1 INTRODUCTION

1.1 Introduction

Garcinia dulcis Kurz. (Guttiferae) grows widely in the tropical rain forest area in Thailand. Its local name is Ma-phut (มะพูด) (เต็ม, 2523). *G. dulcis* is a medium-size tree about 20-40 feet tall. The trunk is simple straight, the branches 4 angled. Leaves are deep green coriaceous ovate-oblong, shortly acuminate, base rounded; nerves 10 pairs, inarching near edge, not very prominent 5-10 inches long, 1.75-4.5 inches wide; petioles 0.4-0.6 inches long stout. Flowers are greenish yellow with 0.25 inches diameter, unisexual or male and bisexual mixed, in dense many-flowered fascicles in the leaf axils; pedicels 0.25-0.35 inches long. Fruits are 2.5-3.0 inches long globular, ovoid or pear-shaped, peduncled, pulpy yellow. Seeds are 1-5 oblong. Fruits can be eaten raw or cooked. Fruiting April-July (The Flora of the Malay Peninsula, 1967).

Figure 1 *Garcinia dulcis* Kurz.

1.2 Review of literatures

1.2.1 Chemical constituents from the genus Garcinia

The genus *Garcinia* (family Guttiferae, sub-family Clusiodeae), which is mainly encountered in lowland rain forests of the tropical world and are found from sea level to the tops of the highest mountains, are well known to be rich in a variety of compounds such as benzophenones (Chiang, 2003; Ito, 2003a; Lakshmi, 2002; Cuesta, 2001; Huang, 2001; Ali, 2000), benzophenones-xanthone dimers (Kosela, 2000), biflavones (Permana, 2003; Okunii, 2002; Thoison, 2000), chalcone (Ilyas, 2002), lactone (Mackeen, 2002), xanthones (Chanmahasathien, 2003a,b; Chiang, 2003; Ito, 2003b; Nguyen, 2003; Rukachaisirikul, 2003a,b; Nilar and Harrison, 2002; Suksamrarn, 2002; Huang, 2001; Ito, 2001; Wu, 2001; Xu, 2001; Gopalakrishnan and Balaganesan, 2000; Nguyen and Harrison, 2000; Okudaira, 2000; Rukachaisirikul, 2000b; Thoison, 2000; Kosela, 2000) and triterpenes (Nguyen and Harrison, 2000; Rukachaisirikul, 2000a; Thoison, 2000). The chemical constituents which were isolated from this genus before 2002 were summarized in the thesis of Dudsadee Sukavisite (2003). The additional constituents of the *Garcinia* genus from 2002-2004, according to the information from NAPRALERT database developed by University of Illinois at Chicago and Chemical Abstracts were summarized in **Table 1**.

Table 1 Isolated compounds from the genus *Garcinia* (2002-2004)

Scientific name (Investigated part)	**Compound**	**Structure**	**Reference**
G. assigu			
(stem bark)	clusianone	1	Ito, *et al*.,
	garcinol	2	2003a
	garcinol 13-*O*-methyl ether	3	
	isogarcinol	5	
	isogarcinol 13-*O*-methyl ether	6	
	maclurin	12	
G. atroviridis			
(fruits)	2-butoxycarbonylmethyl-3-butoxy carbonyl-2-hydroxy-3-propanolide	28	Mackeen, *et al*., 2002
	1′,1′′-dibutylmethylhydroxycitrate	-	
(roots)	(14*Z*)-14-docosenoic acid	115	Permana,
	fukugiside	21	*et al*., 2003
	4-methylhydroatrovirinone	25	
	morelloflavone	19	
	morelloflavone 7-*O*-*β*-D-glucopyranoside	20	
G. cuneifolia			
(stem bark)	cuneifolin	72	Ee, *et al*.,
	stigmasterol	114	2003

Table 1 (Continued)

Scientific name (Investigated part)	Compound	Structure	Reference
G. fusca			
(stem bark)	cowanin	84	Ito, *et al*.,
	cowanol	85	2003b
	cowaxanthone	86	
	fuscaxanthone A	74	
	fuscaxanthone B	82	
	fuscaxanthone C	76	
	fuscaxanthone D	77	
	fuscaxanthone E	39	
	fuscaxanthone F	40	
	fuscaxanthone G	75	
	fuscaxanthone H	83	
	α-mangostin	79	
	β-mangostin	78	
	7-*O*-methylgarcinone	64	
	norcowanin	73	
	rubraxanthone	87	
G. indica			
(seed)	fatty acid	-	Daniel, *et al*., 2003
(stem bark)	isoxanthochymol	4	Lakshmi,
	xanthochymol	7	*et al*., 2002

Table 1 (Continued)

Scientific name (Investigated part)	Compound	Structure	Reference
G. kola (seeds)	GB-1	16	Okunii, *et al*., 2002
	GB-1 7″-*O*-glucoside	17	
	GB-2	18	
	kolaflavanone	15	
G. macrophylla (twigs)	friedelin	113	Williams, *et al*., 2003
	guttiferone A	8	
	guttiferone G	9	
G. mangostana (green fruit hulls)	(-)-epicatechin	27	Suksamrarn, *et al*., 2002
	garcinone B	66	
	mangostanol	81	
	mangostenol	88	
	mangostenone A	91	
	mangostenone B	93	
	α-mangostin	79	
	β-mangostin	78	
	mangostinone	31	
	tovophyllin B	94	
	trapezifolixanthone	30	

Table 1 (Continued)

Scientific name (Investigated part)	Compound	Structure	Reference
G. mangostana			
(fruit hulls)	8-desoxygartanin	34	Ho, *et al*.,
	garcinone E	63	2002
	gartanin	68	
	α-mangostin	79	
	γ-mangostin	80	
	tovophyllin A	65	
(heartwood)	1-(OH)-8-(2-(OH)-3-methyl-3-butenyl)-3,6,7-tri(OMe)-2-(3-methyl-2-butenyl)xanthone	51	Nilar and Harrison, 2002
	(16*E*)-1-(OH)-8-(3-(OH)-3-methyl-1-butenyl)-3,6,7-tri (OMe)-2-(3-methyl-2-butenyl) xanthone	52	
	1-(OH)-2-(2-(OH)-3-methyl-3-butenyl)-3,6,7-tri(OMe)-8-(3-methyl-2-butenyl)xanthone	53	
	1,6-di(OH)-2-(2-(OH)-3-methyl-3-butenyl)-3,7-di(OMe)-8-(3-methyl-2-butenyl)xanthone	54	

Table 1 (Continued)

Scientific name (Investigated part)	Compound	Structure	Reference
G. mangostana (heartwood)	(16*E*)-1,6-di(OH)-8-(3-(OH)-3-methyl-1-butenyl)-3,7-di(OMe)-2-(3-methyl-2-butenyl) xanthone	55	Nilar and Harrison, 2002
	1,6-di(OH)-8-(2-(OH)-3-methyl-3-butenyl)-3,7-di(OMe)-2-(3-methyl-2-butenyl)xanthone	56	
	1,3-di(OH)-2-(2-(OH)-3-methyl-3-butenyl)-6,7-di(OMe)-8-(3-methyl-2-butenyl)xanthone	57	
	1,6-di(OH)-3,7-di-(OMe)-2-(3-methyl-2-butenyl)xanthone	58	
	1,6-di(OH)-3,7-di-(OMe)-2-(3-methyl-2-butenyl)-8-(2-oxo-3-methyl-3-butenyl)xanthone	59	
	garciniafuran	99	
	mangostanin	100	
	β-mangostin	78	
	6-*O*-methylmangostanin	101	

Table 1 (Continued)

