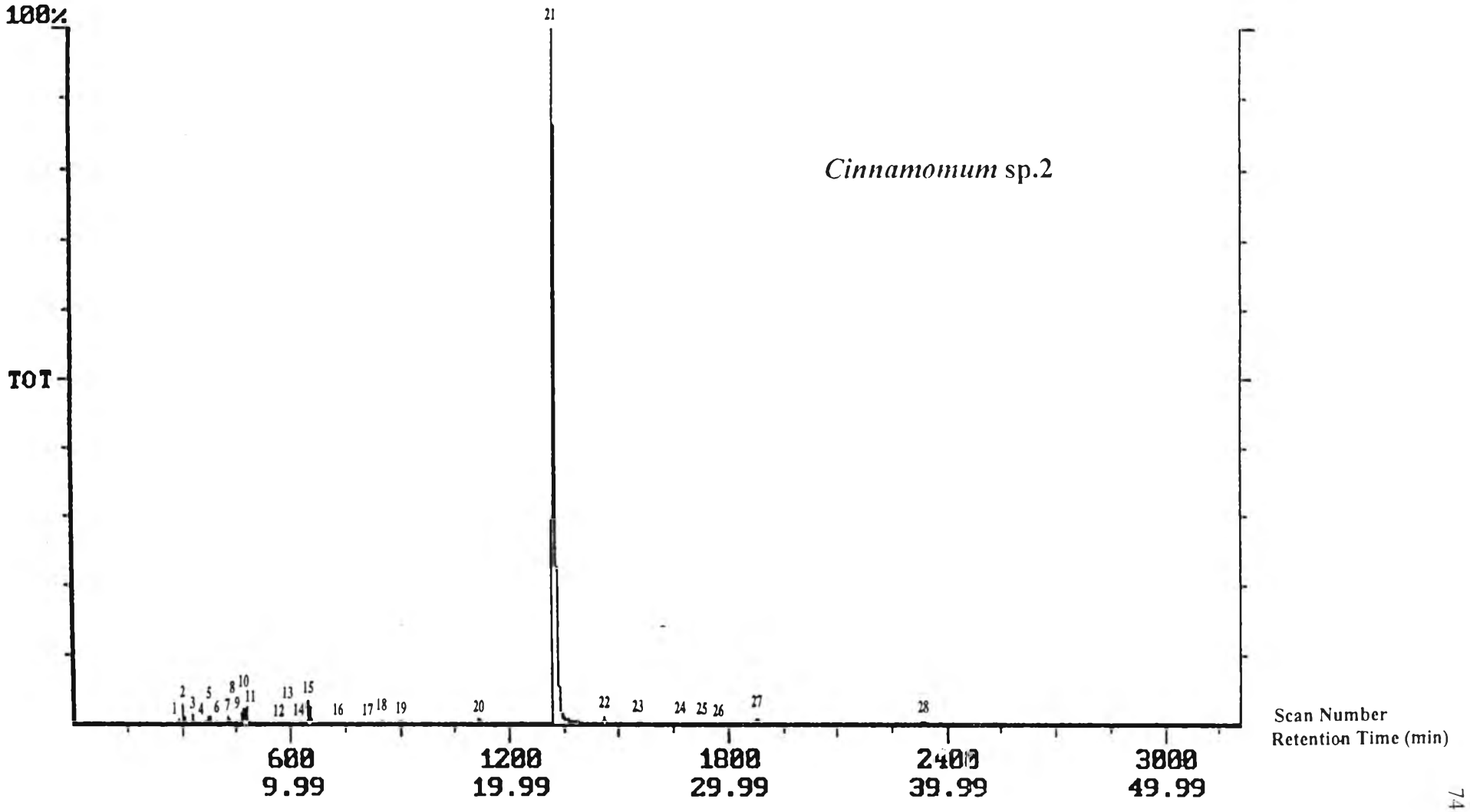


Figure 22 GC chromatogram of the essential oil from *Cinnamomum* sp.2 leaves

Table 13 Essential oil composition of *Cinnamomum* sp.2 leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	0.15
2	α-pinene	5.03	0.94
3	camphene	5.48	0.44
5	β-phellandrene	6.23	0.39
6	β-pinene	6.54	0.07
7	*α*-phellandrene	7.11	0.33
8	*2*-δ-carene	7.44	0.14
9	verbenene	7.78	0.85
10	limonene	7.88	0.44
12	γ-terpinene	8.91	0.15
13	terpinolene	9.93	0.13
	Oxygenated monoterpene		
11	*1,8*-cineole	7.98	1.16
15	linalool	10.81	2.06
17	isoborneol	13.93	0.05
18	terpin-*4*-ol	14.16	0.18
19	α-terpineol	14.98	0.20
	Sesquiterpene		
22	*(E)*-caryophyllene	24.33	0.50
24	bicyclogermacrene	27.59	0.05
25	*trans*-β-guaiene	28.59	0.03
	Oxygenated sesquiterpene		
27	spathulenol	31.29	0.50
	Phenylpropanoid		
20	*(E)*-cinnamaldehyde	18.61	0.61
21	*(Z)*-isoeugenol	22.10	89.59
26	eugenyl acetate	28.84	0.09
	Benzenoid		
28	benzyl benzoate	38.86	0.27
	Long chain hydrocarbon		
14	*n*-heneicocane	10.44	0.15
	Miscellaneous		
4	unknown	6.04	0.12
16	unknown	11.83	0.08
23	unknown	25.91	0.28

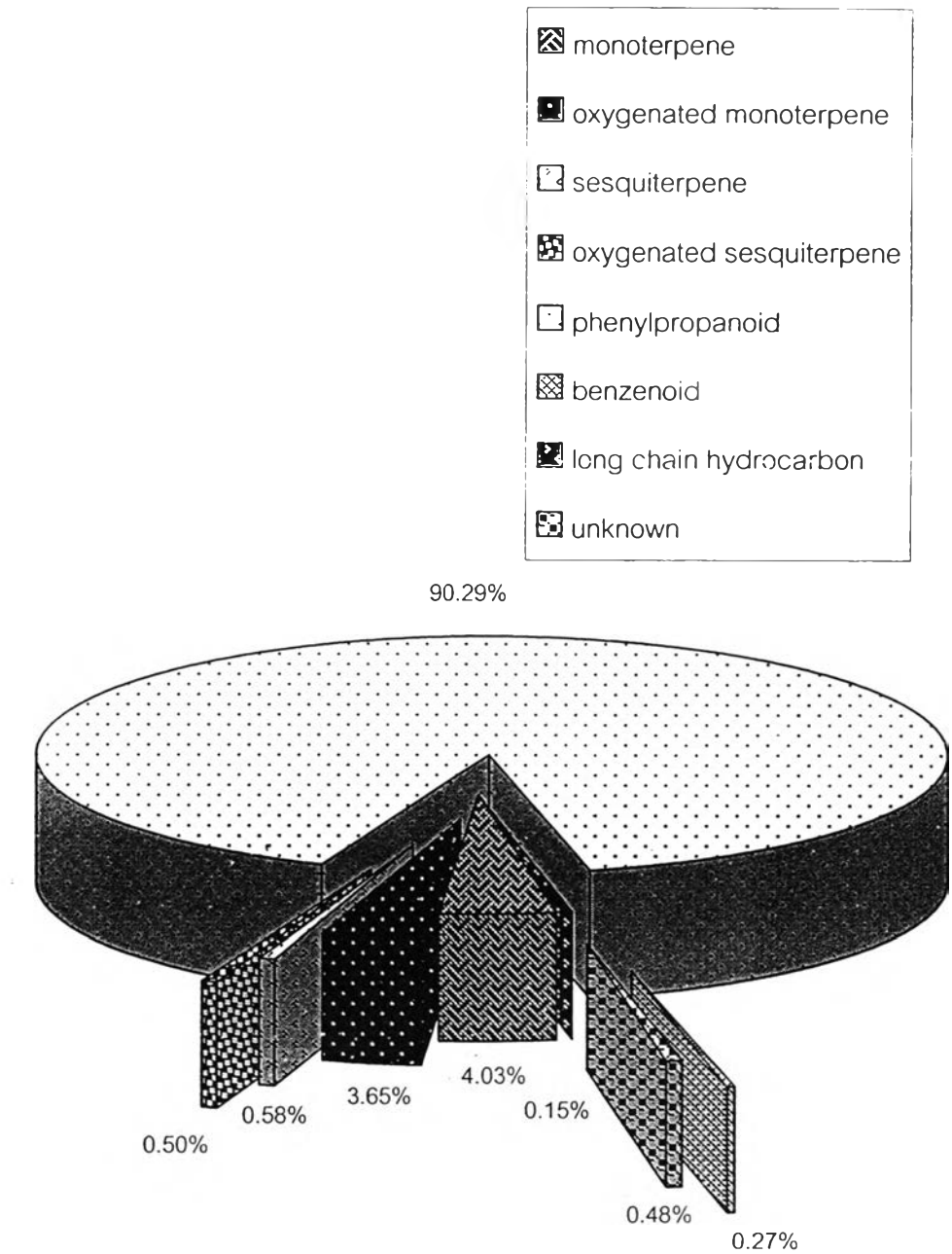


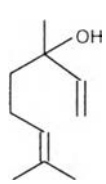
Figure 23 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum* sp.2 leaves

4.1.12. Essential Oil Composition of *Cinnamomum* sp. 3

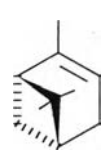
By hydrodistillation, the yield of the essential oil from *Cinnamomum* sp. 3 leaves was found to be 0.14% (v/w) of the fresh weight. GC/MS analysis of the essential oil showed 56 peaks (Fig. 24). These peaks were identified as 14 monoterpenes, 8 oxygenated monoterpenes, 17 sesquiterpenes, 7 oxygenated sesquiterpenes, 1 phenylpropane and 3 non-terpenoid components (Table 14). Among these, linalool (41.17%) was found to be the major component, followed by α-phellandrene (15.56%) and α-pinene (6.59%).

In terms of relative amount, oxygenated monoterpenes appeared to be the major terpenoid group, accounting for 45.34% of the essential oil (Fig. 25). Monoterpenes and sesquiterpenes were present in lesser content, at 39.58 and 6.94%, respectively.

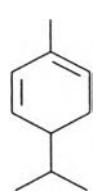
In terms of structure, the major components, linalool, belong to the oxygenated monoterpene group of acyclic monoterpenoids whereas α-pinene and α-phellandrene belong to the monoterpenoid group of pinane and menthane, respectively.



linalool
(acyclic monoterpenoid)



α-pinene
(pinane)



α-phellandrene
(menthane)

