CHAPTER 1

INTRODUCTION

1.1 General Introduction

Cancer is perhaps the most progressive and devastating disease posing a threat of mortality to the entire world despite significant advances in medical technology for its diagnosis and treatment (Pal, *et al*., 2001). Environmental chemicals may be involved in the etiology of a variety of human cancer. The cause for the majority of human tumours has been attributed to exposure to environmental carcinogens, pollutants, pesticides, drugs, UV-radiation, and tobacco products. A nutritional deficit or surplus or the absence of preventive micronutrients in the diet can further increase the susceptibility for developing cancers. In addition, tumours induced by environmental pollutants may be prevented by dietary strategies. It is therefore plausible that an imbalance between the exposure to cancer-causing environmental factors and the dietary intake of preventive nutrients facilitates the initiation and growth of tumours (Verma, Goldin and Lin, 1998). All cells are exposed to oxidative stress, and thus oxidation, and free radicals, may be important in carcinogenesis at multiple tumour sites (Sies, 1997). Metastasis of cancer cells to distant sites is one of the major deciding factors in cancer outcome. In fact, prognosis of cancer is mainly determined by the invasiveness of the tumour and its ability to metastasize. Although there are several drugs available to control cancer growth in humans, there are no drugs presently available to specifically inhibit the metastasis of cancer cells (Menon, Kuttan and Kuttan, 1999). Recently, considerable attention has been focused on identifying naturally occurring chemopreventive substances capable of inhibiting, retarding, or reversing the process of multistage carcinogenesis (Pal, *et al*., 2001). Dietary antioxidants are known to decrease the risk of many chronic diseases such as cancer and cardiovascular disorders. The antioxidant activity may be a result of one of the followings: specific scavenging of reactive free radicals or scavenging of oxygen containing compounds such as hydrogen peroxide or chelation to metals (Priyadarsini,

1997). Wide arrays of phenolic substances, particularly those present in dietary and medicinal plants, have been reported to possess substantial anticarcinogenic and antimutagenic effects. The majority of these naturally occurring phenolics retain anti-oxidative and anti-inflammatory properties, which appear to contribute to their chemopreventive activity (Pal, *et al*., 2001).

The use of medicinal plants is based on the experience of many generations of physicians and traditional systems of medicine from different ethnic societies. The use of medicinal plants in modern medicine suffers from the fact that though hundreds of plants are used in the world to prevent or to cure diseases, scientific evidence in terms of modern medicine is lacking in most cases. However, today it is necessary to provide scientific proof as to whether or not it is justified to use a plant or its active principles (Ammon and Wahl, 1991). Natural products from some plants, fungi, bacteria and other organisms continue to be used in pharmaceutical preparations either as pure compounds or as extracts. There is a great variety of compounds that can be extracted and characterized from plants (Araújo and Leon, 2001).

The Zingiberaceae is a well-known plant family in Southeast Asia and numerous of its species are being used in traditional medicine, which is found to be quite effective in the treatment of several diseases. The five common Zingiberaceous spices used in Thailand, i.e. *Alpinia galanga* (Greater galanga)*, Boesenbergia pandurata* (Fingerroot)*, Curcuma longa* (Turmeric)*, Kaempferia galanga* (Proh hom) and *Zingiber officinale* (Ginger), are perennial herbs widely cultivated in Thailand and tropical regions of Asia. Although there have been reports concerning chemical constituents and some biological activities of these five species, only a few reports focused on cytotoxic activity against human tumour cells and antioxidation against free radical. It is obvious that further study to evaluate the activities of the extracts and isolate compounds responsible for these two activities would provide additional useful data on biological activities of these five plants.

1.2 Review of Literatures

1.2.1 Plants of the family Zingiberaceae

According to a taxonomic survey of the family Zingiberaceae in the world, 52 genera and 1,100 species have been reported (Mabberley, 1997), among which 11 genera and 44 species have been found in southern Thailand (Sirirugsa, 1989). They are classified into four tribes as follows:

1.2.1.1 Tribe Alpineae

A. Genus *Alpinia*

(1) *Alpinia conchigera* Griff.
(2) *A. galanga* (L.) Willd.
(3) *A. javanica* Bl.
(4) *A. mutica* Roxb.
(5) *A. nigra* (Gaert.) B.L. Burtt
(6) *A. oxymitra* Schum.
(7) *A. purpurata* (Vieill.) Schum.

B. Genus *Amomum*

(8) *Amomum aculeatum* Roxb.
(9) *A. biflorum* Jack.
(10) *A. hastilabium* Ridl.
(11) *A. rivale* Ridl.
(12) *A. testaceum* Ridl.
(13) *A. uliginosum* Koenig

C. Genus *Elettariopsis*

(14) *Elettariopsis curtisii* Bak.
(15) *E. smithiae* Kam
(16) *E.* sp. (aff. *triloba* Gagnep.) Loes.

D. Genus *Etlingera*

(17) *Etlingera littoralis* (Koenig) Giseke

(18) *E. maingayi* (Bak.) Smith

(19) *E. venusta* (Ridl.) R.M. Smith

1.2.1.2 Tribe Globbeae

E. Genus *Globba*

(20) *Globba albiflora* Ridl.

(21) *G. fasciata* Ridl.

1.2.1.3 Tribe Hedychieae

F. Genus *Boesenbergia*

(22) *Boesenbergia basispicata* Larsen ex Sirirugsa

(23) *B. curtisii* (Bak.) Schltr.

(24) *B. longipes* (King & Prain) Schltr.

(25) *B. plicata* (Ridl.) Holtt.

(26) *B. rotunda* (L.) Mansf.

(syn: *B. pandurata* (Roxb.) Schltr.)

G. Genus *Curcuma*

(27) *Curcuma* aff. *colorata* Val.

(28) *C. longa* L.

(29) *C. viridiflora* Roxb.

H. Genus *Hedychium*

(30) *Hedychium coronarium* Koen.

I. Genus *Kaempferia*

(31) *Kaempferia angustifolia* Rosc.

(32) *K. galanga* L.

(33) *K. parviflora* Wall.

(34) *K. pulchra* Ridl.

J. Genus *Scaphochlamys*

(35) *Scaphochlamys biloba* (Ridl.) Holtt.

(36) *S.* sp.

1.2.1.4 Tribe Zingibereae

K. Genus *Zingiber*

(37) *Zingiber chrysostachys* Ridl.

(38) *Z. gracile* Jack

(39) *Z. officinale* Rosc.

(40) *Z. ottensii* Val.

(41) *Z. purpureum* Rosc.

(42) *Z. spectabile* Griff.

(43) *Z. zerumbet* Smith

(44) *Z.* sp.

Additionally, some other Zingiberaceous species such as *Amomum krervanh* Pierre, *Curcuma xanthorrhiza* Roxb., *C. parviflora* Wall. and *C. zedoaria* Rosc. have been found in Thailand (Smitinand, 1980).

1.2.2 Chemical constituents of the investigated species

The reported chemical constituents of *Alpinia galanga*, *Boesenbergia pandurata, Curcuma longa, Kaempferia galanga* and *Zingiber officinale* are shown in Tables 1, 2, 3, 4 and 5, respectively. Chemical structures of some constituents found in these five species are illustrated in Figures 1, 2, 3, 4 and 5, respectively.

1.2.2.1 *Alpinia galanga*

Table 1 Chemical constituents found in *A. galanga*

Botanical name	**Part of plant studied**	**Chemical constituents**	**References**
A. galanga	Essential oil (rhizome)	β-Bisabolene	De Pooter, *et al*., 1985
		1,8-Cineole	De Pooter, *et al*., 1985
		ar-Curcumene	De Pooter, *et al*., 1985
		trans-β-Farnesene	De Pooter, *et al*., 1985
		β-Sesquiphellandrene	De Pooter, *et al*., 1985
	Fresh fruit	1′-Acetoxyeugenol acetate	Itokawa, *et al*., 1987
	Leaf	Alanine	Yeoh, Wee and Watson, 1986
		Arginine	Yeoh, Wee and Watson, 1986

Table 1 Chemical constituents found in *A. galanga* (continued)

Botanical name	**Part of plant studied**	**Chemical constituents**	**References**
A. galanga	Leaf	Aspartic acid	Yeoh, Wee and Watson, 1986
		Galanga	Janssen and Scheffer, 1985
		Glutamic acid	Yeoh, Wee and Watson, 1986
		Glycine	Yeoh, Wee and Watson, 1986
		Histidine	Yeoh, Wee and Watson, 1986
		Tyrosine	Yeoh, Wee and Watson, 1986
		Valine	Yeoh, Wee and Watson, 1986
	Rhizome	Acetoxy-1,8-cineole	Kubota, Nakamura and Kobayashi, 1998; Someya, Kobayashi and Kubota, 2001
		1′-Acetoxychavicol acetate	Janssen and Scheffer, 1985; Itokawa, *et al*., 1987; Kondo, *et al*., 1993; Murakami, Ohigashi and Koshimizu, 1994; Yang and Eilerman, 1999; Murakami, *et al*., 2000; Moffatt, *et al*., 2002
		1′-Acetoxyeugenol acetate	Janssen and Scheffer, 1985

