CHAPTER II

HISTORICAL

1. Chemical Constituents of Plants in the Genus *Diospyros*

Members of the family Ebenaceae, especially plants of the genus *Diospyros,* which is the largest genus of the family, have proven to be rich sources of naphthoquinones and their derivatives which often appear as dimers, trimers and, more seldom, as tetramers. Many species containing these compounds have an important place in traditional medicine in the treatment of leprosy (Costa *et al.*, 1998). Over sixty species of *Diospyros* have been investigated and several naphthoquinones, naphthols, sitosterol and triterpenes isolated. The latter are mainly in the lupene series and occur in high yields (Herath *et al.*, 1978). Two major types of the chemical constituents of the genus *Diospyros* are reviewed here, namely the dimeric naphthoquinone derivatives (Table 1) and the triterpenoids (Table 2).

Table 1 Distribution of dimeric naphthoquinones and oligomers in the genus (continued).

Compounds	Sources	References
1. *Quinoid -quinoid*		
Biramentaceone (**1**)	*D. chamaethamnus*	Costa *et al.*, 1998
	D. melanoxylon	Sankaram and Sidhu, 1971; Sankaram, Reddy and Sidhu, 1981
	D. montana	Pardhasaradhi and Krishnakumari, 1979
3,3′-Dimer of 6-hydroxy-5-methoxy-2-methyl-1,4 -naphthoquinone (**2**)	*D. melanoxylon*	Sankaram and Sidhu, 1971
Diosindigo B (**3**)	*D. celebica*	Maiti, Musgrave and Skoyles, 1976 ; Maiti and Musgrave, 1986
	D. melanoxylon	Sankaram *et al.*, 1981
	D. usambarensis	Khan, Kishimba and Locksley, 1989
Dihydrodiosindigo B (**4**)	*D. celebica*	Maiti and Musgrave, 1986
Diosindigo B leucotetraacetate (**5**)	*D. melanoxylon*	Sankaram *et al.*, 1981
Iso-celebaquionoe (**6**)	*D. celebica*	Maiti *et al.*, 1986
Mamegakinone (**7**)	*D. chamaethamnus*	Costa *et al.*, 1998
	D. japonica	Tezuka *et al.*, 1973
	D. kaki	Tezuka *et al.*, 1972
	D. kaki var. *sylvestris*	Tezuka *et al.*, 1973
	D. lotus	Yoshihira, Tezuka and Kanchanapee, 1971a ; Tezuka *et al.*, 1973

Table 1 Distribution of dimeric naphthoquinones and oligomers in the genus (continued).

Compounds	Sources	References
Mamegakinone (7)	*D. lycioides*	Li *et al.*, 1998
	D. mollis	Yoshihira, Tezuka and Kanchanapee, 1971b
	D. montana	Yoshihira, Tezuka and Natori, 1971a
	D. morrisiana	Yoshihira *et al.*, 1971a
	D. obliquifolia	Waterman and Mbi, 1979
	D. usambarensis	Marston *et al.*, 1984
	D. zombensis	Mallavadhani *et al.*, 1998
Mamegakinone dimethyl ether (**8**)	*D. mollis*	Yoshihira *et al.*, 1971b
Violet quinone (**9**)	*D. melanoxylon*	Sankaram *et al.*, 1981
Rotundiquinone (**10**)	*D. ismailli*	Zakaria *et al.*, 1984
	D. rotundifolia	Maiti, Musgrave, and Skoyles, 1976
2. *Quinoid -benzenoid*		
Cyclodiospyrin (**11**)	*D. montana*	Lillie, Musgrave and Skoyles 1976a
2´-Chlorodiospyrin (**12**)	*D. montana*	Lillie *et al.*, 1976a
3´-Chlorodiospyrin (**13**)	*D. montana*	Lillie *et al.*, 1976a
3´-Chloro-2´-hydroxydiospyrin (**14**)	*D. montana*	Lillie *et al.*, 1976a
Diosquinone (**15**)	*D. chamaethamnus*	Costa *et al.*, 1998
	D. mafiensis	Khan and Rwekika, 1999
	D. tricolor	Alake, 1994

Table 1 Distribution of dimeric naphthoquinones and oligomers in the genus (continued).

Compounds	Sources	References
Diospyrin (**16**)	*D. abyssinica*	Zhong, Waterman and Jeffreys, 1984
	D. chamaethamnus	Costa *et al.*, 1998
	D. chloroxylon	Sidhu, and Prasad, 1971
	D. cinnabarina	Waterman and Mbi, 1979
	D. fragrans	Zhong *et al.*, 1984
	D. gracilescens	Waterman and Mbi, 1979
	D. kaki	Tezuka *et al.*,1973
	D. longiflora	Zhong *et al.*, 1984
	D. lotus	Tezuka *et al.*, 1973
	D. mannii	Jeffreys, Zakaria, and Waterman, 1983
	D. maritima	Kuo *et al.*, 1997
	D. montana	Tezuka *et al.*, 1973 ; Pardhasaradhi and Krishnakumari, 1979 ; Likhitwitayawuid, Dej-adisai and Jongbunprasert, 1999 ; Ravishankara *et al.*, 2000
	D. obliquifolia	Waterman and Mbi, 1979
	D. piscatorial	Adeniyi *et al.*, 2000
	D. rotundifolia	Van der Vijver and Gerritsma, 1974
	D. spinescens	Herath *et al.*, 1978

Table 1 Distribution of dimeric naphthoquinones and oligomers in the genus (continued).

Compounds	Sources	References
β'-Dihydrodiospyrin (**17**)	*D. montana*	Kapil and Dhar, 1961 ; Paradhasaradhi and Sidhu, 1972 ; Lillie *et al.*, 1976a ; Paradhasaradhi and Krishnakumari, 1979
Ebenone (**18**)	*D. ebenum*	Sankaram and Reddy, 1984
Ehretione (**19**)	*D. ehretioides*	Lillie, Musgrave and Skoyles, 1976b
Habibone (**20**)	*D. greeniwayi*	Khan and Rwekika, 1998
8-Hydroxyisodiospyrin (**21**)	*D. ferrea*	Tezuka *et al.*, 1973
	D. heterotricha	Ferreira, Costa and Alves, 1972
	D. kaki	Tezuka *et al.*, 1972
	D. lycioides	Ferreira *et al.*, 1972
8'-Hydroxyisodiospyrin (**22**)	*D. maritima*	Kuo *et al.*, 1997
Lemuninol A (**23**)	*Diospyros sp.*	Okuyama *et al.*, 1999
3'-Methoxydiospyrin (**24**)	*D. mannii*	Jeffreys *et al.*, 1983
Neodiospyrin (**25**)	*D. kaki*	Tezuka *et al.*, 1973
	D. ismailii	Zakaria *et al.*, 1984
	D. lotus	Tezuka *et al.*, 1973
Tetrahydrodiospyrin (**26**)	*D. montana*	Pardhasaradhi and Krishuakumari, 1979
3. *Benzenoid –benzenoid*		
Batocanone (**27**)	*D. batacana*	Alves and Costa, 1980

Table 1 Distribution of dimeric naphthoquinones and oligomers in the genus (continued).

Compounds	Sources	References
Ethylidene-6,6′-biplumbagin (**28**)	*D. maritima*	Higa, 1988 ; Higa *et al.*, 1998
2′-Ethoxyisodiospyrin (**29**)	*D. maritima*	Kuo *et al.*, 1998a
3′-Ethoxyisodiospyrin (**30**)	*D. maritima*	Kuo, 1998a
3-Ethoxyisodiospyrin (**31**)	*D. maritima*	Kuo, 1998a
2′-Methoxy isodiospyrin (**32**)	*D. morrisiana*	Chen *et al.*, 1987
3′-Methoxy isodiospyrin (**33**)	*D. morrisiana*	Chen *et al.*, 1987
2, 2′-Dimethoxy isodiospyrin (**34**)	*D. morrisiana*	Chen *et al.*, 1987
2, 3′-Dimethoxy isodiospyrin (**35**)	*D. morrisiana*	Chen *et al.*, 1987
3, 3′-Dimethoxy isodiospyrin (**36**)	*D. morrisiana*	Chen *et al.*, 1987
Ebenone leucopentaacetate (**37**)	*D. ebenum*	Sankaram and Reddy, 1984
Elliptinone dimethyl ether (**38**)	*D. mollis*	Yoshihira *et al.*, 1971b
Elliptinone leucohexaacetate (**39**)	*D. ebenum*	Sankaram and Reddy, 1984
Elliptinone (**40**)	*D. ebenum*	Sankaram and Reddy, 1984
	D. elliptifolia	Yoshihira *et al.*, 1971b
	D. ehretioides	Lillie *et al.*, 1976b
	D. maritima	Yoshimoto *et al.*, 1971 ; Tezuka et al., 1973 ; Higa, 1988 ; Higa *et al.*,1998
	D. mollis	Yoshihira *et al.*, 1971b
	D. samoensis	Richomme *et al.*, 1991

Table 1 Distribution of dimeric naphthoquinones and oligomers in the genus (continued).

Compounds	Sources	References
8´-Hydroxy-3-methoxy isodiospyrin (**41**)	*D. morrisiana*	Chen *et al.*, 1987
Isodiospyrin (**42**)	*D. abyssinica*	Zhong *et al.*, 1984
	D. bipindensis	Waterman and Mbi, 1979
	D. chamaethamnus	Costa *et al.*, 1998
	D. japonica	Tezuka *et al.*, 1973 ; Tezuka *et al.*, 1973
	D. gracilescens	Waterman and Mbi, 1979
	D. kaki	Tezuka *et al.*, 1973
	D. kaki var. *sylvestris*	Tezuka *et al.*, 1973
	D. lotus	Yoshihira *et al.*, 1971a ; Tezuka *et al.*, 1973
	D. lycioides	van der Vijver and Gerritsma, 1974
	D. mafiensis	Khan and Rwekika, 1999
	D. morrisiana	Tezuka *et al.*, 1973 ; Yan *et al.*, 1989
	D. piscatorial	Adeniyi *et al.*, 2000
	D. usambarensis	Marston *et al.*, 1984
Maritinone (**43**)	*D. kaki*	Yoshihira *et al.*, 1971b
	D. maritima	Tezuka *et al.*, 1973 ; Higa, 1988 ; Higa *et al.*, 1998
	D. samoensis	Richomme *et al.*, 1991

Table 1 Distribution of dimeric naphthoquinones and oligomers in the genus (continued).

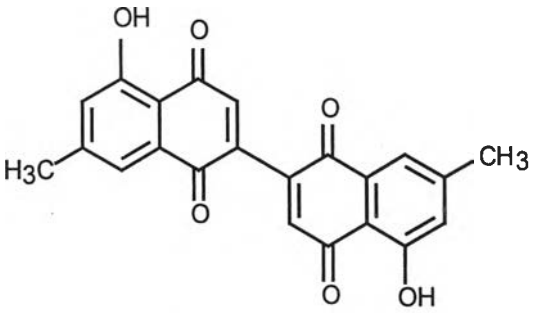
Compounds	Sources	References
4. *Miscellaneous*		
1′,2-Binaphthalen-4-one-2′,3-dimethyl-1,8′-epoxy-1,4′,5,5′,8,8′-hexahydroxy-8-*O*-*β*-glucopyranosyl-5′-*O*-*β*-xylopyranosyl (1→6)-*β*-glucopyranoside (**44**)	*D. lycioides*	Li *et al.*, 1998
1′,2-Binaphthalen-4-one-2′,3-dimethyl-1,8′-epoxy-1,4′,5,5′,8,8′-hexahydroxy-5′,8-di-*O*-*β*-xylopyranosyl(1→6)-*β*-glucopyranoside (**45**)	*D. lycioides*	Li *et al.*, 1998
Canaliculatin (**46**)	*D. canaliculata*	Jeffreys and Zakaria,1983
Cyclo-canaliculatin (**47**)	*D. montana*	Pardhasardhi and Krishnakumari, 1979
	D. canaliculata	Jeffreys and Zakaria,1983
Celebaquinone (**48**)	*D. celebica*	Maiti and Musgrave, 1986
Chromenone acid (**49**)	*D. montana*	Lillie *et al.*, 1976a
Chromenone ester (**50**)	*D. montana*	Lillie *et al.*, 1976a
Diosindigo (**51**)	*D. bipindensis*	Waterman and Mbi, 1979
Diosindigo A (**52**)	*D. buxifolia*	Musgrave and Skoyles, 1974
	D. ferrea	Tezuka *et al.*, 1973
	D. greeniwayi	Khan and Rwekika, 1998

Table 1 Distribution of dimeric naphthoquinones and oligomers in the genus (continued).

