Chapter 2

Review of Literature

1. Antioxidant

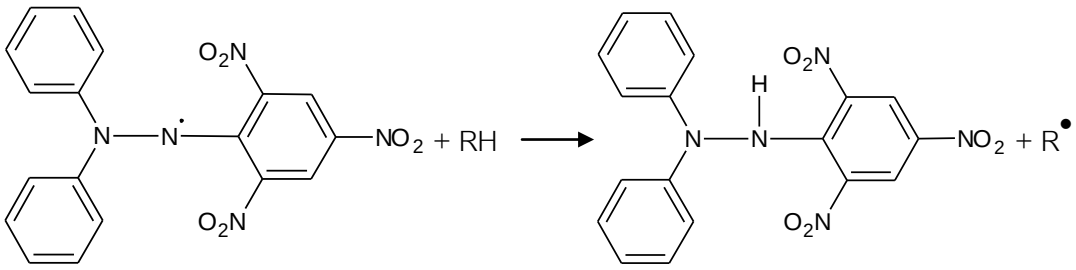
Reactive nitrogen species (RNS) and reactive oxygen species (ROS) include both radical and non-radical molecules with unpaired orbital electrons derived from nitrogen, such as nitric oxide and oxygen, such as peroxyl radical. RNS and ROS play important roles in killing foreign organisms and in acute inflammation but their over-production may cause tissue damage and vascular leakage in septicaemia, rheumatoid arthritis and inflammatory bowel disease (Darley-Usmare, Wiseman, & Halliwell, 1995). Furthermore, the interaction between RNS and ROS can also lead to the production of highly reactive non-radical species such as peroxynitrite, a product of nitric oxide and superoxide; commonly generated by macrophages under pathological conditions (Ischiropoulos, Zhu, & Beckman, 1992).

Oxidants or free radicals are energetically unstable and highly dangerous molecules which are constantly generated during body functions such as respiration, oxidative energy metabolism and immune activity. Free radicals are also produced from other sources (UV radiation, smoke, pollution, heavy metals, rancid fatty acids, etc.) Molecule oxygen is an oxidizing agent, that is, it takes electrons from another species. In healthy aerobic organisms, production of reactive oxygen species is approximately balanced by the antioxidant defence system in the body. These endogenous antioxidants can protect from damage caused by these harmful molecules. The body has evolved its own natural free radical scavengers, which include the antioxidant vitamins (such as vitamin C, and vitamin E), antioxidant minerals (such as selenium, and zinc) and the antioxidant enzyme systems (such as superoxide dismutase, and glutathione peroxidase), which are the backbone of the cellular antioxidant defence system (Itharat, 2002).

An antioxidant is a molecule capable of slowing or preventing the oxidation of other molecules. Oxidation is a chemical reaction that transfers electrons from a substance to an oxidizing agent. Oxidation reactions can produce free radicals,

which start chain reactions that damage cells. Antioxidants terminate these chain reactions by removing free radical intermediates, and inhibit other oxidation reactions by being oxidized themselves (Sies, 1997).

DPPH (1,1-diphenyl-2-picrylhydrazyl) is considered as a stable free radical because of the paramagnetism conferred by its odd electron (delocalization of the spare electron over the molecule as a whole). The solution (in absolute ethanol) appears as a deep violet color and shows a strong absorption band at 520 nm. The DPPH radical can accept an electron or hydrogen radical to become a stable diamagnetic molecule, at which the absorption vanishes and the resulting decolorization is stomachiometric with the number of electrons taken up, the solution has pale violet color (Figure 2.1) (Blois, 1958). A DPPH solution having a concentration of $6x10^{-5}$ M was used in the present study since at this low concentration the color is not too dense and the Lambert-Beer law is obeyed. If the tested substance is mixed with DPPH solution and gives rise to pale violet, it suggests that this substance has an antioxidant effect by the mechanism of free radical scavenging activity. The following assay procedure was modified from those described by Yamasaki (1994).



DPPH$^{\bullet}$ (deep violet color) DPPHH (pale violet color)

Figure 2.1

The 1,1-diphenyl-2-picrylhydrazyl radical (DPPH$^{\bullet}$) scavenging assay. The deep violet color of DPPH$^{\bullet}$ is relatively stable in absolute ethanol and reacts with free radicals or other hydrogen donors resulting in a pale violet color DPPHH

2. Inflammatory activity

2.1 Inflammation

The definition of inflammation is a localized, protective response to trauma or microbial invasion that destroys, or dilutes the injurious agent and the injured tissue (Gallin & Snyderman, 1999). Inflammation is part of the non-specific immune response that occurs in reaction to any type of bodily injury and in which the cardinal signs of inflammation can be explained by increased blood flow, elevated cellular metabolism, vasodilation, release of soluble mediators, extravasation of fluids and cellular influx (Figure 2.2) (Ferrero-Miliani, Nielsen, Andersen, & Girardin, 2006).

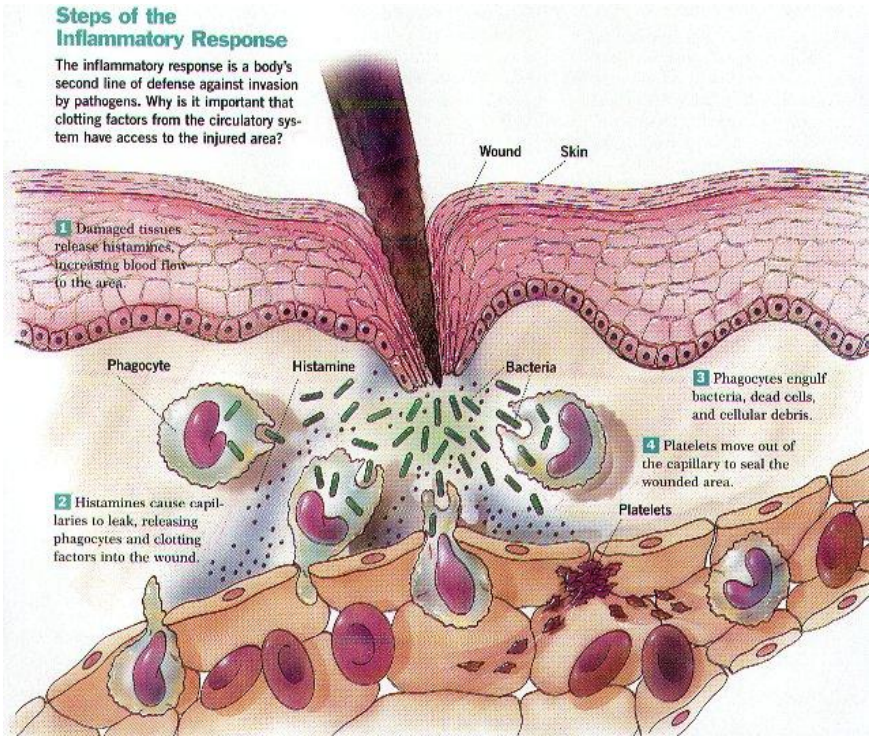


Figure 2.2

Steps of the inflammatory response (Cambridge Public Schools, 2010)

Inflammation can be classified based on duration of inflammation as acute and chronic inflammation.

2.1.1 Acute Inflammation

Acute inflammation is the early (almost immediate) response of a tissue to injury. It is nonspecific and may be evoked by any injury short of one that is immediately lethal (Chandrasoma & Taylor, 1998). Acute inflammation is a process typical of vascularized tissues whereby interstitial fluid and white blood cells accumulate at the site of injury. Upon injury or damage, an increase in microvascular permeability is an early event that leads to edema formation during inflammation. After this change, many other mechanisms are activated, contributing to the amplification of the inflammatory response and tissue damage (Bucci et al., 2005). The cardinal signs of acute inflammation are redness (rubor), heat (calor), swelling (tumor), pain (dolor), and loss of function (function laesa) (Gallin & Snyderman, 1999). Redness and heat are due to increased blood flow to the inflamed area; swelling is due to accumulation of fluid; pain is due to release of chemicals that stimulate nerve endings; and loss of function is due to a combination of factors (Chandrasoma & Taylor, 1998).

Many factors which mediate the events of acute inflammation have been documemted. The mediators either come from cells or are plasma-derived (Table 2.1). Plasma derived mediators gain entry to the damaged area via the inflammatory exudates. They are mostly precursor proteins, which are activated by proteolytic enzymes and, once activated, generally have short half-lives. Once in tissues, they are rapidly inactivated by a variety of enzymatic or scavenging systems (Figure 2.3) (Sae-Wong, 2007).

Table 2.1

Main groups of mediator involed in acute inflammation

Cellular mediators of acute inflammation	
Stored	**Active synthesis**
Histamine	Prostaglandins
	Leukotrienes
	Platelet activating factor
	Cytokines
	Nitric oxide
	Chemokines
Plasma-derived mediators of acute inflammation	
Kinin system	Bradykinin
Clotting pathway	Activated Hageman factor
Thrombolytic system	Plasmin
Complement pathway	C3a, C3b, C5a

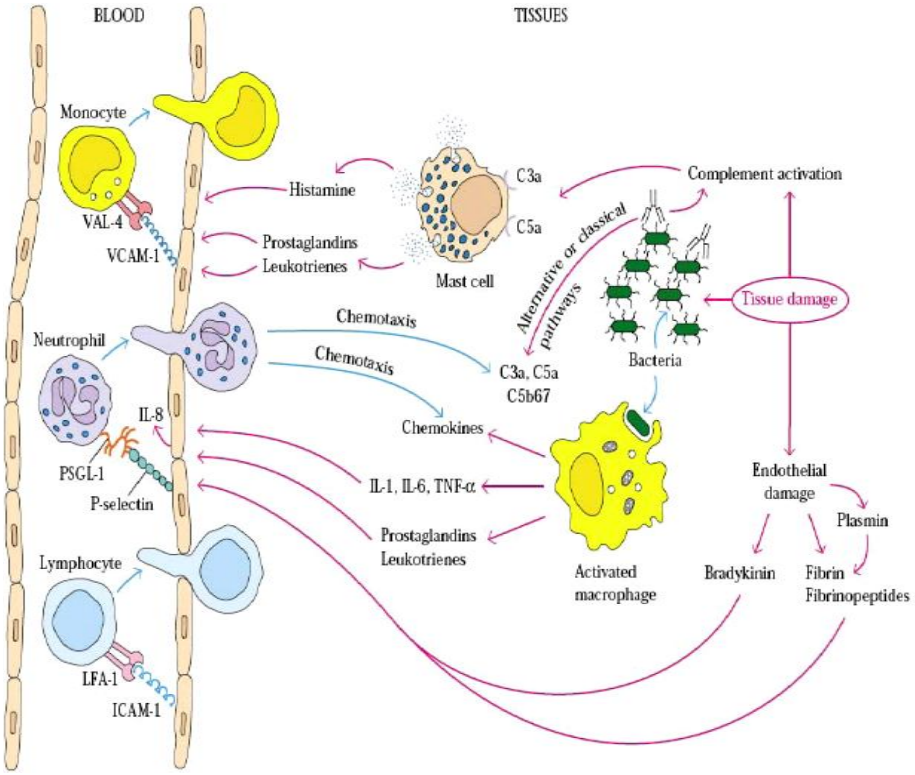


Figure 2.3

The cells and mediators involved in a local acute inflammatory response (Sae-Wong, 2007)

2.1.2 Chronic Inflammation

Chronic inflammation is a prolonged process (weeks to months) in which active inflammation with mononuclear cells, tissue destruction and attempts at healing may all occur simultaneously (Kumar, Abbas, & Fausto, 2005). Chronic inflammation is characterised by the dominating presence of macrophages in the injured tissue. These cells are powerful defensive agents of the body, but the toxins they release (including reactive oxygen species) are injurious to the organism's own tissues as well as invading agents. Consequently, chronic inflammation is almost always accompanied by tissue destruction.

Inflammation has very specific characteristics, whether acute or chronic, and the innate immune system plays a pivotal role, as it mediates the first response. Infiltration of innate immune system cells, specifically neutrophils and macrophages,

characterizes the acute inflammation, while infiltration of T lymphocytes and plasma cells are features of chronic inflammation. Monocyted/macrophages play a central role in both, contributing to the final consequence of chronic inflammation which is respresented by the loss of tissue function due to fibrosis (Ferrero-Miliani, Nielsen, Andersen, & Girardin, 2006).

Inflammation is a complex pathophysiological process mediated by a variety of signaling molecules produced by leukocytes, macrophages, mast cells, platelets, etc. Macrophages play a crucial role in the generation of pro-inflammatory molecules like nitric oxide (NO) (Saha, Lajis, et al., 2004).

2.2 Biological significance of nitric oxide

Nitric oxide (NO, formula $^{\bullet}N=O$) is one of the inflammatory mediators causing inflammation in many organs. Nitric oxide, an inorganic free radical, is involved in various physiological and pathological processes, such as vasodilation, non-specific host defense and acute or chronic inflammation, in organ systems (Aktan, 2004; Tewtrakul & Itharat, 2007). At low concentration NO is shown to play a role as a neurotransmitter and NO production at high concentration is implicated in having a role in the pathogenesis of stroke, septic stroke, and other imflammatory diseases (Kim, Kang, et al., 2000). NO is enzymatically synthesized via the oxidation of L-arginine by a family of nitric oxide synthase (NOS), which are either constitutive (cNOS) or inducible (iNOS). The three isoforms of NOS are encoded by distinct genes. NOS-I, also known as neuronal or brain NOS (nNOS), is found in high concentrations in neuronal and some nonneuronal tissue. NOS-II, also known as macrophage NOS or inducible NOS (iNOS), is originally found in macrophages. Furthermore, it exists in a variety of cell types including hepatocytes, vascular smooth muscle cells, fibroblasts, and epithelial cells. NOS-III, also known as endothelial NOS (eNOS), is identified as the enzyme that produces endothelium-derived relaxing factor. Both NOS-I and NOS-III, often grouped together as constitutive NOS (cNOS), are usually constitutively expressed, and their activities are regulated by intracellular calcium concentration via calmodulin (Davis, Martin, Turko, & Murad, 2001; Hobbs, Higgs, & Moncada, 1999; MacMicking, Xie, & Nathan, 1997). NOS-II, inducible NOS (iNOS), is not present in resting cells but can

be induced by immunostimulatory cytokines, bacterial products or infection in number of cells, including endothelium, hepatocytes, monocytes, mast cells, macrophages and smooth muscle cells. It generates NO independently of intracellular calcium concentrations (Aktan, 2004; Hobbs, Higgs, & Moncada, 1999; MacMicking, Xie, & Nathan, 1997; Tezuka et al., 2001). The isoforms of nitric oxide synthase and their major physiological functions and implications in various diseases are summarized in Figures 2.4 and 2.5.

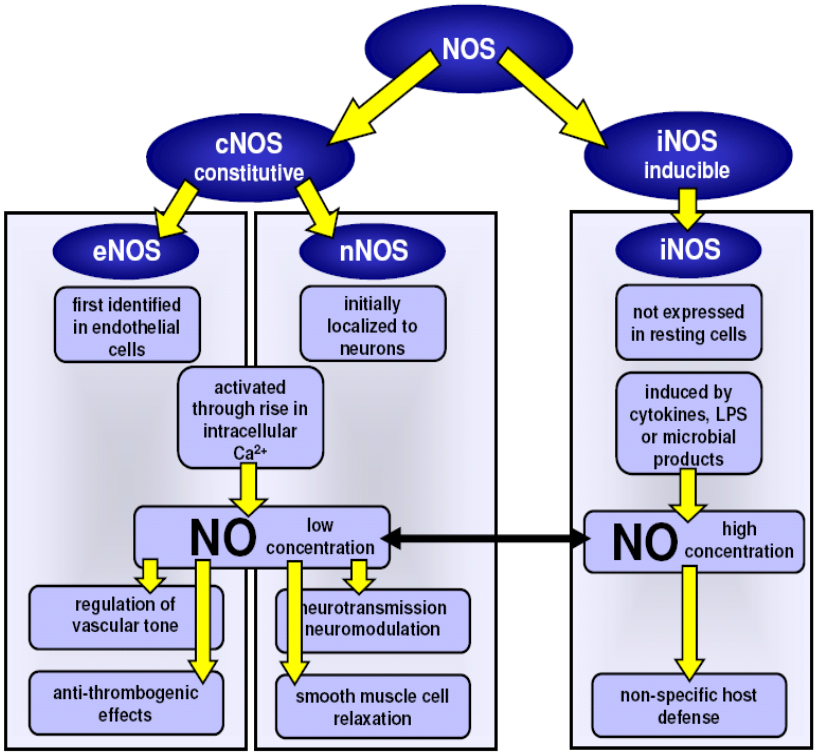


Figure 2.4

The isoforms of nitric oxide synthases. Two cNOS enzymes (eNOS, nNOS) are contrasted by a third, inducible NOS (iNOS) (Wibuloutai, 2006)

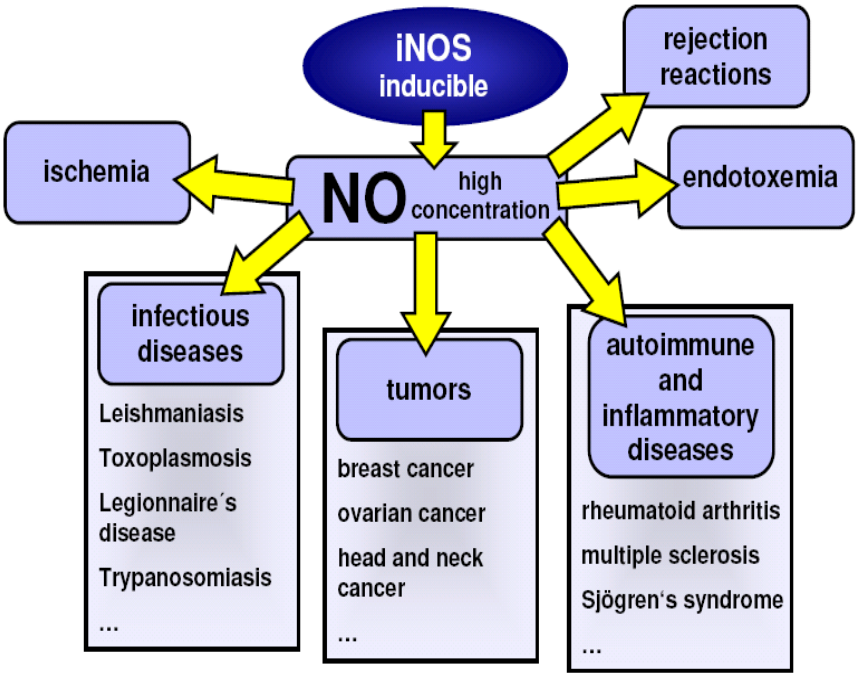


Figure 2.5

Implication of iNOS-derived NO in various human diseases. NO demonstrates its key roles in the human defense against adverse factors from the environment. Furthermore, many chronic inflammatory diseases are associated with sustained iNOS expression (Wibuloutai, 2006)

The nitric oxide is produced by the oxidation of L-arginin by inducible nitric oxide synthase (iNOS) in cells (Tezuka et al., 2001). The overall reaction consists of a two step oxidative conversion of L-arginine to NO and L-citrulline via N^{w}-hydroxy-L-arginine (NOHarginine) as an intermediate, with monooxygenase I and monooxygenase II, each step representing a mixed-function oxidation (Figure 2.6) (Aktan, 2004).

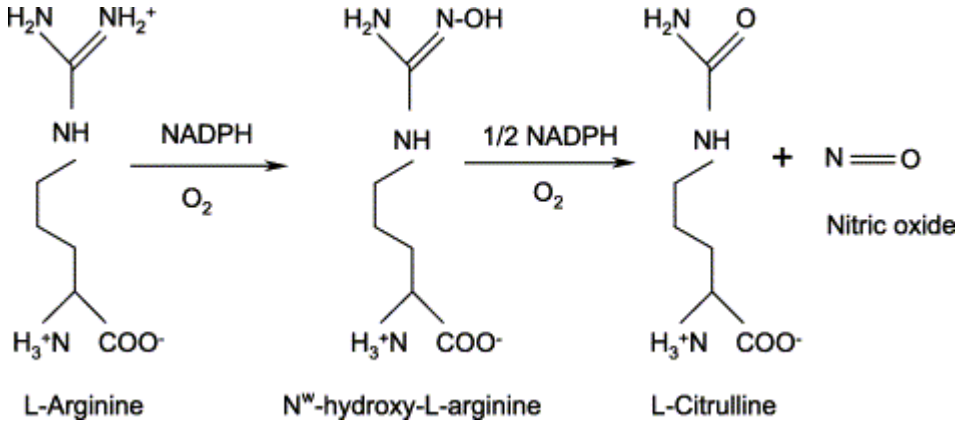


Figure 2.6

The reaction of NO synthesis from L-arginine. NO is synthesized endogenously by the conversion of L-arginine to L-citrulline. During this reaction, NADPH (1.5 molecules) is used as an electron donor and NOHarginine is generated as an intermediate (Aktan, 2004)

2.3 Monitoring NO production (Spectroscopic methods)

One of the most common methods for detecting NO from a wide variety of samples and matrices is the diazotization assay, also known as the Griess assay. The reaction involves reacting NO_2^- with sulfanilamide (SA) and *N*-(1-Naphthyl) ethylenediamine Dihydrochloride (NED) under acidic (phosphoric acid) conditions to yield an azo dye, whose concentration could then be used as an indirect indicator of NO_2^- (and NO) concentration in the sample. This method is the procedure widely used today (Hetrick & Schoenfisch, 2009).

After stimulation with lipopolysaccharide (LPS), a major component of the outer membranes of Gram-negative bacteria (Kim, Reddy, et al., 2004), many cells including macrophages express the iNOS which is responsible for the production of large amount of NO. This inducible enzyme is one of the essential components of the inflammatory response and is implicated in the pathogenesis of several inflammatory diseases (Saha, Lajis, et al., 2004). The Griess assay is used for the determination of NO metabolites in RAW 264.7 cells induced by LPS.

