CHAPTER IV

RESULTS

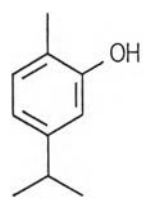
4.1 Chemical Composition of Essential Oil from Thai Lamiaceous plants

4.1.1 Essential Oil Composition of *Coleus amboinicus* Lour.

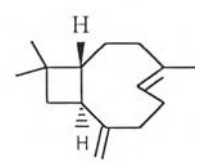
The essential oil from the leaves of *Coleus amboinicus* was isolated by hydrodistillation. The oil yield was found to be 0.1 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed 17 seperate peaks (Fig. 2). These peaks were identified as 8 monoterpenes, 3 oxygenated monoterpenes, 4 sesquiterpenes, and 1 oxygenated sesquiterpene (Table 3). Among these, carvacrol (77.95 %) appeared to be the major compenent, followed by *(E)*-caryophyllene (6.19%).

In terms of relative amount, the oxygenated monoterpenes appeared to be the major terpenoid group, accounting for 79 % of the essential oil (Fig. 3). Sesquiterpenes, monoterpenes and oxygenated sesquiterpenes were present in lesser amount with 14 %, 6 % and 1 %, respectively.

In terms of structure, the major components, carvacrol, belongs to the oxygenated monoterpenoid group of menthane, while *(E)*-caryophyllene belongs to the sesquiterpenoid group of caryophilane.



carvacrol
(*menthane*)



(E)-caryophyllene
(*caryophilane*)

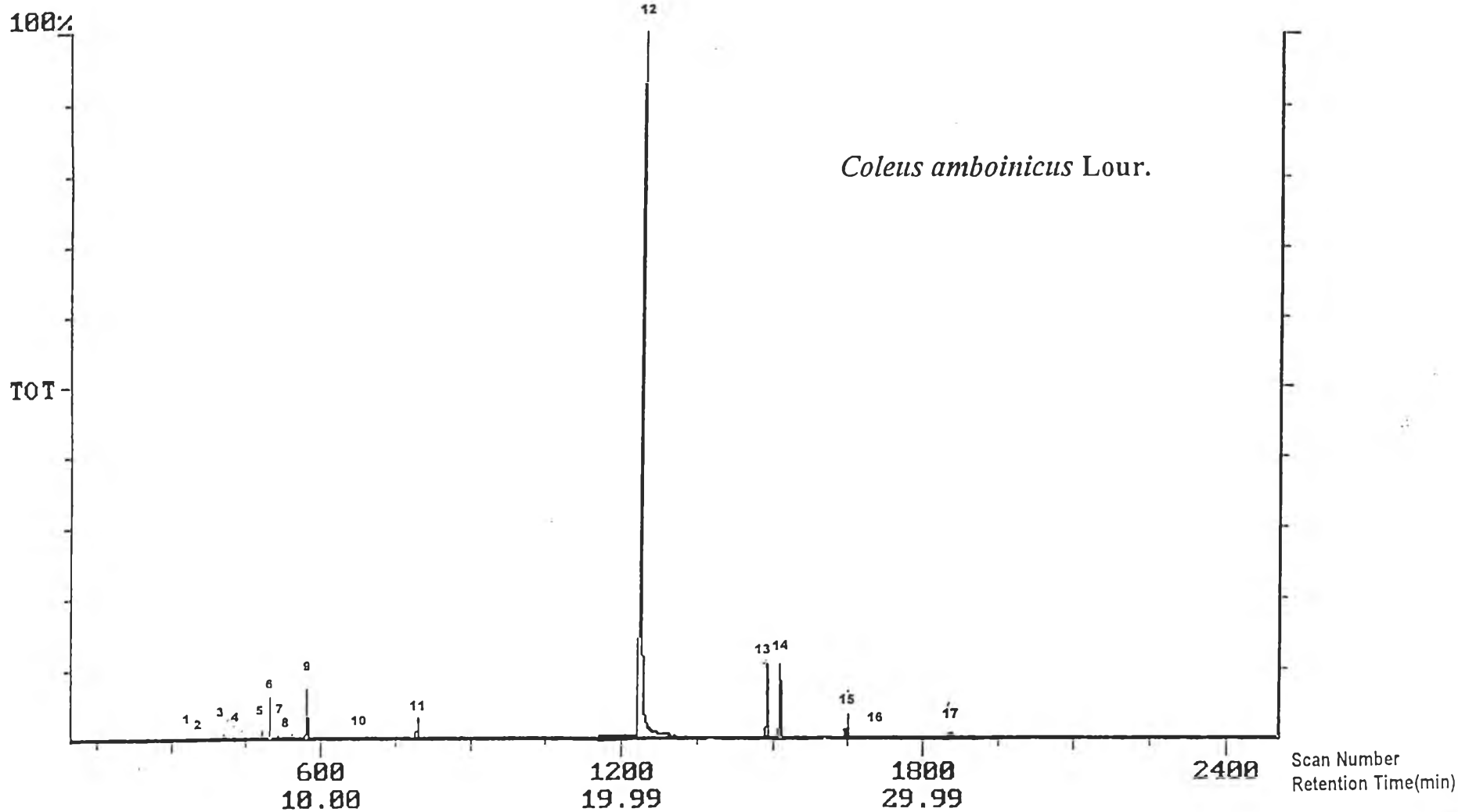


Figure 2 GC chromatogram of the essential oil from *Coleus amboinicus* leaves

Table 3 Essential oil composition of *Coleus amboinicus* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	tricyclene	5.28	0.05
2	α-thujene	5.50	t
4	myrcene	6.90	0.13
5	δ-2-carene	7.12	0.41
6	*o*-cymene	7.75	2.50
7	limonene	8.01	0.11
9	γ-terpinene	9.08	2.89
10	terpinolene	10.13	t
	Oygenated monoterpene		
8	1,8-cineole	8.13	0.19
11	terpin-4-ol	13.94	0.88
12	carvacrol	20.33	77.95
	Sesquiterpene		
13	(*E*)-caryophyllene	24.38	6.19
14	α-*trans*-bergamotene	25.05	5.70
15	(*Z*)-α-bisabolene	27.58	1.78
16	α-cadinene	28.88	0.08
	Oxygenated sesquiterpene		
17	caryophyllene oxide	31.10	0.62
	Long chain hydrocarbon		
3	1-octen-3-ol	6.79	0.48

t = trace

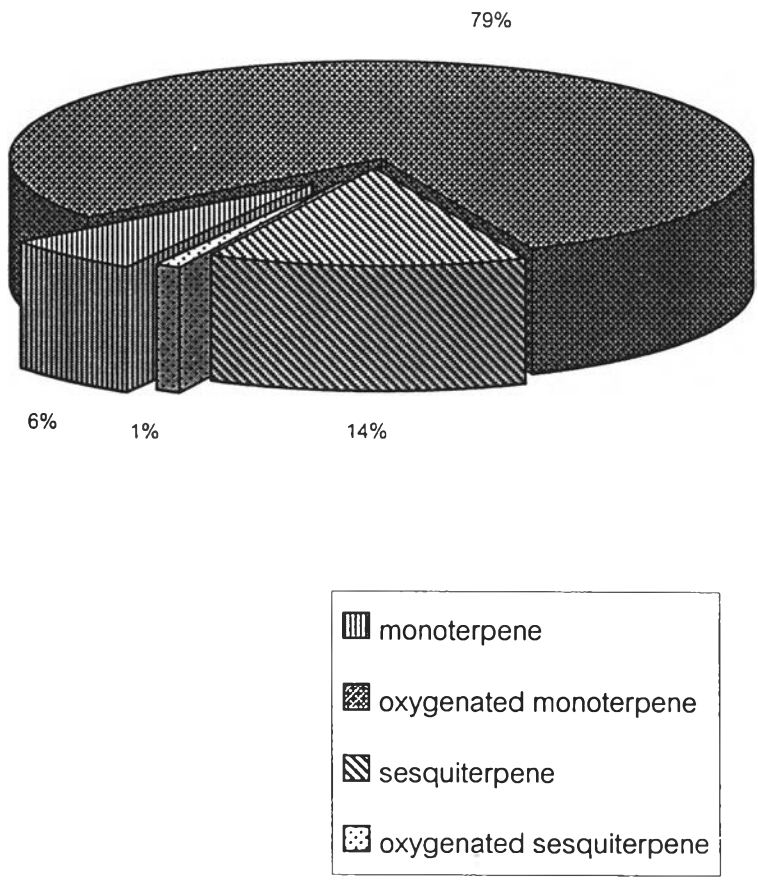


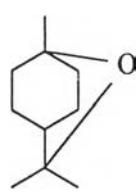
Figure 3 The percentage of various terpenoid groups found in the essential oil of *Coleus amboinicus* leaves

4.1.2 Essential Oil Composition of *Hyptis suaveolens* Poit.

The leaves of *Hyptis suaveolens*. were found to contain essential oil at 0.1 % (v/w) of fresh weight. By GC/MS analysis of essential of it was found that the essential oil had at least 43 peaks in its GC chromatogram (fig 4). These peaks were identified as 9 monoterpenes, 3 oxygenated monoterpenes, 17 sesquiterpenes, 5 oxygenated sesquiterpenes and 2 diterpenes (Table 4). Among these, 1,8-cineole (21.70 %) appeared to be the major component, followed by *(E)*-caryophyllene (17.87 %) and sabinene (16.92 %).

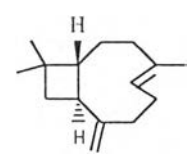
Monoterpenes were found to be the major component, accounting for 33 % of the essential oil. Sesquiterpenes, oxygenated monoterpenes and oxygenated sesquiterpenes were present in a lesser amount, with 31 %,22 % and 2 %, respectively (Fig. 5).

Structurally, the major component, 1,8-cineole and sabinene, belong to the monoterpenoid group of menthane and thujane, respectively, while *(E)*-caryophyllene belongs to the sesquiterpenoid group of caryophilane.



1,8 cineole

(*menthane*)



E-caryophyllene

(*caryophilane*)

sabinene

(*thujane*)

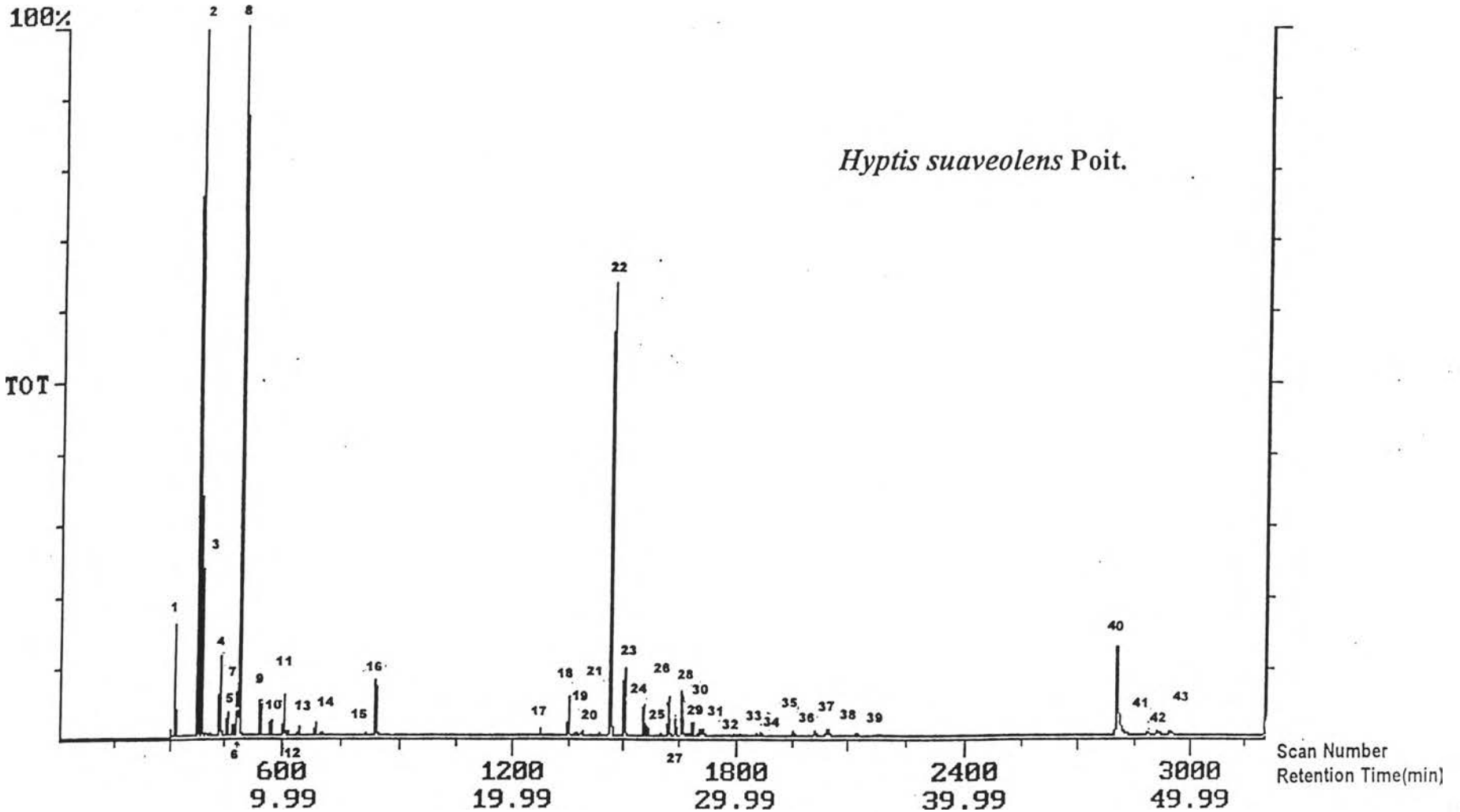


Figure 4 GC chromatogram of the essential oil from *Hyptis suaveolens* leaves

Table 4 Essential oil composition of *Hyptis suaveolens* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	tricyclene	5.28	2.66
2	sabinene	6.35	16.92
3	*β*-pinene	6.41	6.63
4	*α*-phellandrene	7.26	2.19
5	*δ*-3-carene	7.40	0.68
6	*o*-cymene	7.75	0.32
7	limonene	8.02	1.31
9	*γ*-terpinene	9.08	1.16
11	terpinolene	10.13	1.48
	oxygenated monoterpene		
8	1,8-cineole	8.13	21.70
14	*exo*-fenchol	11.39	0.46
15	borneol	13.61	0.12
	Sesquiterpene		
17	*α*-cubebene	21.28	0.26
18	*α*-copaene	22.50	1.60
19	*β*-bourbonene	22.58	0.14
20	*β*-cubebene	23.06	0.17
21	*β*-elemene	23.09	0.16
22	*(E)*-caryophyllene	24.38	17.87
23	*α-trans*-bergamotene	25.01	2.81
24	*α*-humulene	25.91	1.25
25	*allo*-aromadendrene	26.08	0.40

Table 4 Essential oil composition of *Hyptis suaveolens* leaves (continued)

Number of peak	Compound	Retention time (min)	% Area
26	germacrene D	26.56	1.71
27	β-selinene	26.80	0.92
29	germacrene A	27.89	0.10
30	α-bulnesene	28.00	0.65
31	γ-cadinene	28.04	0.32
32	δ-cadinene	28.56	0.32
33	α-cadinene	28.88	0.11
	Oxygenated sesquiterpene		
34	caryophyllene oxide	31.10	0.20
35	longiborneol acetate	32.56	0.25
36	*epi*-α-cadinol	33.55	0.36
37	α-eudesmol acetate	34.13	0.61
38	*Z*-α-*trans*-bergamotol acetate	35.36	0.13
	Diterpene		
41	abietatriene	48.10	0.22
43	abietadiene	49.13	0.43
	Miscellaneous		
10	unknown	9.49	0.55
12	unknown	10.20	0.19
13	unknown	10.68	0.39
16	unknown	13.98	2.24
39	unknown	35.49	0.13
40	unknown	46.73	7.22
42	unknown	48.51	0.38

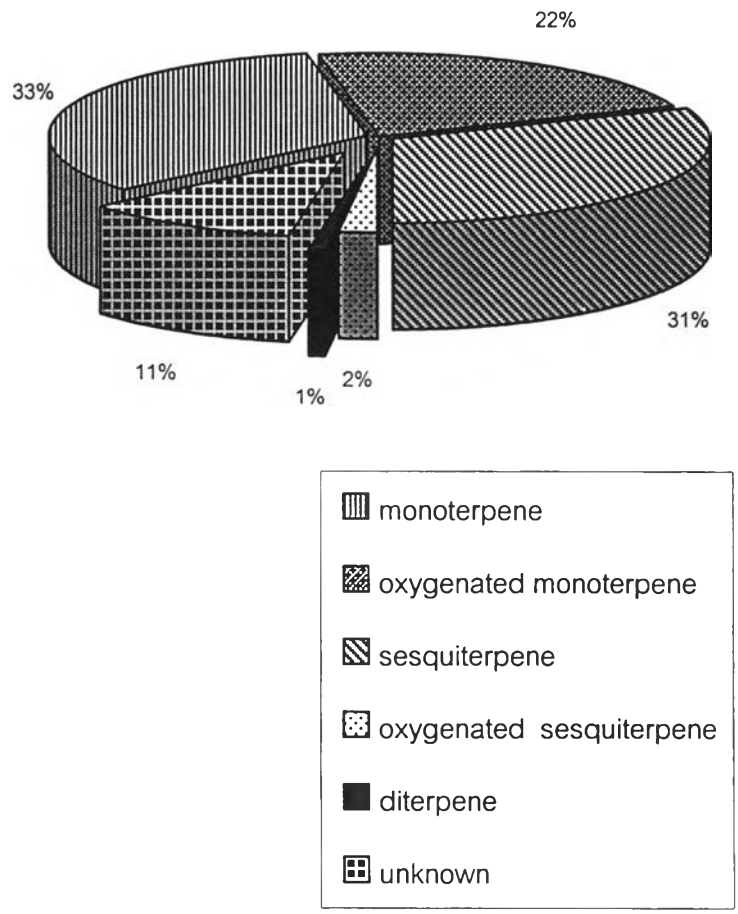


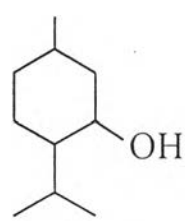
Figure 5 The percentage of various terpenoid groups found in the essential oil of *Hyptis suaveolens* leaves

4.1.3 Essential Oil Composition of *Mentha arvensis* L. var. *piperascens* Malinvaud

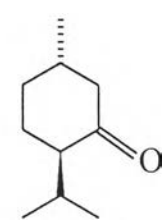
The essential oil hydrodistilled from *Mentha arvensis* L. var. *piperascens* leaves was found to have the yield of 0.9 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed 25 distinct peaks (fig 6). These peaks were identified as 5 monoterpenes, 10 oxygenated monoterpenes, 6 sesquiterpenes and 2 oxygenated sesquiterpenes (Table 5). Among these, menthol (79.44 %) was found to be the major component, followed by menthone (9.44 %) and limonene (2.85 %).

Quantitatively, the oxygenated monoterpene appeared to be the major terpenoid group, accounting for 93 % of the essential oil. Monoterpenes were present in a lesser amount, at 4 % (Fig 7).

Structurally, the major component, menthol and menthone, belong to the oxygenated monoterpenoid group of menthane.



menthol
(*menthane*)



menthone
(*menthane*)

limonene
(*menthane*)

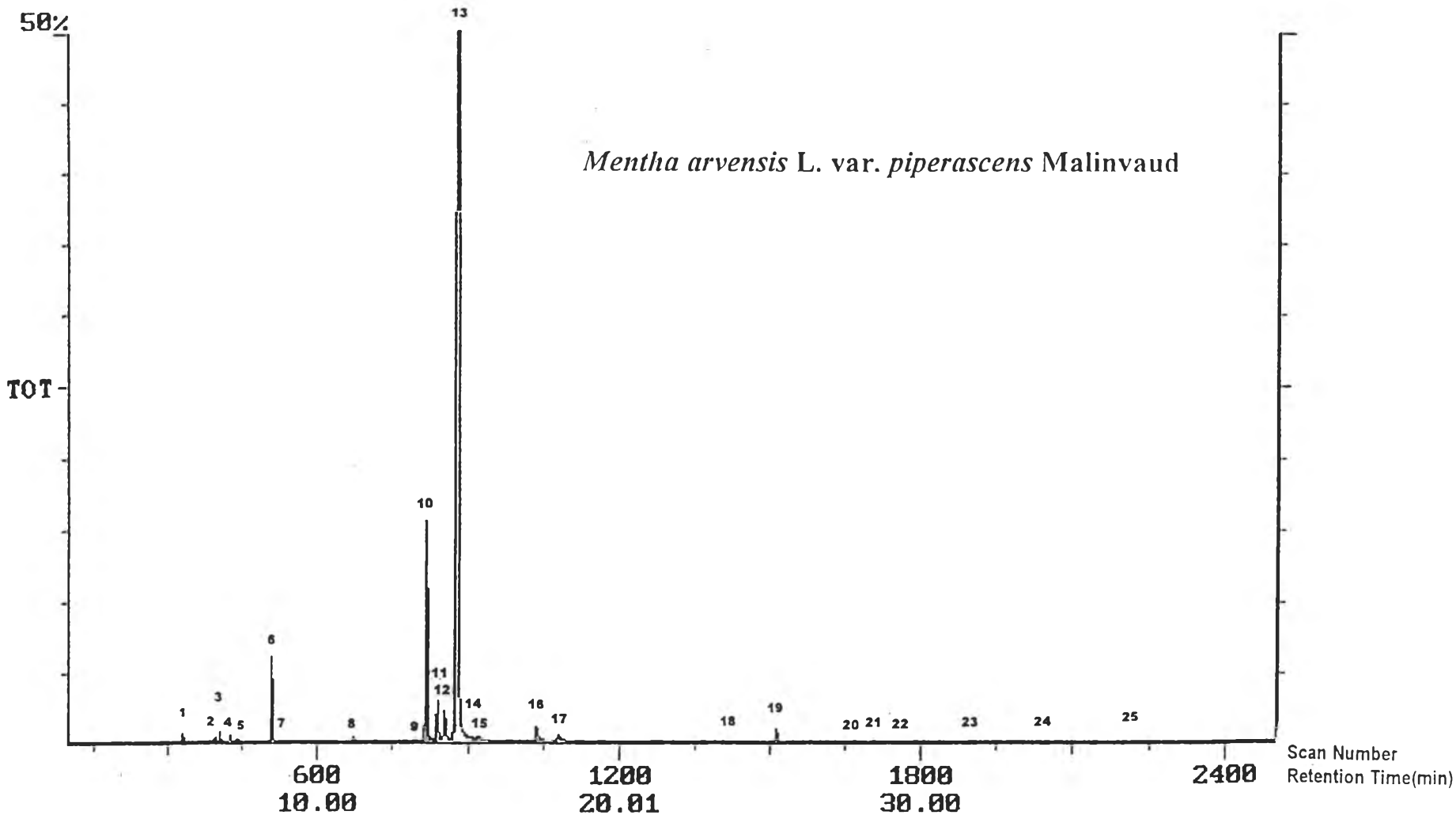


Figure 6 GC chromatogram of the essential oil from *Mentha arvensis* L.var. *piperascens* leaves

Table 5 Essential oil composition of *Mentha arvensis* var. *piperascens* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	*α*-thujene	5.50	0.24
2	sabinene	6.35	0.14
3	*β*-pinene	6.41	0.31
4	myrcene	6.90	0.24
6	limonene	8.01	2.85
	oxygenated monoterpene		
7	1,8-cineole	8.13	0.11
8	linalool	10.63	0.29
9	*neo-iso*-isopulegol	13.30	t
10	menthone	13.62	9.44
12	*neo*-menthol	14.23	1.52
13	menthol	14.64	79.44
14	isomenthol	15.07	0.45
15	isobornyl formate	15.35	0.42
16	pulegone	17.23	1.13
17	piperitone	17.95	0.64
	Sesquiterpene		
18	*β*-bourbonene	22.58	t
19	*9-epi-(E)*-caryophyllene	25.43	0.55
20	*γ*-muurolene	26.43	0.10
21	bicyclogermacrene	27.61	0.15
22	*δ*-cadinene	28.56	t
23	*α* -cadinene	30.01	t

Table 5 Essential oil composition of *Mentha arvensis* var. *piperascens* leaves (continued)

Number of peak	Compound	Retention time (min)	% Area
	Oxygenated sesquiterpene		
24	*epi*-α -cadinol	33.55	t
25	α -cadinol	34.04	t
	Long chain hydrocarbon		
5	3-octanol	7.37	0.08
	Miscellaneous		
11	unknown	14.01	1.82

t = trace

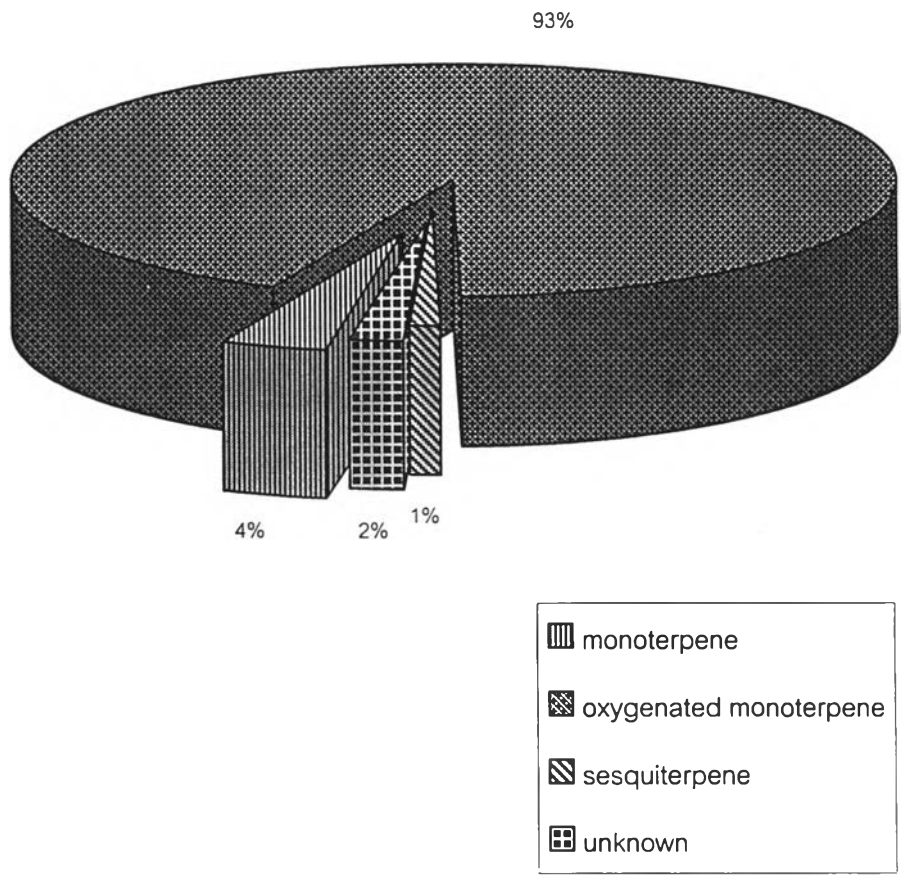


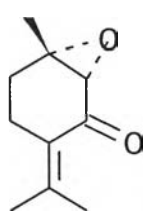
Figure 7 The percentage of various terpenoid groups found in the essential oil of *Mentha arvensis* var. *piperascens* leaves

4.1.4 Essential Oil Composition of *Mentha cordifolia* Opiz

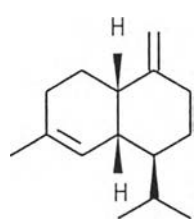
The essential oil from the leaves of *Mentha cordifolia* Opiz was isolated by hydrodistillation. The oil yield was found to be 0.01 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed 37 peaks (Fig 8). These peaks were identified as 5 monoterpenes, 7 oxygenated monoterpenes, 11 sesquiterpenes and 5 oxygenated sesquiterpenes (Table 6). Among these, piperitenone oxide (73.20 %) appeared to be the major component, followed by γ-muurolene (5.80 %) and limonene (4.14 %).

