CHAPTER 2

LITERATURE REVIEW

2. Literature review

2.1 Botanical aspect of *R. nasutus*

Rhinacanthus nasutus (Linn.) Kurz (*Rhinacanthus communis* Nees) is a plant that belonged to the family of Acanthaceae (Figure 2.1). It is so called in Thai "Thong phan chang" or "Yaa man kai". It widely distributes in Southeast Asia, South China and India (Farnsworth and Bunyapraphatsara, 1992).

The plant is a small shrub with 70-200 cm height. The stems are erect and branched. The leaves are simple, opposite. The shape of the leaves is lanceolate with 2.5 - 5 cm wide and 6 - 10 cm long. The base of leaves is oblique. The leaves are glabrous yellowish green. Flowers are bisexual, zygomorphic petal and white color in short auxiliary clusters. The bract is small. The calyx is divided in to 5 deeply acute parted, light green, 5 - 6 mm long. The corolla tube is bilabiate, upper lip erect, bifid, lower lip 3 lobed. The corolla has brownish purples spots at the throat of the tube. There are 4 stamens with didynamous. The ovary is superior with 2-loculed and ovule free placentation and the fruit is a capsule (Panichayupakaranant *et al*., 2006).

2.2 Ecology and propagation of *R. nasutus*

R. nasutus is locally known and widely distributed in tropical countries. It is scattered along the edges of evergreen forests. *R. nasutus* plants are usually grown as ornamentals and require sandy and well-drained soil. They can be propagated by seeds or cutting.

Figure 2.1 *Rhinacanthus nasutus* (Linn.) Kurz

2.3 Distribution of rhinacanthins in *R. nasutus* and effect of harvesting period

Determination of total rhinacanthin content in the leaves, stems, and roots of *R. nasutus*, which were collected at a different period of times, has demonstrated that rhinacanthins markedly accumulated in the roots and leaves, but less so in the stems of the plant. Regarding the effect of harvesting period, it was found that the leaves and roots harvested in July yielded higher amounts of rhinacanthins. In July, *R. nasutus* is not yet in bloom. Thus, *R. nasutus* leaves and roots should be harvested before blossom. Although the leaves and roots that were harvested in other periods gave a lower content of rhinacanthins, they still passed the lower limit of the total rhinacanthins (Panichayupakaranant *et al*., 2006).

2.4 Ethnomedical uses of *R. nasutus*

R. nasutus has long been used in Thai traditional medicine for skin diseases such as pruritis, tinea versicolor, and ringworm. The traditional recipes for treatment of ringworm are as follows (Farnsworth and Bunyapraphatsara, 1992)

- A tincture is prepared by soaking fresh leaves and roots in alcohol. Then it is applied over the infected area.

- The roots (6 -7 roots) are pounded with match tips and vaseline then it is applied over infect area.

- The roots are pounded with lemon and tamarind juices then the mixture is applied over the infected area.

Pounded roots mix with vinegar or alcohol was applied on herpetic-like eruptions. For the same purpose, the leaves are applied with benzoin and sulfur in Malaysia. In Indonesia, the flowers and young leaves are rubbed with vinegar and lime to the skin (Wiart *et al*., 2000).

2.5 Chemical constituents of *R. nasutus*

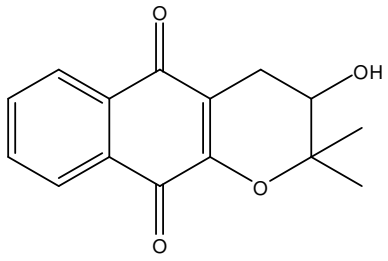
Chemical studies of *R. nasutus* reported on many compounds isolated from different parts of the plant. List of the compounds found in *R. nasutus* is shown in table 2.1. Structures of some compounds are given in Figures 2.2, 2.3, and 2.4.

Table 2.1 Chemical constituents of *Rhinacanthus nasutus*

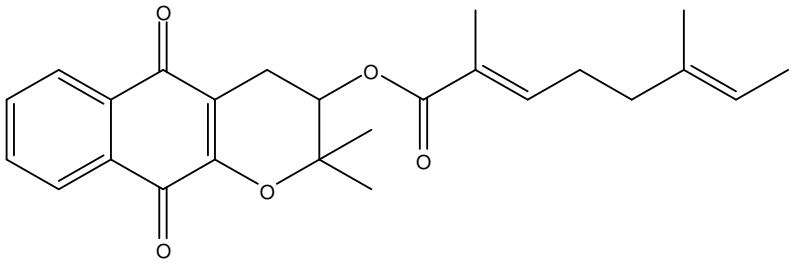
Chemicals	Plant parts	References
1. Naphthoquinones		
1.1 rhinacanthin-A	Roots	Wu *et al*., 1988; Wu *et al*., 1998 [a]; Wu *et al* 1998 [b]; Singh *et al*., 1992
1.2 rhinacanthin-B	Roots	Wu *et al*., 1988; Wu *et al*., 1998 [a]; Wu *et al* 1998 [b]
1.3 rhinacanthin-C	Whole plants	Sendl *et al*., 1996; Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.4 rhinacanthin-D	Whole plants	Sendl *et al*., 1996; Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.5 rhinacanthin-G	Roots	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.6 rhinacanthin-H	Roots	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.7 rhinacanthin-I	Leaves and root	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.8 rhinacanthin-J	Leaves and root	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.9 rhinacanthin-K	Roots	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.10 rhinacanthin-L	Roots	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.11 rhinacanthin-M	Roots	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.12 rhinacanthin-N	Leaves and roots	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.13 rhinacanthin-O	Roots	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]