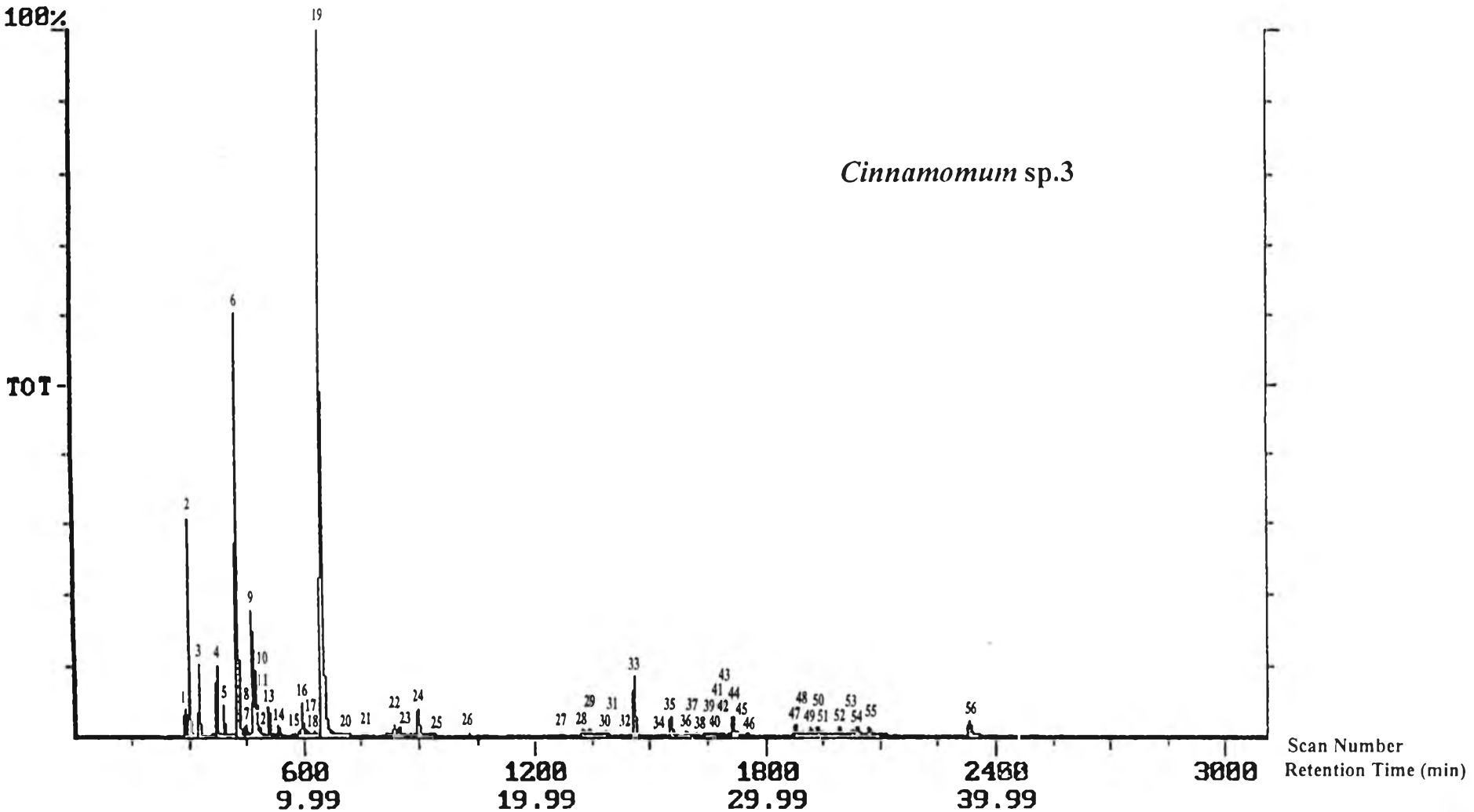


Figure 24 GC chromatogram of the essential oil from *Cinnamomum* sp.3 leaves

Table 14 Essential oil composition of *Cinnamomum* sp.3 leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	0.08
2	α-pinene	5.03	6.59
3	camphene	5.48	2.55
4	β-phellandrene	6.23	2.32
5	β-pinene	6.54	1.02
6	α-phellandrene	7.11	15.56
7	δ-*2*-carene	7.44	0.31
8	*o*-cymene	7.59	0.12
9	verbenene	7.78	4.73
10	limonene	7.88	2.78
13	*(E)*-β-ocimene	8.48	1.02
14	γ-terpinene	8.91	0.40
15	α-terpinene	9.76	0.09
16	terpinolene	9.93	1.29
	Oxygenated monoterpene		
12	terpin-*4-ol* acetate	8.09	0.26
17	*trans*-linalool oxide	10.13	0.26
19	linalool	10.81	41.17
20	*trans-para*-menth-*2*-en-*1*-ol	11.81	0.09
22	borneol	13.93	0.70
23	terpin-*4*-ol	14.16	0.55
24	α-terpineol	14.98	1.90
26	bornyl acetate	18.44	0.41
	Sesquiterpene		
27	β-cubebene	21.13	0.06
29	α-copaene	22.38	0.29
30	germacrene D	22.93	0.07
31	β-elemene	23.09	0.16
33	*(E)*-caryophyllene	24.33	3.20
34	*trans*-calamenene	25.58	0.07
35	α-humulene	25.89	1.00
36	δ-cadinene	26.58	0.18
37	γ-cadinene	26.75	0.05
38	γ-muurolene	26.99	0.11
39	isoledene	27.43	0.17
40	bicyclogermacrene	27.59	0.14
42	germacrene A	28.11	0.17
43	*cis*-muurola-*4(14),5*-diene	28.39	0.04
44	*trans*-β-guaiene	28.59	1.04

Table 14 (continued)

Peak No	Compound	Retention time (min)	%Area
45	α-cadinene	28.76	0.22
46	cadina-*1,4*-diene	29.19	0.07
	Oxygenated sesquiterpene		
41	*epi*-cubebol	27.84	0.12
47	spathulenol	31.29	0.61
48	α-eudesmol acetate	31.63	0.19
49	hinesol acetate	31.96	0.56
52	*1-epi*-cubenol	33.19	0.44
54	*epi*-α-muurolol	33.98	0.86
55	α-cadinol	34.49	0.56
	Phenylpropanoid		
28	*(Z)*-isoeugenol	22.10	0.48
	Benzenoid		
56	benzyl benzoate	38.86	1.33
	Aliphatic alcohol		
32	tetradecanal	24.16	0.09
	Long chain hydrocarbon		
18	*n*-heneicosane	10.44	0.12
	Miscellaneous		
11	unknown	7.96	1.47
21	unknown	12.61	0.10
25	unknown	15.36	0.09
50	unknown	32.28	0.55
51	unknown	32.44	0.14
52	unknown	33.79	0.26

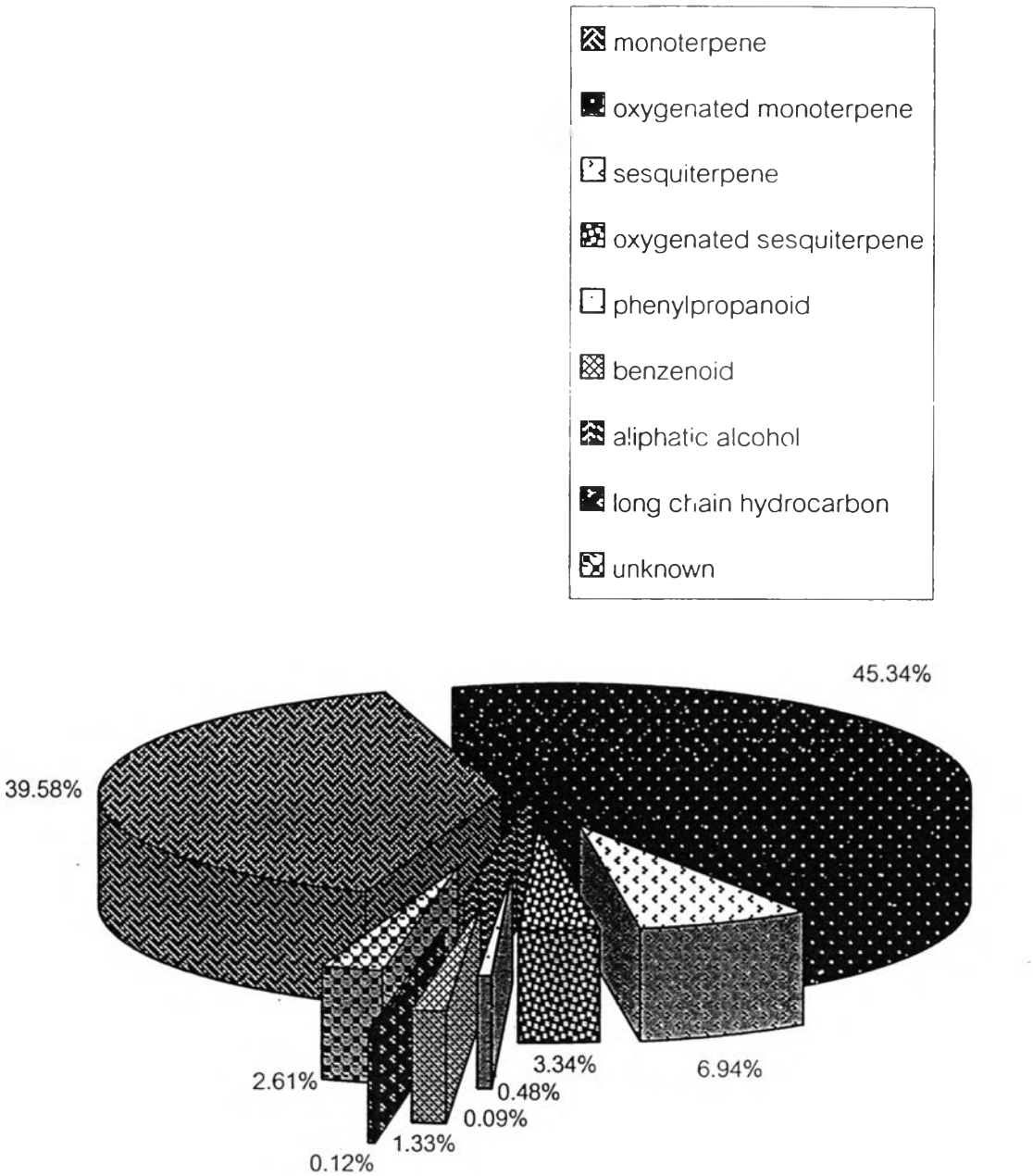


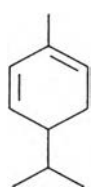
Figure 25 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum* sp.3 leaves

4.1.13. Essential Oil Composition of *Cinnamomum* sp. 4

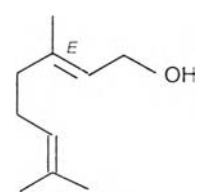
The yield of essential oil isolated from *Cinnamomum* sp.4 leaves was found to be 0.31% (v/w) of the fresh weight. Analysis of the essential oil by GC/MS showed 52 separated peaks (Fig. 26) identiied as 14 monoterpenes, 12 oxygenated monoterpenes, 15 sesquiterpenes, 4 oxygenated sesquiterpene, 1 phenylpropane and 2 non-terpenoid components (Table 15). Among these, α-pinene (15.07%) was found to be the major component followed by geraniol (11.28%) and α-phellandrene (9.15%).

In terms of relative amount, the monoterpenoids appeared to be the major group, accounting for 38.08% of the essential oil. Oxygenated monoterpenoids, phenylpropanoid, sesquiterpenoids and oxygenated sesquiterpenoids were present in lesser amount, at 33.95, 8.75, 8.33 and 3.88%, respectively (Fig. 27).

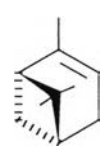
Structurally, α-pinene is a monoterpenoid of the pinane group, geraniol belongs to the oxygenated monoterpenoid group of acyclic monoterpenoid, while α-phellandrene belongs to the monoterpenoid group of menthane.



α-phellandrene
(menthane)



geraniol
(acyclic monoterpenoid)



α-pinene
(pinane)