Scientific name (Investigated part)	Compound	Structure	Reference
G. merguensis (bark)	8-desoxygartanin	34	Nguyen, *et al*., 2003
	6-deoxyjacareubin	29	
	6-deoxyisojacareubin	45	
	1,5-di(OH)-6′-methyl-6′-(4-methyl-3-pentenyl)pyrano (2′,3′:3,2)xanthone	48	
	merguenone	32	
	morusignin G	38	
	rheediachromenoxanthone	47	
	rheediaxanthone A	95	
	subelliptenone H	71	
	1,3,5-tri(OH)-4,8-di-(3-methyl-2-butenyl)xanthone	35	
G. multiflora (stems)	6,3′-di(OH)-2,4-di(OMe) benzophenone	14	Chiang, *et al*., 2003
	3,8-di(OH)-2,4-6-tri(OMe) xanthone	102	
	garcinianone A	69	
	garcinianone B	70	
	maclurin	12	

Table 1 (Continued)

Scientific name (Investigated part)	Compound	Structure	Reference
G. multiflora (stems)	mixture of (1*E*,24*Z*)-1,24-diferuloyloxytetracosane and (1*E*,22*Z*)-1,22-diferuloxyoxydocosane	116	Chiang, *et al*., 2003
	naringenin	26	
	2,4,6,3′-tetra(OH)benzophenone	13	
	4,6,3′,4′-tetra(OH)-2-(OMe) benzophenone	11	
	4,6,4′-tri(OH)-2,3′-di(OMe)-3-prenylbenzophenone	10	
G. nervosa (leaves)	5′-Br-2′-(OH)-4,4′,6′-tri(OMe) chalcone	22	Ilyas, *et al*., 2002
	2′-(OH)-4,4′-di(OMe)chalcone	23	
	2′-(OH)-3,4,4′,6′-tetra(OMe) dihydrochalcone	24	
G. nigrolineata (stem bark)	brasillixanthone	98	Rukachaisiri-kul, *et al*., 2003b
	6-deoxyisojacareubin	45	
	1,5-di(OH)-6′,6′-dimethylpyrano [2′,3′:3,2]xanthone	47	

Table 1 (Continued)

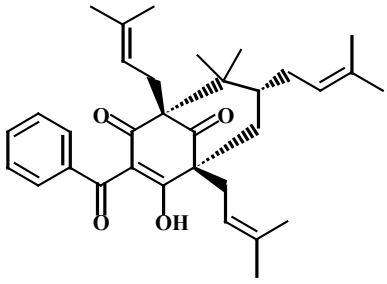
Scientific name (Investigated part)	Compound	Structure	Reference
G. nigrolineata (stem bark)	latisxanthone D	90	Rukachaisiri-kul, *et al*., 2003b
	morusignin C	46	
	nigrolineaxanthone A	41	
	nigrolineaxanthone B	89	
	nigrolineaxanthone C	42	
	nigrolineaxanthone D	36	
	nigrolineaxanthone E	96	
	nigrolineaxanthone F	44	
	nigrolineaxanthone G	97	
	nigrolineaxanthone H	49	
	nigrolineaxanthone I	92	
	rheediaxanthone A	95	
	tovoxanthone	50	
	1,3,5-tri(OH)-4-(3-(OH)-3-methylbutyl)xanthone	43	
	1,3,7-tri(OH)-2-(3-(OH)-3-methylbutyl)xanthone	37	

Table 1 (Continued)

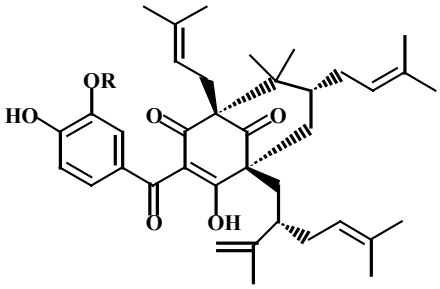
Scientific name (Investigated part)	Compound	Structure	Reference
G. scortechinii (latex)	scortechinone A	103	Rukachaisiri-kul, *et al*., 2003a
	scortechinone B	104	
	scortechinone D	105	
	scortechinone E	106	
	scortechinone F	107	
	scortechinone G	108	
	scortechinone H	109	
	scortechinone I	110	
	scortechinone J	111	
	scortechinone K	112	
G. xanthochymus (wood)	12b-(OH)-des-D-garcigerrin A	33	Chanmaha-sathien, *et al*., 2003a
	1,4,5,6-tetra(OH)-7,8-di(3-methyl-2-butenyl)xanthone	61	
	1,2,6-tri(OH)-5-(OMe)-7-(3-methyl-2-butenyl)xanthone	62	
	garciniaxanthone E	67	Chanmaha-sathien, *et al*., 2003b
	1,3,5,6-tetra(OH)-4,7,8-tri(3-methyl-2-butenyl)xanthone	60	

Structures of isolated compounds from the genus Garcinia (2002-2004)

A. Benzophenones

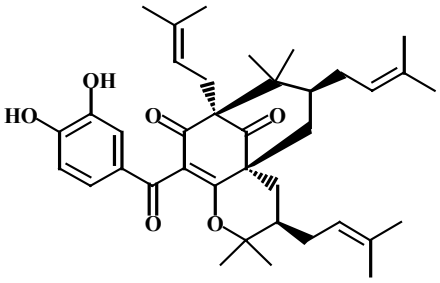


1 clusianone

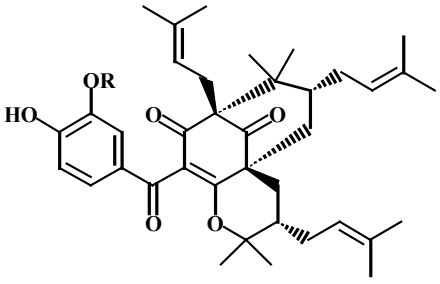


2 R = H : garcinol

3 R = Me : garcinol 13-*O*-methyl ether

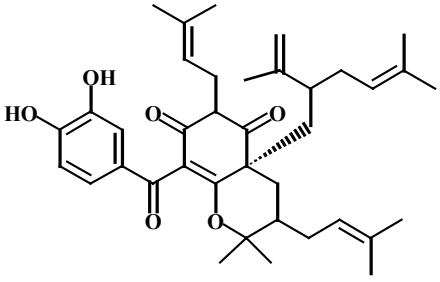


4 isoxanthochymol

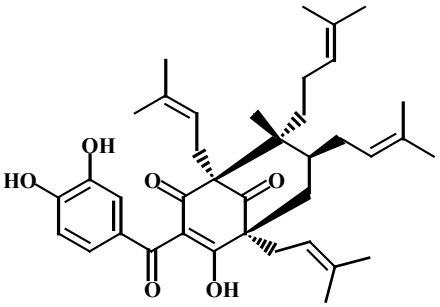


5 R = H : isogarcinol

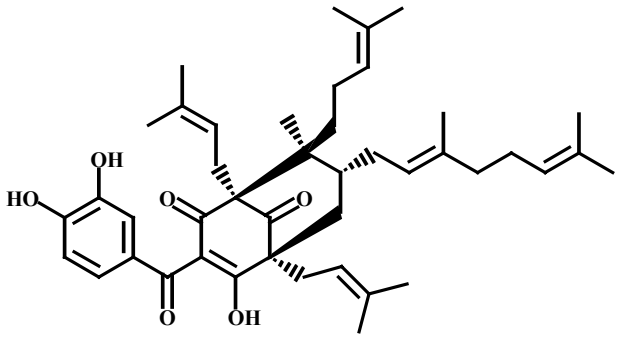
6 R = Me : isogarcinol 13-*O*-methyl ether



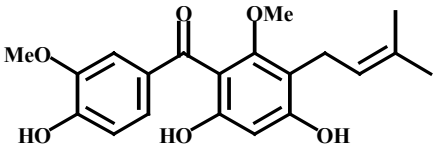
7 xanthochymol



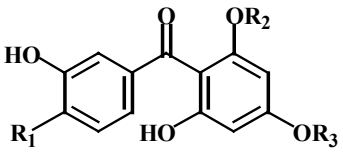
8 guttiferone A



9 guttiferone G



10 4,6,4′-tri(OH)-2,3′-di(OMe)-3-prenylbenzophenone



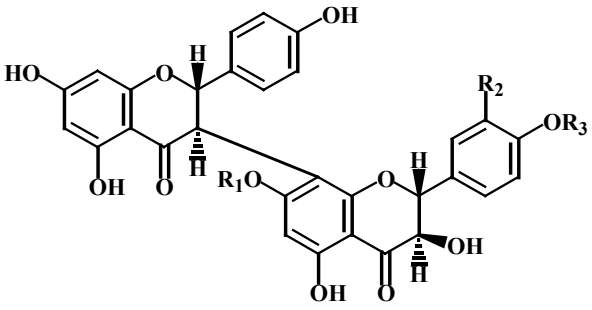
11 R_1 = OH, R_2 = Me, R_3 = H : 4,6,3′,4′-tetra(OH)-2-(OMe)benzophenone