Chemicals	Plant parts	References
1.14 rhinacanthin-P	Roots	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
1.15 rhinacanthin-Q	Roots	Wu *et al*., 1998 [b]
1.16 rhinacanthone	Leaves and stems	Kodama *et al*., 1993; Kuwahara *et al*., 1995
1.17 dehydro-α-lapachone	Roots	Wu *et al*., 1998 [a]; Wu *et al*., 1998 [b]
2. Lignans		
2.1 rhinacanthin-E	Aerial parts	Kernan *et al*., 1997
2.2 rhinacanthin-F	Aerial parts	Kernan *et al*., 1997
3. Benzenoids		
3.1 *p*-hrdroxy-benzaldehyde	Roots	Wu *et al*., 1998 [b]
3.2 vanillic acid	Leaves and stems	Wu *et al*., 1995
3.3 syringic acid	Leaves and stems	Wu *et al*., 1995
3.4 2-methoxy-4 - propionylphenol	Leaves and stems	Wu *et al*., 1995
3.5 methyl valinate	Roots	Wu *et al*., 1998 [b]
3.6 syringaldehyde	Roots	Wu *et al*., 1998 [b]
4. Anthraquinone		
4.12-methyl anthraquinone	Leaves and stems	Wu *et al*., 1995
5. Triterpenoids		
5.1 β-amyrin	Roots	Wu *et al*., 1995
5.2 glutinol	Roots	Wu *et al*., 1995
5.3 lupeol	Roots	Wu *et al*., 1988; Wu *et al*., 1995; Wu *et al*., 1998 [b]
6. Flavonoids		
6.1 wogonin	Roots	Wu *et al*., 1998 [b]
6.2 oroxylin A	Roots	Wu *et al*., 1998 [b]
6.3 rutin	Flowers	Subramanian *et al*, 1981

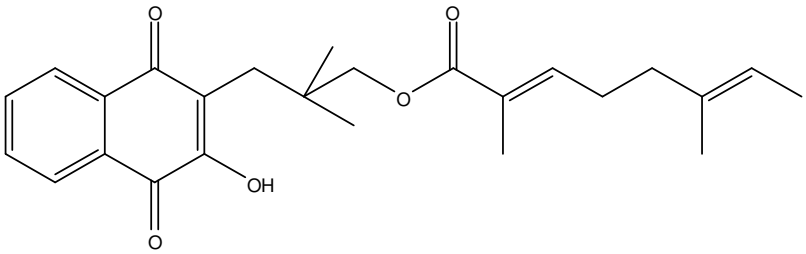
Chemicals	Plant parts	References
7. Sterols		
7.1 stigmasterol	Roots	Wu *et al*., 1988
7.2 *β*-sitosterol	Roots	Wu *et al*., 1988
8. Chlorophyll		
8.1 methylpheophorbide-A	Leaves and stems	Wu *et al*., 1995
9. Coumarins		
9.1 (+)-praeruptorin	Roots	Wu *et al*., 1998 [b]
9.2 umbelliferone	Leaves and stems	Wu *et al*., 1995
10. Amide		
10.1 allantoin	Roots	Wu *et al*., 1998 [b]
11. Carbohydrate		
11.1 methyl-*α*-D-galactopyranoside	Leaves and stems	Wu *et al*., 1995
12. Quinol		
12.1 4-acetonyl-3,5-dimethoxy-*p*-quinol	Leaves and stems	Wu *et al*., 1995
13. Benzoquinone		
13.1 2,6-dimethoxy benzoquinone	Leaves and stems	Wu *et al*., 1995
14. Glycosides		
14.1 sitosterol-*β*-D-glucopyranoside	Leaves and stems	Wu *et al*., 1995
14.2 stigmasterol-*β*-D-glucopyranoside	Leaves and stems	Wu *et al*., 1995
14.3 3,4-dimethylphenol-*β*-D-glucopyranoside	Leaves and stems	Wu *et al*., 1995
14.4 3,4,5-trimethylphenol -*β*-D-glucopyranoside	Leaves and stems	Wu *et al*., 1995



