CHAPTER 2

REVIEW OF LITERATURE

2.1 *Piper chaba* Linn. or *Piper longum* Linn.

Piper chaba Linn. or *Piper longum* Linn. (Piperaceae), its common names in various countries are Di-pli**,** Prik-hang, Dipli-chueak (Thailand) and Long pepper (English). It is considered a native of South Asia and is found both wild as well as cultivated, throughout the hotter parts of India from central to the north-eastern Himalayas. The herb also grows wild in Thailand, Malaysia, Singapore, Bhutan, Myanmar and elsewhere. In Thailand, it was found in all investigated sites throughout the seven floristic regions of Thailand from 200-300 m altitude and common in central and northeastern Thailand. It is commonly spice in Thai food. In Thai traditional medicine, dried mature unripe fruits are used as carminative, element tonic, antidiarrheal, expectorant and oxytocic for post-labor. For cough, used dried fruit 1 handful or 10-15 fruits and decoction or a half of dried fruit grind with lime juice and salts; swap throat or sip frequently. It is not recommended for women during pregnancy (Saralamp *et.al.,* 1996).

Description of *Piper chaba* Linn, shown in Figure 2.1 and Figure 2.2, is a monoecious, climber, many parts finely powdery pubescent when young. Stem often flexuous. Petiole 1-3 cm long. Leaves on creeping branch and epiphytic branches blade ovate or elliptic. Leaves on free branches blade ovate to ovate-oblong. Leaf blade membranous, dark green, 3-5 cm wide, 7-10.5 cm long; apex acuminate; base cordate or oblique; veins 5, one pair basal, one pair arising 1.5 cm apart from base, opposite or alternate. Male spike straight up, 5-8 cm long, 0.3-0.7 cm in diameter; peduncle 0.5 cm long; bract orbicular, stalked; stamens 2. Female spike erect, 0.6-2 cm long, ca. 0.2 cm in diameter; peduncle 0.5 cm long; bract circular, peltate; stigmas 3. Fruiting spike straight up, 0.7-2.5 cm long; drupe globose, sessile, arranged densely on rachis. Flowering from May to September (Chaveerach *et.al.,* 2006).

Figure 2.1 *Piper chaba* Linn. or *Piper longum* Linn. (Piperaceae)

Figure 2.2 Fruit of *Piper chaba* Linn. (Piperaceae)

2.2 *Piper sarmentosum* Roxb.

Piper sarmentosum Roxb. (Piperaceae), its common names in various countries are Cha-phlu (central), Nom wa (peninsular), Phlu ling (northern) (Thailand); Karuk (Sundanese), Cabean (Javanese) (Indonesia) and Chabai, Kadok batu (Malaysia). It is probably native to India, southern China and south-east Asia. In Thai traditional medicine, the whole plant is used as an expectorant, the leaf as a carminative (Jansen, 1999). In addition, the whole plant extract could stimulated intestinal movement and relaxed skeletal muscles (Saralamp *et.al.,* 1996).

Description of *Piper sarmentosum* Roxb, shown in Figure 2.3 and Figure 2.4, is a monoecious, normally small shrubs, 30 cm tall, sometimes climber, all parts glabrous. Petiole 1-2.5 cm long; leaf blade thin to thick chartaceous or papery, light to

dark green, broadly ovate to elliptic, 4.5-6 cm wide, 7.5-9.5 cm long; apex acute; leaves on epiphytic branches base deeply equally cordate with rounded lobes, leaves on free branch base cuneate to subtruncate; veins 7, all basal. Spike with male and female flowers together straight up, cylindrical, 1-1.5 cm long, 0.3-0.5 cm in diameter; peduncle ca. 1.5 cm long; bract rounded; stamen 1; stigmas 3-4. Female spike white cylindric, other characters are as above. Fruiting spike 1-2 cm long, 0.5-1 cm in diameter. Flowering on year round, many in rainy season (Chaveerach *et.al.,* 2006).

Figure 2.3 *Piper sarmentosum* Roxb.(Piperaceae)

Figure 2.4 Fruit of *Piper sarmentosum* Roxb. (Piperaceae) (from http://www.212cafe.com/boardvip/view.php?user=watpo&id=79, 2008)

2.3 *Piper interruptum* Opiz. or *Piper ribesoides* Wall.

Piper interruptum Opiz. (Piperaceae), its Thai vernacular names are Sa-kan, Sa-kan-lek and Sa-kan-youak, found in north and northeast Thailand from 200-1200 m altitude. In Thai traditional medicine, the stem is used as carminative, antiflatulant, and element tonic (Pichiensunthon & Jeerawongs, 2004).

Description of *Piper interruptum* Opiz., shown in Figure 2.5 and Figure 2.6, is a climbers dioecious. Stems 2-4.5 mm thick, ridged, glabrous. Petiole 1-2.5(-4) cm, glabrous, sheathed at base only; leaf blade ovate to long ovate, 6-13 × 4-7 cm, ± membranous or papery, without evident glands, both surfaces glabrous, base rounded or shortly tapered, ± symmetric, apex acute or shortly acuminate; veins 5(-7), all basal; reticulate veins abaxially prominent, lax. Spikes leaf-opposed. Male spikes 11-27 cm × 1.5-3 mm; peduncle ca. as long as petioles, glabrous; bracts oblong, 3-4 × ca. 1 mm, adnate to rachis, margin free, apex ± rounded. Stamens 2(or 3). Female spikes 7-17 cm, flowers unevenly developed, sparse or interrupted in fruit; peduncle nearly as long as opposite leaves, glabrous; rachis and bracts as in male spikes. Ovary distinct, ovoid, apex acute; stigmas 4 or 5. Drupe ovoid or ovoid-globose, 3-6 × 2-4 mm, smooth (Cheng *et.al.,* 1999).

Figure 2.5 *Piper interruptum* Opiz. (Piperaceae) (from http://home.hiroshima-u.ac.jp/shoyaku/photo/Thai/021205Piper.jpg, 2008)

Figure 2.6 Fruit of *Piper interruptum* Opiz. (Piperaceae) (from http://home.kku.ac.th/raccha/Piper.html, 2008)

2.4 *Plumbago indica* Linn. or *Plumbago rosea* Linn.

Plumbago indica Linn. (Plumbaginaceae), its common names in various countries are Chettamun-phloeng-daeng (central), Pit-piu-daeng (northern), Fai-tai-din (peninsular) (Thailand); Rosy-flowered leadwort, Officinal leadwort (English); Akar binasa, Mehulatu (Indonesia); Cheraka merah, Setaka (Malaysia) and Laurel, Pampasapit (Philippines). It is probably native to tropical Africa, tropical Asia and the Pacific region and common throughout South-East Asia. In Thai traditional medicine, the root is used as carminative and emmenagogue for treatment of hemorrhoids. It contained plumbagin which stimulated uterus and intestinal contraction, increase digestive enzyme secretion, stimulated appetite. Because of plumbagin can irritated mucous membrane, it might be used cautiously (Saralamp *et.al.,* 1996).

Description of *Plumbago indica* Linn., shown in Figure 2.7 and Figure 2.8, is a shrub up to 1.5 m tall, branched from the base, stems drooping, sometimes rooting; leaves oblong, 5-15 cm x 2-8 cm, petiole not auriculate; inflorescence a rather sparsely flowered spike, not corymbose, rachis glabrous, 10-30 cm long; flowers with calyx about 1 cm long, covered in glands, red, corolla tube 2.5-4 cm long, lobes 2-3 cm in diameter, distinctly mucronate, red; fruit unknown. *Plumbago indica* is found in the vicinity of (former) anthropogenic localities, locally semi-

spontaneous, often persistent in abandoned cultivation, also in teak forest, up to 1000 m elevation (Chuakul *et.al.,* 1999).

Figure 2.7 *Plumbago indica* Linn. (Plumbaginaceae)

Figure 2.8 Flower of *Plumbago indica* Linn. (Plumbaginaceae)

2.5 *Zingiber officinale* Roscoe.

Zingiber officinale Roscoe (Zingiberaceae), its common names in various countries are Khing (Thailand); Ginger, Common ginger (Enlish); Gingembre (Franch); Jahe, Jae, Lia (Indonesia); Haliya, Jahi, Atuja (Malaysia) and Luya (Tagalog) (Philippines). It is probably native to south-east Asia and is cultivated in the

tropical regions in both the eastern and western hemispheres (WHO, 1999). In Thai traditional medicine, the rhizomes were used as carminative, antiemetic, expectorant, antispasmodic and diaphoretic. Dose as used was thumb-sized portion of fresh rhizome or dried powder, infuse. Volatile oil from rhizome of ginger contained menthol, borneol, fenchone, 6-shogaol and 6-gingerol. Menthol was carminative. Borneol, fenchone and 6-gingerol were increased bile secretion and promoted fat digestion (Saralamp *et.al.,* 1996).

Description of *Zingiber officinale* Roscoe, shown in Figure 2.9 and Figure 2.10, is a perennial herb with a subterranean, digitately branched rhizome producing stems up to 1.50 m in height with linear lanceolate sheathing leaves (5–30 cm long and 8–20 mm wide) that are alternate, smooth and pale green. Flower stems shorter than leaf stems and bearing a few flowers, each surrounded by a thin bract and situated in axils of large, greenish yellow obtuse bracts, which are closely arranged at end of flower stem forming collectively an ovate-oblong spike. Each flower shows a superior tubular calyx, split part way down one side; an orange yellow corolla composed of a tube divided above into 3 linearoblong, blunt lobes; 6 staminodes in 2 rows, the outer row of 3 inserted at mouth of corolla; the posterior 2, small, horn-like; the anterior petaloid, purple and spotted and divided into 3 rounded lobes; an inferior, 3-celled ovary with tufted stigma. Fruit a capsule with small arillate seeds (WHO, 1999).

Rhizome of ginger occurs in horizontal, laterally flattened, irregularly branching pieces; 3–16cm long, 3–4cm wide, up to 2 cm thick; sometimes split longitudinally; pale yellowish buff or light brown externally, longitudinally striated, somewhat fibrous; branches known as “fingers” arise obliquely from the rhizomes, are flattish, obovate, short, about 1–3cm long; fracture, short and starchy with projecting fibres. Internally, yellowish brown, showing a yellow endodermis separating the narrow cortex from the wide stele, and numerous scattered fibrovascular bundles, abundant scattered oleoresin cells with yellow contents and numerous larger greyish points, vascular bundles, scattered on the whole surface (WHO, 1999).

Figure 2.9 The upper stem of *Zingiber officinale* Roscoe (Zingiberaceae) (from http://www.rimbundahan.org/environment/plant_lists/taman_sari/Zingiberofficinale.jpg, 2008)

Figure 2.10 The Rhizome of *Zingiber officinale* Roscoe (Zingiberaceae) (from http://www. herbalextractsplus.com/images/herbs/ginger-root-bsp.jpg, 2008)

2.6 **Benjakul Preparation** (Deevisate *et.al.,* 1994)

Benjakul, a Thai Traditional medicine preparation, is composed of five plants; *Piper chaba* fruit*, Piper sarmentosum* root*, Piper interruptum* stem*, Plumbago indica* root *and Zingiber officinale* rhizome. It is commonly used for a balanced health

preparation in Thai traditional medicine because it could controlled abnormal of the earth, water, wind, fire and air element in the body.