Table 1 Chemical constituents found in *A. galanga* (continued)

Botanical name	**Part of plant studied**	**Chemical constituents**	**References**
A. galanga	Rhizome	4-Hydroxybenzaldehyde	Nori, *et al*., 1988
		α-Bergamotene	De Pooter, *et al*., 1985
		Borneol	De Pooter, *et al*., 1985
		Camphene	De Pooter, *et al*., 1985
		Carveol I	De Pooter, *et al*., 1985
		Carveol II	De Pooter, *et al*., 1985
		cis-2-Acetoxy-1,8-cineol	Kubota, *et al*., 1999
		trans-2-Acetoxy-1,8-cineol	Kubota, *et al*., 1999
		Citronellol acetate	De Pooter, *et al*., 1985
		ar-Curcumene	De Pooter, *et al*., 1985
		Galanga	Kondo, *et al*., 1993
		Galanga acetate	Tanaka, *et al*., 1997
		1′-Hydroxychavicol acetate	Janssen and Scheffer, 1985
		p-Hydroxycinnamaldehyde	Barik, kundu and Dey, 1987
		Limonene	De Pooter, *et al*., 1985

Table 1 Chemical constituents found in *A. galanga* (continued)

Botanical name	Part of plant studied	Chemical constituents	References
A. galanga	Rhizome	Linalool	De Pooter, *et al*., 1985
		Nerol acetate	De Pooter, *et al*., 1985
		Pentadecane	De Pooter, *et al*., 1985
		Sabinene	De Pooter, *et al*., 1985
		Santalene	De Pooter, *et al*., 1985
		Terpinen-4-ol	Janssen and Scheffer, 1985
		Terpinolene	De Pooter, *et al*., 1985
	Seed	Aframodial	Ayafor, *et al*., 1994
		Astragalin	Qiao, *et al*., 2000
		Caryophyllene I	Mitsui, *et al*., 1976
		Caryophyllenol II	Mitsui, *et al*., 1976
		1′-Acetoxy-eugenol acetate	Mitsui, *et al*., 1976
		Galanga	Tanaka, *et al*., 1997
		Galanal A	Morita and Itokawa, 1986
		Galanal B	Morita and Itokawa, 1986

1.2.2.2 *Boesenbergia pandurata*

Table 2 Chemical constituents found in *B. pandurata*

Botanical name	**Part of plant studied**	**Chemical constituents**	**References**
B. pandurata	Entire plant	Alpinetin	Suphat, 1964
		Boesenbergin A	Tuntiwachwuttikul, *et al*., 1980
		2′-6′-Dihydroxy-4′-methoxy chalcone	Tuntiwachwuttikul, *et al*., 1980
		Pinocembrin	Tuntiwachwuttikul, *et al*., 1980
		Pinostrobin	Suphat, 1964
	Essential oil (rhizome)	Camphene	Jantan, *et al*., 2001
		Camphor	Jantan, *et al*., 2001
		1,8-Cineole	Jantan, *et al*., 2001
		Geraniol	Jantan, *et al*., 2001
		Methyl cinnamate	Jantan, *et al*., 2001
		(*E*)-β-Ocimene	Jantan, *et al*., 2001
	Rhizome	Alpinetin	Supat, 1961; Jaipetch, *et al*., 1982; Pandji, *et al*., 1993
		Boesenbergin A	Jaipetch, *et al*., 1982

Table 2 Chemical constituents found in *B. pandurata* (continued)

Botanical name	**Part of plant studied**	**Chemical constituents**	**References**
B. pandurata	Rhizome	Boesenbergin A	Mahidol, *et al*., 1984
		(*dl*)-Boesenbergin B	Mahidol, *et al*., 1984
		Cardamonin	Jaipetch, *et al*., 1982;
			Murakami, *et al.,* 1993;
			Trakoontivakorn, *et al.,* 2001
		Chalcone cardamonin	Pandji, *et al*., 1993
		2′-4′-Dihydroxy-6′-methoxy chalcone	Jaipetch, *et al*., 1982
		2′-6′-Dihydroxy-4′-methoxy chalcone	Jaipetch, *et al*., 1982
		Chrysin dimethyl ether	Pathong, *et al*., 1989
		Geranial	Pandji, *et al*., 1993
		Neral	Pandji, *et al*., 1993
		Panduratin A	Mahidol, *et al*., 1984
			Trakoontivakorn, *et al*., 2001
		4-Hydroxy panduratin A	Trakoontivakorn, *et al*., 2001
		Panduratin B-1	Pancharoen, *et al*., 1987
		Panduratin B-2	Pancharoen, *et al*., 1987

Table 2 Chemical constituents found in *B. pandurata* (continued)

Botanical name	**Part of plant studied**	**Chemical constituents**	**References**
B. pandurata	Rhizome	Pinocembrin	Jaipetch, *et al*., 1982; Pandji, *et al*., 1993; Trakoontivakorn, *et al*., 2001
		Pinocembrin chalcone	Trakoontivakorn, *et al*., 2001
		Pinostrobin	Supat, 1961; Jaipetch, *et al*., 1982; Pandji, *et al*., 1993; Trakoontivakorn, *et al*., 2001
	Root	Cardamonin	Tiwawech, *et al*., 2000

1.2.2.3 *Curcuma longa*

Table 3 Chemical constituents found in *C. longa*

Botanical name	**Part of plant studied**	**Chemical constituents**	**References**
C. longa	Essential oil (rhizome)	1-(3-Cyclopentyl-formyl)-2-benzene	Hu, Du and Tang, 1997
		Borneol	Mitra, 1975
		Camphene	Gopalan, *et al*., 2000
		Camphor	Fang, *et al*., 1982
		Car-3-ene	Mccarron, *et al*., 1995
		Citronellal	Gopalan, *et al*., 2000
		Cineol	Yasuda, *et al*., 1988
		Curcumene	Fang, *et al*., 1982; Gopalan, *et al*., 2000
		p-Cymene	Nguyen, Nguyen and Leclercq, 1995
		Limonene	Fang, *et al*., 1982
		Myrcene	Nguyen, Nguyen and Leclercq, 1995
		Palmitic acid	Richmond and Pombo-Villar, 1997
		α-Phellandrene	Mccarron, *et al*., 1995
		α-Pinene	Nguyen, Nguyen and Leclercq, 1995

Table 3 Chemical constituents found in *C. longa* (continued)

Botanical name	Part of plant studied	Chemical constituents	References
C. longa	Essential oil (rhizome)	β-Pinene	Nguyen, Nguyen and Leclercq, 1995
		(+)-Sabinene	Mitra, 1975
		Terpinene	Fang, *et al*., 1982
		Terpinolene	Mccarron, *et al*., 1995
		ar-Turmerone	Nigam and Ahmed, 1991; Martins, *et al*., 2001; Gopalan, *et al*., 2000
		α-Turmerone	Martins, *et al*., 2001; Gopalan, *et al*., 2000
		β-Turmerone	Martins, *et al*., 2001
		Zerumbone	Richmond and Pombo-Villar, 1997
		Zingiberene	Mitra, 1975
	Powdered turmeric	Curcumin, Bisdemethoxycurcumin, Demethoxycurcumin	Simon, *et al*., 1998
	Rhizome	β-Bisabolene	Richmond and Pombo-Villar, 1997
		Bisabolone	Richmond and Pombo-Villar, 1997

Table 3 Chemical constituents found in *C. longa* (continued)

Botanical name	Part of plant studied	Chemical constituents	References
C. longa	Rhizome	Bisacumol	Ohshiro, Kuroyanagi and Ueno, 1990
		Bisacurone	Ohshiro, Kuroyanagi and Ueno, 1990
		Borneol	Chen, Yu and Fang, 1983
		Caffeic acid	Schultz and Herrmann, 1980
		Campesterol	Moon, Park and Koh, 1976
		Camphor	Chen, Yu and Fang, 1983
		Cholesterol	Moon, Park and Koh, 1976
		Cineol	Yasuda, *et al*., 1988
		Coumarin	Hiserodt, *et al*., 1996
		Curcumene	Hiserodt, *et al*., 1996
		Curcumenol	Ohshiro, Kuroyanagi and Ueno, 1990
		Curcumenone	Ohshiro, Kuroyanagi and Ueno, 1990
		Curcumin	Jentzsch, Spiegl and Kamitz, 1970; Rasmussen, *et al*., 2000
		Bisdemethoxycurcumin	Taylor and Mcdowell, 1992; Rasmussen, *et al.*, 2000
		Demethoxycurcumin	Jentzsch, Spiegl and Kamitz, 1970;

Table 3 Chemical constituents found in *C. longa* (continued)