The Griess reaction involves first reacting NO_2^- with sulfanilamide (SA) under acidic conditions to form a diazonium salt intermediate. The diazonium

salt intermediate is then coupled to *N*-(1-Naphthyl)ethylenediamine Dihydrochloride (NED) to form the stable water-soluble azo dye. The NO_2^- concentration is determined by comparing the absorbance of the azo dye solution to a calibration curve prepared with known concentrations of NO_2^-, as shown in Figure 2.7 (Hetrick & Schoenfisch, 2009).

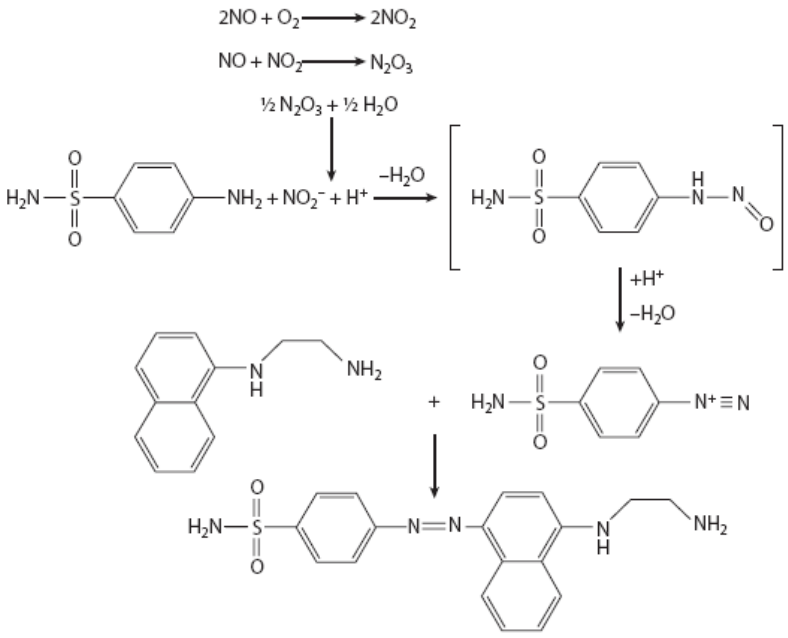


Figure 2.7

The most commonly employed diazotization reaction (also known as the Griess assay). Under aerobic conditions, nitric oxide (NO) reacts to form nitrite (NO_2^-), which reacts with sulfanilamide to form a diazonium salt intermediate. The diazonium salt is then coupled to *N*-(1-Naphthyl)ethylenediamine Dihydrochloride to form the stable water-soluble azo dye (Hetrick & Schoenfisch, 2009)

2.4 Tumor necrosis factor-alpha (TNF-α)

Tumor necrosis factor (TNF, cachexin or cachectin and formally known as tumor necrosis factor-alpha) is a polypeptide cytokine involved in systemic inflammation and is a member of a group of cytokines that stimulate the acute phase reaction.

The primary role of TNF is in the regulation of immune cells. TNF is able to induce apoptotic cell death, to induce inflammation, and to inhibit tumorigenesis and viral replication. Dysregulation of TNF production has been implicated in variety of human diseases, as well as cancer (Locksley, Killeen, & Lenardo, 2001).

The major source of TNF-α is the cells of the monocyte/macrophage lineage, with T lymphocytes, neutrophils, mast cells, and endothelium also contributing under different circumstances. All potentially noxious stimuli, ranging from the physical (ultraviolet light, X-radiation, heat) to the chemical and immunological, can rapidly induce TNF-α production and release. *In vivo* TNF-α is the most rapidly produced pro-inflammatory cytokine, with serum levels detectable in mice in 30 min. Probably the earliest TNF-α comes from preformed stores by cleavage of membrane TNF-α on macrophages, neutrophils, and activated T cells by TNF-α converting enzyme (TACE/ADAM17), and release of cytoplasmic granules from mast cells and eosinophils. Subsequent release of TNF-α is due to new synthesis, chiefly in macrophages and T lymphocytes (Feldmann & Maini, 2001). Large amounts of TNF-α are released in response to lipopolysaccharide, other bacterial products, and Interleukin-1 (IL-1). A local increase in concentration of TNF-α will cause the cardinal signs of inflammation to occur: heat, swelling, redness, and pain.

If the rapid release of TNF-α at times of stress is blocked, the expression of other pro-inflammatory cytokines, such as IL-1 and IL-6, is reduced. This and analogous in vitro data suggest that TNF-α *in vivo* coordinates the cytokine response to injury and acts as a fire alarm. The induction by TNF-α of multiple chemokines and adhesion molecules is of major importance in rapidly attracting immune and inflammatory leukocytes to the site of injury and TNF-α release. TNF-α also acutely upregulates the function of the immune system, but following prolonged exposure to an excess of TNF-α, it is immunosuppressive (Feldmann & Maini, 2001).

2.5 Macrophages

The inflammatory process is usually tightly regulated, involving both signals that initiate and maintain inflammation and signals that shut the process down. An imbalance between the two signals leaves inflammation unchecked, resulting in cellular and tissue damage. Macrophages are a major component of the mononuclear phagocyte system that consists of closely related cells of bone marrow origin, including blood monocytes, and tissue macrophages. From the blood, monocytes migrate into various tissues and transform macrophages. In inflammation, macrophages have three major function; antigen presentation, phagocytosis, and immunomodulation through production of various cytokines and growth factors. Macrophages play a critical role in the initiation, maintenance, and resolution of inflammation. They are activated and deactivated in the inflammatory process. Activation signals include cytokines (interferon gamma, granulocyte-monocyte colony stimulating factor, and tumor necrosis factor alpha), bacterial lipopolysaccharide, extracellular matrix proteins, and other chemical mediators. Inhibition of inflammation by removal or deactivation of mediators and inflammatory effector cells permits the host to repair damages tissues. Activated macrophages are deactivated by anti-inflammatory cytokines (interleukin 10 and transforming growth factor beta) and cytokine antagonists that are mainly produced by macrophages. Macrophages participate in the autoregulatory loop in the inflammatory process. Because macrophages produce a wide range of biologically active molecules participated in both beneficial and detrimental outcomes in inflammation, therapeutic interventions targeted macrophages and their products may open new avenues for controlling inflammatory diseases (Fujiwara & Kobayashi, 2005).

3. Allergic activity

3.1 Allergy

The immune pathways that function as the protective mechanisms can also cause injury. Various models have been developed to investigate allergic or hypersensitivity reactions and to correlate these reactions with specific diseases. The mose widely used classification, which was introduced by Gel and Coombs (1969), desceibes four type of hypersensitivity including type I (immediate hypersensitivity), type II (cytotoxic hypersensitivity), type III (immune complex hypersensitivity), and type IV (delayed hypersensitivity). Type I, II and III are antibody mediated. Type IV is T-cell mediated (Grant, 1984). The allergy is an immunological reaction to a foreign antigen (allergens) such as dust mites, pollen, cosmetics, food, animal hairs and mold spores which cause tissue inflammation and organ dysfunction (Nakatani et al., 2002).

Hypersensitivity type I, an allergic reaction, is an IgE-mediated immune response. This class of antigens induces the production of antigen-specific IgE antibodies that bind to receptors on mast cells or basophils. In the early stage of allergy, a type I hypersensitivity reaction against an allergen, encountered for the first time, causes a response in a type of immune cell called a T_H2 lymphocyte. These T_H2 cells interact with other lymphocytes called B cells, whose role is production of antibodies. Coupled with signals provided by IL-4, this interaction stimulates the B cell to begin production of a large amount of a particular type of antibody known as IgE. Secreted IgE circulates in the blood and binds to an IgE-specific receptor (a kind of Fc receptor called FcεRI) on the surface of other kinds of immune cells called mast cells and basophils. The IgE-coated cells, at this stage are sensitized to the allergen. If later exposure to the same allergen occurs, the allergen can bind to the IgE molecules held on the surface of the mast cells or basophils. Cross-linking of the IgE and Fc receptors occurs when more than one IgE-receptor complex interacts with the same allergenic molecule, and activates the sensitized cell. Activated mast cells and basophils undergo a process called degranulation, during which they release mediators (Charles, Travers, Walport, & Shlomchik, 2001). The early phase reaction in type I allergy occurs within minutes and then the mediators such as histamine and

serotonin are released from the cell. These mediators induce vasodilation, mucous secretion, and bronchoconstriction. The late phase reaction occurs within 4-6 h after the early phase reaction in type I allergy and involves cytokines secretion such as tumor necrosis factor-α (TNF-α) and interleukin-4 (IL-4). These mediators increase endothelial cell adhesion and recruitment on inflammatory cells to the affected site (Matsuda, Tewtrakul, Morikawa, Nakamura, & Yoshikawa, 2004; Matsuda, Tewtrakul, Morikawa, & Yoshikawa, 2004; Tewtrakul, Itharat, Thammaratwasik, & Ooraikul, 2008; Tewtrakul, Tansakul, & Panichayupakaranant, 2009).

The mediators are released from mast cells and basophils such as histamine, prostaglandins, leukotrienes, proteases and platelet activating factors (PAF). Therefore, these mediators lead to hypersensitivity and inflammation. β-Hexosaminidase is also stored in the secretory granules of mast cells and basophils, and released along with histamine when mast cells and basophils are activated. Since, β-hexosaminidase is usually released along with histamine from mast cells or basophils, this enzyme is therefore used as the marker for mast cells degranulation in RBL-2H3 cell line (Matsuda, Tewtrakul, Morikawa, Nakamura, & Yoshikawa, 2004; Tewtrakul, Tansakul, & Panichayupakaranant, 2009). Mechanism of type I hypersensitivity reaction (allergic reaction) is shown in Figure 2.8.

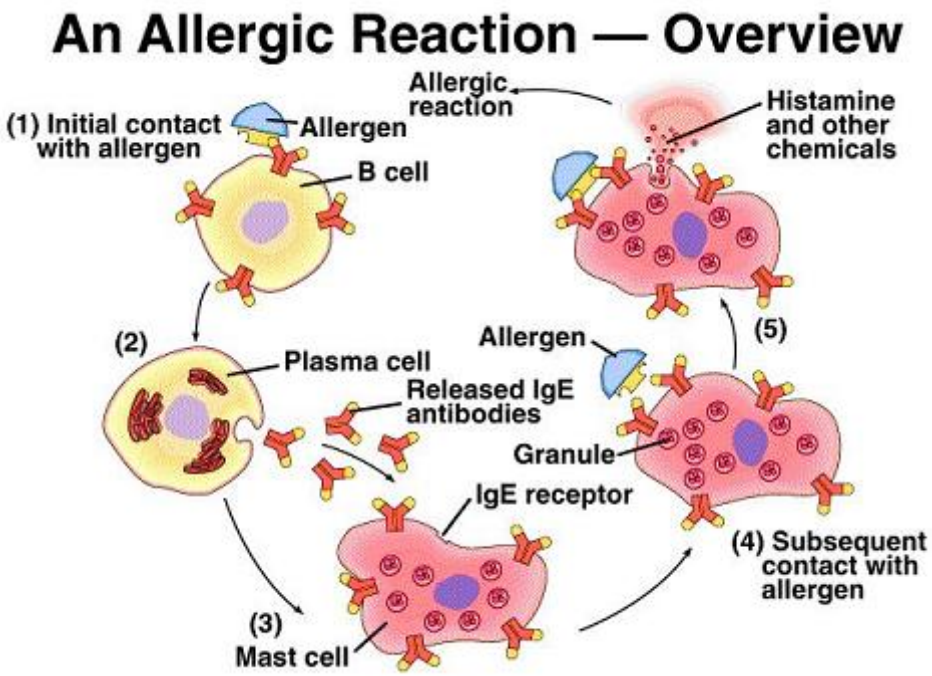


Figure 2.8

Mechanism of allergic reaction (Lewis, 1998)

3.2 Mast cells

Mast cells are found in connective tissues. Mast cells synthesize and store histamine, proteoglycans, and proteases within their granules and have surface receptors (FcεRI) that bind IgE with high affinity. The binding of multivalent antigen to this cell bound IgE results in degranulation and the release of mediators (Figure 2.9). Mast cells activation carried out in response to exposures to a specific allergen, a variety of biological substances (neuropeptides and certain cytokines), and pharmacological compounds (calcium ionophore, compound 48/80), results in the prompt release of preformed mediators, such as histamine and serotonin, together with de novo synthesized lipid mediators, such as leukotrienes and protaglandins, and some cytokines. The physiological effects of immediate hypersensitivity and inflammation are due to the response of other cells to the mediators released from the mast cells (Hirose et al., 2009; Matsushima et al., 2009). IgE-mediated reactions, besides resulting in immediate wheal and erythema reactions, also induce a late-phase response, which occurs within 4-8 h after challenge. Such reactions are clearly

mediated by IgE-antigen interactions and require the presence of mast cells in the tissues. The release of cytokines from mast cells recruits basophils, neutrophils, eosinophils, and macrophages to these sites where mast cells are degranulating. The cytokines released from the mast cells also activate the resident and recruited cells to release other cytokines and inflammatory mediators. Recent data have implicated these late responses for the inflammation that is prominent in asthma and other allergic diseases (Siraganian, 1999).

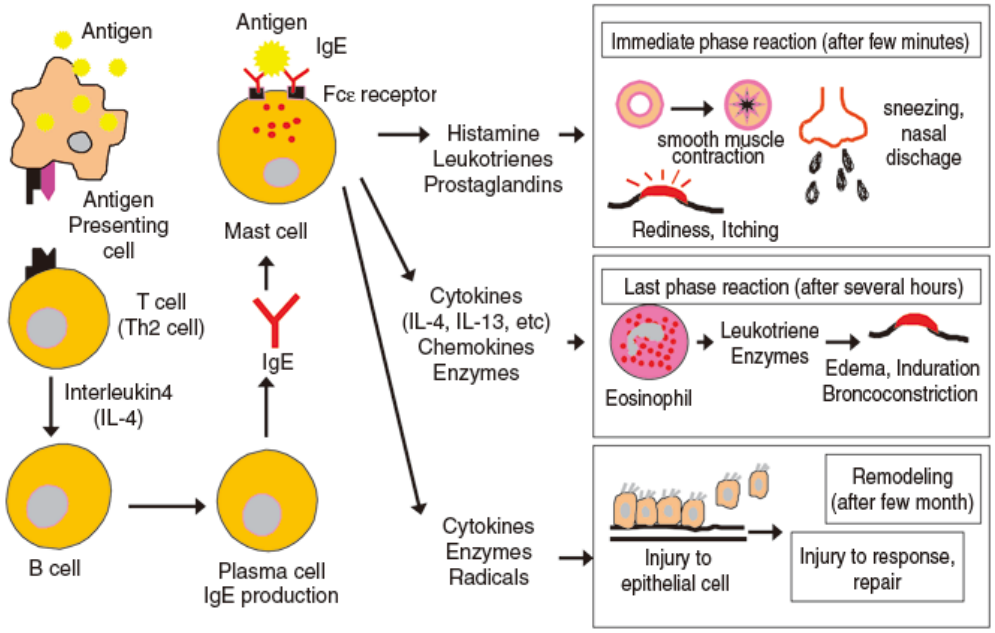


Figure 2.9

The mechanism of IgE mediated allergic reaction

(Nagai, Teramachi, & Tuchiya, 2006)

Rat basophilic leukemia (RBL-2H3) cells are mucosal-type mast cells. The RBL-2H3 cells contain several hundred thousand IgE receptors on the membrane surface after that sensitization with monoclonal IgE. The cells respond to antigen and release histamine (Ikawati, Wahyuono, & Maeyama, 2001) that is major model for study of IgE-mediated degranilation (Yamashita et al., 2000).

4. General data of the plants in Prasaprohyai preparation

4.1 *Amomum testaceum* Ridl. or *Amomum krervanh* Pierre ex Gagnep.

Amomum testaceum Ridl. or *Amomum krervanh* Pierre ex Gagnep. (Zingiberaceae) has common names in various countries which are Krawan (Chanthaburi, Pattani), Krawan khao, Krawan phothisat (Central), Pla ko (Pattani) (Thailand), Ka tepus (Malaysia) and Camphor seed, Siam cardamom (English) (Smitinand, 2001). It is a native plant of peninsular South East Asia. Its small, almost spherical pods are used in the cuisines of Thailand and Cambodia and imitate cardamom's aroma pretty well. Medically, it is used mainly as a flavor and an aid to digestion. It is used more prosaically to treat colds, bronchitis, fevers, inflammatory conditions of the oropharynx, and liver complaints. There is no evidence to support any of these uses (History & Special Collections UCLA Louise M. Darling Biomedical Library, 2002). In Thai traditional medicine, the fruits are used for carminative and relieve flatulence (Chanwitheesuk, Teerawutgulrag, & Rakariyatham, 2005).

Description of *Amomum testaceum* Ridl., shown in Figure 2.10 and Figure 2.11, is a perennial rhizomatous herb, 1-3 m high, often grown in rain forests. The leaf is simple, alternative, oblong, 8-15 cm wide, 40-50 cm long, exstipulate. Inflorescence arises from rhizome. The flowers are white, flowering at 2-3 years and arising from rhizome. The fruits are glabrous capsule, aromatic, pungent taste. In Thai traditional medicine, dried fruits are used as carminative and antiflatulent. It uses dried fruits 1-2 g, infusion (Saralamp, Chuakul, Temsiririrkkul, & Clayton, 1996).

Figure 2.10

Amomum testaceum Ridl. (Ministry of Science and Technology, 2007)

Figure 2.11

Fruit of *Amomum testaceum* Ridl.

4.2 *Anethum graveolens* L. or *Anethum sowa* Roxb. ex J.Fleming

Anethum graveolens L. or *Anethum sowa* Roxb. ex J.Fleming (Umbelliferae) has other common names in various countries which are Thian ta takkataen (Central), Phak chi lao (Nakkhon Ratchasima) (Thailand) and Dill (English) (Smitinand, 2001). It is a native originally of southwestern Asia; however, dill is now naturalized in many parts of Europe and the northern US. Dill is a very popular flavoring in northern, central and eastern European countries, but hardly used at all in France or Italy. Dill is almost indispensable in Russian and Scandinavian cookery. In India, "Sowa" dill, which is more pungent than European and American varieties, is an essential ingredient in curry (Floridata.com LC, 1996). As folk remedy, dill is a common household remedy against a variety of gastrointestinal disorders, e.g. indigestion, flatulence, colic pain. Dill fruit has an antispasmodic effect on the smooth muscles of the gastrointestinal tract (Hosseinzadeh, Karimi, & Ameri, 2002; Kaur & Arora, 2009). Some pharmacological effects have been reported, such as antimicrobial, antihyperlipidaemic and antihypercholesterolaemic activities (Hosseinzadeh et al., 2002). In Thai traditional medicine, the seeds are used for restorative, carminative, expectorant and relieve nausea (Chanwitheesuk, Teerawutgulrag, & Rakariyatham, 2005). The aerial of *A. graveolens* has been reported to possess analgesic (Tangsucharit, Kukongviriyapan, Kukongviriyapan, & Airarat, 2006). The methanolic extract of the leaves were tested for antioxidant activity, and showed antioxidant activity (IC_{50} = 0.5 μg) lower than dl-α-tocopherol (IC_{50} = 0.6 μg) but higher than quercetin (IC_{50} = 0.1 μg) (Souri, Amin, Farsam, & Andaji, 2004).

Description of *Anethum graveolens* L., shown in Figure 2.12 and Figure 2.13, is an erect, freely branching annual herb with finely dissected, lacy, blue-green foliage. "Dill weed" refers to the foliage, and the seeds are usually just called "dill". The leaves are about 1 ft (0.3 m) long and divided pinnately three or four times into threadlike segments each about 1 in (2.5 cm) long. The dill plant grows about 3-5 ft (0.9-1.5 m) tall and sometimes gets top heavy and falls over. The flowers are yellow and borne in large, rounded, compound umbels (umbrella-like clusters in which all the flower stems originate from the same point) on stiff, hollow stems. The whole inflorescence can be 10 in (25 cm) across, and several of them on a feathery blue-

green framework can be showy indeed. The fruit is a flattened pod about an eighth of 1 in (2.5 cm) long. All parts of the dill plant are strongly aromatic (Floridata.com LC, 1996).

Figure 2.12

Anethum graveolens L. (Wikimedia commons, 2007)

Figure 2.13

Fruit of *Anethum graveolens* L.

4.3 *Angelica dahurica* Benth. or *Angelica dahurica* Benth. var *formosana* (Boiss.)

Angelica dahurica Benth. or *Angelica dahurica* Benth. var *formosana* (Boiss.) Shan et Yuan (Umbelliferae) has other common names in various countries which are Kot so (General) (Thailand), Bai Zhi (Chinese) and Dahurian Angelica (English). It is native to mountains and thickets ranging from eastern Siberia to Japan. Today Chinese angelica is cultivated throughout eastern and central China for its medicinal strength. The root is most frequently prescribed as a sedative (Shin, Moon, & Woo, 1991), antipyretic and analgesic for cold, headaches and toothaches in Chinese medical (Piao et al., 2004). It is reported to protect against dexamethasone-induced disorders, and also to possess liver protective activity, antimicrobial activity, anti-inflammatory activity, and antimutagenic activity (Piao et al., 2004; Thanh, Jin, Song, Bae, & Kang, 2004). In Thai traditional medicine, the roots are used as an antipyretic, antiasthmatic and anticough (Foundation of resuscitate and encourage Thai traditional medicine, 2005).

Description of *Angelica dahurica* Benth., shown in Figure 2.14 and Figure 2.15, is perennial 1–2.5 m, stout. The root is cylindric, brown, 3–5 cm thick, strongly aromatic. The stem is purplish green, 2–5 (or 2-8) cm thick, ribbed, pubescent above. The basal and lower leaves are long-petiolate, sheaths oblong-inflated, glabrous; blade triangular-ovate, 30–50 × 25–40 cm, 2–3-ternate-pinnate; leaflets sessile, oblong-elliptic to oblong-lanceolate, 4–10 × 1–4 cm, base slightly decurrent, margin white-cartilaginous and coarse-cuspidate-serrate, apex acute, pubescent along nerves adaxially. The upper leaves are reduced, sheaths saccate-inflated, bladeless. The umbels are 10–30 cm across; peduncles 5–20 cm, scabrous; bracts absent or 1–2, like uppermost leaves; rays 18–40 (or 18-70), short-hairy; bracteoles many, linear-lanceolate, scarious; pedicels many, scabrous. Calyx teeth are obsolete. The petals are white, obovate and notched. The ovary is glabrous or pubescent. The fruit is suborbicular, 4–7 × 4–6 mm; dorsal ribs prominent, obtusely thick-rounded, much wider than furrows, lateral ribs broad-winged; vittae 1 in each furrow, 2 on commissure (Flora of China, 2009a).