12 R_1 = OH, R_2 = R_3 = H : maclurin

13 R_1 = R_2 = R_3 = H : 2,4,6,3′-tetra(OH)benzophenone

14 R_1 = H, R_2 = R_3 = Me : 6,3′-di(OH)-2,4-di(OMe)benzophenone

B. Biflavonoids

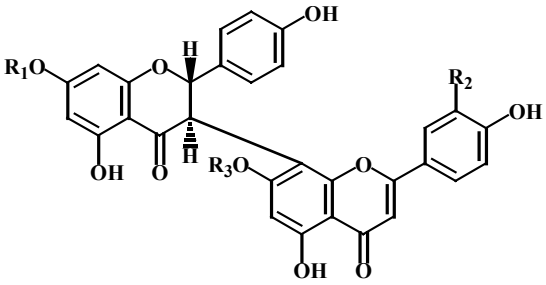


15 $R_1 = R_2 = H, R_3 = Me$: kolaflavanone

16 $R_1 = R_2 = R_3 = H$: GB-1

17 $R_1 = Glc, R_2 = R_3 = H$: GB-1 7″-*O*-glucoside

18 $R_1 = R_3 = H, R_2 = OH$: GB-2

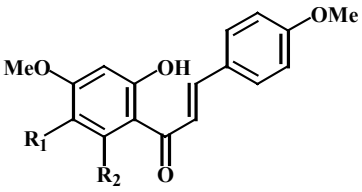


19 $R_1 = R_3 = H, R_2 = OH$: morelloflavone

20 $R_1 = \beta$-D-Glc, $R_2 = OH, R_3 = H$: morelloflavone 7-*O*-β-D-glucopyranoside

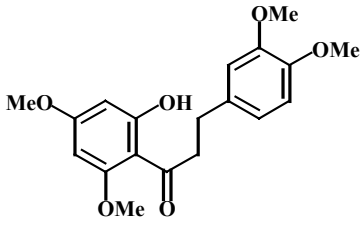
21 $R_1 = H, R_2 = OH, R_3 = \beta$-D-Glc : fukugiside

C. Chalcones



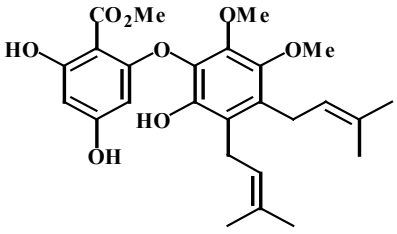
22 R_1 = Br, R_2 = OMe
: 5′-Br-2′-(OH)-4,4′,6′-tri(OMe)chalcone

23 R_1 = R_2 = H
: 2′-(OH)-4,4′-di(OMe)chalcone



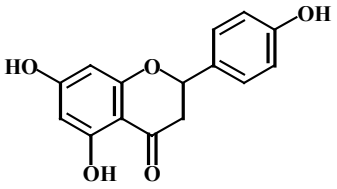
24 2′-(OH)-3,4,4′,6′-tetra(OMe) dihydrochalcone

D. Diphenyl ether

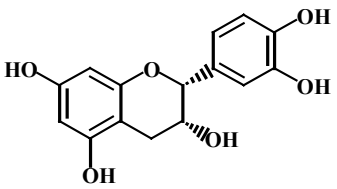


25 4-methylhydroatrovirinone

E. Flavonoids

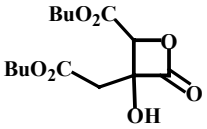


26 naringenin



27 (-)-epicatechin

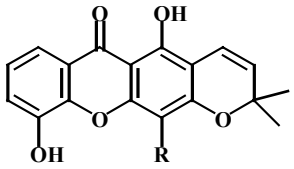
F. Lactone



28 2-butoxycarbonylmethyl-3-butoxycarbonyl-2-hydroxy-3-propanolide

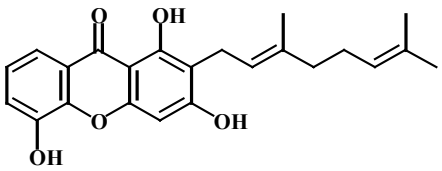
G. Xanthones

Trioxyxanthones

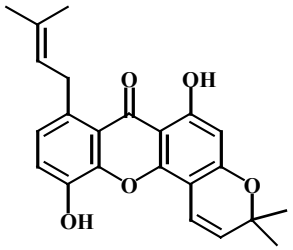


29 R = H : 6-deoxyjacareubin

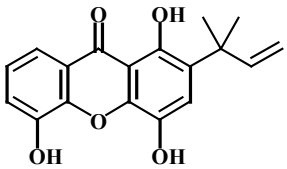
30 R =  : trapezifolixanthone



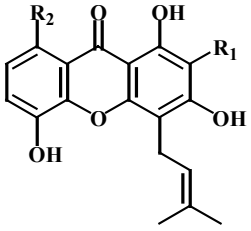
31 mangostinone



32 merguenone

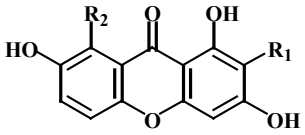


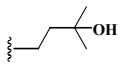
33 12b-(OH)-des-D-garcigerrin A

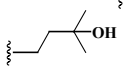


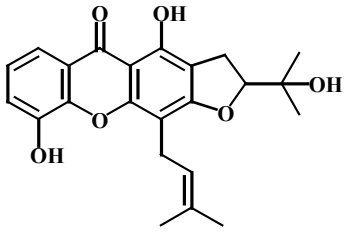
34 R_1 =  , R_2 = H : 8-desoxygartanin

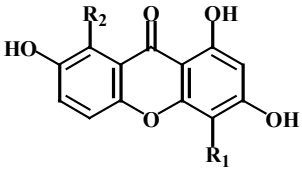
35 R_1 = H, R_2 =  : 1,3,5-tri(OH)-4,8-di(3-methyl-2-butenyl)xanthone



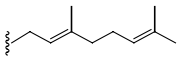
36 R_1 = H, R_2 =  : nigrolineaxanthone D

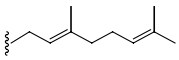
37 R_1 =  , R_2 = H : 1,3,7-tri(OH)-2-(3-(OH)-3-methylbutyl)xanthone

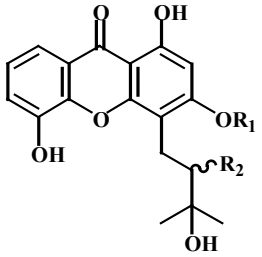


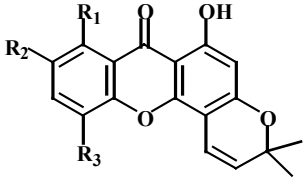


38 morusignin G

39 R_1 =  , R_2 = H : fuscaxanthone E

40 R_1 = H, R_2 =  : fuscaxanthone F





41 R_1 = Me, R_2 = H

: nigrolineaxanthone A

42 R_1 = Me, R_2 = OH

: nigrolineaxanthone C

43 R_1 = R_2 = H

: 1,3,5-tri(OH)-4-(3-(OH)-3-methylbutyl)xanthone

44 R_1 = R_3 = H, R_2 = OH

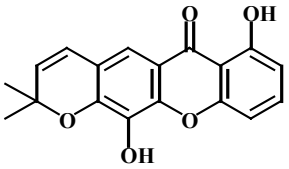
: nigrolineaxanthone F

45 R_1 = R_3 = H, R_2 = OH

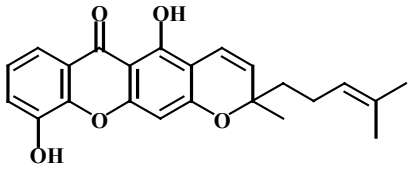
: 6-deoxyisojacareubin

46 R_1 = R_3 = H, R_2 = OH

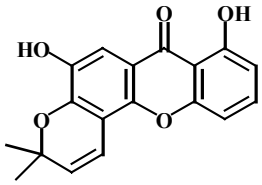
: morusignin C



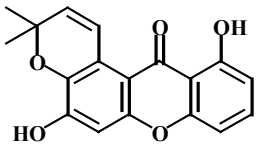
47 1,5-di(OH)-6′,6′-dimethyl pyrano[2′,3′:3,2]xanthone (or rheediachromenoxanthone)