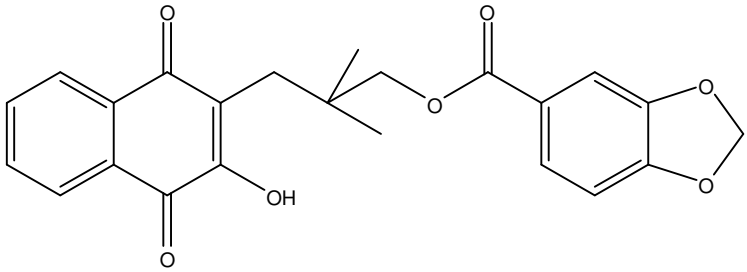
rhinacanthin-A



rhinacanthin-B

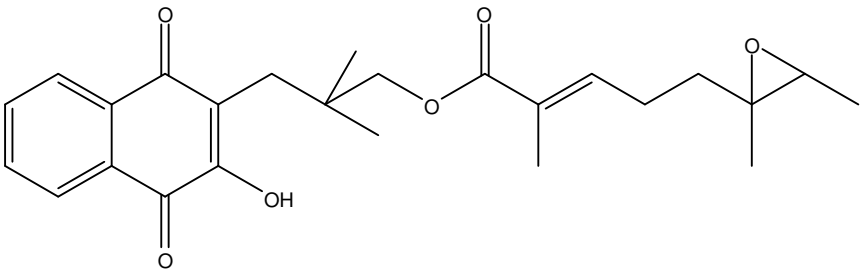


rhinacanthin-C

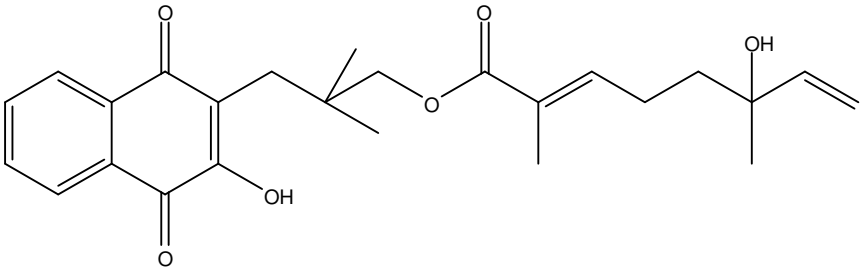


rhinacanthin-D

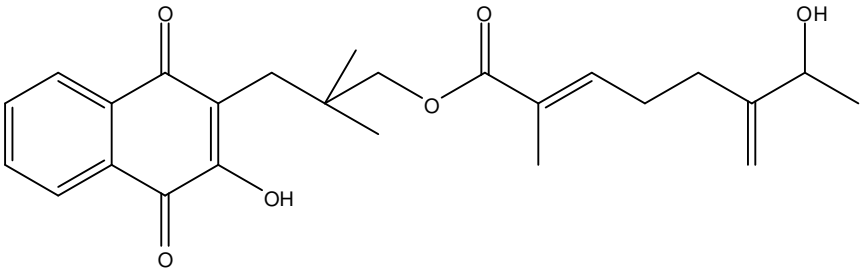
Figure 2.2 Structure of rhinacanthins



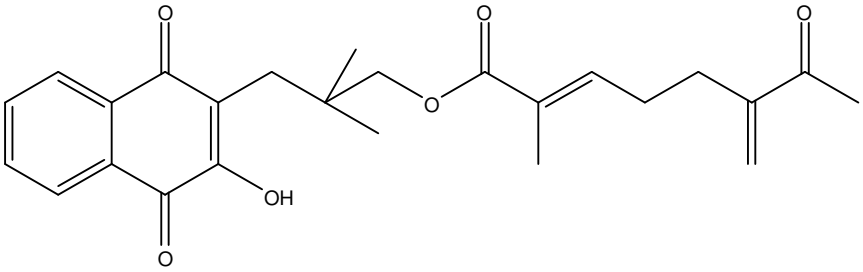
rhinacanthin-G



rhinacanthin-H

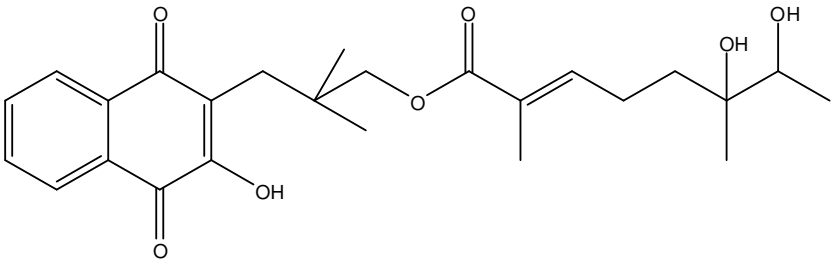


rhinacanthin-I

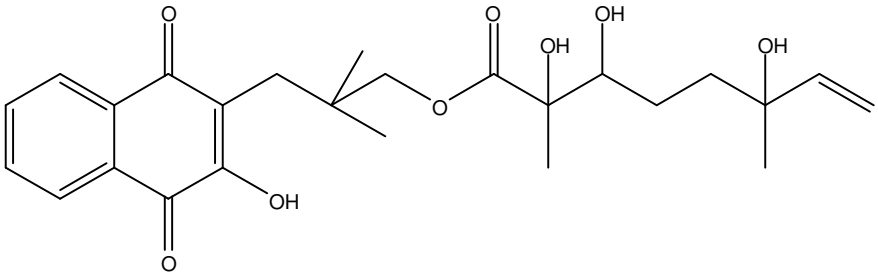


rhinacanthin-J

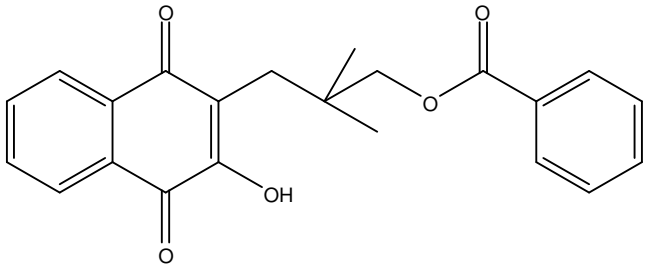
Figure 2.2 Structure of rhinacanthins (continued)