Figure 2.14

Angelica dahurica Benth.

(FuZhou Corona Science & Technology Development Co.,Ltd., 2009)

Figure 2.15

Root of *Angelica dahurica* Benth.

4.4 *Angelica sinensis* (Oliv.) Diels

Angelica sinensis (Oliv.) Diels (Umbelliferae) has other common names in various countries which are Kot chiang (Central) (Thailand), Donggui (Chinese), toki (Japanese), tanggwi (Korean), kinesisk kvan (Danish) and Chinese angelica (English). It is native to mainland China, Japan, and Korea.

Angelica sinensis (Danggui in Chinese), one of the most important traditional Chinese medicines, is used for tonifying blood and treating irregular female menstruation and amenorrhea. It has also been used for treatment of anemia, premenstrual syndrome, menopause, hypertension, chronic bronchitis, asthma, rheumatism and cardiovascular diseases for thousands of years in Asia (Dong, Li, Hong, & Zhu, 2005; Lao et al., 2004; Li, Li, et al., 2006; Yang et al., 2007). It is recorded that 70 formulae in China and 56 formulae in Japan contain Danggui. Besides, the common usage in Asia, Danggui is also used as a health food product for women's care in Europe and America (Lao et al., 2004).

Description of *Angelica sinensis* (Oliv.) Diels, shown in Figure 2.16 and Figure 2.17, is perennial, 0.4–1 m. The root is cylindric, branched, many rootlets, succulent, strongly aromatic. The stem is purplish green, ribbed, branched above. The basal and lower petioles are 5–20 cm, sheaths purplish green, ovate, membranous-margined; blade ovate, 10–30 × 12–25 cm, 2–3-ternate-pinnate, pinnae 3–4 pairs, proximal and middle pinnae long-petiolulate; leaflets ovate or ovate-lanceolate, 2–3.5 × 0.8–2.5 cm, 2–3-lobed, margin irregularly coarse-cuspidate-serrate, sparse papillate-hairy along nerves and margin. The peduncles are 8–20 cm, pubescent or subglabrous; bracts absent or 2, linear; rays 10–30, unequal, scabrous; bracteoles 2–4, linear, 3–5 mm; umbellules 13–36-flowered; pedicels slender, 1–3 cm in fruit. Calyx teeth obsolete, rarely minute, ovate. The petals are white, rarely purplish red. The fruit is ellipsoid or suborbicular, 4–6 × 3–4 mm; dorsal ribs filiform, prominent, lateral ribs broadly thin-winged, wings as wide as or wider than the body; vittae 1 in each furrow, 2 or absent on commissure (Flora of China, 2009b).

Figure 2.16

Angelica sinensis (Oliv.) Diels (Schooley, 2003)

Figure 2.17

Root of *Angelica sinensis* (Oliv.) Diels

4.5 *Artemisia annua* L.

Artemisia annua L. (Compositae), has other common names in various countries which are Kot chula lampha (Central), Ching Hao (Thailand), Qinghao (Chinese) and Sweet wormwood, Sweet Annie, Annual wormwood (English). It is native to Asia, most probably China and Vietnam. It occurs naturally as part of a steppe vegetation in the northern parts of Chahar and Suiyuan provinces in China, at 1000 to 1500 m above sea level. Now it is naturalized in many countries including the United States (Ferreira & Janick, 2009).

Artemisia annua L. is a famous medicinal herb that has commonly been used in Chinese traditional therapy for the treatment of fever and malaria (Tzeng, Lin, Jong, & Chang, 2007). *A. annua* is known to have anti-inflammatory, antitumor and allelopathic effects (Juteau, Masotti, Bessiere, Dherbomez, & Viano, 2002). The tincture from *A. annua* (leaves) is applied as a disinfectant and an antiseptic (Duarte et al., 2007). Artemisinin is separated from this plant. It is well known that artemisinin has anti-malarial effects and exhibits potent immunosuppression activities (Wang et al., 2007). Artemisinin is reported to treat psoriasis and autoimmune disorders (Patwardhan & Gautam, 2005). The whole plant extract and the leaves extract have been reported to possess antimicrobial activity against *C. albicans* (Duarte, Figueira, Sartoratto, Rehder, & Delarmelina, 2005; Kumar, Chauhan, Padh, & Rajani, 2006). The lipid extract (0.1, 0.5 and 5 mg/kg p.o.) of *A. annua* leaves and flowers showed inhibit paw adema caused by administering formalin and ovalbumin (Ul'chenko et al., 2005).

Description of *Artemisia annua* L., shown in Figure 2.18 and Figure 2.19, is branched annual herb, 0.2-1.5 m high. Leaf is outline oblong, bipinnatifid, with pectinately denate segments or teeth, 10-15 cm wide, 30-50 cm long. Inflorescence is in large, terminal panicle with subglobose heads (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996). The nodding flowers (capitula), only 2 to 3 mm in diameter, are greenish-yellow enclosed by numerous, imbricated bracts. Capitula are displayed in loose panicles containing numerous central bisexual florets and marginal pistillate florets, the latter extruding stigmas prior to the central flowers. Both flowers have synpetalous tubular corolla with the top split into five lobes in the hermaphroditic florets and 2-3 lobes in the pistillate florets. The receptacle is

glabrous, not chaffy, and triangular in shape (Ferreira & Janick, 2009). Fruit is glabrous obovoid achene, nearly 1 mm long.

Figure 2.18

Artemisia annua L. (Griffee, 2005)

Figure 2.19

All part of *Artemisia annua* L.

4.6 *Atractylodes lancea* (Thunb.) DC. or *Atractylodes chinensis* (DC.) Koidz.

Atractylodes lancea (Thunb.) DC. (Compositae) has other common names in various countries which are Kot kamao (Bangkok) (Thailand), Cangzhu (Chinese) and Atractylodes (English). It is native to East Asia, where the plant is grown in China, Japan and Korea.

The rhizomes of *A. lancea* are used in China as a traditional remedy against rheumatic diseases, digestive disorders, night blindness, mild diarrhea and influenza (Resch, Steigel, Chen, & Bauer, 1998; Resch, Heilmann, Steigel, & Bauer, 2001). In the Korean and Japanese pharmacopoeias, the rhizomes of *A. lancea* are prescribed in traditional medicine as diuretic and gastric drugs (Wang, Liu, Liu, & Gao, 2008).

Description of *Atractylodes lancea* (Thunb.) DC., shown in Figure 2.20 and Figure 2.21, is a perennial plant. The flowers are hermaphroditr (have both male and female organs). It can grow in semi-shade (light woodland) or no shade, and requires moist soil.

Figure 2.20

Atractylodes lancea (Thunb.) DC.

(FuZhou Corona Science & Technology Development Co.,Ltd., 2009)

Figure 2.21

Rhizome of *Atractylodes lancea* (Thunb.) DC.

4.7 *Cuminum cyminum* L.

Cuminum cyminum L. (Umbelliferae) has other common names in various countries which are Thian khao, Yira (Central) (Thailand), Jeera or Jira (India) and Cumin (English). It is native from the East Mediterranean to East India. Its seeds, which are actually dried fruits, are used in many spice mixtures such as chili and curry powders. Cumin is especially popular in Asian, North African and Latin American cuisines.

Cuminum cyminum is one of the popular spices regularly used as a flavouring agent. In Chinese traditional medicine, the seeds of the plant have been used for the treatment of toothache, dyspepsia, diarrhea, epilepsy and jaundice. It also has stomachic, diuretic, carminative, emmanogogic and antispasmodic properties (Kim, Shin, et al., 2009; Li, Tian, et al., 2009). Moreover, In the Middle East, it is used as a stimulant and astringent. It is valuable in dyspepsia diarrhea and hoarseness, and may relieve flatulence and colic (Jalali-Heravi, Zekavat, & Sereshi, 2007).

Description of *Cuminum cyminum* L., shown in Figure 2.22 and Figure 2.23, is an herbaceous annual plant, with a slender branched stem 20-30 cm tall. The leaves are 5-10 cm long, pinnate or bipinnate, thread-like leaflets. The flowers are small, white or pink, and borne in umbels. The fruit is a lateral fusiform or ovoid achene 4-5 mm long, containing a single seed. Cumin seeds are similar to fennel and anise seeds in appearance, but are smaller and darker in color. Cumin used pant part of fruits often called seeds (Wikipedia, 2009).

Figure 2.22

Cuminum cyminum L. (Katzer, 2006a)

Figure 2.23

Fruit of *Cuminum cyminum* L.

4.8 *Dracaena loureiri* Gagnep.

Dracaena loureiri Gagnep. (Dracaenaceae) has other common names in various region of Thailand which are Chan daeng (Central, Surat Thani), Chan pha (Northern), Lakka chan (Central) (Smitinand, 2001).

The stem wood of *Dracaena loureiri* infected by fungi, red color, a Thai medicinal plant possessing antipyretic, antidiaphoretic (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996), antibacterial activity (Meksuriyen, Cordell, Ruangrungst, & Tantivatana, 1987). Animal tests proved antipyretic action of water extract, onset time slower than aspirin (Saralamp et al., 1996).

Description of *Dracaena loureiri* Gangnep., shown in Figure 2.24 and Figure 2.25, is a shrub or slender much-branched tree, up to 4 m high. The leaf is simple, alternate, crowded at the top, linear, 5-7 cm wide, 50-70 cm long. Inflorescence is arising from terminal, large panicle, bent downwards. The flowers are small, yellowish white. The fruit is globose baccate (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996). When this plant becomes old, it has a red core in the stem and then the stem graduslly decays until all cores become red; this core wood is called Chan daeng. Most of this plant grows in the high mountains. It can be found in many parts of Thailand (Reanmongkol, Subhadhirasakul, & Bouking, 2003).

Figure 2.24

Dracaena loureiri Gagnep. (Natural Products Research Center, 2008)

Figure 2.25

Stem of *Dracaena loureiri* Gagnep.

4.9 *Foeniculum vulgare* Mill. var. *dulce* (Mill.) Thell.

Foeniculum vulgare Mill. var. *dulce* (Mill.) Thell. (Umbelliferae) has other common names in various countries which are Thian khao plueak (Thailand) and Sweet fennel (English). It is naturally found in Mediterranean countries, but it now can be found growing worldwide.

The essential oil of sweet fennel is used in cosmetics, pharmaceuticals, perfumery, and as a food additive (Charles, Morales, & Simon, 1993).

Description of *Foeniculum vulgare* Mill. var. *dulce* (Mill.) Thell., shown in Figure 2.26 and Figure 2.27, is a tall, erect, glabrous, herbaceous perennial with glaucous, striate branching stems and a strong aroma of anise or licorice. The leaves are alternate and about a foot long, ovate to deltoid in outline, and pinnately dissected into many filiform divisions. The leaf stems are conspicuously sheathed at the base. The yellow flowers are in large compound umbels with 15-40 unequal rays on ± bare stems rising well above the leaves, and the five petals are wide with narrow tips. There are five stamens. The calyx is rudimentary-vestigial or absent. The fruit is a 3/4" long oblong to ovoid, slightly laterally flattened schizocarp with prominent ribs which splits into two 1-seeded compartments (Charters, 2009).

Figure 2.26

Foeniculum vulgare Mill. var. *dulce* (Mill.) Thell. (Lotus Herbs Egypt, 2009)

Figure 2.27

Fruit of *Foeniculum vulgare* Mill. var. *dulce* (Mill.) Thell.

4.10 *Kaempferia galanga* L.

Kaempferia galanga L. (Zingiberaceae) has other common names in various countries which are Proh hom, Hom proh (Central), Wan tin din, Wan phaen din yen, Wan hom (Northern) (Thailand) (Smittinand, 2001), Cekur (Malaysia), Kencur (Indonesia), Gisol (Philippines), Shan-nai (Chinese) and East-Indian galangal (English). It is an acaulescent perennial growing in Southern China, Indochina, Malaysia, India and Thailand (Kanjanapothi et al., 2004; Ridtitid, Sae-Wong, Reanmongkol, & Wongnawa, 2008).

In Thailand, the rhizome of *K. galanga* is used for relieving toothache, abdominal pain, muscular swelling and rheumatism. The stem is used for menstrual stimulation and in the treatment of dyspepsia. The leaves and flowers are used for the treatment of Tinea versicolor, and eye diseases and seizures (Ridtitid, Sae-Wong, Reanmongkol, & Wongnawa, 2008). In China, *K. galanga* is used as a food spice and in the medicinal industry, traditionally treating symptoms ranging from hypertension, pectoral and abdominal pains, headache, toothache, rheumatism, dyspepsia, coughs and inflammatory tumor (Huang, Yagura, & Chen, 2008). In Malaysia, *K. galanga* is commonly used as traditional treatment against hypertension, rheumatism and asthma (Othman, Ibrahim, Mohd, Mustafa, & Awang, 2006). The rhizome is applied locally to the forehead to relieve colds and nosebleeds. Extract of rhizome relaxes smooth muscles of the small intestine (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996). The rhizomes of *K. galanga* have been used in a decoction or powder for indigestion, cold, pectoral and abdominal pains, headache and toothache. Its alcoholic maceration has also been applied as liniment for rheumatism (Kanjanapothi et al., 2004). The aqueous extract of *K. galangal* leaves has been reported to show antinociceptive and anti-inflammatory activity (Zhang, Zhong, & Zhou, 2007).

Description of *Kaempferia galanga* L., shown in Figure 2.28 and Figure 2.29, is a rhizomatous herb. The leaf is simple, broadly elliptic or orbicular with rounded-subcordate base, glabrous above, sparsely hairy beneath, 4-10 cm wide, 6-14 cm long, more or less strongly appressed against soil. Inflorescence is arising from terminal on rhizome between the leaves. The flowers are white with a purple

spot at the center. The fruit is 3-locular capsule (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996).

Figure 2.28

Kaempferia galanga L. (Skinner, 2000)

Figure 2.29

Rhizome of *Kaempferia galanga* L.

4.11 *Lepidium sativum* L.

Lepidium sativum L. (Cruciferae) has other common names in various countries which are Thian daeng (Central) (Thailand) and Cress, Garden Cress (English) (Smitinand, 2001). *Lepidium sativum* is grown worldwide as a spicy salad herb. Its origin is not known, but is possibly from Ethiopia or Iran (Brotonegoro & Wiharti, 2001).

Lepidium sativum L. is a well known culinary herb and the leaves are widely used as a garnish and are consumed raw in salads. The plant is known to possess varied medicinal properties. The seeds are aperient, diuretic, tonic, demulcent, aphrodisiac, caeminative, galactagogue and emmenagogue. The root is used in treatment of secondary syphilis and tenesmus (Patel, Kulkarni, Undale, & Bhasale, 2009). The seed oils are used in treating dysentery and diarrhea (Afaf, Nuha, & Mohammed, 2008). *L. sativum* have been reported to exhibit a hypoglycaemic, antiseptic, emmenagogue, antirheumatic, antitussive, antiasthmatic and pulmonary diseases (Bnouham, Mekhfi, Legssyer, & Ziyyat, 2002).

Description of *Lepidium sativum* L., shown in Figure 2.30 and Figure 2.31, is an annual erect herbaceous plant, growing up to 30 cm. The leaves are alternate, membranaceous, ovate-oblong in outline, up to 12 cm x 9 cm, imparipinnati- or bipinnatipartite, with 2-4 pairs of lateral lobes, lobes linear, lanceolate or oblanceolate, up to 3 cm long, uppermost leaves sometimes simple, serrate, glabrous or sparsely pubescent; petiole up to 4 cm long in basal leaves; stipules absent. Inflorescence is arising from terminal or axillary raceme, 1-3 cm long, accrescent to 25 cm when fruiting. The flowers are bisexual, rather conspicuous, whitish to violet, pedicel 3-6 mm long in fruit, ascending; sepals 4, elliptical, 1-1.5 mm long, green, margins membranaceous; petals 4, spathulate to slightly clawed, 1.5-3 mm long, apex rounded; stamens 6, unequal in length, nectaries 6, alternating with filaments; ovary superior, flattened dorso-ventrally, apex emarginate, lateral margins wing-like, style up to 0.5 mm long, stigma capitate, finely pappilate. The fruit is an ovoid, flattened silique, 4.5-6.5 mm x 3-4 mm, pale green to yellowish, apical wings prominent, apex emarginate, dehiscing by 2 valves, leaving the replum with thin, white septum; 1 seed per locule. The seed is subovoid, flattened, 2-3 mm x 1.5 mm, wingless, reddish-brown (Brotonegoro & Wiharti, 2001).

Figure 2.30

Lepidium sativum L. (Katzer, 2006b)

Figure 2.31

Seed of *Lepidium sativum* L.

4.12 *Ligusticum sinense* Oliv. cv. Chuanxiong or *Ligusticum chuanxiong* Hort.

Ligusticum sinense Oliv. cv. Chuanxiong (Umbelliferae) has other common names in various countries which are Kot hua bua (Thailand), Tousenkyu (Japanese), Chuan xiong (Chinese) and Szechuan lovage (English). It is native to China.

The dried rhizome is a traditional Chinese medicinal herb for prevention and treatment of inflammatory and cardiovascular diseases. The root of *L. chuanxiong* is mainly used for the treatment of headaches, theumatic arthralgia, menstrual disorders, swelling and pain due to traumatic injury, pricking pain in the chest and costal region, and coronary heart disease (Sun & Wang, 2008).

Description of *Ligusticum sinense* Oliv. cv. Chuanxiong, shown in Figure 2.32 and Figure 2.33, is a perennial herb with massive fist-like rhizomes of brown colour and irregular shape. Its erect stems are quite thin and tender, but they can reach the height of about 1 m. The leaves resemble those of a carrot or parsley: feathery pinnate with multiple leaflets. The small flowers, gathered in umbels, bloom from July to August and are pollinated by insects.

Figure 2.32

Ligusticum sinense Oliv. cv. Chuanxiong

(Cyber Herb Medicine Simulation Room, 2009)

Figure 2.33

Rhizome of *Ligusticum sinense* Oliv. cv. Chuanxiong

4.13 *Mammea siamensis* Kosterm. or *Ochrocarpus siamensis* T. And.

Mammea siamensis Kosterm. or *Ochrocarpus siamensis* T. And. (Guttiferae) has other common names in various region of Thailand which are Thoraphi (Chanthaburi), Soi phi (Peninsular, Southern), Saraphi (General), Saraphi naen (Chiang Mai) (Smitinand, 2001). It is native to Myanmar, Thailand, Laos, Cambodia and Vietnam (Subhadhirasakul & Pechpongs, 2005).

The dried flower is ingredient in Ya-hom, used for faintness, cardiac tonic (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996). The flowers of this plant are used as a heart tonic, reducing fever and enhancement of appetite in Thai traditional medicine (Subhadhirasakul & Pechpongs, 2005). The active components of *M. siamensis* seed include suragin C and therapin B showed cytotoxic activity against MCF-7, HeLa, HT-29 and KB (Laphookhieo et al., 2007).

Description of *Mammea siamensis* Kosterm., shown in Figure 2.34 and Figure 2.35, is an evergreen tree which grows up to 15 m high and 10-30 cm in diameter. The leaf is simple, opposite, oblong-obovate, 4-5 cm wide, 10-15 cm long, coriaceous, glabrous. The flower is solitary or few-flowered fascicle, ramiflorous or cauliflorous, white fragranst; stamens numerous, yellow. The fruit is drupe, ellipsoid, 1-seeded (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996).

Figure 2.34

Mammea siamensis Kosterm. (Panich, 2009)

Figure 2.35

Flower of *Mammea siamensis* Kosterm.

4.14 *Mesua ferrea* L.

Mesua ferrea L. (Guttiferae) has other common names in various countries which are Ka-ko (Karen-Mae Hong Son), Kam-ko (Shan-Mae Hong Son), Bunnak (General), Nakbut (Southern), Pa-na-kho (Malay-Pattani), Saraphi doi (Chiang Mai) (Thailand) and Iron Wood, Indian Rose Chestnut Tree (English) (Smitinand, 2001). It is native to India and South East Asia.

The dried flower is astringent, element tonic, carminative, blood tonic, cardiac tonic. The leaf is used locally for wound healing (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996). *M. ferrea* is used in folk medicine for the treatment of fever, dyspepsis and renal deseases (Verotta et al., 2004). Mesuarin has previously been identified as the active compound of *M. ferrea* seed. It has been reported to possess antibacterial agents against *Bacillus firmis* (Bhattacharyya, Chakrabartty, & Chowdhuty, 1988). The methanol extract of *M. ferrea* seed was tested for antibacterial activity using agar well diffusion method, and showed maximum antibacterial activity against *S. subfava* and *S. aureus* (Inhibition zone = 16 and 13 mm) (Parekh & Chanda, 2008).

Description of *Mesua ferrea* L., shown in Figure 2.36 and Figure 2.37, is a tree of tropical Asia which grows up to 15 m high, young shoots red or white. The leaf is simple, opposite, lanceolate or oblong-lanceolate, 2-4 cm wide, 7-12 cm long, coriaceous, glabrous. The flower is solitary, terminal or leaf-axil, white fragranst; stamens numerous, yellow. The fruit is ellipsoid drupe (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996).

Figure 2.36

Mesua ferrea L. (Siriit-tiwong & Sae-sue, 2006)

Figure 2.37

Flower of *Mesua ferrea* L.

4.15 *Mimusops elengi* L. or *Mimusops elengi* var. parvifolia (R.Br.) H.J.Lam

Mimusops elengi L. (Sapotaceae) has other common names in various countries which are Kun (Peninsular, Southern), Kaeo (Northern), Sang dong (Lampang), Phikun (Central), Phikun khao, Phikun thuean (Nakhon Si Thammarat), Phikun pa (Satun) (Thailand) and Bullet Wood (English) (Smitinand, 2001). It is a native to India, Burma and Pakistan, but it now is widely distributed throughout tropical and subtropical regions of Asia (Shahwar & Raza, 2009).