In terms of relative amount, oxygenated monoterpenes appeared to be the major terpenoid group, accounting for 76 % of the essential oil (Fig. 9). Sesquiterpenes, monoterpenes and oxygenated sesquiterpenes were present in lesser amount, with 13%, 6%, and 2%, respectively.

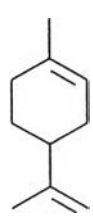
In terms of structure, the major components, piperitenone oxide and limonene, belong to the oxygenated monoterpenoid group of menthane, whereas γ–muurolene belongs to the sesquiterpenoid group of cadinane, respectively.



piperitenone oxide
(*menthane*)



γ-muurolene
(cadinane)



limonene
(menthane)

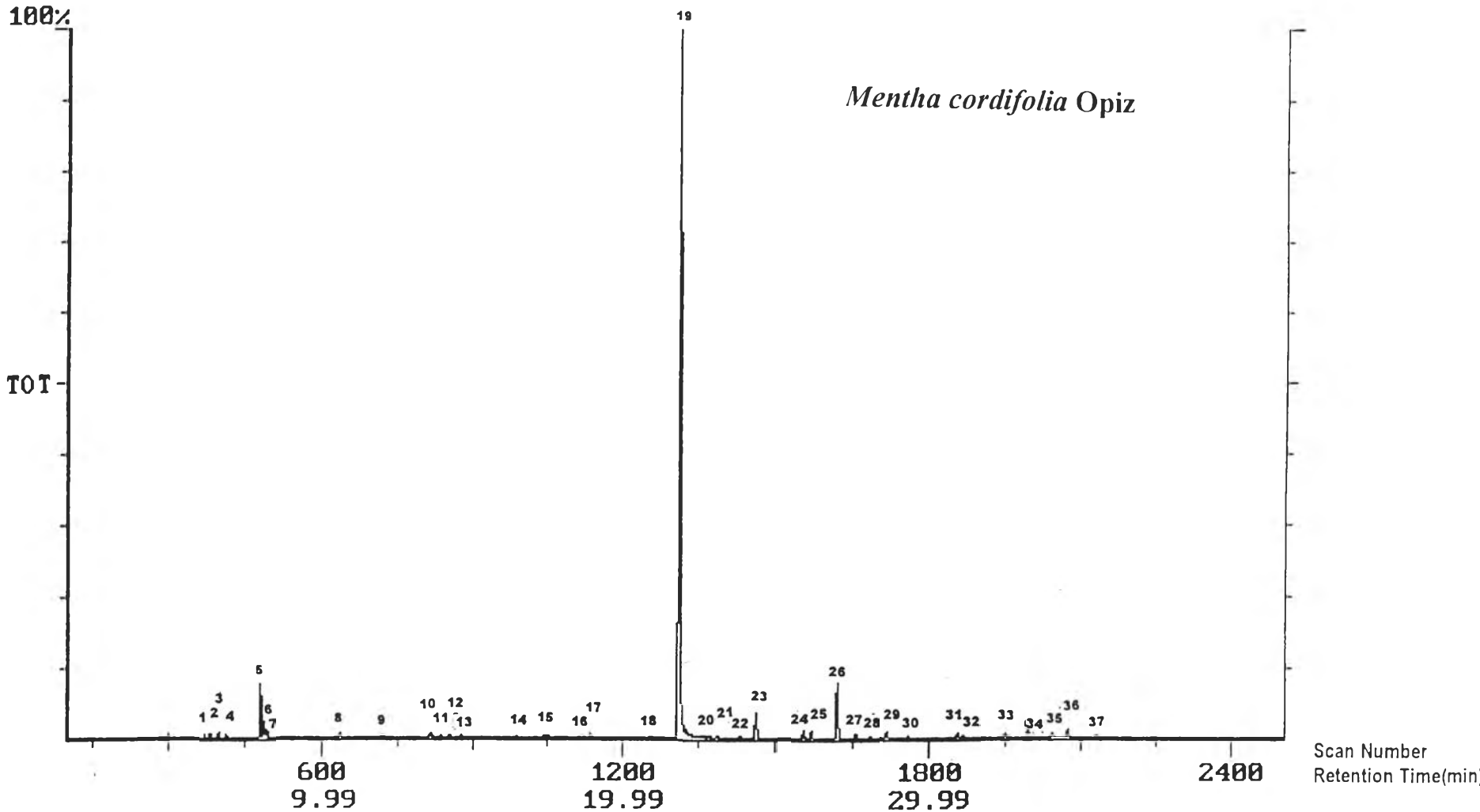


Figure 8 GC chromatogram of the essential oil from *Mentha cordifolia* leaves

Table 6 Essential oil composition of *Mentha cordifolia* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	sabinene	6.35	0.25
2	β-pinene	6.41	0.34
3	myrcene	6.90	0.58
5	limonene	8.01	4.14
7	(*Z*)-β-ocimene	8.23	0.74
	Oxygenated monoterpene		
6	1,8-cineole	8.13	1.32
8	linalool	10.63	0.49
10	borneol	13.58	0.50
11	terpin-4-ol	13.96	0.11
13	α-terpineol	14.21	0.17
18	piperitenone	20.86	0.20
19	piperitenone oxide	21.83	73.20
	Sesquiterpene		
20	β-bourbonene	22.58	0.46
21	β-elemene	23.11	0.37
22	α-gurjunene	23.86	0.18
23	(*E*)-caryophyllene	24.36	2.47
24	α-humulene	25.91	0.85
25	*cis*-muurola-4(14), 5-diene	26.10	0.82
26	γ-muurolene	26.43	5.80
27	bicyclogermacrene	27.61	0.37
28	germacrene A	27.89	0.26
29	*cis*-calamenene	28.61	0.84
30	α-cadinene	28.88	0.18

Table 6 Essential oil composition of *Mentha cordifolia* leaves (continued)

Number of peak	Compound	Retention time (min)	% Area
	Oxygenated sesquiterpene		
31	spathulenol	30.91	0.42
32	caryophyllene oxide	31.10	0.17
33	1-*epi*-cubenol	32.48	0.61
34	*epi*-α-cadinol	33.56	0.12
35	α-cadinol	34.04	0.65
	Long Chain hydrocarbon		
4	3-octanol	7.37	0.42
	Miscellaneous		
9	unknown	12.01	0.28
12	unknown	14.28	0.31
14	unknown	16.41	0.35
15	unknown	17.38	0.23
16	unknown	18.66	0.12
17	unknown	18.91	0.41
36	unknown	34.56	1.04
37	unknown	35.49	0.23

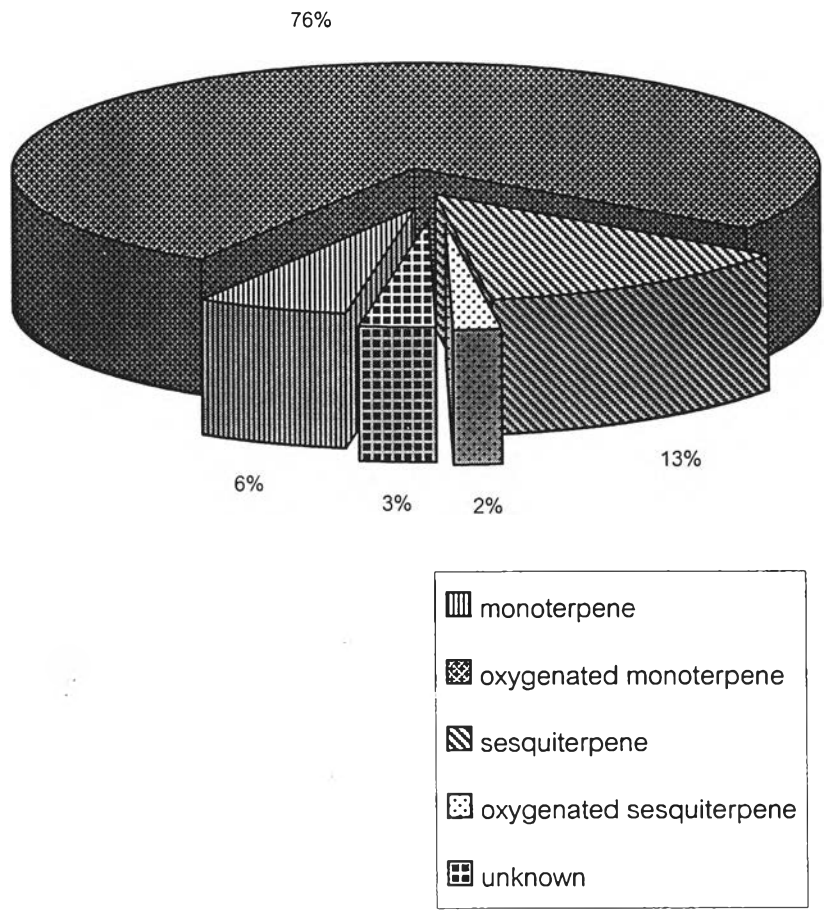


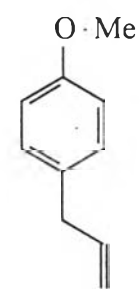
Figure 9 The percentage of various terpenoid groups found in the essential oil of *Mentha cordifolia* leaves

4.1.5 Essential Oil Composition of *Ocimum basilicum* L.

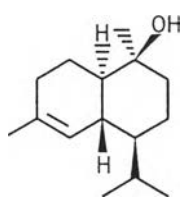
The yield of the essential oil isolated from *Ocimum basilicum* leaves was found to be 0.1 % (v/w) of fresh weight. GC/MS analysis of the essential oil showed that there were 24 components in the oil (Fig. 10). These peaks were identified as 3 monoterpenes, 3 oxygenated monoterpenes, 11 sesquiterpenes, 3 oxygenated sesquiterpenes and 2 non-terpenoid components (Table 7). Among these, methyl chavicol (88.40 %) appeared to be the major component , followed by *epi*-α-cadinol (2.38 %) and α-*trans*-bergamotene (1.98 %).

Quantitatively, the phenylpropanoid appeared to be the major group, accounting for 89 % of the essential oil (Fig. 11). Sesquiterpenoids, oxygenated sesquiterpenoids, monoterpenoids and oxygenated monoterpenoids were present in lesser amount, at 5 %, 3 %, 2 % and 1 %, respectively.

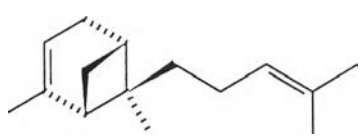
Structurally, the major component, methylchavicol, belongs to the phenylpropanoid group, whereas *epi*-α-cadinol and α-*trans*-bergamotene belong to the sesquiterpenoid group of cadinane and bicyclic sesquiterpene, respectively.



methylchavicol
(*phenylpropane*)



epi-α-cadinol
(*cadinane*)



α-trans-bergamotene
(*bicylic sesquiterpene*)

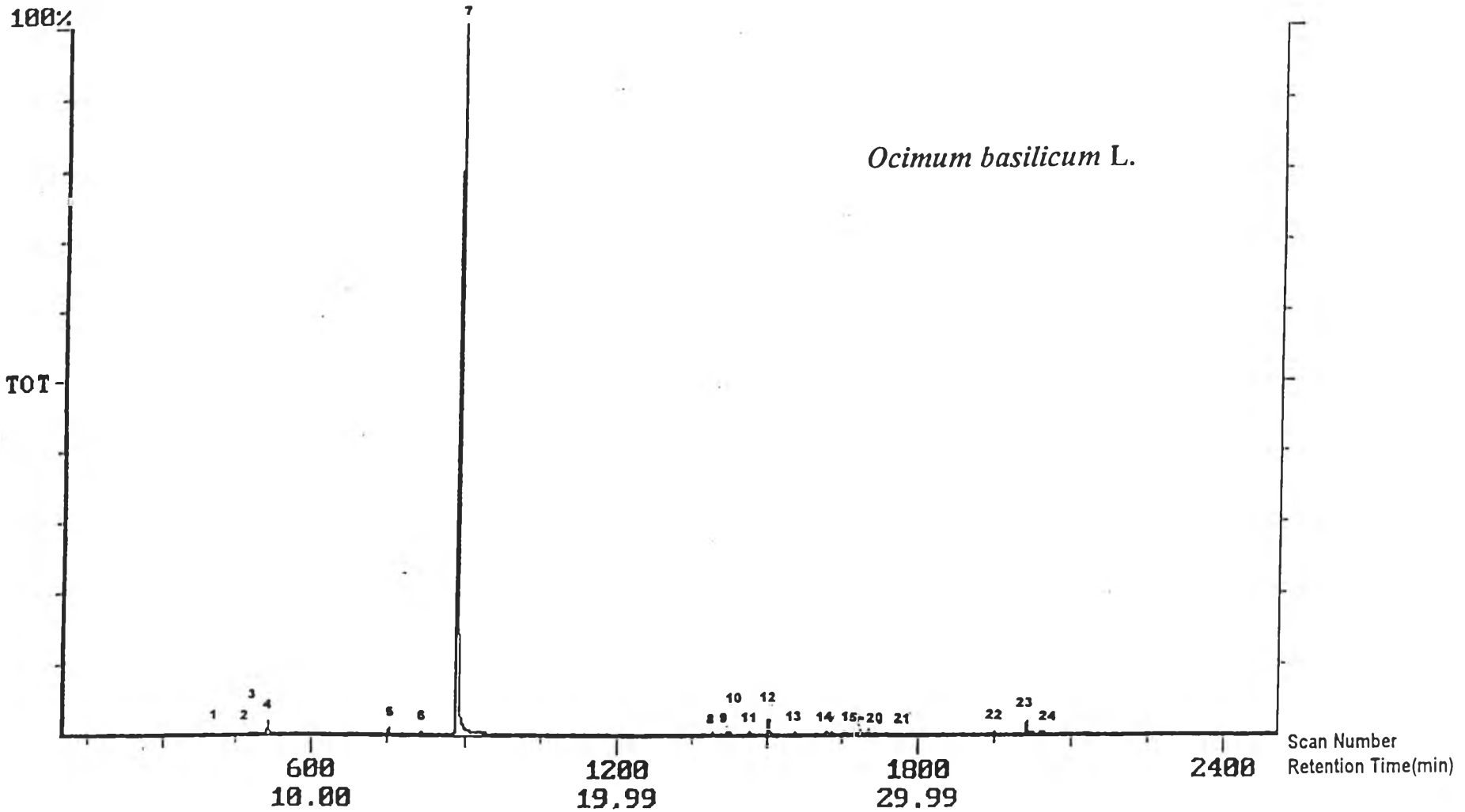


Figure 10 GC chromatogram of the essential oil from *Ocimum basilicum* leaves

Table 7 Essential oil composition of *Ocimum basilicum* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	myrcene	6.90	0.11
2	limonene	8.01	0.15
4	*(E)*-β-ocimene	8.59	1.29
	Oxygenated monoterpene		
3	1,8-cineole	8.13	0.31
5	camphor	12.56	0.71
6	borneol	13.61	0.16
	sesquiterpene		
8	β-elemene	23.13	0.15
11	(*E*)-caryophyllene	24.38	0.18
12	α-*trans*-bergamotene	25.01	1.98
13	α-humulene	25.91	0.25
14	germacrene D	26.56	0.38
15	*(Z)*-α-bisabolene	27.59	0.13
16	β-bisabolene	27.78	0.35
17	germacrene A	27.88	0.27
18	α-bulnesene	28.00	0.41
19	γ-cadinene	28.04	0.54
20	δ-cadinene	28.58	0.17
	Oxygenated sesquiterpene		
22	*l-epi*-cubenol	32.48	0.24
23	*epi*-α-cadinol	33.54	2.38
24	α-cadinol	34.04	0.41

Table 7 Essential oil composition of *Ocimum basilicum* leaves (continued)

Number of peak	Compound	Retention time (min)	% Area
	Phenyl propane		
7	methy chavicol	14.73	88.40
9	methyl eugenol	23.66	0.75
	Miscellaneous		
10	unknown	24.18	0.14
21	unknown	29.19	0.14

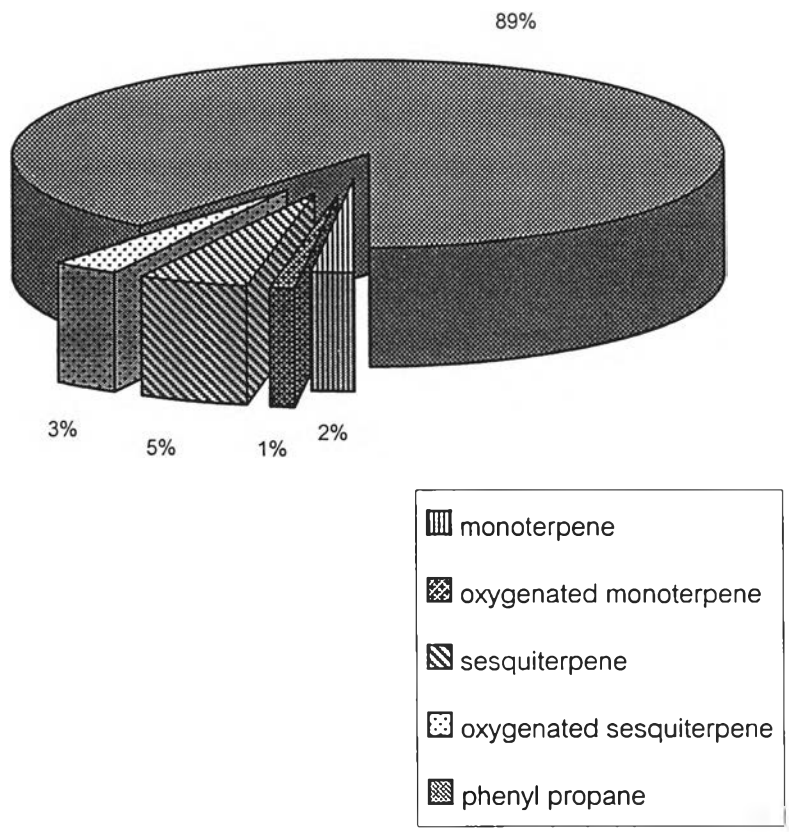


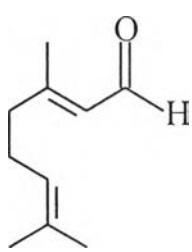
Figure 11 The percentage of various terpenoid groups found in the essential oil of *Ocimum basilicum* leaves

4.1.6 Essential Oil Composition of *Ocimum canum* Sims.

By hydrodistillation, the yield of the essential oil from *Ocimum canum* leaves was found to be 0.2 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed 35 separate peaks (Fig.12). These peaks were identified as 5 monoterpenes, 12 oxygenated monoterpenes, 11 sesquiterpenes, 2 oxygenated sesquiterpenes and 1 non-terpenoid component (Table 8). Among these, geranial (22.36 %) appeared to be the major component, followed by geranyl acetate (13.10 %) and (*E*)-caryophyllene (9.55 %).

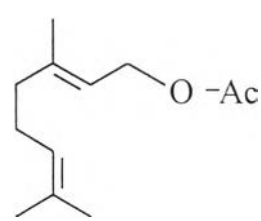
These major components were in the oxygenated monoterpenoid group, accounting for 49 % of the essential oil (Fig.13). Sesquiterpenes, monoterpenes and oxygenated sesquiterpenes were present in lesser amount, at 26 %, 3 %,1 %, respectively.

In terms of structure, the major components, geranial and geranyl acetate, belong to the oxygenated monoterpenoid group of acyclic monoterpenoid whereas *(E)*-caryophyllene belongs to sesquiterpenoid group of caryophilane.