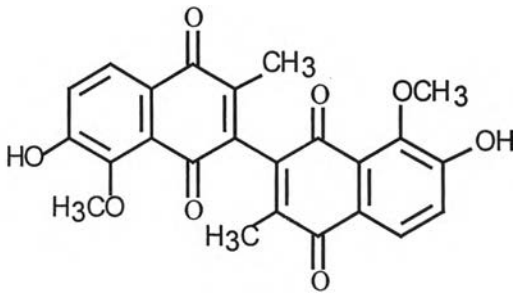
Compounds	Sources	References
Diosindigo A (**52**)	*D. hirsute*	Tezuka *et al.*, 1973 ; Herath *et al.*, 1978
	D. kaki	Tezuka *et al.*, 1973
	D. kaki var. *sylvestris*	Yoshihira *et al.*, 1971b
	D. kirkii	Tezuka *et al.*, 1973
	D. japonica	Tezuka *et al.*, 1973
	D. lotus	Khan and Rwekika, 1999
	D. mafiensis	Musgrave and Skoyles, 1974 ; Khan and Rwekika, 1999
	D. maingayi	Herath *et al.*, 1978 ; Sankaram *et al.*, 1981
	D. melanoxylon	Sankaram *et al.*, 1981
	D. sumatrana	Musgrave and Skoyles, 1974
	D. variegata	Musgrave and Skoyles, 1974
	D. verrucosa	Khan, Kishimba and Locksley, 1987
	D. zenkeri	Zhong *et al.*, 1984
	D. zombensis	Khan *et al.*, 1987
Diospyrol (**53**)	*D. mollis*	Yoshihira *et al.*, 1971b
Diospyrol-8, 8'-di-*O*-6-*β*-D-epiofuranosyl-*β*-D-glucopyranoside (**54**)	*D. mollis*	Yoshihira *et al.*, 1971b
Lemuninol B (**55**)	*Diospyros* sp.	Okuyama *et al.*, 1999
Lemuninol C (**56**)	*Diospyros* sp.	Okuyama *et al.*, 1999

Table 1 Distribution of dimeric naphthoquinones and oligomers in the genus.

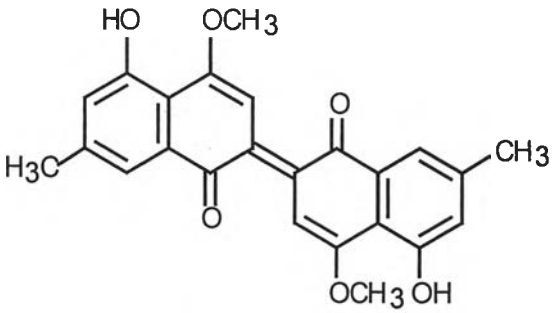
Compounds	Sources	References
5. *Naphthoquinone trimer*		
Ismailin (**57**)	*Diospyros ismailii*	Jeffreys and Zakaria, 1983 ; Zakaria *et al.*, 1984
Xylospyrin (**58**)	*D. chamaethamnus*	Costa *et al.*, 1998
6. *Naphthoquinone tetramer*		
Bis-isodiospyrin (**59**)	*D. japonica*	Kuroyanagi, Yoshihira and Natori, 1971 ; Tezuka *et al.*, 1973
	D. lotus	Yoshihira *et al.*, 1971a ; Tezuka *et al.*, 1973
	D. maingay	Yoshihira *et al.*, 1971a ; Tezuka *et al.*, 1973
	D. morrisiana	Yan *et al.*, 1989
	D. piscatoria	Adeniyi *et al.*, 2000
	D. usambarensis	Marston *et al.*, 1984
6″, 8′-Bisdiosquinone (**60**)	*D. mafiensis*	Khan and Rwekika, 1999



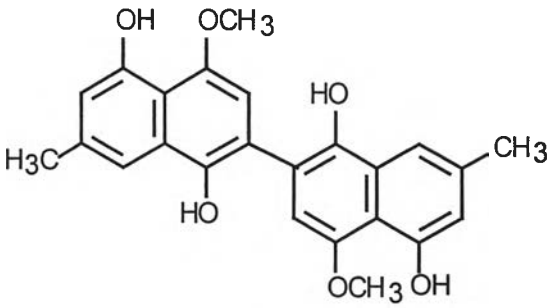
Biramentaceone (**1**)



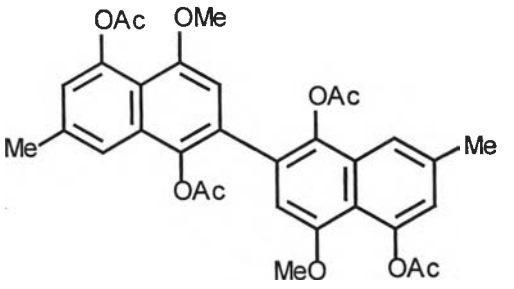
3,3′-Dimer of 6-hydroxy-5-methoxy
-2-methyl-1,4 – naphthoquinone (**2**)



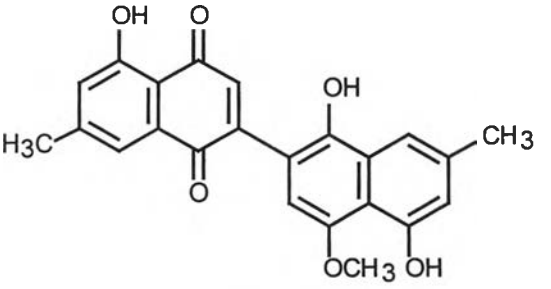
Diosindigo B (**3**)



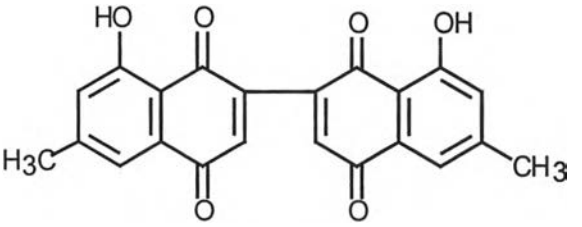
Dihydrodiosindigo B (**4**)



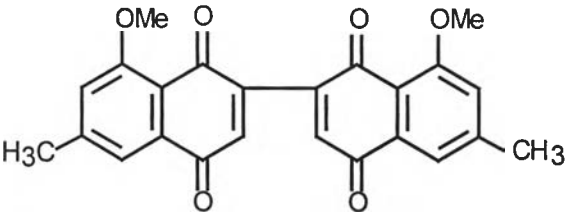
Diosindigo B leucotetraacetate (**5**)



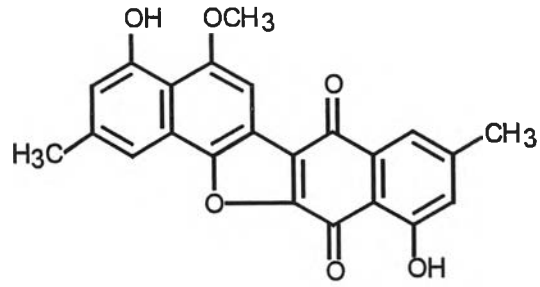
Iso-celebaquinone (**6**)



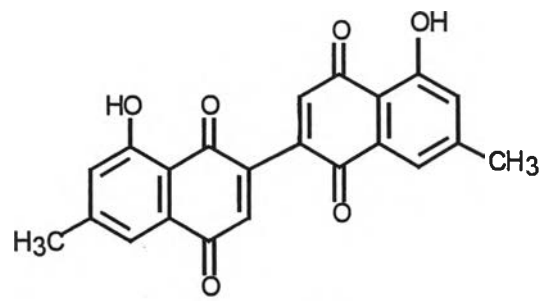
Mamegakinone (**7**)



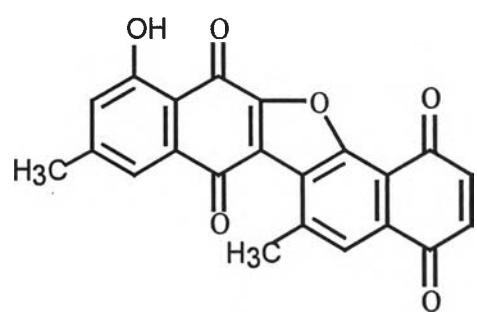
Mamegakinone dimethyl ether (**8**)



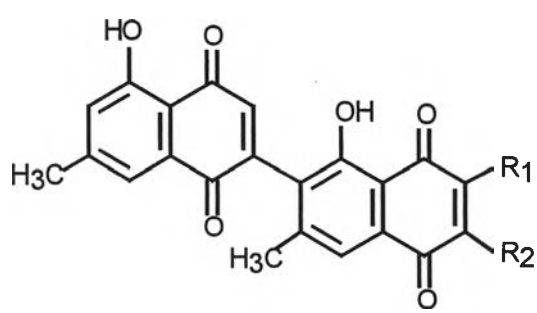
Violet quinone (**9**)



Rotundiquinone (**10**)



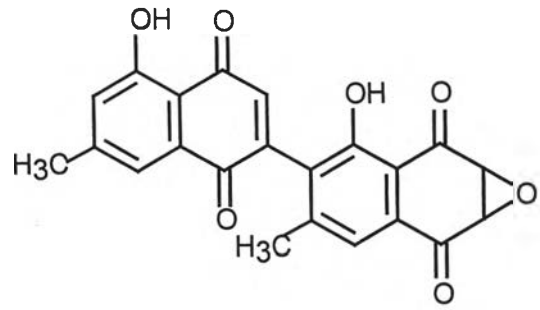
3,5′-O-Cyclodiospyrin (**11**)



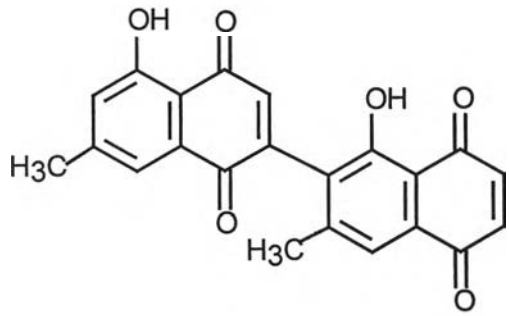
2′-Chlorodiospyrin (**12**) R_1 = H, R_2 = Cl

3′-Chlorodiospyrin (**13**) R_1 = Cl, R_2 = H

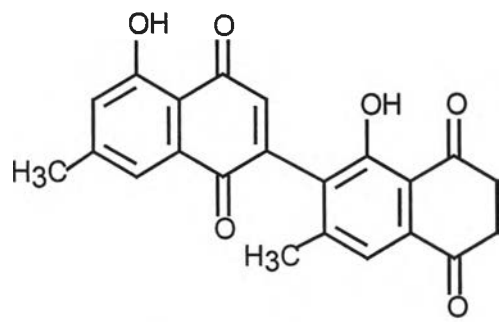
3′-Chloro-2′-Hydroxydiospyrin (**14**) R_1 = Cl, R_2 = OH