The plants, which are ingredients of Benjakul preparation, have different properties for tonic element as described below:

Piper chaba or Di-pli (Thailand) was a drug used for tonic earth element and controlled abnormal of earth element such as muscle and tendon painful, stress and dried skin.

Piper sarmentosum or Cha-phlu (Thailand) was a drug used for tonic water element and controlled abnormal of water element such as too much saliva, bloody mouth, dry teeth or too much urinate.

Piper interuptum or Sa-kan (Thailand) was a drug used for tonic wind element and controlled abnormal of wind element such as low or high blood pressure, flatulent, dry mouth, emetic or headache.

Plumbago indica or Chettamun-phloeng-daeng (Thailand) was a drug used for tonic fire element and controlled abnormal of fire element such as dried cough, lower body temperature, beriberi and anorexia.

Zingiber officinale or Khing (Thailand) was a drug used for tonic air element and controlled abnormal of air element such as blur and tinnitus.

Investigation of indigenous wisdom on cancer treatment of Thai traditional doctors by Itharat *et. al*. (1998) revealed that a Benjakul preparation has been used as an adaptogen drug for cancer patients. Folk doctors would give this preparation to cancer patients for 2 or 3 weeks before treatment by cancer preparation. By the reason, it can make balance element in patient body or make increase immunity in their body. Benjakul extracts showed no toxicity for body tissue and biomaterial changes when tested by a sub-chronic toxicity method (Chauvaltthamrong *et. al*., 1996).

2.7 Chemical constituents of the investigated species

The reports of chemical constituents of these five plants are shown in Table 2.1 to 2.5. Their chemical structures are showed in Figure 2.11 to 2.15.

Table 2.1 Chemical constituents found in *Piper chaba* Linn.

Botanical name	Part of plant used	Chemical constituents	References
***Piper chaba* Linn.** or	Fruit	Guineensine (1)	Wu *et.al.,* 2004; Lee *et.al.,* 2008a
***Piper longum* Linn.**		Retrofracamide C (2)	Lee *et.al.,* 2008a
		(2*E*,4*Z*,8*E*)-*N*-[9-(3,4-methylenedioxyphenyl)-2,4,8-nonatrienoyl]piperidine (3)	Lee *et.al.,* 2008 a
		Pipernonaline (4)	Wu *et.al.,* 2004; Lee *et.al.,* 2008 a
		Piperrolein B (5)	Lee *et.al.,* 2008 a
		Piperchabamide D (6)	Lee *et.al.,* 2008 a
		Dehydropipernonaline (8)	Lee *et.al.,* 2008 a
		Piperine (9)	Park *et.al.,* 2007; Wu *et.al.,* 2004
		Piperlongumine (10)	Wu *et.al.,* 2004; Park *et.al.,* 2007

Table 2.1 (continued)

Botanical name	Part of plant used	Chemical constituents	References
***Piper chaba* Linn.** or	Fruit	Piperoctadecalidine (11)	Park *et.al.,* 2007
***Piper longum* Linn.**		Retrofractamides A (12)	Zhang *et.al.,* 2008
		Retrofractamides B (13)	Zhang *et.al.,* 2008
		Pipataline	Pullela *et.al.,* 2006
		Brachystamide B (14)	Pullela *et.al.,* 2006; Zhang *et.al.,* 2008
		Piperinic acid (15)	Devan *et.al.,* 2007
		(2*E*,4*E*)-*N*-Isobutyleicosa-2,4-dienamide (16)	Wu *et.al.,* 2004
		(2*E*,4*E*,14*Z*)-*N*-Isobutyleicosa-2,4,14-trienamide (17)	Wu *et.al.,* 2004
		(2*E*,4*E*,12*Z*)-*N*-Isobutylocatadeca-2,4,12-trienamide (18)	Wu *et.al.,* 2004
		Piperanine (19)	Wu *et.al.,* 2004
		Tetrahydropiperine (20)	Madhusudhan and Vandana, 2001
		Piperchabamide A (21)	Zhang *et.al.,* 2008
		Methyl piperate (22)	Zhang *et.al.,* 2008

Table 2.1 (continued)

Botanical name	Part of plant used	Chemical constituents	References
***Piper chaba* Linn.** or	Fruit	Piperchabamide B (23)	Zhang *et.al.,* 2008
***Piper longum* Linn.**		Piperundecalidiene (24)	Zhang *et.al.,* 2008
		N-isobutyl-(2*E*,4*E*)-decadienamide (25)	Zhang *et.al.,* 2008
		N-isobutyl-(2*E*,4*E*)-dodecadienamide (26)	Zhang *et.al.,* 2008
		N-isobutyl-(2*E*,4*E*)-octadecadienamide (27)	Zhang *et.al.,* 2008
		N-isobutyl-(2*E*,4*E*,14*Z*)-eicosatrienamide (28)	Zhang *et.al.,* 2008
		Piperchabamide C (29)	Matsuda *et.al.,* 2008
		Piperchabamide E (30)	Matsuda *et.al.,* 2008

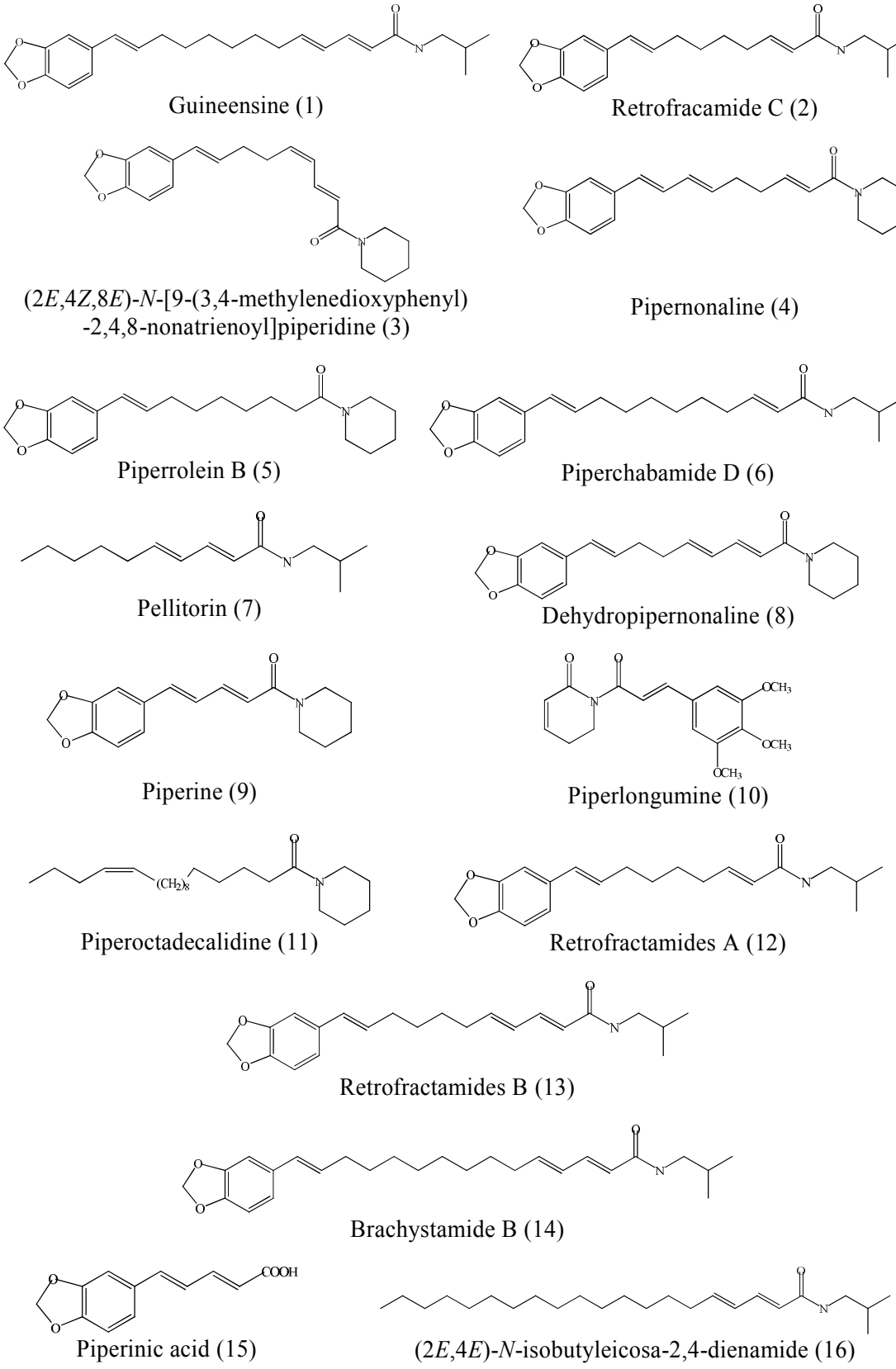
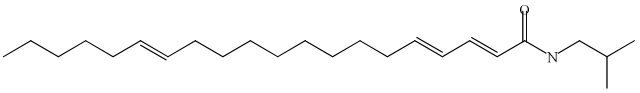
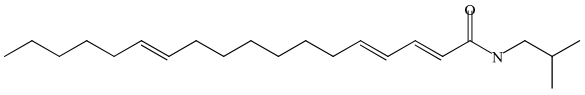


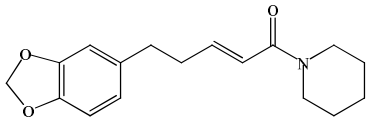
Figure 2.11 Structures of some chemical constituents found in *Piper chaba*



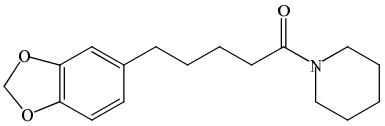
(2*E*,4*E*,14*Z*)-*N*-Isobutyleicosa-2,4,14-trienamide (17)



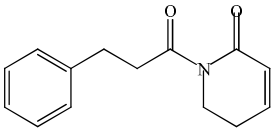
(2*E*,4*E*,12*Z*)-*N*-isobutylocatadeca-2,4,12-trienamide (18)



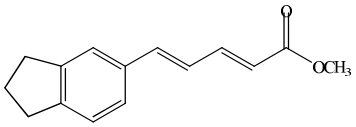
Piperanine (19)



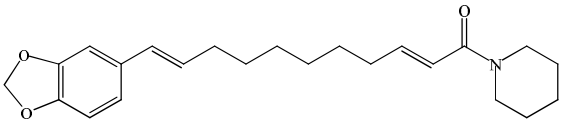
Tetrahydropiperine (20)