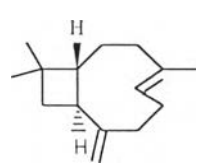
geranial

(*acyclic monoterpenoid*)



geranyl acetate

(*acyclic monoterpenoid*)



(*E*)-caryophyllene

(*caryophilane*)

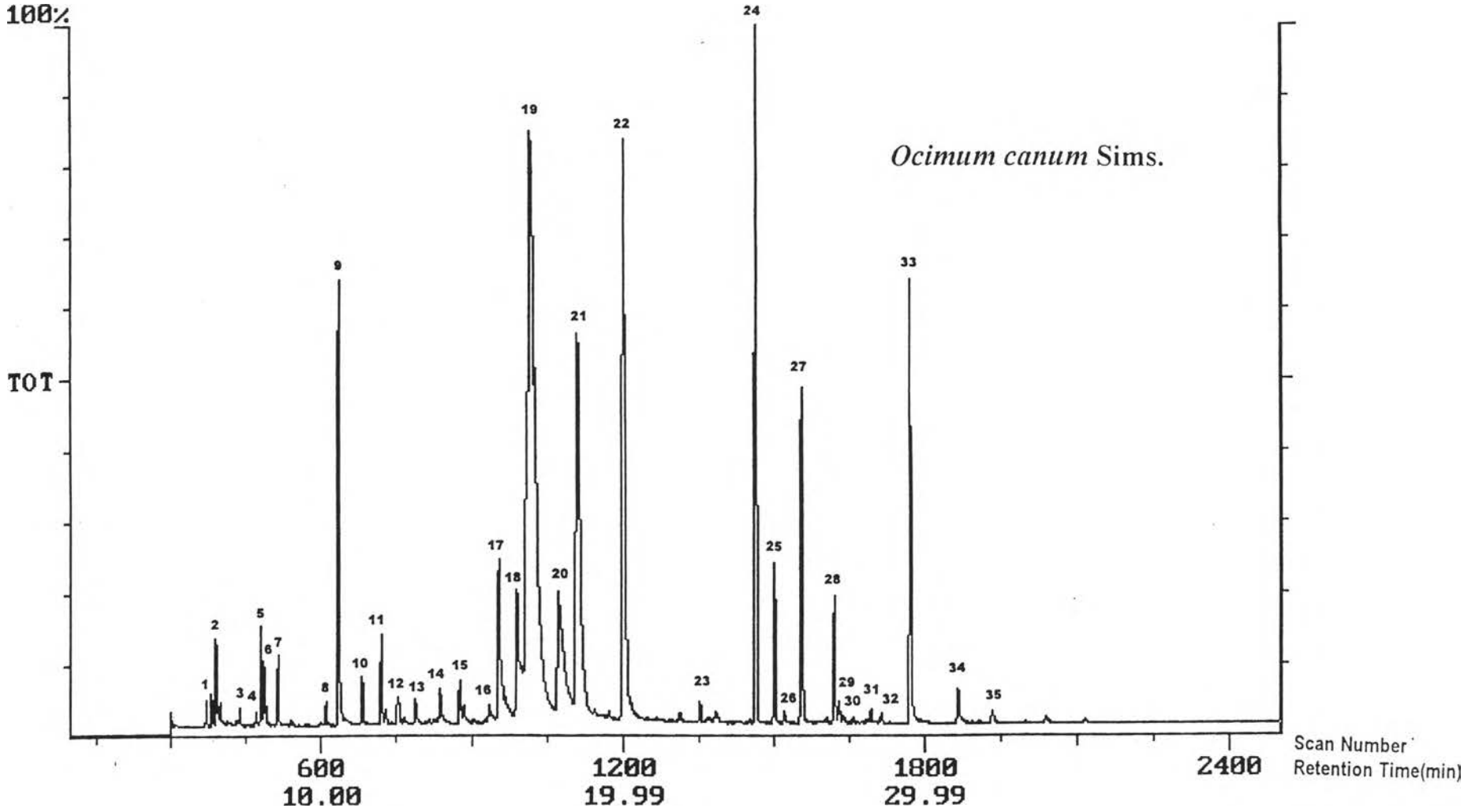


Figure 12 GC chromatogram of the essential oil from *Ocimum canum* leaves

Table 8 Essential oil composition of *Ocimum canum* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	sabinene	6.35	0.26
3	δ-3-carene	7.40	0.14
4	*o*-cymene	7.75	0.13
5	limonene	8.01	1.11
7	(*E*)-β-ocimene	8.60	0.78
	Oxygenated monoterpene		
6	1,8-cineole	8.13	0.63
8	fenchone	10.08	0.21
9	linalool	10.63	5.42
10	(*exo*)-fenchol	11.40	0.56
12	β-pinene oxide	12.76	0.57
13	*trans*-verbenol	13.06	0.36
14	*cis*-chrysanthenol	13.33	0.60
15	α-terpineol	14.21	0.66
17	linalool acetate	15.88	2.98
18	*cis*-carveol	16.48	1.70
19	geranial	17.81	22.36
22	geranyl acetate	21.15	13.10
	Sesquiterpene		
23	α-copaene	22.51	0.30
24	(*E*)-caryophyllene	24.36	9.55
25	α-*trans*-bergamotene	25.00	2.26
26	(*Z*)-β-farnesene	25.34	0.17
27	α-humulene	25.89	4.81
28	γ-muurolene	26.43	1.88

Table 8 Essential oil composition of *Ocimum canum* leaves (continued)

Number of peak	Compound	Retention time (min)	% Area
29	*β*-selinene	26.80	0.32
30	*α*-selinene	27.18	0.10
31	*β*-bisabolene	27.78	0.20
32	*δ*-cadinene	28.56	0.14
33	germacrene B	29.51	6.57
	Oxygenated sesquiterpene		
34	caryophyllene oxide	31.09	0.70
35	humulene epoxide II	32.23	0.22
	Phenyl propane		
16	methyl chavicol	14.73	0.38
	Long chain hydrocarbon		
2	*6-methyl-5*-hepten-2-one	6.53	1.14
	Miscellaneous		
11	unknown	12.05	1.13
20	unknown	18.45	5.57
21	unknown	19.96	12.98

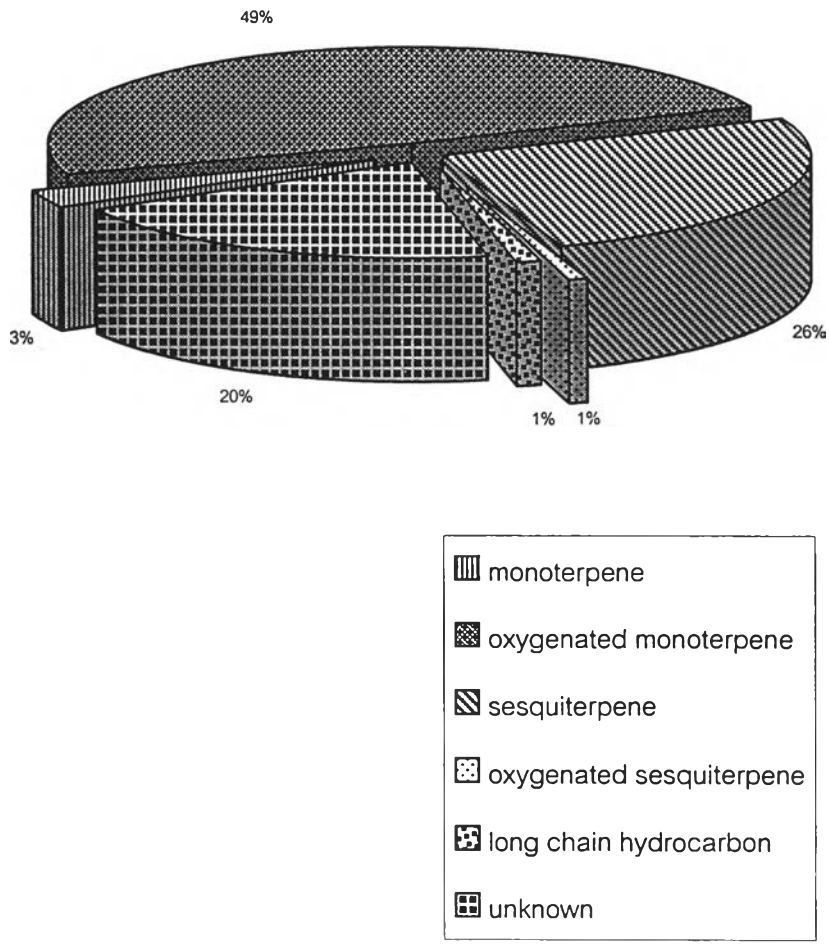


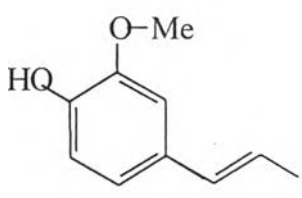
Figure 13 The percentage of various terpenoid groups found in the essential oil of *Ocimum canum* leaves

4.1.7 Essential Oil Composition of *Ocimum gratissimum* L.

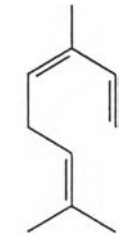
The yield of essential oil isolated from *Ocimum gratissimum* leaves was found to be 0.3 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed 18 peaks (Fig.14). These peaks were identified as 4 monoterpenes, 1 oxygenated monoterpene, 12 sesquiterpenes and 1 non-terpenoid compound (Table 9). Among these, (*E*)-isoeugenol (58.92 %) was found to be the major component, followed by (*Z*)-*β*-ocimene (20.35 %) and germacrene D (7.66 %).

In terms of relative amount, the phenylpropanoid appeared to be the major group, accounting for 59 % of the essential oil (Fig. 15). Monoterpenoids, sesquiterpenoids and oxygenated monoterpenoids were present in lesser amount, with 22 %, 18 % and 1 % , respectively (Fig. 15).

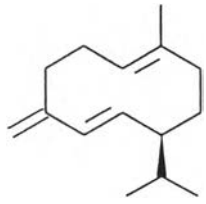
Structurally, (*E*)-isoeugenol is a phenylpropanoid compound. (*Z*)-*β*-ocimene belongs to the group of acyclic monoterpenoid, while germacrene D belongs to the group of sesquiterpenoid of simple germacrane respectively.



(E)-isoeugenol
(*phenylpropane*)



(*Z*)-*β*-ocimene
(acyclic monoterpenoid)



germacrene D
(*simple germacrane*)

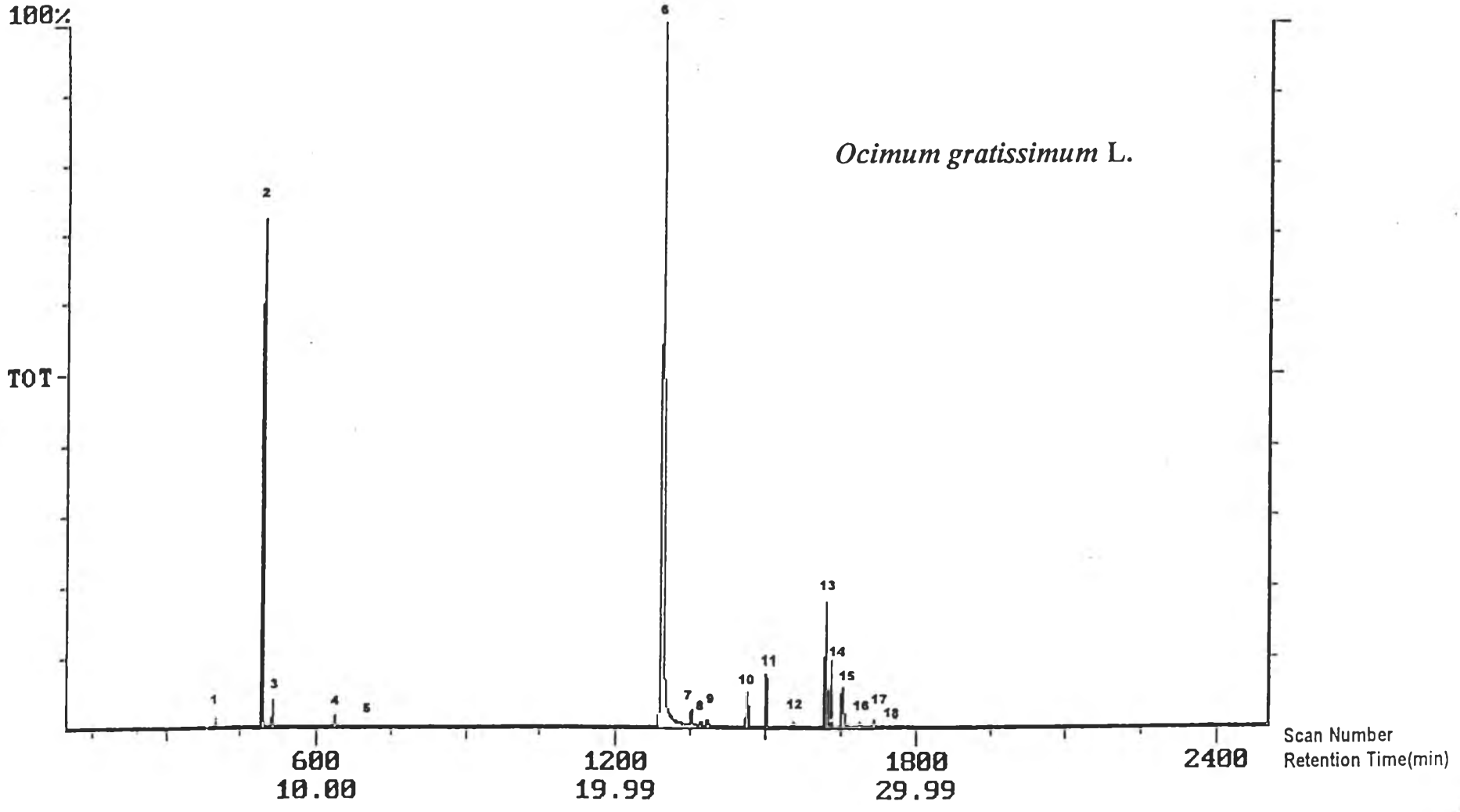


Figure 14 GC chromatogram of the essential oil from *Ocimum gratissmum* leaves

Table 9 Essential oil composition of *Ocimum gratissimum* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	myrcene	6.90	0.29
2	*(Z)*-*β*-ocimene	8.23	20.35
3	*(E)*-*β*-ocimene	8.59	1.13
5	*neo-allo*-ocimene	11.76	0.07
	Oxygenated monoterpene		
4	linalool	10.63	0.64
	Sesquiterpene		
7	*α*-copaene	22.51	0.83
8	*β*-bourbonene	22.60	0.15
9	*β*-cubebene	23.06	0.11
10	(*E*)-caryophyllene	24.38	2.19
11	*α-trans*-bergamotene	25.03	3.28
12	*α*-humulene	25.91	0.24
13	germacrene D	26.56	7.65
14	*β*-selinene	26.80	0.35
15	*(E,E)*-*α*-farnesene	27.73	2.94
16	germacrene A	27.90	0.26
17	*δ*-cadinene	28.58	0.41
18	*β*-sesquiphellandrene	28.84	0.18
	Phenyl propane		
6	(*E*)-isoeugenol	21.53	58.92

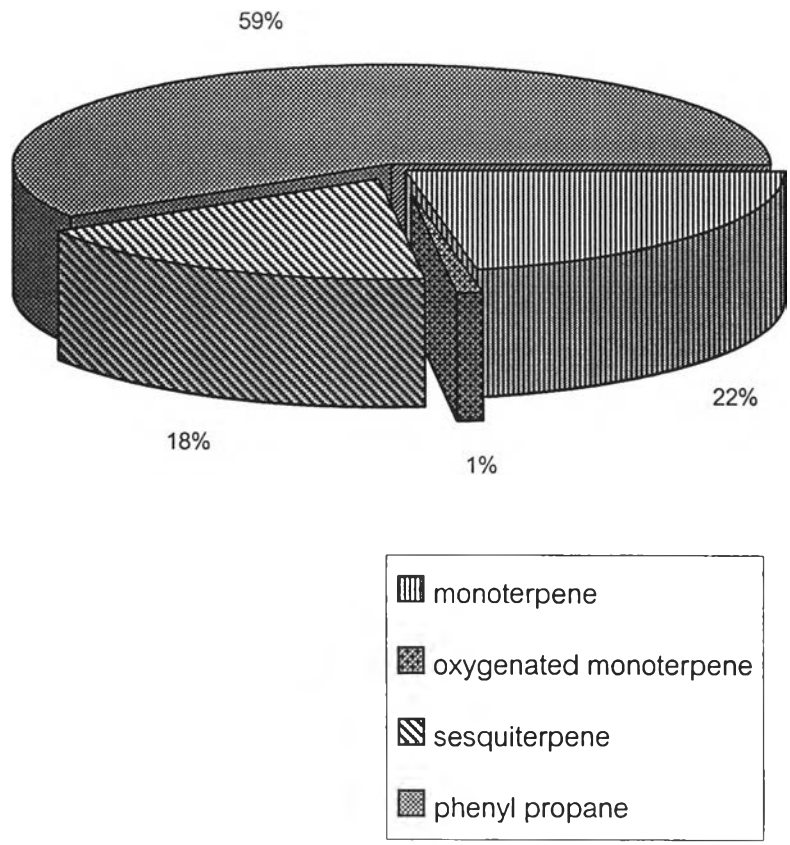


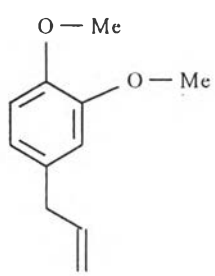
Figure 15 The percentage of various terpenoid groups found in the essential oil of *Ocimum gratissimum* leaves

4.1.8 Esssential Oil Composition of *Ocimum sanctum* L.

The yield of essential oil hydrodistilled from *Ocimum sanctum* L. leaves was found to be 0.2 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed 18 peaks (Fig. 16). These peaks were identified as 5 monoterpenes, 3 oxygenated monoterpenes, 8 sesquiterpenes and 2 non-terpenoid components (Table 10). Among these, methyl eugenol (46.08 %) was found to be the major component, followed by 9-*epi* (*E*)-caryophyllene (23.69 %) and eugenol (19.18 %).

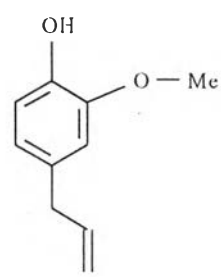
Quantitatively, the phenylpropanoid appeared to be the major group, accounting for 65% of the essential oil. Sesquiterpenoids, oxygenated monoterpenoids and monoterpenoids were present in lesser amount, with 33 %, 1 % and 1 %, respectively (Fig. 17).

Structurally, the major components, methyl eugenol and eugenol belong to the phenylpropanoid group, whereas 9-*epi* (*E*)-caryophyllene belongs to the group of sesquiterpenoid of caryophilane.



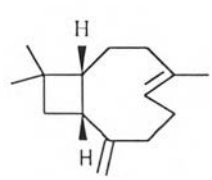
methyl eugenol

(phenyl propane)



eugenol

(phenyl propane)



9-*epi* (*E*)-caryophyllene

(caryophilane)

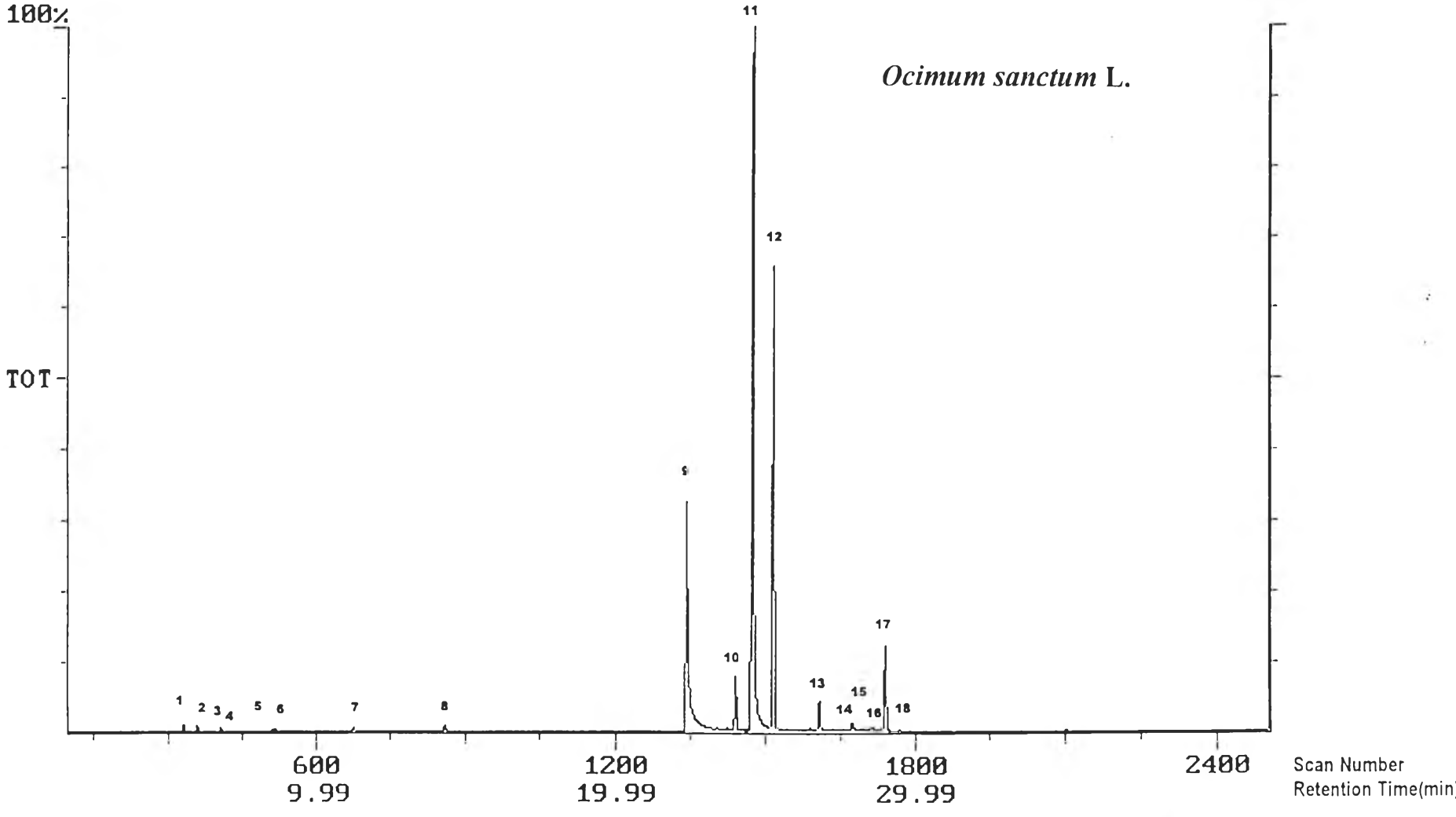


Figure 16 GC chromatogram of the essential oil from *Ocimum sanctum* leaves

Table 10 Esssential oil composition of *Ocimum sanctum* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	α-thujene	5.50	0.20
2	camphene	5.66	0.21
3	sabinene	6.35	t
4	β-pinene	6.41	0.14
5	limonene	8.01	0.07
	Oxygenated monoterpene		
6	1,8-cineole	8.13	0.07
7	linalool	10.63	0.32
8	borneol	13.61	0.55
	Sesquiterpene		
10	β-elemene	23.09	2.65
12	9-*epi* (*E*)-caryophyllene	25.43	23.69
13	α-humulene	25.91	1.53
14	γ-muurolene	26.43	0.39
15	β-selinene	26.80	0.12
16	α-selinene	27.18	0.14
17	α-bulnesene	28.00	4.51
18	δ-cadinene	28.56	0.11
	Phenyl propane		
9	eugenol	21.31	19.18
11	methyl eugenol	23.66	46.08

t = trace

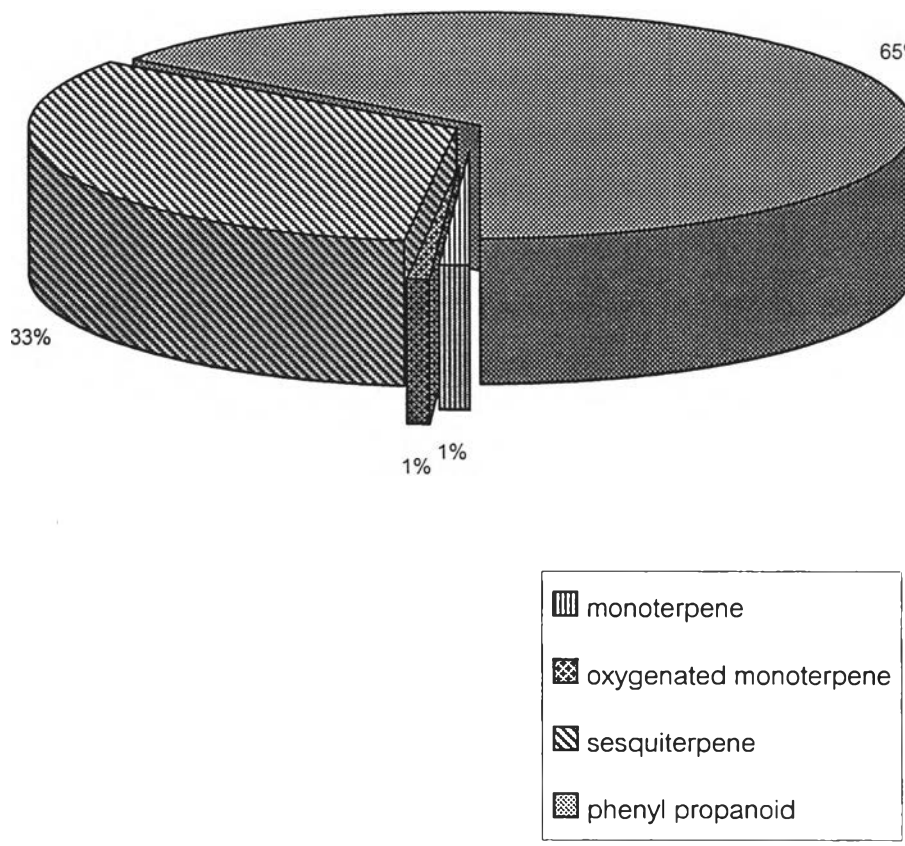


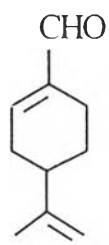
Figure 17 The percentage of various terpenoid groups found in the essential oil of *Ocimum sanctum* leaves

4.1.9 Essential Oil Composition of *Perilla frutescens* Britt.

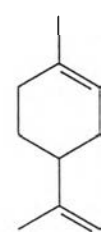
By hydrodistillation, the yield of the essential oil from *Perilla frutescens* leaves was found to be 0.1 % (v / w) of fresh weight. GC/MS analysis of the essential oil showed 19 peaks (Fig. 18). These peaks were identified as 4 monoterpenes, 7 oxygenated monoterpenes and 5 sesquiterpenes (Table 11). Among these, perilla aldehyde (57.31 %) was found to be the major component, followed by limonene (20.22 %) and piperitone (7.85 %).

In terms of relative amount, oxygenated monoterpenes appeared to be the major terpenoid group, accounting for 67 % of the essential oil (Fig. 19). Monoterpenes and sesquiterpenes were present in lesser content, with 21 % and 9 %, respectively.