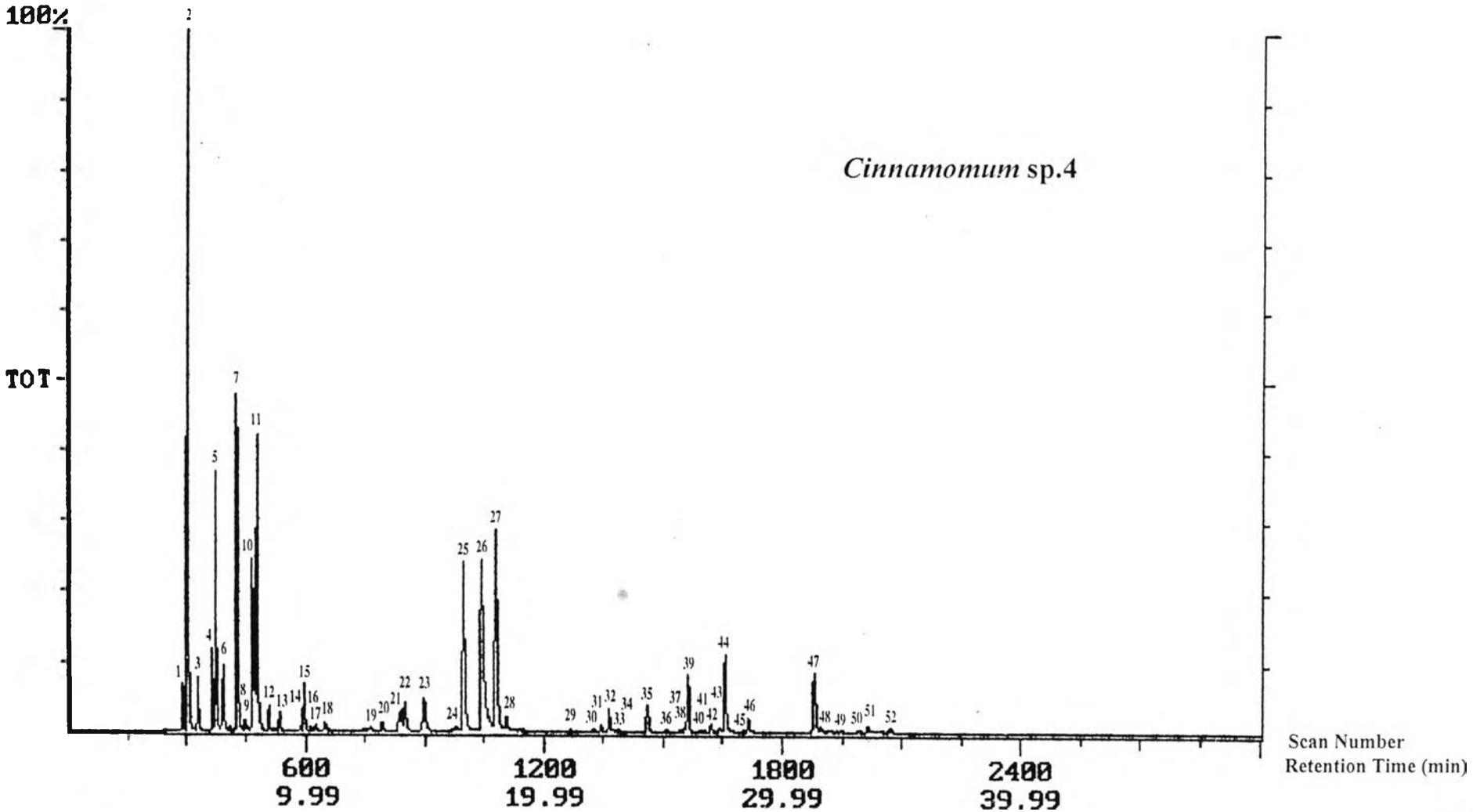


Figure 26 GC chromatogram of the essential oil from *Cinnamomum* sp.4 leaves

Table 15 Essential oil composition of *Cinnamomum* sp.4 leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	1.03
2	α-pinene	5.03	15.07
3	camphene	5.48	1.38
4	sabinene	6.08	1.91
5	β-phellandrene	6.23	6.28
6	β-pinene	6.54	1.88
7	α-phellandrene	7.11	9.15
8	δ-2-carene	7.44	0.24
9	*o*-cymene	7.59	0.11
10	verbenene	7.78	4.36
12	*(E)*-β-ocimene	8.48	0.62
13	γ-terpinene	8.91	0.51
14	α-terpinene	9.76	0.13
15	terpinolene	9.93	1.41
	Oxygenated monoterpene		
11	*1,8*-cineol	7.98	8.84
18	linalool	10.81	0.40
19	citronellal	12.76	0.15
20	*cis*-limonene oxide	13.19	0.33
21	borneol	13.99	1.19
22	terpin-*4*-ol	14.16	1.40
23	α-terpineol	14.98	1.79
24	citronellol	16.34	0.42
25	neral	16.63	6.84
26	geraniol	17.38	11.28
28	isobornyl acetate	18.46	0.37
32	geranyl acetate	22.73	0.88
	Sesquiterpene		
29	β-cubebene	21.13	0.04
31	α-copaene	22.38	0.21
33	germacrene D	22.93	0.06
34	β-elemene	23.09	0.07
35	*E*-caryophyllene	24.33	1.06
36	longifolene	25.11	0.06
37	*cis*-β-guaiene	25.73	0.02
38	α-humulene	25.89	0.17
39	valencene	26.03	2.15
41	γ-cadinene	26.75	0.21
42	γ-muurolene	26.99	0.34

Table 15 (continued)

Peak No	Compound	Retention time (min)	%Area
43	viridiflorene	27.38	0.22
44	bicyclogermacrene	27.59	3.09
45	*cis*-muurola-*4(14),5*-diene	28.39	0.06
46	trans-β-guaiene	28.59	0.57
	Oxygenated sesquiterpene		
47	spathulenol	31.29	3.09
48	α-eudesmol acetate	31.59	0.35
49	hinesol acetate	31.96	0.12
52	α-cadinol	34.49	0.32
	Phenylpropane		
27	*(Z)*-methyl cinnamate	17.94	8.75
	Long chain hydrocarbon		
16	*2*-nonanone	10.23	0.16
17	*n*-heneicosane	10.44	0.17
	Miscellaneous		
30	unknown	22.09	0.09
40	unknown	26.56	0.16
50	unknown	33.21	0.10
51	unknown	33.59	0.36

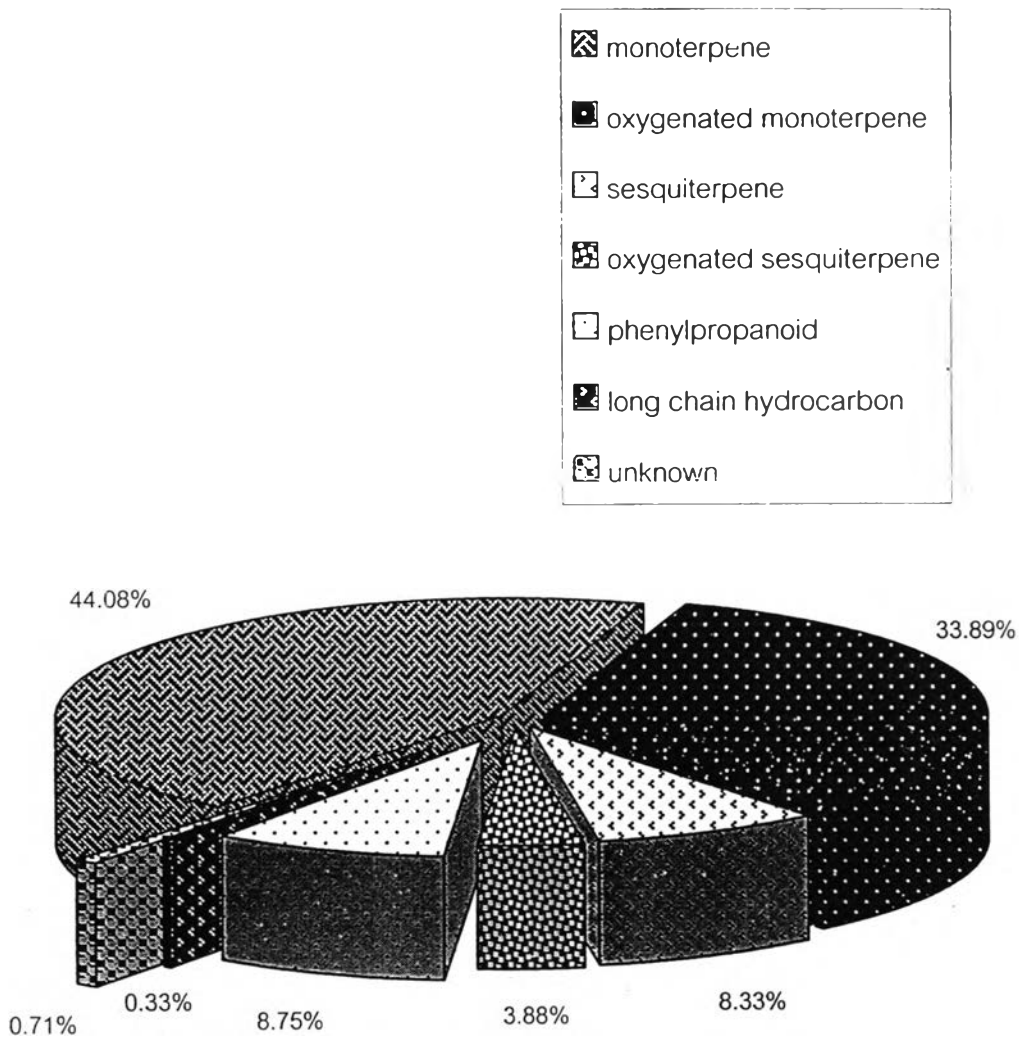


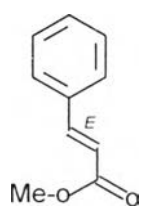
Figure 27 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum* sp.4 leaves

4.1.14. Essential Oil Composition of *Cinnamomum* sp.5

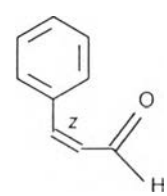
The yield of essential oil hydrodistilled from *Cinnamomum* sp. 5 leaves was found to be 0.6% (v/w) of the fresh weight. Analysis of the essential oil by GC/MS showed 9 peaks (Fig. 28). These peaks were identified as 1 oxygenated monoterpene, 1 sesquiterpene, 4 phenylpropanoids and 2 benzenoids (Table 16). Among these, *(E)*-methyl cinnamate (64.66%) was found to be the major component, followed by *(Z)*-cinnamaldehyde (18.42%) and linalool (6.89%).

In terms of relative amount, the phenylpropanes appeared to be the major group, accounting for 85.11% of the essential oil (Fig. 29). Oxygenated monoterpene and benzenoid were present in lesser amount, at 6.89 and 0.84%, respectively.

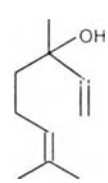
In terms of structure, the major components, *(E)*-methyl cinnamate and *(Z)*-cinnamaldehyde belong to the phenylpropanoid group, while linalool belongs to the oxygenated acyclic monoterpenoid group.



(E)-methyl cinnamate
(phenylpropane)



(Z)-cinnamaldehyde
(phenylpropane)



linalool
(acyclic monoterpenoid)

