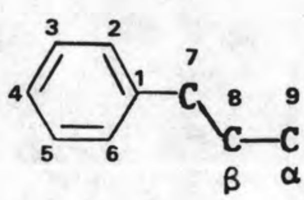
CHAPTER II

HISTORICAL

1. INTRODUCTION TO PHENYLPROPANOIDS

Phenylpropanoids is a large group of naturally occurring compounds. These compounds contain a phenyl group (C_6) with an attached n-propyl side chain (C_3). They are derived from phenylalanine and tyrosine. Many of the phenylpropanoids found in volatile oils are phenol or phenolic ether (Luckner, 1972;Tyler *et al.*, 1981).

The aliphatic portion may contain an alcoholic hydroxyl, a carbonyl, or a carboxyl group, but most often the three membered side chain (allyl or propenyl) does not contain oxygen at all. In some cases, the side chains from two phenylpropanoids apparently have reacted with each other to form lignan compounds (Ramstad, 1959). The polymerization of many phenylpropane unit (C_6-C_3) is lignin which is an important constituent of the plant cell walls. If the side chain of the phenylpropane unit (C_6-C_3) is linked to another phenyl group, these are called "the flavonoids" (Goodwin and Mercer, 1983).



Phenylpropane unit (C_6-C_3) (1)

2. CLASSIFICATION OF PHENYLPROPANOIDS

Phenylpropanoids which are based on the phenylpropane unit (C_6-C_3), can be divided into four groups of compounds :

2.1 Simple phenylpropanoids (C_6-C_3)

2.1.1 Hydroxycinnamic acids

2.1.2 Phenylpropenes

2.1.3 Coumarins

2.1.4 Chromones

2.2 Lignans and neolignans $(C_6\text{-}C_3)_2$

2.3 Lignin $(C_6\text{-}C_3)_n$

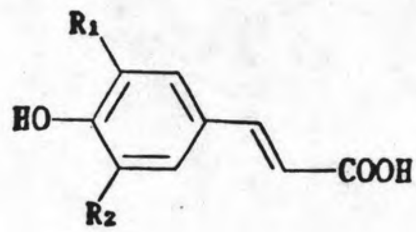
2.4 Flavonoids (C_6-C_3-C_6)

2.1 SIMPLE PHENYLPROPANOIDS

2.1.1 HYDROXYCINNAMIC ACIDS

The hydroxycinnamic acids are apparently universally present in higher plants. They occur free and in a very large range of esterified forms. It should be noted that in sugar derivatives the sugar is attached by an ester and not a glycosidic linkage.

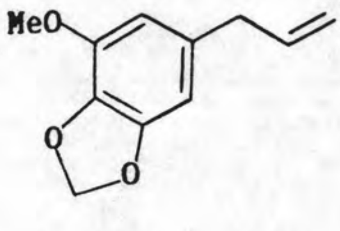
Example of the group of compounds are p-coumaric acid (2), caffeic acid (3), ferulic acid (4), sinapic acid (5) (Goodwin and Mercer, 1983).



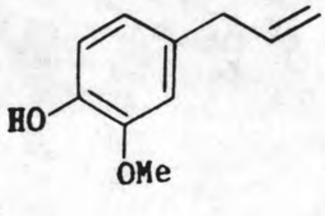
	R_1	R_2
p-Coumaric acid (2)	H	H
Caffeic acid (3)	OH	H
Ferulic acid (4)	OMe	H
Sinapic acid (5)	OMe	OMe

2.1.2 PHENYLPROPENES

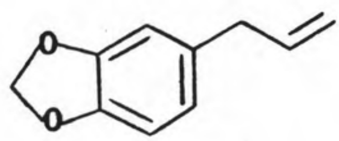
The Phenylpropenes are not widely distributed but occur sporadically in essential oils, especially in essential oil of plants in many families as follows. (The most important of which are underlined.) Agavaceae, Amaryllidaceae, Araceae, Aristolochiaceae, Canellaceae, Cannabinaceae, Cistaceae, Gramineae, Hamamelidaceae, Labiatae, Lauraceae, Liliaceae, Magnoliaceae, Monimiaceae, Myristicaceae, Myrtaceae, Piperaceae, Rosaceae, Rubiaceae, Rutaceae, Styraceae, Theaceae, Umbelliferae, and Violaceae. Example of these compounds are myristicin (6), eugenol (7), safrole (8), coniferol (9) (Friedrich, 1976;Goodwin and Mercer, 1983;Ramstad, 1959)



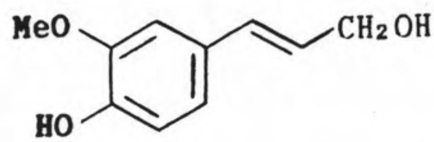
Myristicin (6)



Eugenol (7)



Safrole (8)



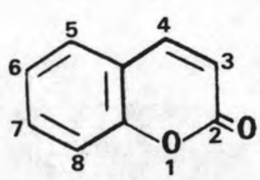
Coniferol (9)

2.1.3 <u>COUMARINS</u>

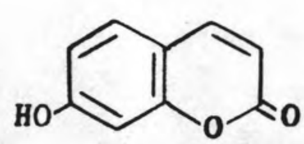
Coumarin is a group of naturally occurring phenylpropanoid lactones exerting a wide range of physiological effects. They are elaborated by many plants and in a few microbial species. Coumarins have been classified into five groups : (Brown, 1979; Tandon and Rastogi, 1979).

2.1.3.1 SIMPLE COUMARINS

In this type of coumarins, only the benzene ring in the benzopyran nucleus could be substituted eg. coumarin (10), umbelliferone (11) (Gibbs, 1974).