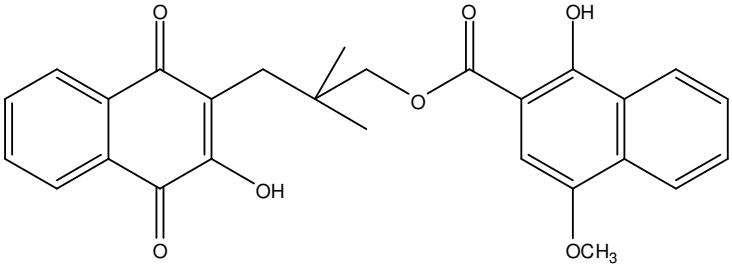
rhinacanthin-K



rhinacanthin-L

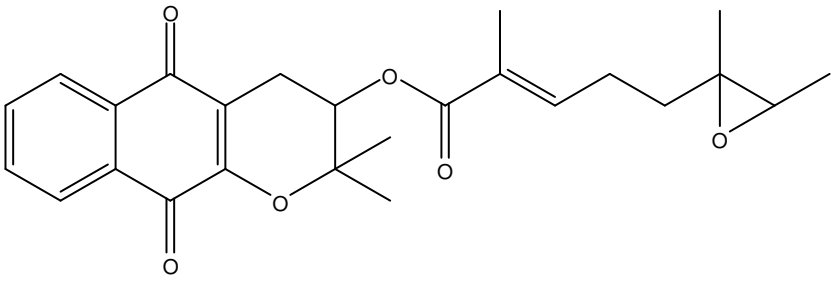


rhinacanthin-M

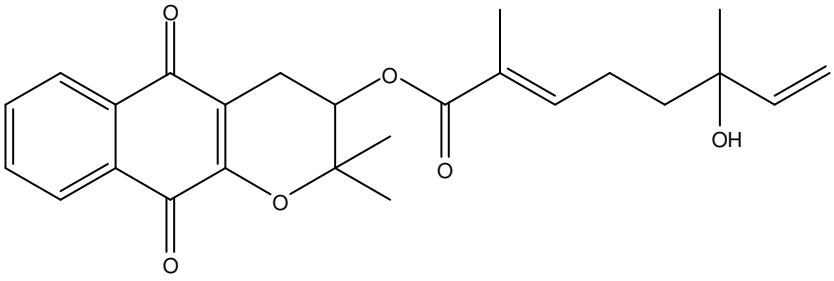


rhinacanthin-N

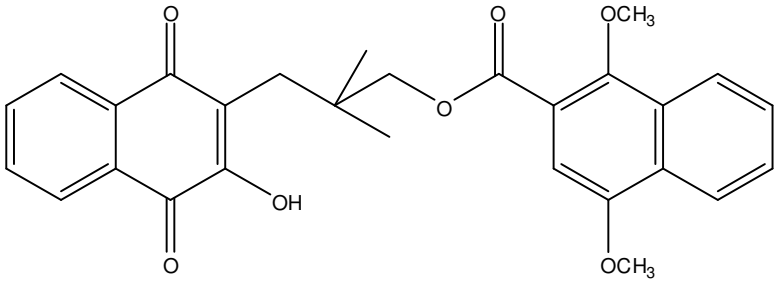
Figure 2.2 Structure of rhinacanthins (continued)



rhinacanthin-O

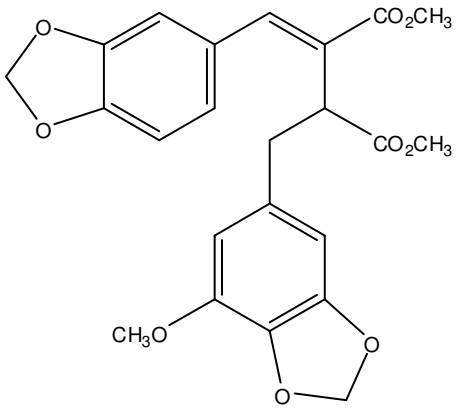


rhinacanthin-P



rhinacanthin-Q

Figure 2.2 Structure of rhinacanthins (continued)



rhinacanthin-E: Δ7E

rhinacanthin-F: Δ7Z

Figure 2.3 Structure of lignans

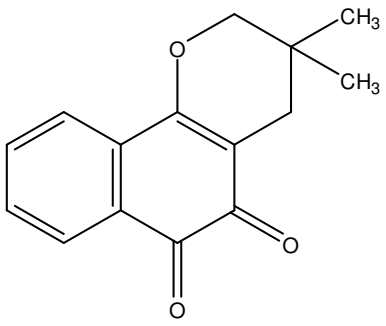
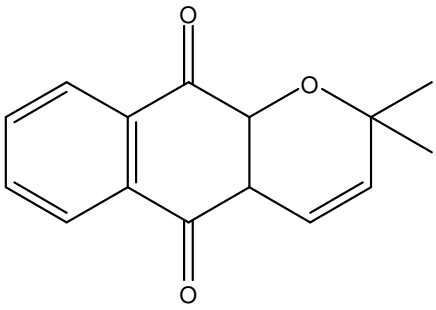
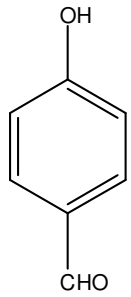


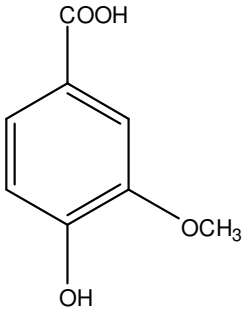
Figure 2.4 Structure of rhinacanthone



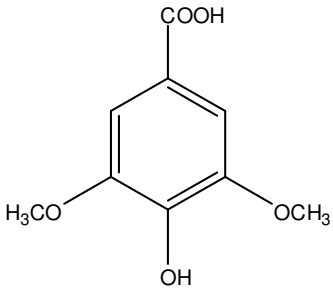
Dehydro-α-lapachone



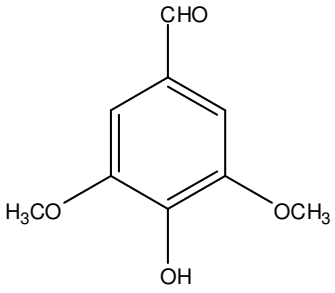
P-hydroxy benzaldehyde



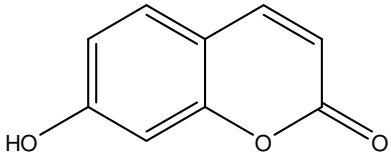
Vanillic acid



Syringic acid

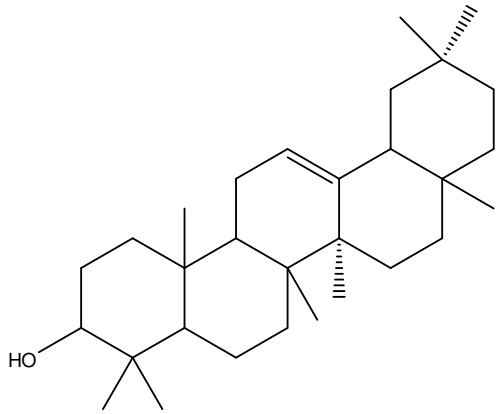


Syringaldehyde

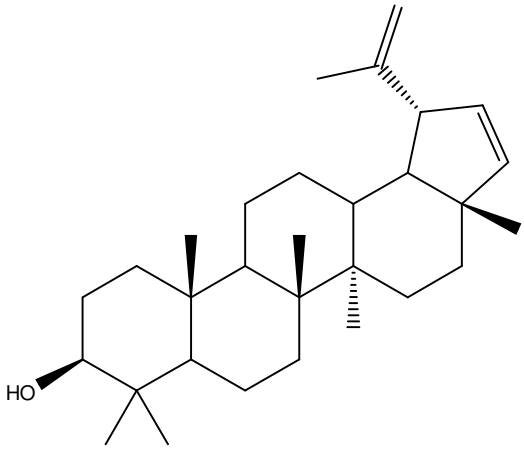


Umbelliferone

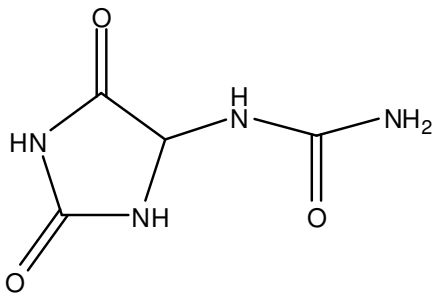
Figure 2.5 Structure of other substances in *R. nasutus*