The dried flower is an ingredient in Ya-hom, used for cardiac tonic, treatment of sore throats and muscular pain. The decoction of stem bark is used in mouthwash to relieve gingivitis. The wood infected by fungi, is used for cardiac tonic, liver and lung tonic, and tonic for pregnant women (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996). The bark is used as a gargle for odontopathy, ulitis, and ulemorrhagia. The fruit is used as an astringent, coolant, and anthelmintic. The tender stems are used as tooth brushes, and in cystorrhea, diarrhea and dysentery. The flower's lotion is used for wounds and ulcers. The seeds are used in constipation (Nair & Chanda, 2007). The stem barks of *M. elengi* have antibacterial agents against *B. subtilis* and *N. asteroids* (Shahwar & Raza, 2009). The leaves of *M. elengi* have antibacterial agents against *P. mirabilis*, *S. aureus*, *A. fecalis*, *B. cereus* and inactive against *P.aeruginosa*, *S. typhimurium* (Nair & Chanda, 2007). The methanol extract of *M. elengi* leaves showed antioxidant activity with IC_{50} value of 43.26 μg/ml (Saha, Hasan, et al., 2008).

Description of *Mimusops elengi* L., shown in Figure 2.38 and Figure 2.39, is a tree growing up to 15 m high, lactiferous. The leaf is simple, alternative, ovate or elliptic, 3-6 cm wide, 5-12 cm long, undulate, coriaceous. The flower is solitary or 2-6 flowered fascicle, axillary, fragrant, white turning brown. The fruit is berry, ovoid, yellow or orange. The seed is hard and dark brown (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996).

Figure 2.38

Mimusops elengi L. (Katprasat & Matthawarat, 2006)

Figure 2.39

Flower of *Mimusops elengi* L.

4.16 *Myristica fragrans* Houtt.

Myristica fragrans Houtt. (Myristicaceae) has other common names in various countries which are Chan thet (Central), Chan-ban (Shan-Northern) (Thailand) and Nutmeg Tree (English) (Smitinand, 2001). It is a native of Molucca Islands of Indonesia and is also now cultivated in Grenada (Iyer, 2007).

The wood is used as an antipyretic, lung and liver tonic (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996). The seed is used for tonic, carminative, antidiarrheal, relieves of uterin spasm, stimulant, narcotic, astringent, aphrodisiac, hypolipidemic, antithrombotic, anti-platelet aggregation, antifungal, anti-dysenteric, anti-inflammatory activities and condiment (Jukic, Politeo, & Milos, 2006; Saralamp et al., 1996). The aril of the seed is used for blood tonic and condiment (Saralamp et al., 1996). The aril has been used in Indonesian folk medicine as aromatic stomachics, analgesic, a medicine foe rheumatism, etc (Ozaki, Soedigdo, Wattimena, & Suganda, 1989).

Description of *Mimusops elengi* L., shown in Figure 2.40, Figure 2.41, Figure 2.42 and Figure 2.43, is a tree growing up to 18 m high, clear scent of nutmeg. The leaf is simple, alternative, oblong-elliptic or elliptic-ovate, glabrous, 4-5 cm wide, 10-15 cm long, dark green above, pale green beneath. The flower is solitary or fascicled, axillary, urceolate, light yellow, dioecious. The fruit is freshly, aril red, fragrant (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996). The nutmeg tree produces two spices—mace and nutmeg. Nutmeg is the seed kernel inside the fruit and mace is the lacy covering (aril) on the kernel (Jukic, Politeo, & Milos, 2006).

Figure 2.40

Myristica fragrans Houtt. (Hijjas, 2008)

Figure 2.41

Stem of *Myristica fragrans* Houtt.

Figure 2.42

Mace (Aril) of *Myristica fragrans* Houtt.

Figure 2.43

Nutmeg (Seed) of *Myristica fragrans* Houtt.

4.17 *Nelumbo nucifera* Gaertn.

Nelumbo nucifera Gaertn. (Nelumbonaceae) has other common names in various countries which are Chok (Khmer-Buri Ram), Bua, Bua luang (Central), Satta bongkot, Sattabut (Ubon) (Central) (Thailand) and Egyptian bean, Sacred lotus, Lotus (English) (Smitinand, 2001). It is native to Southern Asia and Australia.

In Thailand, the stamen (pollen) is used as a cardiac tonic, and for treatment of faintness and vertigo (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996). In China, the seed can hold back diarrhea. The fruit uses the efficacy of hemostasia. The stamen (pollen) can prohibit pathological spermatorrhoes. The leaf can dispel one's thirst in summer (Guo, 2009). The hydroalcoholic extract of *N. nucifera* seed exhibited strong free radical scavenging activity as evidenced by the low IC_{50} values in both DPPH (6.12 μg/ml) and nitric oxide (84.86 μg/ml) methods (Rai, Wahile, Mukherjee, Saha, & Mukherjee, 2006) while the lotus plumule has been reported to show decreased visceral organ inflammation and increased production of anti-inflammatory cytokine IL-10 from splenocytes (Lin, Lai, Liu, & Wu, 2007). The rhizome knot extract was found to exhibit high antioxidative capacity (Hu & Skibsted, 2002).

Description of *Nelumbo nucifera* Gaertn., shown in Figure 2.44 and Figure 2.45, is an aquatic perennial herb, 1-2.5 m hight. The rhizome is long-jointed. The leaf is simple, peltate, glaucous above, 30-60 cm in diameter. The petiole is long, raised above water. The flower is solitary, projecting from rhizome above water, fragrant, white or pink; stamen numerous, yellow, around the obconical redeptacle. The fruit is nutlets, in cavities of enlarged receptacle (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996).

Figure 2.44

Nelumbo nucifera Gaertn. (Briand, 2009)

Figure 2.45

Pollen of *Nelumbo nucifera* Gaertn.

4.17 *Nigella sativa* L.

Nigella sativa L. (Ranunculaceae) has other common names in various countries which are Thian dam (Thailand) and Black cumin, Black Seed (English). It is widely distributed in countries bordering the Mediterranean Sea, central Europe and western Asia. It is widely used as spice condiments in vegetarian and nonvegetarian preparations along with other spices in India and Arabia (Thippeswamy & Naidu, 2005). The seeds are black and triagonal in shape.

In Egypt and Greece, the seed is used to treat headache, nasal congestion, and tooth ache, and is used as adiuretic to promote menstruation and increase milk production. In the Middle and Far East, the seed is used for bronchial asthma, headache, dysentery, infections, obesity, back pain, hypertension and gastrointestinal problems (Salem, 2005). *N. sativa* has been reported to exhibit a toxic, hypoglycaemic, hypotensive, abortive, antitussive, antiasthmatic, sinusitis, broncho-pulmonary infections, carminative, against influenza, emmenagogue, antihelmintic and antidote poison (Bnouham, Mekhfi, Legssyer, & Ziyyat, 2002). The seeds of *N. sativa* have been reported to possess anti-inflammatory, antimicrobial and immunomodulatory agents (Hart, 2005; Salem, 2005). Furthermore, the seeds of *N. sativa* have been reported to possess analgesic (Hart, 2005), antioxidant, anti-histamine and anti-tumor agents (Salem, 2005). The methanol extract of *N. sativa* leaves showed andioxidant activity with IC_{50} value of 3.36 μg/ml (Cho et al., 2003).

Description of *Nigella sativa* L., shown in Figure 2.46 and Figure 2.47, is an annual herb, about 30-60 cm in height. The leaves are multiple pinnate and the leaflets are narrow and lanceolate to linear. The small flowers bear 5 white petals and numerous stamens with a circular arrangement of 5-10 nectorial petals in between, and 4-7 fused ovaries. The ripe follicles contain numerous black seeds.

Figure 2.46

Nigella sativa L. (Schopke, 2009)

Figure 2.47

Seed of *Nigella sativa* L.

4.18 *Syzygium aromaticum* (L.) Merr. et Perry or *Eugenia caryophyllus* Bullock et Harrison

Syzygium aromaticum (L.) Merr. et Perry or *Eugenia caryophyllus* Bullock et Harrison (Myrtaceae) has other common names in various countries which are Kan phlu (Central) (Thailand) and Clove (English) (Smitinand, 2001). It is a native of Moluccas. It is abundantly cultivated in Tanzania, Indonesia, Sri Lanka and Malagasy Republic (Kim, Oh, et al., 2003).

S. aromaticum have been reported to exhibit a hypoglycaemic, hypotensive, hair-care, pulmonary diseases, antiseptic, mouth hygiene, diuretic, stimulant and against cold (Bnouham, Mekhfi, Legssyer, & Ziyyat, 2002). The cloves have been used for asthma and various allergic disorders by oral administration (Lee & Shibamoto, 2001). The clove has been used as traditional medicine for treatment of vermifuge, antibacterial agent and toothache in China, Japan and Korea (Kim, Oh, et al., 2003). The fruits of *S. aromaticum* have been reported to possess antibacterial agents (Viuda-Martos, Ruiz-Navajas, Fernandez-Lopez, & Perez-Alvarez, 2008) and antioxidant agents (Wojdylo, Oszmianski, & Czemerys, 2007). Eugenol, isolated from the cortexs of *S. aromaticum*, have been reported to exhibit inhibition of PGE_2 production and suppressed the cyclooxygenase-2 (COX-2) gene expression in LPS-stimulated mouse macrophage cells and inhibited the COX-2 enzyme activity (Kim, Oh, et al., 2003)

Description of *Syzygium aromaticum* (L.) Merr. et Perry, shown in Figure 2.48 and Figure 2.49, is a tree, 5-10 m high. The leaves are simple, opposite, elliptic or lanceolate, 2.5-4 cm wide, 6-10 cm long, undulate. The young leaves are red or brownish red. Inflorescence is in axillary corymb. The flowers are whitish, deciduous, calyx-tube subterete, subquadrangular, yellowish green with red flush. The fruit is berry, ellipsoid-obovoid, dark red. In Thai traditional medicine, dried flower-buds are used as carminative, stomachic, antidiarrheal, local anesthetic for toothache and gargle for mounth-deodorant. It used 5-6 flower-buds, infuse or chew; macerate with alcohol, moisten cotton and plug in inflamed hole of carries (Saralamp, Chukul, Temsiririrkkul, & Clayton, 1996).

Figure 2.48

Syzygium aromaticum (L.) Merr. et Perry (Katzer, 2006c)

Figure 2.49

Flower-bud of *Syzygium aromaticum* (L.) Merr. et Perry

5. Biological activity of plants in Prasaprohyai preparation

Previous investigations on biological activity of plants in Prasaprohyai Preparation are shown in Table 2.2 to 2.20.

Table 2.2

Biological activities of *Amomum testaceum* Ridl.

Botanical name	Plant part	Activity	Result of biological activity	References
Amomum testaceum Ridl.	Fruit	Antimalarial	Crude hexane extract showed high potency against *P. falciparum* (EC_{50} = 8×10^{-7} g/ml)	Kamchonwongpaisan et al., 1995
		Antimalarial	Myrtenal, myrtenol and *trans*-pinocarveol exhibited moderate activity against *P. falciparum* (EC_{50} ranging from 5 to 50 μM)	Kamchonwongpaisan et al., 1995
		Antioxidant	Methanolic extract exhibited antioxidant activity with the index of 4.00 using β-carotene bleaching method	Chanwitheesuk, Teerawutgulrag, & Rakariyatham, 2005

Table 2.3

Biological activities of *Anethum graveolens* L.

Botanical name	Plant part	Activity	Result of biological activity	References
Anethum graveolens L.	Fruit or Seed	Antibacterial	Aqueous extracts showed effective against *E. faecalis, S. aureus, E. coli, P. aeruginosa 2, S. typhimurium* and *S. flexneri* (zone of inhibition = 12-15 mm) and organic solvent extracts showed effective against *E. faecalis, S. aureus, E. coli, K. pneumoniae 2, P. aeruginosa, S. typhi, S. typhimurium* and *S. flexneri* (zone of inhibition = 11-30 mm). MIC for aqueous and acetone extracts ranged from 20-50 mg/ml and 5-15 mg/ml, respectively	Kaur & Arora, 2009

Table 2.3 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Anethum graveolens L.	Fruit or Seed	Antioxidant	Aqueous extract showed strong antioxidant superior to known antioxidant ascorbic acid (50% scavenging of superoxide radicals = 190 μg (dill), 260 μg (ascorbic acid); 50% inhibition of lipid peroxide = 3100 μg (dill), 5000 μg (ascorbic acid); 50% inhibition of hydroxyl radicals = 575 μg (dill), 4500 μg (ascorbic acid))	Satyanarayana, Sushruta, Sarma, Srinivas, & Raja, 2004
		Antioxidant	Hydroalcoholic extract showed IC_{50} = 87 μg/ml in the DPPH (1,1-diphenyl-2-picrylhydrazyl) radical reduction assay	Ramos et al., 2003

Table 2.3 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Anethum graveolens L.	Fruit or Seed	Antioxidant	Methanolic extract exhibited antioxidant activity with the index of 1.09 using β-carotene bleaching method	Chanwitheesuk, Teerawutgulrag, & Rakariyatham, 2005

Table 2.4

Biological activities of *Angelica dahurica* Benth.

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica dahurica Benth.	Root	Hepatoprotective	(±)-Byakangelicol and (+)-oxypeucedanin showed moderate activities with EC_{50} = 112.7 and 286.7 μM, respectively	Oh et al., 2002

Table 2.4 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica dahurica Benth.	Root	Hepatoprotective	Imperatorin and (+)-byakangelicin exhibited strong hepatoprotective activities with EC_{50} = 36.6 and 47.9 μM, respectively	Oh et al., 2002
		Anti-histamine	Bergapten, oxypeucedanin hydrate, and byakangelicin inhibited compound 48/48 induced histamine elevation at a dose of 25 mg/kg.	Kimura, Okuda, & baba, 1997
		Antioxidant	9-Hydroxy-4-methoxypsoralen and alloisoimperatorin isolated from methylene chloride extract of *Angelica dahurica* showed effective antioxidant activity (IC_{50} = 6.1, 9.4 μg/ml, respectively)	Piao et al., 2004

Table 2.4 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica dahurica Benth.	Root	Antioxidant	n-Hexane extract possessed strong antioxidant activity (IC_{50} = 1.45 mg/ml)	Tsai & Yang, 1997
		Anti-inflammation	Isoimperatorin inhibited the cyclooxygenase-2 (COX-2), COX-1-dependent phases of prostaglandin D2, 5-lipoxygenase and degranulation reaction in BMMC (IC_{50} = 10.7, 24, 5.7 and 9 μM, respectively)	Moon, Jin, Son, & Chang, 2008
		Anti-inflammation	Byakangelicol (conc. 10-50 μM) inhibited IL-1β-induced COX-2 expression, IL-1β-induced PGE2 release and the activity of COX-2 enzyme in human pulmonary epithelial cell line (A549)	Lin, Chang, Wang, & Yang, 2002

Table 2.4 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica dahurica Benth.	Root	Anti-inflammation	5-Methoxy-8-(2-hydroxy-3-buthoxy-3-methylbutyloxy)-psoralen isolated from the *n*-butanol extract of *Angelica dahurica* inhibited COX-2 (IC_{50} = 23.5 μM) and 5-LOX (IC_{50} = 2.5 μM) in mouse bone marrow-derived mast cells	Hua et al., 2008
		Anti-inflammation	Imperatorin showed the most potent inhibitory activity on the LPS-induced PGE2 production, the LPS-induced expressions of cyclooxgenase (COX-2) and microsomal prostaglandin E synthase (mPGES)	Ban et al., 2003

Table 2.4 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica dahurica Benth.	Root	Antimicrobial	*(R)*-Heraclenol showed effective against *B. subtilis* (MIC = 62.5 μg/ml)	Kwon et al., 1997
		Antimicrobial	Scopoletin showed effective against *E. coli* (MIC > 250 μg/ml)	Kwon et al., 1997
		Antimicrobial	Ferulic acid and byakangelicin showed the same effective against *C. herbarum* (MIC = 62.5 μg/ml)	Kwon et al., 1997
		Antimicrobial	5,8-Di(2,3-dihydroxy-3-methylbutoxy)-psoralen showed effective against *A. candidus* (MIC > 62.5 μg/ml)	Kwon et al., 1997

Table 2.4 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica dahurica Benth.	Root	Cytotoxic	Pangelin and oxypeucedamin hydrate acetonide showed a potent cytotoxic activity against L1210, HL-60, K562, and B16F10 tumor cell lines (IC_{50} = 8.6-14.6 μg/ml)	Thanh, Jin, Song, Bae, & Kang, 2004

Table 2.5

Biological activities of *Angelica sinensis* (Oliv.) Diels

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica sinensis (Oliv.) Diels	Root	Antioxidant	The 15- and 16 min water extracts showed a higher DPPH scavenging effect than 30- and 90 min water extracts	Huang, Chen, Lin, & Chiang, 2008

Table 2.5 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica sinensis (Oliv.) Diels	Root	Antioxidant	The 15 min ethanol extract showed a highest scavenging activity and exhibited a higher inhibitory activity on lipid peroxidation	Huang, Chen, Lin, & Chiang, 2008
		Antioxidant	Coniferyl ferulate showed potent DPPH free radical scavenging activity, with an EC_{50} value of 3.6±0.1 μg/ml	Ho, Kumaran, & Hwang, 2009
		Antioxidant	The trolox equivalent antioxidant capacity (TEAC) values for methanolic and aqueous extracts displayed 101.7 and 104.7 μmol trolox equivalent/100 g DW, respectively	Cai, Luo, Sun, & Corke, 2004

Table 2.5 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica sinensis (Oliv.) Diels	Root	Anti-inflammation	The water and ethanol extracts in the concentration range of 20-200 μg/ml showed inhibitory effects on NO production in LPS activated RAW 264.7 macrophage	Huang, Chen, Lin, & Chiang, 2008
		Anti-inflammation	Ethyl acetate fraction of *A. sinensis* decreased NF-κB luciferase activity and also the secretion of NO and PGE_2 in LPS/IFN-γ stimulated mouse peritoneal macrophages	Chao, Kuo, Li, & Lin, 2009
		Anti-inflammation	Ferulic acid, at 300 mg/kg, inhibited the edema induced by carrageenin, the increase of the dye leakage induced by acetic acid, the granuloma formation induced by cotton pellet	Ozaki, 1992

Table 2.5 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica sinensis (Oliv.) Diels	Root	Analgesic	Ferulic acid, at 300 mg/ml, reduced dose-dependently the number of writhes induced by acetic acid	Ozaki, 1992
		Analgesic	Ligustilide (2.5-10 mg/kg) could cause a does-related reduction of acetic acid-induced writhing response and formalin-induced licking time in both the early and late phases	Du et al., 2007
		Cytotoxic	Z-ligustilide showed the strongest cytotoxicity against L1210 and K562 cell lines with IC_{50} values of 2.27 and 4.78 μM, respectively	Chen et al., 2007

Table 2.5 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica sinensis (Oliv.) Diels	Root	Anti-Alzheimer	Z-ligustilide, coniferyl ferulate, 11-angeloylsenkyunolide F and ferulic acid inhibited amyloid β-peptide ($A\beta_{1-40}$) toxicity on dPC-12 cells at lower concentrations (1-10 μg/ml), but at high concentrations (>50 μg/ml) they were toxic to the dPC-12 cells, except 11-angeloylsenkyunolide F	Ho, Kumaran, & Hwang, 2009
		Antiproliferation	The acetone extract showed dose-dependently antiproliferative effect on A549, HT29, DBTrg-05MG and J5 human cancer cells, with IC_{50} = 35-50 μg/ml after 24 h of treatment	Cheng et al., 2004

Table 2.5 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Angelica sinensis (Oliv.) Diels	Root	Antiproliferation	The IC_{50} values for inhibition of cell proliferation for senkyunolide A, Z-ligustilide and n-Butylidenephthalide were 54.17, 60.63 and 236.90, respectively, in human colon cancer HT-29 cells	Kan, Cho, Rudd, & Lin, 2008
	Fresh root	Immunomodulator	Polysaccharide fraction from *A. sinensis* (AP) showed increase the proliferation of T cells, production of IL-2 and IFN-γ, the percentage of $CD4^+$ cell in total spleen cells, while that of IL-4 and $CD8^+$ were decreased	Yang, Jia, Meng, Wu, & Mei, 2006

Table 2.6

Biological activities of *Artemisia annua* L.

Botanical name	Plant part	Activity	Result of biological activity	References
Artemisia annua L.	All part	Antioxidant	The trolox equivalent antioxidant capacity (TEAC) values for methanolic and aqueous extracts displayed 582.3 and 629.4 μmol trolox equivalent/100 g DW, respectively	Cai, Luo, Sun, & Corke, 2004
		Antioxidant	The essential oil of *A. annua*, consisting of camphor, germacrene D, *trans*-pinocarveol, β-selinene, β-caryophyllene and artemisia ketone, showed weak antioxidant activity	Juteau, Masotti, Bessiere, Dherbomez, & Viano, 2002
		Antiulcer	The ethanolic and water extracts showed antiulcer activity in several experimental ulcer models in rats	Falcao, Mariath, Diniz, Batista, & Barbosa-Filho, 2008

Table 2.6 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Artemisia annua L.	All part	Antimalarial	Artemesinin (qinghaosu) was found to be active against chloroquine-resistant *Plasmodium falciparum* in the treatment of cerebral malaria	Yang, Roberts, O'Neili, Bucar, & Phillipson, 1995
		Antibacterial	The essential oil of *A. annua*, consisting of camphor, germacrene D, *trans*-pinocarveol, β-selinene, β-caryophyllene and Artemisia ketone, inhibited the growth of tested gram-positive bacteria (*E. hirae*) and tested fungi (*C. albicans* and *S. cerevisiae*)	Juteau, Masotti, Bessiere, Dherbomez, & Viano, 2002
		Antimicrobial	The high monoterpenes hydrocarbons seem to contribute for strong antimicrobial activity of *A. annua*	Rasooli, Rezaee, Moosavi, & Jaimand, 2003

Table 2.6 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Artemisia annua L.	All part	Cytotoxic	The artemisinin analog, dihydroartemisinin (DHA), at the 24 h time-point and 20 μM concentration reduced the number of Molt-4 cells in the culture by approximation 40%	Singh & Lai, 2005

Table 2.7

Biological activities of *Atractylodes lancea* (Thunb.) DC.