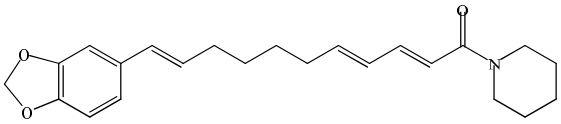
Piperchabamide A (21)



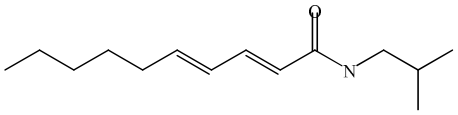
Methyl piperate (22)



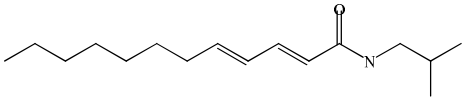
Piperchabamide B (23)



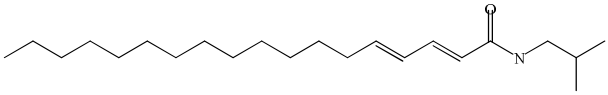
Piperundecalidiene (24)



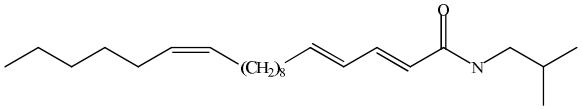
N-isobutyl-(2*E*,4*E*)-decadienamide (25)



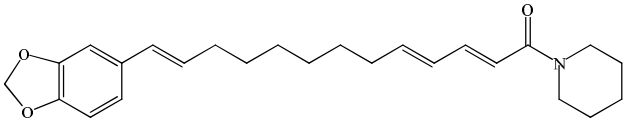
N-isobutyl-(2*E*,4*E*)-dodecadienamide (26)



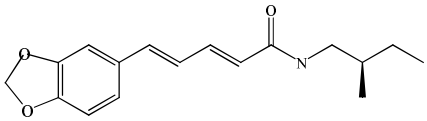
N-isobutyl-(2*E*,4*E*)-octadecadienamide (27)



N-isobutyl-(2*E*,4*E*,14*Z*)-eicosatrienamide (28)



Piperchabamide C (29)



Piperchabamide E (30)

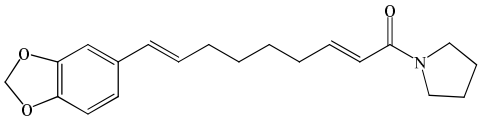
Figure 2.11 (continued)

Table 2.2 Chemical constituents found in *Piper sarmentosum* Roxb.

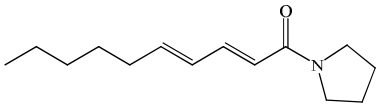
Botanical name	Part of plant used	Chemical constituents	References
***Piper sarmentosum* Roxb.**	Fruit	Pellitorine (7)	Rukachaisirikul *et al.,* 2004
		Guineensine (1)	Rukachaisirikul *et al.,* 2004
		Brachymide B (31)	Rukachaisirikul *et al.,* 2004
		Sarmentine (32)	Rukachaisirikul *et al.,* 2004
		Brachystamide B (33)	Rukachaisirikul *et al.,* 2004
		1-piperettyl pyrrolidine (34)	Rukachaisirikul *et al.,* 2004
		3′,4′,5′-trimethoxycinnamoyl pyrrolidine (35)	Rukachaisirikul *et al.,* 2004
		Sarmentosine (36)	Rukachaisirikul *et al.,* 2004
		(+)-Asarinin (37)	Rukachaisirikul *et al.,* 2004
		Sesamin (38)	Rukachaisirikul *et al.,* 2004
		1-(3,4-methylenedioxyphenyl)-1E-tetradecene (39)	Rukachaisirikul *et al.,* 2004
		Methyl piperate (22)	Rukachaisirikul *et al.,* 2004
		β-sitosterol (40)	Rukachaisirikul *et al.,* 2004
		Stigmasterol (41)	Rukachaisirikul *et al.,* 2004

Table 2.2 (continued)

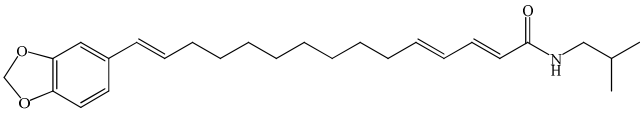
Botanical name	Part of plant used	Chemical constituents	References
***Piper sarmentosum* Roxb.**	Aerial	2*E*,4*E*-diene-isobutylamides	Stöhr *et.al.,* 1999
		N-2′-methylbutyl-2*E*,4*E*-decadieneamide	Stöhr *et.al.,* 1999
	Root	1-allyl-2-methoxy-4,5-methylenedioxybenzene (42)	Tuntiwachwuttikul *et al.,* 2006
		Pyrrole amide (43)	Tuntiwachwuttikul *et al.,* 2006
		Horsfieldin (44)	Tuntiwachwuttikul *et al.,* 2006
		Sarmentamide A (45)	Tuntiwachwuttikul *et al.,* 2006
		Sarmentamide B (46)	Tuntiwachwuttikul *et al.,* 2006
		Sarmentamide C (47)	Tuntiwachwuttikul *et al.,* 2006



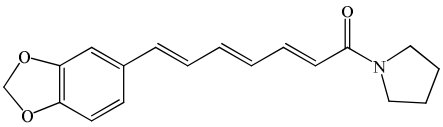
Brachyamide B (31)



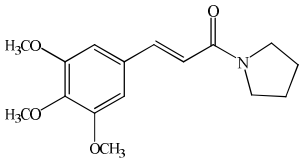
Sarmentine (32)



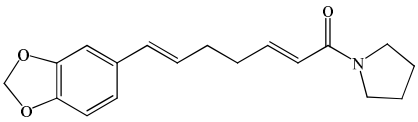
Brachystamide B (33)



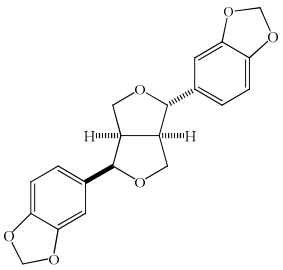
1-piperettyl pyrrolidine (34)



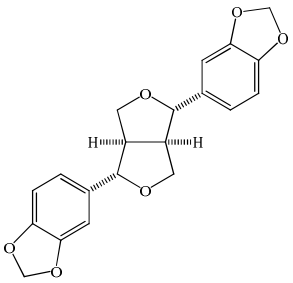
3′,4′,5′-trimethoxycinnamoyl pyrrolidine (35)



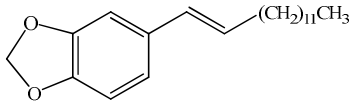
Sarmentosine (36)



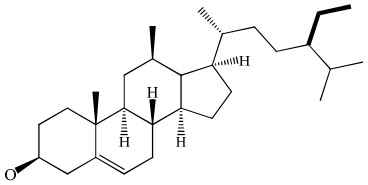
(+)-Asarinin (37)



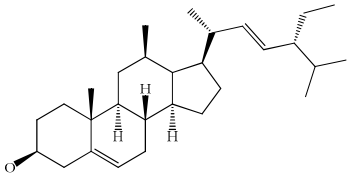
Sesamin (38)



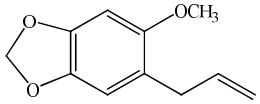
1-(3,4-methylenedioxyphenyl)-1E-tetradecene (39)



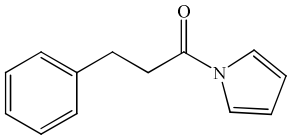
β-sitosterol (40)



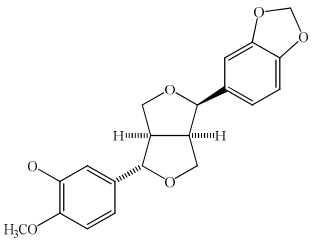
Stigmasterol (41)



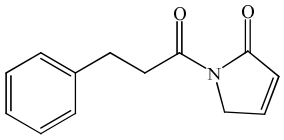
1-allyl-2-methoxy-4,5-methylenedioxybenzene (42)



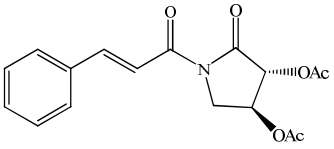
Pyrrole amide (43)



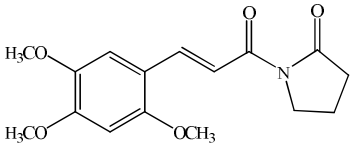
Horsfieldin (44)



Sarmentamide A (45)



Sarmentamide B (46)



Sarmentamide C (47)

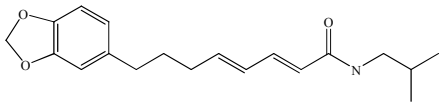
Figure 2.12 Structures of some chemical constituents found in *Piper sarmentosum*

Table 2.3 Chemical constituents found in *Piper interruptum* Opiz.

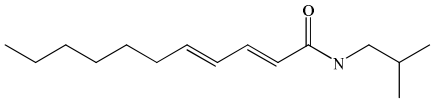
Botanical name	Part of plant used	Chemical constituents	References
***Piper interruptum* Opiz.**		Pipercallosine (48)	Parmar *et.al.,* 1997
or ***Piper ribesoides* wall.**		(2*E*,4*E*)-*N*-Isobutyldecadienamide (49)	Parmar *et.al.,* 1997
		4-Hydroxy-3-methoxy-*N*-methylpiperolactam (50)	Parmar *et.al.,* 1997
		(-)-Cubebin (51)	Parmar *et.al.,* 1997
		Eupomatene (52)	Parmar *et.al.,* 1997
		Eupomatenoid-7 (53)	Parmar *et.al.,* 1997
		α-Elemol (54)	Parmar *et.al.,* 1997
		Bomyl *p*-coumarate (55)	Parmar *et.al.,* 1997
		Crotepoxide (56)	Parmar *et.al.,* 1997
		(+)-3,7-Dimethyl-3-hydroxy-4-(*p*-coumaroyloxy-1,6-octadiene) (57)	Parmar *et.al.,* 1997
		Methyl piperate (22)	Parmar *et.al.,* 1997
		Methyl 2*E*,4*E*,6*E*-7-phenylheptatrienoate (58)	Parmar *et.al.,* 1997

Table 2.3 (Continued)

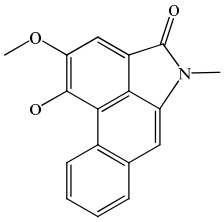
Botanical name	Part of plant used	Chemical constituents	References
***Piper interruptum* Opiz.**		Palmitic acid ($CH_3(CH_2)_{14}COOH$)	Parmar *et.al.,* 1997
or ***Piper ribesoides* wall.**		Senediol (59)	Parmar *et.al.,* 1997
		Steak acid ($CH_3(CH_2)_{16}COOH$)	Parmar *et.al.,* 1997



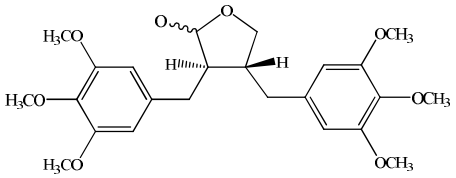
Pipercallosine (48)