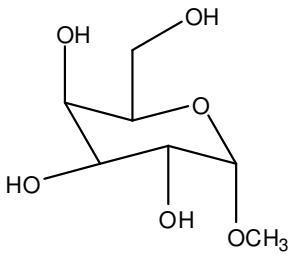
β-amyrin



Lupeol

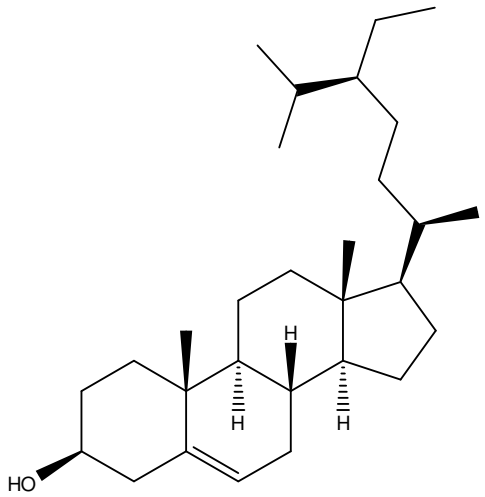


Allantoin

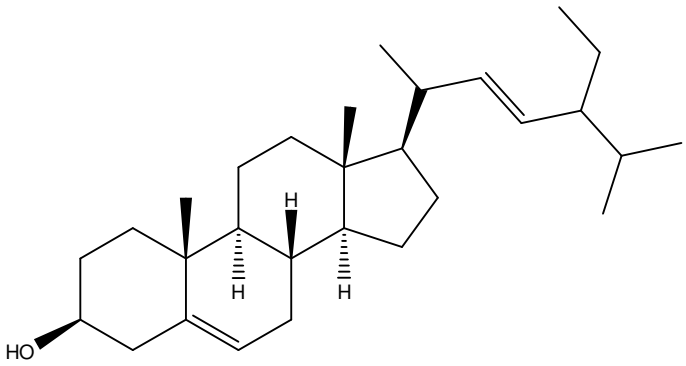


Methyl-α-D-galactopyranoside

Figure 2.5 Structure of other substances in *R. nasutus* (continued)

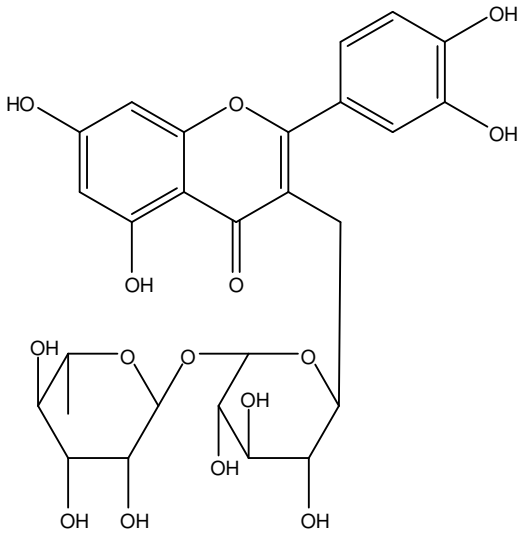


β-sitosterol

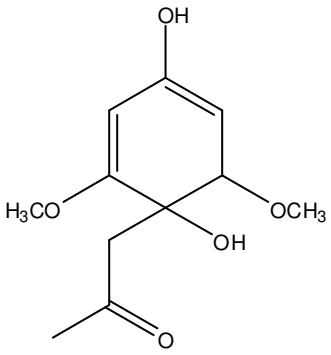


Stigmasterol

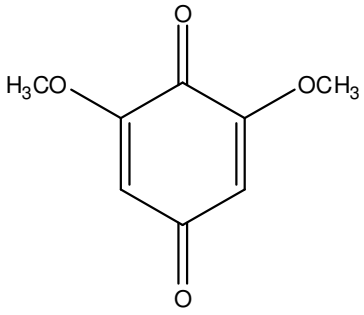
Figure 2.5 Structure of other substances in *R. nasutus* (continued)