48 1,5-di(OH)-6′-methyl-6′-(4-methyl-3-pentenyl)pyrano (2′,3′:3,2)xanthone

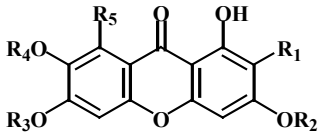


49 nigrolineaxanthone H



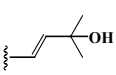
50 tovoxanthone

Tetraoxyxanthones

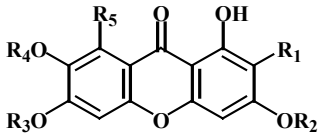


51 R_1 =  , $R_2 = R_3 = R_4$ = Me, R_5 = 

: 1-(OH)-8-(2-(OH)-3-methyl-3-butenyl)-3,6,7-tri(OMe)-2-(3-methyl-2-butenyl)xanthone

52 R_1 =  , $R_2 = R_3 = R_4$ = Me, R_5 = 

: (16*E*)-1-(OH)-8-(3-(OH)-3-methyl-1-butenyl)-3,6,7-tri(OMe)-2-(3-methyl-2-butenyl)xanthone

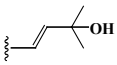


53 R_1 =  , $R_2 = R_3 = R_4$ = Me, R_5 = 

: 1-(OH)-2-(2-(OH)-3-methyl-3-butenyl)-3,6,7-tri(OMe)-8-(3-methyl-2-butenyl)xanthone

54 R_1 =  , $R_2 = R_4$ = Me, R_3 = H, R_5 = 

: 1,6-di(OH)-2-(2-(OH)-3-methyl-3-butenyl)-3,7-di(OMe)-8-(3-methyl-2-butenyl)xanthone

55 R_1 =  , $R_2 = R_4$ = Me, R_3 = H, R_5 = 

: (16*E*)-1,6-di(OH)-8-(3-(OH)-3-methyl-1-butenyl)-3,7-di(OMe)-2-(3-methyl-2-butenyl)xanthone

56 R_1 =  , $R_2 = R_4$ = Me, R_3 = H, R_5 = 

: 1,6-di(OH)-8-(2-(OH)-3-methyl-3-butenyl)-3,7-di(OMe)-2-(3-methyl-2-butenyl)xanthone

57 R_1 =  , R_2 = H, $R_3 = R_4$ = Me, R_5 = 

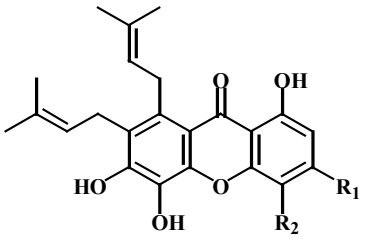
: 1,3-di(OH)-2-(2-(OH)-3-methyl-3-butenyl)-6,7-di(OMe)-8-(3-methyl-2-butenyl)xanthone

58 R_1 =  , $R_2 = R_4$ = Me, $R_3 = R_5$ = H

: 1,6-di(OH)-3,7-di(OMe)-2-(3-methyl-2-butenyl)xanthone

59 R_1 =  , $R_2 = R_4$ = Me, R_3 = H, R_5 = 

: 1,6-di(OH)-3,7-di(OMe)-2-(3-methyl-2-butenyl)-8-(2-oxo-3-methyl-3-butenyl)xanthone

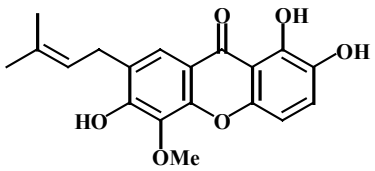


60 R_1 = OH, R_2 = 

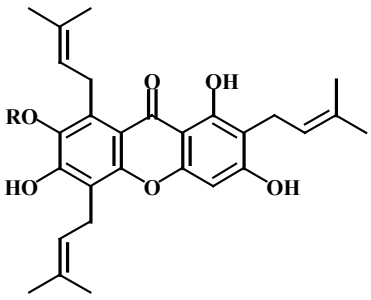
: 1,3,5,6-tetra(OH)-4,7,8-tri(3-methyl-2-butenyl)xanthone