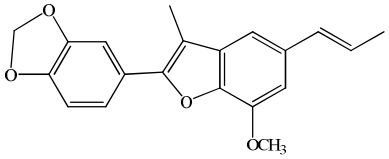
(2*E*,4*E*)-*N*-Isobutyldecadienamide (49)



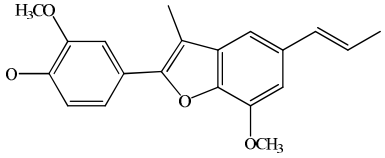
4-Hydroxy-3-methoxy-*N*-methylpiperolactam (50)



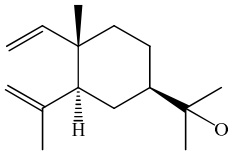
(-)-Cubebin (51)



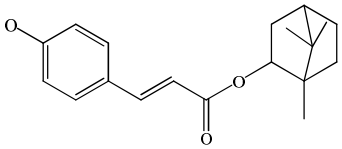
Eupomatene (52)



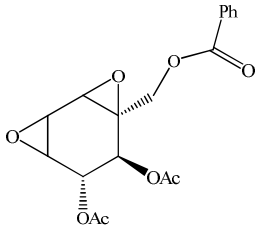
Eupomatenoid-7 (53)



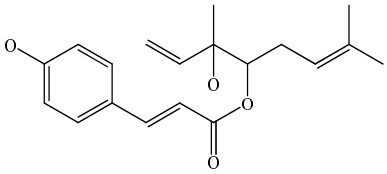
Elemol (54)



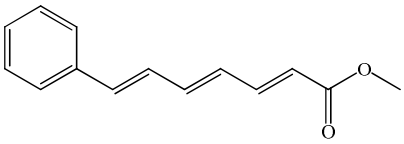
Bomyl *p*-coumarate (55)



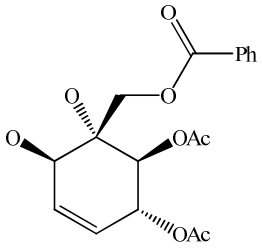
Crotepoxide (56)



(+)-3,7-Dimethyl-3-hydroxy-4-(*p*-coumaroyloxy-1,6-octadiene) (57)



Methyl 2*E*,4*E*,6*E*-7-phenylheptatrienoate (58)

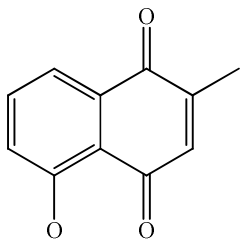


Senediol (59)

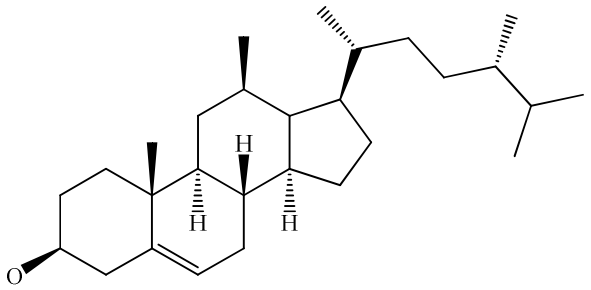
Figure 2.13 Structures of some chemical constituents found in *Piper interruptum*

Table 2.4 Chemical constituents found in *Plumbago indica* Linn.

Botanical name	Part of plant used	Chemical constituents	References
***Plumbago indica* Linn.** or	Root	Plumbagin (60)	Dinda & Chel, 1992
***Plumbago rosea* Linn.**		β-sitosterol (40)	Dinda & Chel, 1992
		Stigmasterol (41)	Dinda & Chel, 1992
		Campesterol (61)	Dinda & Chel, 1992
		6-Hydroxyplumbagin	Dinda & Chel, 1992



Plumbagin (60)



Campesterol (61)

Figure 2.14 Structures of some chemical constituents found in *Plumbago indica*

Table 2.5 Chemical constituents found in *Zingiber officinale* Roscoe.

Botanical name	Part of plant used	Chemical constituents	References
***Zingiber officinale* Roscoe.**	Rhizome	[6]-gingerol (62)	Surh *et.al.,* 1999; Wei *et.al.,* 2005
		[6]-paradol (63)	Surh *et.al.,* 1999; Wei *et.al.,* 2005
		(3*R*,5*S*)-3,5-diacetoxy-1,7-bis(4-hydroxy-3-methoxyphenyl) heptane (64)	Wei *et.al.,* 2005
		(3*R*,5*S*)-3-acetoxy-5-hydroxy-1,7-bis(4-hydroxy-3-methoxyphenyl)heptane (65)	Wei *et.al.,* 2005
		(3*R*,5*S*)-3,5-dihydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)-7-(4-hydroxy-3-methoxyphenyl)-heptane (66)	Wei *et.al.,* 2005
		(3*R*,5*S*)-3,5-dihydroxy-1,7-bis(4-hydroxy-3methoxyphenyl)heptane (67)	Wei *et.al.,* 2005
		(5*S*)-5-acetoxy-1,7-bis(4-hydroxy-3-methoxyphenyl) heptan-3-one (68)	Wei *et.al.,* 2005
		5-hydroxy-1-(4-hydroxy-3-methoxyphenyl) -7-(3,4-dihydroxyphenyl)heptan-3-one (69)	Wei *et.al.,* 2005
		Hexahydrocurcumin (70)	Wei *et.al.,* 2005

Table 2.5 (continued)

Botanical name	Part of plant used	Chemical constituents	References
***Zingiber officinale* Roscoe.**	Rhizome	[6]-gingerdiol (71)	Wei *et.al.,* 2005
		(3*R*,5*S*)-3,5-diacetoxy-[6]-gingerdiol (72)	Wei *et.al.,* 2005
		[4]-gingerol (73)	Wei *et.al.,* 2005; Kim *et.al.,* 2008
		[8]-gingerol (74)	Wei *et.al.,* 2005; Kim *et.al.,* 2008
		[10]-gingerol (75)	Wei *et.al.,* 2005; Kim *et.al.,* 2008
		5-acetoxy-[6]-gingerol (76)	Wei *et.al.,* 2005
		[6]-shogaol (77)	Wei *et.al.,* 2005; Kim *et.al.,* 2008
		[10]-shogaol (78)	Wei *et.al.,* 2005
		Dehydrogingerdione (79)	Wei *et.al.,* 2005
		1-(3,4-dimethoxyphenyl)-5-hydroxydecan-3-one (80)	Wei *et.al.,* 2005
		3-acetoxy-l,5-epoxy-1-(3,4-dihydroxy-5-methoxyphenyl)-7- (4-hydroxy-3-methoxy-phenyl) heptane (81)	Wei *et.al.,* 2005
		1,7-bis(4-hydroxy-3-methoxyphenyl)hept-4-en-3-one (82)	Wei *et.al.,* 2005

Table 2.5 (continued)

Botanical name	Part of plant used	Chemical constituents	References
***Zingiber officinale* Roscoe.**	Rhizome	1-(4-hydroxy-3-methoxyphenyl)propan-1,2-diol (83)	Wei *et.al.,* 2005
		Zingerone (84)	Kuo *et.al.,* 2005
		Dehydrozingerone (85)	Kuo *et.al.,* 2005
		Methyl [6]-paradol (86)	Jolad *et.al.,* 2005
		[8]-Paradol (87)	Jolad *et.al.,* 2005
		Methyl [8]-paradol (88)	Jolad *et.al.,* 2005
		[10]-Paradol (89)	Jolad *et.al.,* 2005
		Methyl [4]-gingerol (90)	Jolad *et.al.,* 2005
		[5]-Gingerol (91)	Jolad *et.al.,* 2005
		Methyl [6]-gingerol (92)	Jolad *et.al.,* 2005
		[4]-Isogingerol (93)	Jolad *et.al.,* 2005
		Methyl [6]-isogingerol (94)	Jolad *et.al.,* 2005
		Methyl [4]-shogaol (95)	Jolad *et.al.,* 2005
		[5]-Shogaol (96)	Jolad *et.al.,* 2005
		Methyl [6]-shogaol (97)	Jolad *et.al.,* 2005

Table 2.5 (continued)

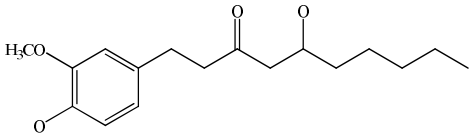
Botanical name	Part of plant used	Chemical constituents	References
***Zingiber officinale* Roscoe.**	Rhizome	Methyl [8]-shogaol (98)	Jolad *et.al.,* 2005
		[12]-Shogaol (99)	Jolad *et.al.,* 2005
		[6]-Isoshogaol (100)	Jolad *et.al.,* 2005
		[6]-Gingerdione (101)	Jolad *et.al.,* 2005
		[8]-Gingerdione (102)	Jolad *et.al.,* 2005
		[10]-Gingerdione (103)	Jolad *et.al.,* 2005
		[12]-Gingerdione (104)	Jolad *et.al.,* 2005
		1-Dehydro-[6]-gingerdione (105)	Jolad *et.al.,* 2005
		1-Dehydro-[8]-gingerdione (106)	Jolad *et.al.,* 2005
		1-Dehydro-[10]-gingerdione (107)	Jolad *et.al.,* 2005
		Acetoxy-[4]-gingerol (108)	Jolad *et.al.,* 2005
		Acetoxy-[10]-gingerol (109)	Jolad *et.al.,* 2005
		Methoxy-[4]-gingerol (110)	Jolad *et.al.,* 2005
		Methoxy-[6]-gingerol (111)	Jolad *et.al.,* 2005
		Methoxy-[8]-gingerol (112)	Jolad *et.al.,* 2005
		Methoxy-[10]-gingerol (113)	Jolad *et.al.,* 2005

Table 2.5 (continued)

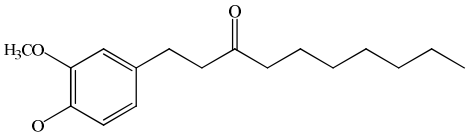
Botanical name	Part of plant used	Chemical constituents	References
***Zingiber officinale* Roscoe.**	Rhizome	[4]-Gingerdiol (114)	Jolad *et.al.,* 2005
		[8]-Gingerdiol (115)	Jolad *et.al.,* 2005
		[10]-Gingerdiol (116)	Jolad *et.al.,* 2005
		5-Acetoxy-[4]-gingerdiol (117)	Jolad *et.al.,* 2005
		Methyl 5-acetoxy-[4]-gingerdiol (118)	Jolad *et.al.,* 2005
		3-Acetoxy-[4]-gingerdiol (119)	Jolad *et.al.,* 2005
		5-Acetoxy-[6]-gingerdiol (120)	Jolad *et.al.,* 2005
		Methyl 5-acetoxy-[6]-gingerdiol (121)	Jolad *et.al.,* 2005
		Diacetoxy-[4]-gingerdiol (122)	Jolad *et.al.,* 2005
		Methyl diacetoxy-[4]-gingerdiol (123)	Jolad *et.al.,* 2005
		Diacetoxy-[6]-gingerdiol (124)	Jolad *et.al.,* 2005
		Methyl diacetoxy-[6]-gingerdiol (125)	Jolad *et.al.,* 2005
		Diacetoxy-[8]-gingerdiol (126)	Jolad *et.al.,* 2005
		Methyl diacetoxy-[8]-gingerdiol (127)	Jolad *et.al.,* 2005
		Dihydro-[6]-paradol (128)	Jolad *et.al.,* 2005
		Demethoxy-[6]-shogaol (129)	Jolad *et.al.,* 2005