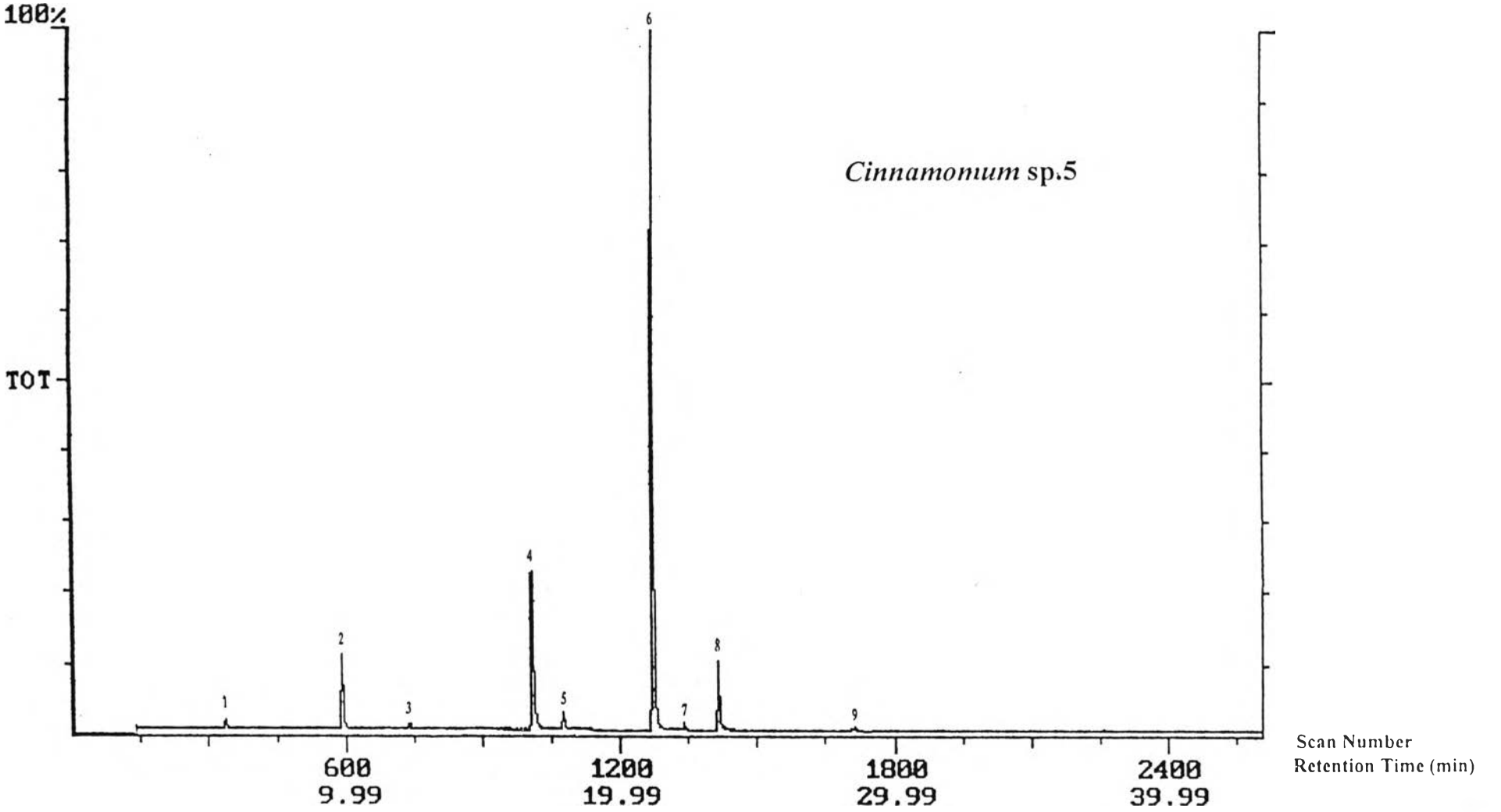


Figure 28 GC chromatogram of the essential oil from *Cinnamomum* sp.5 leaves

Table 16 Essential oil composition of *Cinnamomum* sp.5 leaves

Peak No	Compound	Retention time (min)	%Area
	Oxygenated monoterpene		
2	linalool	10.81	6.89
	Sesquiterpene		
7	*(E)*-caryophyllene	24.33	0.58
	Phenylpropanoid		
3	*(Z)*-cinnamyl alcohol	13.46	0.47
4	*(Z)*-cinnamaldehyde	16.81	18.42
5	*(Z)*-methyl cinnamate	17.94	1.56
6	*(E)*-methyl cinnamate	21.21	64.66
8	*(Z)*-cinnamyl acetate	24.89	6.42
	Benzenoid		
1	benzaldehyde	6.01	0.84
	Miscellaneous		
9	unknown	28.54	0.14

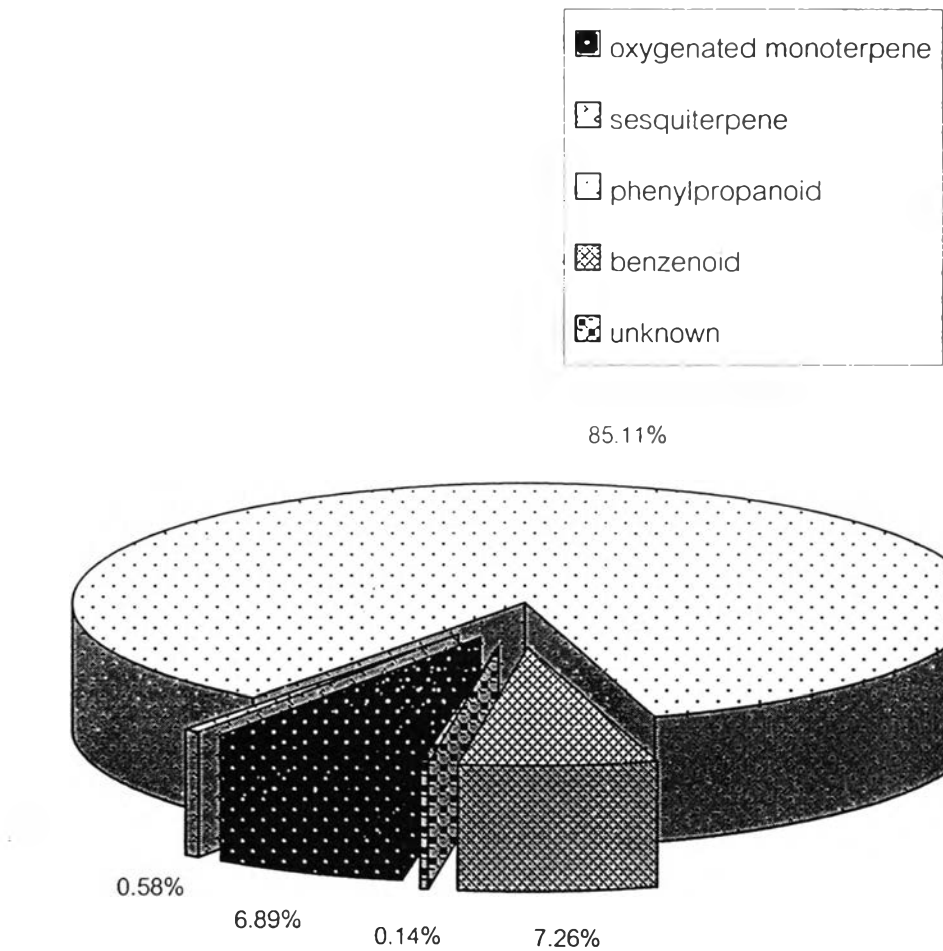
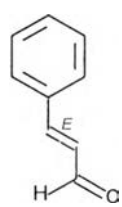


Figure 29 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum* sp.5 leaves

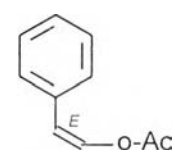
4.1.15. Essential Oil Composition of *Cinnamomum* sp. 6

By hydrodistillation, the yield of the essential oil from *Cinnamomum* sp. 6 leaves was found to be 0.66% (v/w) of fresh the weight. GC/MS analysis of the essential oil showed 13 peaks (Fig. 30). These peaks were identified as 2 oxygenated monoterpenes, 1 sesquiterpene, 2 oxygenated sesquiterpenes, 3 phenylpropanoids and 3 benzenoids (Table 17). Among these, *(E)*-cinnamaldehyde (56.64%) was appeared to be the major component, followed by *(Z)*-cinnamyl acetate (32.72%) and linalool (6.73%).

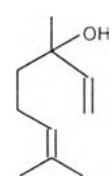
As for the component, the phenylpropanes appeared to be the major group, accounting for 89.91% of the essential oil (Fig. 31), whereas the oxygenated monoterpenoids and benzenoid were present in lesser amount, at 6.98 and 1.55%. In terms of structure the major components, *(E)*-cinnamaldehyde and *(Z)*-cinnamyl acetate belong to the phenylpropanoid group of compounds, while linalool belongs to the group of acyclic monoterpenoids.



(E)-cinnamaldehyde
(phenylpropane)



(Z)-cinnamyl acetate
(phenylpropane)



linalool
(acyclic monoterpenoid)

Table 17 Essential oil composition of *Cinnamomum* sp.6 leaves

Peak No	Compound	Retention time (min)	%Area
	Oxygenated monoterpene		
2	*1,8*-cineole	7.98	0.25
3	linalool	10.81	6.73
	Sesquiterpene		
9	α-cubebene	20.17	0.07
	Oxygenated sesquiterpene		
12	*(E)*-nerolidol	30.66	0.33
13	caryophyllene oxide	31.32	0.67
	Phenylpropanoid		
6	*(Z)*-cinnamaldehyde	16.81	0.45
8	(E)-cinnamaldehyde	18.61	56.64
10	*(E)*-methyl cinnamate	21.21	0.10
11	*(Z)*-cinnamyl acetate	24.89	32.72
	Benzenoid		
1	benzaldehyde	6.01	1.39
5	acetophenone	13.25	0.16
	Miscellaneous		
4	unknown	12.31	0.21
7	unknown	15.89	0.25

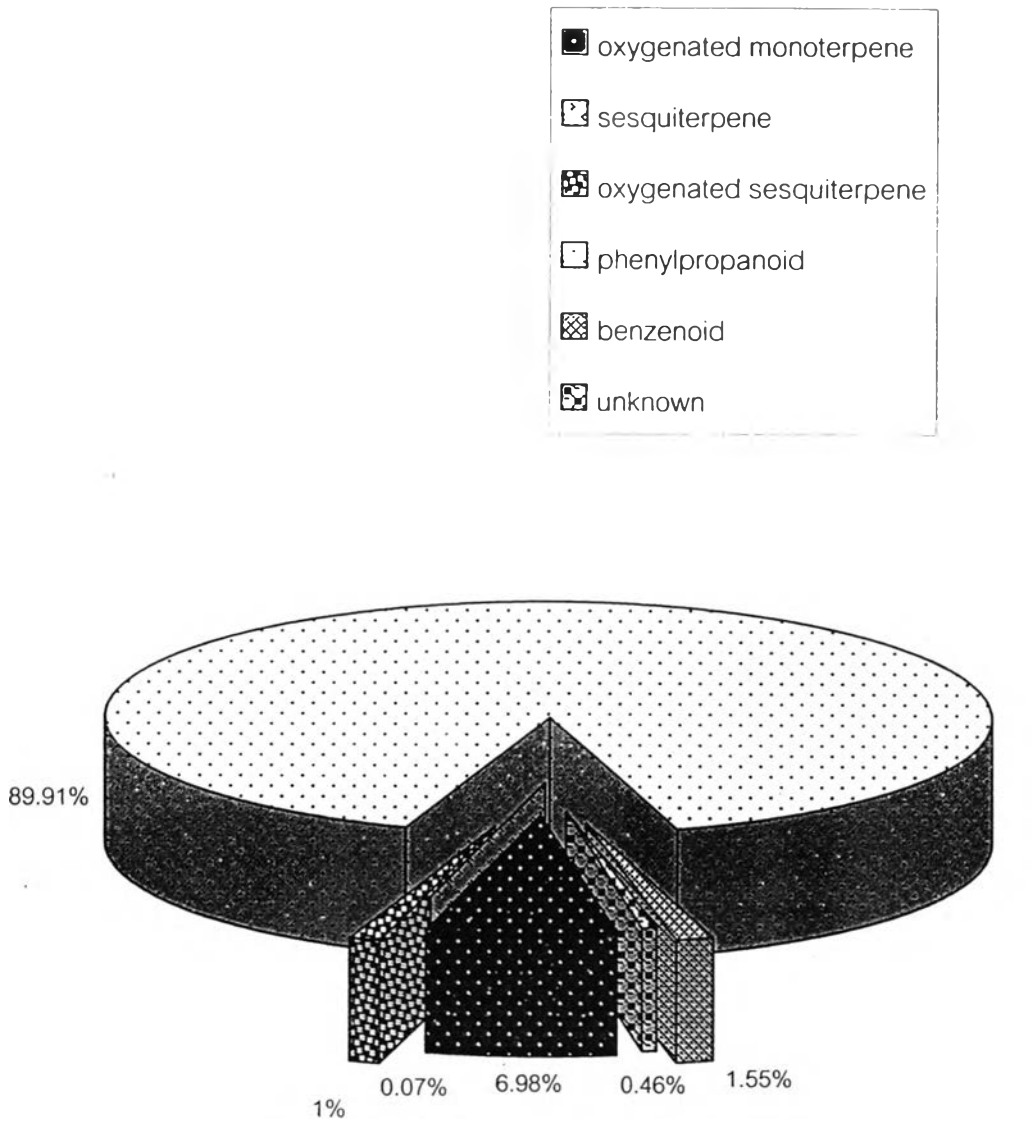


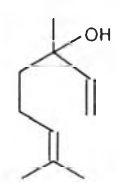
Figure 31 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum* sp.6 leaves

4.1.16. Essential Oil Composition of *Cinnamomum* sp.7

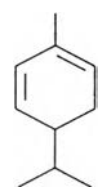
The yield of essential oil isolated from *Cinnamomum* sp.7 leaves was found to be 0.15% (v/w) of the fresh weight. Analysis of the essential oil by GC/MS showed 46 peaks (Fig. 32). These peaks were identified as 11 monoterpenes, 5 oxygenated monoterpenes, 13 sesquiterpenes, 8 oxygenated sesquiterpenes and 3 non-terpenoid compounds (Table 18). Among these, linalool (40.01%) was found to be the major component, followed by α-phellandrene (10.84%) and *O*-cymene (8.78%).

In terms of relative amount, the oxygenated monoterpenoids appeared to be the major group, accounting for 44.36% of the essential oil (Fig. 33). Monoterpenoids, sesquiterpenoids and oxygenated sesquiterpenoids were present in lesser amount, at 31.86, 8.61 and 7.81%, respectively.