61 R_1 = H, R_2 = OH

: 1,4,5,6-tetra(OH)-7,8-di(3-methyl-2-butenyl)xanthone

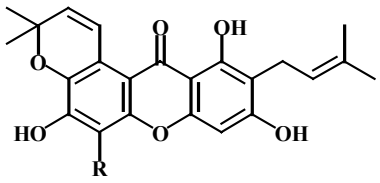


62 1,2,6-tri(OH)-5-(OMe)-7-(3-methyl-2-butenyl)xanthone



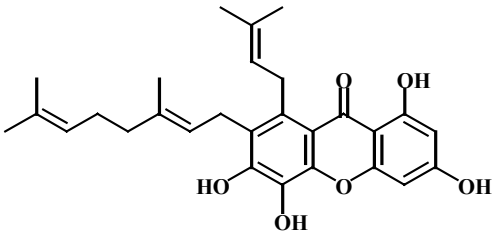
63 R = H : garcinone E

64 R = Me : 7-*O*-methylgarcinone

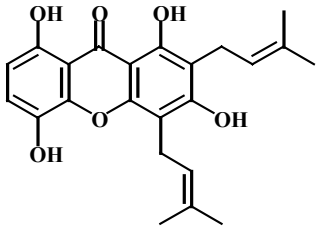


65 R =  : tovophyllin A

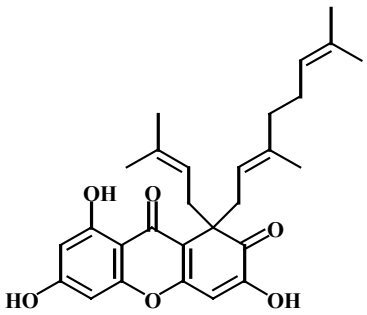
66 R = H : garcinone B



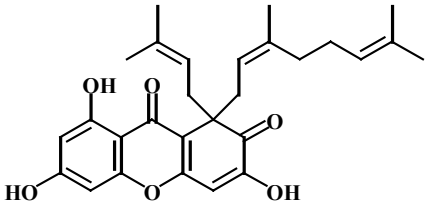
67 garciniaxanthone E



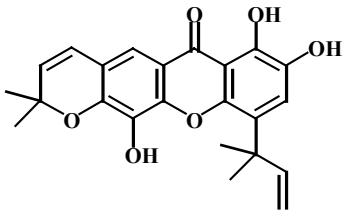
68 gartanin



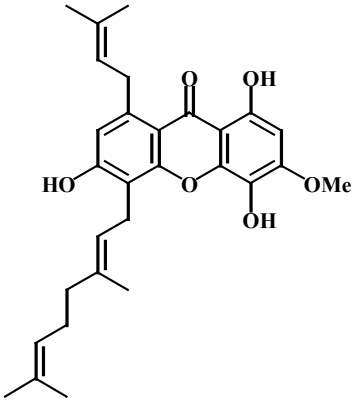
69 garcinianone A



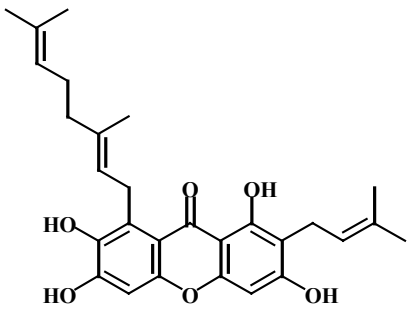
70 garcinianone B



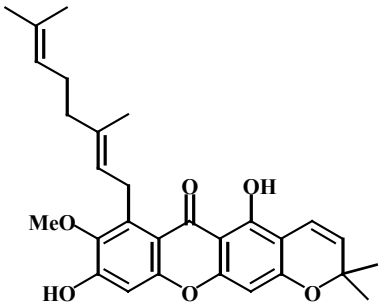
71 subelliptenone H



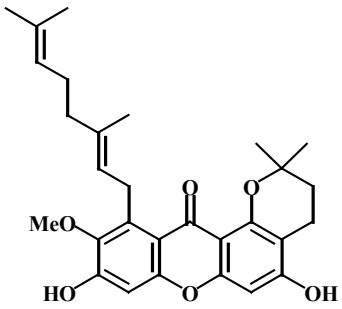
72 cuneifolin



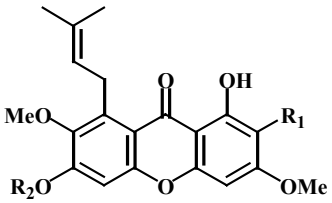
73 norcowanin



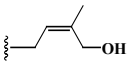
74 fuscaxanthone A

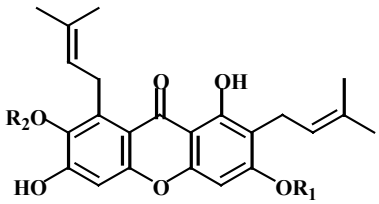


75 fuscaxanthone G



76 R_1 =  , R_2 = Me : fuscaxanthone C

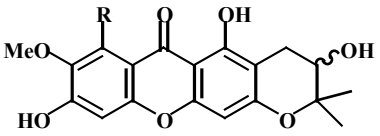
77 R_1 =  , R_2 = H : fuscaxanthone D



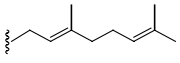
78 $R_1 = R_2$ = Me : β-mangostin

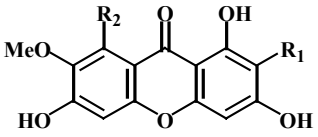
79 R_1 = H, R_2 = Me : α-mangostin

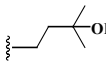
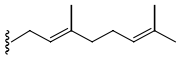
80 $R_1 = R_2$ = H : γ-mangostin

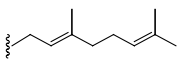


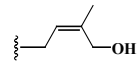
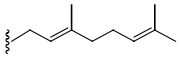
81 R =  : mangostanol

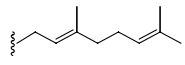
82 R =  : fuscaxanthone B

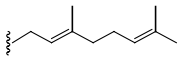


83 R_1 =  , R_2 =  : fuscaxanthone H

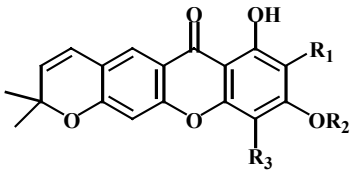
84 R_1 =  , R_2 =  : cowanin

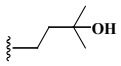
85 R_1 =  , R_2 =  : cowanol

86 R_1 =  , R_2 = H : cowaxanthone

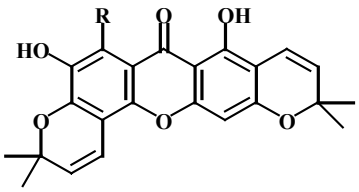
87 R_1 = H, R_2 =  : rubraxanthone

88 R_1 =  , R_2 =  : mangostenol



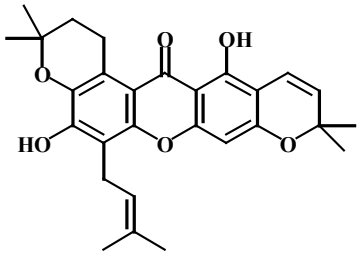
89 R_1 = H, R_2 = Me, R_3 =  : nigrolineaxanthone B