Botanical name	Plant part	Activity	Result of biological activity	References
Atractylodes lancea (Thunb.) DC.	Rhizome	Anti-inflammation	Atractylochromene showed a potent inhibitor in 5-LOX and COX-1, with IC_{50} = 0.6 and 3.3 μM, respectively	Resch, Steigel, Chen, & Bauer, 1998

Table 2.7 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Atractylodes lancea (Thunb.) DC.	Rhizome	Antioxidant	The trolox equivalent antioxidant capacity (TEAC) values for methanolic and aqueous extracts displayed 89.3 and 52.8 μmol trolox equivalent/100 g DW, respectively	Cai, Luo, Sun, & Corke, 2004
		Anti-inflammation	Atractylenolide I showed inhibit LPS-induction of TNF-α, IL-1β and NO production in a dose-dependent manner, with IC_{50} values were 5.3, 5.1 and 7.5 μg/ml, respectively	Wang, Wang, & Liu, 2009
		Anti-inflammation	The *n*-hexane extract exhibited potent inhibitory activities in 5-lipoxygenase (5-LOX) and cyclooxygenase-1 (COX-1) , with IC_{50} = 2.9 and 30.5 μg/ml, respectively	Resch, Steigel, Chen, & Bauer, 1998

Table 2.7 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Atractylodes lancea (Thunb.) DC.	Rhizome	Anti-inflammation	The 2-[(2*E*)-3,7-dimethyl-2,6-octadienyl]-6-methyl-2,5-cyclohexadiene-1,4-dione showed a selective inhibitory activity against 5-LOX [IC_{50} (5-LOX) = 0.2 μM, IC_{50} (COX-1) = 64.3 μM]	Resch, Steigel, Chen, & Bauer, 1998
		Anti-inflammation	Atractylenolide I showed inhibit LPS-induction of TNF-α, IL-1β and NO production in a dose-dependent manner, with IC_{50} values were 5.3, 5.1 and 7.5 μg/ml, respectively	Wang, Wang, & Liu, 2009
		Anti-tumor	β-Eudesmol (2.5-5 mg/kg) inhibited growth of H_{22} and S_{180} mouse tumor *in vivo*	Ma et al., 2008

Table 2.7 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Atractylodes lancea (Thunb.) DC.	Rhizome	Cytotoxic	*trans*-2-Hydroxyisoxypropyl-3-hydroxy-7-isopentene-2,3-dihydrobenzofuran-5-carboxylic acid exhibited cytotoxicity against cancer cell lines HCT-116 (human colon cancer) and MKN-45 (human gastric cancer), with IC_{50} values of 0.402 and 0.525 μM, respectively	Duan, Wang, Qian, Su, & Tang, 2008
		Antiproliferation	β-Eudesmol (10-100 μM) inhibited proliferation of HeLa, SGC-7901 and BEL-7402 tumor cells in a time- and dose-dependent manner	Ma et al., 2008

Table 2.8

Biological activities of *Cuminum cyminum* L.

Botanical name	Plant part	Activity	Result of biological activity	References
Cuminum cyminum L.	Fruit or Seed	Antibacterial	*C. cyminum* essential oil showed antibacterial activity against *L. curvatus*, *L. sakei*, *S. carnosus*, *S. xylosus*, *E. gergoviae* and *E. ammigenus* (Inhibition zone = 32.65, 31.23, 37.22, 34.34, 38.17 and 35.04 mm)	Viuda-Martos, Ruiz-Navajas, Fernandez-Lopez, & Perez-Alvarez, 2008
		Antibacterial	Cumin showed the antibacterial activity against *B. brevis*, *E. aerogenes* and *E. coli* O157:H7 (Inhibition zone = 14, 26 and 19 mm)	Sagdic & Ozcan, 2003
		Antimicrobial	Essential oils were less active against *P. putida* showing MIC and MTC ≥ 0.8%	Oussalah, Caillet, Saucier, & Lacroix, 2006

Table 2.8 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Cuminum cyminum L.	Fruit or Seed	Antimicrobial	*C. cyminum* oil exhibited antimicrobial activity against *E. coli*, *S. aureus* and *L. monocytogenes*	Gachkar et al., 2007
		Antifungal	*C. cyminum* oil exhibited a strong activity against *C. albicans* (MIC = 280 μg/ml, Inhibition zone = 50 mm)	Naeini, Khosravi, Chitsaz, Shokri, & Kamlnejad, 2009
		Antioxidant	The methanolic extract of cumin showed a good on lipoxygenase-dependent lipid peroxidation system, the DPPH radical scavenging system and the rat liver microsomal lipid peroxidation system, with IC_{50} values of 1.72, 0.52 and 0.16 mg dry weight, respectively	Thippeswamy & Naidu, 2005

Table 2.8 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Cuminum cyminum L.	Fruit or Seed	Antioxidant	In the DPPH assay, *C. cyminum* essential oil obtained by $SCCO_2$ extraction showed higher antioxidant activity than steam distillation extract, with radical scavenging activity ranging from 87.1 to 92.0 %	Topal, Sasaki, Goto, & Otles, 2008
		Antioxidant	Aqueous extract showed strong antioxidant superior to known antioxidant ascorbic acid (50% scavenging of superoxide radicals = 220 μg (cumin), 260 μg (ascorbic acid); 50% inhibition of lipid peroxide = 4300 μg (cumin), 5000 μg (ascorbic acid); 50% inhibition of hydroxyl radicals = 470 μg (cumin), 4500 μg (ascorbic acid))	Satyanarayana, Sushruta, Sarma, Srinivas, & Raja, 2004

Table 2.8 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Cuminum cyminum L.	Fruit or Seed	Antioxidant	Cumin showed moderate the DPPH radical-scavenging activity (32.7 μmol Trolox eq./g) and peroxy radical-scavenging activity (126.3 μmol Trolox eq./g)	Khatun, Eguchi, Yamaguchi, Takamura, & Matoba, 2006
		Anti-inflammation	Essential oil had no anti-inflammatory effect against formalin-induced edema	Sayyah, Peirovi, & Kamalinejad, 2002
		Antinociceptive	Essential oils at the doses ranging between 0.0125 and 0.20 ml/kg exhibited a significant and dose-dependent analgesic effect in the model of chronic and inflammatory pain (formalin test). The essential oil had no analgesic effect in the model of acute pain (tail flick test)	Sayyah, Peirovi, & Kamalinejad, 2002

Table 2.9

Biological activities of *Dracaena loureiri* Gagnep.

Botanical name	Plant part	Activity	Result of biological activity	References
Dracaena loureiri Gagnep.	Stem	Anti-inflammation	The three stilbene, including pterostilbene, pinostilbene and resveratrol showed possessed the most potent COX-2 inhibitory activity	Sawasdee, 2001
		Antiproliferation	The methanolic extract of *D. loureiri* showed inhibited Jurkat cell proliferation by apoptosis, at the concentration 50 μg/ml	Chirathaworn, Kongcharoensuntorn, Charadram, Pongpanich, & Poovorawan, 2005
		Antioxidant	The TEAC values for methanolic extract of *D. loureiri* showed 3.0354 mmol/l trolox/100 g DW	Kongcharoensuntorn et al., 2005

Table 2.9 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Dracaena loureiri Gagnep.	Stem	Antimicrobial	The 2 mg of methanolic extract showed the antimicrobial activity against *S. aureus* ATCC 25913, *S. aureus, B. subtilis, C. albicans, E. coli* TISTR 512, *K. pneumoniae* and *S. marcescens* (Inhibition zone = 1.37, 1.23, 1.17, 0.93, 0.97, 1.30 and 0.97 cm, respectively), but the results showed less effective than antibiotics (Amphicillin, tetracycline and Erythromycin)	Kongcharoensuntorn et al., 2005
		Antipyretic	The methanol fraction of *D. loureiri* suppressed yeast-induced fever in rats	Reanmongkol, Subhadhirasakul, & Bouking, 2003

Table 2.9 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Dracaena loureiri Gagnep.	Stem	Antinociceptive	Oral administration of the methanol extract and methanol fraction (100-400 mg/kg) dose dependently decreased the number of writhings and stretchings induced by acetic acid and licking activity of the phase in the formalin test	Reanmongkol, Subhadhirasakul, & Bouking, 2003
		Toxicity	The LD_{50} value of IP injection the methanol, hexane, methanol fraction, ethyl acetate fraction, and chloroform fraction extracts in mice was 1.67 g/kg, >7 g/kg, 739.73 mg/kg, 489.77 mg/kg and 1.67 g/kg, respectively	Reanmongkol, Subhadhirasakul, & Bouking, 2003

Table 2.10

Biological activities of *Foeniculum vulgare* Mill. var. *dulce* (Mill.) Thell.

Botanical name	Plant part	Activity	Result of biological activity	References
Foeniculum vulgare Mill. var. *dulce* (Mill.) Thell.	Fruit or Seed	Antibacterial	Aqueous extracts showed effective against *E. faecalis, S. aureus, E. coli, P. aeruginosa 2, S. typhi, S. typhimurium 2* and *S. flexneri* (inhibition zone = 11-24 mm) and organic solvent extracts showed effective against *E. faecalis, S. aureus, E. coli, P. aeruginosa, S. typhi, S. typhimurium* and *S. flexneri* (inhibition zone = 9-29 mm). MIC for aqueous and acetone extracts ranged from 20-60 mg/ml and 5-10 mg/ml, respectively	Kaur & Arora, 2009

Table 2.10 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Foeniculum vulgare Mill. var. *dulce* (Mill.) Thell.	Fruit or Seed	Antifungal	*F. vulgare* oil exhibited a strong activity against *C. albicans* (MIC = 300 μg/ml, Inhibition zone = 18 mm)	Naeini, Khosravi, Chitsaz, Shokri, & Kamlnejad, 2009
		Antioxidant	The trolox equivalent antioxidant capacity (TEAC) values for methanolic and aqueous extracts displayed 105.9 and 150.6 μmol trolox equivalent/100 g DW, respectively	Cai, Luo, Sun, & Corke, 2004
		Antioxidant	In the DPPH assay, *F. vulgare* essential oil obtained by $SCCO_2$ extraction showed higher antioxidant activity than steam distillation extract, with radical scavenging activity ranging from 87.1 to 92.0 %	Topal, Sasaki, Goto, & Otles, 2008

Table 2.10 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Foeniculum vulgare Mill. var. *dulce* (Mill.) Thell.	Fruit or Seed	Antioxidant	Fennel showed moderate the DPPH radical-scavenging activity (20.6 μmol Trolox eq./g) and peroxy radical-scavenging activity (104.4 μmol Trolox eq./g)	Khatun, Eguchi, Yamaguchi, Takamura, & Matoba, 2006
		Antioxidant	Aqueous extract showed strong antioxidant superior to known antioxidant ascorbic acid (50% scavenging of superoxide radicals = 205 μg (fennel), 260 μg (ascorbic acid); 50% inhibition of lipid peroxide = 4600 μg (fennel), 5000 μg (ascorbic acid); 50% inhibition of hydroxyl radicals = 700 μg (fennel), 4500 μg (ascorbic acid))	Satyanarayana, Sushruta, Sarma, Srinivas, & Raja, 2004

Table 2.11

Biological activities of *Kaempferia galanga* L.

Botanical name	Plant part	Activity	Result of biological activity	References
Kaempferia galanga L.	Rhizome	Antibacterial	The methanolic extract of *K. galanga* inhibited the growth of all *H. pylori* strains with minimum inhibitory concentration (MIC) of 25.0 μg/ml	Bhamarapravati, Pendland, & Mahady, 2003
		Antimicrobial	The volatile oil of *K. galanga* showed antimicrobial activity against *S. aureus* ATCC 25923, *S. faecalis*, *B. subtilis*, *S. typhi*, *S. flexneri*, *E. coli* ATCC 25299 and *C. albicans* using agar dish diffusion method with the inhibition zones from 8.0-31.0 mm	Tewtrakul, Yuenyongsawad, Kummee, & Atsawajaruwan, 2005
		Antifungal	The volatile oil of *K. galanga* exhibited *A. fumigatus*, with a MIC value of 0.63 μg/μl	Bin Jantan *et al*., 2003

Table 2.11 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Kaempferia galanga L.	Rhizome	Antinociceptive	The methanolic extract administered at 200 mg/kg, p.o. showed a stronger antinociceptive effect than aspirin (100 mg/kg, p.o.) but less than morphine (5 mg/kg, s.c.) (using acetic acid-induced writhings, formalin test, hot plate test and tail-flick test)	Ridtitid, Sae-Wong, Reanmongkol, & Wongnawa, 2008
		Anti-allergy	The ethanolic extract, water extract and volatile oil of *K. galanga* exhibited the anti-allergic effect against antigen-induced β-hexosaminidase release as a maker of degranulation in RBL-2H3, with IC_{50} = 78.6, 49.5 and 80.5 μg/ml, respectively	Tewtrakul & Subhadhirasakul, 2007

Table 2.11 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Kaempferia galanga L.	Rhizome	Cytotoxic	Ethyl-*p*-methoxy-*trans*-cinnamate exhibited inhibitory activity against HeLa cells	Kosuge et al., 1985
		Toxicity	The ethanolic extract of *K. galanga* showed no mortality in acute toxicity (at dose 5 g/kg) and subacute toxicity test (at dose 25, 50 or 100 mg/kg)	Kanjanapothi et al., 2004

Table 2.12

Biological activities of *Lepidium sativum* L.

Botanical name	Plant part	Activity	Result of biological activity	References
Lepidium sativum L.	Seed	Antibacterial	Agar disc diffusion method for aqueous extract showed maximum antibacterial activity against *S. aureus* (Inhibition zone = 12 mm)	Parekh & Chanda, 2008
		Antipyretic	The ethanolic extract (500 mg/kg) reduced the yeast-induced hyperpyrexia in mice	Al-Yahya, Mossa, Ageel, & Rafatullah, 1994
		Analgesic	Administration of the ethanolic extract of *L. sativum* (500 mg/kg) prolonged the hot plate reaction time in mice	Al-Yahya, Mossa, Ageel, & Rafatullah, 1994

Table 2.12 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Lepidium sativum L.	Seed	Anti-inflammation	The ethanolic extract of *L. sativum* (500 mg/kg) showed inhibition of carrageenan-induced pedal oedema in rats and weak inhibition of cotton pellet-induced granuloma	Al-Yahya, Mossa, Ageel, & Rafatullah, 1994
		Hepatoprotective	The methanolic extract of *L. sativum* (200 and 400 mg/kg body weight) exhibited possess hepatoprotective activity in rats	Afaf, Nuha, & Mohammed, 2008

Table 2.13

Biological activities of *Ligusticum sinense* Oliv. cv. Chuanxiong

Botanical name	Plant part	Activity	Result of biological activity	References
Ligusticum sinense Oliv. cv. Chuanxiong	Rhizome	Immunosuppressive	Ligustiphenol showed strong immunosuppressive activity with an $IC_{50} = 2.4 \times 10^{-8}$ M	Yu, 1998
		Antioxidant	The essential oil showed good antioxidant properties, in that IC_{50} value in DPPH and ABTS showed 1.58 and 1.58 μg/ml	Jeong et al., 2009

Table 2.14

Biological activities of *Mammea siamensis* Kosterm.

Botanical name	Plant part	Activity	Result of biological activity	References
Mammea siamensis Kosterm.	Flower	Antibacterial	The chloroform extract showed active against *S. aureus* and *B. subtilis* with inhibition zone of 7.8 and 9.0 mm, respectively	Subhadhirasakul & Pechpongs, 2005
		Antibacterial	The methanol extract exhibited inhibition zone (6.0 mm) for *B. subtilis*	Subhadhirasakul & Pechpongs, 2005
		Antibacterial	3,4-Dihydroxybenzoic acid and gallic acid showed antibacterial activity against *E. coli*, *B. cereus*, *S. aureus* and flat sour spoilage	Phuwapraisirisan et al., 2001
		Antioxidant	Both the chloroform and the methanol extract inactive at concentration 400 μg/ml	Subhadhirasakul & Pechpongs, 2005

Table 2.14 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Mammea siamensis Kosterm.	Flower	Antioxidant	The absolutes (solvent extract) of *M. siamensis* exhibited the highest antioxidant activity with IC_{50} of 0.3271 mg/ml	Leelapornpisid, Chansakaow, Chiyasut, & Wongwattananukul, 2008
		Cytotoxic	Both the chloroform and the methanol extract exhibited lethality effects on brine shrimp with LC_{50} value of 5.2 and 43.2 μg/ml, respectively	Subhadhirasakul & Pechpongs, 2005

Table 2.15

Biological activities of *Mesua ferrea* L.

Botanical name	Plant part	Activity	Result of biological activity	References
Mesua ferrea L.	Flower	Antibacterial	The methanol extract active against a large number of gram-positive and gram-negative bacteria at concentration ranges of 100 to 50 μg/ml	Mazumder, Dastidar, Basu, Mazumder, & Singh, 2004
		Antimicrobial	The CH_2Cl_2:MeOH (1:1) extract inactive against *B. cereus*, *B. pumilus*, *B. subtilis*, *B. bronchiseptica*, *M. luteus*, *S. aureus*, *S. epidermidis*, *E. coli*, *K. pneumoniae*, *P. aeruginosa*, *S.faecalis*, *C. albicans*, *A. niger* and *S.cerevisiae* at concentration 500 and 1000 μg/ml	Kumar, Chauhan, Padh, & Rajani, 2006

Table 2.15 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Mesua ferrea L.	Flower	Antimicrobial	The methanol extract showed a weak antimicrobial activity against *S. aureus*, *B. subtilis* and *P. aeruginosa*	Nordin, Ahmad, Taufiq-Yap, & Ali, 2004
		Antimicrobial	The *Mesua* derivatives exhibited antimicrobial activities against 42 strains of *Staphylococcus* spp. (MIC 50% = 2-4 μg/ml)	Verotta et al., 2004
		Cytotoxic	The methanol extract showed a strong cytotoxic activity toward T-lymphocyte leukemia cells	Nordin, Ahmad, Taufiq-Yap, & Ali, 2004

Table 2.16

Biological activity of *Mimusops elengi* L.

Botanical name	Plant part	Activity	Result of biological activity	References
Mimusops elengi L.	Flower	Antioxidant	The flower extract showed the antioxidant activity with EC_{50} value range 0.230-0.550 μg/ml	Aromdee, Vorarat, & Benjamapriyagoon, 2005

Table 2.17

Biological activities of *Myristica fragrans* Houtt.

Botanical name	Plant part	Activity	Result of biological activity	References
Myristica fragrans Houtt.	Stem	Antiproliferation	The methanolic extract of *M. fragrans* showed inhibited Jurkat cell proliferation by apoptosis, at the concentration 50 and 100 μg/ml	Chirathaworn, Kongcharoensuntorn, Charadram, Pongpanich, & Poovorawan, 2005; Chirathaworn et al., 2007

Table 2.17 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Myristica fragrans Houtt.	Stem	Antioxidant	The TEAC values for methanolic extract of *M. fragrans* showed 2.1337 mmol/l trolox/100 g DW	Kongcharoensuntorn et al., 2005
	Aril	Antioxidant	Mace showed weak the DPPH radical-scavenging activity (18.1 μmol Trolox eq./g) and peroxy radical-scavenging activity (58.6 μmol Trolox eq./g)	Khatun, Eguchi, Yamaguchi, Takamura, & Matoba, 2006
		Antibacterial	The methanolic extract inhibited the growth of all *H. pylori* strains with minimum inhibitory concentration (MIC) of 12.5 μg/ml	Bhamarapravati, Pendland, & Mahady, 2003

Table 2.17 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Myristica fragrans Houtt.	Aril	Anti-inflammation	The methanol extract inhibited the edema induced by carrageenin (at conc. 1.5 g/kg) and the increase of dye leakage induced by acetic acid (at conc. 1 g/kg) and reduced the number of the writhings induced by acetic acid (at conc. 0.3 and 1 g/kg)	Ozaki, Soedigdo, Wattimena, Suganda, 1989
		Analgesic	Myriaticin inhibited the increase of the dye leakage induced by acetic acid at concentration 0.17 g/kg	Ozaki, Soedigdo, Wattimena, Suganda, 1989
	Seed	Antibacterial	The macelignan of methanol extract active against cariogenic *S. mutans* (MIC = 3.9 μg/ml and MBC = 7.8 μg/ml)	Chung, Choo, Lee, & Hwang, 2006

Table 2.17 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Myristica fragrans Houtt.	Seed	Antimicrobial	The 2 mg of methanolic extract showed the antimicrobial activity against *B. subtilis*, *C. albicans*, *E. coli* TISTR 512, *K. pneumoniae*, *P. mirabilis* and *S. marcescens* (Inhibition zone = 0.93, 0.87, 0.83, 1.43, 0.90 and 0.80 cm, respectively), but the results showed less effective than antibiotics (Amphicillin, tetracycline and Erythromycin)	Kongcharoensuntorn et al., 2005
		Antioxidant	Macelignan showed the strong DPPH free-radical scavenging activity (IC_{50} = 25 μM)	Jin, Lim, Hwang, Ha, & Han, 2005

Table 2.17 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Myristica fragrans Houtt.	Seed	Antioxidant	Nutmeg showed moderate the DPPH radical-scavenging activity (50.9 μmol Trolox eq./g) and peroxy radical-scavenging activity (104.3 μmol Trolox eq./g)	Khatun, Eguchi, Yamaguchi, Takamura, & Matoba, 2006
		Anti-inflammation	Macelignan potently suppressed the expression of cyclooxygenase-2 and inducible nitric oxide synthase, that consequently resulted in the reduction of nitric oxide in LPS-treated microglial cells	Jin, Lim, Hwang, Ha, & Han, 2005

Table 2.17 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Myristica fragrans Houtt.	Seed	Hepatoprotective	Myristicin from nutmeg was found to possess extraordinary potent hepatopotective activity. It markedly suppressed LPS/D-GalN-induced enhancement of serum TNF-α concentrations and hepatic DNA fragmentation in mice	Morita et al., 2003

Table 2.18

Biological activities of *Nelumbo nucifera* Gaertn.