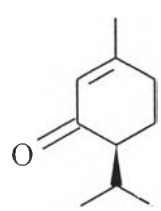
In terms of structure, the major components, perilla aldehyde, piperitone and limonene, belong to the oxygenated monoterpenoid and monoterpenoid groups of menthane.



perilla aldehyde
(*menthane*)



limonene
(*menthane*)



piperitone
(*menthane*)

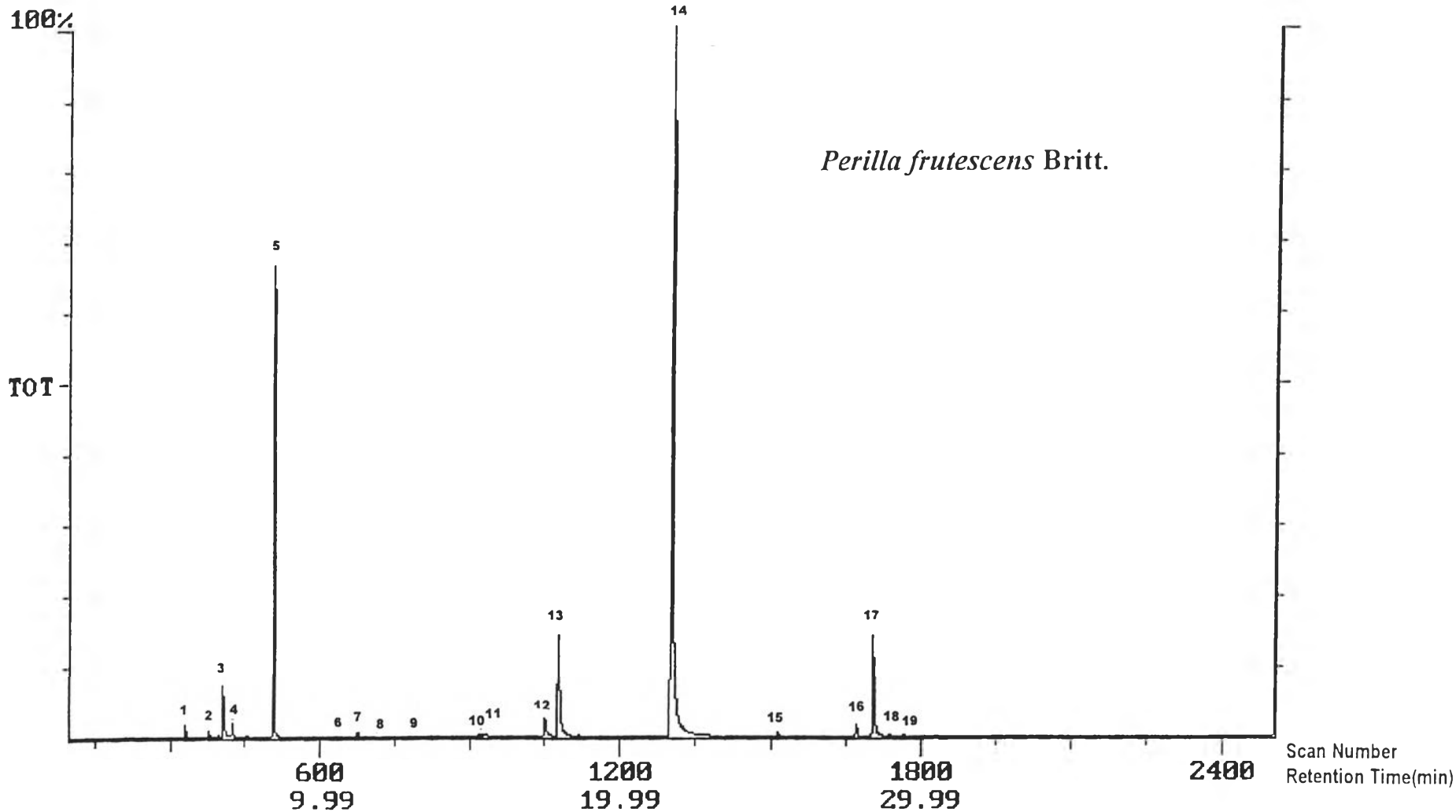


Figure 18 GC chromatogram of the essential oil from *Perilla frutescens* leaves

Table 11 Essential oil composition of *Perilla frutescens* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	α-thujene	5.50	0.41
4	myrcene	6.90	0.50
5	limonene	8.01	20.22
6	terpinolene	10.13	0.08
	Oxygenated monoterpene		
8	linalool	10.63	0.39
9	camphor	12.55	t
10	α-terpineol	14.25	0.12
11	dihydro carveol	15.73	0.08
12	carvone	17.86	1.66
13	piperitone	17.93	7.85
14	perilla aldehyde	21.69	57.31
	Sesquiterpene		
15	*9-epi-(E)*-caryophyllene	25.39	0.23
16	germacrene D	26.56	0.78
17	*(E,E)*-α-farnesene	27.73	7.29
18	germacrene A	27.89	0.18
19	δ-cadinene	28.56	0.09
	Miscellaneous		
2	benzaldehyde	6.31	0.35
3	unknown	6.79	2.38
7	dimethyl styrene isomer # 1	10.83	t

t = trace

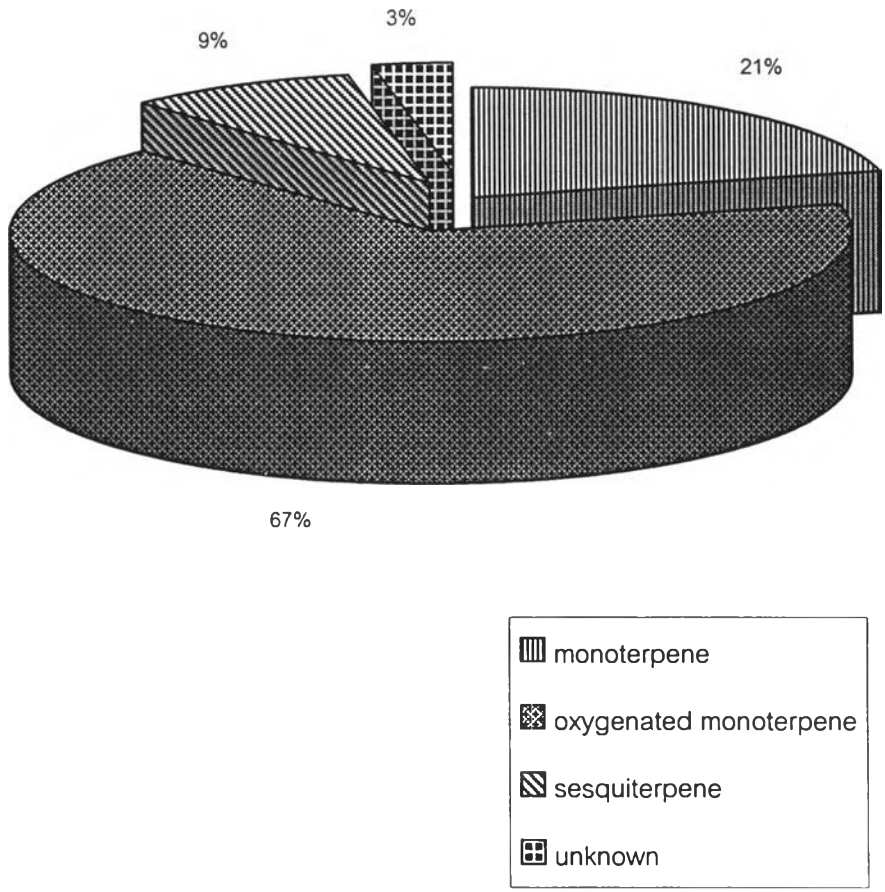


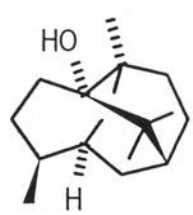
Figure 19 The percentage of various terpenoid groups found in the essential oil of *Perilla frutescens* leaves

4.1.10 Essential Oil Composition of *Pogostemon cablin* Benth.

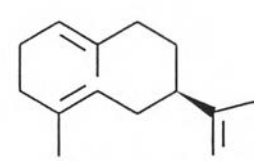
The essential oil from the leaves of *Pogostemon cablin* Benth. was isolated by hydrodistillation. The oil yield was found to be 0.30 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed 23 peaks (Fig. 20). These peaks were identified as 18 sesquiterpenes, 3 oxygenated sesquiterpenes (Table 12). Among these, patchouli alcohol (60.30 %) appeared to be the major component, followed by germacrene A (11.73 %).

In terms of relative amount, the oxygenated sesquiterpenes appeared to be the major terpenoid group, accounting for 65 % of the essential oil and sesquiterpenes were present in a lesser content 35 %. (Fig.21)

In terms of structure, the major components, patchouli alcohol and germacrene A, belong to the sesquiterpenoid group of rearranged patchoulane and simple germacrane, respectively.



patchouli alcohol
(rearranged patchoulane)



germacrene A
(simple germacrane)

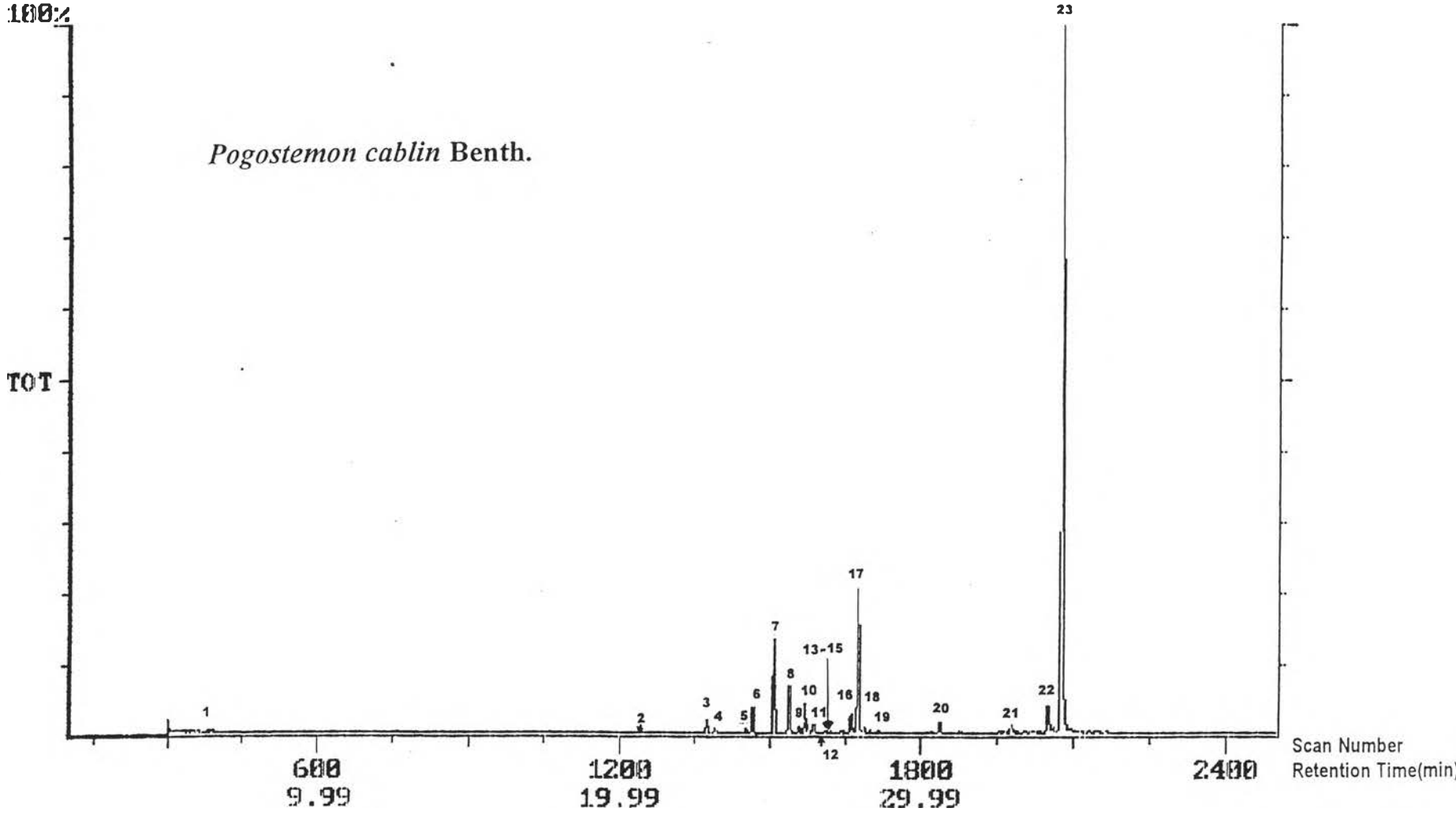


Figure 20 GC chromatogram of the essential oil from *Pogostemon cablin* leaves

Table 12 Essential oil composition of *Pogostemon cablin* leaves

Number of peak	Compound	Retention time (min)	% Area
	Sesquiterpene		
2	δ-elemene	20.79	t
3	β-patchoulene	22.90	t
4	β–elemene	23.09	0.33
5	*cis*-thujopsene	24.20	0.25
6	(*E*)-caryophyllene	24.38	2.24
7	α–guaiene	24.85	7.22
8	γ-patchoulene	25.63	3.89
9	α-humulene	25.91	0.48
10	α-patchoulene	26.15	2.27
11	seychellene	26.28	0.98
12	valencene	26.45	0.85
13	germacrene D	26.56	0.15
14	β-selinene	26.80	t
15	α–selinene	27.18	0.23
16	viridiflorene	27.68	1.91
17	germacrene A	27.89	11.73
18	α-bulnesene	28.00	0.86
19	7-*epi*-α-selinene	28.59	0.17
	Oxygenated sesquiterpene		
21	longipinanol	33.01	t
22	globulol	34.18	4.62
23	patchouli alcohol	34.64	60.30
	Long chain hydrocarbon		
1	1-octen-3-ol	6.79	0.20
	Miscellaneous		
20	unknown	30.12	1.19

t=trace

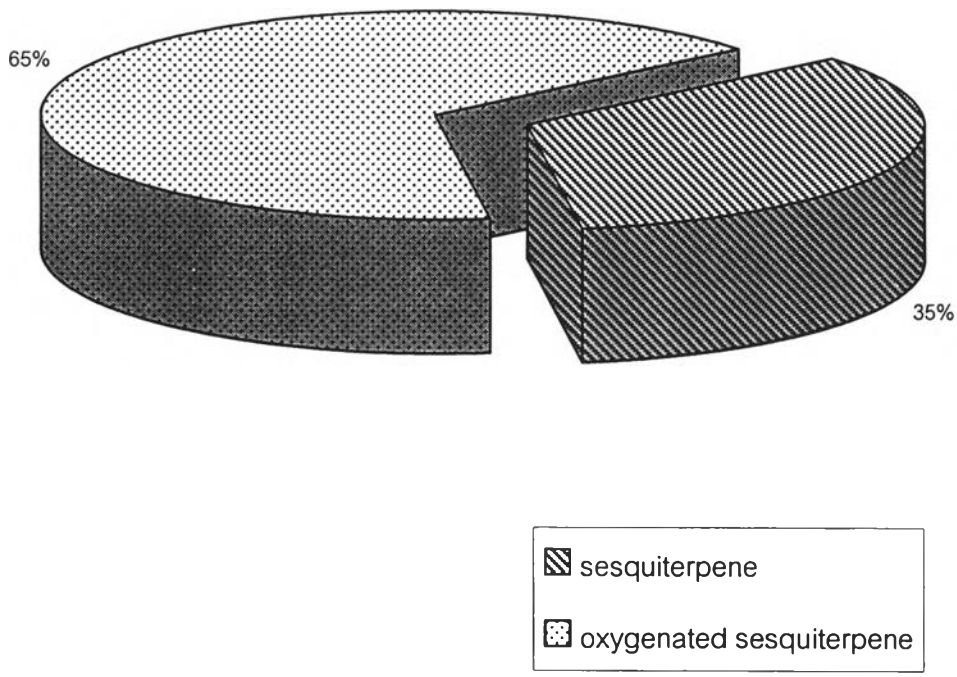


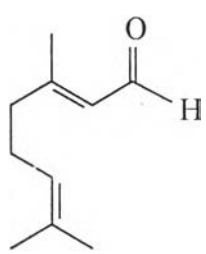
Figure 21 The percentage of various terpenoid groups found in the essential oil of *Pogostemon cablin* leaves

4.2 Chemical Composition of Essential Oil from Western Country

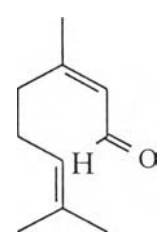
4.2.1 Essential Oil Composition of *Melissa officinalis* L.

The yield of essential oil hydrodistilled from *Melissa officinalis* leaves was found to be 0.1 % (v/w) of fresh weight. Analysis of this essential oil by GC/MS showed that there were 16 components (Fig. 22). These peaks were identified as 3 monoterpenes, 10 oxygenated monoterpenes, and 1 sesquiterpene (Table 13). Among these, geranial (40.75 %) appeared to be the major component, followed by neral (28.85 %) and terpin-4-ol (7.95 %). Therefore, the oxygenated monoterpene was found to be the major terpenoid group, accounting for 90 % of the essential oil (Fig. 23). Sesquiterpenes and monoterpenes were present in much lesser amount with 5 % and 3 %, respectively.

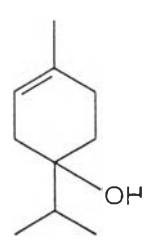
Structurally, geranial and neral belong to the oxygenated monoterpenoid group of acyclic monoterpenoid whereas terpin-4-ol belongs to the group of menthane.



geranial
(*acyclic monoterpenoid*)



neral
(*acyclic monoterpenoid*)



terpin-4-ol
(*menthane*)

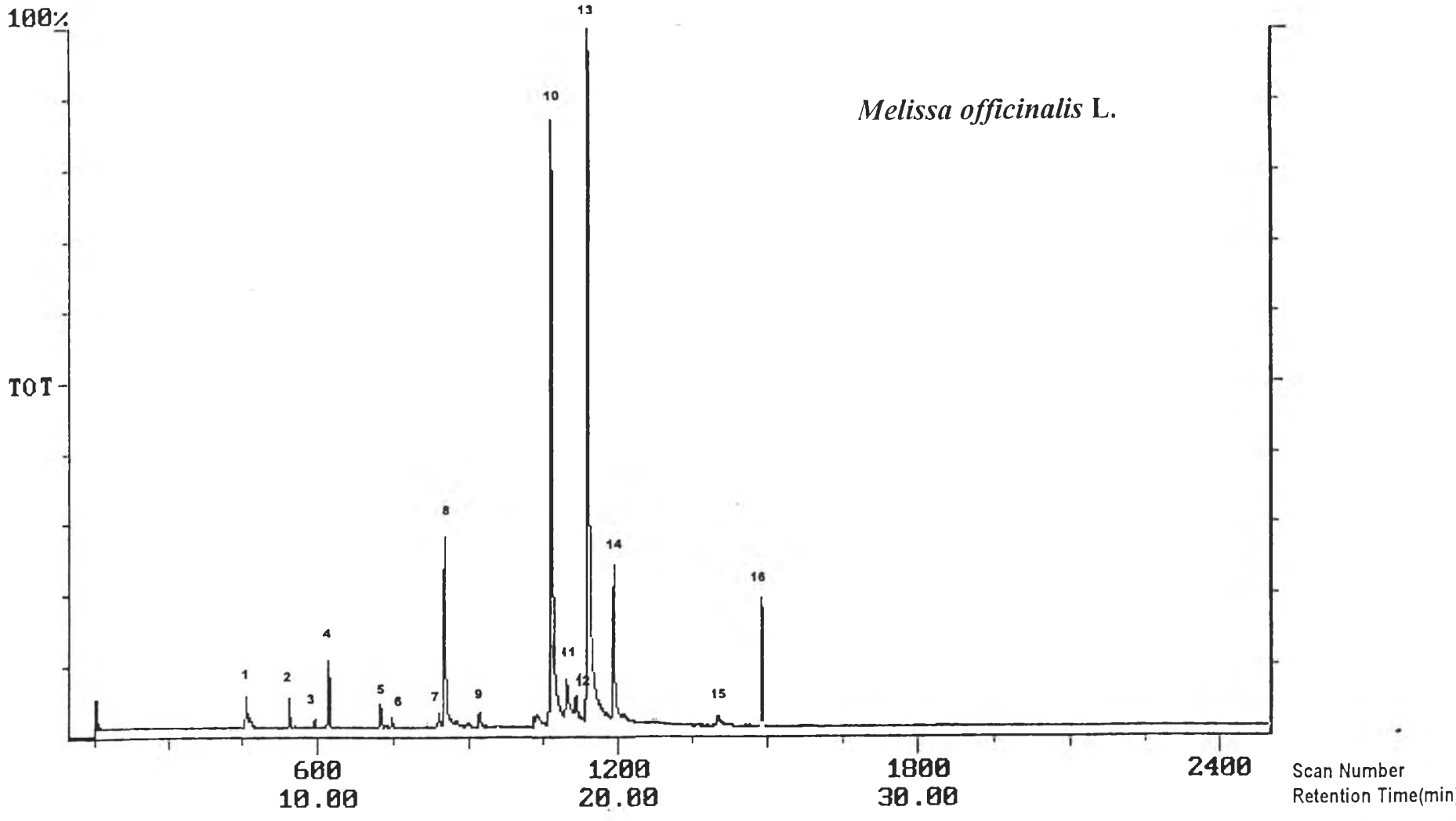


Figure 22 GC chromatogram of the essential oil from *Melissa officnalis* leaves

Table 13 Essential oil composition of *Melissa officinalis* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
2	*o*-cymene	7.75	0.73
3	γ-terpinene	9.08	0.26
4	terpinolene	10.14	2.06
	Oxygenated monoterpene		
5	isopulegol	12.13	1.04
6	citronellal	12.88	0.34
7	neo-iso-isopulegol	13.30	0.56
8	terpin-4-ol	13.94	7.95
10	neral	16.60	28.85
11	geraniol	17.01	2.77
12	methyl citronellate	17.53	0.78
13	geranial	17.81	40.75
14	thymol	20.01	6.64
15	geranyl acetate	21.15	0.64
	Sesquiterpene		
16	9-epi-*(E)*-caryophyllene	25.43	4.55
	Long chain hydrocarbon		
1	*6-methyl-5*-hepten-2-one	6.53	2.06
	Miscellaneous		
9	unknown	15.33	0.67

t = trace

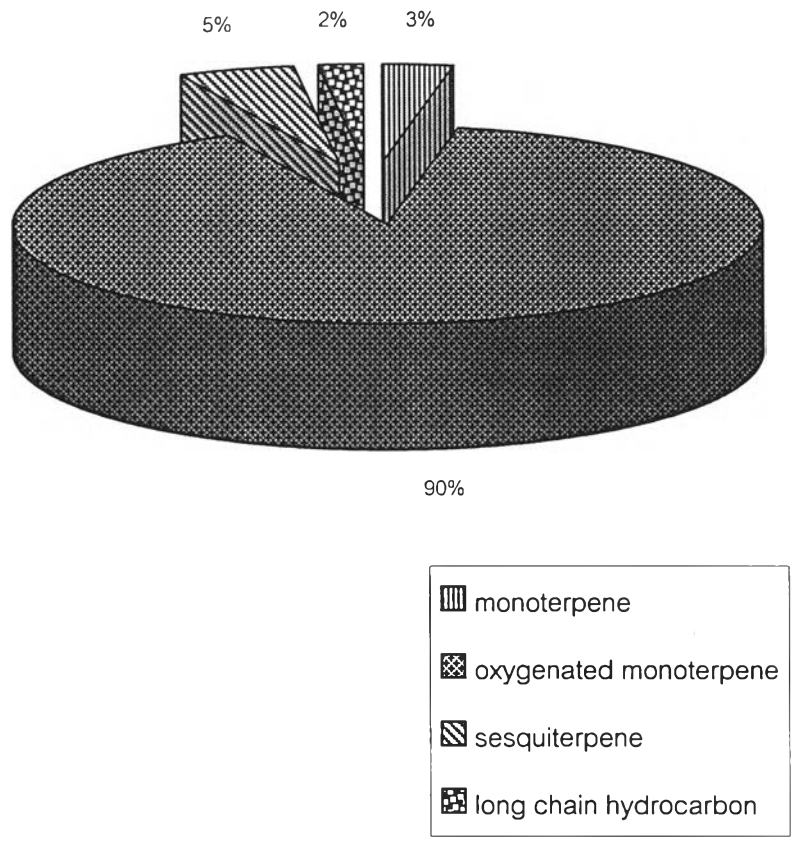
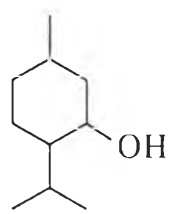


Figure 23 The percentage of various terpenoid groups found in the essential oil of *Melissa officinalis* leaves

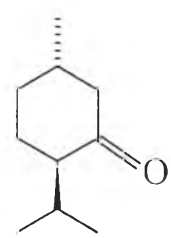
4.2.2 Essential oil composition of *Mentha piperita* L.