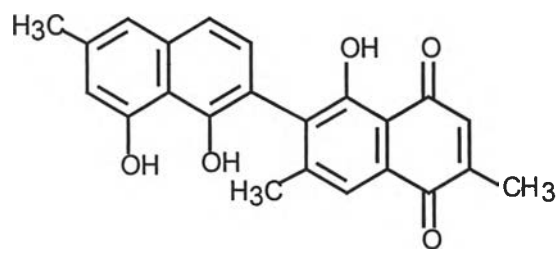
Diosquinone (**15**)



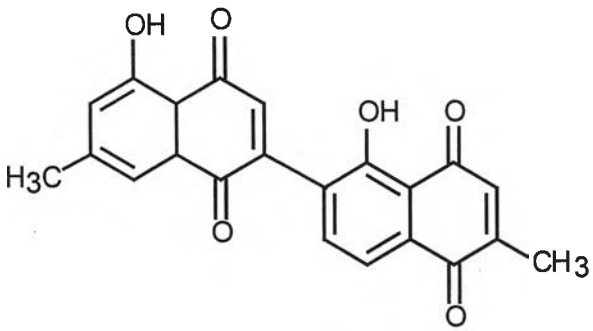
Diospyrin (**16**)



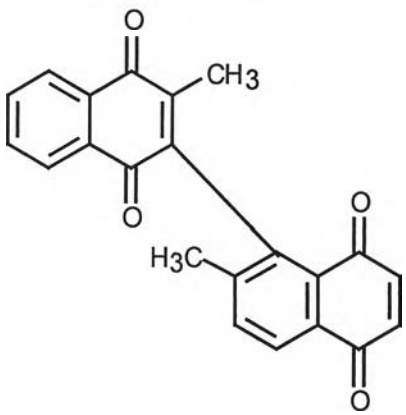
β'-Dihydrodiospyrin (**17**)



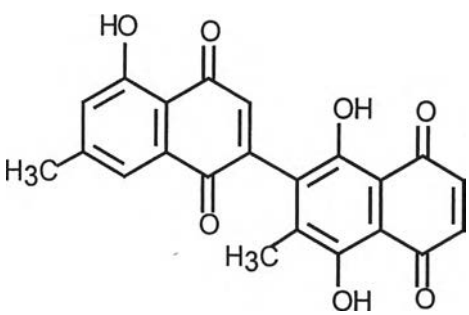
Ebenone (**18**)



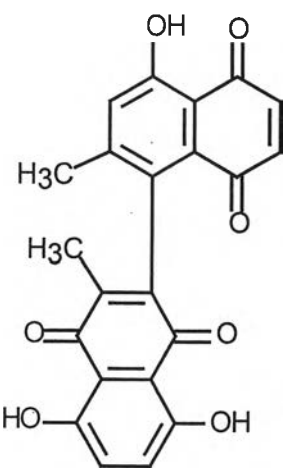
Ehretinone (**19**)



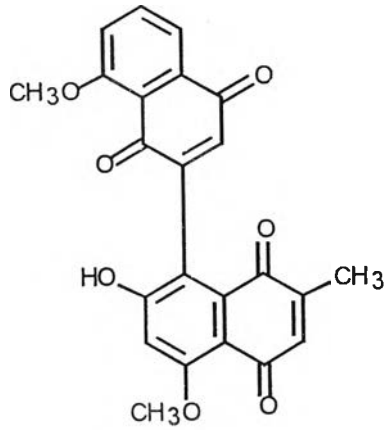
Habibone (**20**)



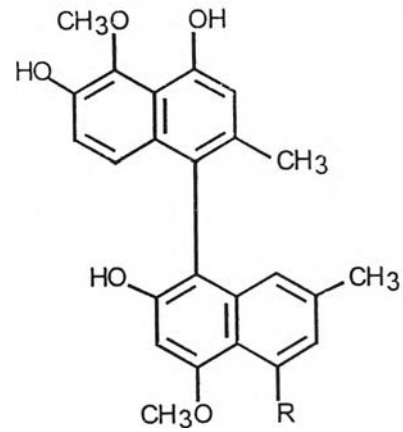
8-Hydroxyisodiospyrin (**21**)



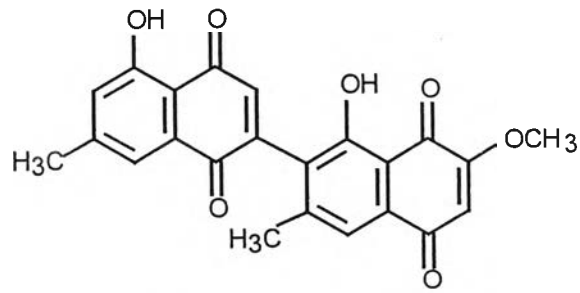
8′-Hydroxyisodiospyrin (**22**)



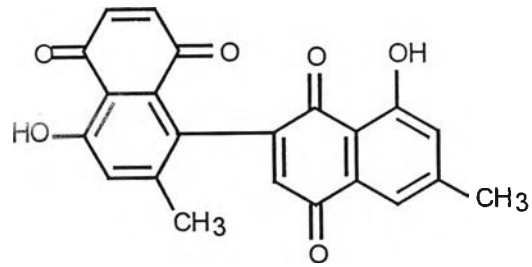
Lemuninol A (**23**)



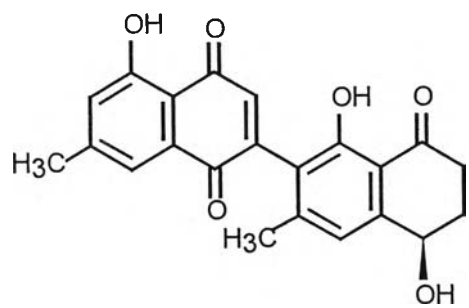
Lemuninol B (**55**) R = H
Lemuninol C (**56**) R = OCH_3



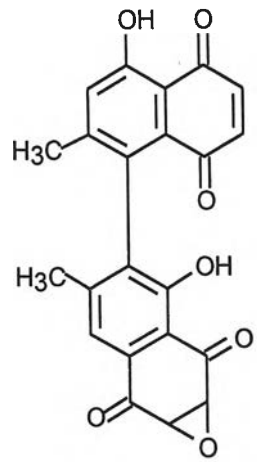
3′-Methoxydiospyrin (**24**)



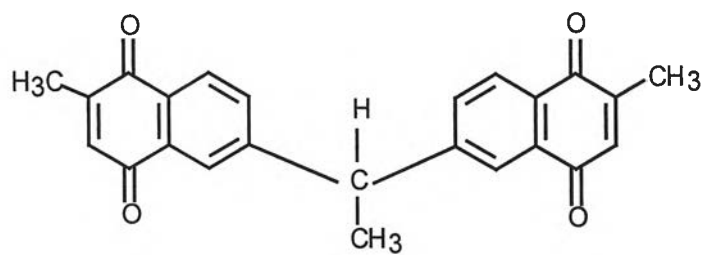
Neodiospyrin (**25**)



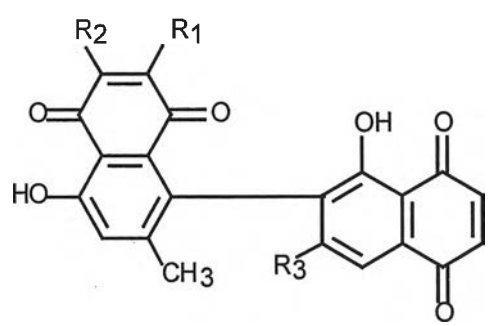
Tetrahydrodiospyrin (**26**)



Batocanone (**27**)



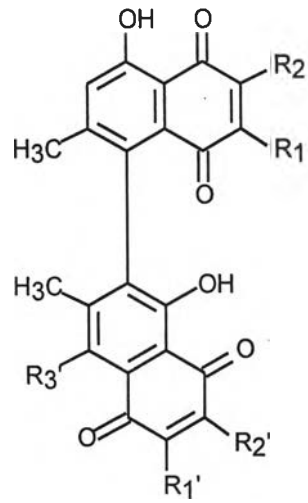
Ethylidene-6,6′-biplumbagin (**28**)



2′-Ethoxyisodiospyrin (**29**) $R_1 = OCH_2CH_3$, $R_2 = H$, $R_3 = CH_3$

3′-Ethoxyisodiospyrin (**30**) $R_1 = H$, $R_2 = OCH_2CH_3$, $R_3 = CH_3$

3-Ethoxyisodiospyrin (**31**) $R_1 = H$, $R_2 = H$, $R_3 = OCH_2CH_3$



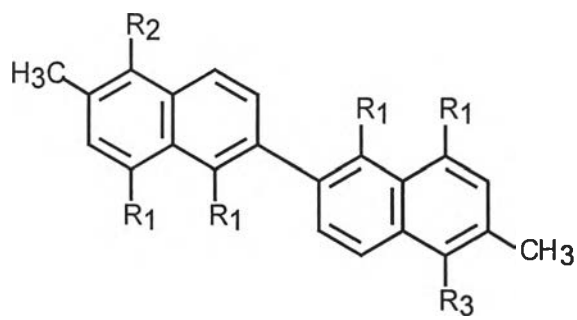
2′ - Methoxy isodiospyrin (**32**) $R_1 = R_2 = R_1' = R_2' = R_3' = OCH_3$

3′ - Methoxy isodiospyrin (**33**) $R_1 = R_2 = R_1' = R_2' = R_3' = OCH_3$

2, 2′ - Dimethoxy isodiospyrin (**34**) $R_1 = R_2 = R_1' = R_2' = R_3' = OCH_3$

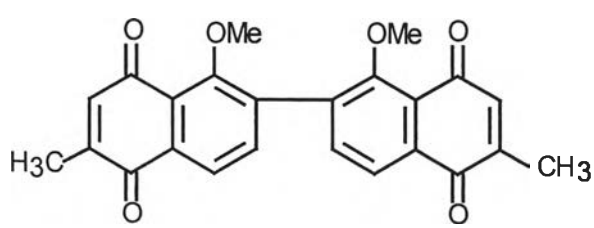
2, 3′ - Dimethoxy isodiospyrin (**35**) $R_1 = R_2 = R_1' = R_2' = R_3' = OCH_3$

3, 3′ - Dimethoxy isodiospyrin (**36**) $R_1 = R_2 = R_1' = R_2' = R_3' = OCH_3$

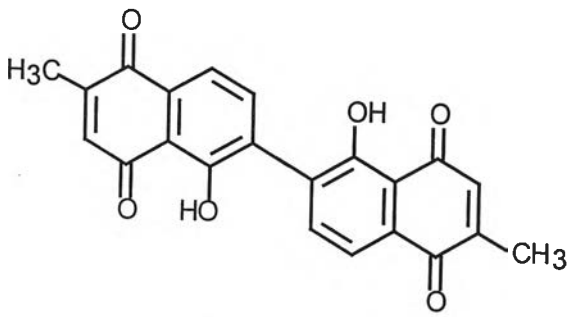


Ebenone leucopentaacetate (**37**) $R_1 = R_3 = OCOMe$, $R_2 = H$

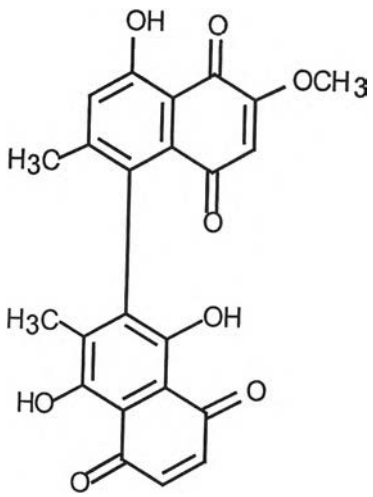
Elliptinone leucohexaacetate (**39**) $R_1 = R_2 = R_3 = OCOMe$