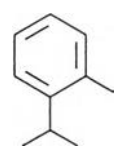
Structurally, linalool is an acyclic oxygenated monoterpenoid, whereas α-phellandrene and *o*-cymene both belongs to the monoterpenoid group of menthane.



linalool
(acyclic monoterpenoid)



α-phellandrene
(menthane)



o-cymene
(menthane)

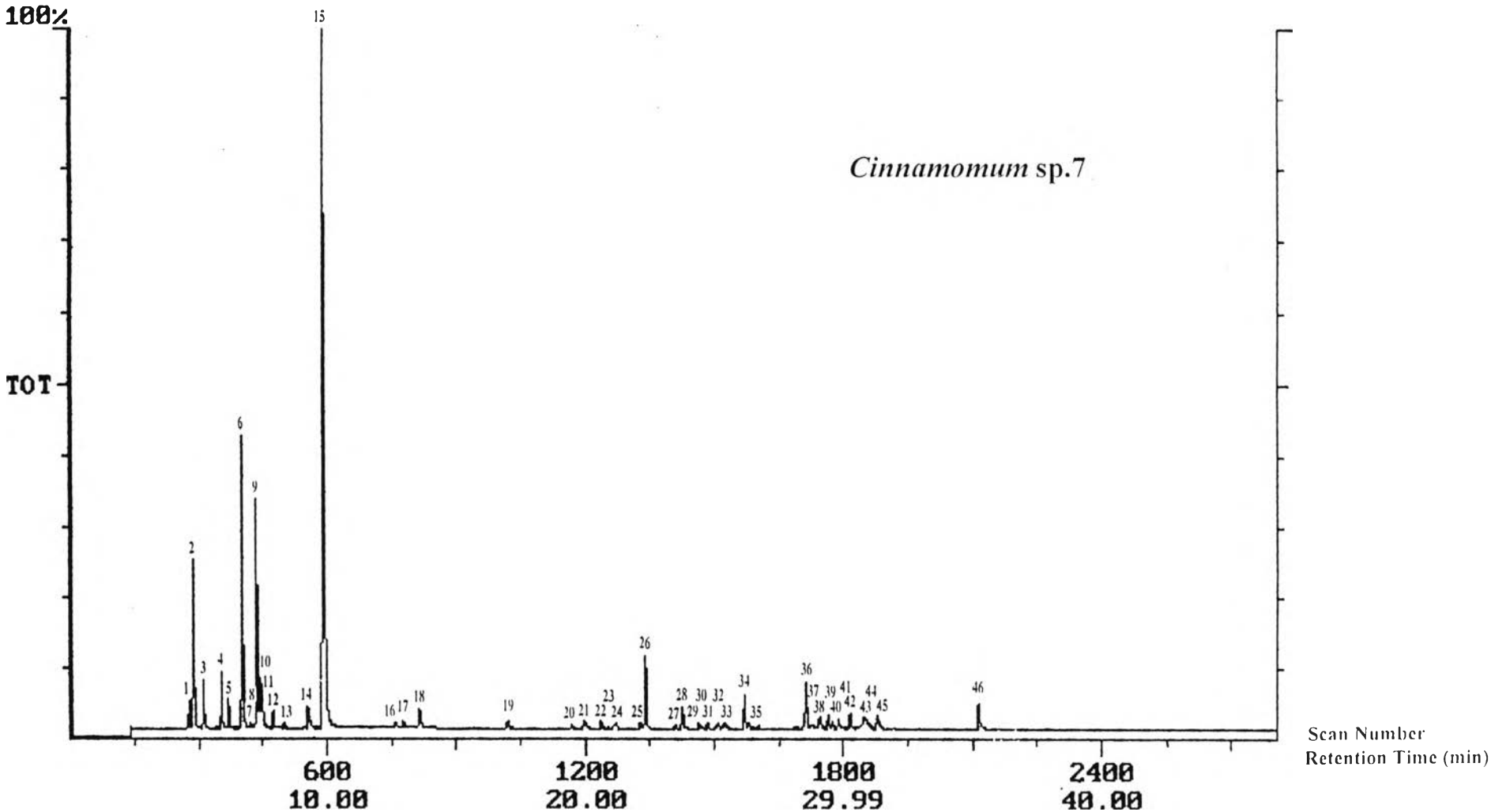


Figure 32 GC chromatogram of the essential oil from *Cinnamomum* sp.7 leaves

Table 18 Essential oil composition of *Cinnamomum* sp.7 leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	0.08
2	tricyclene	4.98	5.27
3	sylvestrene	5.98	1.61
4	sabinene	6.08	1.94
5	myrcene	6.11	1.08
6	α-phellandrene	7.11	10.84
7	δ-*2*-carene	7.44	0.13
9	*o*-cymene	7.59	8.78
12	*(E)*-β-ocimene	8.48	0.61
13	γ-terpinene	8.91	0.22
14	terpinolene	9.93	0.58
	Oxygenated monoterpene		
11	*1,8*-cineole	7.98	1.99
15	linalool	10.81	40.01
16	borneol	13.99	0.47
18	α-terpineol	14.98	1.45
19	bornyl acetate	18.44	0.44
	Sesquiterpene		
20	α-cubebene	20.17	0.14
22	α-copaene	22.38	0.37
23	germacrene D	22.93	0.16
24	α-bulnesene	24.10	0.30
26	*9-epi-(E)*-caryophyllene	25.07	3.63
27	seychellene	25.37	0.14
28	*(Z)*-α-bisabolene	25.44	1.13
29	*allo*-aromadendrene	25.56	0.13
30	*trans*-calamenene	25.58	0.26
31	γ-cardinene	26.75	0.28
32	γ-muurolene	26.99	0.28
34	*trans*-β-guaiene	28.59	1.67
35	cadina-*1,4*-diene	29.19	0.12
	Oxygenated sesquiterpene		
33	*epi*-cubebol	27.84	0.51
36	caryophyllene oxide	31.32	2.62
38	globulol	31.47	0.74
40	humulene epoxide II	32.44	0.46
42	*1-epi*-cubenol	33.19	0.90
43	cubenol	33.68	0.84

Table 18 (continued)

Peak No	Compound	Retention time (min)	%Area
44	*epi*-α-muurolol	33.98	0.71
45	α-cadinol	34.49	1.03
	Phenylpropanoid		
21	*(E)*-isoeugenol	21.02	0.61
	Benzenoid		
46	benzyl benzoate	38.85	1.88
	Aliphatic alcohol		
25	tetradecanal	24.16	0.29
	Miscellaneous		
8	unknown	7.48	0.13
10	unknown	7.85	2.21
17	unknown	14.05	0.43
37	unknown	31.40	0.33
39	unknown	31.95	0.77
41	unknown	33.01	0.58

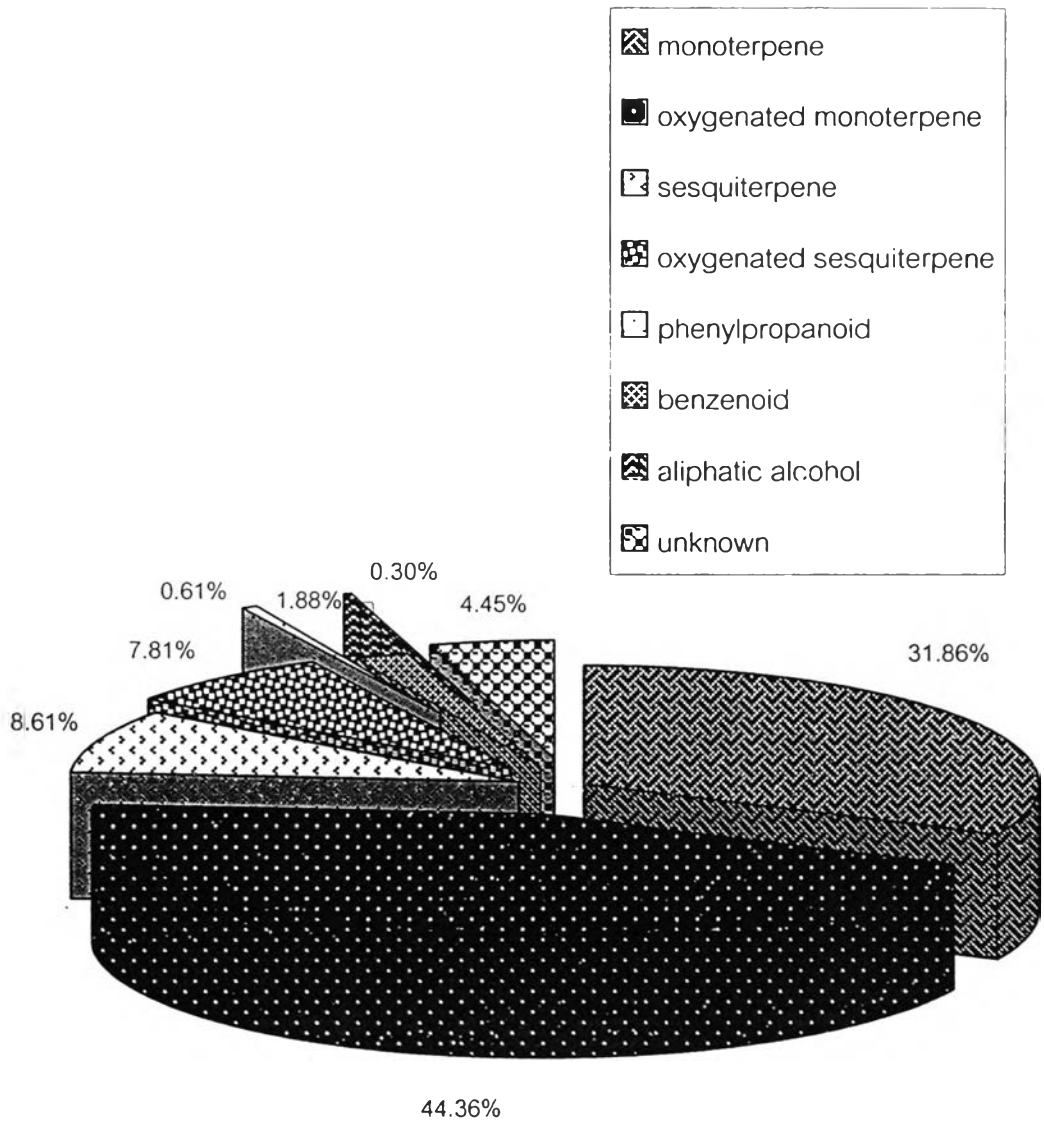
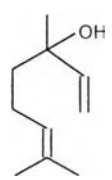


Figure 33 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum* sp.7 leaves

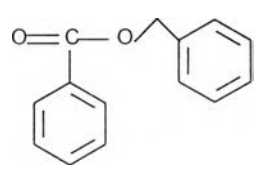
4.1.17. Essential Oil Composition of *Cinnamomum* sp. 8

The yield of essential oil hydrodistilled from *Cinnamomum* sp.8 leaves was found to be 0.08% (v/w) of the fresh weight. Analysis of this essential oil by GC/MS showed that there were 49 components (Fig. 34). These peaks were identified as 8 monoterpenes, 4 oxygenated monoterpenes, 17 sesquiterpenes. 11 oxygenated sesquiterpenes and 4 non-terpenoid components (Table 19). Among these, linalool (20.16%) appeared to be the major component, followed by benzyl benzoate (16.91%) and *9-epi-(E)*-caryophyllene (11.60%). Therefore, the sesquiterpenes was found to be the major terpenoid group, accounting for 24.41% of the essential oil (Fig. 35). Oxygenated monoterpenes, benzenoid, oxygenated sesquiterpenes and monoterpenes were present in lesser amount at 21.87, 16.91, 16.21 and 15.08%, respectively.