Table 2.5 (continued)

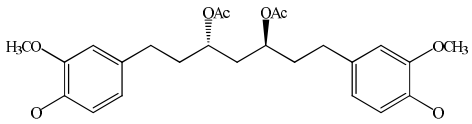
Botanical name	Part of plant used	Chemical constituents	References
***Zingiber officinale* Roscoe.**	Rhizome	3-Acetoxy-3-dihydrodemethoxy-[6]-shogaol (130)	Jolad *et.al.,* 2005
		5-Acetoxy-3-deoxy-[6]-gingerol (131)	Jolad *et.al.,* 2005
		1-Hydroxy-[6]-paradol (132)	Jolad *et.al.,* 2005
		6-Hydroxy-[6]-shogaol (134)	Jolad *et.al.,* 2005
		6-Hydroxy-[8]-shogaol (133)	Jolad *et.al.,* 2005
		6-Hydroxy-[10]-shogaol (135)	Jolad *et.al.,* 2005
		Demethoxy-[6]-gingerol (136)	Jolad *et.al.,* 2005
		6-Dehydro-[6]-gingerol (137)	Jolad *et.al.,* 2005
		1-Dehydro-[6]-gingerol (138)	Jolad *et.al.,* 2005
		[6]-Gingerdiol, cyclic methyl orthoester (139)	Jolad *et.al.,* 2005
		[10]-Gingerdiol, cyclic methyl orthoester (140)	Jolad *et.al.,* 2005
		[7]-gingerol (141)	Jolad *et.al.,* 2005



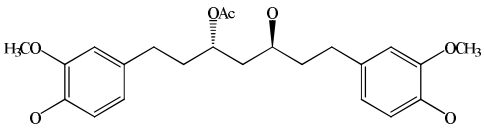
[6]-gingerol (62)



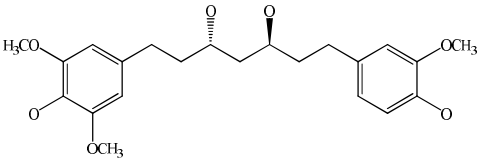
[6]-paradol (63)



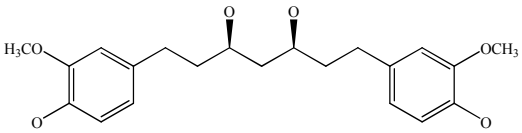
(3*R*,5*S*)-3,5-diacetoxy-1,7-bis(4-hydroxy-3-methoxyphenyl) heptane (64)



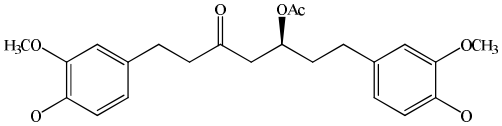
(3*R*,5*S*)-3-acetoxy-5-hydroxy-1,7-bis(4-hydroxy-3-methoxyphenyl)heptane (65)



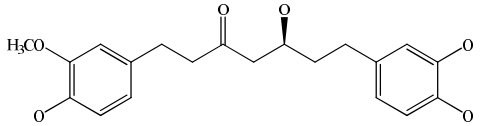
(3*R*,5*S*)-3,5-dihydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)-7-(4-hydroxy-3-methoxyphenyl)-heptane (66)



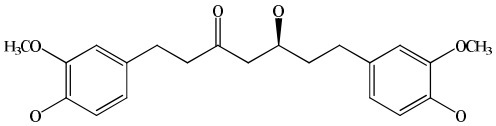
(3*R*,5*S*)-3,5-dihydroxy-1,7-bis(4-hydroxy-3methoxyphenyl)heptane (67)



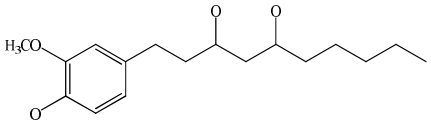
(5*S*)-5-acetoxy-1,7-bis(4-hydroxy-3-methoxyphenyl) heptan-3-one (68)



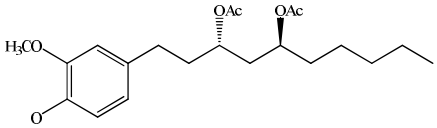
5-hydroxy-1-(4-hydroxy-3-methoxyphenyl)-7-(3,4-dihydroxyphenyl)heptan-3-one (69)



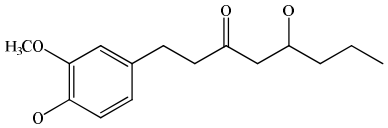
Hexahydrocurcumin (70)



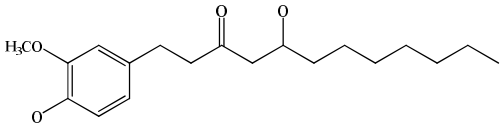
[6]-gingerdiol (71)



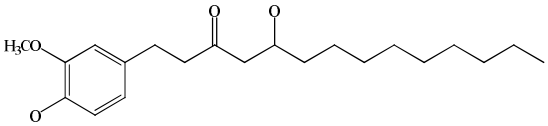
(3*R*,5*S*)-3,5-diacetoxy-[6]-gingerdiol (72)



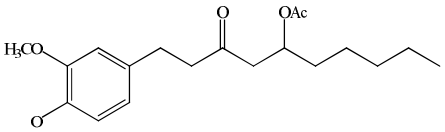
[4]-gingerol (73)



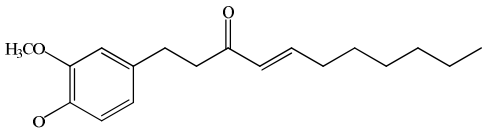
[8]-gingerol (74)



[10]-gingerol (75)

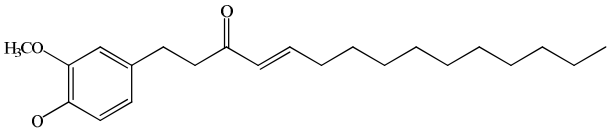


5-acetoxy-[6]-gingerol (76)

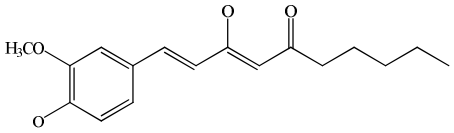


[6]-shogaol (77)

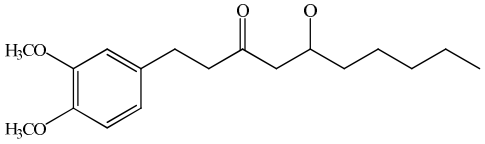
Figure 2.15 Structures of some chemical constituents found in *Zingiber officinale*



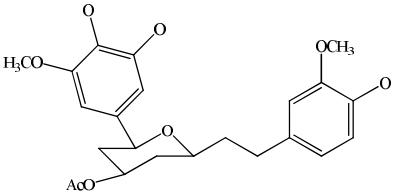
[10]-shogaol (78)



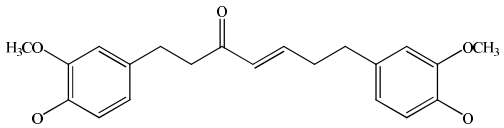
Dehydrogingerdione (79)



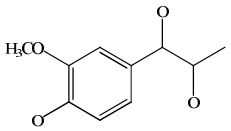
1-(3,4-dimethoxyphenyl)-5-hydroxydecan-3-one (80)



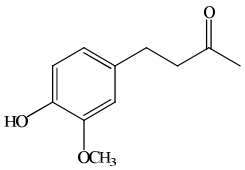
3-acetoxy-l,5-epoxy-1-(3,4-dihydroxy-5-methoxyphenyl)-7-(4-hydroxy-3-methoxy-phenyl) heptane (81)



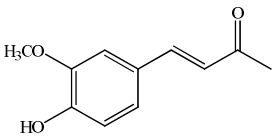
1,7-bis(4-hydroxy-3-methoxyphenyl)hept-4-en-3-one (82)



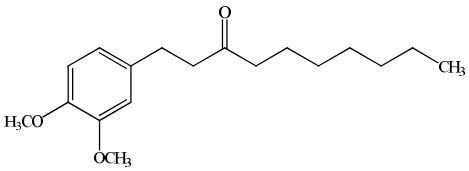
1-(4-hydroxy-3-methoxyphenyl)propan-1,2-diol (83)



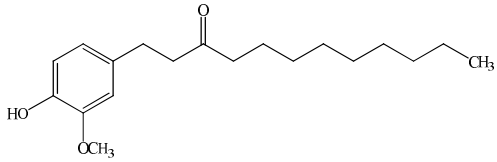
Zingerone (84)



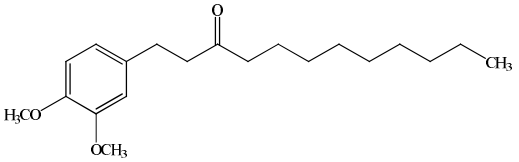
Dehydrozingerone (85)



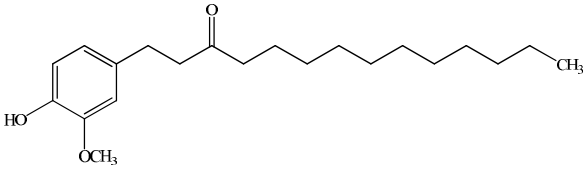
Methyl [6]-paradol (86)



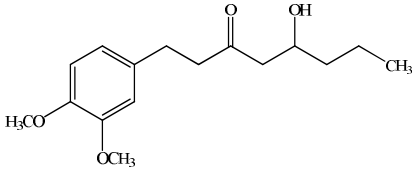
[8]-Paradol (87)



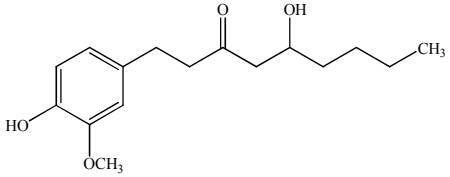
Methyl [8]-paradol (88)



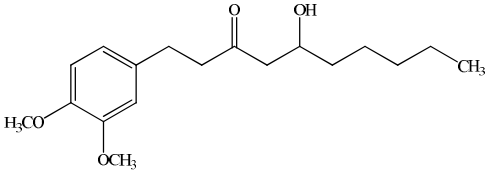
[10]-Paradol (89)



Methyl [4]-gingerol (90)