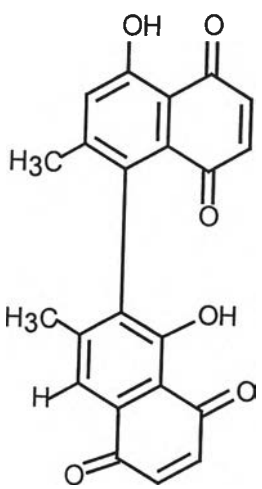
Elliptinone dimethyl ether (Di-*O*-methyldiospyroquinone) (**38**)



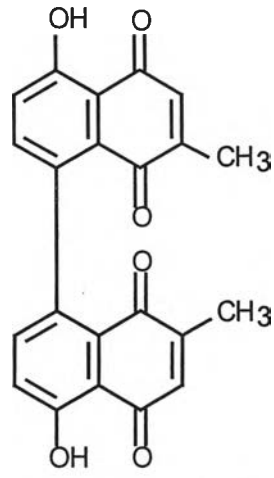
Elliptinone (**40**)



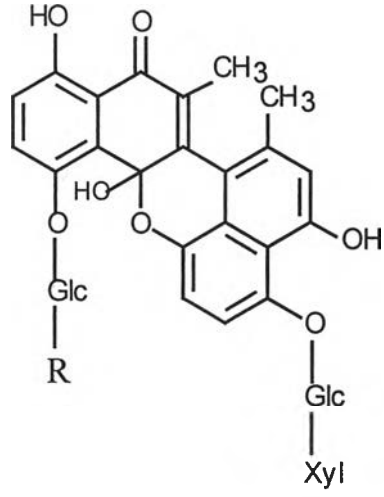
8′-Hydroxy-3-methoxy isodiospyrin (**41**)



Isodiospyrin (**42**)

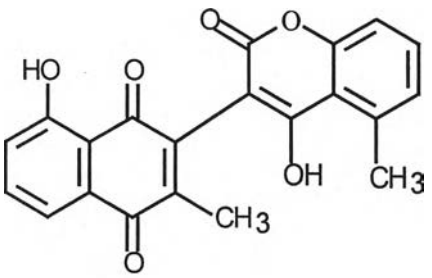


Maritinone (**43**)

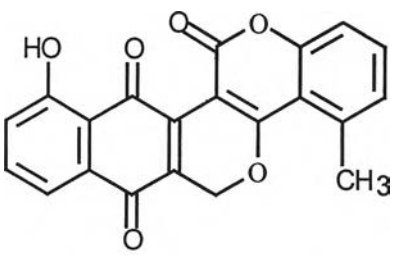


1′,2-binaphthalen-4-one-2′,3-dimethyl-1,8′-epoxy-1,4′,5,5′,8,8′-hexahydroxy-8-*O*-*β*-glucopyranosyl-5′-*O*-*β*-xylopyranosyl (1→6)-*β*-glucopyranoside (**44**) R = H

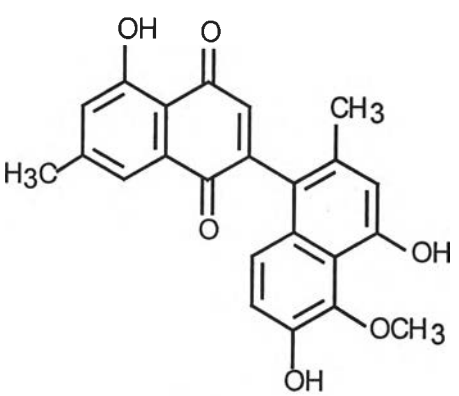
1′,2-binaphthalen-4-one-2′,3-dimethyl-1,8′-epoxy-1,4′,5,5′,8,8′-hexahydroxy-5′,8-di-*O*-*β*-xylopyranosyl(1→6)-*β*-glucopyranoside (**45**) R = Xyl



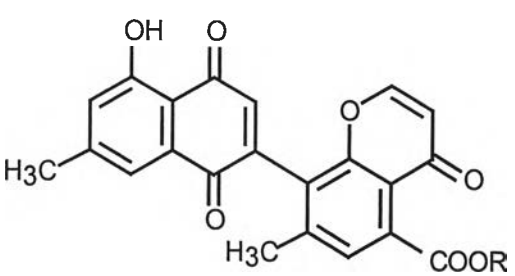
Canaliculatin (**46**)



Cyclo-canaliculatin (**47**)

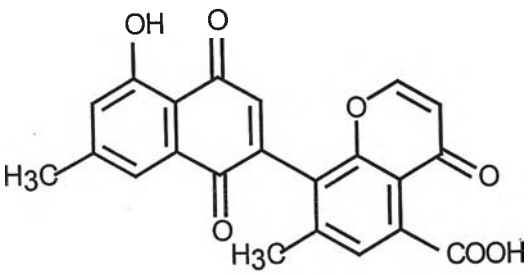


Celebaquinone (**48**)

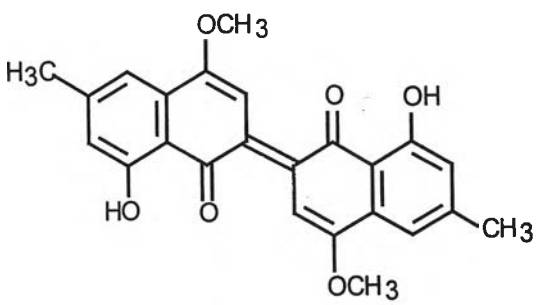


Chromenone acid (**49**) R = H

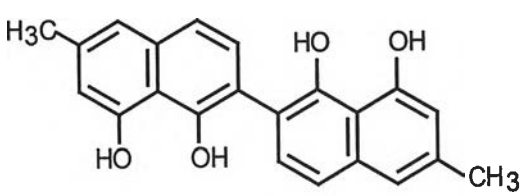
Chromenone ester (**50**) R = C_2H_5



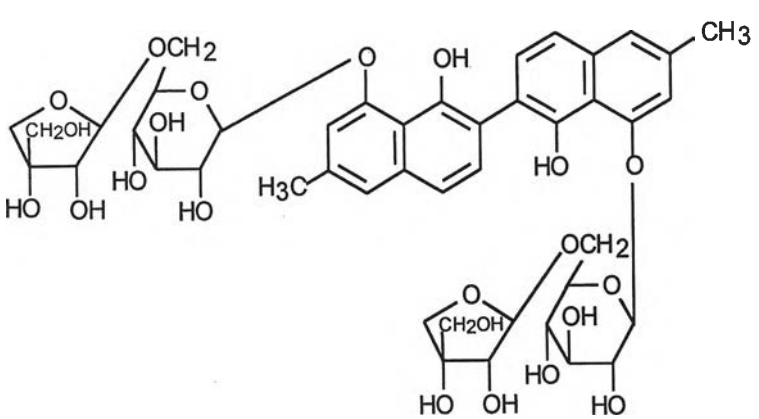
Diosindigo (**51**)



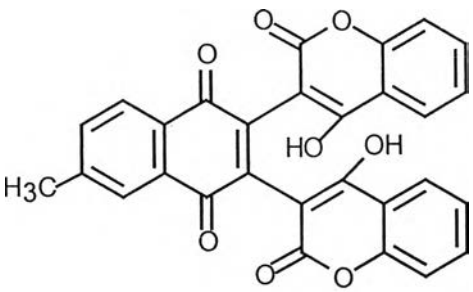
Diosindigo A (**52**)



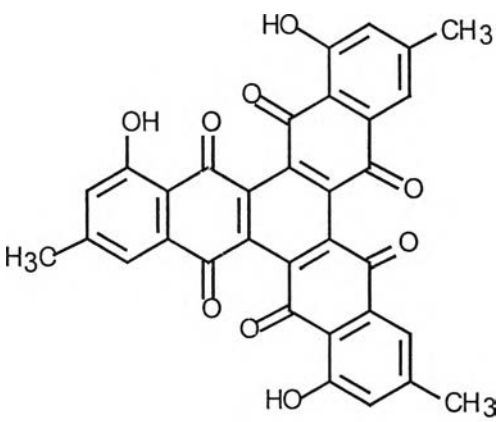
Diospyrol (**53**)



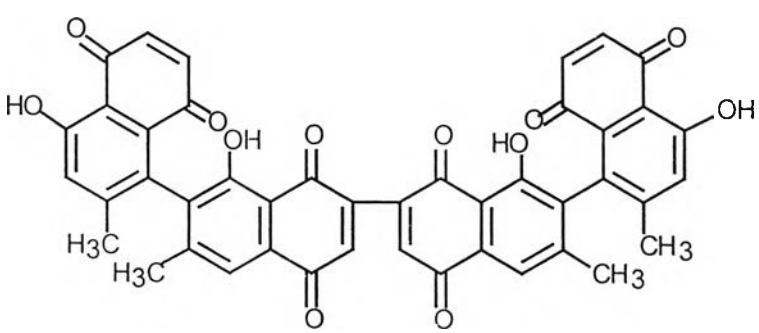
Diospyrol-8,8′-di-*O*-6-*β*-D-epiofuranosyl-*β*-D-glucopyranoside (**54**)



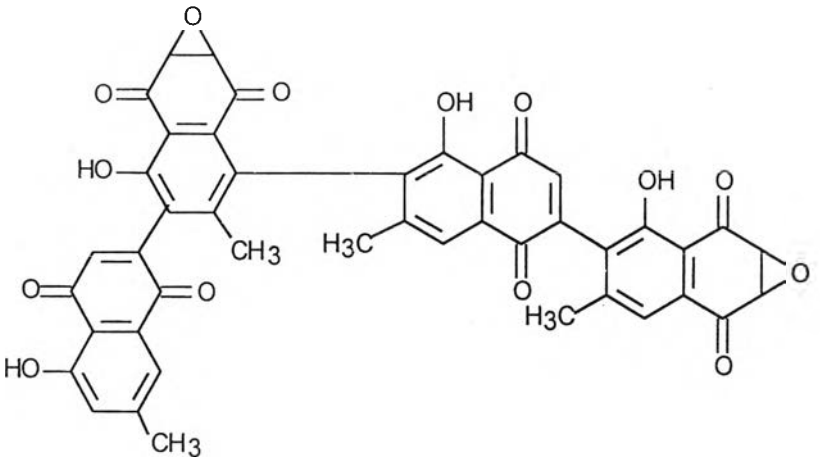
Ismailin (**57**)



Xylospyrin (**58**)



Bis-isodiospyrin (**59**)



6″, 8′-Bisdiosquinone (**60**)

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
1. *Friedelane type*		
Friedelin (**61**)	*D. eriantha*	Chen *et al.*, 1994
	D. maritima	Higa *et al.*, 1998
Friedelin-3-ol (**62**)	*D. ferrea*	Chandler and Hooper, 1979
Glut-5(6)-ene-3-β-ol (**63**)	*D. iturensis*	Zhong *et al.*, 1984
	D. sanzaminika	Zhong *et al.*, 1984
2α-Hydroxyfriedelin (**64**)	*D. iturensis*	Zhong *et al.*, 1984
	D. sanzaminika	Zhong *et al.*, 1984
2. *Lupane type*		
28-Acetyl-3-(*E*)-coumaroylbetulin (**65**)	*D. maritima*	Kuo *et al.*, 1997b
Allobetulin (**66**)	*D. montana*	Lillie *et al.*, 1976a
Betulin (**67**)	*D. abyssinica*	Zhong *et al.*, 1984
	D. argentea	Zakaria *et al.*, 1984

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Betulin (**67**)	*D. bipindensis*	Waterman and Mbi, 1979
	D. buxifolia	Bhakuni *et al.*, 1971
	D. canaliculata	Zhong *et al.*, 1984
	D. chevalieri	Hayek *et al.*, 1989
	D. candolleana	Desai *et al.*, 1970
	D. consolatae	Khan, Nkunya and Wevers, 1980
	D. castanea	Musgrave *et al.*, 1974
	D. cauliflora	Musgrave *et al.*, 1974
	D. chevalieri	Zhong *et al.*, 1984
	D. chloroxylon	Matsuura *et al.*, 1971
	D. cinnabarina	Waterman and Mbi, 1979 ; Zhong *et al.*, 1984
	D. cornii	Khan *et al.*, 1980
	D. crassiflora	Zhong *et al.*, 1984
	D. curranii	Musgrave *et al.*, 1974
	D. dendo	Zhong *et al.*, 1984
	D. diepenhorstii	Balza *et al.*, 1989
	D. discolor	Zakaria *et al.*, 1984
	D. ebenaster	Dominguez *et al.*, 1979
	D. elliptifolia	Musgrave *et al.*, 1974