Botanical name	Part of plant studied	Chemical constituents	References
C. longa	Rhizome	Demethoxycurcumin	Rasmussen, *et al.,* 2000
		Curlone	Kiso, *et al*., 1983
		Diferuloyl-methane	Gupta and Ghosh, 1999
		Eugenol	Chen, Yu and Fang, 1983
		Germacron-13-al	Ohshiro, Kuroyanagi and Ueno, 1990
		Germacrone	Uehara, *et al*., 1992a
		Linalool	Fang, *et al*., 1982
		β-Pinene	Chen, Yu and Fang, 1983
		β-Sitosterol	Moon, Park and Koh, 1976
		Stigmasterol	Moon, Park and Koh, 1976
		Tolyl-methyl-carbinol	Supniewski and Hano, 1935
		ar-Tumerol	Hiserodt, *et al*., 1996
		Turmerin	Cohly, *et al*., 1998a
		ar-Turmerone	Suzuki, Murata and Yasuda, 2000
		Zedoarondiol	Ohshiro, Kuroyanagi and Ueno, 1990
		Zingiberene	Uehara, *et al*., 1992b

Table 3 Chemical constituents found in *C. longa* (continued)

Botanical name	Part of plant studied	Chemical constituents	References
C. longa	Root	α-Atlantone	Su, Horvat and Jilani, 1982
		γ-Atlantone	Su, Horvat and Jilani, 1982
		Bisabolene	Su, Horvat and Jilani, 1982
		Borneol	Su, Horvat and Jilani, 1982
		Cineol	Su, Horvat and Jilani, 1982
		Curcumin	Choiu and Chang, 1983
		Bisdemethoxycurcumin	Choiu and Chang, 1983
		Demethoxycurcumin	Choiu and Chang, 1983
		(+)-α-Phellandrene	Mitra, 1975
		(+)-Sabinene	Mitra, 1975
		ar-Turmerone	Su, Horvat and Jilani, 1982
		Zingiberene	Su, Horvat and Jilani, 1982

1.2.2.4 *Kaempferia galanga*

Table 4 Chemical constituents found in *K. galanga*

Botanical name	**Part of plant studied**	**Chemical constituents**	**References**
K. galanga	Essential oil (rhizome)	*p*-Methoxy-*trans*-cinnamic acid	Liu and Jinag, 1993
	Leaf	4-Hydroxy benzoic acid	Merh, Daniel and Sabnis, 1986
		Chlorogenic acid	Merh, Daniel and Sabnis, 1986
		Vanillic acid	Merh, Daniel and Sabnis, 1986
	Rhizome	Car-3-en-5-one	Kiuchi, Nakamura and Tsuda, 1987
		Cinnamic acid	Pandji, *et al*., 1993
		Cinnamic acid ethyl ester	Kosuge, *et al*., 1985; Kiuchi, *et al*., 1988
		p-Methoxy-*trans*-cinnamic acid	Noro, *et al*., 1983
		Deoxypodophyllotoxin	Kosuge, *et al*., 1985
		Ethyl cinnamate	Othman, *et al*., 2002
		p-Methoxycinnamate	Pandji, *et al*., 1993
		Ethyl *p*-methoxy-*trans*-cinnamate	Kosuge, *et al*., 1985
	Root	*p*-Methoxy-*trans*-cinnamic acid	Chau, Hong and Quy, 1979

1.2.2.5 *Zingiber officinale*

Table 5 Chemical constituents found in *Z. officinale*

Botanical name	**Part of plant studied**	**Chemical constituents**	**References**
Z. officinale	Aerial parts	Cysteine	Takahashi, *et al*., 1982
	Essential oil (rhizome)	ar-Curcumene	Variyar, Gholap and Thomas, 1997
		Calamenene	Miyazawa and Kameoka, 1988
		Camphor	Miyazawa and Kameoka, 1988
		Citral-1,8-cineole	Menut, *et al*., 1994
		Geranial	Sakamura, 1987;
			Onyenekwe and Hashimoto, 1999
		Geraniol	Sakamura, 1987
		Geranyl acetate	Sakamura, 1987
		Neral	Sakamura, 1987;
			Onyenekwe and Hashimoto, 1999
		β-Sesquiphellandrene	Variyar, Gholap and Thomas, 1997
		Zingiberin	Variyar, Gholap and Thomas, 1997
	Leaf	Shikimic acid	Yoshida, Tazaki and Minamikawa, 1975

Table 5 Chemical constituents found in *Z. officinale* (continued)

Botanical name	Part of plant studied	Chemical constituents	References
Z. officinale	Rhizome	Asparagine	Murakami, *et al*., 1965
		Benzaldehyde	Wu, Kuo and Ho, 1990
		Bisabolene	Wu, Kuo and Ho, 1990
		Borneol	Van-Beek, *et al*., 1987
		Caffeic acid	Schultz and Herrmann, 1980
		Camphene	Tanabe, *et al*., 1991
		Chrysanthemin	Fu, *et al*., 1993
		Cineol	Nishimura, 1995
		Citronellal	Nishimura, 1995
		p-Coumaric acid	Schultz and Herrmann, 1980
		ar-Curcumene	Yoshikawa, *et al*., 1993a
		Curcumin	Kikuzaki and Nakatani, 1993
		6-Dehydrogingerdione	Charles,Garg and Kumar, 2000
		(or 1-Dehydrogingerdione)	
		6, 8, 10-Dehydroshogaol	Wu, *et al*., 1998
		Diethyl sulfide	Kami, Nakayama and Hayashi, 1972

Table 5 Chemical constituents found in *Z. officinale* (continued)

Botanical name	Part of plant studied	Chemical constituents	References
Z. officinale	Rhizome	Furanogermenone	Shiba, *et al*., 1986
		Galanolactone	Yoshikawa, *et al.*, 1993b
		Geranial	Tanabe, *et al*., 1991; Sekiwa-Iijima, Aizawa and Kubota, 2001
		Geraniol	Sakamura, *et al.*, 1986; Sekiwa-Iijima, Aizawa and Kubota, 2001
		6-Gingerdiol	Kikuzaki, Tsai and Nakatani,1992; He, *et al*., 1998; Sekiwa, Kubota and Kobayashi, 2000
		10-Gingerdione	Kiuchi, Shibuya and Sankawa, 1982
		Gingerenone A, Gingerenone B, Isogingerenone B, Gingerenone C	Endo, Kanno and Oshima, 1990
		Gingerol	Sane, *et al*., 1998
		6, 8,10-Gingerol	Shoji, *et al*., 1982; Balladin, *et al*., 1998; Hiserodt, Franzblau and Rosen, 1998; He, *et al*., 1998

Table 5 Chemical constituents found in *Z. officinale* (continued)

Botanical name	Part of plant studied	Chemical constituents	References
Z. officinale	Rhizome	6, 8, 10, 12, 14-Gingerol	Chen, Rosen and Ho, 1986a
		8, 10-Gingerol	Yamada, kikuzaki and Nakatani, 1992
		Limonene	Kami, Nakayama and Hayashi, 1972
		Linalool	Sakamura, *et al*., 1986
		Myrcene	Sakamura, *et al*., 1986
		Neral	Tanabe, *et al*., 1991
		Nerolidol	Wu, Kuo and Ho, 1990
		6-Paradol	Chung, *et al*., 2001
		8-Paradol	Tjendraputra, *et al*., 2001
		6-Shogaol	Suekawa, *et al*., 1988
		8-Shogaol	Tjendraputra, *et al*., 2001
		6, 8, 10, 12-Shogaol	Chen, Rosen and Ho, 1986b
		6, 8, 10-Shogaol	Balladin, *et al*., 1998
			He, *et al*., 1998
		Terpinen-4-ol	Nishimura, 1995
		Zerumbodienone	Fujimoto, Maruno and Made, 1989
		Zingerone	Chen, *et al*., 1986

Table 5 Chemical constituents found in *Z. officinale* (continued)

Botanical name	Part of plant studied	Chemical constituents	References
Z. officinale	Rhizome	Zingiberene	Millar, 1998
		Zingiberenol	Terhune, *et al*., 1975
		Zingiberone	Nomura, 1917
	Root	Bisabolene	Mcgaw, Yen and Dyal,1984
		Citral	Mcgaw, Yen and Dyal, 1984
		6-Dehydrogingerdione	Kiuchi, Shibuya and Sankawa, 1982
		(or 1-Dehydrogingerdione)	
		10-Dehydrogingerdione	Kiuchi, Shibuya and Sankawa, 1982
		6, 10-Gingerdione	Kiuchi, Shibuya and Sankawa, 1982
		6-Gingerol	Kiuchi, Shibuya and Sankawa, 1982
	Seed	Aframodial	Ayafor, *et al*., 1994
	Tuber	Arginine	Takahashi, *et al*., 1982
		Leucine	Takahashi, *et al*., 1982

1.2.3 Biological activities of the investigated species

Previous investigations on biological activity of *Alpinia galanga, Boesenbergia pandurata*, *Curcuma longa, Kaempferia galanga* and *Zingiber officinale* are shown in Tables 6, 7, 8, 9 and 10, respectively.