Botanical name	Plant part	Activity	Result of biological activity	References
Nelumbo nucifera Gaertn.	Pollen or Stamen	Antioxidant	Kaempferol possessed good activities in the DPPH, ROS, DCHF-DA and $ONOO^-$ tests	Jung, Kim, Chung, & Choi, 2003
		Antioxidant	Kaempferol 3-*O*-β-D-glucuronopyranosyl methylester and kaempferol 3-*O*-β-D-glucuronopyranoside showed scavenging activities in the DPPH and $ONOO^-$ tests	Jung, Kim, Chung, & Choi, 2003
		Antioxidant	Kaempferol 3-*O*-β-D-glucopyranoside and kaempferol 3-*O*-β-D-galactopyranoside showed only active in the $ONOO^-$ tests	Jung, Kim, Chung, & Choi, 2003

Table 2.18 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Nelumbo nucifera Gaertn.	Pollen or Stamen	Antioxidant	β-Sitosterol glucopyranoside showed no activities in the DPPH, ROS, DCHF-DA and $ONOO^-$ tests	Jung, Kim, Chung, & Choi, 2003
		Antioxidant	Isorhamnetin-3-*O*-β-D-glucopyranoside, isorhamnetin 3-*O*-rutinoside, nelumboroside A and nelumboroside B showed potent antioxidant activities with IC_{50} values of 11.76, 9.01, 9.21, and 7.43 μM in the DPPH assay, and 3.34, 2.56, 2.62 and 2.12 μM in the $ONOO^-$ assay, respectively	Hyun, Jung, Chung, Jung, & Choi, 2006

Table 2.18 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Nelumbo nucifera Gaertn.	Pollen or Stamen	Antimicrobial	The *N. nucifera* pollen essential oil showed antimicrobial activity against *S. typhimurium* ATCC 14028 and *E. coli* ATCC 25922 with MIC = 10 and 40 and MBC = 20 and 80 ml/L, respectively	Sittiwet, 2009

Table 2.19

Biological activities of *Nigella sativa* L.

Botanical name	Plant part	Activity	Result of biological activity	References
Nigella sativa L.	Seed	Antipyretic	The aqueous extract (500 mg/kg-body weight) showed no effect on yeast induced pyrexia	Al-Ghamdi, 2001

Table 2.19 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Nigella sativa L.	Seed	Antifungal	*N. sativa* oil exhibited a weak activity against *C. albicans* (MIC = 2300 μg/ml, Inhibition zone = 35 mm)	Naeini, Khosravi, Chitsaz, Shokri, & Kamlnejad, 2009
		Antibacterial	Black seed oil exhibited a strong antibacterial activity against all the strains of *L. monocytogenes*, yielding a mean inhibition zone of 31.50 mm	Nair, Vasudevan, & Venkitanarayanan, 2005
		Antibacterial	The methanol extract exhibited antibacterial activity against *S. aureus*, *M. luteus* and *B. cereus* (Inhibition zone = 7-9, 7-9 and >15 mm, respectively)	Bonjar, 2004

Table 2.19 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Nigella sativa L.	Seed	Antioxidant	The methanolic extract showed a good on lipoxygenase-dependent lipid peroxidation system, the DPPH radical scavenging system and rat liver microsomal lipid peroxidation system (IC_{50} = 4.63, 1.24 and 0.18 mg dry weight, respectively)	Thippeswamy & Naidu, 2005
		Cytotoxic	The ethyl-acetate fraction exhibited cytotoxicity against Molt4, P388, J82, Wehi 164, LL/2, SW620 and Hep G2 with ED_{50} values of 12, 17, 22, 14, 16, 18 and 11 μg/ml, respectively	Swamy & Tan, 2000

Table 2.19 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Nigella sativa L.	Seed	Anti-inflammation	The aqueous extract (500 mg/kg-body weight) showed inhibition of Carrageenan induced paw edema	Al-Ghamdi, 2001
		Anti-inflammation	The aqueous extract exhibited an inhibitory effect on nitric oxide production by murine macrophages	Mahmood, Gilani, Khwaja, Rashid, & Ashfaq, 2003
		Anti-inflammation	The *n*-hexane Soxhlet extract (concentration 100 μg/ml) showed strong inhibitory activity in COX-2 and COX-1 assays with 78.13% inhibition and 100% inhibition, respectively	Landa, Marsik, Vanek, & Kokoska, 2007
		Anti-inflammation	Thymoquinone showed inhibitory effect on COX-2 protein expression and PGD2 production	El-Mezayen et al., 2006

Table 2.19 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Nigella sativa L.	Seed	Anti-inflammation	Thymoquinone showed dose- and time-dependently reduced nitrite production by rat peritoneal macrophages with IC_{50} values of 1.4-2.76 μM	El-Mahmoudy et al., 2002
		Anti-inflammation	Thymoquinone (2.5 and 5 mg/kg) exerted anti-inflammatory effects on experimentally induced arthritis in rats	Tekeoglu, Dogan, Ediz, Budancamanak, & Demirel, 2007
		Anti-inflammation	Thymol exhibited the most active against COX-1 with the same IC_{50} value as indomethacin (0.2 μM)	Marsik et al., 2005

Table 2.19 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Nigella sativa L.	Seed	Anti-inflammation	Thymohydroquinone and thymoquinone exhibited more inhibitory than indomethacin on COX-2 with IC_{50} values of 0.1, 0.3 and 0.6 μM, respectively	Marsik et al., 2005
		Analgesic	The aqueous extract (500 mg/kg-body weight) produced increase in the hot plate reaction time in mice	Al-Ghamdi, 2001

Table 2.20

Biological activities of *Syzygium aromaticum* (L.) Merr. et Perry

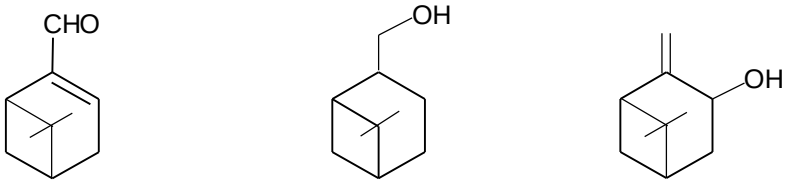
Botanical name	Plant part	Activity	Result of biological activity	References
Syzygium aromaticum (L.) Merr. et Perry	Flower-bud	Antioxidant	The clove bud extract, eugenol, eugenyl acetate and benzyl alcohol inhibited malonaldelhyde formation from cod liver oil by 93, 88, 79 and 63%, respectively, at the level of 160 μg/ml	Lee & Shibamoto, 2001
		Antioxidant	The clove bud extract, eugenol, eugenyl acetate and benzyl alcohol inhibited oxidation of hexanal by 100, 99, 99 and 82%, respectively, for a period of 30 days at 500 μg/ml	Lee & Shibamoto, 2001
		Immediate hypersensitivity	The aqueous extract of *S. aromaticum* inhibited compound 48/80-induced systemic anaphylaxis in rats (IC_{50} = 31.25 mg/kg, i.p.)	Kim, Lee, et al., 1998

Table 2.20 (Continued)

Botanical name	Plant part	Activity	Result of biological activity	References
Syzygium aromaticum (L.) Merr. et Perry	Flower-bud	Immediate hypersensitivity	The aqueous extract of *S. aromaticum* inhibited local immunoglobulin E (IgE)-mediated passive cutaneous anaphylactic reaction (IC_{50} = 17.78 mg/kg, i.v., IC_{50} = 19.81 mg/kg, p.o.)	Kim, Lee, et al., 1998
		Antimicrobial	The essential oil showed a lower antimicrobial activity against *E. coli* O157:H7, *L. monocytogenes* 2812 1/2a, *S.* Typhimurium SL 1344 and *S. aureus* (MIC ≤ 0.4% (vol/vol))	Oussalah, Caillet, Saucier, & Lacroix, 2007
		Antimicrobial	The essential oil showed antimicrobial activity against *E. coli* (ATCC25128), with MIC and MBC values of 0.25 and 0.3 ml/100 ml, respectively	Moreira, Ponce, del Valle, & Roura, 2005

6. Chemical constituents of plants in Prasaprohyai preparation

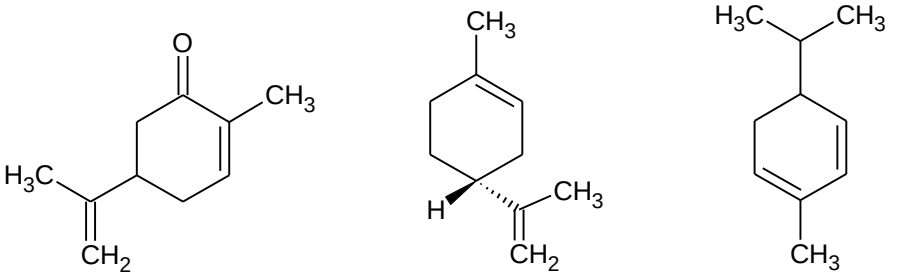
The investigations on chemical constituents of plants in Prasaprohyai Preparation are shown in Figure 2.50 to 2.68.



Myrtenal Myrtenol *trans*-Pinocarveol

Figure 2.50

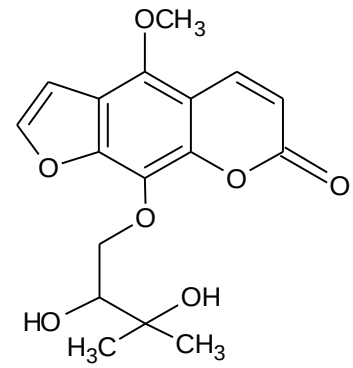
Structures of some chemical constituents found in *Amomum testaceum* Ridl.
(Kamchonwongpaisan et al., 1995; Sirat, Hong, & Khaw, 2000, 2001)



Carvone *d*-Limonene α-Phellandrene

Figure 2.51

Structures of some chemical constituents found in *Anethum graveolens* L.
(Bakkali, Averbeck, Averbeck, & Idaomar, 2008; Benchaar et al., 2008;
Singh, Maurya, de Lampasona, & Catalan, 2005;
Surveswara, Cai, Corke, & Sun, 2007)



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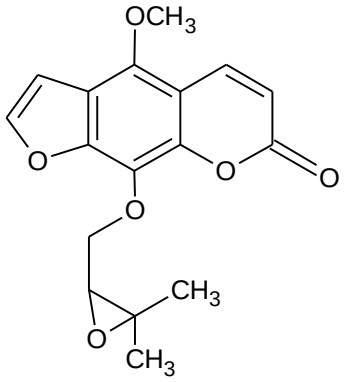
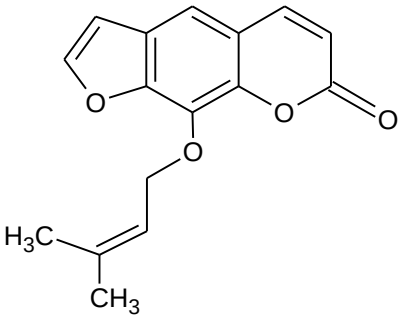
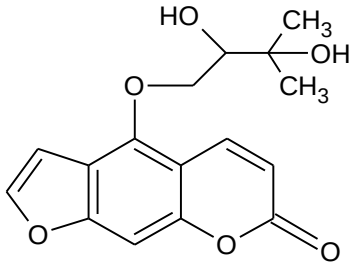


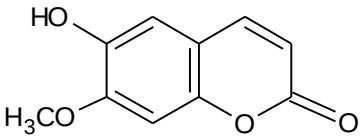
Byakangelicol



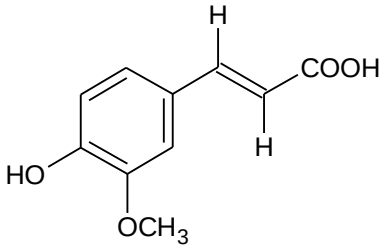
Imperatorin



Oxypeucedanin hydrate



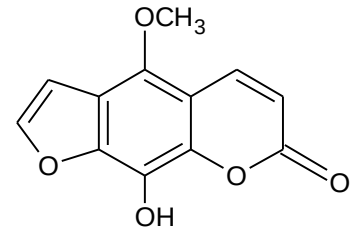
Scopoletin



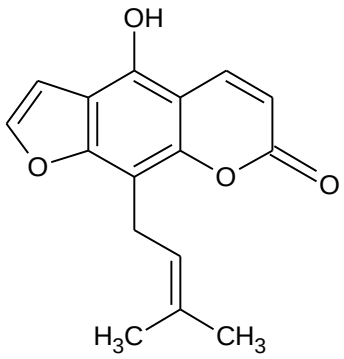
Ferulic acid

Figure 2.52

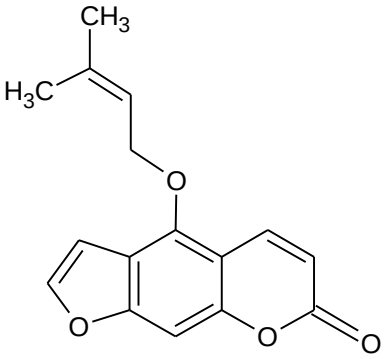
Structures of some chemical constituents found in *Angelica dahurica* Benth. (Baek, Ahn, Kim, & Park, 2000; Ban et al., 2003; Kimura et al., 1982; Kimura, Okuda, & Baba, 1997; Kwon et al., 1997; Oh et al., 2002; Piao et al., 2004; Qiao, Yao, & Wang, 1996; Thanh, Jin, Song, Bae, & Kang, 2004; Tsai & Yang, 1997)



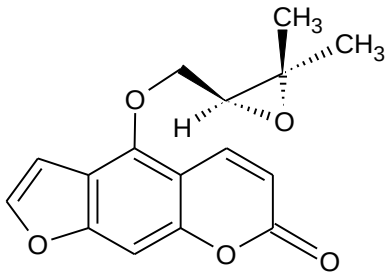
9-Hydroxy-4-methoxypsoralen



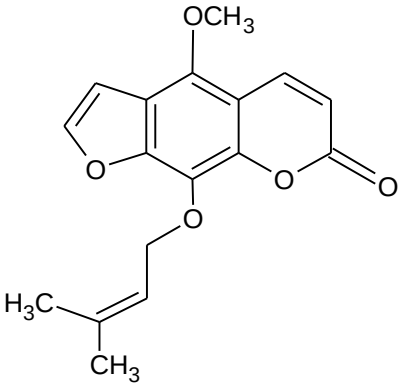
Allisoimperatorin



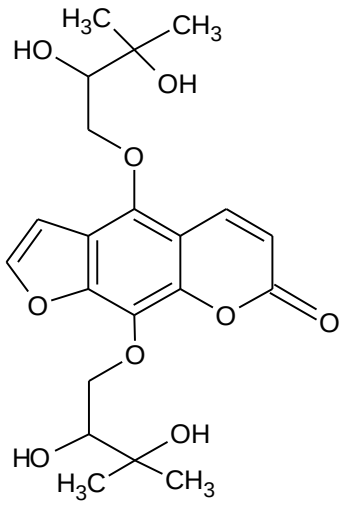
Isoimperatorin



Oxypeucedanin

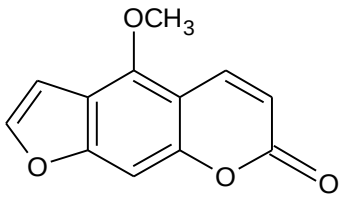


Phellopterin

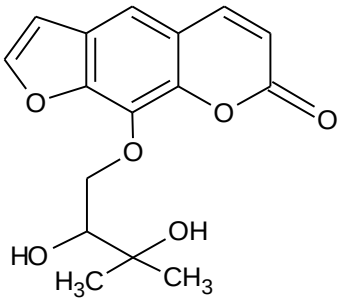


5,8-Di(2,3-dihydroxy-3-methylbutoxy)-psoralen

Figure 2.52 (Continued)

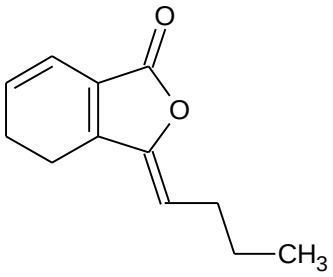


Bergapten

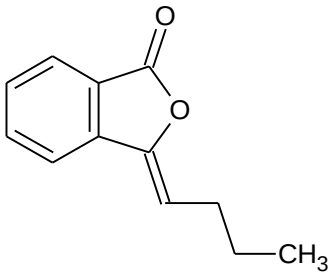


(R)-Heraclenol

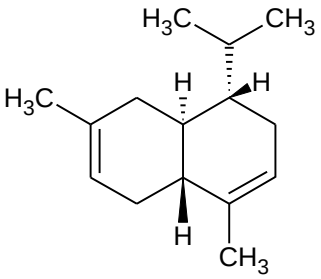
Figure 2.52 (Continued)



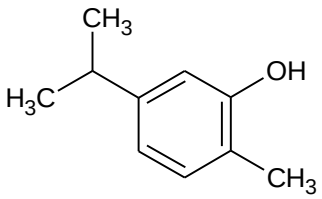
(*Z*)-Ligustilide



(*Z*)-Butylidenephthalide
((*Z*)-Ligusticum lactone)



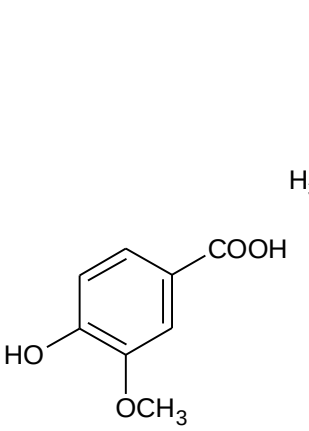
β-Cadinene



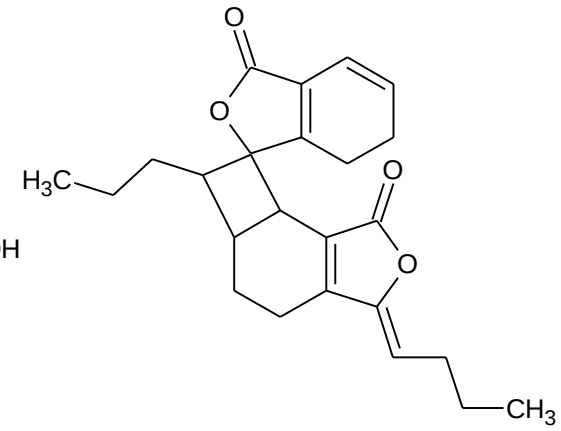
Carvacrol

Figure 2.53

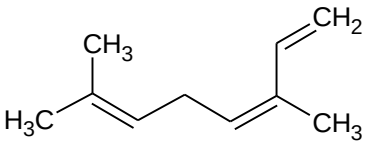
Structures of some chemical constituents found in *Angelica sinensis* (Oliv.) Diels (Cai, Luo, Sun, & Corke, 2004; Chao, Kuo, Li, & Lin, 2009; Deng , 2005; Ho, Kumaran, & Hwang, 2009; Lao et al., 2004; Lu et al., 2005; Lu, Zhang, Liang, & Zhao, 2004; WHO, 2002)



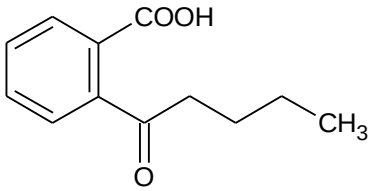
Vanillic acid



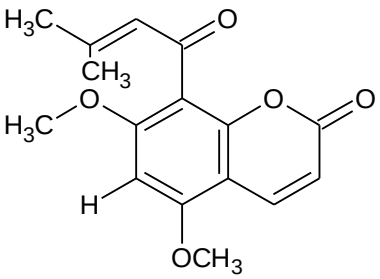
Angelicide



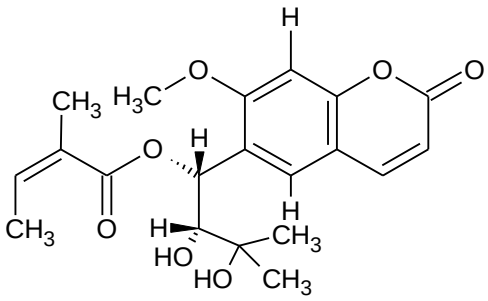
cis-β-Ocimene



Valerophenone-*O*-carboxylic acid (Ligusticumic acid)

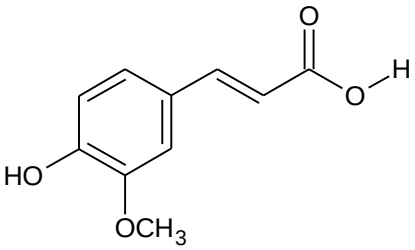


Angelicone

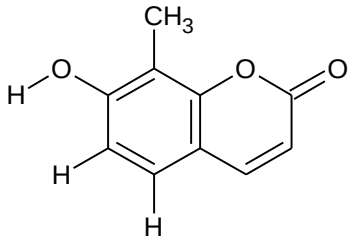


Angelol G

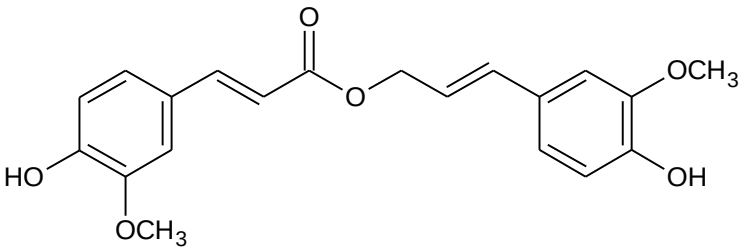
Figure 2.53 (Continued)



(*E*)-Ferulic acid

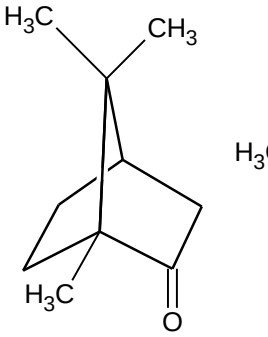


Umbelliferone

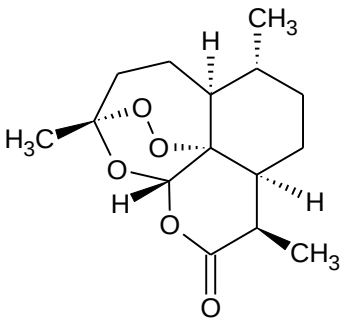


Coniferyl ferulate

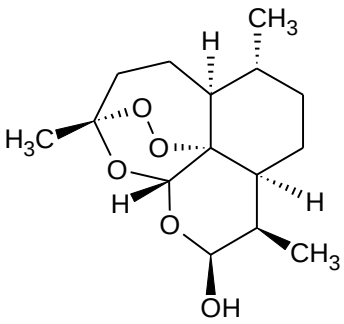
Figure 2.53 (Continued)