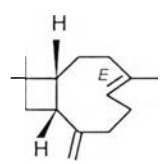
Structurally, linalool belongs to the cyclic oxygenated monoterpenoid group , whereas benzyl benzoate belongs to the benzenoid group, and *9-epi-(E)*-caryophyllene belongs to the sesquiterpenoid group of caryophyllane.



linalool
(acyclic monoterpenoid)



benzyl benzoate
(benzenoid)



9-epi-(E)-caryophyllene
(caryophyllane)

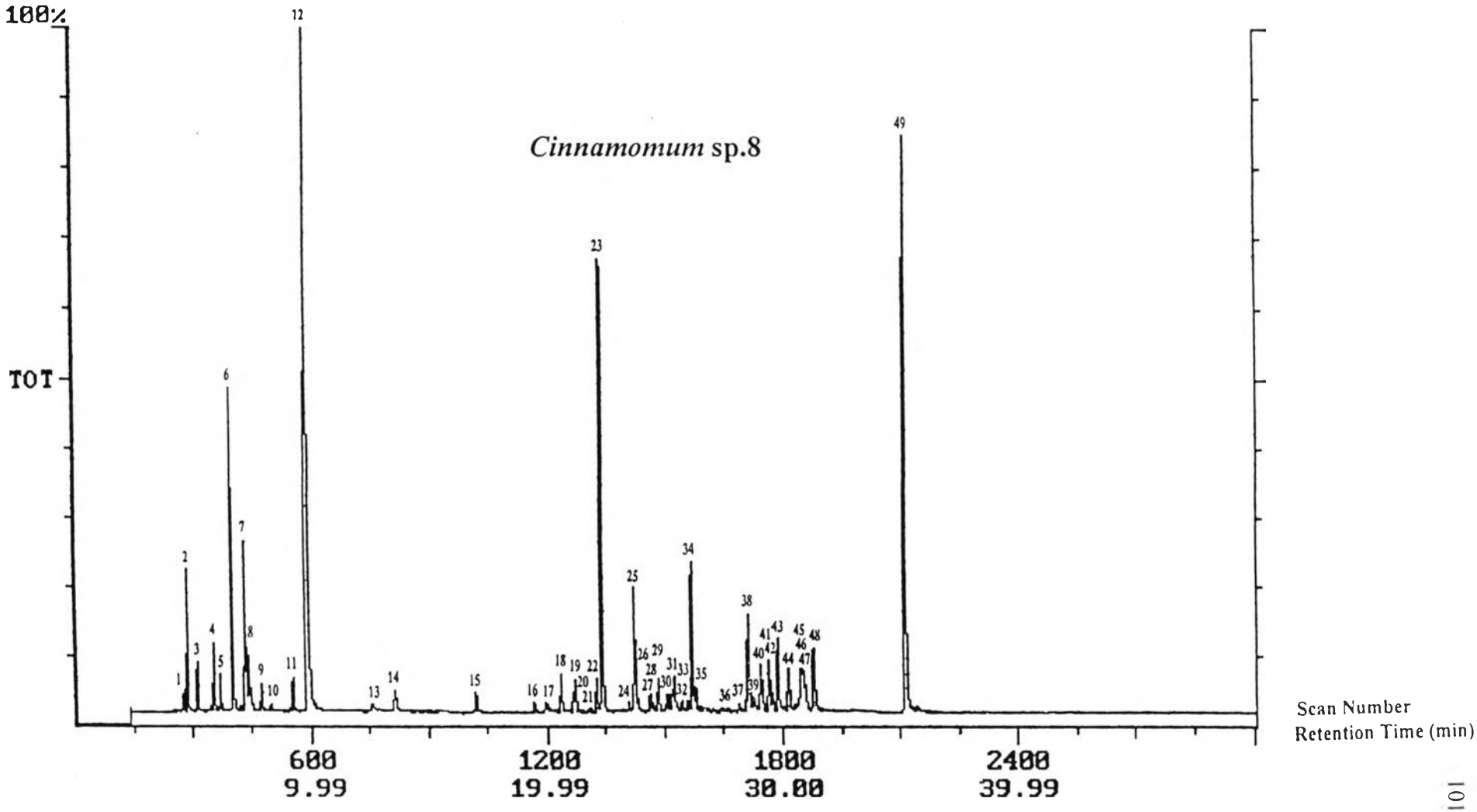


Figure 34 GC chromatogram of the essential oil from *Cinnamomum* sp.8 leaves

Table 19 Essential oil composition of *Cinnamomum* sp.8 leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	0.27
2	tricyclene	4.98	1.97
3	camphene	5.48	0.79
4	sabinene	6.08	1.01
6	α-phellandrene	7.11	6.40
7	*o*-cymene	7.59	3.46
9	*(E)*-β-ocimene	8.48	0.51
11	terpinolene	9.93	0.67
	Oxygenated monoterpene		
12	linalool	10.81	20.16
13	borneol	13.99	0.43
14	α-terpineol	14.98	0.80
15	bornyl acetate	18.44	0.48
	Sesquiterpene		
16	α-cubebene	20.17	0.21
18	β-cubebene	21.13	0.95
19	α-copane	22.38	0.49
20	β-elemene	23.09	0.82
21	*cis*-β-guaiene	23.71	0.10
23	*9-epi-(E)*-caryophyllene	25.07	11.60
24	seychellene	25.37	0.15
25	*(Z)*-α-bisabolene	25.44	3.10
26	*allo*-aromadendrene	25.56	0.26
27	*trans*-calamenene	25.58	0.42
28	γ-cadinene	26.75	0.21
29	γ-muurolene	26.99	0.83
30	isoledene	27.43	0.54
32	germacrene A	28.11	0.32
33	*cis*-muurola-*4(14),5*-diene	28.39	0.27
34	α-cadinene	28.76	3.86
35	cadina-*1,4*-diene	29.19	0.28
	Oxygenated sesquiterpene		
31	*epi*-cubebol	27.84	1.53
38	caryophyllene oxide	31.32	3.16
39	globulol	31.47	0.69
40	β-eudesmol acetate	31.63	1.59
41	ledol	32.30	1.43
42	humulene epoxide II	32.44	0.54

Table 19 (continued)

Peak No	Compound	Retention time (min)	%Area
45	cubenol	33.68	1.78
46	α-muurolol	33.93	1.12
47	*epi*-α-muurolol	33.98	0.90
48	α-cadinol	34.49	2.29
	Phenylpropanoid		
17	*(E)*-isoeugenol	21.02	0.42
	Benzenoid		
49	benzyl benzoate	38.86	16.91
	Aliphatic alcohol		
22	tetracecanal	24.16	0.76
43	decanal	32.64	1.80
	Miscellaneous		
5	unknown	6.14	0.61
8	unknown	8.20	1.35
10	unknown	9.11	0.14
36	unknown	29.65	0.08
37	unknown	30.13	0.20

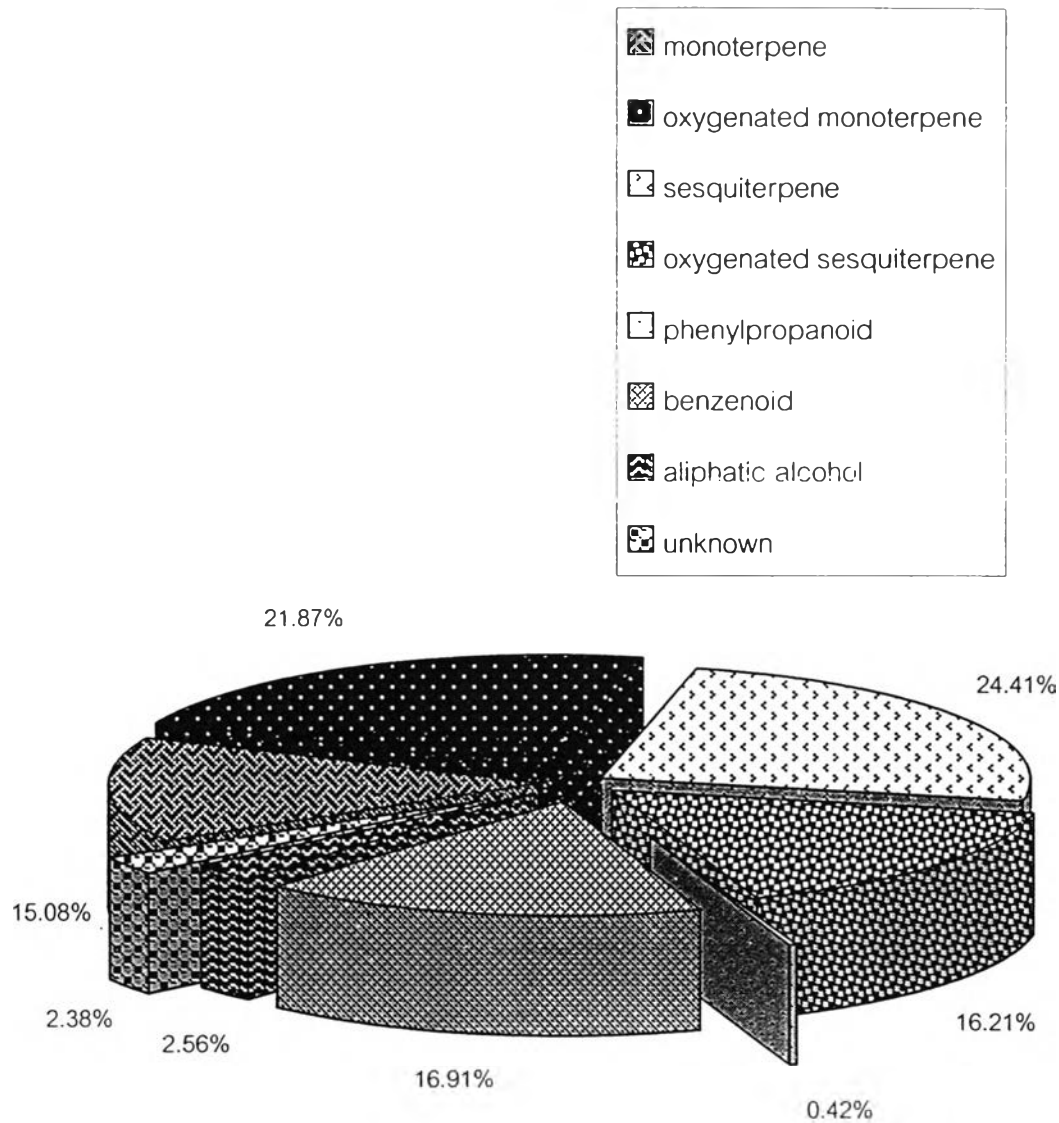


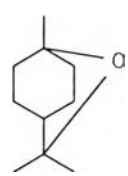
Figure 35 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum* sp.8 leaves

4.1.18. Essential Oil Composition of *Cinnamomum* sp. 9

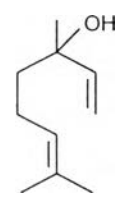
The yield of essential oil from *Cinnamomum* sp. 9 leaves was found to be 3.0% (v/w) of the fresh weight. Analysis of the essential oil by GC/MS showed that there were at least 27 components (Fig. 36). These components were identified as 10 monoterpenes, 7 oxygenated monoterpenes, 2 sesquiterpenes and 3 non-terpenoid components (Table 20). Among these, linalool (67.50%) was found to be the major component, followed by *1,8*-cineol (19.56%) and sabinene (2.27%).

In terms of relative amount, the oxygenated monoterpenes appeared to be the major terpenoid group, accounting for 93.52% of the essential oil. Monoterpenoids and phenylpropanoid were present in lesser amount, with 15.53% and 4.55%, respectively (Fig. 37).

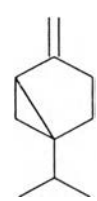
Structurally, both major components, *1,8*-cineol and linalool, belong to the oxygenated monoterpenoid group of menthane and acyclic monoterpenoid, whereas sabinene belongs to the monoterpenoid group of thujane.