1.2.3.1 *Alpinia galanga*

Table 6 Biological activities of *A. galanga*

Plant	**Part of plant used**	**Activity**	**References**
A. galanga	Dried entire plant	Aphrodisiac activity	Islam, *et al*., 2000
	Dried rhizome	Antifungal activity	Chinsiriwong and Hirankarn,1983
		Antimicrobial activity	Janssen and Scheffer, 1985
		Antiyeast activity	Chinsiriwong and Hirankarn,1983
	Dried roots	Antifungal activity	Haraguchi, *et al*., 1996
	Dried stem	Antibacterial activity	George and Pandalai, 1949
	Essential oil (rhizome)	Antiamebic activity	Chopra, Khajuria and Chopra, 1957
		Antibacterial activity	Janssen and Scheffer, 1985
		Antifungal activity	Janssen and Scheffer, 1985

Table 6 Biological activities of *A. galanga* (continued)

Plant	Part of plant used	Activity	References
A. galanga	Essential oil	Antimycobacterial activity	Chopra, Khajuria and Chopra, 1957
	(rhizome)	Antiprotozoan activity	Chopra, Khajuria and Chopra, 1957
		Insecticide activity	Chopra, Khajuria and Chopra, 1957
	Fresh rhizome	Antitumour against sarcoma 180	Itokawa, *et al*., 1987
	Rhizome	Antiascariasis activity	Kaleysaraj, 1975
		Antibacterial activity	Ross, *et al*., 1980
		Antimutagenic activity	Ruangchom and Vinitketkummuen, 1993
		Antioxidative activity by thiocyanate and TBA method	Jitoe, *et al*., 1992
		Antitumour activity	Itokawa, *et al*., 1987
		Antiulcer activity	Al-yahya, *et al*., 1990
		Cytotoxic activity	Murakami, *et al*., 1993
		Diuretic activity	Dhawan, *et al*., 1977
		Inhibition of tumour promoter-induced Epstein-Barr virus activation	Kondo, *et al*., 1993; Murakami, *et al*., 2000
	Root and seed	Antifungal activity	Haraguchi, *et al*., 1996
		Antimicrobial activity	Haraguchi, *et al*., 1996
	Seed	Antiulcer activity	Mitsui, *et al*., 1976

1.2.3.2 *Boesenbergia pandurata*

Table 7 Biological activities of *B. pandurata*

Plant	Part of plant used	Activity	References
B. pandurata	Dried entire plant	Smooth muscle relaxant activity	Apisariyakul, 1984
	Dried rhizome	Anticholinergic activity	Apisariyakul and Anantasarn, 1984
		Antifungal activity	Achararit, Panyayong and Ruchatakomut, 1983
		Antispasmodic activity	Apisariyakul and Anantusarn, 1984
		Antitumour-promoting activity	Maurakami, *et al*., 1997
		Smooth muscle relaxant activity	Apisariyakul and Anantasarn, 1984
	Dried root	Cocarcinogenic activity	Tiwawech, *et al*., 2000
	Fresh rhizome	Antispasmodic activity	Mahidol, 1985
		Antitumour-promoting activity	Murakami, *et al*., 1993
		Inhibition of tumour promoter-induced Epstein-Barr virus (EBV) activation	Murakami, *et al*., 1993
	Fresh root	Antitumour-promoting activity	Tiwawech, *et al*., 2000

1.2.3.3 *Curcuma longa*

Table 8 Biological activities of *C. longa*

Plant	Part of plant used	Activity	References
C. longa	Aqueous extracts (rhizome)	Antidepressant activity	Yu, Kong and Chen, 2002
	Dried bulb	Antibacterial activity	Alkofahi, *et al*., 1997
		Cytotoxic activity	Alkofahi, *et al*., 1997
	Dried leaf	Antioxidative activity	Maulik, *et al*., 1997
		Radical scavenging effect	Maulik, *et al*., 1997
	Dried rhizome	Anticoagulant activity	Kosuge, *et al.*, 1984
		Antifungal activity	Roth, Chandra and Nair, 1998
		Antiinflammatory activity	Kinoshita, Nakamura and Maruyama, 1986
		Antitumour activity	Kinoshita, Nakamura and Maruyama, 1986
	Dried rhizome	Antiviral activity	Cai, *et al*., 1988
		Carcinogenesis inhibition	Soni, *et al*., 1997
	Dried root	Antioxidative activity	Lee, *et al*., 1998

Table 8 Biological activities of *C. longa* (continued)

Plant	Part of plant used	Activity	References
C. longa	Dried root	Radical scavenging effect	Lee, *et al*., 1998
	Essential oil (rhizome)	Antibacterial activity	Rath, *et al*., 1999; Negi, *et al*., 1999
		Antiinflammatory activity	Gupta, Chandra and Mishra, 1972
		Antifungal activity	Apisariyakul, Vanittanakom and Buddhasukh, 1995
		Antimicrobial activity	Martins, *et al*., 2001
	Extract	Antiinflammatory activity	Ammon and Wahl, 1991
		Antioxidative activity	Selvam, *et al*., 1995
	Fresh tuber	Induction of chromosome aberrations	Abraham, Abraham and Radhamony, 1976
	Rhizome	Antiamoebic activity	Dhar, *et al*., 1968
		Antibacterial activity	Bhavani-Shankar and Murthy, 1979
		Antiinflammatory activity	Okuyama, *et al*., 1995
		Antioxidative activity	Selvam, *et al*., 1995
		Antioxidative activity by thiobarbituric acid (TBA) assay and free radical scavenging activity by DPPH	Kim, *et al*., 1997

Table 8 Biological activities of *C. longa* (continued)

Plant	Part of plant used	Activity	References
C. longa	Rhizome	Carcinogenesis inhibition	Deshpande, Ingle and Maru, 1997
		Cytotoxic activity	Lee, Kang and Ahn, 1986
		Lipid peroxide formation inhibition	Cohly, *et al*., 1998b
		Nematocidal activity	Kiuchi, 1995
	Turmeric powder (rhizome)	Antioxidative activity	Srinivas, Shalini and Shylaja,1992
	ar-Turmerone (pure compound)	Antivenom effect	Ferreira, *et al*., 1992
	Curcumin (pure compound)	Antiinflammatory in *in vivo* animal models	Ammon, *et al*., 1993
		Antioxidant against lipid peroxidation	Noguchi, *et al*., 1994
		Antispasmodic activity	Ammon and Wahl, 1991
		Antitumour activity in AK-5 tumour cell	Khar, *et al*., 1999
	Curcumin (pure compound)	Inhibit lipid autoxidation by coupling with peroxyl radicals	Masuda, *et al*., 2001

Table 8 Biological activities of *C. longa* (continued)

Plant	Part of plant used	Activity	References
C. longa	Curcumin (pure compound)	Chemopreventive action during the promotion/progression stage of colon cancer	Kawamori, *et al*., 1999
		Cytotoxic activity against urinary bladder cancer	Sindhwani, *et al*., 2000
		Free radical reactions	Priyadarsini, 1997
		Free radical scavenging ability and antioxidant efficiency	Khopde, *et al*., 1999
		Induce HL-60 cells death (promyelocytic leukemia)	Kuo, Huang and Lin, 1996
	Curcumin (pure compound)	Inhibit the process of carcinogenesis	Limtrakul, *et al*., 1997
		Inhibit tumourigenesis during both initiation and promotion period in several experimental animal models	Huang, Newmark and Frenkel, 1997
		Inhibition of cyclooxygenase-2 (COX-2) in HT-29 human colon cancer cells	Goel, Boland and Chauhan, 2001

Table 8 Biological activities of *C. longa* (continued)

Plant	Part of plant used	Activity	References
C. longa	Curcumin (pure compound)	Inhibition of HIV-1 integrase	Barthelemy, *et al*., 1998
		Inhibitory effects on the growth of human breast cancer MCF7 cells	Verma, Salamone and Goldin, 1997
	Curcumin (pure compound)	Telomerase inhibitor through human telomerase reverse transcritpase in MCF7 breast cancer cell line	Ramachandran, *et al*., 2002
	Curcumin, Bisdemethoxycurcumin, Demethoxycurcumin (pure compound)	Antiprotozoal activity	Rasmussen, *et al*., 2000
	Curcumin, Bisdemethoxycurcumin, Demethoxycurcumin (pure compound)	Antitumour and antioxidative activity	Ruby, *et al*., 1995
	Curcuminoids (mixture)	Inhibit MCF7 cell proliferation	Simon, *et al*., 1998