90 R_1 =  , R_2 = R_3 = H : latisxanthone D

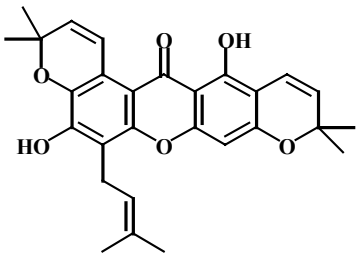


91 R =  : mangostenone A

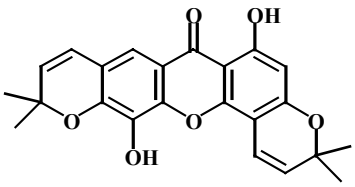
92 R = H : nigrolineaxanthone I



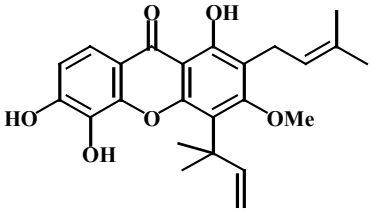
93 mangostenone B



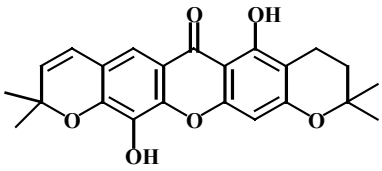
94 tovophyllin B



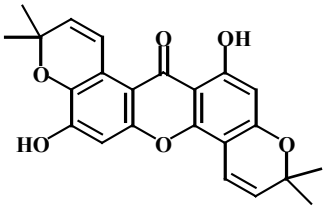
95 rheediaxanthone A



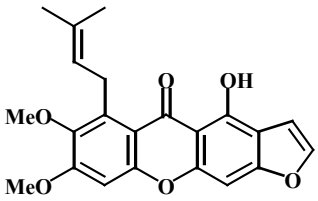
96 nigrolineaxanthone E



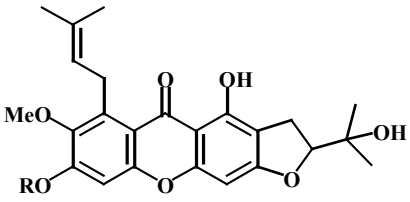
97 nigrolineaxanthone G



98 brasillixanthone



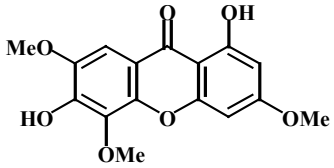
99 garciniafuran



100 R = H : mangostanin

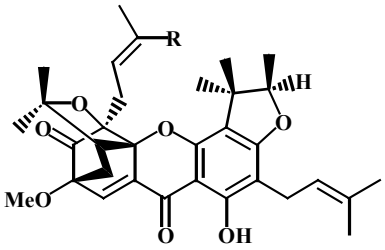
101 R = Me : 6-*O*-methylmangostanin

Pentaoxyxanthone



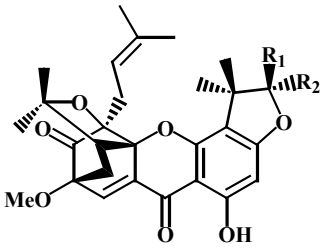
102 3,8-di(OH)-2,4,6-tri(OMe)xanthone

Caged-polyprenylated xanthones



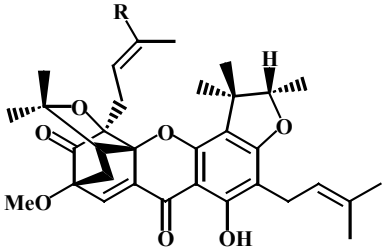
103 R = Me : scortechinone A

104 R = CO_2H : scortechinone B



105 R_1 = Me, R_2 = H : scortechinone D

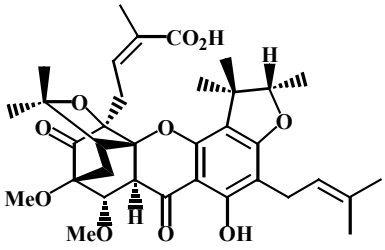
106 R_1 = H, R_2 = Me : scortechinone E



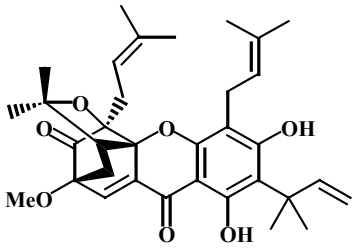
107 R = CO_2H : scortechinone F

108 R = CO_2Me : scortechinone G

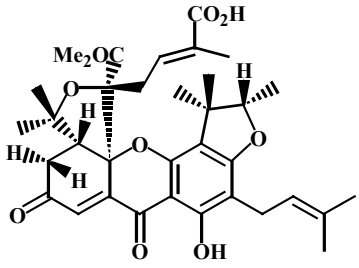
109 R = CHO : scortechinone H



110 scortechinone I

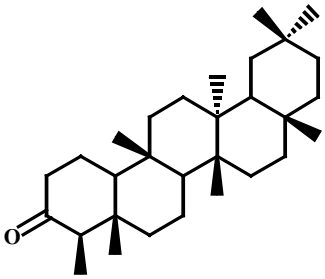


111 scortechinone J



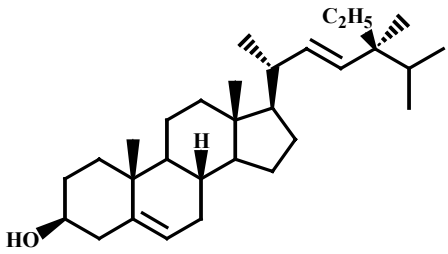
112 scortechinone K

H. Triterpene



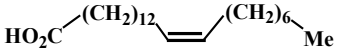
113 friedelin

I. Steroid

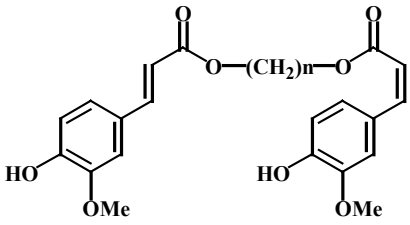


114 stigmasterol

J. Miscellaneous



115 (14*Z*)-14-docosenoic acid



116 n = 22 or 24

(1*E*,22*Z*)-1,22-diferuloxyoxydocosane

or

(1*E*,24*Z*)-1,24-diferuloyloxytetracosane

1.2.2 Chemical constituents from Garcinia dulcis

Garcinia dulcis was first investigated by Ansari and co-worker in 1976, five biflavonoids were isolated from the leaves. Further investigation of the leaves by Kosela and co-workers in 1999 and 2000 resulted in isolation of xanthones. In 1994 Harrison and co-workers isolated biflavonoids and xanthones from the branches. The roots were reported to have xanthones by Iinuma and co-workers in 1996a; 1996b; 1996c. The presence of xanthones in the stem bark was shown by Ito and co-workers (1997, 1998) and Likhitwitayawuid and co-workers (1998a). The seeds were reported to compose of several fatty acids (Faisal, *et al*., 1982). These chemical constituents are presented in **Table 2**.

Table 2 Isolated compounds from *Garcinia dulcis*

Investigated part	Compound	Structure	Reference
branches	3,8″-biapigenin	8	Harrison,
	friedelin	51	*et al*., 1994
	3′-(3-methyl-2-butenyl)naringenin	-	
	podocarpusflavone A	9	
	1,4,6-tri(OH)-5-(OMe)-7-(3-methyl-2-butenyl)xanthone	30	
leaves	amentoflavone	10	Ansari,
	morelloflavone (fukugetin)	7	*et al*., 1976
	GB-2a	5	
	I-4′,I-5,II-5,I-7,II-7-penta(OMe) flavanone-[I-3,II-8]-chromone	11	
	volkensiflavone	6	
	dulxanthone E	47	Kosela, *et al.*, 1999
	dulxanthone F	48	Kosela,
	dulxanthone G	49	*et al*., 2000
	dulxanthone H	50	
roots	12b-(OH)-des-D-garcigerrin A	18	Iinuma,
	dulciol A	37	*et al*.,1996a
	dulciol B	45	
	dulciol C	46	
	dulciol D	20	

Table 2 (Continued)

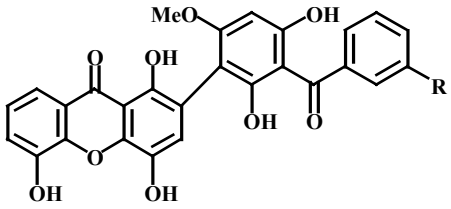
Investigated part	Compound	Structure	Reference
roots	dulciol E	21	Iinuma,
	garciniaxanthone A	19	*et al*.,1996a
	garciniaxanthone B	22	
	garciniaxanthone D	23	
	globuxanthone	24	
	subelliptenone C	43	
	subelliptenone D	44	
	subelliptenone F	42	
	toxyloxanthone B	39	
	garciduol A	1	Iinuma,
	garciduol B	2	*et al*.,1996b; 1996c
	2,5-di(OH)-1-(OMe)xanthone	17	Iinuma,
	garciduol C	3	*et al*., 1996c
	subelliptenone G	14	
	1,3,6-tri(OH)-7-(OMe)-8-(3-methyl-2-butenyl)xanthone	35	
	1,3,6-tri(OH)-5-(OMe)xanthone	36	
	1,3,6-tri(OH)-7-(OMe)xanthone	34	
	1,3,5-tri(OH)xanthone	15	
seeds	linoleic acid	-	Faisal,
	linolenic acid	-	*et al*., 1982

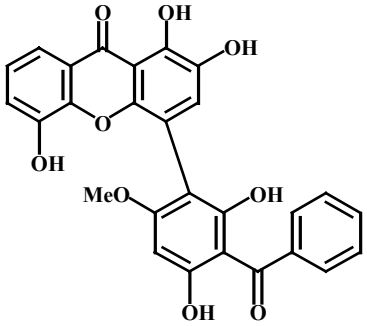
Table 2 (Continued)

Investigated part	Compound	Structure	Reference
seeds	myristic acid	-	Faisal,
	oleic acid	-	*et al*., 1982
	palmitic acid	-	
	palmitoleic acid	-	
	stearic acid	-	
stem bark	euxanthone	12	Likhitwita-
	garciniaxanthone	33	yawuid,
	12b-(OH)-des-D-garcigerrin A	18	*et al*., 1998a
	1-*O*-methylsymphoxanthone	26	
	symphoxanthone	25	
	isoprenylxanthone	32	Ito, *et al*.,
	ugaxanthone	31	1997
	dulxanthone D	38	
	dulxanthone A	27	Ito, *et al*.,
	dulxanthone B	28	1997; 1998
	dulxanthone C	29	
	GB-1a	4	
	gentisein	13	
	jacareubin	40	
	toxyloxanthone B	39	
	1,3,7-tri(OH)-2-(3-methyl-2-butenyl) xanthone	16	
	xanthone V-1	41	