Rutin

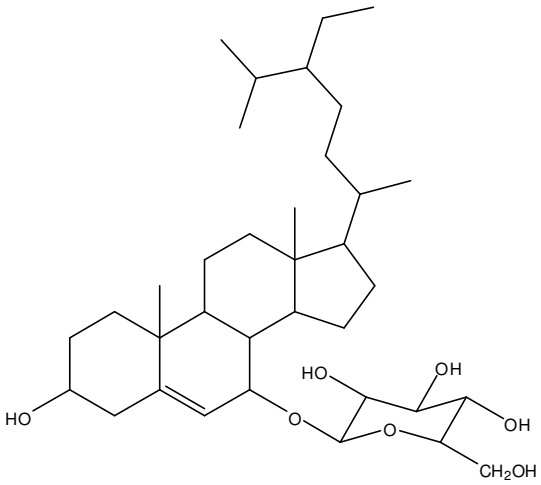


4-acetonyl-3,5-dimethoxy-*p*-quinol

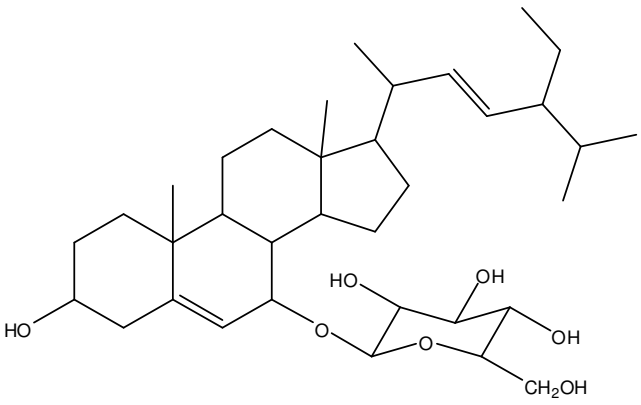


2,6-dimethoxy benzoquinone

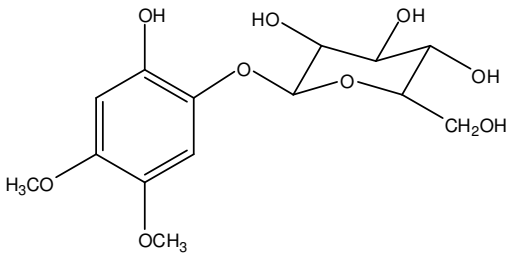
Figure 2.5 Structure of other substances in *R. nasutus* (continued)



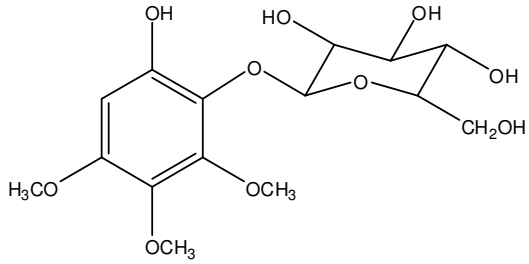
Sitosterol-β-D-glucopyranoside



Stigmasterol-β-D-glucopyranoside



3,4-dimethylphenol-β-D-glucopyranoside



3,4,5-trimethylphenol-β-D-glucopyranoside

Figure 2.5 Structure of other substances in *R. nasutus* (continued)

2.6 Biological activity of *R. nasutus* and rhinacanthins

It has been reported that *R. nasutus* extract and compounds isolated from this plant exhibited the interesting biological activities as follows:

Antifungal activity

The *R. nasutus* extract possessed an antifungal activity against *Microsporum gypseum, Microsporum canis, Trichophyton rubrum, Trichophyton mentagrophytes, Epidermophyton floccosum, Candida albicans, Cryptococcus neoformans* and *Saccharomyces* spp. (Farnsworth and Bunyapraphatsara, 1992; Kodama *et al*., 1993; Akatsuka *et al.*, 2006; Panichayupakaranant *et al.*, 2000; Darah and Jain, 2001). It has been demonstrated that the water extract of *R. nasutus* leaves and stems exhibited the lowest antifungal activity, while the chloroform and 95% ethanol extracts showed similarly inhibitory activity against filamentous fungi (Farnsworth and Bunyapraphatsara, 1992).

The minimum inhibitory concentration (MIC) value of the leaf extract against *T. mentagrophytes* var. *mentagrophytes*, *T. mentagrophytes* var. *interdigitate*, *T. rubrum*, *M. gypseum* was reported at 13.6 mg/mL. The leaf extract exhibited fungistatic activity at lower concentration (<13.6 mg/mL) and fungicidal activity at higher concentration (>13.6 mg/mL). Moreover, it has been suggested that *R. nasutus* leaf extract acted on the cell wall of dermatophytes which subsequently leading to the degeneration of cytoplasm and membrane structure and finally leading to cell lysis and death (Darah and Jain, 2001).

Rhinacanthone, also has been demonstrated to be an antifungal active compound, which exhibited inhibitory action on the spore germination of *Pyricularia oryzae* (Kuwahara *et al*., 1995).

There is a report that shows antifungal activity of rhinacanthin-C, -D, and -N in *R. nasutus* leaf extract against *M. gypseum, T. rubrum,* and *T. mentagrophytes* that cause tinea in

human. The MIC values were showed in the Table 2.2 (Kongchai and Panichayupakaranant, 2002).

Table 2.2 Antifungal activity of naphthoquinones isolated from the leaves of *R. nasutus*

Compound	MIC (μg/mL)		
	T. rubrum	*T. mentagrophytes*	*M. gypseum*
Rhinacanthin-C	31.2	31.2	125
Rhinacanthin-D	62.5	62.5	250
Rhinacanthin-N	125	125	250

In addition, there is a report that show antifungal activity of rhinacanthin-C, -D, and -N in *R. nasutus* leaf extract against *Candida albicans* and MIC values are 512, 64, and 64 μg/mL, respectively (Panichayupakaranant *et al*., 2000).

Antibacterial activity

The leaf and stem extract of *R. nasutus* exhibited inhibitory activity against oral *Streptococcus* spp. (22 isolates strains), which were isolated from dental plaque of 25 patient cases. It was found that the MIC of the extract was 3.8 ng/mL (Apisariyakul *et al*., 1991).

Furthermore, studies on antibacterial activity of 75% ethanolic *R. nasutus* leaves extract against gram positive bacteria such as *Bacillus cereus, Bacillus globigii, Bacillus subtilis*c, and *Staphylococcus aureus* and gram negative bacteria such as *Proteus morgani, Proteus mirabilis, Salmonella typhi, Pseudomonas aeruginosa,* and *Escherichia coli* by conventional agar plate-diffusion method showed that the extract can inhibit only gram positive bacteria (Sattar *et al*., 2004).