1.2.3.4 *Kaempferia galanga*

Table 9 Biological activities of *K. galanga*

Plant	Part of plant used	Activity	References
K. galanga	Dried rhizome	Antibacterial activity	Inada, *et al*., 1998
		Antispasmodic activity	Itokawa, *et al*., 1983
		Antitumour-promoting activity	Murakami, *et al*., 1993
		Colony formation inhibition	Kosuge, *et al*., 1985
		Nematocidal activity	Ali, *et al*., 1991
		Smooth muscle stimulant activity	Mokkhasmit, *et al*., 1971
	Dried root	Antibacterial activity	George and Pandalai, 1949
	Fresh rhizome	Cytotoxic activity on Hela cells	Mackeen, *et al*., 1997
	Rhizome	Antiascariasis activity	Kaleysaraj, 1975
		Cytotoxic activity against Hela cell	Kosuge, *et al*., 1985
		Insecticide activity	Insun, *et al*., 1999
		Monoamine oxidase inhibition	Noro, *et al*., 1983
		Vasorelaxant effect	Othman, *et al*., 2002
	Essential oil (rhizome)	Glutathione-*S*-transferase induction	Lam and Zheng, 1991

Table 9 Biological activities of *K. galanga* (continued)

Plant	**Part of plant used**	**Activity**	**References**
K. galanga	Tuber	Anticancer	Kosuge, *et al*., 1985
		Larvacidal	Kiuchi, Nakamura and Tsuda, 1987

1.2.3.5 *Zingiber officinale*

Table 10 Biological activities of *Z. officinale*

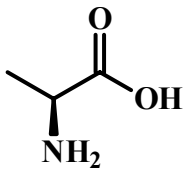
Plant	Part of plant used	Activity	References
Z. officinale	Dried aerial parts	Diuretic activity	Aswal, *et al*., 1984
		Hypoglycemic activity	Aswal, *et al*., 1984
	Dried entire plant	Hyperglycemic activity	Singhal and Joshi, 1983
	Dried rhizome	Antibacterial activity	Alkofahi, *et al*., 1997
		Cytotoxic activity	Alkofahi, *et al*., 1997
	Essential oil (rhizome)	Antibacterial activity	Meena and Sethi, 1994
		Antifungal activity	Meena and Sethi, 1994
		Antiinflammatory activity	Sharma, Srivastava and Gan, 1994
		Antimicrobial activity	Martins, *et al*., 2001
		Antimutagenic activity	Hashim, *et al*., 1994
		Antioxidative activity	Kawamura and Okada, 1992
	Fresh aerial parts	Tumour promotion inhibition	Koshimizu, *et al*., 1988
	Fresh rhizome	Antiemetic activity	Yamahara, *et al*., 1989
		Antimutagenic activity	Sakai, *et al*., 1988

Table 10 Biological activities of *Z. officinale* (continued)

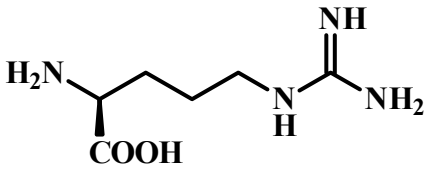
Plant	Part of plant used	Activity	References
Z. officinale	Fresh rhizome	Antimycobacterial activity	Hiserodt, Franzblau and Rosen, 1998
		Antitumour promoting activity	Vimala, Norhanom and Yadav, 1999
	Immature rhizome	Antitumour promoting activity	Murakami, *et al*., 1995
	Plant extract	Antiviral activity	Roy, Sinha and Gupta, 1979
	Rhizome	Antibacterial activity	Alzoreky and Nakahara, 2002
		Anticonvulsant activity	Sugaya, *et al*., 1978
		Anaesthetic activity	Sugaya, *et al*., 1979
		Antihepatotoxic effect	Hikino, *et al*., 1985
		Antioxidative activity	Lee, Kim and Ashmore, 1986
		Antioxidative activity by DPPH	Sekiwa, Kubota and Kobayashi, 2000
		Antiulcer activity	Yamahara, *et al*., 1992
	Root	Antimicrobial activity	Cheeptham and Towers, 2002
	6-Dehydrogingerdione (or 1-Dehydrogingerdione) 10-Dehydrogingerdione (pure compound)	Inhibitors of prostaglandin biosynthesis	Kiuchi, Shibuya and Sankwa, 1982

Table 10 Biological activities of *Z. officinale* (continued)

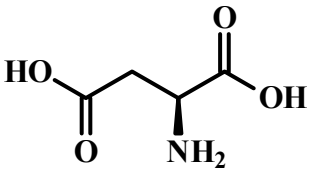
Plant	Part of plant used	Activity	References
Z. officinale	6,10-Gingerdione (pure compound)	Inhibitors of prostaglandin biosynthesis	Kiuchi, Shibuya and Sankwa, 1982
	Gingerenone A (pure compound)	Antifungal activity and anticoccidium activity	Endo, Kanno and Oshima, 1990
	6-Gingerol	Antitumour promoting activity	Park, *et al*., 1998
	(pure compound)	Antitumour promoting activity on HL-60 cells	Surh, *et al*., 1999
		Cytotoxic activity on HL-60 cells	Lee and Surh, 1998
	6, 8,10-Gingerol	Antimicrobial effects against *B.subtilis* and	Yamada, Kikuzaki and Nakatani,
	(pure compound)	*E. coli* K-12	1992
		Inhibition of *Mycobacterium avium* and	Hiserodt, Franzblau and Rosen, 1998
		Mycobacterium tuberculosis	
	6-Paradol	Antioxidative and antitumour promoting	Chung, *et al*., 2001
	(pure compound)	activity	
		Cytotoxic activity on HL-60 cells	Lee and Surh, 1998



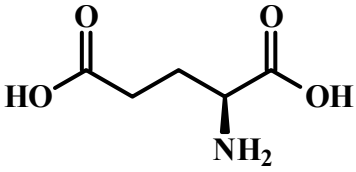
Alanine



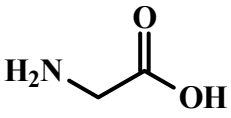
Arginine



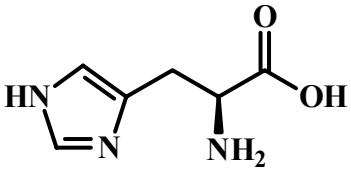
Aspartic acid



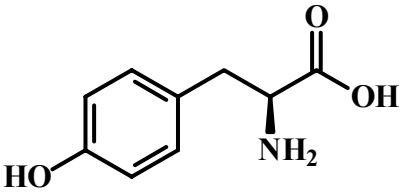
Glutamic acid



Glycine



Histidine



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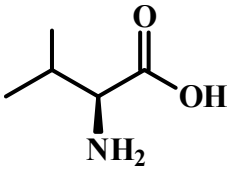
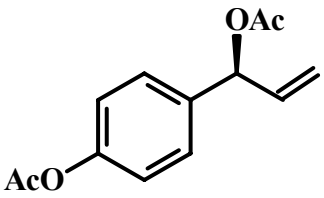
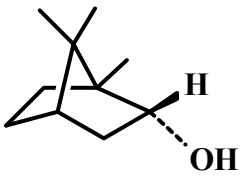


Valine

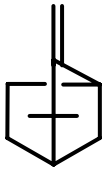
Figure 1 Structures of some chemical constituents found in *A. galanga*



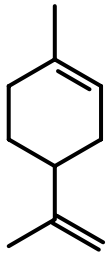
1′-Acetoxychavicol acetate



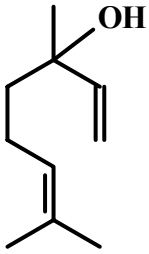
Borneol



Camphene

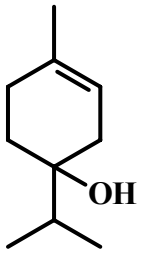


Limonene



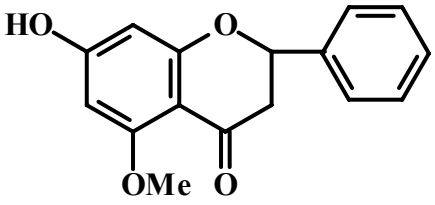
Linalool

Sabinene

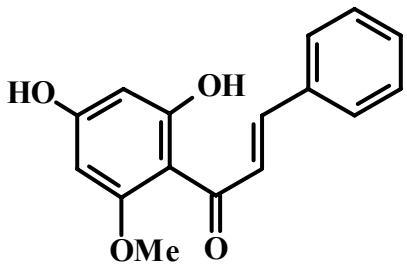


Terpinen-4-ol

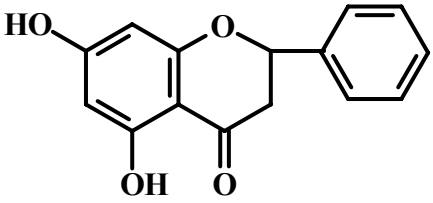
Figure 1 Structures of some chemical constituents found in *A. galanga* (continued)