Camphor



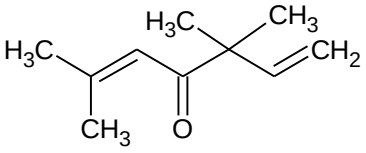
Artemisinin



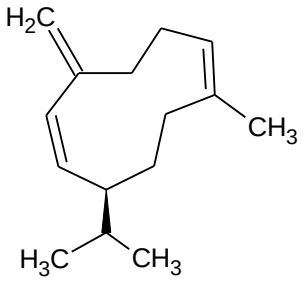
Dihydroartemisinin

Figure 2.54

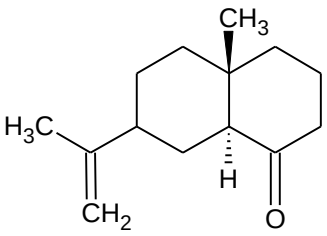
Structures of some chemical constituents found in *Artemisia annua* L. (Ahmad & Misra, 1994; Baraldi et al., 2008; Juteau, Masotti, Bessiere, Dherbomez, & Viano, 2002; Kohler, Haerdi, Christen, & Veuthey, 1997; Rasooli, Rezaee, Moosavi, & Jaimand, 2003)



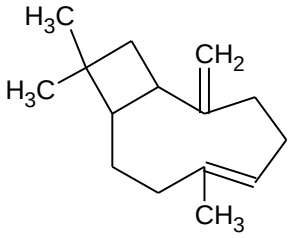
Artemisia ketone



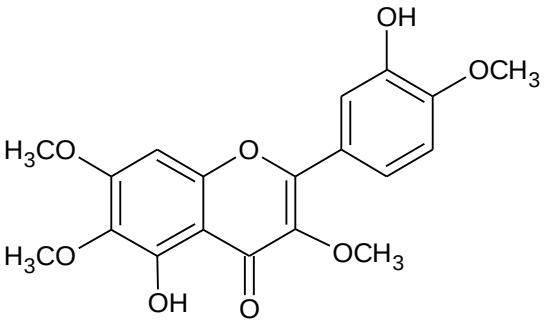
Germacrene D



β-Selinene

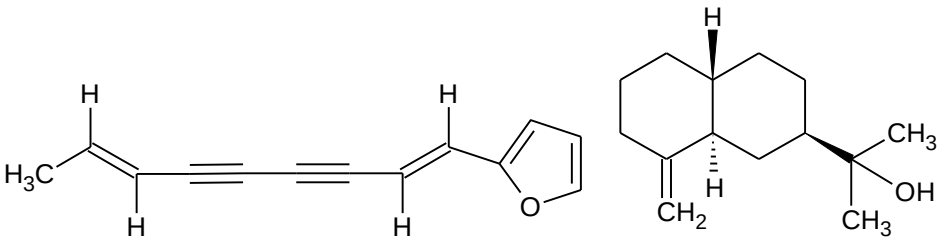


β-Caryophyllene

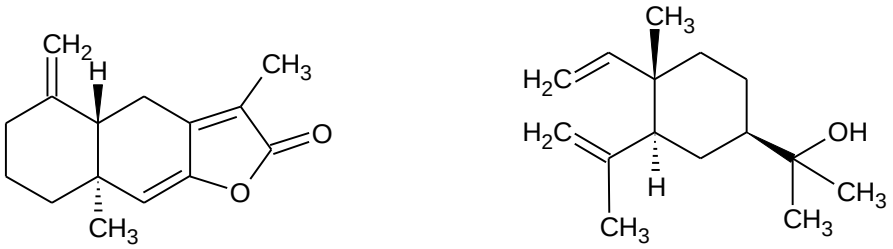


Casticin

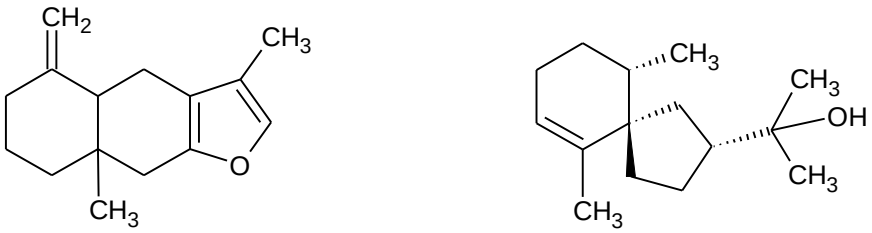
Figure 2.54 (Continued)



Atractylodin β-Eudesmol



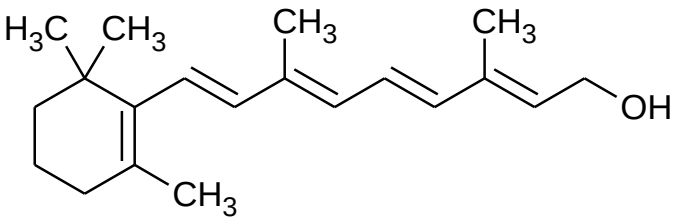
Atractylenolide I Elemol



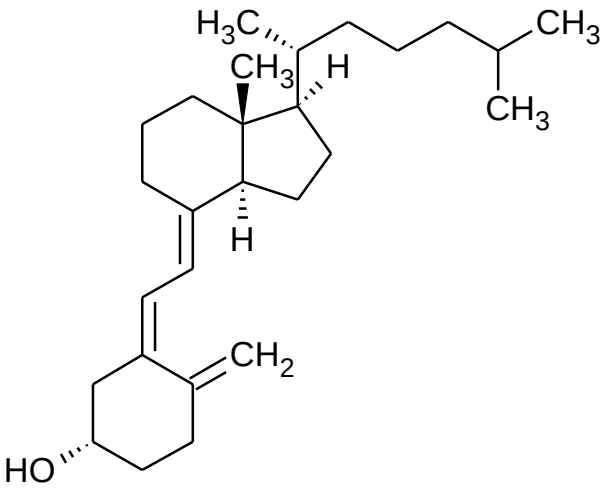
Atractylon Hinesol
(Atractylone)

Figure 2.55

Structures of some chemical constituents found in *Atractylodes lancea* (Thunb.) DC.
(Duan, Wang, Qian, Su, & Tang, 2008; Hiraoka & Tomita, 1990;
Nakai et al., 2003; Resch, Steigel, Chen, & Bauer, 1998;
Wang, He, Wang, & Liu, 2009)

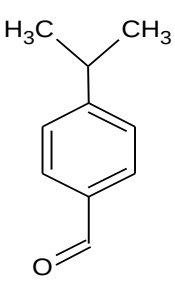


Vitamin A

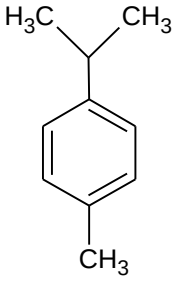


Vitamin D

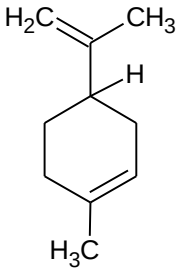
Figure 2.55 (Continued)



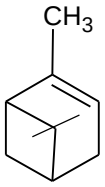
Cuminic aldehyde
(Cuminaldehyde, Cuminal)



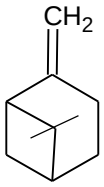
p-Cymene



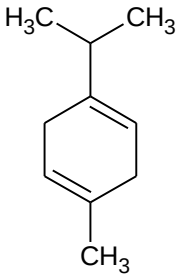
Dipentine



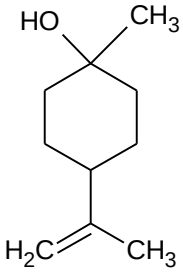
α-Pinene



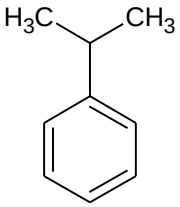
β-Pinene



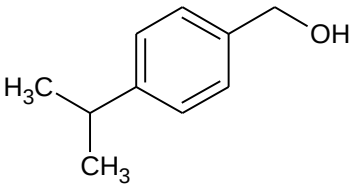
γ-Terpinene



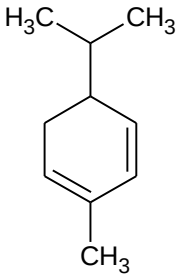
β-Terpeneol



Cumene



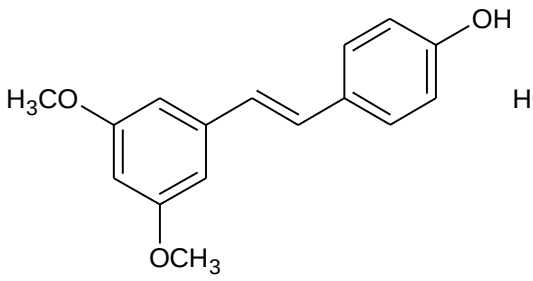
Cuminic alcohol



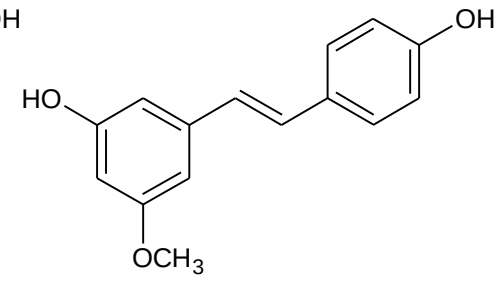
α-Phellandrene

Figure 2.56

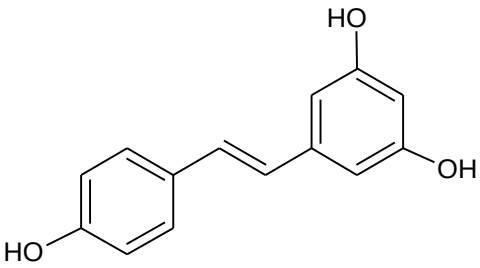
Structures of some chemical constituents found in *Cuminum cyminum* L. (Gachkar et al., 2007; Jalali-Heravi, Zekavat, & Sereshi, 2007; Khatun, Eguchi, Yamaguchi, Takamura, & Matoba, 2006; Li & Jiang, 2004; Li, Tian, et al., 2009; Naeini, Khosravi, Chitsaz, Shokri, & Kamlnejad, 2009; Oussalah, Caillet, Saucier, & Lacroix, 2006; Sayyah, Peirovi, & Kamalinejad, 2002; Surveswaran, Cai, Corke, & Sun, 2007; Tippeswamy & Naidu, 2005; Viuda-Martos, Ruiz-Navajas, Fernandez-Lopez, & Perez-Alvarez, 2007)



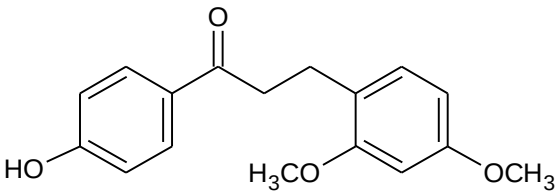
Pterostilbene



Pinostilbene



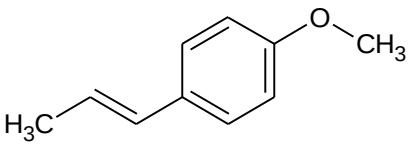
Resveratrol



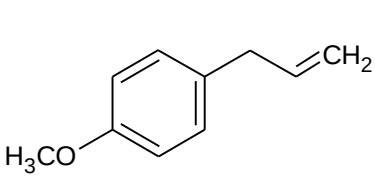
Loureirin B

Figure 2.57

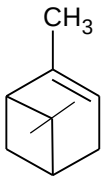
Structures of some chemical constituents found in *Dracaena loureiri* Gagnep. (Ichikawa et al., 1997; Sawasdee, 2001)



trans-Anethole



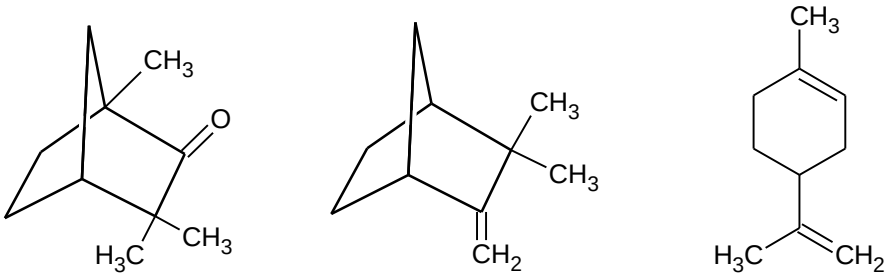
Estragole
(Methyl chavicol)



α-Pinene

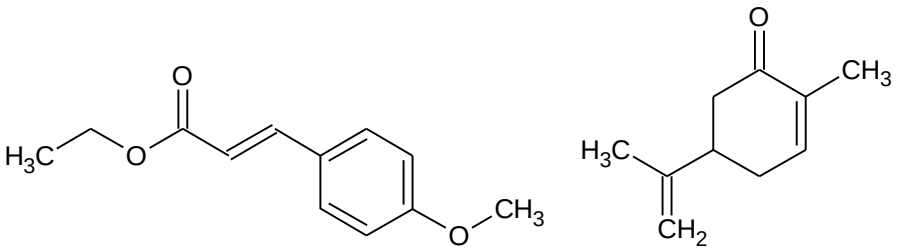
Figure 2.58

Structures of some chemical constituents found in *Foeniculum vulgare* Mill. var. *dulce* (Mill.) Thell. (Charles, Morales, & Simon, 1993; Telci, Demirtas, & Sahin, 2009)

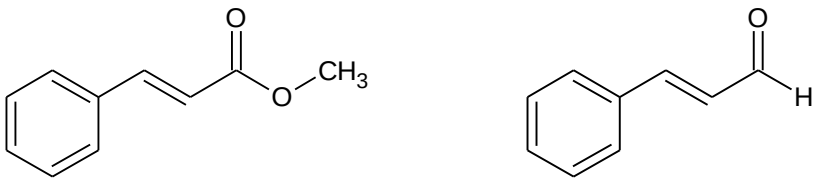


Fenchone Camphene Limonene

Figure 2.58 (Continued)



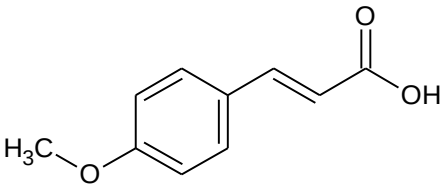
Ethyl-*p*-methoxycinnamate Carvone



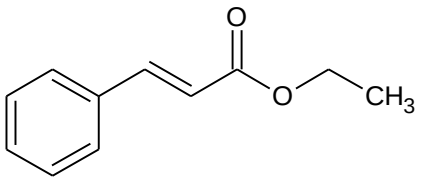
Methylcinnamate Cinnamaldehyde

Figure 2.59

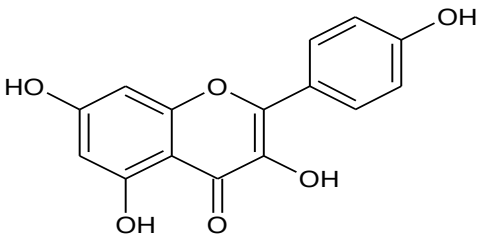
Structures of some chemical constituents found in *Kaempferia galanga* L. (Chithra, Martin, Sunandakumari, & Madhusoodanan, 2005; Kanjanapothi et al., 2004; Kosuge et al., 1985; Ridtitid, Sae-Wong, Reanmongkol, & Wongnawa, 2008; Surveswaran, Cai, Corke, & Sun, 2007; Tewtrakul, Yuenyongsawad, Kummee, & Atsawajaruwan, 2005; Zhang, Zhong, & Zhou, 2007)



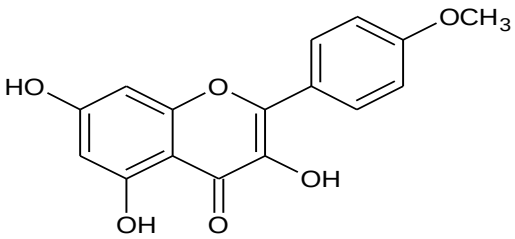
p-Methoxycinnamate



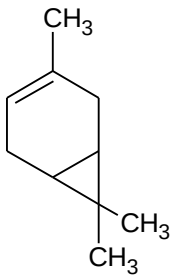
Ethyl cinnamate



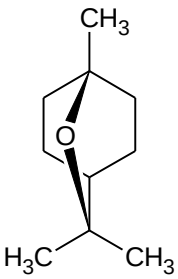
Kaempferol



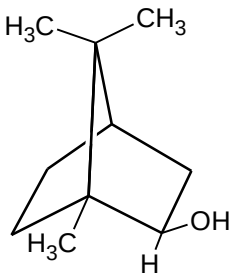
Kaempferide



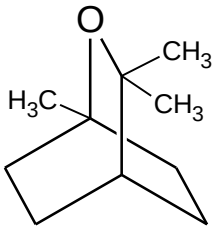
3-Carene



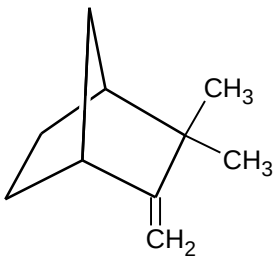
Cineol



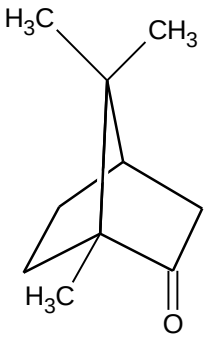
Borneol



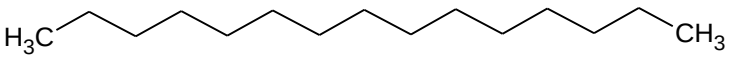
Eucalyptol



Camphene

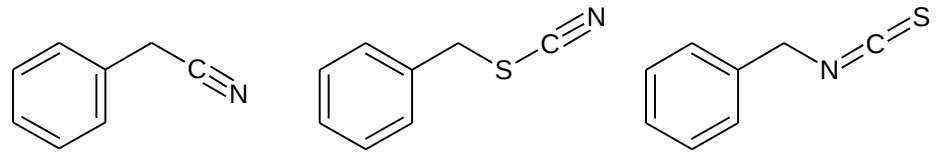


Camphor



n-Pentadecane

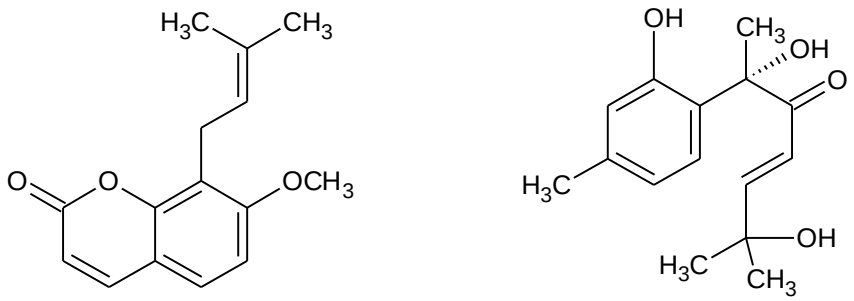
Figure 2.59 (Continued)



Benzylcyanide Benzylthiocyanate Benzylisothiocyanate

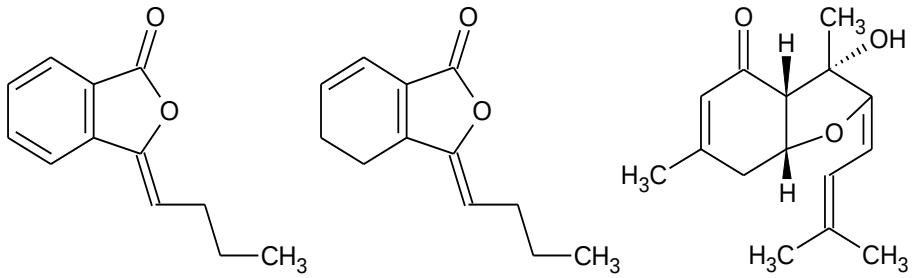
Figure 2.60

Structures of some chemical constituents found in *Lepidium sativum* L.
(Parekh & Chanda, 2008)



Cnidium lactone
(Osthole)

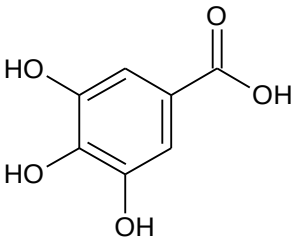
Ligustiphenol



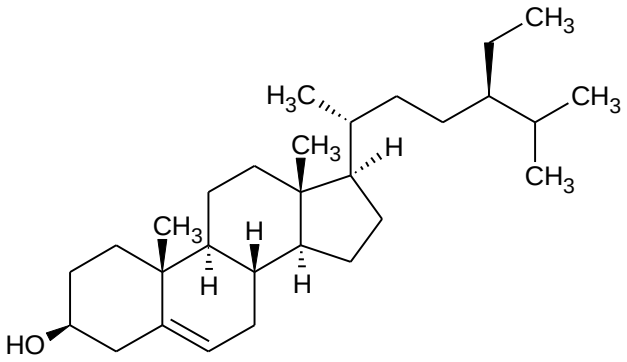
Butylidenephthalide Ligustilide Ligustilone

Figure 2.61

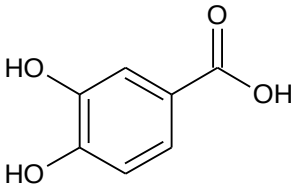
Structures of some chemical constituents found in *Ligusticum sinense* Oliv. cv.
Chuanxiong (Chan, Cheng, & Lin, 2007; Huang & Pu, 1988;
Liang, He, & Yang, 2005; Yu, 1998)



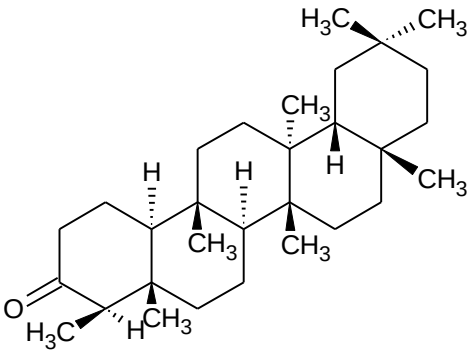
Gallic acid



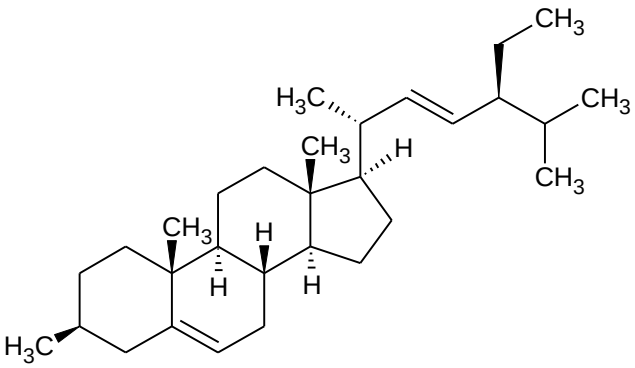
β-Sitosterol



3,4-Dihydroxybenzoic acid



Friedelin

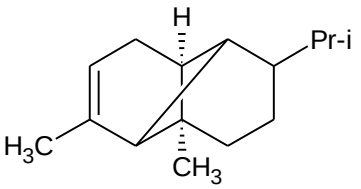


Stigmasterol

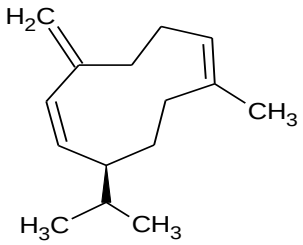
Figure 2.62

Structures of some chemical constituents found in *Mammea siamensis* Kosterm.