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Betulin (67)	*D. embryopteris*	Bhakuni *et al.*, 1971
	D. eriantha	Chen *et al.*, 1994
	D. evena	Musgrave *et al.*, 1974
	D. exsculpta	Bhakuni *et al.*, 1971
	D. fragrans	Zhong *et al.*, 1984
	D. gabunensis	Zhong *et al.*, 1984
	D. gracilescens	Waterman and Mbi, 1979 ; Zhong *et al.*, 1984
	D. guianensis	Hayek, Jordis, Moche, and Sauter, 1989
	D. hirsuta	Herath *et al.*, 1978
	D. hoyleana	Zhong *et al.*, 1984
	D. indica	Hayek *et al.*, 1989
	D. ismailii	Zakaria *et al.*, 1984
	D. iturensis	Zhong *et al.*, 1984
	D. kaki	Matsuura *et al.*, 1971 ; Andriamasy and Fouraste, 1978
	D. kaki var. *sylvestris*	Tezuka *et al.*, 1972
	D. kamerunensis	Zhong *et al.*, 1984
	D. kirkii	Maria *et al.*, 1980
	D. leucomelas	Recio *et al.*, 1995

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Betulin (67)	*D. longifolia*	Zhong *et al.*, 1984
	D. lotus	Yoshihira *et al.*, 1971a ; Zakaria *et al.*, 1984
	D. maingayi	Musgrave *et al.*, 1974 ; Zakaria *et al.*, 1984
	D. malanonilau	Hayek *et al.*, 1989
	D. mannii	Jeffreys and Zakaria, 1983
	D. maritima	Tezuka *et al.*, 1973
	D. melanoxylon	Hayek *et al.*, 1989
	D. mespiliformis	Zhong *et al.*, 1984
	D. microphylla	Bhakuni *et al.*, 1971
	D. mollis	Yoshihira *et al.*, 1971b ; Musgrave and Skoyles, 1974
	D. monobuttensis	Zhong *et al.*, 1984
	D. montana	Dutta, Dutta and Chakrararti, 1972 ; Misra, Nigam and Mitra, 1972 ; Musgrave *et al.*, 1974
	D. moonii	Herath *et al.*, 1978
	D. morrisiana	Yoshihira *et al.*, 1971a
	D. obliquifolia	Waterman and Mbi, 1979
	D. oblongifolia	Herath *et al.*, 1978
	D. peregrina	Misra *et al.*, 1971 ; Bhaumik *et al.*, 1981 ; Dinda *et al.*, 1995

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Betulin (**67**)	*D. pseudo-malabarica*	Musgrave *et al.*, 1974
	D. quaesita	Herath *et al.*, 1978
	D. reiantha	Chen, Yu and Huang, 1992
	D. rotundifolia	Hayek *et al.*, 1989
	D. sanza-minika	Musgrave *et al.*, 1974 ; Zhong *et al.*, 1984
	D. siamang	Zakaria *et al.*, 1974
	D. siamensis	Musgrave *et al.*, 1974
	D. siderophylla	Li *et al.*, 1982
	D. singaporensis	Zakaria *et al.*, 1984
	D. spinescens	Herath *et al.*, 1984
	D. sumatrana	Zakaria *et al.*, 1984
	D. sylvatica	Hayek *et al.*, 1989
	D. thwaitesii	Herath *et al.*, 1978
	D. tomentosa	Bhakuni *et al.*, 1971
	D. variegata	Musgrave and Skoyles, 1974
	D. verrucosa	Khan *et al.*, 1987
	D. virainiana	Hayek *et al.*, 1989
	D. walkeri	Herath *et al.*, 1978
	D. wallichii	Zakaria *et al.*, 1984
	D. zenkeri	Zhong *et al.*, 1984

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Betulinic acid (**68**)	*D. abyssinica*	Zhong *et al.*, 1984
	D. alboflavescena	Bouquet, 1972
	D. argentea	Zakaria *et al.*, 1984
	D. bipindensis	Waterman and Mbi, 1979
	D. buxifolia	Bhakuni *et al.*, 1971
	D. canaliculata	Zhong *et al.*, 1984
	D. candolleana	Desai *et al.*, 1970
	D. castanea	Musgrave *et al.*, 1974
	D. cauliflora	Musgrave *et al.*, 1974
	D. chevalieri	Zhong *et al.*, 1984
	D. chloroxylon	Matsuura *et al.*, 1971
	D. consolatae	Khan *et al.*, 1980
	D. cinnabarina	Waterman and Mbi, 1979 ; Zhong *et al.*, 1984
	D. crassiflora	Zhong *et al.*, 1984
	D. curranii	Musgrave *et al.*, 1974
	D. dendo	Zhong *et al.*, 1984
	D. discolor	Lin, 1978 ; Zakaria *et al.*, 1984
	D. ebenum	Brown and Thomson, 1965
	D. elliptifolia	Musgrave *et al.*, 1974

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Betulinic acid (**68**)	*D. embryopteris*	Bhakuni *et al.*, 1971
	D. eriantha	Chen *et al.*, 1994
	D. evena	Musgrave *et al.*, 1974
	D. exsculpta	Bhakuni *et al.*, 1971
	D. ferrea	Bhakuni *et al.*, 1971
	D. fragrans	Zhong *et al.*, 1984
	D. gabunensis	Zhong *et al.*, 1984
	D. gilleti	Bouquet, 1973
	D. gracilescens	Waterman and Mbi, 1979 ; Zhong *et al.*, 1984
	D. hirsuta	Herath *et al.*, 1978
	D. hoyleana	Zhong *et al.*, 1948 ; Bouquet, 1973
	D. ismailii	Zakaria *et al.*, 1984
	D. iturensis	Zhong *et al.*, 1984
	D. kaki	Matsuura *et al.*, 1971
	D. kaki var. *sylvestris*	Tezuka *et al.*, 1972
	D. kamerunensis	Zhong *et al.*, 1984
	D. leucomelas	Recio *et al.*, 1995
	D. longifolia	Zhong *et al.*, 1984

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Betulinic acid (**68**)	*D. lotus*	Yoshihira *et al.*, 1971a ; Zakaria *et al.*, 1984
	D. mafiensis	Khan and Rwekika, 1999
	D. maingayi	Musgrave *et al.*, 1974 ; Zakaria *et al.*, 1984
	D. mannii	Jeffreys *et al.*, 1983
	D. maritima	Tezuka *et al.*, 1973
	D. mespiliformis	Zhong *et al.*, 1984
	D. monobuttensis	Zhong *et al.*, 1984
	D. montana	Musgrave *et al.*, 1974 ; Likhitwitayawuid *et al.*, 1999 ; Narayan *et al.*, 1978
	D. moonii	Herath *et al.*, 1978
	D. morrisiana	Yoshihira *et al.*, 1971a
	D. obliquifolia	Waterman and Mbi, 1979
	D. palmeri	Dominguez *et al.*, 1979
	D. peregrina	Misra *et al.*, 1971 ; Dinda *et al.*, 1995
	D. pseudo-malabarica	Musgrave *et al.*, 1974
	D. quaesita	Herath *et al.*, 1978
	D. reiantha	Chen *et al.*, 1992
	D. sanza-minika	Musgrave *et al.*, 1974 ; Zhong *et al.*, 1984

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Betulinic acid (**68**)	*D. siamang*	Zakaria *et al.*, 1974
	D. siamensis	Musgrave *et al.*, 1974
	D. siderophylla	Li *et al.*, 1981
	D. singaporensis	Zakaria *et al.*, 1984
	D. spinescens	Herath *et al.*, 1984
	D. sumatrana	Zakaria *et al.*, 1984
	D. thwaitesii	Herath *et al.*, 1978
	D. tomentosa	Bhakuni *et al.*, 1971
	D. verrucosa	Khan *et al.*, 1980; Khan *et al.*, 1987
	D. walkeri	Herath *et al.*, 1978
	D. wallichii	Zakaria *et al.*, 1984
	D. zenkeri	Zhong *et al.*, 1984
Betulinaldehyde (**69**)	*D. canaliculata*	Zhong *et al.*, 1984
	D. eriantha	Chen *et al.*, 1992

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
3-(*E*)-Coumaroylbetulinaldehyde (**70**)	*D. maritima*	Chang and Kuo, 1999
3-(*Z*)-Coumaroyllupeol (**71**)	*D. maritima*	Chang and Kuo, 1998
3-(*E*)-Coumaroyl-28-palmitoylbetulin (**72**)	*D. maritima*	Chang and Kuo, 1999
3-(*Z*)-Coumaroyl-28- palmitoylbetulin (**73**)	*D. maritima*	Chang and Kuo, 1998
3-(*E*)-Coumaroylbetulin-28-yl ethyl nonanedioate (**74**)	*D. maritima*	Kuo and Chang, 2000
3-(E)-Coumaroylbetulin-28-yl ethyl (2R)-2-hydroxysuccinate (**75**)	*D. maritima*	Kuo and Chang, 2000
3-(*E*)-Coumaroylbetulin-28-yl ethyl succinate (**76**)	*D. maritima*	Kuo and Chang, 2000

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Epi-lupeol (**77**)	*D. ebenaster*	Dominguez *et al.*, 1979
	D. palmeri	Dominguez *et al.*, 1979
3-(E)-Feruloyl-28-palmitoylbetulin (**78**)	*D. maritima*	Chang and Kuo, 1998
3-(E)-Feruloylbetulin (**79**)	*D. maritima*	Kuo *et al.*, 1997b
Lupenone (**80**)	*D. mollis*	Yoshihira *et al.*, 1971b
Lupeol (**81**)	*D. abyssinica*	Zhong *et al.*, 1984
	D. acuta	Herath *et al.*, 1978
	D. argentea	Zakaria *et al.*, 1984
	D. bipindensis	Waterman and Mbi, 1979
	D. buxifolia	Bhakuni *et al.*, 1971
	D. canaliculata	Zhong *et al.*, 1984
	D. candolleana	Desai *et al.*, 1970
	D. castanea	Musgrave *et al.*, 1974

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Lupeol (**81**)	*D. cauliflora*	Musgrave *et al.*, 1974
	D. chevalieri	Zhong *et al.*, 1984
	D. cinnabarina	Waterman and Mbi, 1979 ; Zhong *et al.*, 1984
	D. cornii	Khan *et al.*, 1980
	D. crassiflora	Zhong *et al.*, 1984
	D. curranii	Musgrave *et al.*, 1974
	D. dendo	Zhong *et al.*, 1984
	D. diepenhorstii	Balza *et al.*, 1989
	D. discolor	Zakaria *et al.*, 1984
	D. elliptifolia	Musgrave et al., 1974
	D. embryopteris	Bhakuni *et al.*, 1971
	D. evena	Musgrave *et al.*, 1974
	D. exsculpta	Bhakuni *et al.*, 1971
	D. fragrans	Zhong *et al.*, 1984
	D. gabunensis	Zhong *et al.*, 1984
	D. gracilescens	Waterman and Mbi, 1979 ; Zhong *et al.*, 1984
	D. greeniwayi	Khan and Rwekika, 1998