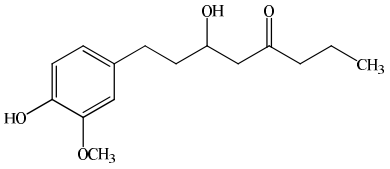


[5]-Gingerol (91)

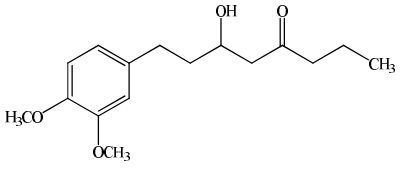


Methyl [6]-gingerol (92)

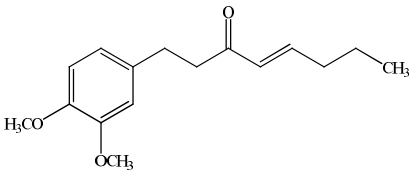
Figure 2.15 (continued)



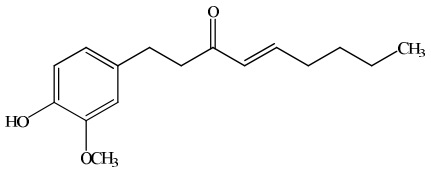
[4]-Isogingerol (93)



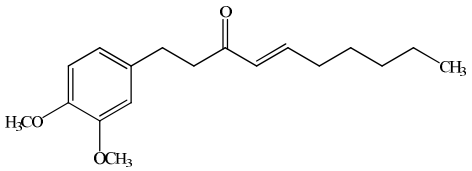
Methyl [6]-isogingerol (94)



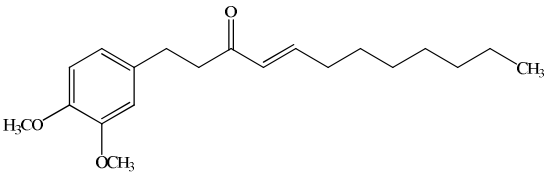
Methyl [4]-shogaol (95)



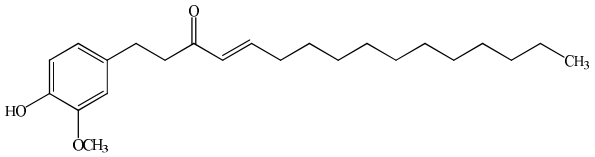
[5]-Shogaol (96)



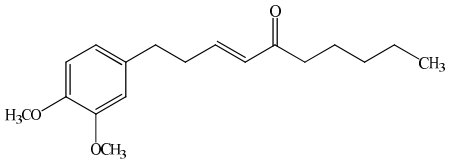
Methyl [6]-shogaol (97)



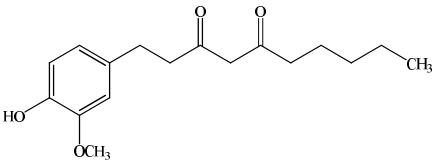
Methyl [8]-shogaol (98)



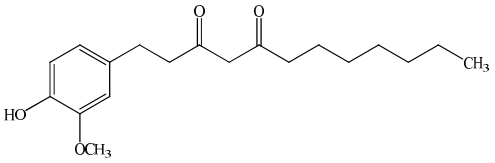
[12]-Shogaol (99)



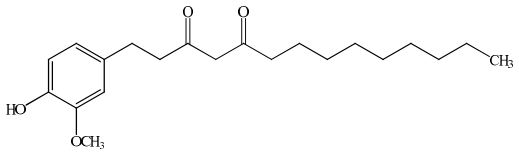
[6]-Isoshogaol (100)



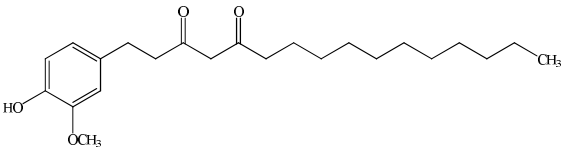
[6]-Gingerdione (101)



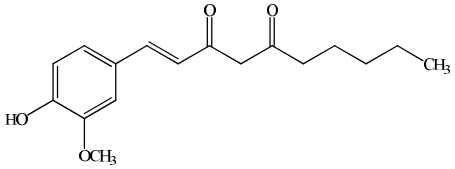
[8]-Gingerdione (102)



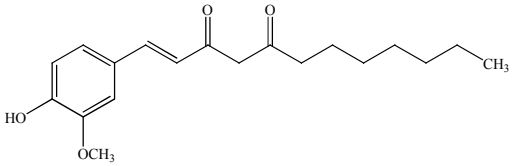
[10]-Gingerdione (103)



[12]-Gingerdione (104)

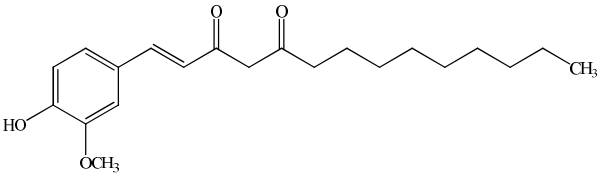


1-Dehydro-[6]-gingerdione (105)

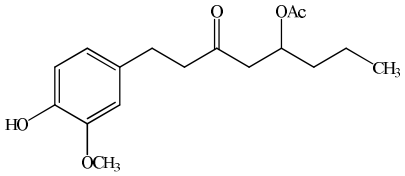


1-Dehydro-[8]-gingerdione (106)

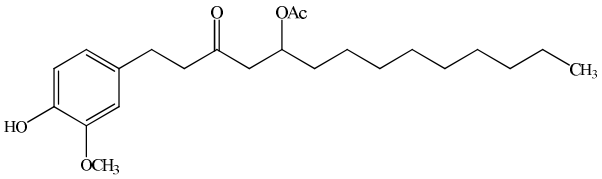
Figure 2.15 (continued)



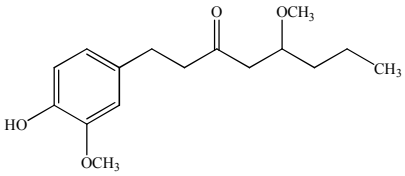
1-Dehydro-[10]-gingerdione (107)



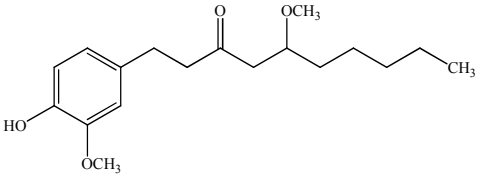
Acetoxy-[4]-gingerol (108)



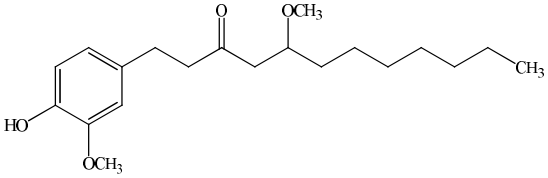
Acetoxy-[10]-gingerol (109)



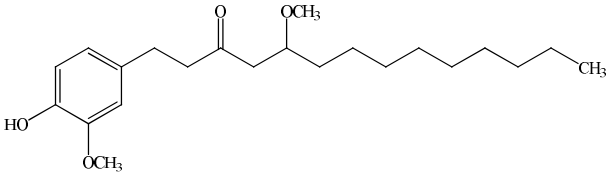
Methoxy-[4]-gingerol (110)



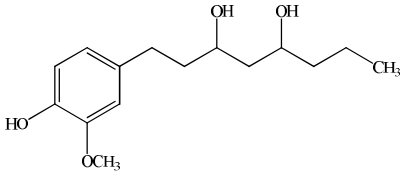
Methoxy-[6]-gingerol (111)



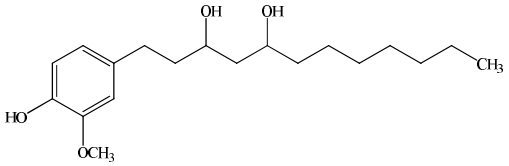
Methoxy-[8]-gingerol (112)



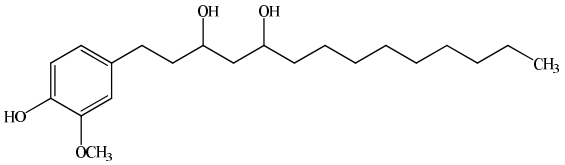
Methoxy-[10]-gingerol (113)



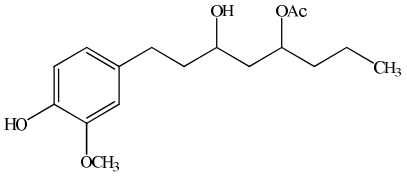
[4]-Gingerdiol (114)



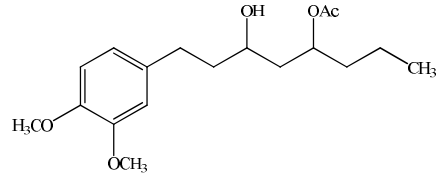
[8]-Gingerdiol (115)



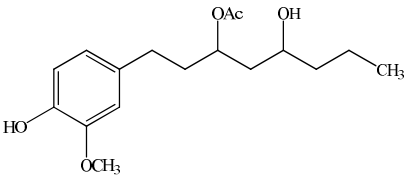
[10]-Gingerdiol (116)



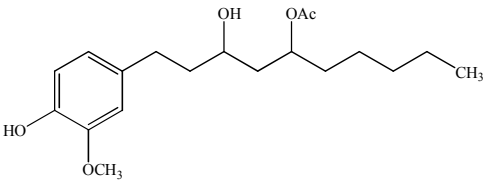
5-Acetoxy-[4]-gingerdiol (117)



Methyl 5-acetoxy-[4]-gingerdiol (118)

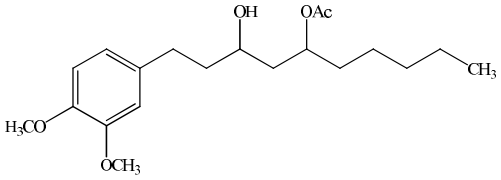


3-Acetoxy-[4]-gingerdiol (119)

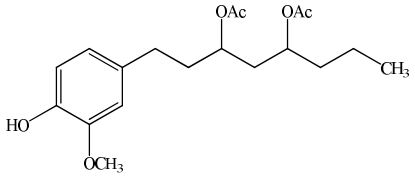


5-Acetoxy-[6]-gingerdiol (120)

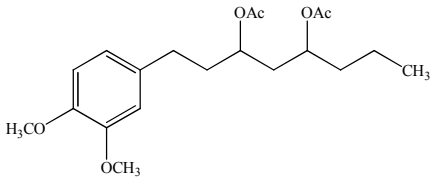
Figure 2.15 (continued)



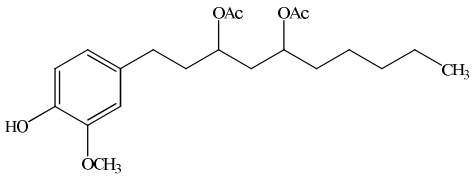
Methyl 5-acetoxy-[6]-gingerdiol (121)