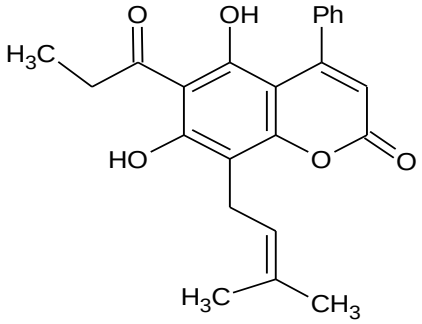
(Phuwapraisirisan et al., 2001; Subhadhirasakul & Pechpongs, 2005)



α-Copaene



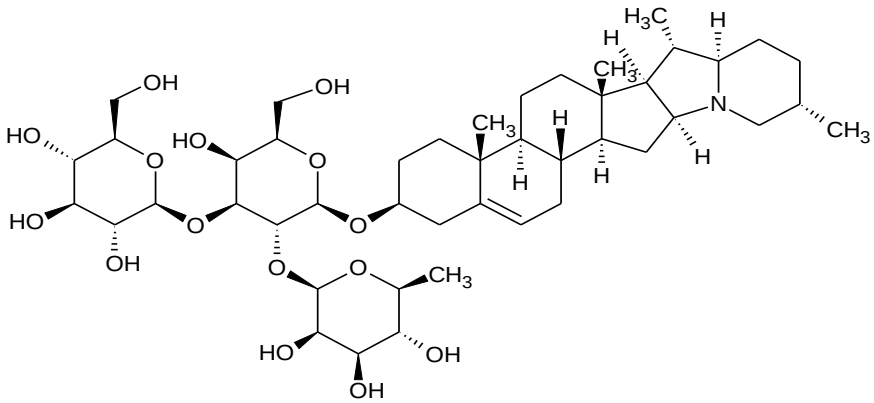
Germacrene D



Mesuol

Figure 2.63

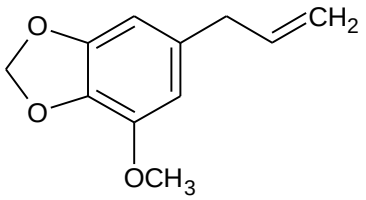
Structures of some chemical constituents found in *Mesua ferrea* L. (Choudhury, Ahmed, Barthel, & Leclercq, 1998; Verotta et al., 2004)



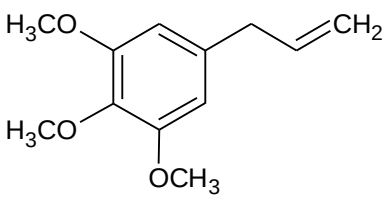
Saponin

Figure 2.64

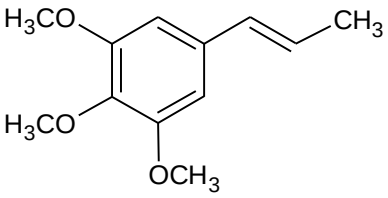
Structure of some chemical constituents found in *Mimusopa elengi* L.



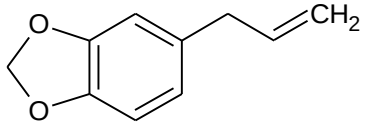
Myristicin



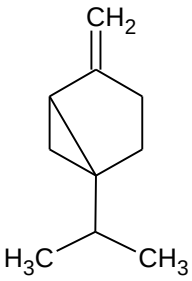
Elemicin



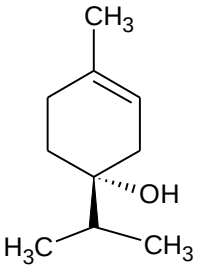
Isoelemicin



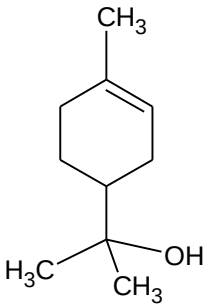
Safrole



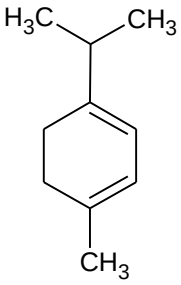
Sabinene



Terpinen-4-ol



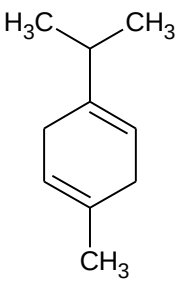
Terpineol



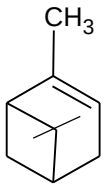
α-Terpinene

Figure 2.65

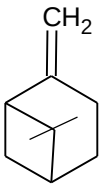
Structures of some chemical constituents found in *Myristica fragrans* Houtt. (Chirathaworn et al., 2007; Chung, Choo, Lee, & Hwang, 2006; Jukic, Politeo, & Milos, 2006; Morita et al., 2003; Oussalah, Caillet, Saucier, & Lacroix, 2006; Singh, Marimuthu, De Heluani, & Catalan, 2005; Surveswaran, Cai, Corke, & Sun, 2007; Tomaino et al., 2005)



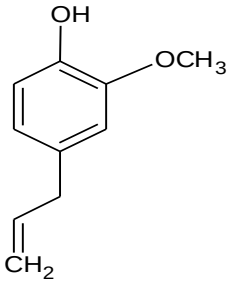
γ-Terpinene



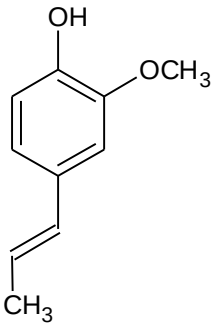
α-Pinene



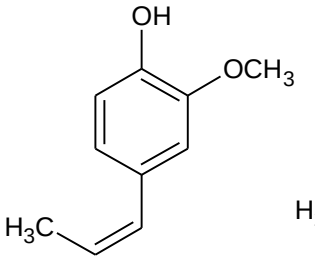
β-Pinene



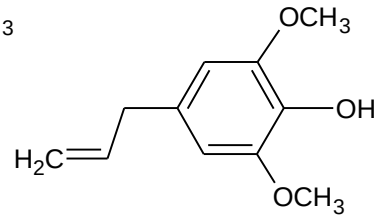
Eugenol



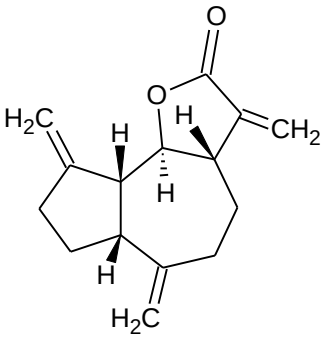
Isoeugenol (*trans*-Isoeugenol)



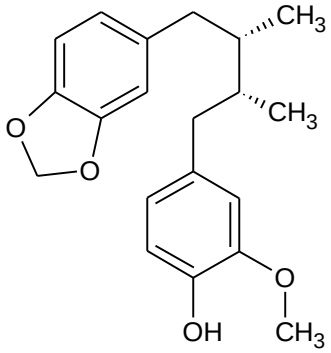
cis-Isoeugenol



Methoxyeugenol

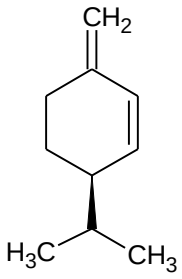


Dehydrodiisoeugenol

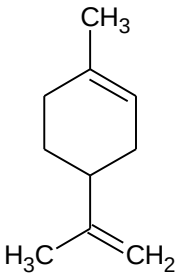


Macelignan

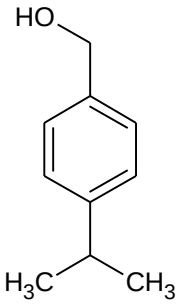
Figure 2.65 (Continued)



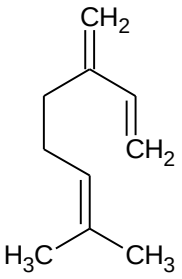
β-Phellandrene



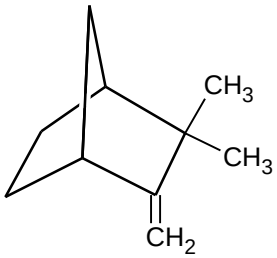
Limonene



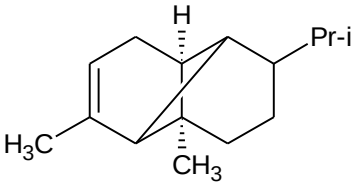
Cuminol



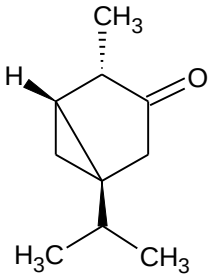
β-Myrcene



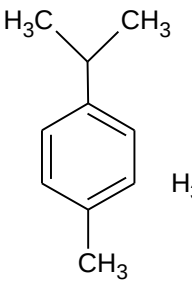
Camphene



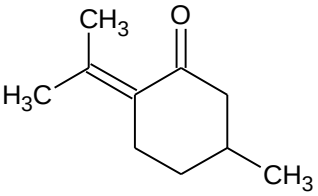
α-Copaene



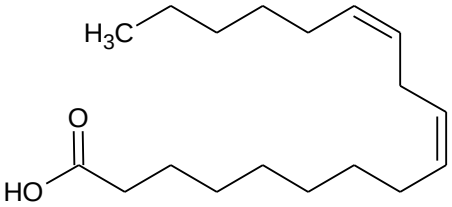
β-Thujone



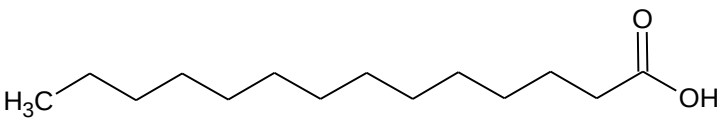
p-Cymene



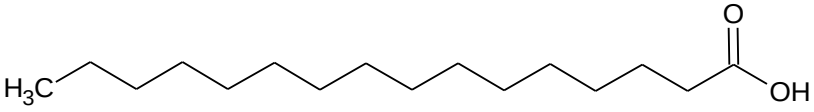
Pulegone



Linoleic acid

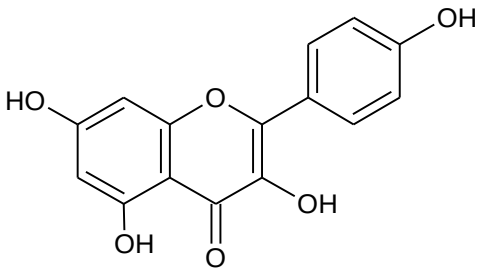


Myristic acid

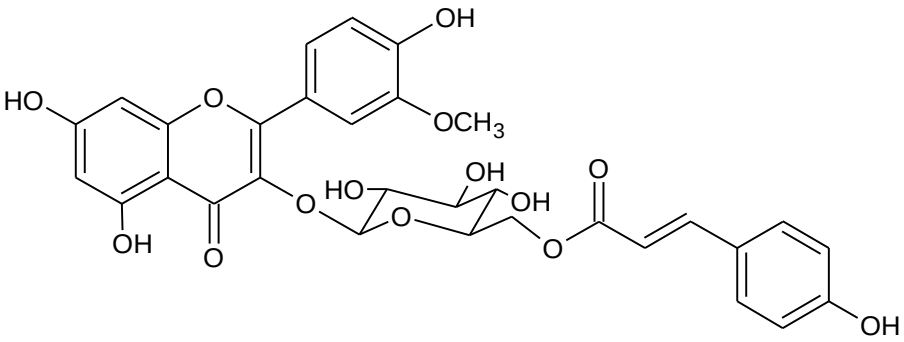


Palmitic acid

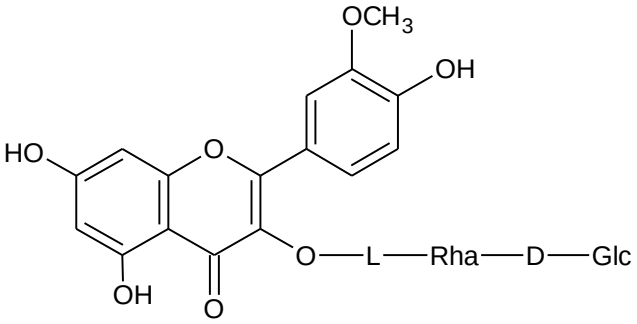
Figure 2.65 (Continued)



Kaempferol



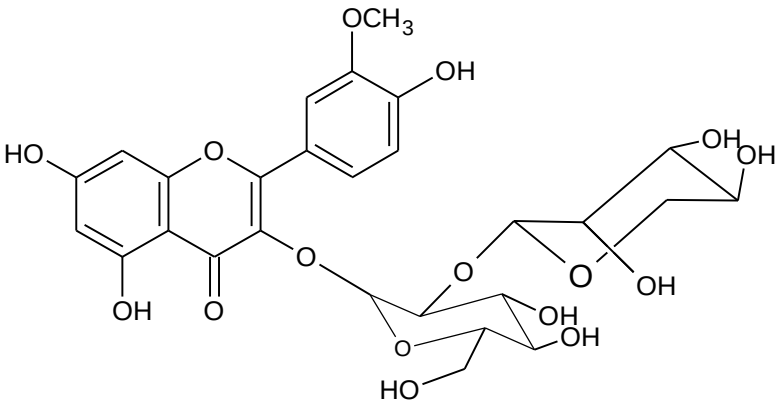
Isorhamnetin 3-*O*-β-D-glucopyranoside



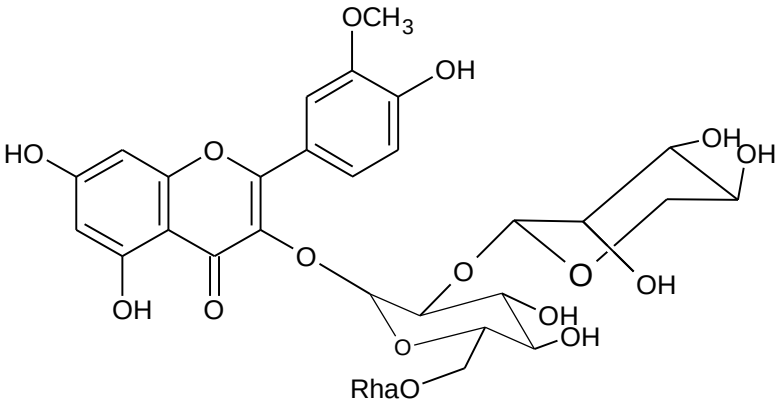
Isorhamnetin-3-*O*-rutinoside

Figure 2.66

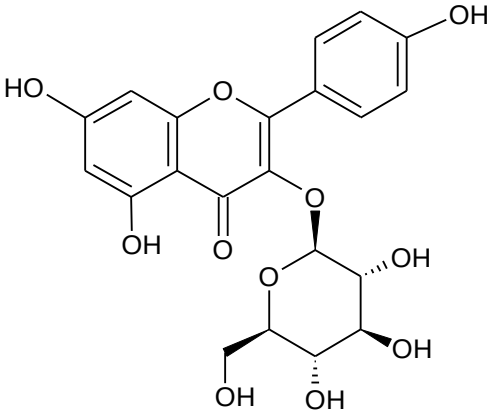
Structures of some chemical constituents found in *Nelumbo nucifera* Gaertn. (Hyun, Jung, Chung, Jung, & Choi, 2006; Jung, Kim, Chung, & Choi, 2003)



Nelumboroside A

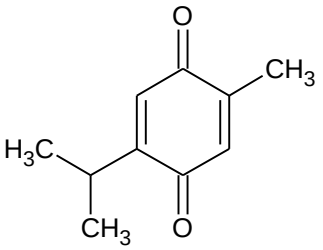


Nelumboroside B

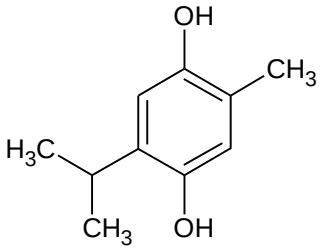


Kaempferol-3-*O*-β-D-glucopyranoside

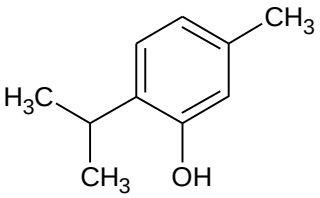
Figure 2.66 (Continued)



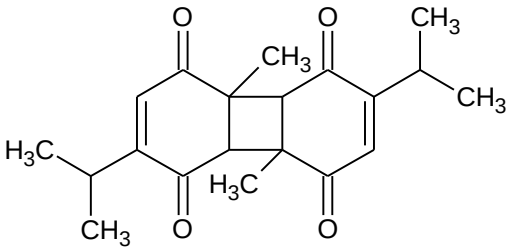
Thymoquinone



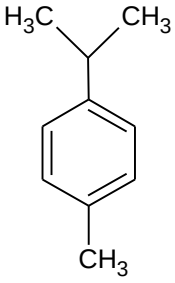
Thylmohydroquinone



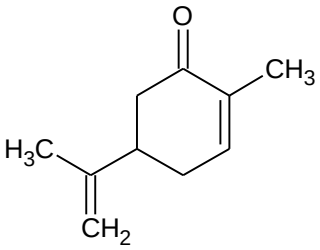
Thymol



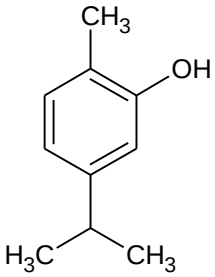
Dithymoquinone



p-Cymene



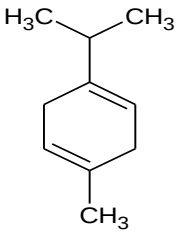
Carvone



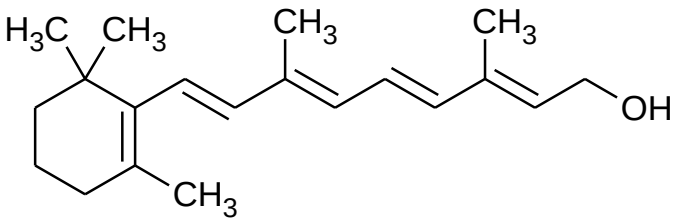
Carvacrol

Figure 2.67

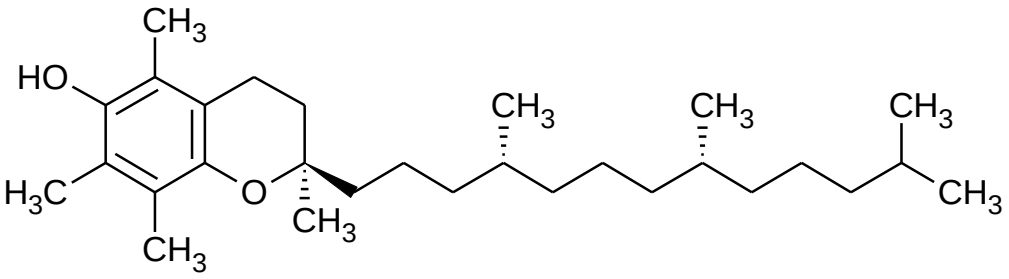
Structures of some chemical constituents found in *Nigella sativa* L. (Al-Saleh, Billedo, & El-Doush, 2006; El-Gazzar et al., 2006; Marsik et al., 2005; Naeini, Khosravi, Chitsaz, Shokri, & Kamlnejad, 2009; Nair, Vasudevan, & Venkitanarayanan, 2005; Salem, 2005; Tippeswamy & Naidu, 2005)



γ-Terpinene

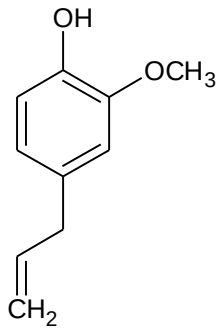


All-*trans*-ratinol (Vitamin A)

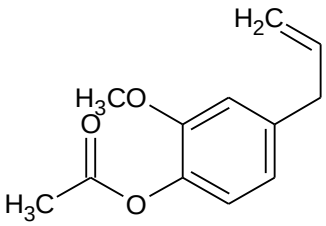


α-Tocopherol (Vitamin E)

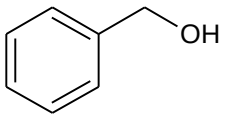
Figure 2.67 (Continued)



Eugenol



Eugenyl acetate
(Acetyleugenol)



Benzyl alcohol

Figure 2.68

Structures of some chemical constituents found in *Syzygium aromaticum* (L.) Merr. et Perry (Kim, Oh, et al., 2003; Lee & Shibamoto, 2001; Oussalah, Caillet, Saucier, & Lacroix, 2007)