By hydrodistillation, the yield of the essential oil from *Mentha piperita* leaves was found to be 0.2 % (v/w) of fresh weight. GC/MS analysis of the essential oil showed 16 peaks (Fig. 24). These peaks were identified as 3 monoterpenes, 11 oxygenated monoterpenes and 2 sesquiterpenes (Table 14). Among these, menthol (30.37 %) was found to be the major component, followed by menthone (24.63 %) and isomenthyl acetate (20.46 %).

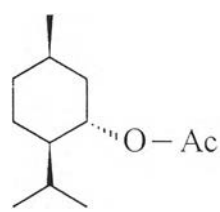
As for the component , the oxygenated monoterpene appeared to be the major terpenoid group, accounting for 99% of the essential oil (Fig. 25). Whereas the sesquiterpenoid was present in much lesser amount, at 1 %. In terms of structure, the major components, menthol, menthone and isomenthyl acetate, belong to the oxygenated monoterpenoid group of menthane.



menthol
(*menthane*)



menthone
(*menthane*)



isomenthyl acetate
(*menthane*)

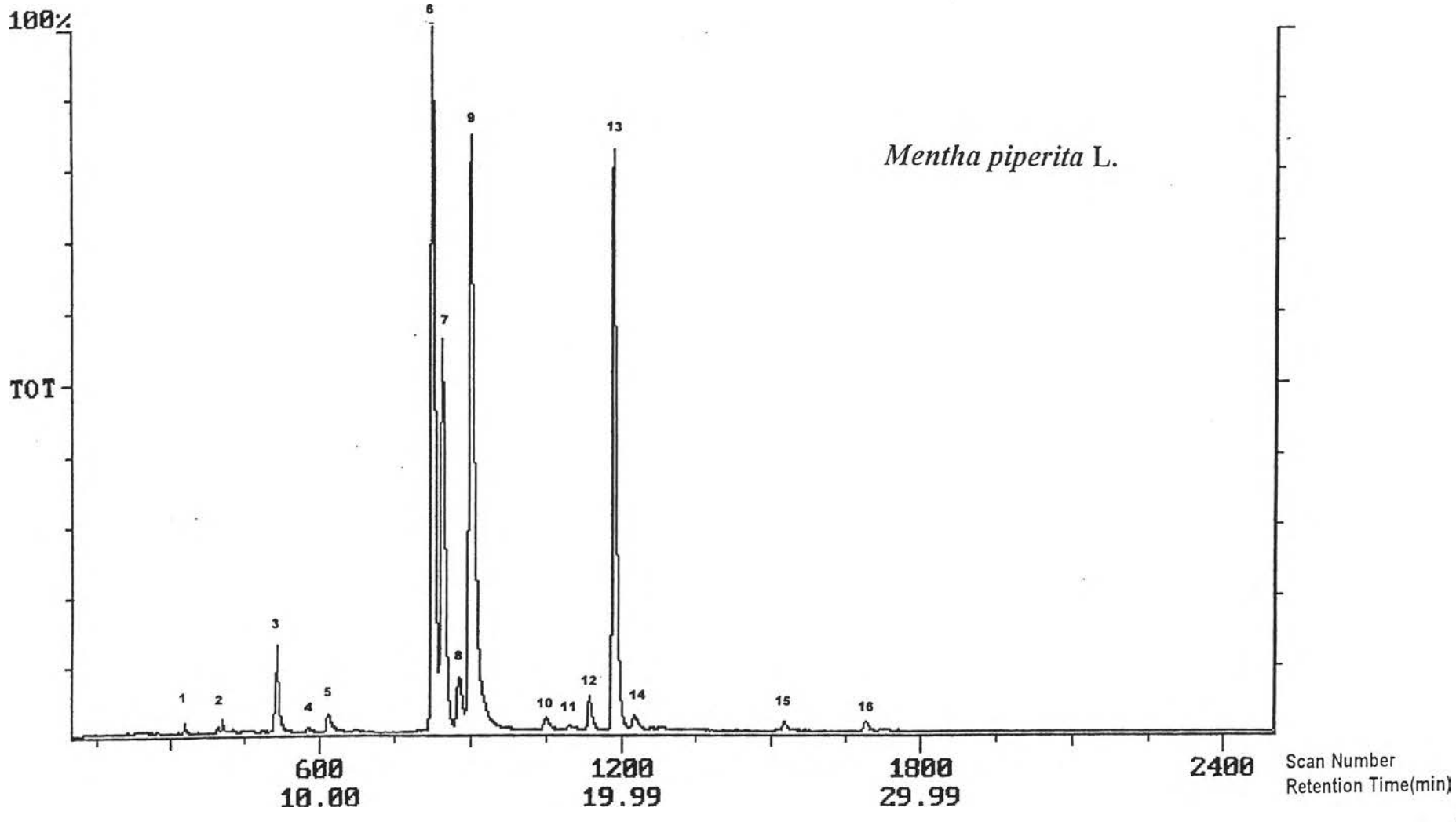


Figure 24 GC chromatogram of the essential oil from *Mentha piperita* leaves

Table 14 Essential oil composition of *Mentha piperita* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	α-thujene	5.50	0.12
2	sabinene	6.35	0.22
4	γ-terpinene	9.08	0.11
	Oxygenated monoterpene		
3	1,8-cineole	8.14	2.41
5	*trans*-sabinene hydrate	10.48	0.71
6	menthone	13.62	24.63
7	menthofuran	14.10	15.32
8	*neo*-menthol	14.23	2.25
9	menthol	14.64	30.37
10	pulegone	17.23	0.61
11	piperitone	17.95	0.17
12	menthyl acetate	18.73	1.30
13	isomenthyl acetate	19.68	20.46
14	*neo-iso*-carvomenthyl acetate	20.38	0.58
	Sesquiterpene		
15	*9-epi-(E)*-caryophyllene	25.43	0.35
16	γ-cadinene	28.04	0.39

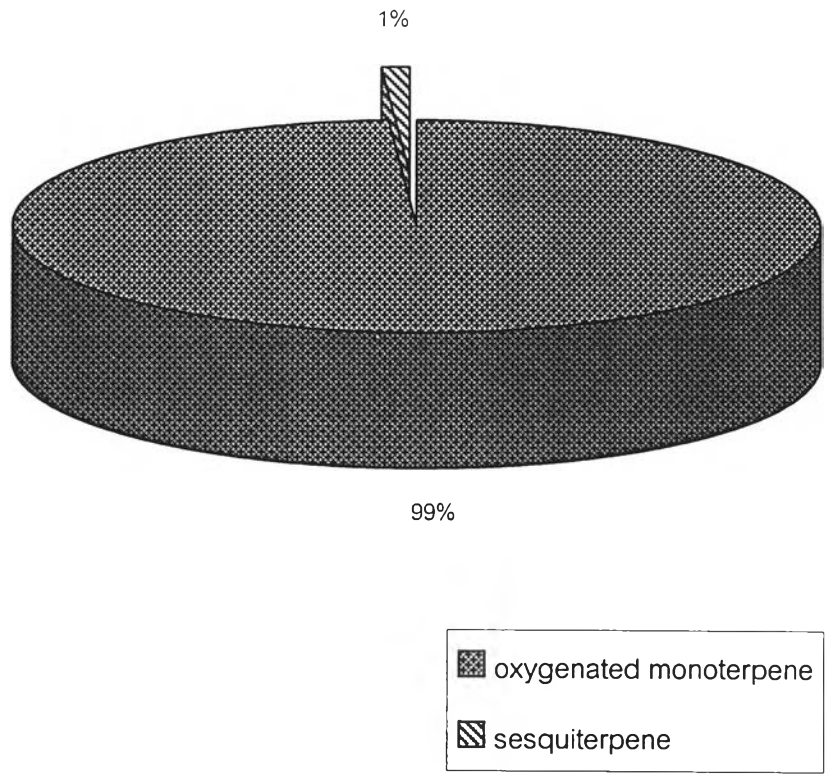
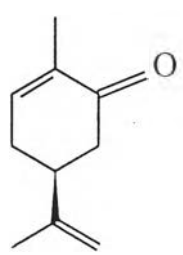


Figure 25 The percentage of various terpenoid groups found in the essential oil of *Mentha piperita* leaves

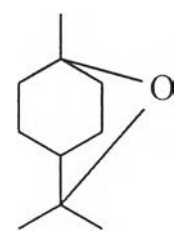
4.2.3 Essential oil Composition of *Mentha spicata* L.

The yield of the essential oil isolated from *Mentha spicata* leaves was found to be 0.3 % (v/w) of fresh weight. GC analysis of the essential oil showed that there were at least 25 components present in the oil (Fig. 26). These components were identified as 8 monoterpenes, 9 oxygenated monoterpenes and 5 sesquiterpenes (Table 15). Among these, carvone (57.68 %) was found to be the major components contributed greatly to the overall oxygenated monoterpenoids content which appeared to be the major terpenoid group, accounting for 91 % of the essential oil (Fig. 27). This was followed by the sesquiterpenes and monoterpenes were present in much lesser amount, with 4 % and 4 %.

In terms of structure type, the major components, carvone and 1,8-cineole, belong to the oxygenated monoterpenoid group of menthane.



carvone
(*menthane*)



1,8-cineole
(*menthane*)

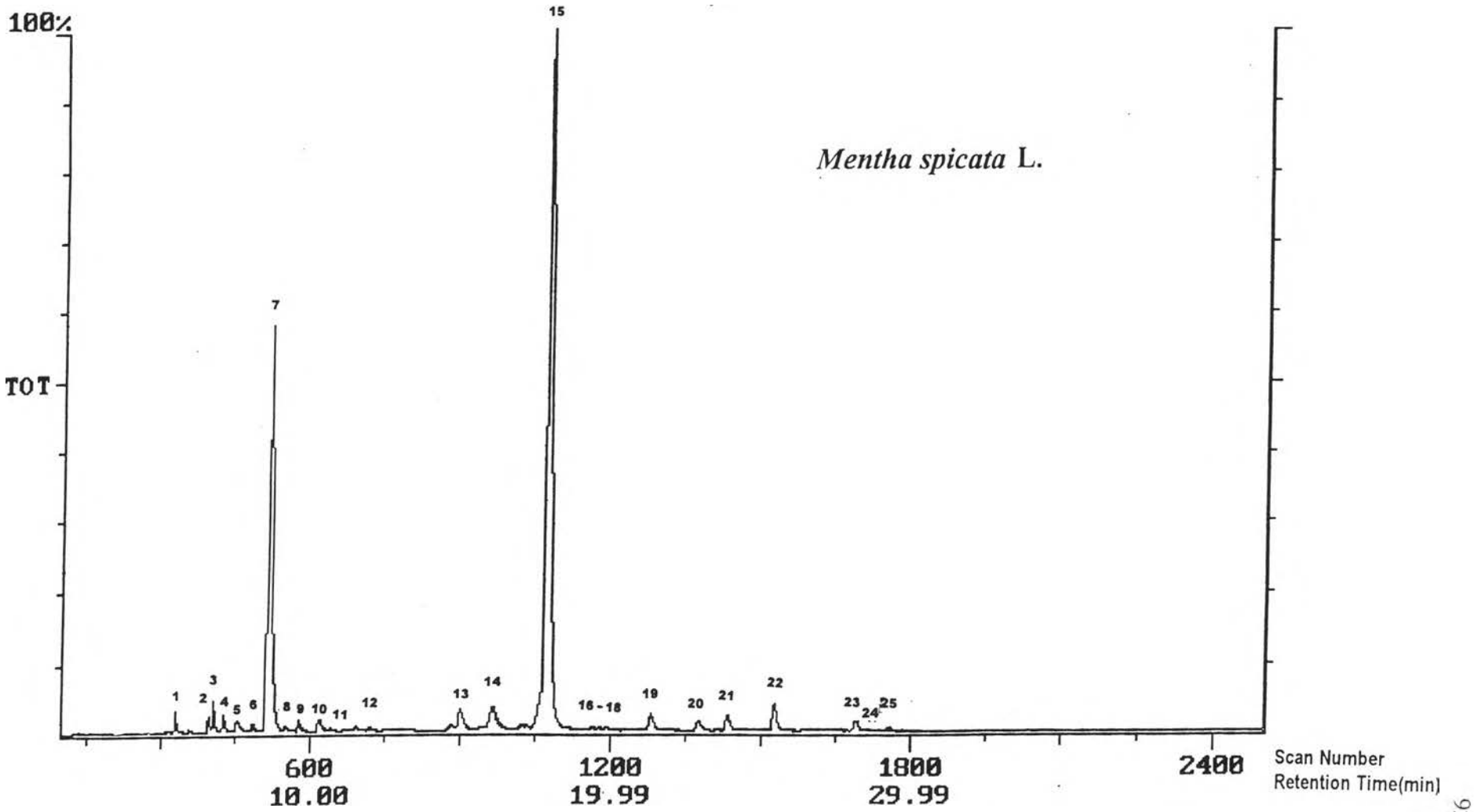


Figure 26 GC chromatogram of the essential oil from *Mentha spicata* leaves

Table 15 Essential oil composition of *Mentha spicata* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	α-thujene	5.50	0.52
2	sabinene	6.35	0.50
3	β-pinene	6.41	1.08
4	myrcene	6.90	0.61
6	α-terpinene	7.61	0.21
8	(*E*)-β-ocimene	8.60	t
9	γ-terpinene	9.08	0.52
11	terpinolene	10.13	0.15
	Oxygenated monoterpene		
7	1,8-cineole	8.14	25.00
10	*cis*-sabinene hydrate	10.01	0.80
13	terpin-4-ol	13.94	1.85
14	*neo-iso*-dihydrocarveol	16.05	2.90
15	carvone	17.86	57.68
16	bornyl acetate	18.50	0.30
19	*neo-iso*-dihydrocarveol acetate	21.31	1.19
20	*cis*-carvyl acetate	21.60	0.85
	Sesquiterpene		
21	β-bourbonene	22.58	1.24
22	*9-epi-(E)*-caryophyllene	25.43	2.03
23	germacrene D	26.56	0.74
24	bicycolgermacrene	27.61	0.25
25	germacrene A	27.89	0.21

Table 15 Essential oil composition of *Mentha spicata* leaves (continued)

Number of peak	Compound	Retention time (min)	% Area
	Long chain hydrocarbon		
5	3-octanol	7.56	0.82
12	3-octanol acetate	11.66	0.16
	Miscellaneous		
17	unknown	19.59	0.15
18	unknown	19.83	0.24

t = trace

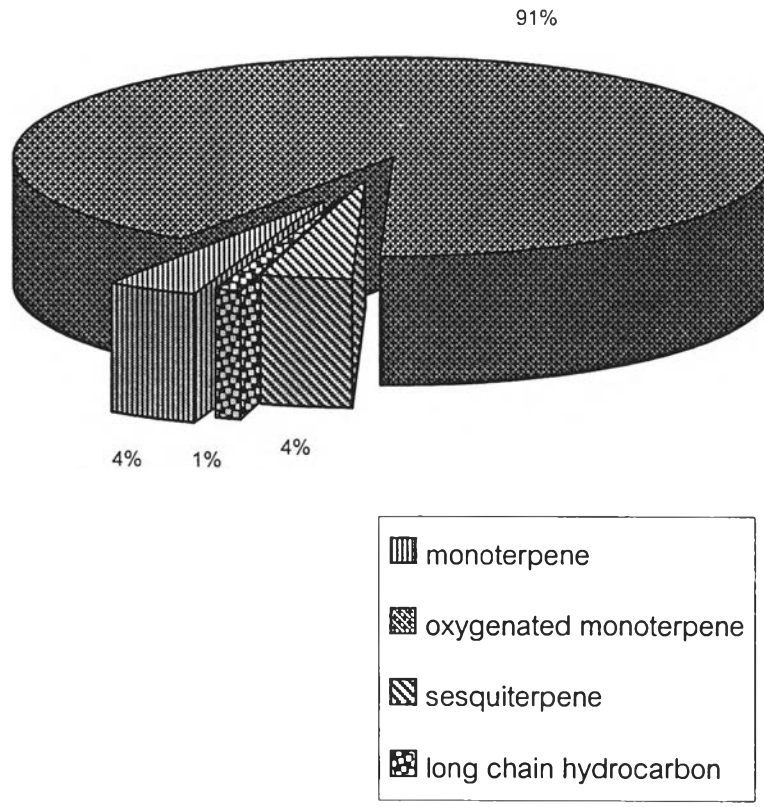


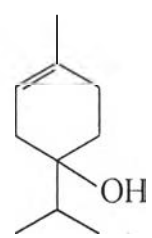
Figure 27 The percentage of various terpenoid groups found in the essential oil of *Mentha spicata* leaves

4.2.4 Essential Oil Composition of *Origanum majorana* L.

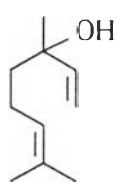
The yield of essential oil from *Origanum majorana* leaves was found to be 0.1 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that there were at least 24 components (Fig. 28). These components were identified as 8 monoterpenes, 5 oxygenated monoterpenes and 3 sesquiterpenes (Table 16). Among these, terpin-4-ol (28.37 %) was found to be the major component, followed by linalool (20.7 %) and *β*-phellandrene (10.75 %).

In terms of relative amount, the oxygenated monoterpene appeared to be the major terpenoid group , accounting for 54 % of the essential oil. Monoterpenoid and sesquiterpenoid were present in lesser amount , with 33 % and 5 % , respectively (Fig. 29).

Structurally, the major components, terpin-4-ol and linalool, belong to the oxygenated monoterpenoid group of menthane and acyclic monoterpenoid whereas *β*-phellandrene belongs to the monoterpenoid group of menthane.



terpin-4-ol
(*menthane*)



linalool
(acyclic monoterpenoid)

β-phellandrene
(*menthane*)

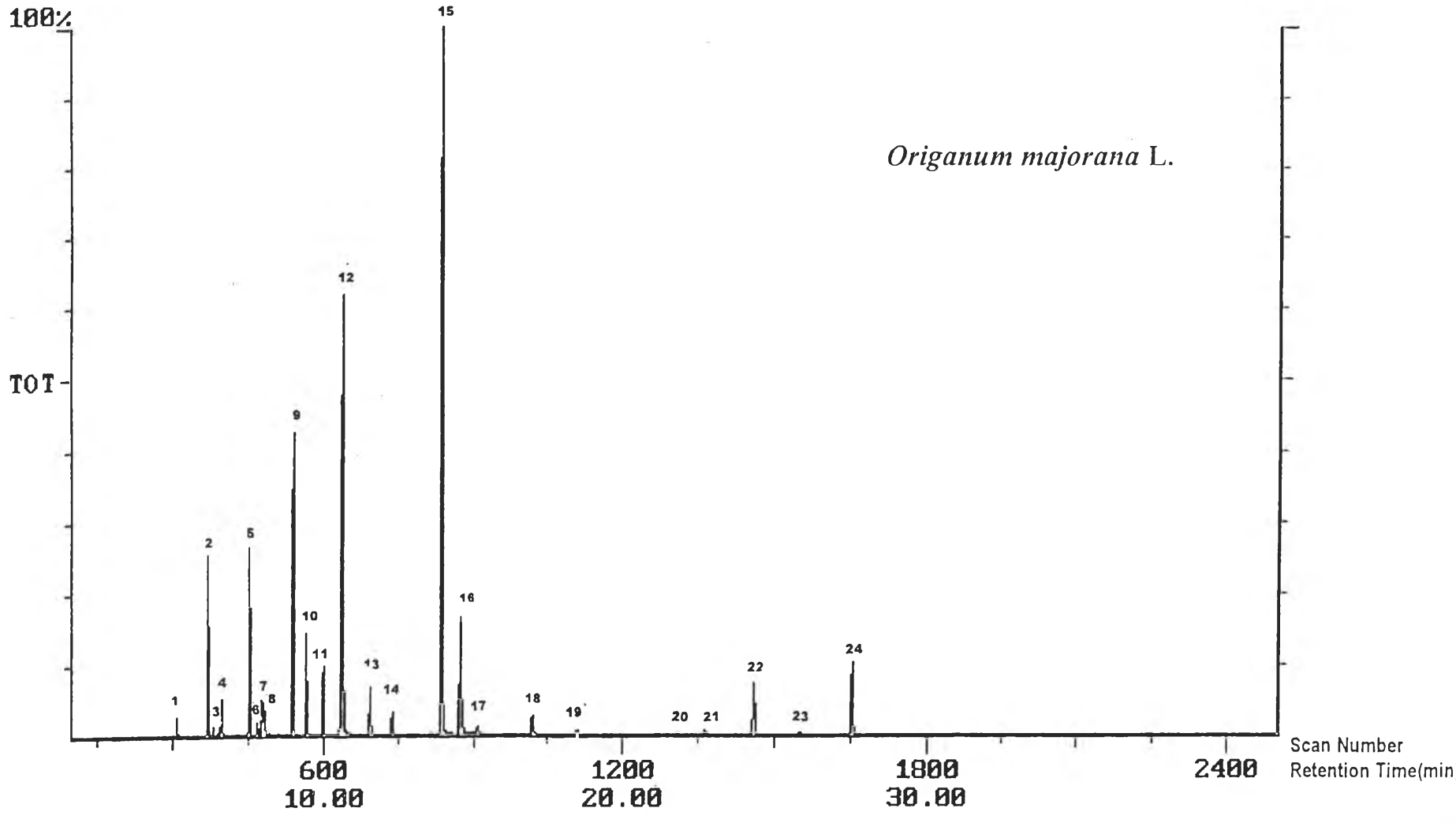


Figure 28 GC chromatogram of the essential oil from *Origanum majorana* leaves

Table 16 Essential oil composition of *Origanum majorana* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	tricyclene	5.28	0.41
2	sabinene	6.35	3.57
5	δ-2-carene	7.12	5.12
6	o-cymene	7.75	0.40
7	limonene	8.01	1.26
8	β-phellandrene	8.03	10.75
9	γ-terpinene	9.08	8.68
11	terpinolene	10.13	2.30
	Oxygenated monoterpene		
12	linalool	10.64	20.74
15	terpin-4-ol	13.94	28.37
16	α-terpineol	14.21	4.97
17	*trans*-dihydro carvone	14.97	t
19	bornyl acetate	18.49	t
21	geranyl acetate	21.15	0.21
	Sesquiterpene		
22	(*E*)-caryophyllene	24.33	2.19
23	α-humulene	25.91	0.10
24	bicyclogermacrene	27.61	2.99
	Miscellaneous		
3	unknown	6.36	0.23
4	unknown	6.63	0.96
10	unknown	9.43	3.37
13	unknown	11.57	1.55
14	unknown	12.30	0.88
18	unknown	16.97	0.83
20	unknown	20.90	0.12

t = trace

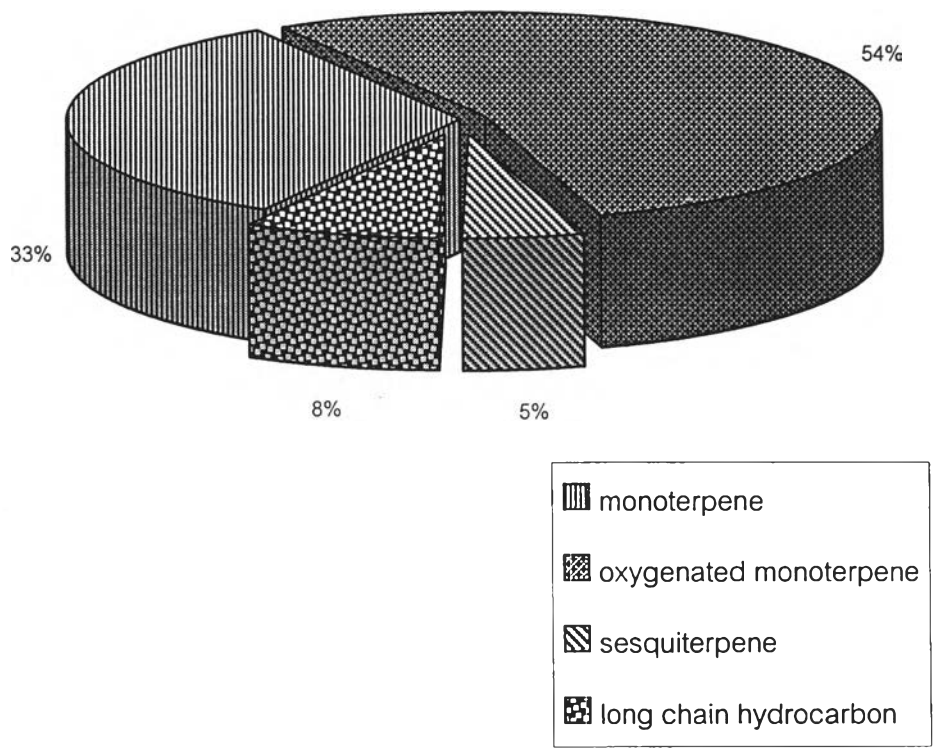


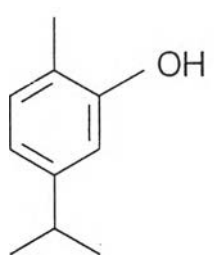
Figure 29 The percentage of various terpenoid groups found in the essential oil of *Origanum majorana* leaves

4.2.5 Essential oil Composition of *Origanum vulgare* L.

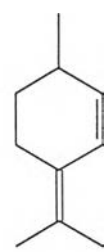
The leaves of *Origanum vulgare* were found to contain essential oil with the content of 0.2 % (v/w) of fresh weight. GC/MS analysis showed at least 26 peaks in its GC chromatogram (Fig. 30). These peaks were identified as 13 monoterpenes, 6 oxygenated monterpenes and 5 sesquiterpenes (Table 17). Among these, the major components were found to be carvacrol (75.63 %) , *p*-mentha-2,4(8)-diene (10.11 %) and *o*-cymene 2.34 %.