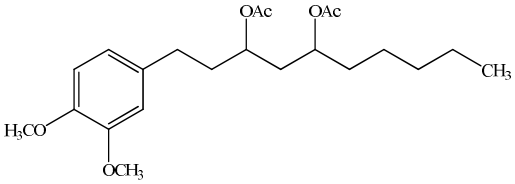
Diacetoxy-[4]-gingerdiol (122)



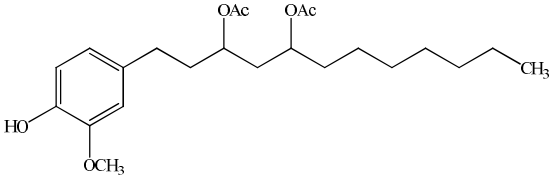
Methyl diacetoxy-[4]-gingerdiol (123)



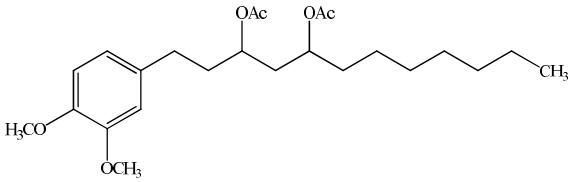
Diacetoxy-[6]-gingerdiol (124)



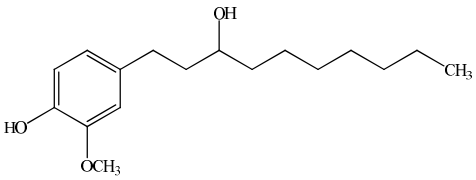
Methyl diacetoxy-[6]-gingerdiol (125)



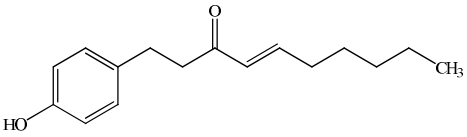
Diacetoxy-[8]-gingerdiol (126)



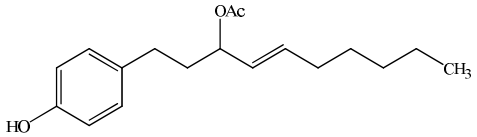
Methyl diacetoxy-[8]-gingerdiol (127)



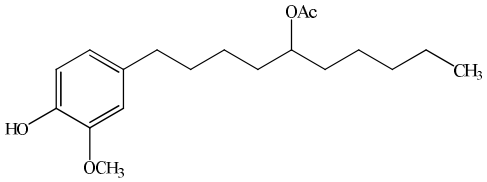
Dihydro-[6]-paradol (128)



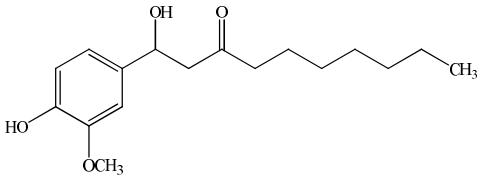
Demethoxy-[6]-shogaol (129)



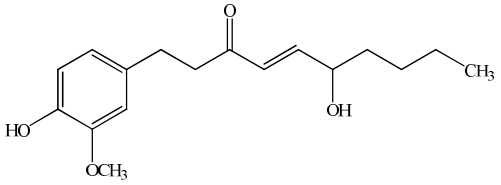
3-Acetoxy-3-dihydrodemethoxy-[6]-shogaol (130)



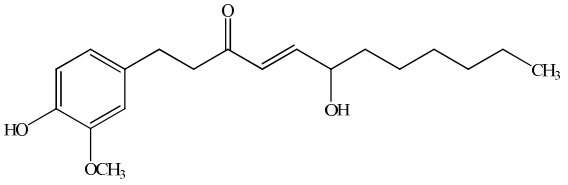
5-Acetoxy-3-deoxy-[6]-gingerol (131)



1-Hydroxy-[6]-paradol (132)

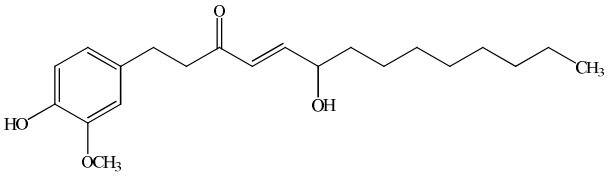


6-Hydroxy-[6]-shogaol (133)

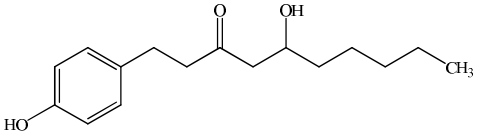


6-Hydroxy-[8]-shogaol (134)

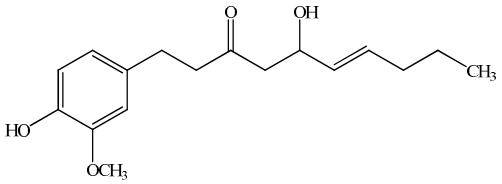
Figure 2.15 (continued)



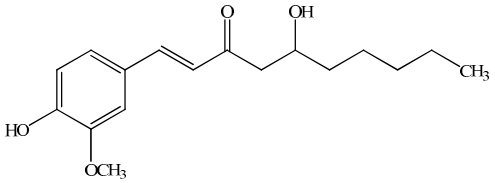
6-Hydroxy-[10]-shogaol (135)



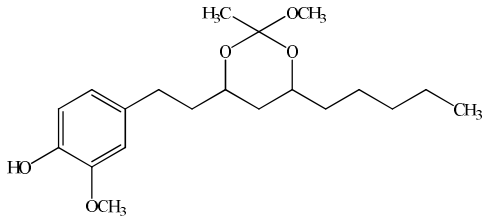
Demethoxy-[6]-gingerol (136)



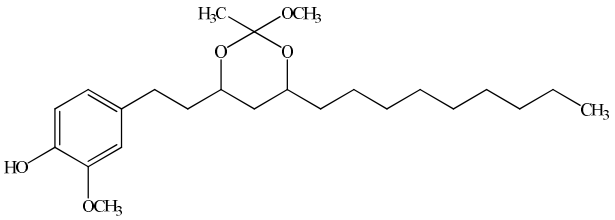
6-Dehydro-[6]-gingerol (137)



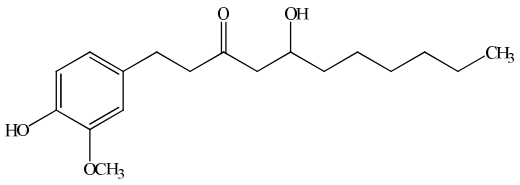
1-Dehydro-[6]-gingerol (138)



[6]-Gingerdiol, cyclic methyl orthoester (139)



[10]-Gingerdiol, cyclic methyl orthoester (140)



[7]-gingerol (141)

Figure 2.15 (continued)

2.8 Biological activities of the investigated species

Previous investigations on biological activity of five plants in Benjakul preparation are shown in Table 2.6 to 2.10.

Table 2.6 Biological activities of *Piper chaba* Linn.

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Piper chaba* Linn.**	Fruit	Anti-inflammatory	(2E,4Z,8E)-N-[9-(3,4-methylenedioxyphenyl)-2,4,8-nonatrienoyl]piperidine inhibited the direct binding between sICAM-1 and LFA-1 of THP-1 cells, with IC50 values of 10.7, μg/mL.	Lee *et.al.,* 2008b
		Anti-inflammatory	Piperine inhibits adhesion of neutrophils to endothelial monolayer due to its ability to block the tumor necrosis factor-α (TNF-α) induced expression of cell adhesion molecules i.e. ICAM-1, VCAM-1 and E-selectin	Kumar *et.al.,* 2007

Table 2.6 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Piper chaba* Linn.**	Fruit	Anti-inflammatory	Chloroform extract was significantly blocking the TNF-a-induced expression of CAMs at 17.5 µg/ml and E-selectin at 15 µg/ml concentration on human umbilical vein endothelial cells and also inhibited the NADPH catalyzed rat liver microsomal lipid peroxidation.	Singh *et.al.,* 2008
		Adipogenesis	Retrofractamide A increased adiponectin, mRNA levels of adiponectin, PPARc2, GLUT4 and insulin receptor substrate 1 (IRS-1) of the 3T3-L1 cells.	Zhang *et.al.,* 2008

Table 2.6 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Piper chaba* Linn.**	Fruit	Hepatoprotective	The methanolic extract was found to have a hepatoprotective effect on D-galactosamine (D-GalN)/ lipopolysaccharide (LPS)-induced liver injury in mice.	Matsuda *et.al.,* 2008
		Cytotoxicity	Alcoholic extract was 100% toxic at a concentration of 500 µg/ml to DLA cells and 250 µg/ml to EAC cells. Alcoholic extract was also found to produce cytotoxicity towards L929 cells in culture at a concentration of 100 and 50 µg/ml, respectively.	Sunila & Kuttan, 2004

Table 2.6 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Piper chaba* Linn.**	Fruit	Antitumor	Administration of alcoholic extract (10 mg/dose) as well as piperine (1.14 mg/dose) could inhibit the solid tumor development in mice induced with DLA cells and increase the life span of mice bearing EAC tumor to 37.3 and 58.8%, respectively	Sunila & Kuttan, 2004
		Chemopreventive	Piperine was found to suppress benzo(a)pyrene (B(a)p) induced lung cancer in Swiss albino mice by decreased the total protein and protein bound carbohydrate levels of lung cancer bearing animals in during initiation and post-initiation phases.	Selvendiran *et.al.,* 2006

Table 2.6 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Piper chaba* Linn.**	Fruit	Antiangiogenesis	Intraperitoneal administration of the extract (10 mg/dose) significantly inhibited (50.6%) the number of tumor-directed capillaries induced by injecting B16F-10 melanoma cells on the ventral side of C57BL/6 mice.	Sunila & Kuttan, 2006
		Immunomodulator	EtOAc extract showed a dose dependent decrease of lymphocytes (CD4+ and CD8+ T cells) and cytokine levels in sensitized Balb/C mice. At an in vitro dose of 20 μg/ml of extract and 5 μg/ml of piperinic acid, there was a significant inhibition of mitogen induced human PBMC proliferation, mRNA transcripts of IL-2 and TNFα, IL-1β and iNOS.	Devan *et.al.,* 2007

Table 2.7 Biological activities of *Piper sarmentosum* Roxb.

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Piper sarmentosum* Roxb.**	Fruit	Antidiabetic	Oral administration of the water extract at a dose of 0.125 g/kg for 7 days produced a significant hypoglycemic effect in the diabetic rats	Peungvicha *et.al.,* 1998
	Leave	Neuromuscular blocking	Methanolic extract, studied for the neuromuscular blocking activity in rat phrenic nerve-hemidiaphragm preparations at concentrations of 3.2, 4.0, 4.8 and 6.4 mg/ml, exhibited an initially transient increase in twitch tension which was followed by a marked dose-related neurally-evoked twitch depression leaves.	Ridtitid *et.al.,* 1998

Table 2.7 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Piper sarmentosum* Roxb.**	Leave	Antioxidant	Methanolic extract showed high antioxidant activity in β-carotene bleaching method.	Chanwitheesuk *et.al.,* 2005
	Aerial	Anti-inflammation	*n*-Hexane extract was found to possess cyclooxygenase-1 (COX-1) and 5-lipoxygenase (5-LO) inhibitory activity (COX-1 IC_{50} = 19 μg/ml; 5-LO IC_{50} = 10 μg/ml)	Stöhr *et.al.,* 1999
	Leave	Antibacterial	Methanolic extract showed potential antibacterial activities to both gram positive S. aureus and Methicillin Resistant S. aureus (MRSA).	Zaidan *et.al.,* 2005

Table 2.8 Biological activities of *Piper interruptum* Opiz.