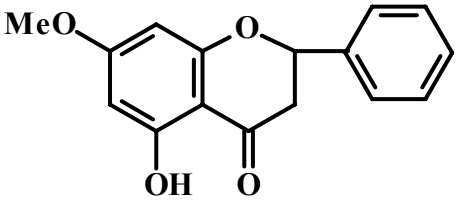
Alpinetin



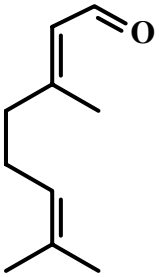
Cardamonin



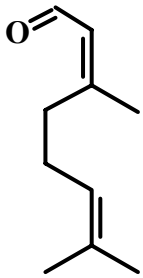
Pinocembrin



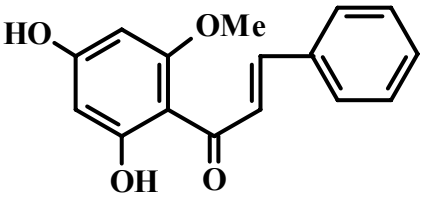
Pinostrobin



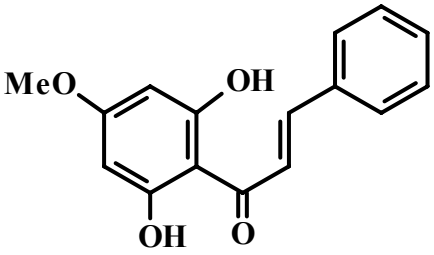
Geranial (*E*-Citral)



Neral (*Z*-Citral)

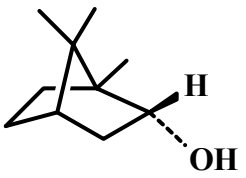


Chalcone cardamonin

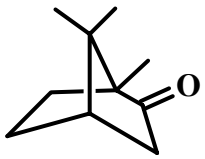


2′-6′-Dihydroxy-4′-methoxy chalcone

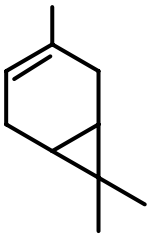
Figure 2 Structures of some chemical constituents found in *B. pandurata*



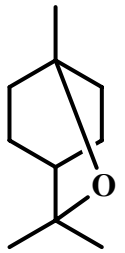
Borneol



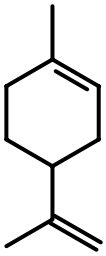
Camphor



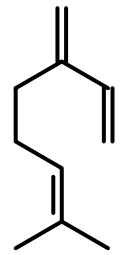
Car-3-ene



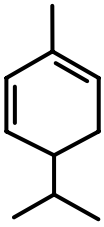
Cineol



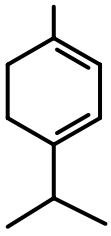
Limonene



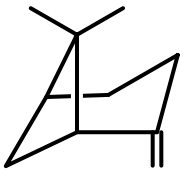
Myrcene



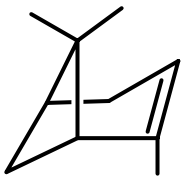
α-Phellandrene



Terpinene

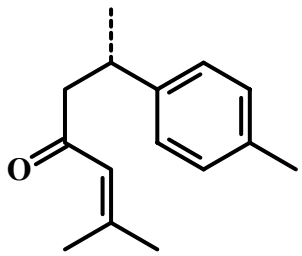


β-Pinene

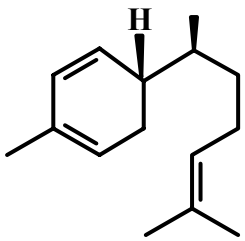


α-Pinene

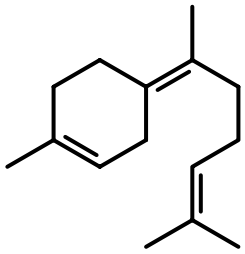
Figure 3 Structures of some chemical constituents found in *C. longa*



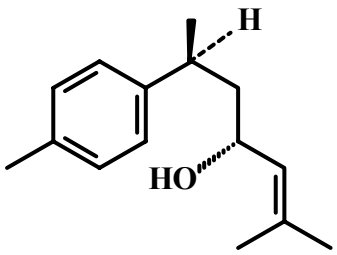
ar-Turmerone



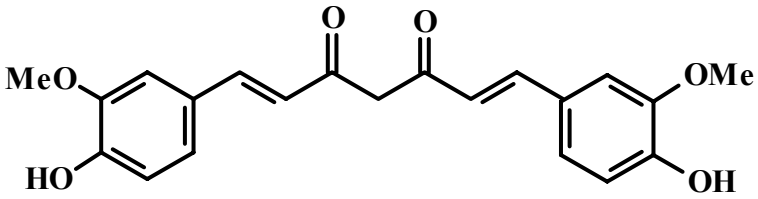
Zingiberene



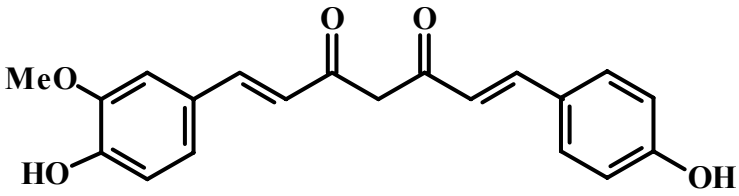
Bisabolene



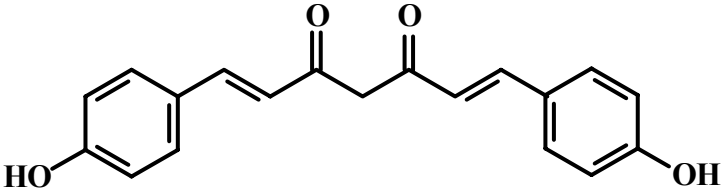
Bisacumol



Curcumin

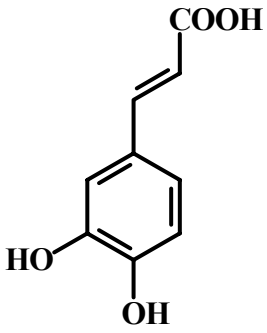


Demethoxycurcumin

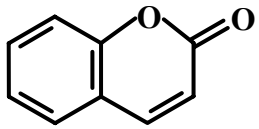


Bisdemethoxycurcumin

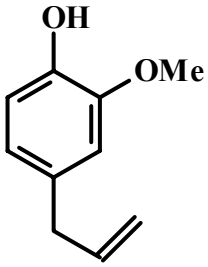
Figure 3 Structures of some chemical constituents found in *C. longa* (continued)



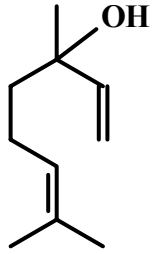
Caffeic acid



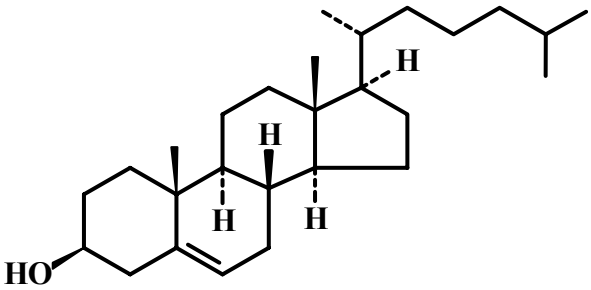
Coumarin



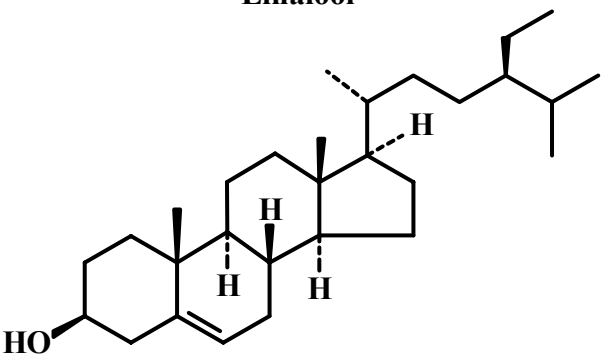
Eugenol



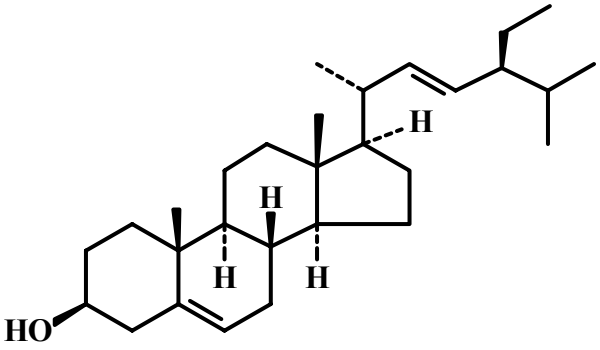
Linalool



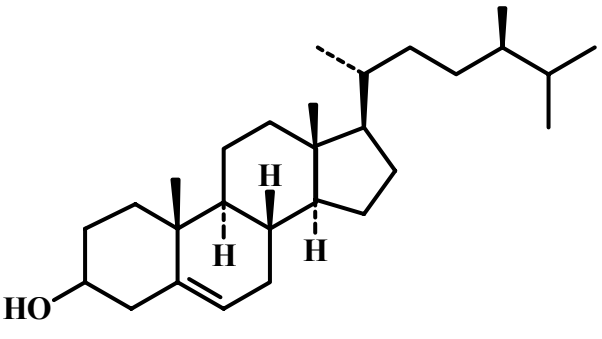
Cholesterol



β-Sitosterol

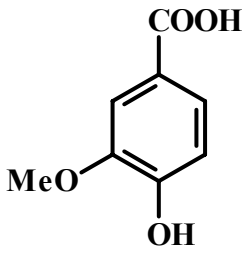


Stigmasterol

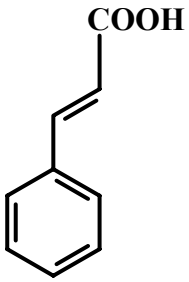


Campesterol

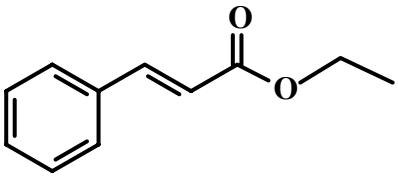
Figure 3 Structures of some chemical constituents found in *C. longa* (continued)