1,8-cineol
(menthane)



linalool
(acyclic monoterpenoid)



sabinene
(thujane)

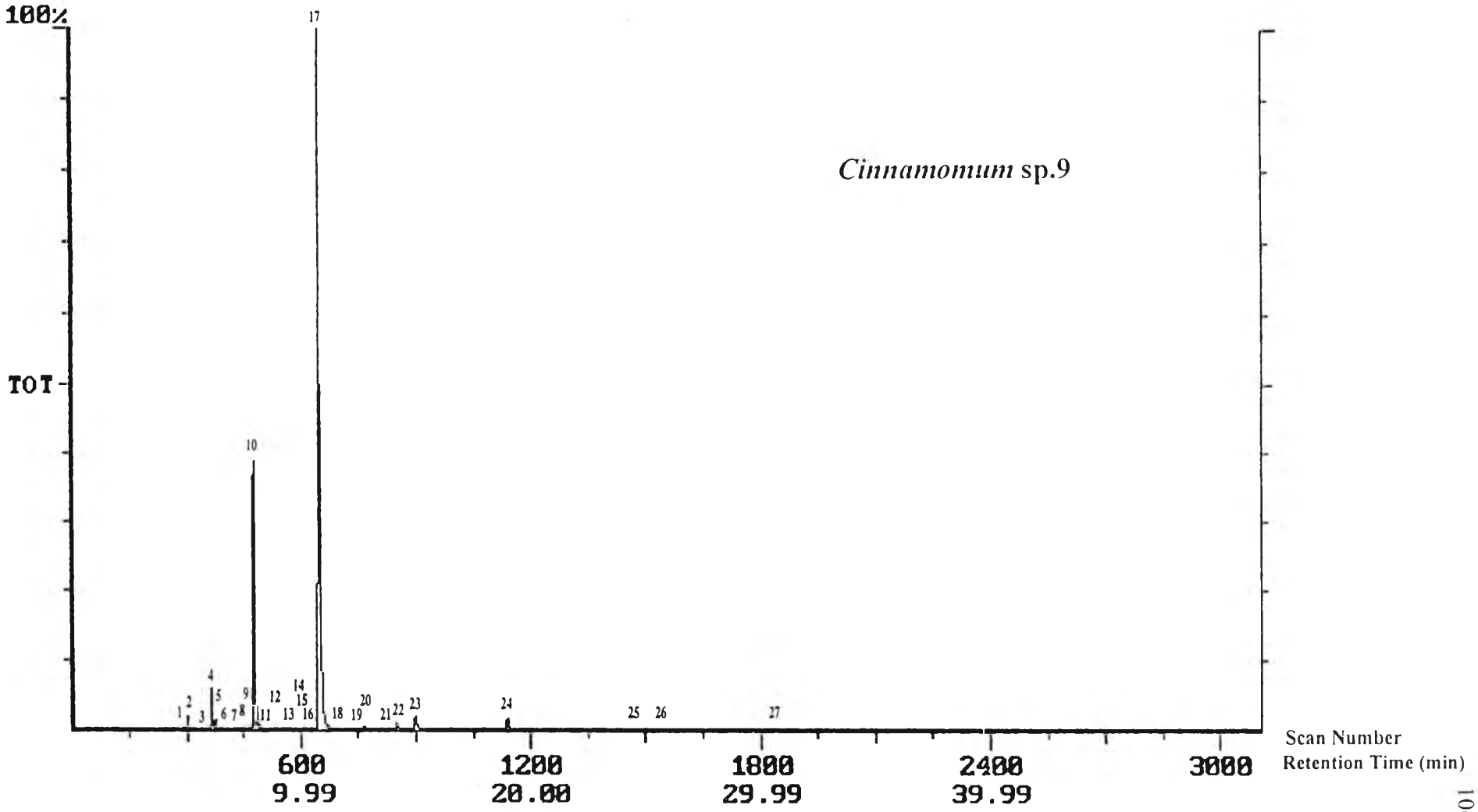


Figure 36 GC chromatogram of the essential oil from *Cinnamomum* sp.9 leaves

Table 20 Essential oil composition of *Cinnamomum* sp.9 leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	0.15
2	α-pinene	5.03	0.64
3	camphene	5.48	0.04
4	sabinene	6.08	2.27
5	β-phellandrene	6.23	0.61
6	β-pinene	6.54	0.20
8	δ-*2*-carene	7.44	0.11
9	verbenene	7.78	0.24
12	γ-terpinene	8.91	0.19
14	terpinolene	9.93	0.05
	Oxygenated monoterpene		
10	*1,8*-cineole	7.79	19.56
13	*cis*-linalool oxide	9.51	0.21
15	*trans*-linalool oxide	10.13	0.25
17	linalool	10.81	71.09
21	satolina alcohol	13.88	0.10
22	terpin-*4-ol*	14.16	0.68
23	α-terpineol	14.98	1.63
	Sesquiterpene		
25	*(E)*-caryophyllene	24.33	0.06
26	α-humulene	25.89	0.04
	Phenylpropanoid		
24	*(Z)*-isosafrole	18.99	1.32
	Long chain hydrocarbon		
7	*n*-decane	6.83	0.06
16	*n*-heneicosane	25.89	0.13
	Miscellaneous		
11	unknown	8.48	0.05
18	unknown	11.79	0.04
19	unknown	12.59	0.03
20	unknown	12.78	0.21
27	unknown	31.26	0.03

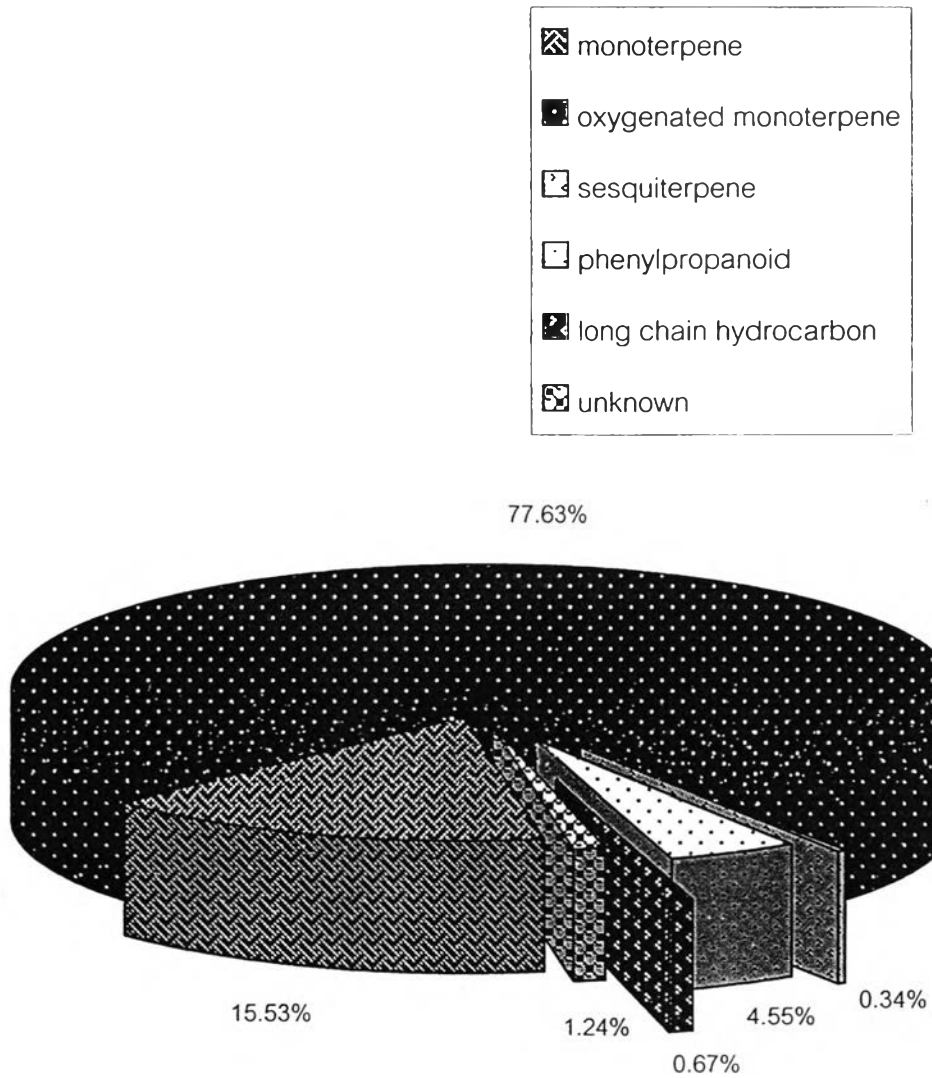


Figure 37 The percentage of various terpenoid groups found in the essential oil of *Cinnamomum* sp.9 leaves

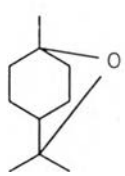
4.2 Chemical Composition of Essential Oil from Western Country in Thailand

4.2.1 Essential Oil Composition of *Laurus nobilis* L.

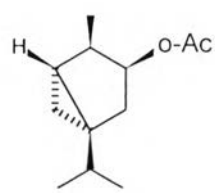
The essential oil from the leaves of *Laurus nobilis* was isolated by hydrodistillation. The oil yield was found to be 0.6 % (v/w) of the fresh weight. Analysis of the essential oil by GC/MS showed 50 peaks well separated from each other (Fig. 38). These peaks were identified as 15 monoterpenes, 9 oxygenated monoterpenes, 12 sesquiterpenes, 4 oxygenated sesquiterpenes and 4 non-terpenoid components (Table 21). Among these, *1,8*-cineole (45.48 %) appeared to be the major compenent, followed by *3*-thujyl acetate (12.58) and methyl eugenol (8.44 %).

In terms of relative amount, the oxygenated monoterpenes appeared to be the major terpenoid group, accounting for 63.23 % of the essential oil (Fig. 39). Monoterpenes, phenylpropanoids, sesquiterpenes and oxygenated sesquiterpenes were present in lesser amount at 12.39, 11.01, 2.52 and 2.36% , respectively.

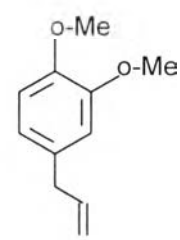
In terms of structure, the major components, *1,8*-cineole and 3-thujyl acetate belongs to the oxygenated monoterpenoid group of menthane and thujane, respectively, while methyl eugenol belongs to the phenylpropanoid group.



1,8-cineole
(menthane)



3-thujyl acetate
(thujane)



methyl eugenol
(phenylpropane)