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Lupeol (**81**)	*D. hirsuta*	Herath *et al.*, 1978
	D. hoyleana	Zhong *et al.*, 1984
	D. ismailii	Zakaria *et al.*, 1984
	D. iturensis	Zhong *et al.*, 1984
	D. kaki var. *sylvestris*	Tezuka *et al.*, 1972
	D. kamerunensis	Zhong *et al.*, 1984
	D. kirkii	Maria *et al.*, 1979
	D. longifolia	Zhong *et al.*, 1984
	D. lotus	Yoshihira *et al.*, 1971a ; Zakaria *et al.*, 1984
	D. maingayi	Musgrave *et al.*, 1974 ; Zakaria *et al.*, 1984
	D. mannii	Jeffreys *et al.*, 1983
	D. maritima	Tezuka *et al.*, 1973
	D. mespiliformis	Zhong *et al.*, 1984
	D. microphylla	Bhakuni *et al.*, 1971
	D. mollis	Yoshihira *et al.*, 1971b ; Musgrave and Skoyles, 1974
	D. monobuttensis	Zhong *et al.*, 1984
	D. montana	Musgrave *et al.*, 1974 ; Narayan, Row and Satyanarayana, 1978 ; Raj and Agrawal, 1979

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Lupeol (**81**)	*D. moonii*	Herath *et al.*, 1978
	D. morrisiana	Yoshihira *et al.*, 1971a
	D. obliquifolia	Waterman and Mbi, 1979
	D. oblongifolia	Herath *et al.*, 1978
	D. oppositifolia	Herath *et al.*, 1978
	D. peregrina	Bhaumik *et al.*, 1981 ; Dinda *et al.*, 1995
	D. pseudo-malabarica	Musgrave *et al.*, 1974
	D. quaesita	Herath *et al.*, 1978
	D. quiloensis	Harper, Kemp and Tannock, 1970
	D. reiantha	Chen *et al.*, 1992
	D. rheophytica	Herath *et al.*, 1978
	D. rhodocalyx	Musgrave and Skoyles, 1974 ; Sutthivaiyakit *et al.*, 1995
	D. sanza-minika	Musgrave *et al.*, 1974 ; Zhong *et al.*, 1984
	D. siamang	Zakaria *et al.*, 1974
	D. siamensis	Musgrave *et al.*, 1974
	D. siderophylla	Li *et al.*, 1981
	D. singaporensis	Zakaria *et al.*, 1984
	D. spinescens	Herath *et al.*, 1978

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Lupeol (**81**)	*D. sumatrana*	Zakaria *et al.*, 1984
	D. thwaitesii	Herath *et al.*, 1978
	D. tomentosa	Bhakuni *et al.*, 1971
	D. toposia	Musgrave and Skoyles, 1974
	D. variegata	Musgrave and Skoyles, 1974
	D. walkeri	Herath *et al.*, 1978
	D. zenkeri	Zhong *et al.*, 1984
Oxyallobetulin (**82**)	*D. lotus*	Bhakuni et al., 1971 ; Yoshihira *et al.*, 1971a
	D. montana	Lillie, Musgrave and Skoyles, 1976a
	D. morrisiana	Yoshihira *et al.*, 1971a
Peregrinol (**83**)	*D. peregrina*	Jain and Yadava, 1994

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
3. *Oleanane type*		
β-Amyrin (**84**)	*D. lotus*	Yoshihira *et al.*, 1971a
	D. morrisiana	Yan *et al.*, 1989
Oleanolic acid (**85**)	*D. castanea*	Musgrave *et al.*, 1974
	D. cauliflora	Musgrave *et al.*, 1974
	D. curranii	Musgrave *et al.*, 1974
	D. evena	Musgrave *et al.*, 1974
	D. kaki	Matsuura *et al.*, 1977
	D. montana	Dutta *et al.*, 1972 ; Misra *et al.*, 1972 ; Musgrave and Skoyles, 1974
	D. moonii	Herath *et al.*, 1978
	D. oblongifolia	Herath *et al.*, 1978
	D. tomentosa	Bhakuni *et al.*, 1971
	D. zombensis	Gafner *et al.*, 1987 ; Gafner and Rodriguez, 1988

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Olean-12-ene-3-one (**86**)	*D. morrisiana*	Yan *et al.*, 1989
Oleanolic acid glycosides (**87-90**)	*D. zombensis*	Gafner *et al.*, 1987 ; Gafner and Rodriguez, 1988
Oleanolic acid acetate (**91**)	*D. eriantha*	Chen *et al.*, 1992
	D. lotus	Zakaria *et al.*, 1984
Oleanolic acid palmitate (**92**)	*D. montana*	Misra *et al.*, 1972
Oleanolic acid stearate (**93**)	*D. montana*	Misra *et al.*, 1972
4. *Taraxerane type*		
Taraxerol (**94**)	*D. ferrea*	Bhakuni *et al.*, 1971
	D. hirsute	Herath *et al.*, 1978
	D. kaki	Zhong and Feng, 1987
	D. lotus	Bhakuni *et al.*, 1971 ; Yoshihira *et al.*, 1971a ; Zakaria *et al.*, 1984

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Taraxerol (**94**)	*D. hirsuta*	Herath *et al.*, 1978
	D. mollis	Yoshihira *et al.*, 1971b
	D. morisiana	Yoshihira *et al.*, 1971a
Taraxerone (**95**)	*D. acuta*	Herath *et al.*, 1978
	D. ferrea	Bhakuni *et al.*, 1971
	D. lotus	Zakaria *et al.*, 1984
	D. maritima	Kuo *et al.*, 1997c
	D. moonii	Herath *et al.*, 1978
	D. quaesita	Herath *et al.*, 1978
	D. thwaitesii	Herath *et al.*, 1978
	D. oblongifolia	Herath *et al.*, 1978
	D. oppositifolia	Herath *et al.*, 1978
	D. peregrina	Jain and Yadava, 1994
	D. rheophytica	Herath *et al.*, 1978
Taraxeryl acetate (**96**)	*D. maingayi*	Zakaraia *et al.*, 1984
	D. singaporensis	Zakaraia *et al.*, 1984

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

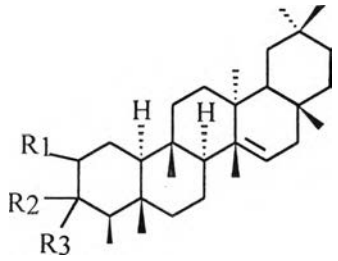
Compounds	Sources	References
5. *Ursane type*		
3β-Acetoxy-urs-11-ene-28,13-olide (**97**)	*D. eriantha*	Chen *et al.*, 1992
α-Amyrenone (**98**)	*D. ebenum*	Sharma and Gupta, 1985
α -Amyrin (**99**)	*D. cordifolia*	
	D. cornii	Khan *et al.*, 1980 ; Gafner *et al.*, 1987
	D. ebenum	Brown and Thomson, 1965
	D. kaki	Andriamasy and Fouraste, 1978
	D. kirkii	Khan *et al.*, 1980 ; Khan *et al.*, 1987
	D. mafiensis	Khan and Rwekika, 1999
	D. maingayi	Zakaria *et al.*, 1984
	D. melanoxylon	Chowdhury, 1973
	D. mespiliformis	Khan *et al.*, 1980
	D. montana	Misra *et al.*, 1972

Table 2 Distribution of triterpenoids in the genus *Diospyros* (continued).

Compounds	Sources	References
Bauerenol (**100**)	*D. sylvatica*	Khan *et al.*, 1980
	D. ebenum	Khan *et al.*, 1980
	D. kirkii	Khan *et al.*, 1980
	D. melanoxylon	Khan *et al.*, 1980
	D. mespiliformis	Khan *et al.*, 1980
	D. sylvatica	Khan *et al.*, 1980
Epi-uvaol (**101**)	*D. montana*	Dutta *et al.*, 1972
19*a*-Hydroxyursolic acid (**102**)	*D. kaki*	Matsuura and Iinuma, 1977
Marsformosanone (**103**)	*D. peregrina*	Bhaumik *et al.*, 1981
Ursolic acid (**104**)	*D. castama*	Musgrave and Skoyles, 1974
	D. cauliflora	Musgrave and Skoyles, 1974
	D. curranii	Musgrave and Skoyles, 1974
	D. ebenum	Sharma and Gupta, 1985

Table 2 Distribution of triterpenoids in the genus *Diospyros*.

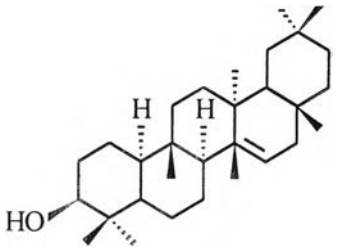
Compounds	Sources	References
Ursolic acid (**104**)	*D. evena*	Musgrave and Skoyles, 1974
	D. ferrea	Bhakuni *et al.*, 1971
	D. hirsuta	Herath *et al.*, 1978
	D. kaki	Matsuura *et al.*, 1971 ; Matsuura and Iinuma, 1977
	D. leucomelas	Recio *et al.*, 1995
	D. lotus	Yoshihira *et al.*, 1971a ; Zakaria *et al.*, 1984
	D. montana	Misra *et al.*, 1972 ; Musgrave *et al.*, 1974 ; Zafar, Singh and Khan, 1991
	D. morrisiana	Yoshihira *et al.*, 1971a
	D. quaesita	Herath *et al.*, 1978
	D. tomentosa	Bhakuni *et al.*, 1971
Ursolic acid acetate (**105**)	*D. eriantha*	Chen *et al.*, 1992
	D. lotus	Yoshihira *et al.*, 1971a
Ursolic acid palmitate (**106**)	*D. montana*	Misra *et al.*, 1972
Ursolic acid stearate (**107**)	*D. montana*	Misra *et al.*, 1972
Uvaol (**108**)	*D. lotus*	Zakaria *et al.*, 1984
	D. maingayi	Zakaria *et al.*, 1984



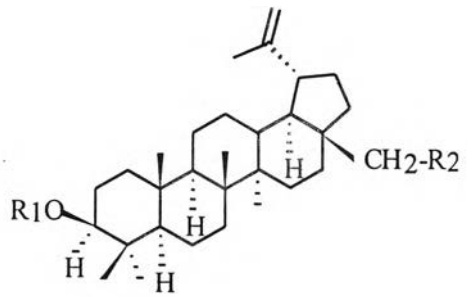
Friedelin (**61**) $R_1 = H$; R_2 ,R_2=O

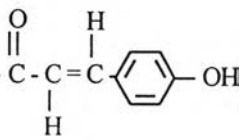
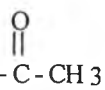
Friedelin-3-ol (**62**) $R_1 = H$; R_2=H ,R_3=OH

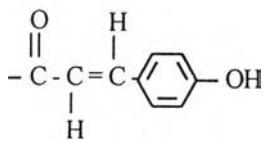
Friedelin-3-ol (**64**) $R_1 = OH$; R_2=H ,R_3=O

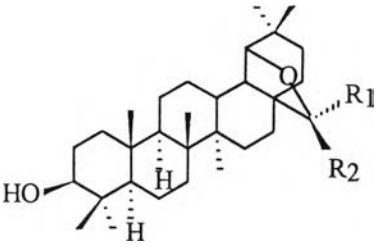


Glut-5(6)-ene-3β-ol (**63**)



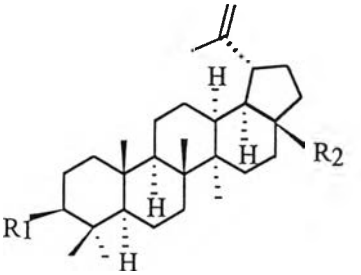
28-Acetyl-3-(*E*)-coumaroylbetulin (**65**) R_1 =  ; R_2 = 

3-(*E*)-Feruloylbetulin (**79**) R_1 =  ; R_2 = OH



Allobetulin (**66**) $R_1 = R_2 = H$

Oxyallobetulin (**82**) $R_1 = R_2 = O$



Betulin (**67**) $R_1 = \beta$-OH ; $R_2 = CH_2OH$

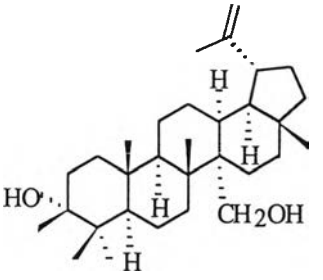
Betulinic acid (**68**) $R_1 = \beta$-OH ; $R_2 = COOH$