In terms of relative amount, the oxygenated monoterpenes appeared to be the major terpenoid group, accounting for 77 % of the essential oil (Fig. 31). Monoterpenes and sesquiterpenes were present in lesser amount , with 19 % and 4 % , respectively.

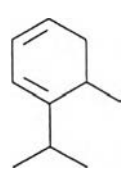
In terms of structure, the major components, carvacrol, belongs to the oxygenated monoterpenoid group of menthane whereas *p*-mentha -2,4 (8) diene and *o*-cymene belong to the monoterpenoid groups of menthane and *o*-menthane respectively.



carvacrol
(*menthane*)



p-mentha-2,4(8)-diene
(*menthane*)



o-cymene
(*o-menthane*)

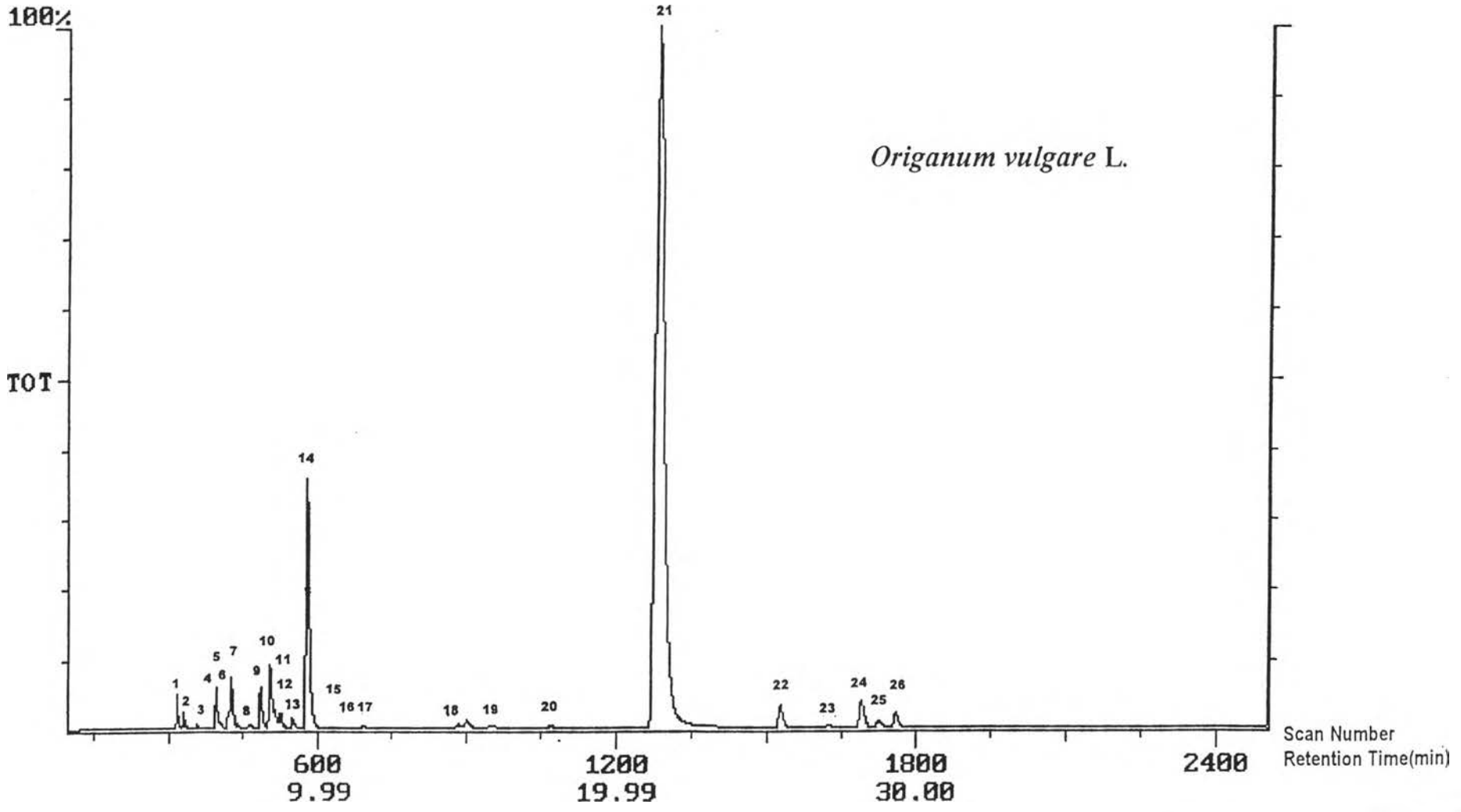


Figure 30 GC chromatogram of the essential oil from *Origanum vulgare* leaves

Table 17 Essential oil composition of *Origanum vulgare* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	tricyclene	5.28	0.71
2	α-thujene	5.50	0.29
3	camphene	5.66	0.11
4	sabinene	6.35	0.98
7	myrcene	6.92	1.65
8	δ-3-carene	7.41	0.17
9	α-terpinene	7.62	1.28
10	o-cymene	7.76	2.34
11	(*Z*)-β-ocimene	8.23	0.51
12	(*E*)-β-ocimene	8.60	0.56
13	γ-terpinene	9.08	0.36
14	*p*-mentha-2,4(8)-diene	9.63	10.11
16	terpinolene	10.13	0.06
	Oxygenated monoterpene		
15	*trans*- sabinene hydrate	10.48	0.07
17	*trans-para*-menth-2-en-1-ol	11.59	0.19
18	borneol	13.62	0.13
19	α-terpineol	14.20	0.26
20	carvone	17.86	0.18
21	carvacrol	20.33	75.63
	Sesquiterpene		
22	9-*epi*-*E*-caryophyllene	25.43	1.19
23	α-humulene	25.91	0.14
24	germacrene D	26.56	1.49
25	bicyclogermacrene	27.61	0.38

Table 17 Essential oil composition of *Origanum vulgare* leaves (continued)

Number of peak	Compound	Retention time (min)	% Area
26	β-bisabolene	27.78	0.78
	Long chain hydrocarbon		
6	1-octen-3-ol	6.79	0.25
	Miscellaneous		
5	unknown	6.78	0.18

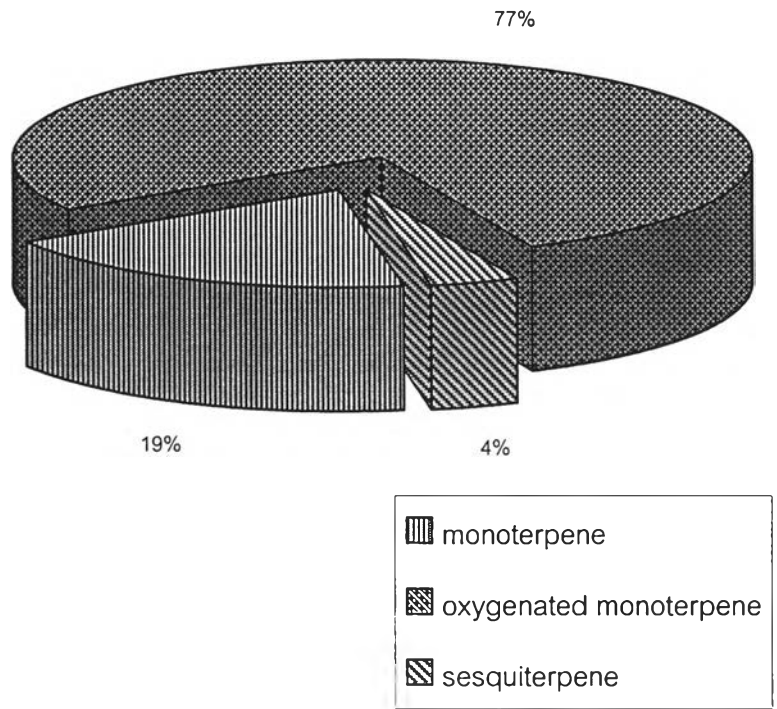


Figure 31 The percentage of various terpenoid found in the essential oil of *Origanum vulgare* leaves

4.2.6 Esssential Oil Composition of *Rosmarinus officinalis* L.

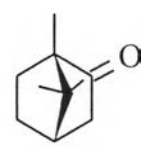
The yield of essential oil hydrodistilled from *Rosmarinus officinalis* leaves was found to be 0.9 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed 40 peaks (Fig.32). These peaks were identified as 14 monoterpenes, 19 oxygenated monoterpenes, 3 sesquiterpenes and 1 oxygenated sesquiterpene (Table 18). Among these, α-pinene (22.48 %) appeared to be the major component followed by camphor (20.07 %).

In terms of relative amount, the oxygenated monoterpene was found to be the major terpenoid group, accounting for 59 % of the essential oil. Monoterpenes and sesquiterpenes were present in lesser amount , with 38 % and 2 %, respectively (Fig. 33).

In terms of structure type, the major components, α-pinene, belongs to the monoterpenoid group of pinane, while camphor belongs to the oxygenated monoterpenoid group of camphane.

α-pinene

(*pinane*)



camphor

(*camphane*)

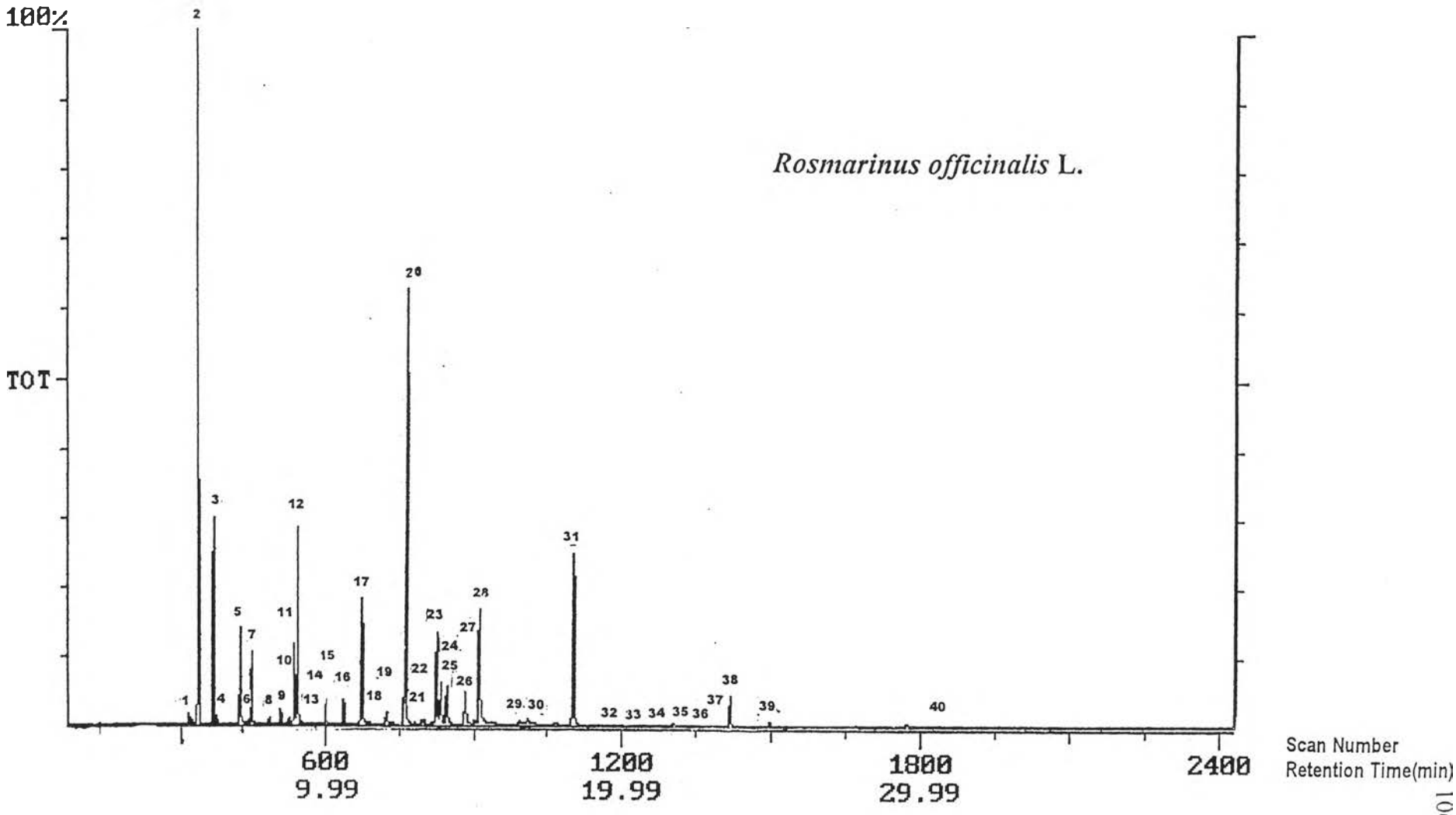


Figure 32 GC chromatogram of the essential oil from *Rosmarinus officinalis* leaves

Table 18 Esssential oil composition of *Rosmarinus officinalis* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	tricyclene	5.30	0.26
2	α-pinene	5.33	22.48
3	camphene	5.66	2.96
4	thuja 2,4(10)-diene	5.78	0.32
5	β-pinene	6.43	3.41
7	myrcene	6.90	2.42
8	α-phellandrene	7.26	t
9	δ-3-carene	7.40	0.54
10	o-cymene	7.75	t
11	sylvestrene	7.90	3.26
13	(Z)-β-ocimene	8.23	t
14	γ-terpinene	9.08	1.00
16	terpinolene	10.14	0.99
	Oxygenated monoterpene		
12	1,8-cineole	8.13	7.82
17	linalool	10.63	5.63
19	chrysanthenone	11.43	0.50
20	camphor	12.56	20.07
21	*trans*-pinocamphone	13.09	t
22	pinocarvone	13.34	t
23	borneol	13.61	4.63
24	*cis*-pinocamphone	13.76	1.95
25	terpin-4-ol	13.94	1.81

Table 18 Esssential oil composition of *Rosmarinus officinalis* leaves (continued)

Number of peak	Compound	Retention time (min)	% Area
26	α-terpineol	14.21	1.65
27	isobornyl formate	15.35	t
28	(*E*)-ocimenone	16.30	6.26
31	bornyl acetate	18.49	8.67
32	*cis*-pinocarvyl acetate	21.13	0.08
34	*neo-iso*-dihydro carveol acetate	21.31	0.08
35	*trans*-myrtanol acetate	22.93	0.21
	Sesquiterpene		
36	γ-elemene	24.60	t
38	*9-epi-(E)*-caryophyllene	25.43	1.48
39	(*Z*)-α-bisabolene	27.59	0.23
	Oxygenated sesquiterpene		
40	caryophyllene oxide	31.09	0.29
	Phenpyl propane		
37	(*Z*)-methyl isoeugenol	25.23	0.12
	Long chain hydrocarbon		
6	3-octanone	6.67	t
	Miscellaneous		
15	unknown	10.00	0.08
18	unknown	11.36	0.09
29	unknown	17.80	0.23
30	unknown	18.06	0.48
33	unknown	21.53	t

t=trace

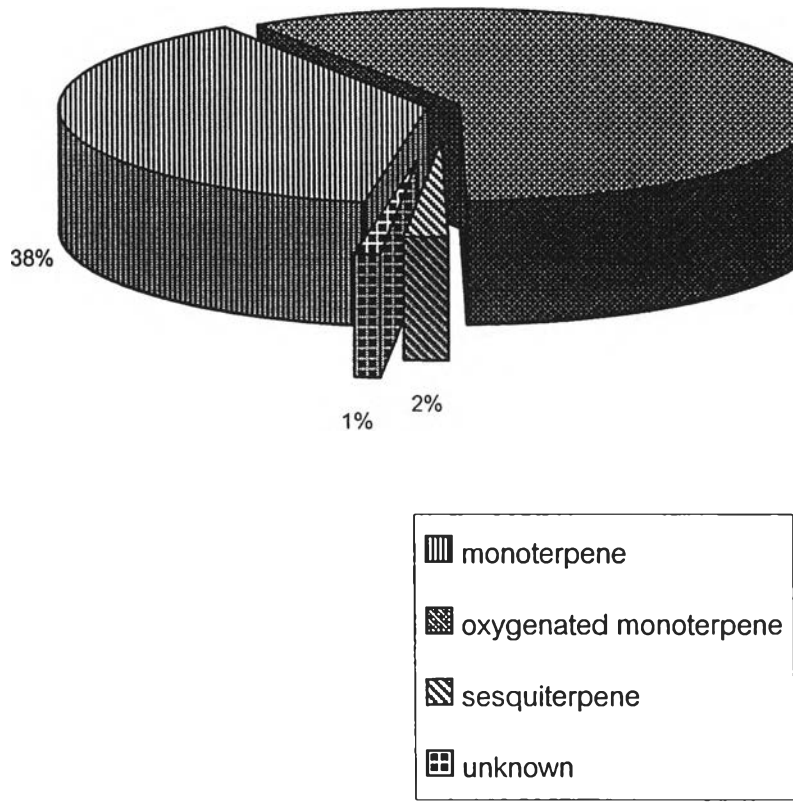


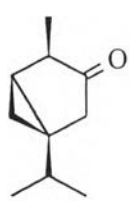
Figure 33 The percentage of terpenoid groups found in the essential oil of *Rosmarinus officinalis* leaves

4.2.7 Esssential Oil Composition of *Salvia officinalis* L.

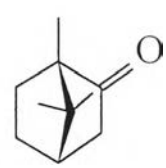
The yield of essential oil hydrodistilled from *Salvia officinalis* leaves was found to be 0.3 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed 26 peaks (Fig. 34). These peaks were identified as 7 monoterpenes, 11 oxygenated monoterpenes and 4 sesquiterpenes (Table 19). Among these, *cis*-thujone (37.49 %) was found to be the major component followed by camphor (13.79 %) and α-humulene (9.46 %) .

In terms of relative amount, the oxygenated monoterpene appeared to be the major terpenoid group, accounting for 71 % of the essential oil (Fig. 35). Sesquiterpenes and monoterpenes were present in lesser amount , at 20 % and 4 % , respectively.

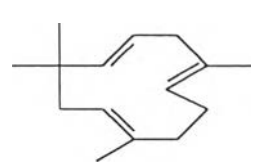
In terms of structure, the major components, *cis*-thujone and camphor, belong to the oxygenated monoterpenoid groups of thujane and camphane, respectively.



cis-thujone
(*thujane*)



camphor
(*camphane)*



α-humulene
(*humulane*)

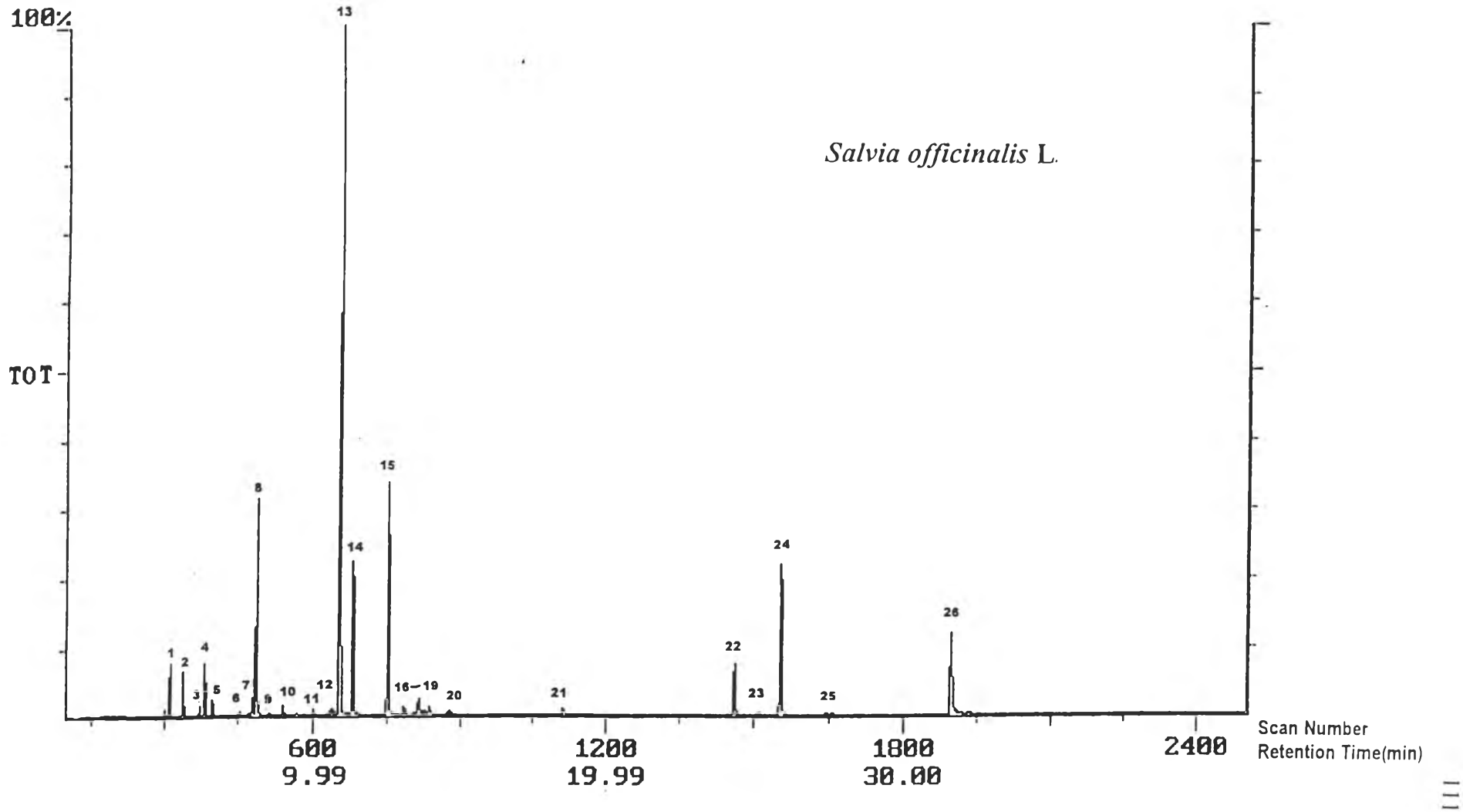


Figure 34 GC chromatogram of the essential oil from *Salvia officinalis* leaves

Table 19 Esssential oil composition of *Salvia officinalis* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	tricyclene	5.28	1.80
3	sabinene	6.35	0.35
6	δ-2-carene	7.12	0.22
7	limonene	8.01	0.81
9	(Z) β-ocimene	8.23	0.44
10	γ-terpinene	9.08	0.44
11	terpinolene	10.13	t
	Oxygenated monoterpene		
8	1,8-cineole	8.14	9.38
12	linalool	10.63	t
13	*cis*-thujone	10.89	37.49
14	*trans*-thujone	11.33	7.89
15	camphor	12.55	13.79
16	*trans*-pinocamphone	13.09	0.59
17	borneol	13.59	0.91
18	*cis*-pinocamphone	13.76	t
19	terpin-4-ol	13.94	0.41
20	α-terpineol	14.20	t
21	bornyl acetate	18.51	0.44
	Sesquiterpene		
22	(*E*)-caryophyllene	24.36	3.30
24	α-humulene	25.88	9.46
25	bicyclogermacrene	27.61	0.16
26	germacrene B	31.60	7.33

Table 19 Esssential oil composition of *Salvia officinalis* leaves (continued)

Number of peak	Compound	Retention time (min)	% Area
	Miscellaneous		
2	unknown	5.63	1.63
4	unknown	6.38	2.33
5	unknown	6.66	0.65
23	unknown	25.15	0.15

t = trace

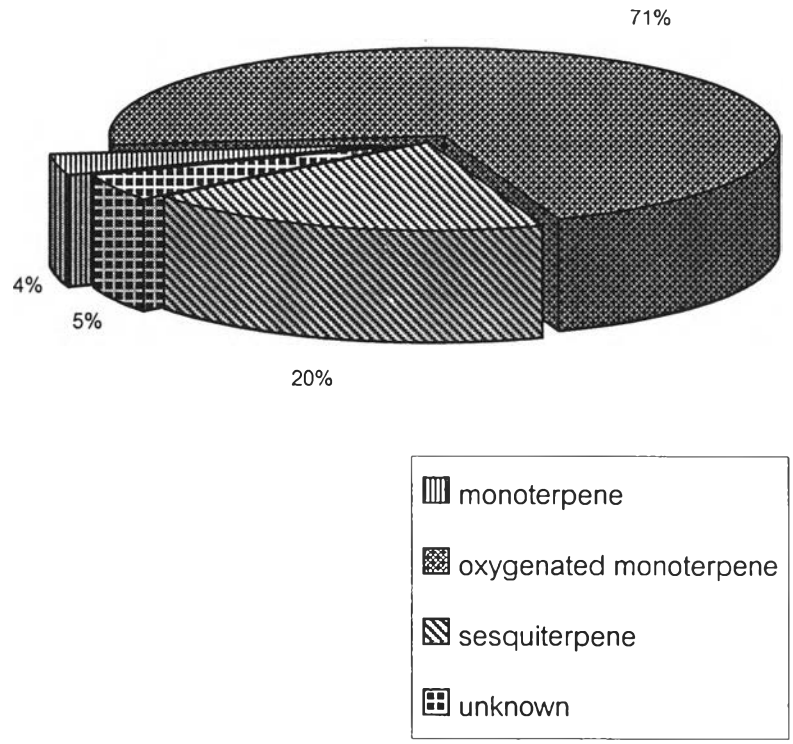


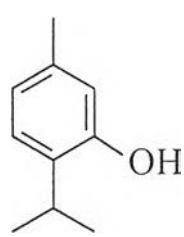
Figure 35 The percentage of various terpenoid groups found in the essential oil of *Salvia officinalis* leaves

4.2.8 Esssential Oil Composition of *Thymus* sp. 1 (summer thyme)

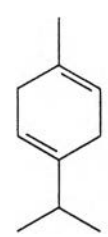
The yield of essential oil from *Thymus* sp.1 leaves was found to be 0.9 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that there were at least 18 components (Fig. 36). These components were identified as 8 monoterpenes, 8 oxygenated monoterpenes and 2 sesquiterpenes (Table 20). Among these, thymol (26.43 %) appeared to be the major component followed by γ-terpinene (21.63 %) and *o*-cymene (15.87 %).