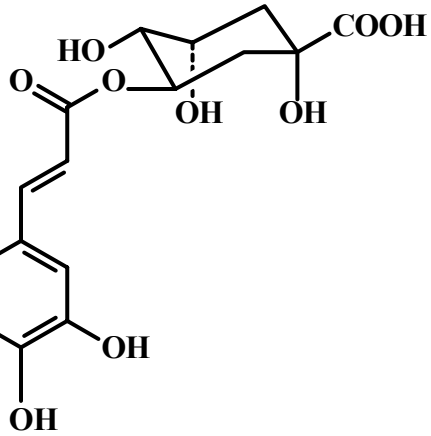
Vanillic acid



Cinnamic acid

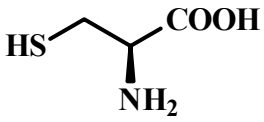


Ethyl cinnamate

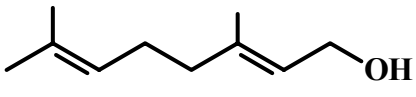


Chlorogenic acid

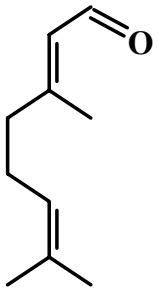
Figure 4 Structures of some chemical constituents found in *K. galanga*



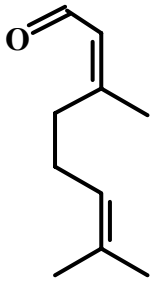
Cysteine



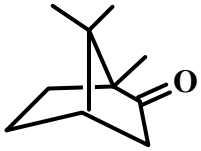
Geraniol



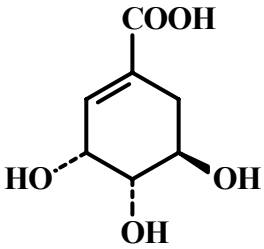
Geranial (*E*-Citral)



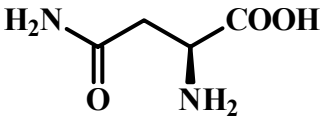
Neral (*Z*-Citral)



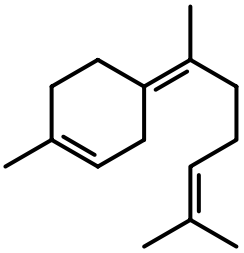
Camphor



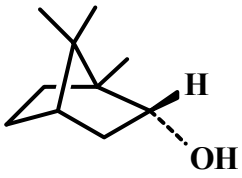
Shikimic acid



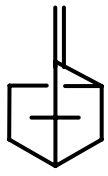
Asparagine



Bisabolene

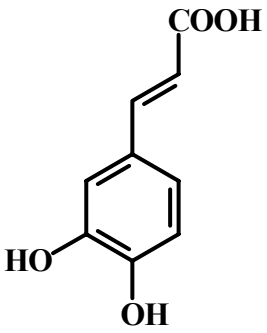


Borneol

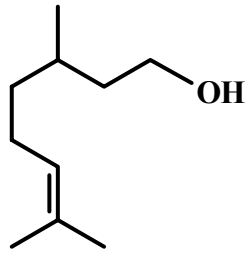


Camphene

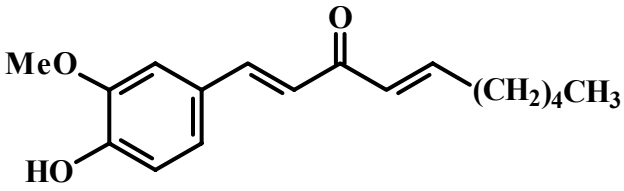
Figure 5 Structures of some chemical constituents found in *Z. officinale*



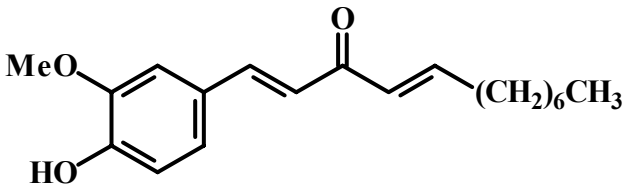
Caffeic acid



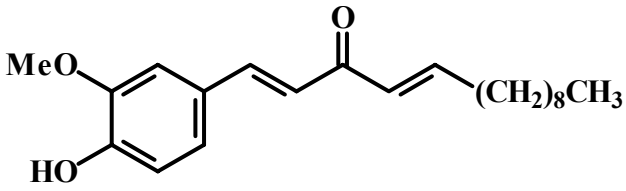
Citronellal



6-Dehydroshogaol

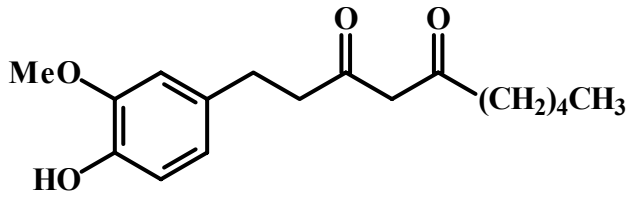


8-Dehydroshogaol

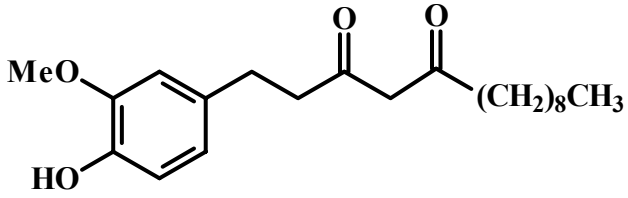


10-Dehydroshogaol

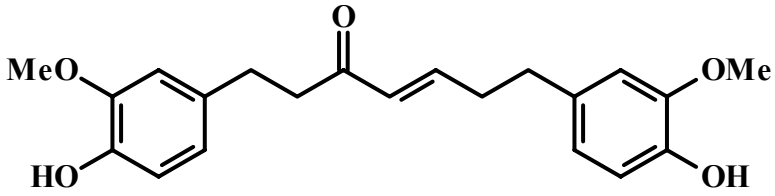
Figure 5 Structures of some chemical constituents found in *Z. officinale* (continued)



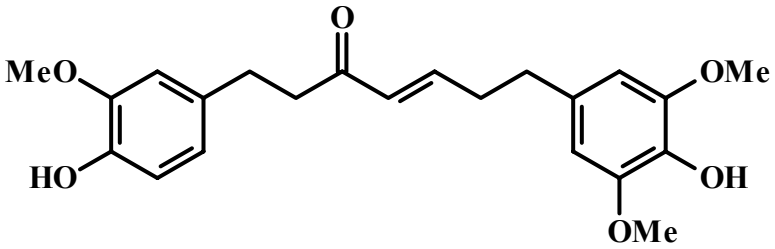
6-Gingerdione



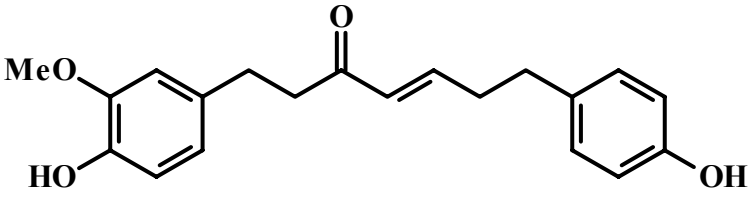
10-Gingerdione



Gingerenone A

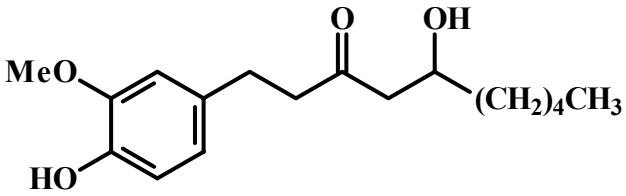


Gingerenone B

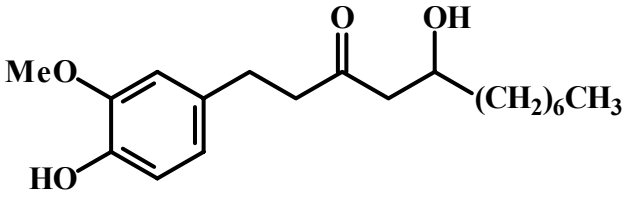


Gingerenone C

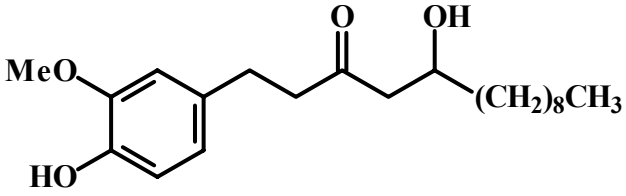
Figure 5 Structures of some chemical constituents found in *Z. officinale* (continued)