Betulinaldehyde (**69**) $R_1 = \alpha$-OH ; $R_2 = CHO$

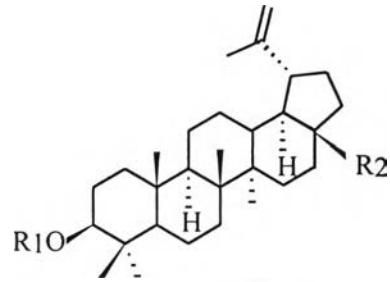
Epi-lupeol (**77**) $R_1 = \alpha$-OH ; $R_2 = CH_3$

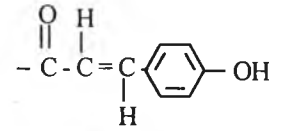
Lupenone (**80**) $R_1 = O$; $R_2 = CH_3$

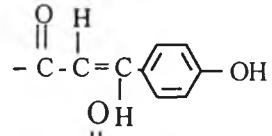
Lupeol (**81**) $R_1 = \beta$-OH ; $R_2 = CH_3$



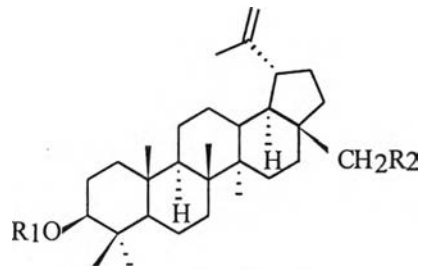
Peregrinol (**83**)

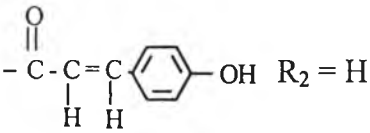


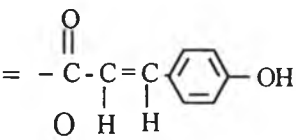
3-(*E*)-Coumaroylbetulinaldehyde (**70**) R_1 =  ; R_2=CHO

3-(*E*)-Coumaroyl-28-palmitoylbetulin (**72**) R_1 =  ;

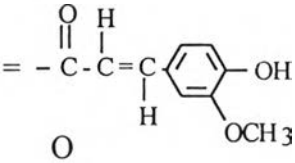
$R_2 = CH_2O\overset{O}{\overset{\|}{C}}CH_2CH_2(CH_2)_{10}CH_2CH_2CH_3$



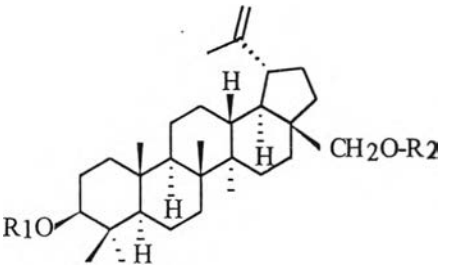
3-(*Z*)-Coumaroyllupeol (**71**) R_1=  $R_2 = H$

3-(*Z*)-Coumaroyl-28-palmitoylbetulin (**73**) R_1 =  ;

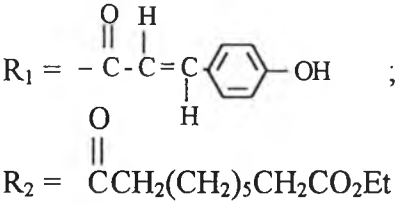
$R_2 = O\overset{O}{\overset{\|}{C}}CH_2CH_2(CH_2)_{12}CH_3$

3-(*E*)-Feruloyl-28-palmitoylbetulin (**78**) R_1 =  ;

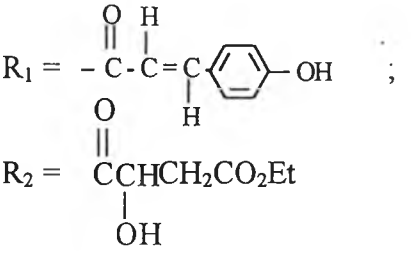
$R_2 = O\overset{O}{\overset{\|}{C}}CH_2CH_2(CH_2)_{12}CH_3$



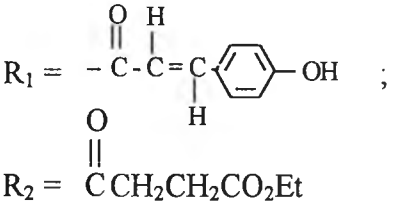
3-(*E*)-Coumaroylbetulin-28-yl ethyl nonanedioate (**74**)

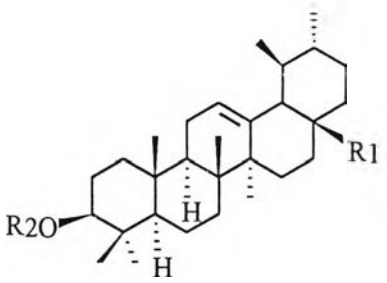


3-(*E*)-Coumaroylbetulin-28-yl ethyl (2*R*)-2-hydroxysuccinate (**75**)

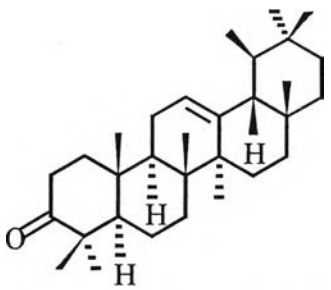


3-(*E*)-Coumaroylbetulin-28-yl ethyl succinate (**76**)

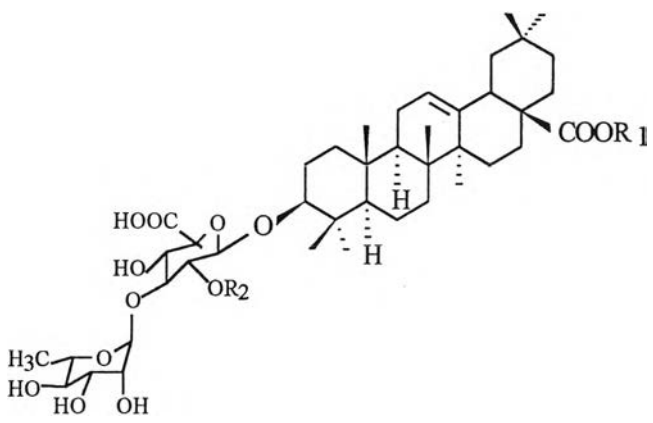




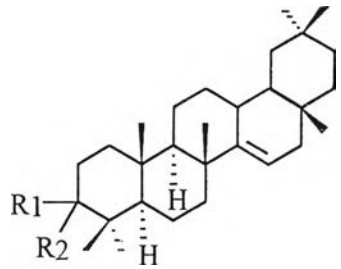
β-Amyrin(**84**)	R_1 =	CH_3 ; R_2 =	H
Oleanolic acid (**85**)	R_1 =	COOH ; R_2 =	H
Oleanolic acid acetate (**91**)	R_1 =	COOH ; R_2 =	$COCH_3$
Oleanolic acid palmitate (**92**)	R_1 =	COOH ; R_2 =	$CO(CH_2)_{14}CH_3$
Oleanolic acid stearate (**93**)	R_1 =	COOH ; R_2 =	$CO(CH_2)_{16}CH_3$



Olean-12-en-3-one (**86**)



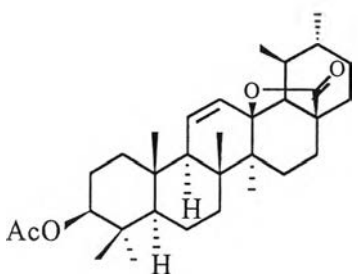
Oleanolic acid gylcosides : (**87**) R_1 = R_2 = H
(**88**) R_1 = Glu ; R_2 = H
(**89**) R_1 = Glu ; R_2 = Xyl
(**90**) R_1 = H ; R_2 = Xyl



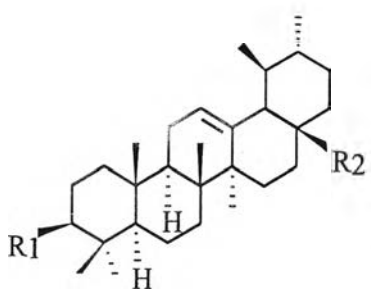
Taraxerol (**94**) R_1 = H ; R_2 = β-OH

Taraxerone (**95**) R_1 = R_2 = O

Taraxeryl acetate (**96**) R_1 = H ; R_2 = β-$OCOCH_3$



3β-Acetoxy-urs-11-ene-28,13-olide (**97**)



α-Amyrenone (**98**) R_1 = R_2 = CH_3

α-Amyrin (**99**) R_1 = β-OH ; R_2 = CH_3

Epi-uvaol (**101**) R_1 = α-OH; R_2 = CH_2OH

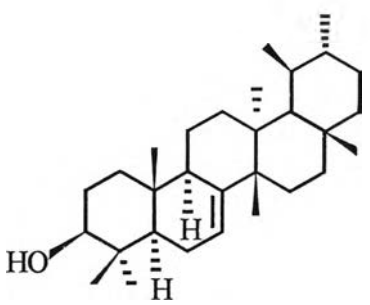
Ursolic acid (**104**) R_1 = β-OH ; R_2 = COOH

Ursolic acid acetate (**105**) R_1 = β-$OCOCH_3$; R_2 = COOH

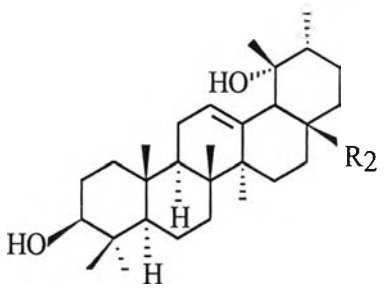
Ursolic acid palmitate (**106**) R_1 = β-$OCO(CH_2)_{14}CH_3$; R_2 = COOH

Ursolic acid stearate (**107**) R_1 = β-$OCO(CH_2)_{16}CH_3$; R_2 = COOH

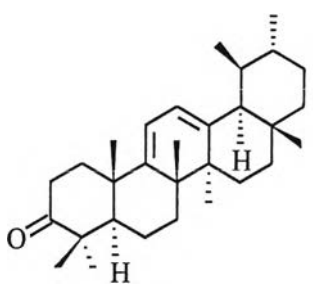
Uvaol (**108**) R_1 = β-OH ; R_2 = CH_2OH



Baurenol (**100**)



19α-Hydroxyursolic acid (**102**)



Marsformosanone (**103**)

1.1 Dimeric Naphthoquinone Derivatives

Similar to other plant secondary metabolites, the quinones are derived from a few key intermediates, principally acetate, shikimate and mevalonate, by a series of reactions which leads to the formation of benzenoid compounds. It is assumed that the last stage involves the oxidation of a phenol. In the fungi, most quinones probably arise by the acetate-malonate pathway and the extent to which shikimate is involved is still a matter for conjecture. However, shikimate appears to be an important intermediate in the formation of many quinones in higher plants. Wholly terpenoid quinones are relatively few but some quinones of mixed origins possess a side chain or ring derived from mevalonate (Thomson, 1971).

The distribution of the naphthoquinones is sporadic. Nearly half of them occur in higher plants, scatter through some twenty families. They have been found in the leaves, flowers, wood, bark, roots, and fruit (Thomson, 1971). The polyketide route to the naphthalene nucleus, and consequently naphthoquinones, is well established in microorganisms but appears to be quite rare in higher plants, where other biosynthetic pathways are preferred (Manitto, 1981).