The oxygenated monoterpene was found to be the major terpenoid group, accounting for 53 % of the essential oil (Fig. 37). Monoterpenes and sesquiterpenes were present in lesser amount, with 45 % and 2 %, respectively.

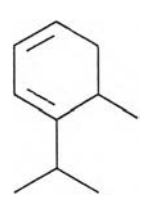
Structurally, the major components, thymol and γ-terpinene, belong to the monoterpenoid group of menthane, while *o*-cymene belongs to the group of *o*-menthane.



thymol
(*menthane*)



γ-terpinene
(*menthane*)



o-cymene
(*o-menthane*)

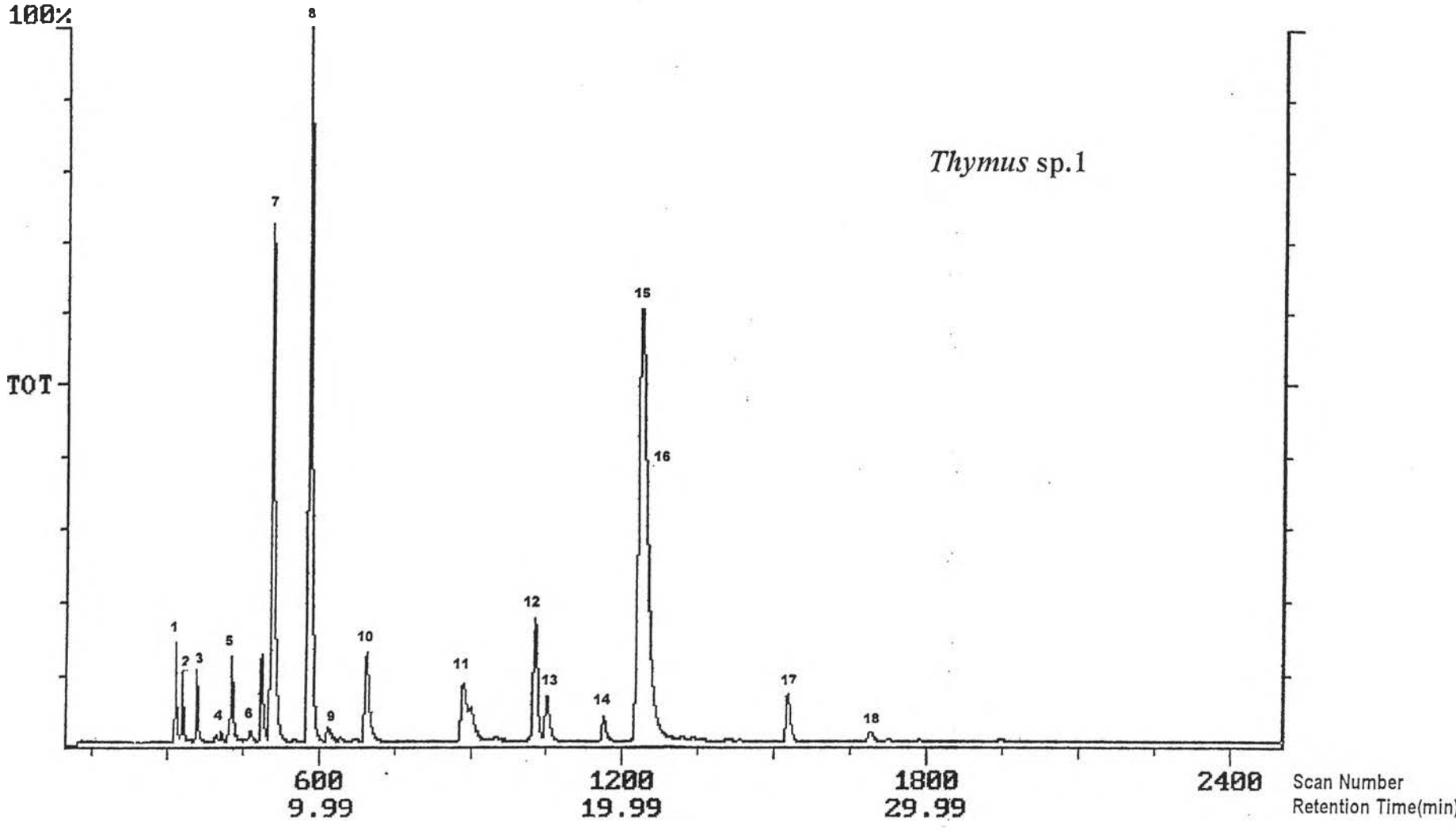


Figure 38 GC chromatogram of the essential oil from *Thymus* sp. 1 leaves

Table 20 Esssential oil composition of *Thymus* sp. 1 (summer thyme) leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	tricyclene	5.28	1.44
2	α-thujene	5.49	0.88
3	camphene	5.66	1.30
4	sabinene	6.35	0.17
5	myrcene	6.92	1.51
6	α-terpinene	7.62	2.19
7	o-cymene	7.75	15.87
8	γ-terpinene	9.08	21.63
	Oxygenated monoterpene		
9	*cis*-sabinene hydrate	10.01	t
10	linalool	10.63	4.14
11	borneol	13.61	3.17
12	methyl ether, thymol	17.06	5.17
13	methyl ether, carvacrol	17.50	2.05
14	bornyl acetate	18.51	0.97
15	thymol	20.04	26.43
16	carvacrol	20.33	11.08
	Sesquiterpene		
17	*9-epi-(E)*-carylphyllene	25.44	2.00
18	γ-cadinene	28.04	t

t = trace

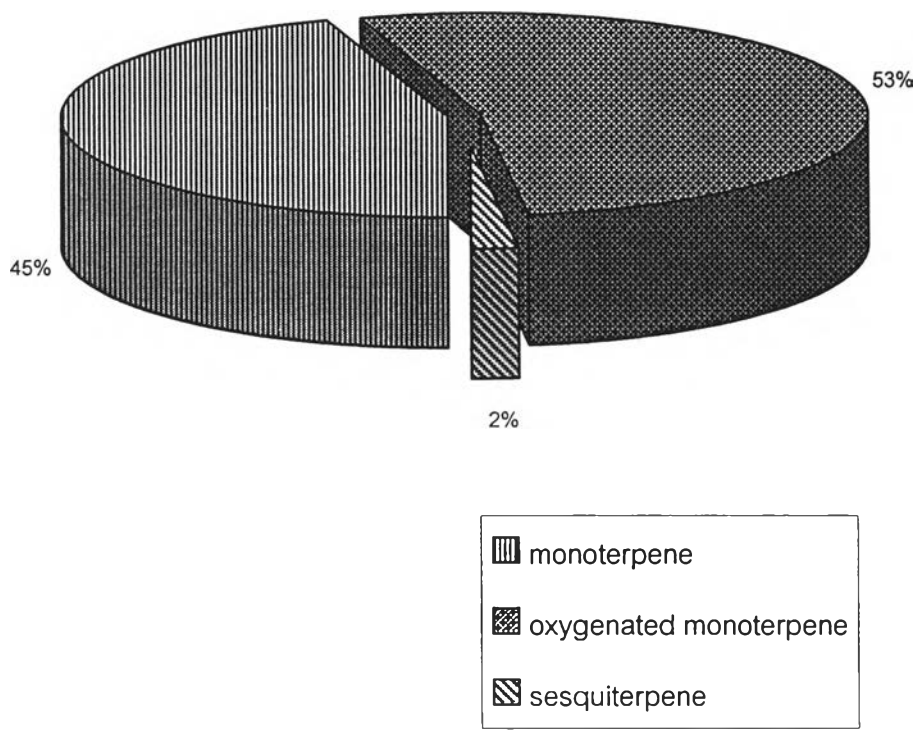


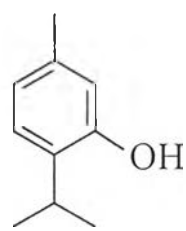
Figure 37 The percentage of various terpenoid groups found in the essential oil of *Thymus* sp.1 leaves

4.2.9 Esssential Oil Composition of *Thymus* sp. 2 (winter thyme)

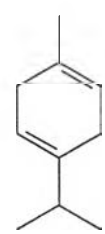
The leaves of *Thymus* sp.2 was found to contain essential oil with the content of 0.9 % (v/w) of fresh weight. By GC/MS analysis, the oil was shown to have at least 23 components (Fig. 38). These peaks were identified as 9 monoterpenes, 10 oxygenated monoterpenes and 3 sesquiterpenes (Table 21). Among these, the major components were found to be thymol (59.27 %), γ-terpinene (15.20 %) and *o*-cymene (9.37 %).

In terms of relative amount, the oxygenated monoterpene appeared to be the major terpenoid group, accounting for 66 % of the essential oil (Fig.39). Monoterpenes and sesquiterpenes were present in lesser amount, with 30 % and 3 %, respectively.

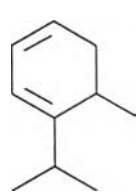
In terms of structure, the major component of thymol belongs to the oxygenated monoterpenoid group of menthane whereas γ-terpinene and *o*-cymene belong to the monoterpenoid group of menthane and *o*-menthane, respectively.



thymol
(*menthane*)



γ-terpinene
(*menthane*)



o-cymene
(*o-menthane*)

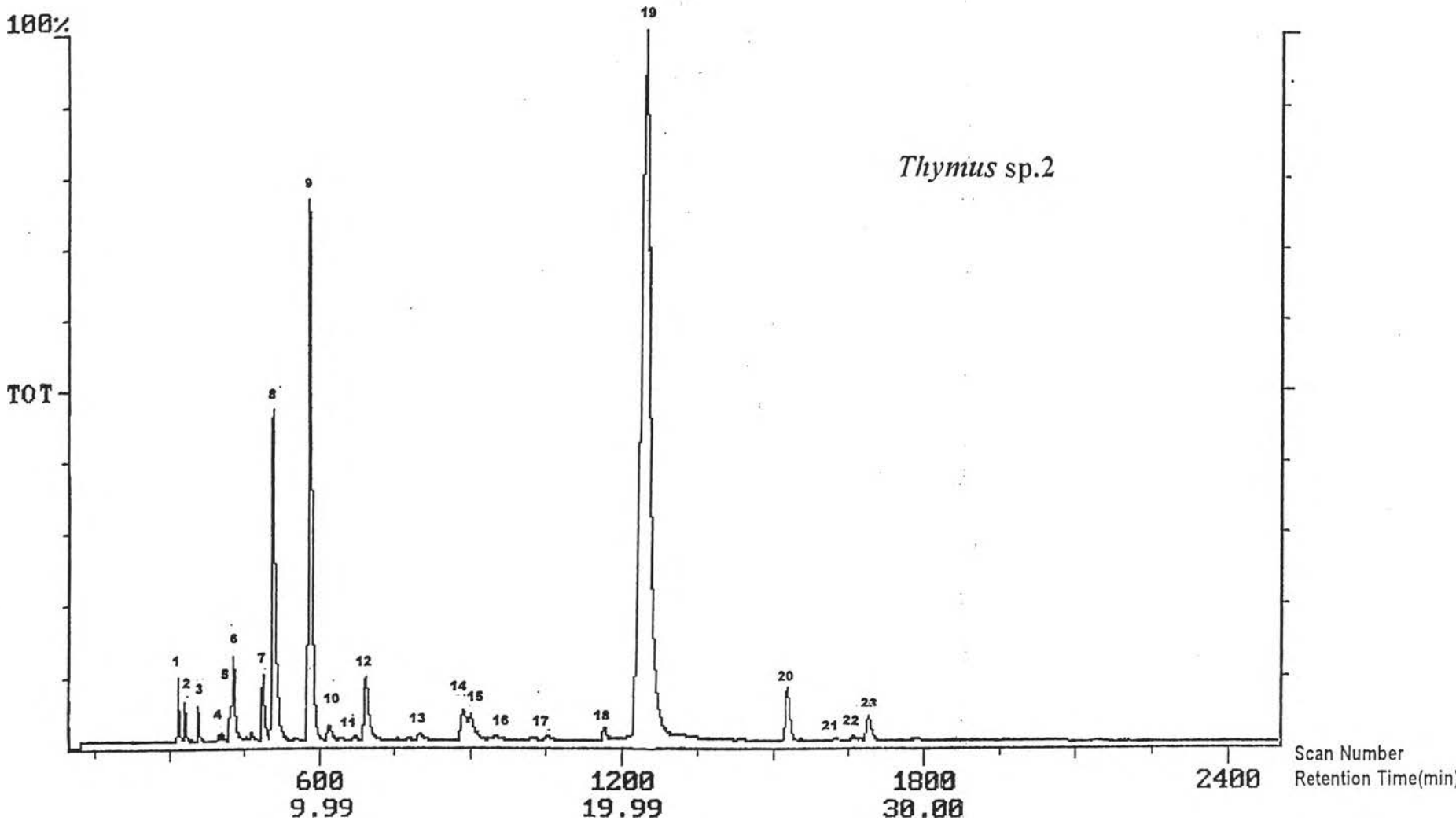


Figure 38 GC chromatogram of the essential oil from *Thymus* sp. 2 leaves

Table 21 Esssential oil composition of *Thymus* sp.2 (winter thyme) leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
1	tricyclene	5.28	0.81
2	α-thujene	5.49	0.53
3	camphene	5.66	0.49
4	sabinene	6.35	0.09
6	myrcene	6.90	1.97
7	α-terpinene	7.61	1.52
8	*o*-cymene	7.75	9.37
9	γ-terpinene	9.08	15.20
11	terpinolene	10.13	0.07
	Oxygenated monoterpene		
10	*cis*-sabinene hydrate	10.01	0.53
12	linalool	11.54	2.67
13	camphor	12.55	0.19
14	borneol	13.61	1.46
15	terpin-4-ol	13.94	1.30
16	α-terpineol	14.21	0.10
17	methyl ether, carvacrol	17.49	0.19
18	bornyl acetate	18.50	0.47
19	thymol	20.04	59.27
22	geranyl N propanoate	27.63	0.07
	Sesquiterpene		
20	*9-epi-(E)*-carylphyllene	25.44	2.11
21	(*Z*)-α-bisabolene	27.59	0.09
23	γ-cadinene	28.04	0.94
	Long chain hydrocarbon		
5	1-octen-3-ol	6.79	0.55

t = trace

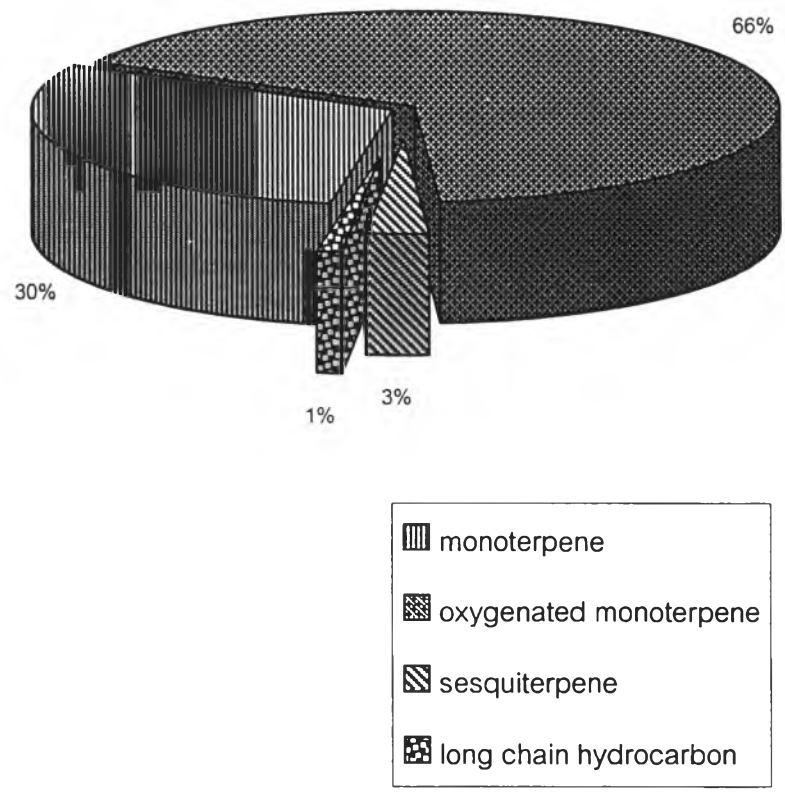


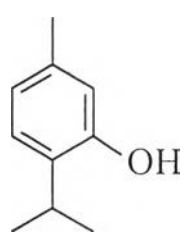
Figure 39 The percentage of various terpenoid groups found in the essential oil of *Thymus* sp.2 leaves

4.2.10 Esssential Oil Composition of *Thymus vulgaris* L.

By hydrodistillation, the yield of the essential oil from *Thymus vulgaris* leaves was found to be 0.2 % (v/w) of fresh weight. GC/MS analysis of the essential oil showed 17 peaks (Fig. 40). These peaks were identified as 8 monoterpene, 7 oxygenated monoterpenes, and 1 sesquiterpene (Table 22). Among these, thymol (47.87%) appeared to be the major component, followed by γ-terpinene (23.35 %) and *o*-cymene (9.88 %).

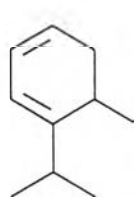
The oxygenated monoterpene appeared to be the major terpenoid group, accounting for 57 % of the essential oil. (Fig. 41). Monoterpenes and sesquiterpenes were present in lesser amount, at 41 %, 1 %, respectively.

Structurally, the major components, thymol, belongs to the oxygenated monoterpenoid group of menthane, while γ-terpinene and *o*-cymene belong to the monoterpenoid group of menthane and *o*-menthane, respectively.



thymol
(*menthane*)

γ-terpinene
(*menthane*)



o-cymene
(*o-menthane*)

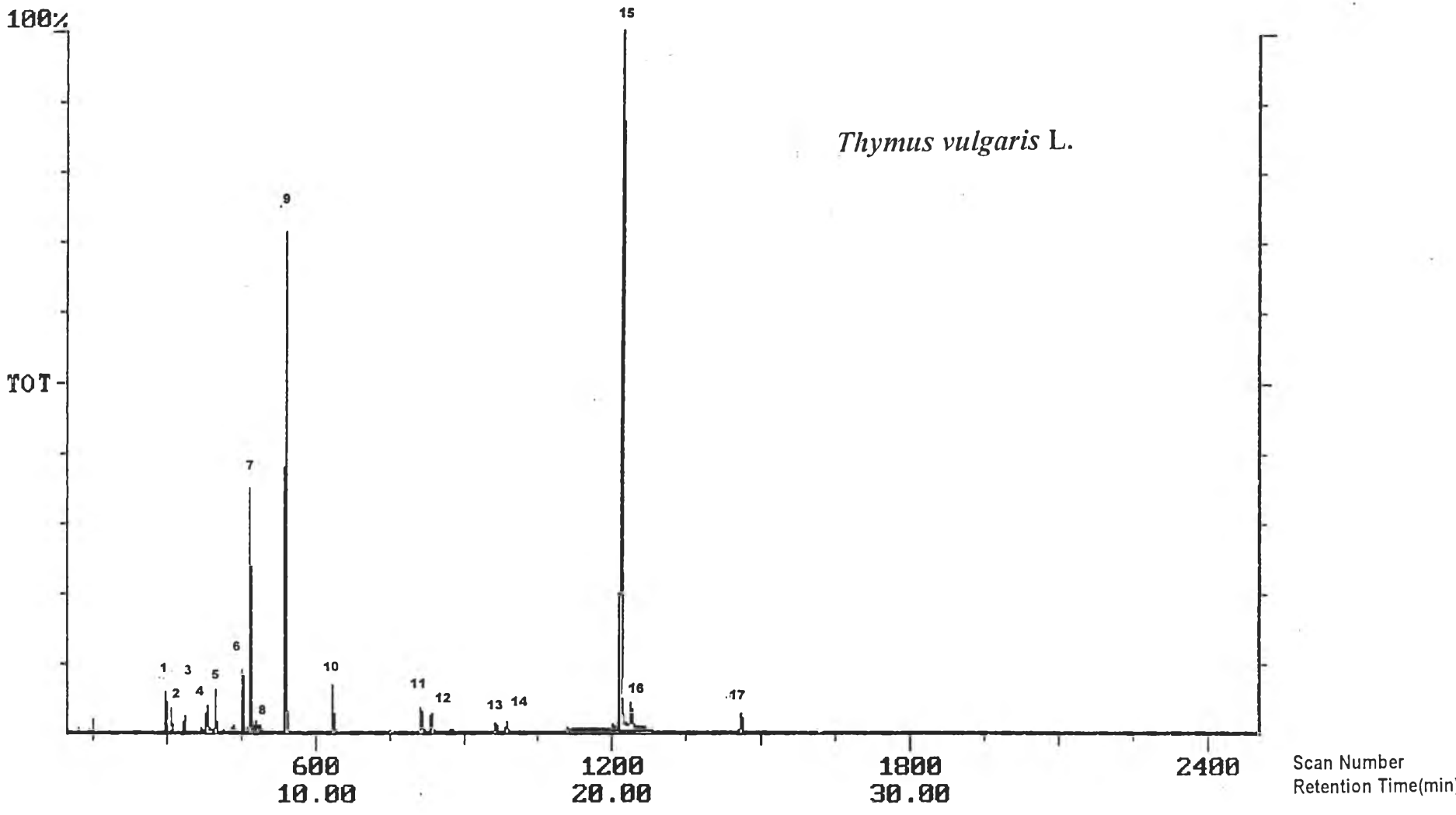


Figure 40 GC chromatogram of the essential oil from *Thymus vulgaris* leaves

Table 22 Esssential oil composition of *Thymus vulgaris* leaves

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene		
2	tricyclene	5.28	0.85
3	camphene	5.66	0.66
4	sabinene	6.34	1.47
5	myrcene	6.41	1.60
6	α-terpinene	7.61	2.65
7	o-cymene	7.75	9.88
8	limonene	8.01	0.42
9	γ-terpinene	9.08	23.35
	Oxygenated monoterpene		
10	linalool	10.63	2.86
11	borneol	13.61	1.73
12	terpin-4-ol	13.94	1.14
13	methyl ether, thymol	17.06	0.61
14	methyl ether, carvacrol	17.50	0.66
15	thymol	20.04	47.87
16	carvacrol	20.33	1.65
	Sesquiterpene		
17	(*E*)-caryophyllene	24.38	1.25
	Miscellaneous		
1	unknown	4.98	1.33

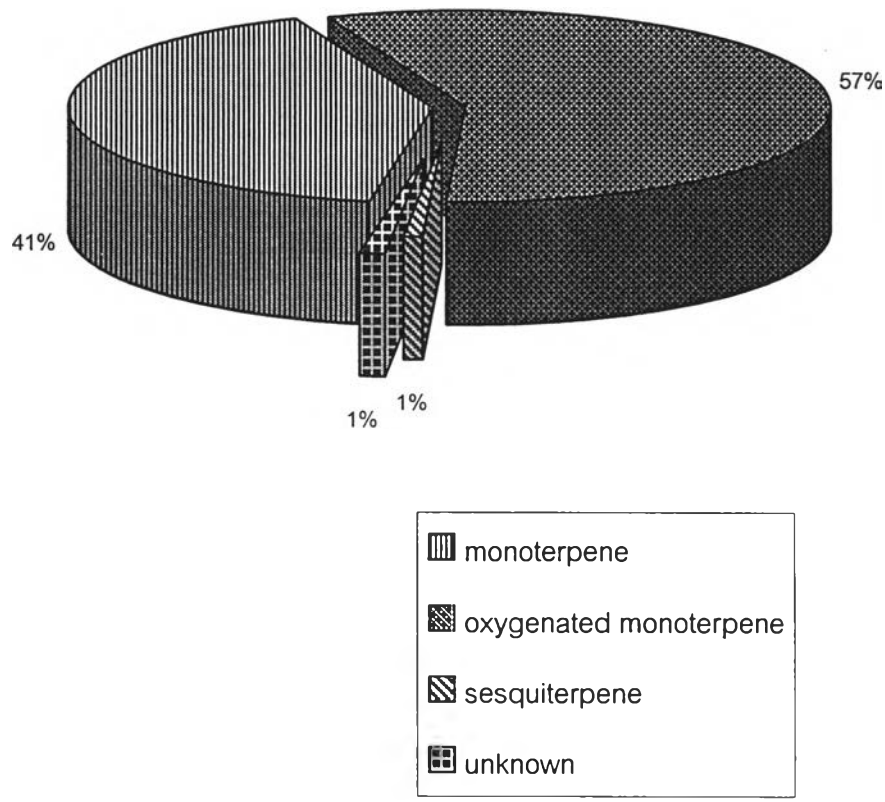


Figure 41 The percentage of various terpenoid groups found in the essential oil of *Thymus vulgaris* leaves

4.3 Scanning electron microscopic observation

Leaves of Lamiaceous plants were examined under scanning electron microscope. Their scan electron micrograph revealed for glandular trichomes as shown in figures 42-51.