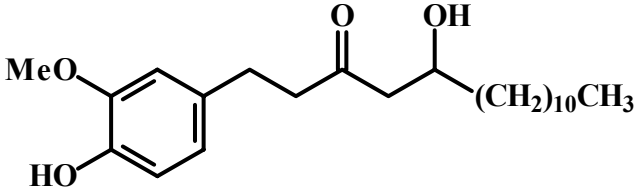
6-Gingerol



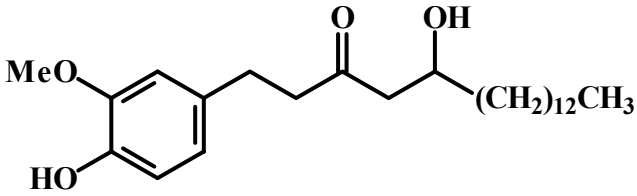
8-Gingerol



10-Gingerol

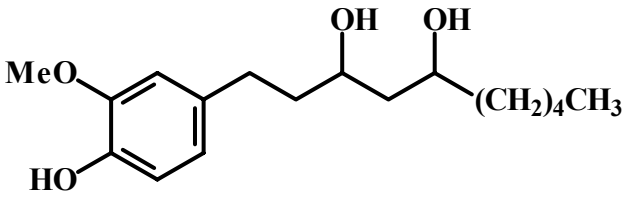


12-Gingerol

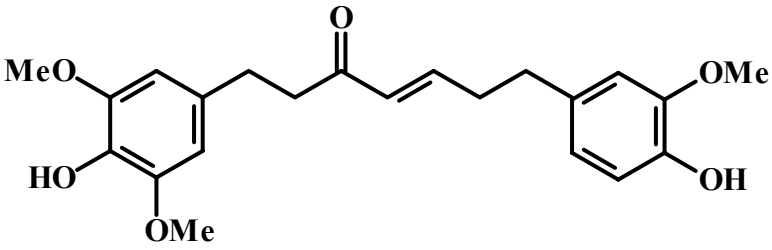


14-Gingerol

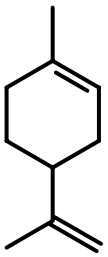
Figure 5 Structures of some chemical constituents found in *Z. officinale* (continued)



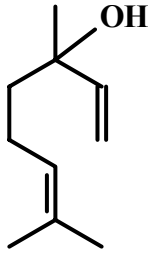
6-Gingerdiol



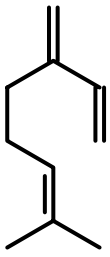
Isogingerenone B



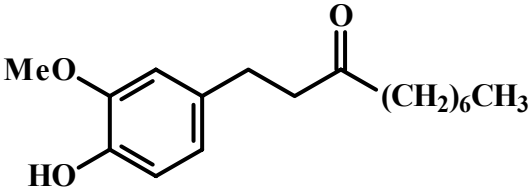
Limonene



Linalool

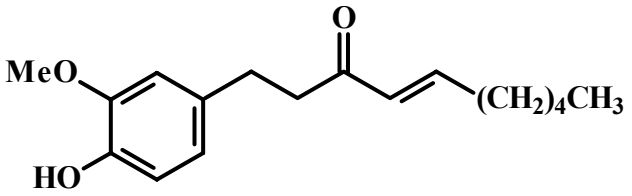


Myrcene

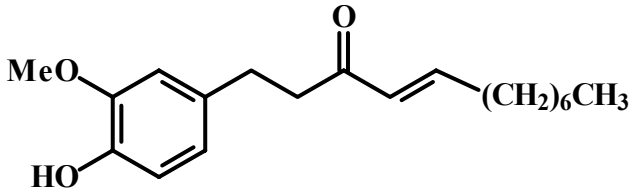


6-Paradol

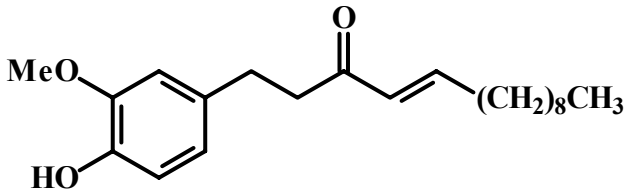
Figure 5 Structures of some chemical constituents found in *Z. officinale* (continued)



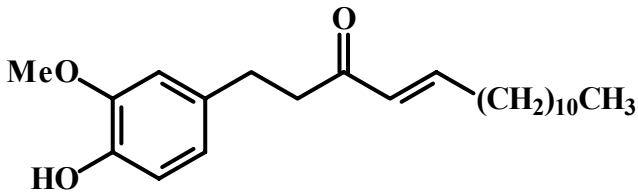
6-Shogaol



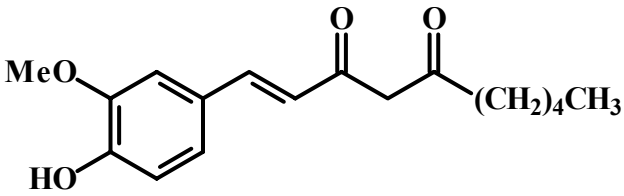
8-Shogaol



10-Shogaol

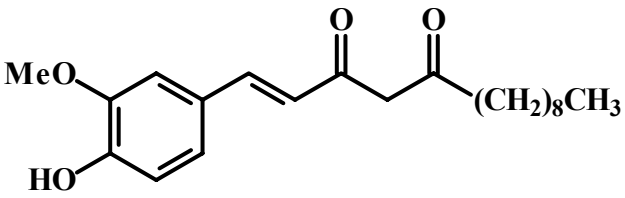


12-Shogaol

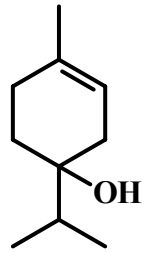


6-Dehydrogingerdione (or 1-Dehydrogingerdione)

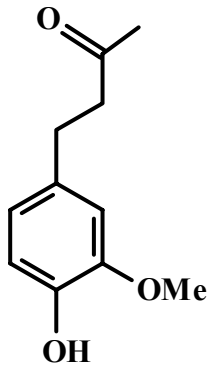
Figure 5 Structures of some chemical constituents found in *Z. officinale* (continued)



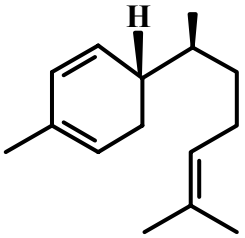
10-Dehydrogingerdione



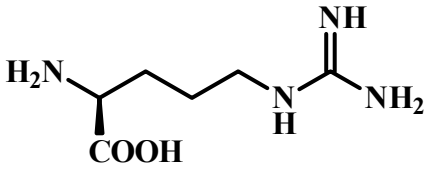
Terpinen-4-ol



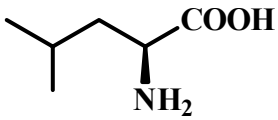
Zingerone



Zingiberene



Arginine



Leucine

Figure 5 Structures of some chemical constituents found in *Z. officinale* (continued)

The above data revealed that the five plants possessed diverse biological activities, for instance, antimicrobial activity, antiinflammatory activity, antioxidant activity, cytotoxic activity and antispasmodic activity. However, plant materials used in the previous studies were mainly crude extracts with exceptions of curcuminoids from *C. longa* and some gingerols from *Z. officinale*. A few data for cytotoxic activity were reported but the activity against human colon adenocarcinoma cell line LS174T of the five plants have not previously been reported. In addition, pure compounds responsible for antioxidant activity have not yet been identified from *A. galanga, B. pandurata* and *K. galanga*. Apparently, further work on biological evaluation and chemical investigation of these five plants is needed.

1.3 Objectives

1. To study free radical scavenging activity and cytotoxic activity against tumour cells of the extracts and volatile oils from the fresh rhizomes of *Alpinia galanga*, *Boesenbergia pandurata, Curcuma longa, Kaemferia galanga* and *Zingiber officinale*.
2. To study chemical constituents of the extracts and volatile oils which show free radical scavenging activity and/or cytotoxic activity against tumour cells.
3. To assess free radical scavenging activity and/or cytotoxic activity against tumour cells of the isolated compounds.