Antiviral activity

Sendl and his group had studied antiviral activity of rhinacanthin-C and rhinacanthin-D against cytomegalovirus in mice (mCMV) and human (hCMV), influenza virus type A, herpes simplex virus type 2 and respiratory syncytial virus compared with gancyclovir, amantadine, acyclovir, and ribavirin. The result showed a good activity of rhinacanthin-C and rhinacanthin-D against hCMV with the IC_{50} values of 0.02 and 0.22 µg/mL, respectively (Sendl *et al*., 1996).

In addition, rhinacanthin-E and rhinacanthin-F, which were isolated from the aerial parts of *R. nasutus* showed significant antiviral activity against influenza virus type A, which IC_{50} values of 7.4 and 3.1 µg/mL, respectively (Kernan *et al*., 1997).

Cytotoxic activity

The methanol *R. nasutus* extract and rhinacanthin-B isolated from the root of *R. nasutus* showed significant cytotoxicity against human KB tumor cell (human epidermoid carcinoma), rhinacanthin-B showed the ED_{50} value of 3.0 µg/mL (Wu *et al*., 1988).

The naphthoquinones and flavonoid including rhinacanthin-A, -B, -C, -G, -H, -I, -K, -M, -N, -Q, and wogonin, isolated from the root of *R. nasutus* showed significant cytotoxic activity against murine leukemia (P-388), human lung carcinoma (A-549), human colon adenocarcinoma (HT-29), and leukemia (HL-60) cells with the ED_{50} values as shown in Table 2.3 (Wu *et al*., 1998[b]).

Panichayupakaranant and his group had studied antitumor activity of rhinacanthins in *R. nasutus* leaves against HeLa (human cervical carcinoma) and MCF (human Caucasian breast adenocarcinoma). Rhinacanthin-C showed the ED_{50} values of 0.85 and 1.02 µg/mL, rhinacanthin-D showed the ED_{50} values of 14.54 and 3.34 µg/mL, and rhinacanthin-N

showed the ED_{50} values of 1.59 and 2.78 μg/mL against HeLa and MCF cell lines, respectively (Panichayupakaranant, 2003).

Table 2.3 Cytotoxic activity of naphthoquinones and flavonoid from the roots of *R. nasutus*

Compounds	Cell lines ED_{50} (μg/mL)				
	KB	P-388	A-549	HT-29	HL-60
Rhinacanthin-A	6.75	0.72	3.06	2.17	1.16
Rhinacanthin-B	8.01	0.35	6.50	3.01	2.57
Rhinacanthin-C	6.26	0.26	0.35	0.68	0.68
Rhinacanthin-D	25.0	3.79	8.26	8.89	11.8
Rhinacanthin-G	4.45	0.14	0.75	0.57	1.14
Rhinacanthin-H	23.8	6.43	9.97	11.5	8.87
Rhinacanthin-I	13.2	4.88	7.18	6.30	5.12
Rhinacanthin-K	17.3	3.17	16.4	7.75	6.81
Rhinacanthin-M	19.2	3.95	8.90	10.1	19.9
Rhinacanthin-N	4.80	0.71	1.97	2.67	1.38
Rhinacanthin-Q	>50	0.61	3.61	7.60	8.90
Wogonin	4.46	1.70	4.14	3.35	4.66

The rhinacanthin-M, -N, and -Q synthesized from esterification of naphthoquinone-3-(propan-3′-ols) with benzoic or naphthoic acids showed significant cytotoxic activity against KB, HeLa (human cervical carcinoma), and $HepG_2$ (human hepatocellular carcinoma) cell lines with the ED_{50} values as shown in Table 2.4 (Kongkathip *et al*., 2004).

Table 2.4 Cytotoxic activity of rhinacanthin-M, -N, and -Q

Compounds	Cell lines ED_{50} (μg/mL)		
	KB	HeLa	$HepG_2$
Rhinacanthin-M	1.53	3.02	4.85
Rhinacanthin-N	<0.22	0.30	0.38
Rhinacanthin-Q	0.35	1.09	0.97

The antitumour activity of rhinacanthone against Dalton's ascetic lymphoma (DAL) in mice has been reported (Thirumurugan *et al*., 2000). A significant enhancement of mean survival time of tumor bearing mice and peritoneal cell count in normal mice was observed with respect to the control group.

Gotoh and his group had studied *in vitro* antiproliferative activity of leaf and root extract of *R. nasutus* and rhinacanthin-C against human cervix adenocarcinoma (Hela), MDR 1-overexpressing subline of human cervical carcinoma (Hvr100-6), human prostatic cancer cell (PC-3), and human bladder carcinoma (T24) cell lines. The result showed antiproliferative activities with the IC_{50} values as shown in Table 2.5 (Gotoh *et al*., 2004).

Table 2.5 *In vitro* antiproliferative activities of the *R. nasutus* extract and rhinacanthin-C in tested cell lines

Compounds	IC_{50}			
	HeLa	Hvr100-6	PC-3	T24
Root extract (µg/mL)	1239	977	567	373
Leaf extract (µg/mL)	1499	1582	359	616
Rhinacanthin-C (µM)	26.2	11.2	1.92	0.66

In vivo antiproliferative activity was also observed. Sarcoma180-bearing ICR mice were used to assess the experiment. The ethanol extract of root and aqueous extract of leaves of *R. nasutus* showed significant antiproliferative activity with inhibition of 52.5 % and 44.2 %, respectively (Gotoh *et al*., 2004).

Rhinacanthin-C, -N, and -Q isolated from the roots of *R. nasutus* were capable of inhibiting cell proliferation and induced apoptosis of human cervical carcinoma (HeLS3) cells in a dose and time dependent manners. It can be considered that the antitumor efficacy of rhinacanthin drugs results from multiple of actions, such as interfering with cell cycle progression, inducing apoptosis mediated by the activation of caspase3 activity as well as targeting DNA topoisomerase II of tumor cells (Siripong *et al*., 2006).

Immunomodulatory activity

The ethanol extract of *R. nasutus* leaf and stem with lipopolysaccharide (LPS) exhibited an induction of NO and TNF-α production. These may augment macrophage function and thus contribute to cytotoxicity towards viruses, other pathogens and tumor cells (Punturee *et al*., 2004).