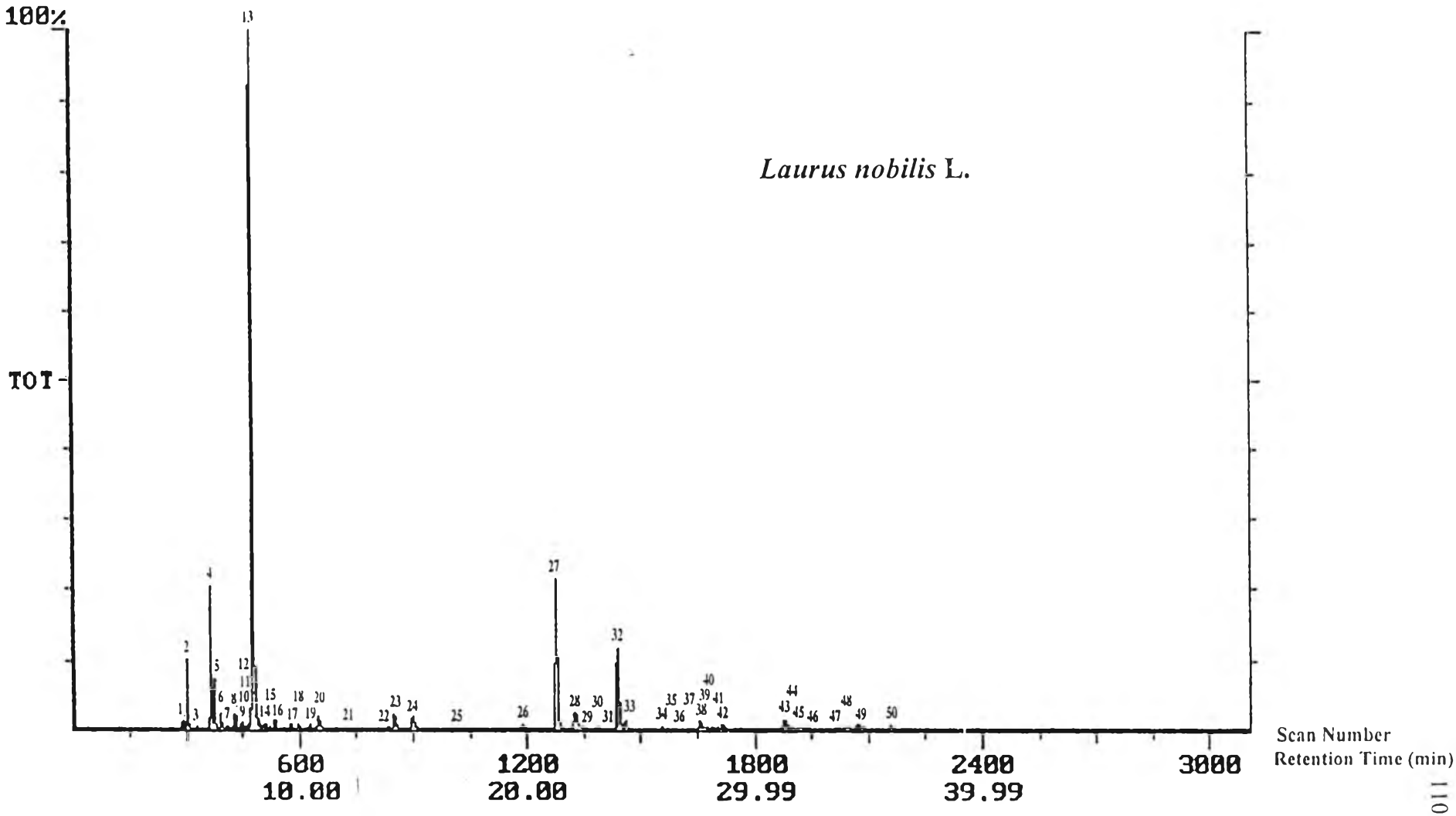


Figure 38 GC chromatogram of the essential oil from *Laurus nobilis* L. leaves

Table 21 Essential oil composition of *Laurus nobilis* L. leaves

Peak No	Compound	Retention time (min)	%Area
	Monoterpene		
1	α-thujene	4.83	0.41
2	α-pinene	5.03	3.35
3	camphene	5.48	0.36
4	sabinene	6.08	7.39
5	β-phellandrene	6.23	2.88
6	β-pinene	6.54	0.84
8	δ-3-carene	7.16	0.96
9	δ-2-carene	7.44	0.30
10	*o*-cymene	7.59	0.14
11	verbenene	7.78	0.29
12	limonene	7.88	0.97
14	*(E)*-β-ocimene	8.48	0.33
16	γ-terpinene	8.91	0.55
17	*trans*-sabinene hydrate	9.61	0.38
18	terpinolene	9.93	0.24
	Oxygenated monoterpene		
13	*1,8*-cineol	7.98	45.48
20	linalool	10.81	1.46
21	*trans-para*-menth-*2*-en-*1*-ol	11.81	0.06
22	santolina alcohol	13.88	0.23
23	terpin-*4-ol*	14.16	1.47
24	α-terpineol	14.98	1.54
25	isobornyl acetate	18.46	0.04
26	α-terpinyl acetate	19.79	0.37
27	*3*-thujyl acetate	21.29	12.58
	Sesquiterpene		
30	β-elemene	23.09	0.09
31	*cis*-β-guaiene	25.73	0.04
33	*(E)*-caryophyllene	24.33	0.69
34	α-humulene	25.89	0.06
35	valencene	26.03	0.04
36	γ-muurolene	26.99	0.07
37	β-selinene	27.34	0.06
38	bicyclogermacrene	27.59	0.78
39	β-gurjunene	27.88	0.17
40	germacrene A	28.11	0.15
41	*cis*-muurola-*4(14),5*-diene	28.39	0.07
42	trans-β-guaiene	28.59	0.30

Table 21 (continued)

Peak No	Compound	Retention time (min)	%Area
	Oxygenated sesquiterpene		
43	spathulenol	31.29	1.22
45	hinesol acetate	31.96	0.29
47	*epi*-α-muurolol	33.98	0.20
48	α-cadinol	34.49	0.65
	Phenylpropanoid		
28	*(Z)*-isoeugenol	22.10	2.57
32	methyl eugenol	23.98	8.44
	Long chain hydrocarbon		
7	*n*-decane	6.83	0.08
19	*n*-heneicosane	10.44	0.17
	Miscellaneous		
15	unknown	8.71	0.06
29	unknown	22.74	0.06
44	unknown	31.62	0.24
46	unknown	32.28	0.16
49	unknown	34.78	0.16
50	unknown	35.99	0.43

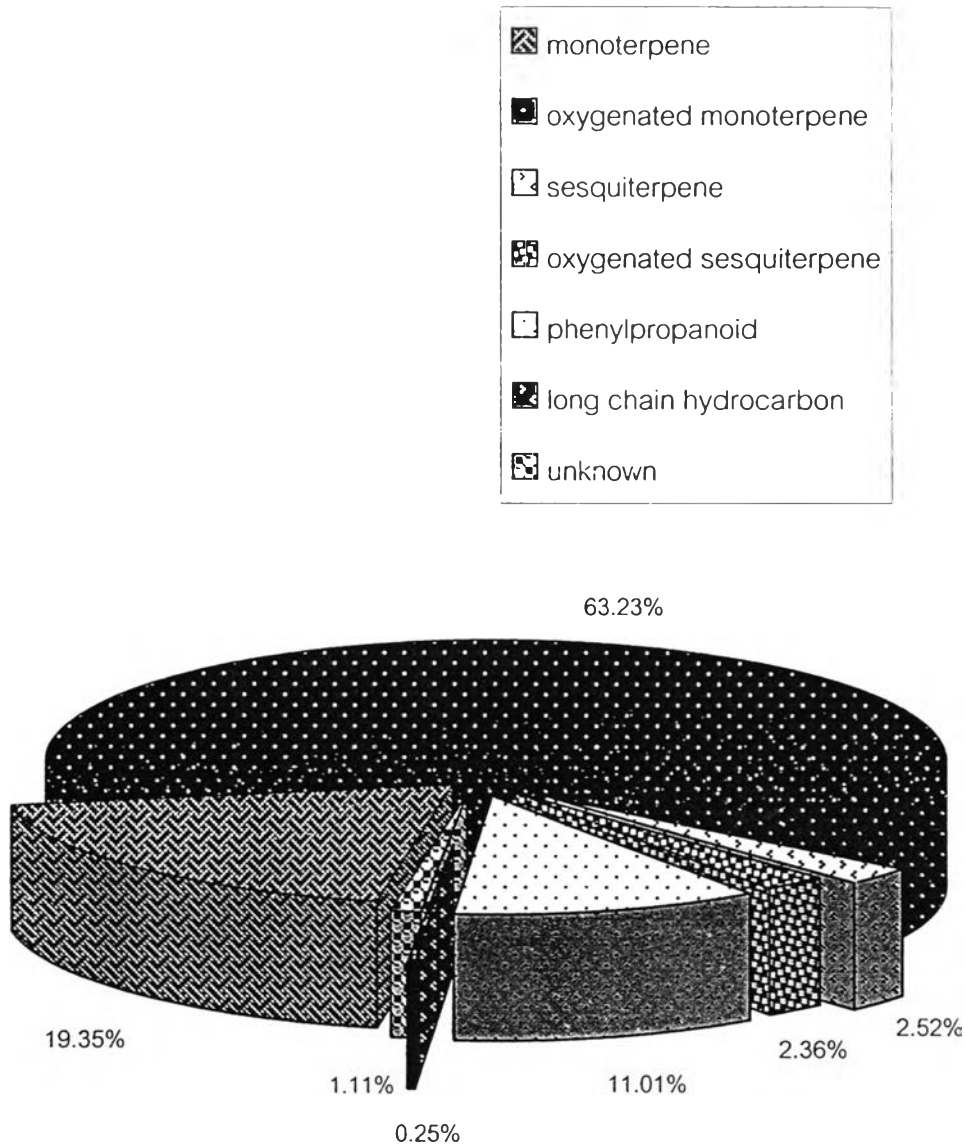


Figure 39 The percentage of various terpenoid groups found in the essential oil of *Laurus nobilis* L. leaves

4.3 Antimicrobial activitiy of the essential oils from Thai Lauraceous Plants

Antimicrobial activity of the essential oils was shown in Table 22. It was found that none of the essential oils had any apparent activity against *P. aeruginosa* and *M. gypseum*. The antimicrobial activity of the essential oil from *Cinnamomum* sp7 displayed the broadest spectrum. It was active against *S. aureus*, *E. faecalis*, *B. subtilis*, *E. coli* and *C. albicans*. Although essential oil from the leaves of *L. petiolata* had no activity against any test organism, that from its bark could inhibit *C. albicans*. Essential oils *from L. cubeba* (leaves) and *L. glutinosa* (fruits) inhibited only *S. aureus* and *C. albicans*, respectively.

Most essential oils of *Cinnamomum* had broader spectrum of activity than those of *Litsea* except *C. pathenoxylon* which inhibited only *C. albicans*. Most of them exhibited activities against both *S. aureus* and *C. albicans*. The essential oils from *Cinnamomum*. sp5 and sp6 had the lowest MIC (0.019%). Most essential oils of *Cinnamomum*. sp could inhibit *E. coli*.

In terms of location, leaves of *C. camphora* collected from different places yielded essential oils with different activities. That from Bangkok contained oil that inhibited both *S. aureus* and *B. subtilis*, whereas that from Rayong contained oil that inhibited only *S. aureus*. Essential oil from the leaves of *L. nobilis* was effective against both *S. aureus* and *C. albicans*.

Table 22 Antimicrobial activitity of essential oils from Thai Lauraceous plants

Plant	*Staphylococcus aureus* ATCC 29213		*Escherichia coli* ATCC 25922		*Bacillus subtilis* ATCC 6633		*Enterococcus faecalis* ATCC 29212		*Pseudomonas aeruginosa* ATCC 27853		*Candida albicans* ATCC 10231		*Microsporum gypseum* (clinical isolate)	
	mm± SD[a]	MIC (%)	mm± SD[a]	MIC (%)	mm± SD[a]	MIC (%)	mm± SD[a]	MIC (%)	mm± SD[a]	MIC (%)	mm± SD[a]	MIC (%)	mm± SD[a]	MIC (%)
1. *Cinnamomum camphora* Th. Fries. (leaves;Bangkok)	8.20 ± 1.40	0.63	0	ND[b]	9.3 ± 0.99	1.25	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]
2. *Cinnamomum camphora* Th. Fries. (leaves ; Rayong)	9.03 ± 0.99	2.5	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]
3. *Cinnamomum inner* Bl.(leaves)	11.0 ± 2.42	0.312	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	9.7 ± 3.14	0.078	0	ND[b]
4. *Cinnamomum porrectum* Kosterm. (leaves)	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	11.9 ± 1.91	0.078	0	ND[b]
5. *Litsea cubeba* Pers (leaves)	10.3 ± 2.42	0.312	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]
6. *Litsea glutinosa* C.B. Robinson. (fruits)	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	13.65± 0.45	1.25	0	ND[b]
7. *Litsea petiolata* Hook. f. (leaves)	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]
8. *Litsea petiolata* Hook. f. (bark)	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	19.60± 3.96	0.078	0	ND[b]
9. *Cinnamomum* sp.1 (leaves)	7.73 ± 2.07	0.63	6.10 ± 3.78	1.25	7.7 ± 3.11	0.63	0	ND[b]	0	ND[b]	23.2 ± 3.12	0.312	0	ND[b]
10.*Cinnamomum* sp.2 (leaves)	10.0 ± 3.79	0.63	7.43 ± 3.21	0.63	0	ND[b]	0	ND[b]	0	ND[b]	20.8 ± 4.15	0.312	0	ND[b]
11.*Cinnamomum* sp.3 (leaves)	8.3 ± 1.23	0.63	19.6 ± 3.36	1.25	20.26± 0.63	1.25	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]
12.*Cinnamomum* sp.4 (leaves)	16.3 ± 4.44	0.156	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	11.8 ± 2.76	0.312	0	ND[b]
13.*Cinnamomum* sp.5 (leaves)	9.73 ± 0.81	0.156	6.8 ± 0.78	0.63	0	ND[b]	0	ND[b]	0	ND[b]	17.20± 2.89	0.019	0	ND[b]
14.*Cinnamomum* sp.6 (leaves)	0	ND[b]	7.9 ± 3.37	0.156	0	ND[b]	0	ND[b]	0	ND[b]	23.0 ± 4.12	0.019	0	ND[b]
15.*Cinnamomum* sp.7 (leaves)	14.7 ± 3.26	0.63	6.86 ± 0.31	1.25	12.2 ± 2.96	1.25	16.3 ± 2.86	1.25	0	ND[b]	9.83 ± 2.10	0.078	0	ND[b]
16.*Cinnamomum* sp.8 (leaves)	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	9.85 ± 2.17	0.156	0	ND[b]
17.*Cinnamomum* sp.9 (leaves)	6.3 ± 0.98	0.63	7.23 ± 1.30	0.63	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]
18.*Laurus nobilis* L. (leaves)	11.8 ± 1.07	1.25	0	ND[b]	0	ND[b]	0	ND[b]	0	ND[b]	16.4 ± 1.96	ND[b]	0	ND[b]

[a] inhibiton zone diameter resulted from 10% oil in 0.1% tween 80
[b] not determined