These yellow phenolic pigments may be formed by any one of four distinct routes. The first, perhaps the most primitive pathway, from acetate-mevalonate, operates in the synthesis of plumbagin which occurs in the root of *Plumbago europaea* (Plumbaginaceae). The second pathway, known as the *o*-succinylbenzoic acid route, starts from shikimic acid and is followed in the walnut tree, *Juglans regia* (Juglandaceae). The third pathway to naphthoquinones operates in *Chimaphila* (Pyrolaceae), a plant genus which produces dimethyl naphthoquinones such as chimaphilin. The fourth pathway to naphthoquinones starts from *p*-hydroxybenzoic acid. In this case, di-isoprenylation is involved, with the addition of geranylpyrophosphate to the phenolic starting material. The product can be alkannin or shikonin, found in plants of the family Boraginaceae (Mann *et al.*, 1994).

The *Diospyros* genus elaborates a large number of 1,4-naphthoquinone metabolites belonging to the juglone class. About 75 % of the phytochemical reports on *Diospyros* species involve the detection and isolation of 1,4-naphthoquinones, which include several dimers, together with a few trimers and tetramers. As a matter of fact, these species are characterized by their ability to produce 1,4-naphthoquinones, which therefore can be used as chemical markers in the taxonomic study of these plants.

They are also the source of compounds with potential pharmacological and other biological activities, e.g. molluscicidal (Marston, Msonthi and Hostettmann, 1984) and piscidal activity (Balza *et al.*, 1989).

The dimeric naphthoquinones of *Diospyros* can be classified into four major groups according to the ring structure of each monomer that the linkage occurs i.e. quinoid-quinoid , quinoid-benzenoid , benzenoid-benzenoid and miscellaneous groups.

The first group, quinoid-quinoid dimeric naphthoquinones, can be subdivided according to the linkage position into 2 subgroups. They are either the dimer with 2-2′ or 2-3′ linkage. An example of the former subgroup is mamegakinone (**7**) found in twelve *Diospyros* species, while examples of the latter are biramentaceone (**1**) from *D. chamaethamnus* and rotundiquinone (**10**) from *D. ismailli* and *D. rotundifolia.*

The second group of dimeric naphthoquinones having quinoid-benzenoid linkage can be connected at either 2-6′ or 2-8′ position. One of the most widely found members of this group is diospyrin (**16**), which was shown to inhibit the *in vivo* growth of Ehrlich ascites carcinoma (EAC) in Swiss albino mice (Mallavadhani, Panda and Rao, 1998). The compound also displayed strong cytotoxicity against hepatoma (HEPA-3B), nasopharynx carcinoma (KB), colon carcinoma (COLO-205) and cervical carcinoma (HELA) cells with the ED_{50} of 0.25, 1.81, 0.13 and 0.27 μg/mL, respectively Another compound, 8′-hydroxyisodiospyrin (**22**) from *D. maritima*, showed cytotoxicity against these four cell lines with the ED_{50} of 1.72, 1.85, 2.24 and 1.92 μg/mL, respectively (Kuo *et al.*, 1997c).

The benzenoid-benzenoid group is another example of naphthoquinone dimers derived from plumbagin and 7-methyljuglone. Several members of this group displayed significant biological activities. For example, ethylidene-6,6′-biplumbagin (**28**), maritinone (**43**) and elliptinone (**44**) all showed ichthyotoxic, germination inhibitory and antifungal activities (Higa, Ogihara and Yogi, 1998). Isodiospyrin (**42**), which is widely distributed in twenty-eight *Diospyros* species, was shown to be cytotoxic against both colon tumer (HCT-8) and lymphocytic leukaemia (P-388) cells with ED_{50} values of 4.9 and 0.59 μg/mL, respectively (Yan *et al.*, 1989). Gafner and his co-workers (1987) also reported cytotoxicity of this compound, isolated from the root-bark of *D. zombensis*, against human colon carcinoma cells.

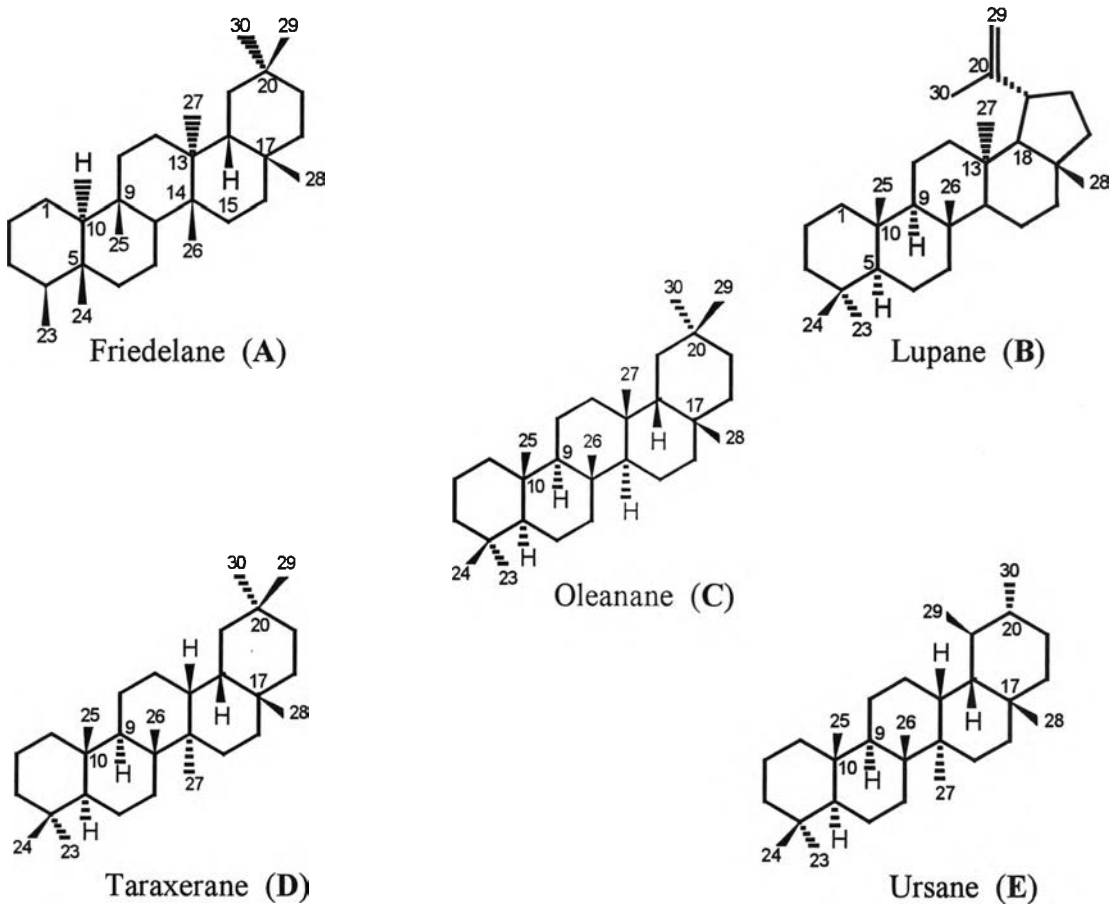
The last group includes dimers of naphthoquinones with miscellaneous types of compounds. Dimers with chromenone acid (**49**) and chromenone ester (**50**) were isolated from *D. montana* (Mallavadhani et al., 1998) Two binaphthalenone glycosides, 1′,2-binaphthalen-4-one-2′,3-dimethyl-1,8′-epoxy-1,4′,5,5′,8,8′-hexahydroxy-8-*O*-*β*-glucopyranosyl-5′-*O*-*β*-xylopyranosyl (1→6)-*β*-glucopyranoside (**44**) and 1′,2-binaphthalen-4-one-2′,3-dimethyl-1,8′-epoxy-1,4′,5,5′,8,8′-hexahydroxy-5′,8-di-*O*-*β*-xylopyranosyl (1→6)-*β*-glucopyranoside (**45**), isolated from African chewing sticks (*D. lycioides*) were demonstrated to possess antimicrobial activity against common oral pathogens including *Streptococcus mutans* and *Porphyromonas gingivalis* with MICs of 2.5 and 0.156 mg/mL, respectively (Li, vander Bijl and Wu, 1998). The fruits of *D. mollis* are recommended for use as anthelmintic. Diospyrol (**53**), the dimeric naphthoquinone found in this plant, exhibited anthelmintic activity when tested in hamsters infected with the human hookworm *Necator americanus* and was also effective against *Hymenolepis nana* and *Nematospiroides dubius* parasites in mice (Mallavadhani *et al.*, 1998).

1.2 Triterpenes

Triterpenoids can be found abundantly in the plants of the genus *Diospyros*. They have been isolated from all parts of *Diospyros* plants, i.e. from the leaves, fruits, root bark and heartwood.

The triterpenes are derived from mevalonic acid through squalene and, in most cases, via 2,3-epoxysqualene. Their various structures, of which there are about 20 skeletal types, depend on the tendency of squalene, with its six double bonds, to undergo multiple cyclizations mediated by enzymes (cyclases) capable of exerting rigorous stereochemical controls (Manitto, 1981).

The *Diospyros* triterpenoids isolated so far all have pentacyclic core and belong to friedelane (**A**), lupane (**B**), oleanane (**C**), taraxerane (**D**) or ursane (**E**) skeleton. Several of these pentacyclic triterpenoids have been reported as possessing useful pharmacological activities, such as anticancer, anti-HIV and anti-inflammatory activity.



Scheme 2. Skeletal types of triterpenoids found in *Diospyros* species

The use of friedelin (**61**) or friedelane-type triterpenoids has been considered for the treatment of cancer of the bladder, convulsions, inflammation, topical ulcers, rheumatic inflammation, fever and dysentery. Friedelin has also been found to possess ichthyotoxic activity, germination inhibitory activity and antifungal activity (Higa *et al.*, 1998).

Twenty-two lupane-type triterpenoids including lupeol (**81**), have been reported from seventy-three *Diospyros* species. It is very interesting to note that, lupeol (**81**) was able to inhibited stress-induced ulcers in rats, and decrease the incidence of gastric ulceration induced by pyloric ligation (Mallavadhani *et al.*, 1998) wheras betulin (**67**) from displayed anti-inflammatory activity in the carrageenan and serotonin paw edema tests and the 12-*O*-tetradecanoyl-phorbol-13-acetate (TPA) and ethyl phenylpropiolate (EPP) ear edema tests (Recio *et al.*, 1995). In addition, betulin was effective against Walker-Carcinoma-256 (intramuscular) tumor system (Mallavadhani *et al.*, 1998). Betulinic acid (**68**), another triterpenoid widely found in the genus, showed potent anti-inflammatory activity against TPA-induced edema. This triterpenoid was active against the Walker-Carcinoma-256 tumor system and inhibited P-388 leukaemia cell growth. Recently, it was found to possess highly selective activity against human melanoma both *in vitro* and *in vivo* (Mallavadhani *et al.*, 1998). Two rearranged derivatives of betulin (**67**), oxyallobetulin (**82**) and allobetulin (**66**), have been reported from four *Diospyros* species.

Taraxerol (**94**) inhibited stress induced ulcers in rats and also decreased the incidence of gastric ulceration induced by pyloric ligation (Mallavadhani *et al.*, 1998). Taraxasteryl acetate (**96**), which was found in both *D. maingayi* and *D. singaporensis*, displayed antispasmodic and spasmogenic activities (Kirimer *et al.*, 1997). The 3-keto derivative of taraxerone (**95**), has been detected in ten *Diospyros* plants.

Ten oleanane-type triterpenoids including oleanolic acid (**85**) were shown to be potent inhibitors of TPA-induced Epstein-Barr virus activation, Oleanolic acid (**85**) was found in six *Diospyros* species and there were two reports of oleanolic acid glycosides (**87-90**) from *D. peregrin* (Mallavadhani *et al.*, 1998) and *D. zombensis* (Gafner, Chapuis, Msonthi and Hostettmann, 1987) . Various triterpenoids of *Diospyros* are listed in Table 2.