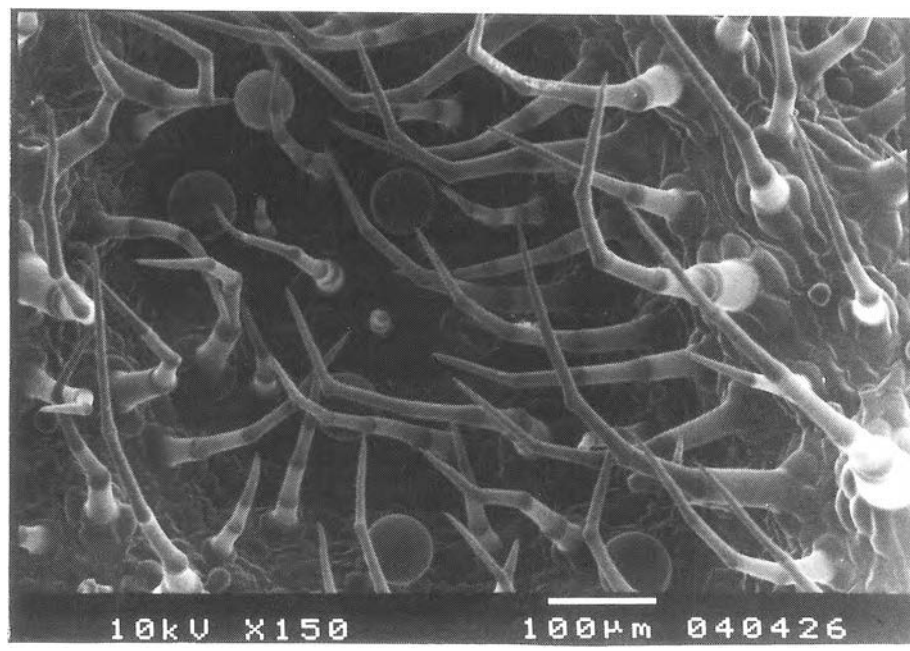


Fig.42 Scanning electron micrograph of glandular trichomes of *Coleus amboinicus* Lour.

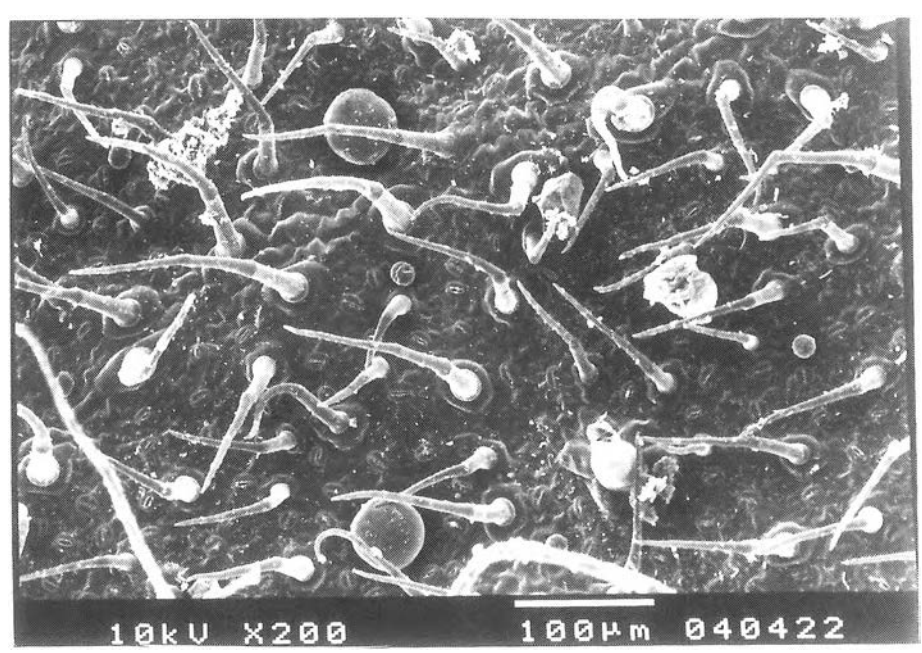


Fig. 43 Scanning electron micrograph of glandular trichomes of *Hyptis suaveolens* Poit.

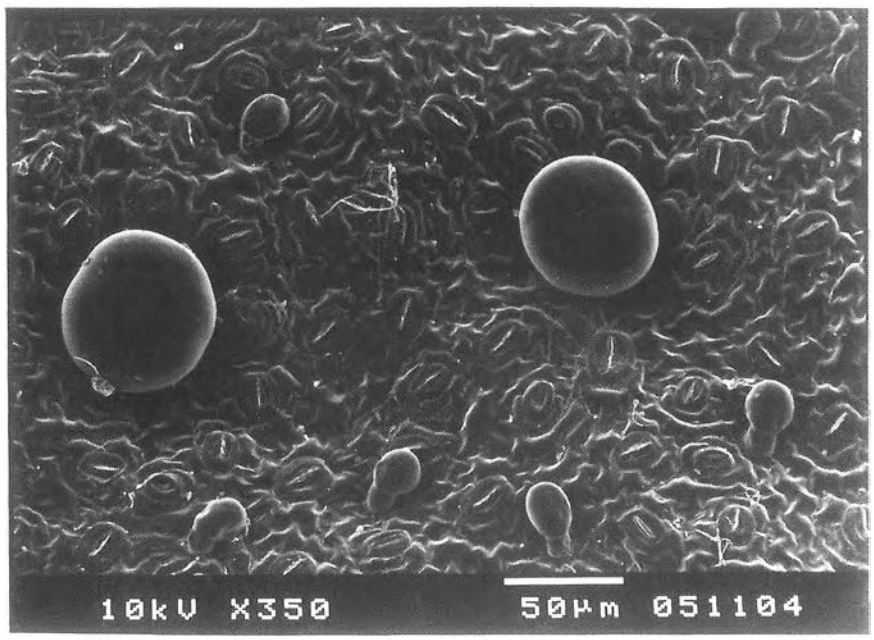


Fig.44 Scanning electron micrograph of glandular trichomes of *Mentha arvensis* L. var *piperascens* Malinvaud

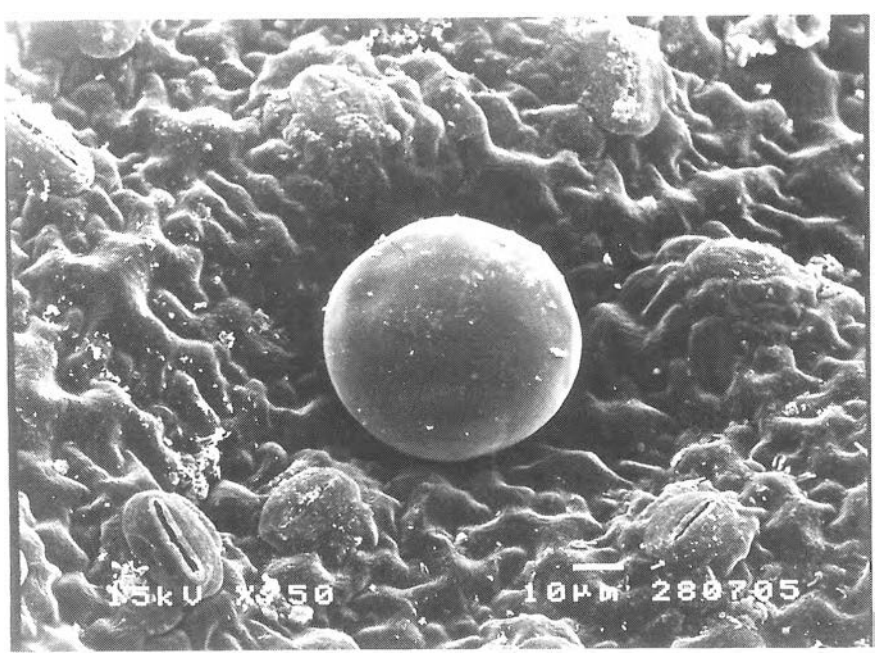


Fig.45 Scanning electron micrograph of glandular trichomes of *Mentha cordifolia* Opiz

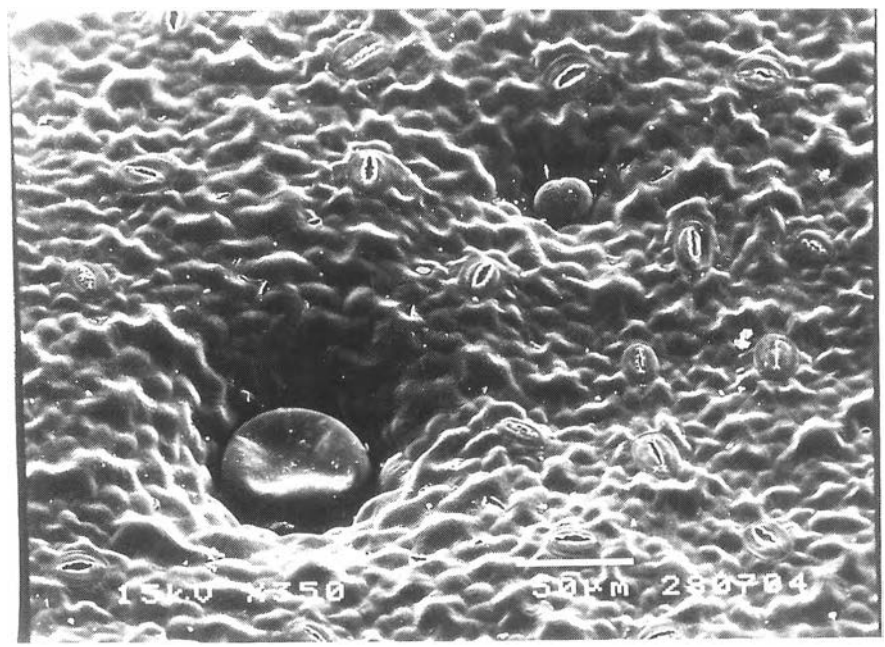


Fig.46 Scanning electron micrograph of glandular trichomes of *Ocimum basilicum* L.

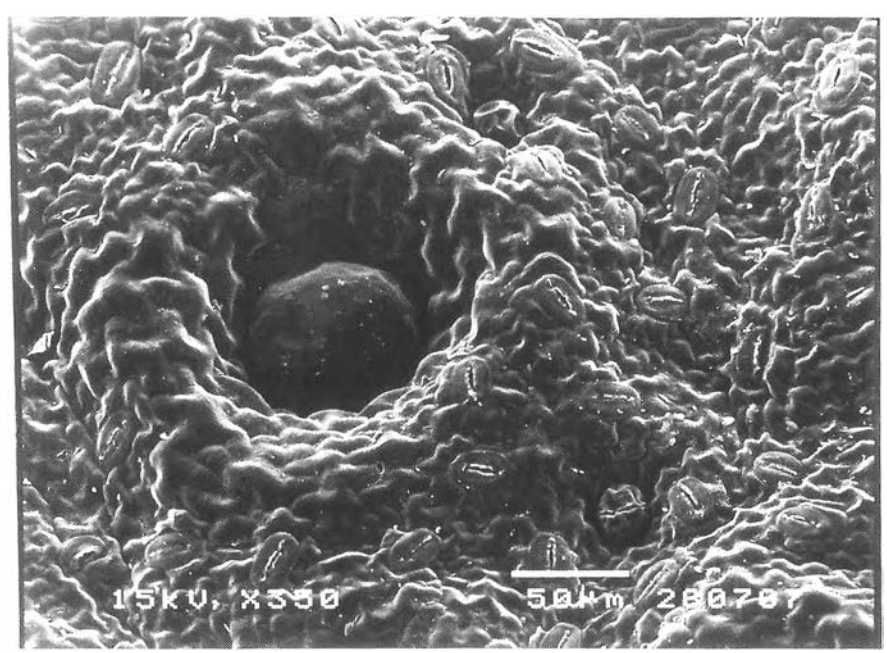


Fig.47 Scanning electron micrograph of glandular trichomes of *Ocimum canum* Sims.

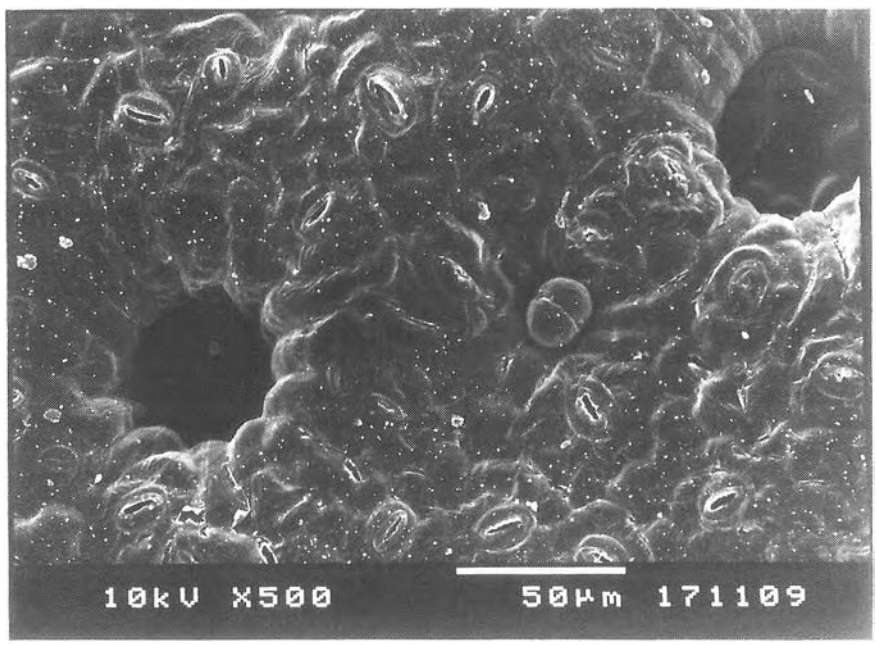


Fig.48 Scanning electron micrograph of glandular trichomes of *Ocimum grattissimum* L.

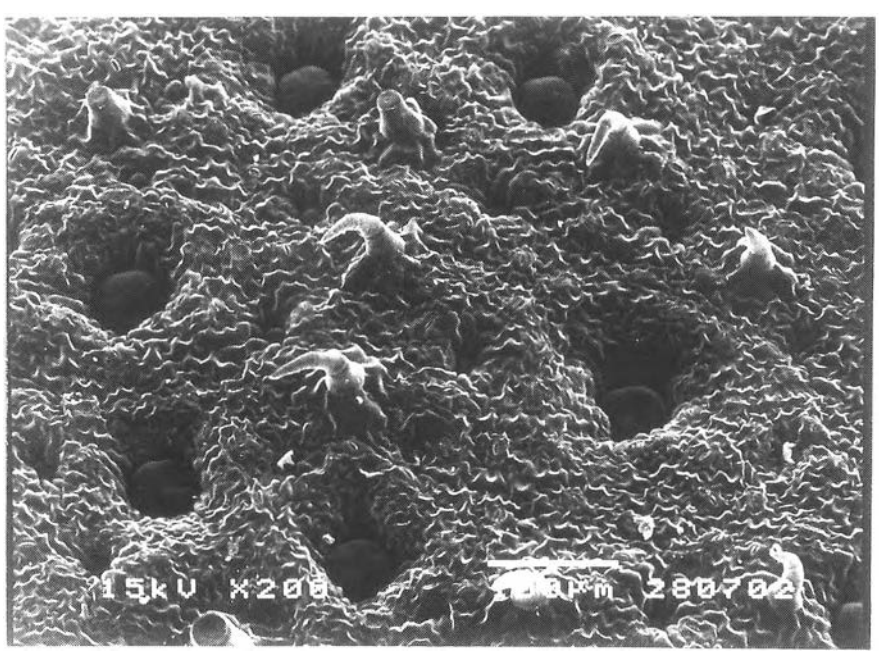


Fig.49 Scanning electron micrograph of glandular trichomes of *Ocimum sanctum* L.

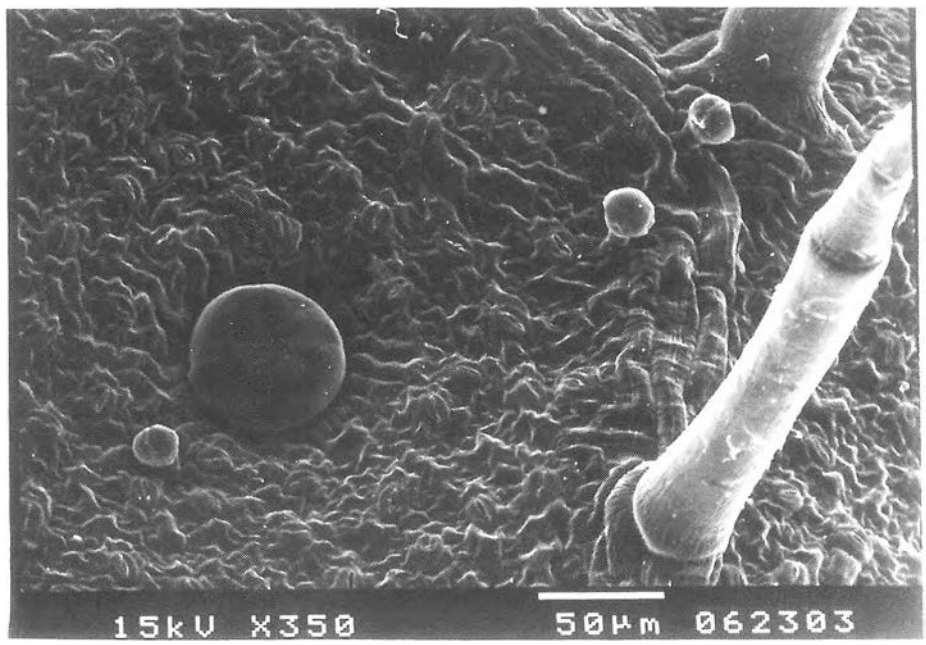


Fig.50 Scanning electron micrograph of glandular trichomes of *Perilla frutescens* Britt.

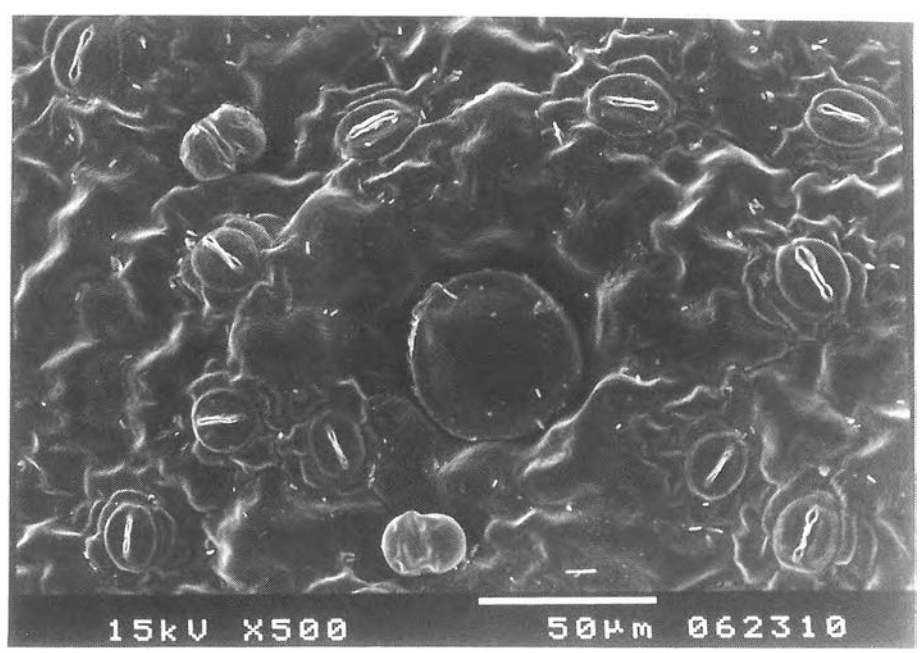


Fig.51 Scanning electron micrograph of glandular trichomes of *Pogostemon cablin* Benth

4.4 Antimicrobial activities of the essential oil from Thai Lamiaceous plants

Antimicrobial activities of the essential oils were shown in Table 23. It was found that the essential oils tested had no activities against *P.aeruginosa*, *C. albicans* and *M. gypseum*. Most of them, except the essential oils from *M. arvensis* L. var *piperascens* Malinvaud and *O. basilicum* L., exhibited antimicrobial activities against *S. aureus* and *B. subtilis*. The essential oils from *O. gratissimum* L. and *O. canum* L. had the lowest MIC against *S. aureus* (0.078%) and *B. subtilis* (0.156%), respectively. Some of them, including the oils from *C. amboinicus* Lour, *O. gratissimum* L. and *P. frutescens* Britt., inhibited *E. coli*. For *E. faecalis*, only the essential oils from *C. amboinicus* Lour. and *O. canum* L. could inhibit this strain and their MICs (1.25%) were the highest comparing to those against other strains. It was found that 0.1% Tween 80 had no activity against the test organisms but 1.25% and higher concentrations of DMSO inhibited growth of *S. aureus* in some extent. The degree of growth inhibition was 91.65%, 58.73% and 29.16% in 5%, 2.5% and 1.25% DMSO, respectively.

Table 23 Antimicrobial activities of essential oil

Plant	*Staphylococcus aureus* ATCC 29213		*Escherichia coli* ATCC 25922		*Bacillus subtilis* ATCC 6633		*Enterococcus faecalis* ATCC 29212	
	mm ± SD[a]	MIC (%)	mm ± SD[a]	MIC (%)	mm ± SD[a]	MIC (%)	mm ± SD[a]	MIC (%)
1. *Coleus amboinicus* Lour	17.23 ± 0.67	0.63	11.2 ± 1.06	0.63	17.03 ± 4.07	ND[b]	17.53 ± 0.35	1.25
2. *Hyptis suaveolens* Poit	12.50 ± 1.41	0.156	0	0	9.87 ± 0.91	5	0	0
3. *Mentha arvensis* Linn var *piperascens* Malinvaud	0	0	0	0	0	0	0	0
4. *Mentha cordifolia* Opiz	8.05 ± 0.35	5	0	0	10.27 ± 0.75	5	0	0
5. *Ocimum basilicum* L.	0	0	0	0	0	0	0	0
6. *Ocimum canum* L.	13.80 ± 0.36	0.156	0	0	17.01 ± 2.1	0.156	10.85 ± 1.20	1.25
7. *Ocimum gratissimum* L.	19.87 ± 0.45	0.078	8.23 ± 0.21	≥5	11.37 ± 1.84	5	0	0
8. *Ocimum sanctum* L.	9.96 ± 1.05	0.312	0	0	8.75 ± 0.35	5	0	0
9. *Perilla frutescens* Britt	9.87 ± 1.46	1.25	8.6 ± 0.69	ND[b]	12.1 ± 1.28	ND[b]	0	0
10. *Pogostemon cablin* Benth	8.63 ± 0.67	0.63	0	0	10.4 ± 1.14	0.312	0	0

[a] inhibition zone diameter resulted from 10 % oils in 0.1% Tween 80

[b] not determined