Hypotensive activity

The extract obtained from hot water maceration (decoction) was studied in anesthetized rats for their pharmacological action. The hypotensive activity of *R. nasutus* extract was found to increase with correlation to the amount of the extract (วรรณดี แต้โสตถิกุล, 2528).

Antioxidant activity

Food, cosmetics, and pharmaceuticals containing *R. nasutus* extract are reported to have antioxidant activity. The mechanism is to remove superoxide from the human body. Cosmetic containing the extract may be useful to reduce aging and hair loss (Wiart *et al*., 2000).

Antiplatelet activity

The antiplatelet aggregation of naphthoquinone, isolated from the roots of *R. nasutus* including rhinacanthin-A, -B, -C, -G, -H, -I, -K, -M, and -Q has been reported. These compounds demonstrated 36 – 100 % inhibition of rabbit platelet aggregation induced by arachidonic acid (100 mM). Rhinacanthin-A, -B, and -C (10 μg/mL) showed 72 – 100 % inhibition of the rabbit platelet aggregation induced by collagen, while rhinacanthin-B (2 ng/mL) inhibited platelet aggregation induced by platelet activation factor (Wu *et al*., 1998 [b]).

Insect attraction and signaling properties

The ether extract of the roots of *R. nasutus* exhibited the properties of an insect attractant and signaling to male Mediterranean fruit flies but showed equivocal results on *Aspiculurus tetraptera*, both male and female melon flies and oriental fruit flies (*Dacus dorsalis*) (Farnsworth and Bunyapraphatsara, 1992).

Juvenile hormone activity

The ether extract of *R. nasutus* roots, at a dose of 500.0 µg/animal exhibited juvenile hormone activity on *Oncopeltus fasciatus*, but no activity was observed at a dose of 250.0 µg/animal (Farnsworth and Bunyapraphatsara, 1992).

2.7 Toxicity test of *R. nasutus*

There is a study of acute toxicity of *R. nasutus* by feeding the mice with 50 % ethanol of *R. nasutus* extract and by injecting the *R. nasutus* extract with 10 g/kg (animal) but there is no toxicity (นันทวัน บุณยะประภัศร, 2530; 2541).

2.8 Formulation of *R. nasutus* cream

The antifungal creams prepared from the extract of *R. nasutus* was established and showed satisfactory physical appearance and antifungal activity against *T. rubrum, T. mentagrophtes*, and *M. gypseum*. The most suitable preparation that possessed satisfactory stability contained of *R. nasutus* leaf extract, cetyl alcohol, stearyl alcohol, glyceryl monostearate, cetomacrogol 1000, soft paraffin, mineral oil, glycerin, paraben concentrate, and water (Kongchai, 2004).

2.9 Dermatophytes

Dermatophytes are fungi that infect skin, hair, and nails due to their ability to utilize keratin (Gupta *et al*., 1998). The organisms colonize the keratin tissues. Inflammation is then caused by host response to metabolic by-products. The dermatophytes consist of three genera:

Epidermophyton spp. The macroconidia are broadly clavate with typically smooth, thin to moderately thick walls and one to nine septa, with 20 - 60 x 4 - 13 µm in size. They are usually abundant and borne singly or in clusters. Microconidia are absent. This genus has only two known species to date, and only *E. floccosum* is pathogenic.

Microsporum spp. Macroconidia is characterized by the presence of rough walls which may be asperulate, echinulate, or verrucose (Weitzman and Summerbell, 1995). There are 19 described species but only 9 (*Microsporum audouinii, Microsporum canis, Microsporum cooeki, Microsporum ferrugineum, Microsporum gallinae, Microsporum gypseum, Microsporum nanum,* and *Microsporum persicolor*) are involved in human or animal infections.

Trichophyton spp. Macroconidia, which have smooth, usually thin walls and one to 12 septa, are borne singly or in clusters. They may be elongate and pencil shaped, clavate, fusiform, or cylindrical. Their size is in the range of 8 - 86 x 4 - 14 µm. Microconidia, usually more abundant than macroconidia, may be globose, pyriform or clavate, or sessile or stalked, and borne singly along the sides of the hyphae or in grape-like clusters (Weitzman and Summerbell, 1995). There are 20 species (*Trichophyton ajelloi, Trichophyton concentricum, Trichophyton equinum, Trichophyton erinacei, Trichophyton flavescens, Trichophyton gloriae, Trichophyton interdigitale, Trichophyton megnini, Trichophyton mentagrophytes, Trichophyton phaseoliforme, Trichophyton rubrum, Trichophyton schoenleinii, Trichophyton simii, Trichophyton soudanense, Trichophyton terrestre, Trichophyton tonsurans, Trichophyton Vanbreuseghemii, Trichophyton verrucosum, Trichophyton violaceum,* and *Trichophyton yaoundei*) causing infections in humans or animals.

2.10 Dermatophyte infection

Dermatophytes invade the stratum corneum or keratinized structure derived from the epidermis, causing skin lesions, hair and nail infection (Duek *et al*., 2004). Dermatophyte infections are commonly known as ringworm because the appearance of the lesions led to the erroneous belief that the infected skin harbored worms beneath its surface. Ringworm infections are named "tinea" followed by a second word that designates the infected site. For example, tinea capatis is ringworm of scalp; tinea corporis is ringworm of the body; tinea pedis is the disease popularly known as athlete's foot; tinea cruris is jock itch; and tinea unguium is ringworm of the nails (Mckanne and Kandel, 1996). Tinea pedis is the most common type of dermatophyte infection in the US and the rest of the world. Tinea capatis is one of the most common infections in children (Weinstein and Summerbell, 2002). *T. rubrum* is the most common cause of tinea corporis, tinea cruis, tinea pedis, and nail infection worldwide (Wilson and Sande, 2001; Weinstein and Summerbell, 2002).