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Piper interruptum* Opiz.**	Root	Antimicrobial	The methanol extract was effective on *S. aureus*. The MIC and MBC values were 3.125 mg/ml and 6.250 mg/ml, respectively.	Zakaria *et.al.,* 2007
	Stem	Antimosquitoes	Ethanolic extract was evaluated for efficacy against early 4^{th} instar larvae of *A. aegypti* mosquitoes using larvicidal bioassays and exhibited LC_{50} values at 4.06 ppm.	Chaithong *et.al.,* 2006
		Acetylcholinesterase inhibitory	The methanol extract exhibited percent AChE inhibitory activity at 65.16%.	Ingkaninan *et.al.,* 2003

Table 2.9 Biological activities of *Plumbago indica* Linn.

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Plumbago indica* Linn.**	Root	Antifungal	Plumbagin exhibited antifungal against *C. albicans*, *C. glabrata*, *C. krusei*, *C. tropicalis*, *C. neoformans*, *A. niger*, *A. flavus*, *Alternaria sp.*, *Cladosporium sp.*, *G. candidum*, *Fusarium sp.* and *Penicillium sp.* with diameter of inhibition zones varied from 12 to 18 mm.	Dzoyem *et.al.,* 2007
		Antiproliferation	Cell viability studied on A549 cell indicated that the IC_{50} value for plumbagin is 14.6 μM. *In* V*itro* polymerization of tubulin into microtubules is inhibited by plumbagin with IC_{50} value of (38 ±0.5 μM)	Acharya *et.al.,* 2008

Table 2.9 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Plumbago indica* Linn.**	Root	Antiproliferation	Plumbagin induces G_2-M arrest and autophagy in breast cancer cells	Kuo *et.al.,* 2006
		Antitumor	Plumbagin inhibited Prostate cancer cell invasion and selectively induced apoptosis. In addition, i.p. administration of Plumbagin (2 mg/kg b.w.) in mice, delayed tumor growth by 3 weeks and reduced both tumor weight and volume by 90%.	Aziz *et.al.,* 2008
		Antitumor	Plumbagin exhibited antitumor activity against Dalton's lymphoma (DAL) in Swiss albino mice.	Kavimani *et.al.,* 1996

Table 2.9 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Plumbago indica* Linn.**	Root	Apoptosis	Plumbagin inhibits the growth of human cervical cancer cell line (ME-180) caused by loss of mitochondrial membrane potential, morphological changes, release of mitochondrial cytochrome c and apoptosis inducing factor (AIF).	Srinivas *et.al.,* 2004
		Apoptosis	Plumbagin has exhibited effective cell growth inhibition by inducing human nonsmall cell lung cancer cells (A549) to undergo G2/M phase arrest and apoptosis.	Hsu *et.al.,* 2006

Table 2.9 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Plumbago indica* Linn.**	Root	Apoptosis	Plumbagin exhibited human melanoma (A375.S2) cell growth inhibition by inducing cells to undergo S-G2/M phase arrest and apoptosis. Blockade of cell cycle was associated with increased levels of p21 and reduced amounts of cyclin Bl, cyclin A, Cdc2, and Cdc25C.	Wang *et.al.,* 2008
		Apoptosis	Plumbagin exhibited apoptosis-inducing properties (in HL-60/MX2 cells) by ROS-mediated inhibition of Topo II as an important mechanism.	Lukasz *et.al.,* 2007

Table 2.9 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Plumbago indica* Linn.**	Root	Apoptosis	Plumbagin-mediated decrease in cell viability of prostate cancer cells (PC-3, LNCaP, and C4-2) correlated with apoptosis induction, which was accompanied by ROS generation and depletion of intracellular GSH levels.	Powolny & Singh, 2008
		Apoptosis	Plumbagin has induced apoptosis in BRCA1-mutated/defective ER-positive cancers.	Thasni *et.al.,* 2008

Table 2.10 Biological activities of *Zingiber officinale* Roscoe.

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Zingiber officinale* Roscoe.**	Rhizome	Cytotoxicity	(3*R*,5*S*)-3,5-diacetoxy-1,7-bis(4-hydroxy-3-methoxyphenyl) heptane, (3*R*,5*S*)-3-acetoxy-5-hydroxy-1,7-bis(4-hydroxy-3-methoxyphenyl)heptane, 3-acetoxy-l,5-epoxy-1-(3,4-dihydroxy-5-methoxyphenyl)-7-(4-hydroxy-3-methoxy-phenyl) heptane, [6]-shogaol, [10]-shogaol and 1,7-bis(4-hydroxy-3-methoxyphenyl) hept-4-en-3-one possess significant cytotoxicity against HL-60 cells (IC_{50} <50 μM) and that the cytotoxic activity is associated with the cell apoptosis.	Wei *et.al.,* 2005

Table 2.10 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Zingiber officinale* Roscoe.**	Rhizome	Cytotoxicity	[6]-gingerol and [6]-paradol were found to exert inhibitory effects on the viability and DNA synthesis of human promyelocytic leukemia (HL-60) cells.	Lee & Surh, 1998
		Cytotoxicity	[6]-shogaol exhibited potent cytotoxicity against human A549, SK-OV-3, SK-MEL-2, and HCT15 tumor cells. [6]-shogaol also inhibited proliferation of the transgenic mouse ovarian cancer cell lines, C1 (genotype:p53-/-, c-myc, K-ras) and C2 (genotype: p53-/-, c-myc, Akt), with ED50 values of 0.58 μM (C1) and 10.7 μM (C2).	Kim *et.al.,* 2008

Table 2.10 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Zingiber officinale* Roscoe.**	Rhizome	Cytotoxicity	[6]-gingerol induced cell death in HL-60 cells, caused DNA fragmentation and inhibited Bcl-2 expression.	Wang *et.al.,* 2003
		Antitumor	[6]-gingerol and [6]-paradol inhibited the tumor-promoter-stimulated inflammation, TNF-alpha production, and activation of epidermal ornithine decarboxylase in mice.	Surh *et.al.,* 1999
		Antimetastasis	[6]-gingerol inhibits cell adhesion, invasion, motility and activities of MMP-2 and MMP-9 in MDA-MB-231 human breast cancer cell lines.	Lee *et.al.,* 2008b

Table 2.10 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Zingiber officinale* Roscoe.**	Rhizome	Antiproliferation	[6]-gingerol enhances TRAIL-induced viability reduction of gastric cancer cells (HGC cells) by inhibiting TRAIL-induced NF-jB activation while [6]-shogaol alone reduces viability by damaging microtubules.	Ishiguro *et.al.,* 2007
		Antioxidant	The total phenols of the alcohol extract were found to be 870.1 mg/g dry extract. The IC_{50} concentration for inhibition of DPPH was 0.64 µg/ml. The antioxidant activity at 37 °C was efficient: 71.6% for conjugated dienes formation, 73.2% for TBARS and 79.6% for hydroxyl radicals.	Stoilova *et.al.,* 2007

Table 2.10 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Zingiber officinale* Roscoe.**	Rhizome	Antioxidant	Dehydrozingerone ($IC_{0.20}$= 12.8 μM) showed radical scavenging activity (DPPH assay) equal to or higher than α-tocopherol ($IC_{0.20}$= 8.3 μM) and ascorbic acid ($IC_{0.20}$= 23.7 μM).	Kuo *et.al.,* 2005
		Antioxidant	The total phenols of the alcohol extract were found to be 870.1 mg/g dry extract and the IC_{50} for inhibition of DPPH was 0.64 μg/ml.	Stoilova *et.al.,* 2007
		Antilipidemia	Ethanolic extract (200 mg:kg, p.o.) was significantly reduced serum and tissue cholesterol, serum triglycerides, serum lipoproteins and phospholipids.	Bhandari *et.al.,* 1998

Table 2.10 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Zingiber officinale* Roscoe.**	Rhizome	Antidiabetes	Ethanolic extract (200 mg/kg, p.o.) showed antihyperglycaemic effect in STZ-induced diabetes rats and lowered serum total cholesterol, TG and increased HDL levels	Bhandari *et.al.,* 2005
		Antiangiogenesis	*In vitro*, [6]-gingerol inhibited both the VEGF- and bFGF-induced proliferation of human endothelial cells and caused cell cycle arrest in the G1 phase. It also blocked capillary-like tube formation by endothelial cells in response to VEGF.	Kim *et.al.,* 2005

Table 2.10 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Zingiber officinale* Roscoe.**	Rhizome	Anti-carcinogenesis	Ginger powder (50 mg/kg body weight/everyday p.o.) was given to the rats at the initiation, post-initiation stages of carcinogenesis. The number of tumors as well as the incidence of cancer was significantly decreased. In addition, ginger supplementation at the initiation stage and also at the post-initiation stages of carcinogenesis significantly reduced lipid peroxidation and significantly enhanced the enzymic and non-enzymic antioxidants as compared to unsupplemented DMH-treated rats.	Manju & Nalini, 2005

Table 2.10 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
Zingiber officinale **Roscoe.**	Rhizome	Anti-inflammation	[6]-gingerol inhibited the production of proinflammatory cytokines (TNF-α, IL-12, and IL-1β) production from LPS stimulated macrophages.	Tripathi *et.al.,* 2007
		Anti-inflammation	[8]-paradol exhibited COX-1 inhibitory activity (IC_{50}=4±1 μM).	Tjendraputra *et.al.,* 2003
		Antiplatelet	[8]-Gingerol, [8]-shogaol and [8]-paradol exhibited anti-platelet activities, using the ChronoLog whole blood platelet aggregometer, with IC_{50} values ranging from 3 to 7 μM.	Tjendraputra *et.al.,* 2003
		Antiplatelet	Gingerols and related analogues inhibited the AA-induced platelet release reaction in a similar dose range as aspirin, with IC_{50} values between 45.3 and 82.6 mM.	Koo *et.al.,* 2001

Table 2.10 (continued)

Botanical name	Part of plant used	Activities	Results of biological activities	References
***Zingiber officinale* Roscoe.**	Rhizome	Immunomodulatory	*In vitro*, the volatile oil of ginger (0.001–10 ng/mL) inhibited T-lymphocyte proliferation and increased the percentage of T-suppressor cells to the total T-lymphocytes in the mice. In addition, the volatile oil of ginger (0.001–10 ng/mL) inhibited IL-1α secretion by the mice peritoneal macrophages.	Zhou *et.al.,* 2006