Structures of isolated compounds from Garcinia dulcis

A. Benzophenone-xanthone dimers



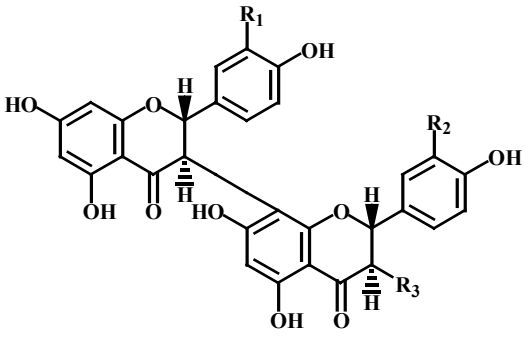


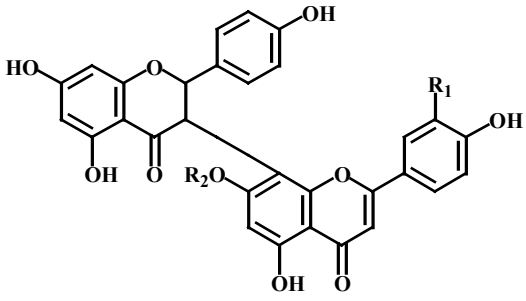
1 R = H : garciduol A

2 R = OH : garciduol B

3 garciduol C

B. Biflavonoids



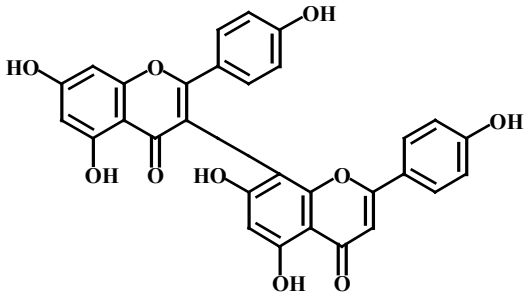


4 $R_1 = R_2 = R_3 = H$: GB-1a

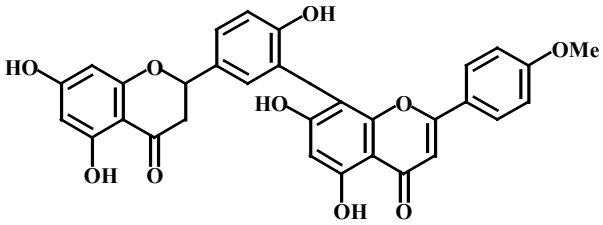
5 $R_1 = R_3 = H$, $R_2 = OH$: GB-2a

6 $R_1 = R_2 = H$: volkensiflavone

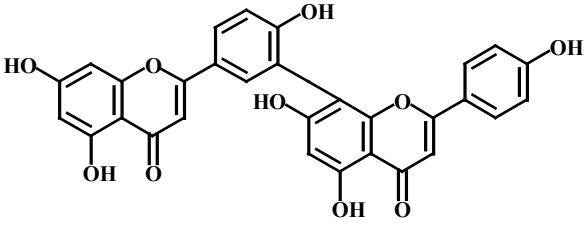
7 $R_1 = OH$, $R_2 = H$: morelloflavone



8 3,8″-biapigenin

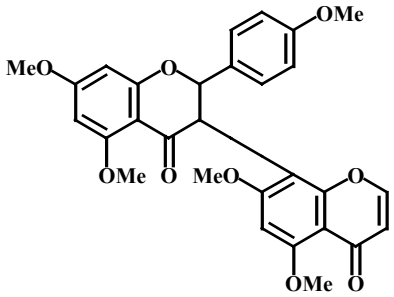


9 podocarpusflavone A



10 amentoflavone

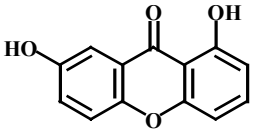
C. Chromone



11 I-4′,I-5,II-5,I-7,II-7-penta(OMe)flavanone-[I-3,II-8]-chromone

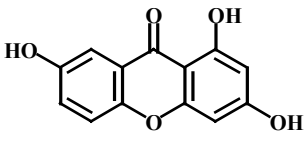
D. Xanthones

Dioxyxanthone

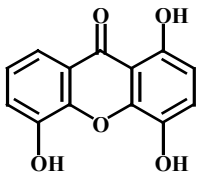


12 euxanthone

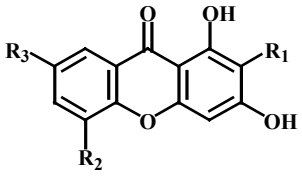
Trioxyxanthones



13 gentisein

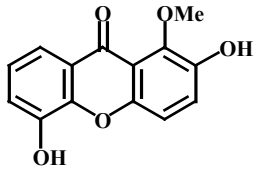


14 subelliptenone G

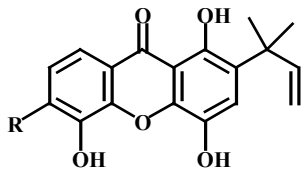


15 $R_1 = R_3 = H$, $R_2 = OH$: 1,3,5-tri(OH)xanthone

16 $R_1 =$  , $R_2 = H$, $R_3 = OH$: 1,3,7-tri(OH)-2-(3-methyl-2-butenyl)xanthone



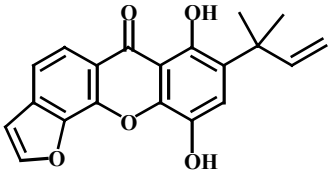
17 2,5-di(OH)-1-(OMe)xanthone



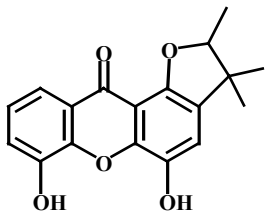
18 R = H

: 12b-(OH)-des-D-garcigerrin A

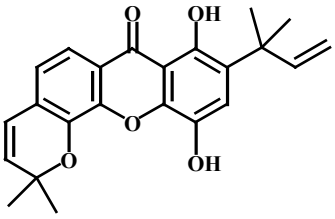
19 R =  : garciniaxanthone A



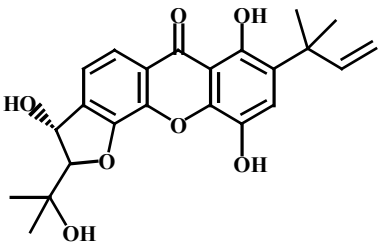
20 dulciol D



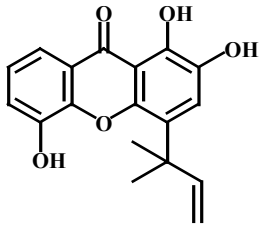
21 dulciol E



22 garciniaxanthone B

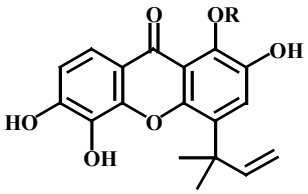


23 garciniaxanthone D



24 globuxanthone

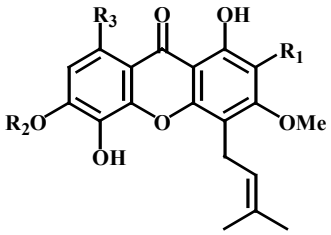
Tetraoxyxanthones



25 R = H : symphoxanthone

26 R=Me

: 1-*O*-methylsymphoxanthone



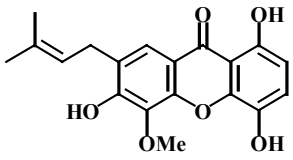
27 $R_1 = R_2 = R_3 = H$: dulxanthone A

28 $R_1 =$  , $R_2 = R_3 = H$

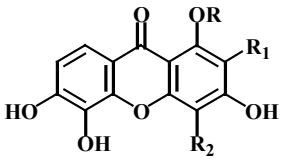
: dulxanthone B

29 $R_1 = H$, $R_2 = Me$, $R_3 =$ 

: dulxanthone C

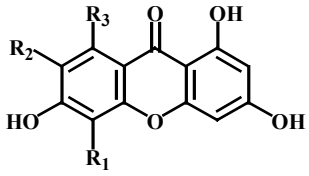


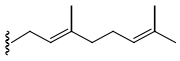
30 1,4,6-tri(OH)-5-(OMe)-7-(3-methyl-2-butenyl)xanthone



31 $R_1 = H$, $R_2 =$  : ugaxanthone

32 $R_1 =$  , $R_2 = H$: isoprenylxanthone



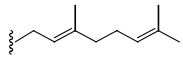
33 R_1 = OH, R_2 =  , R_3 =  : garciniaxanthone

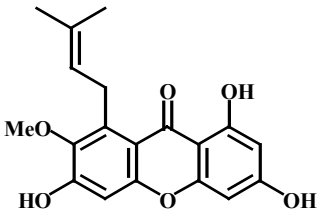
34 $R_1 = R_3$ = H, R_2 = OMe : 1,3,6-tri(OH)-7-(OMe)xanthone

35 R_1 = H, R_2 = OMe, R_3 = 

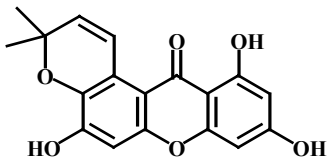
: 1,3,6-tri(OH)-7-(OMe)-8-(3-methyl-2-butenyl)xanthone

36 R_1 = OMe, $R_2 = R_3$ = H : 1,3,6-tri(OH)-5-(OMe)xanthone

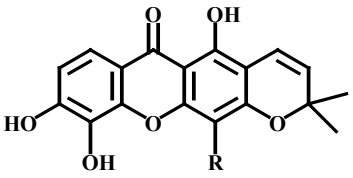
37 R_1 =  , R_2 = OH, R_3 =  : dulciol A



38 dulxanthone D

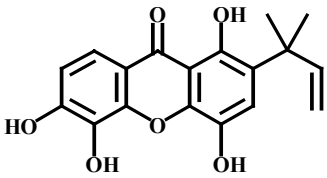


39 toxyloxanthone B

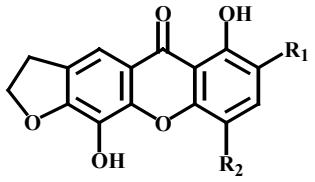


40 R = H : jacareubin

41 R =  : xanthone V-1

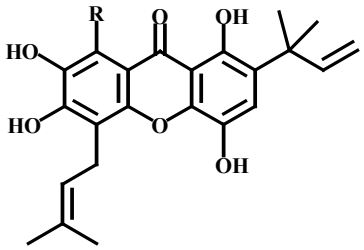


42 subelliptenone F

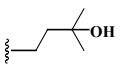


43 R_1 =  , R_2 = OH : subelliptenone C

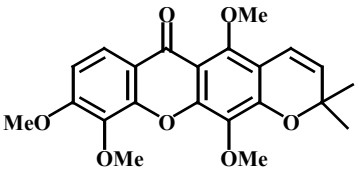
44 R_1 = OH, R_2 =  : subelliptenone D



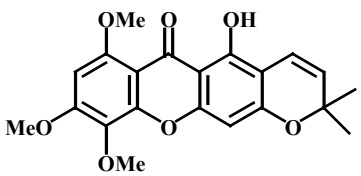
45 R =  : dulciol B

46 R =  : dulciol C

Pentaoxyxanthones

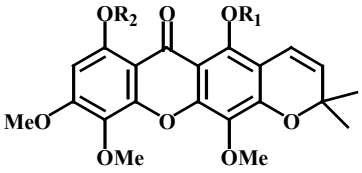


47 dulxanthone E



48 dulxanthone F

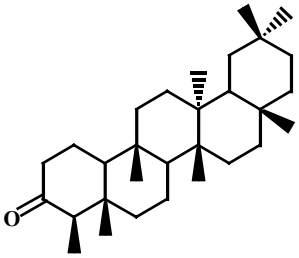
Hexaoxyxanthones



49 R_1 = H, R_2 = Me : dulxanthone G

50 R_1 = Me, R_2 = H : dulxanthone H

E. Triterpene



51 friedelin

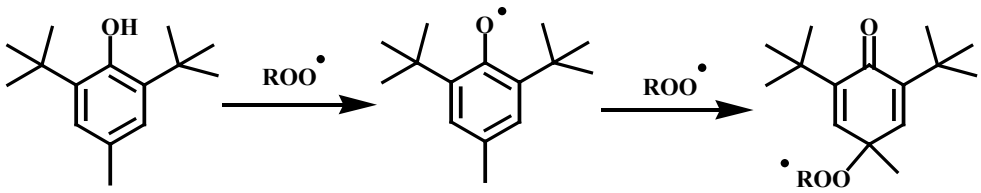
1.2.3 Biological activities of Garcinia dulcis

Garcinia dulcis Kurz. (Guttiferae) is known as an Asian medicinal plants used in folk medicines. In Thailand, its stem bark has been used as an antiinflammatory agent (มาโนชและเพ็ญนภา, 2540). The fruit juice has been used in traditional medicine as an expectorant (วุฒิ, 2540). In Indonesia, the leaves and seeds have been used for the treatment of lymphatitis, parotitis and struma (Kasahara and Henmi, 1986). Five xanthones from this plant, 12b-hydroxy-des-D-garcigerrin A, 1,7-dihydroxyxanthone, 1-*O*-methylsymphoxanthone, symphoxanthone and garciniaxanthone, were reported to show antimalarial activity (Likhitwitayawuid, 1998a).

1.2.4 Antioxidants

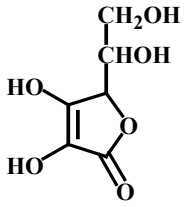
Recently, natural antioxidants have attracted attention because some synthetic antioxidants have been found to be carcinogenic and harmful to lungs and liver (Yamasaki, 1994). Reactive oxygen species such as hydroxyl (OH•), peroxyl radicals (ROO•) and the superoxide anion (O_2•-) are constantly produced as a result of metabolic reactions in living systems (Wang, 1999). Living systems are protected from oxidative damage by these reactive species by enzymes such as superoxide dismutase and glutathione peroxidase and by antioxidant compounds such as ascorbic acid, tocopherols and carotenoids (Wang, 1999). However, when free radical production exceeds the antioxidant capacity of the organism, these radical species attack lipids, proteins and DNA, thus damaging structural integrity and function of cell membranes, enzymes and genetic material (Wang, 1999). A growing body of evidence indicates that various pathological conditions, including cardiovascular disease, arthritis, various cancers and Alzheimer's disease, are associated, at least in part, with the damaging effects of uncontrolled free radical production (Wang, 1999). An excellent example of

this of inhibitor is the synthetic hindered phenol 2,6-di-tert-butyl-4-methylphenol, often called 'BHT', which reacts with two mol of peroxy radicals and converts them to much less active products (Larson, 1988).

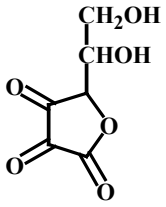


BHT + ROOH

Ascorbic acid (vitamin C) has been proposed for a long time as a biological antioxidant. Ascorbate reduces two equivalents of O_2- to produce H_2O_2 and triketo derivative dehydroascorbic acid (Larson, 1988).



ascorbic acid



triketo derivative

dehydroascorbic acid

Natural antioxidants occur in all higher plants and in all parts of the plant, these are usually phenolic or polyphenolic compounds (Kim, 1997). Benzophenones, xanthones, flavonoids and biflavonoids have received the most attention and much is known about the structural requirements for antioxidant activity (Larson, 1998; Mahabusarakam, 2000; Ito, 2003a,b). In addition, several compounds from *Garcinia* genus have been reported to show antioxidant activity such as mangostin from fruit hulls of *G. mangostana* (Yoshikawa, 1994; Williams, 1995), garciniaxanthone D, F, G

and H from the stem bark of *G. subelliptica* (Minami, 1995; 1996), garcinol from fruit hulls of *G. indica* (Yamaguchi, 2000), the extracts from fruits, leaves, stem bark, branches and roots of *G. atroviridis* (Mackeen, 2000), kolaviron from seeds of *G. kola* (Farombi, 2000) and garcinoic acid from seeds of *G. kola* (Terashima, 2002).

1.3 The objective

Up to the present, ten reports revealed the isolation of the chemical constituents from *G. dulcis*. However, the chemical constituents and biological activities of flowers, fruits and seeds of *G. dulcis* have not been investigated, it was therefore of interest to investigate the chemical constituents and evaluate the biological activities of isolated compounds. This research involved isolation, purification, structural determination of the chemical constituents from flowers, fruits and seeds of *G. dulcis* and evaluation of the antioxidative activities of crude extracts and pure compounds.