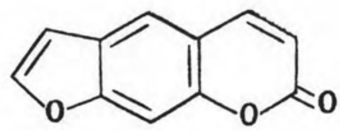
Coumarin (10)



Umbelliferone (11)

2.1.3.2 FURANOCOUMARINS

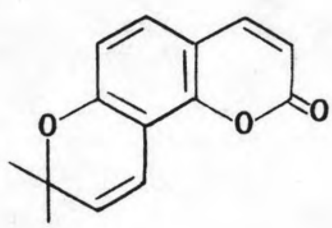
Furanocoumarins have a furan ring fused with the coumarin nucleus at the various positions on the benzene ring to form linear or angular structures eg. psoralen (12) (Dean, 1963).



Psoralen (12)

2.1.3.3 PYRANOCOUMARINS

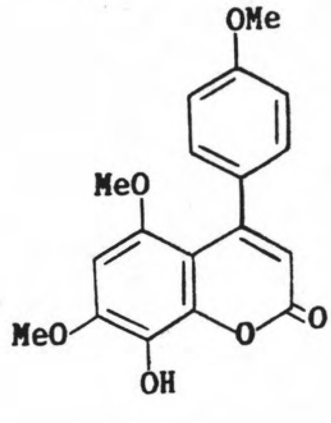
This type of coumarins has a pyran ring fused to the benzene ring. These coumarins may be called chromano-coumarins. The pyran ring may be variously placed eg. seselin (13) (Gibbs, 1974).



Seselin (13)

2.1.3.4 PHENYLCOUMARINS

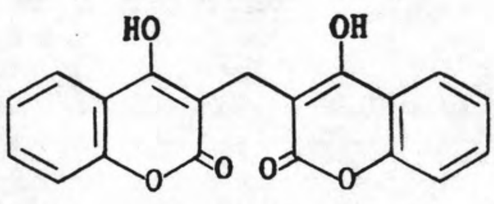
This type of coumarins has phenyl substitution at C-3 or C-4 of coumarin nucleus eg. exostemin (14) (Tandon and Rastogi, 1979).



Exostemin (14)

2.1.3.5 BICOUMARINS

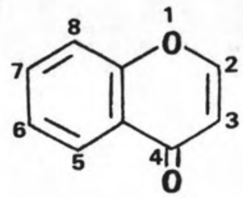
These group of compounds consist of coumarin nuclei in their structure, eg. dicoumarol (15) (Tandon and Rastogi, 1979).



Dicoumarol (15)

2.1.4 <u>CHROMONES</u>

Chromones which are a group of naturally occurring compounds possessing a 4-H-1-benzopyran-4-one nucleus, are isomeric with coumarins (keto groups at C-4 and C-2, respectively) (Goodwin and Mercer, 1983).

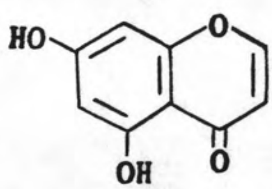


Chromone nucleus (16)

Chromones can be divided into five groups based on the substitution patterns at C-2 and C-3 (Saengchantara and Wallace, 1986).

2.1.4.1 2,3-UNSUBSTITUTED CHROMONES

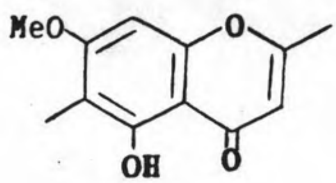
For example is 5,7-dihydroxychromone (17) that isolated from *Silybum marianum* (Szilagi *et al.*, 1981).



5,7 Dihydroxychromone (17)

2.1.4.2 2-SUBSTITUTED CHROMONES

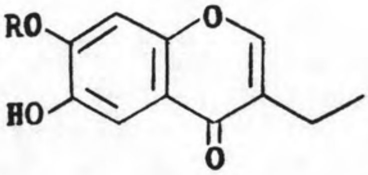
One group of this type that is oxygenated 2-methyl chromones is widespread in nature eg. stellatin (18), (Saengchantara and Wallace, 1986).



Stellatin (18)

2.1.4.3 3-SUBSTITUTED CHROMONES

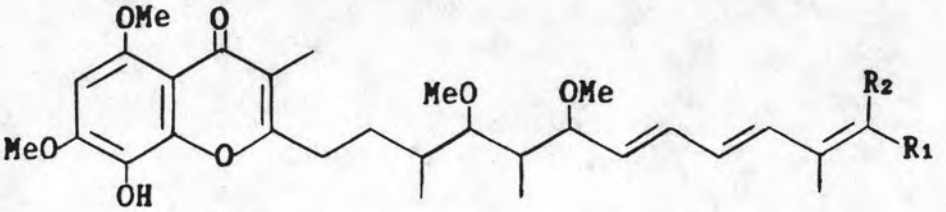
Several interesting 3-substituted chromones have been reported recently. The 3-ethylated systems lathodoratin (19) and methyl-lathodoratin (20) are phytoalexins. (Saengchantara and Wallace, 1986)



Lathodoratin	(19)	R = H
Methyl-lathodoratin	(20)	R = Me

2.1.4.4 2,3-DISUBSTITUTED CHROMONES

Two novel chromones, stigmatellin A (21) and stigmatellin B (22), have been isolated by a research group investigating the antibiotics that are produced by *Stigmatella aurantiaca* (strain Sg a15) (Saengchantara and Wallace, 1986).

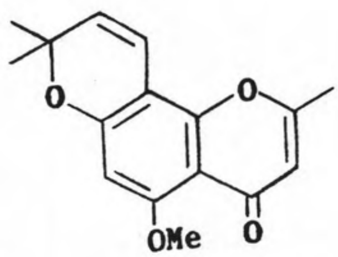


Stigmatellin A (21) R_1 = Me, R_2 = H

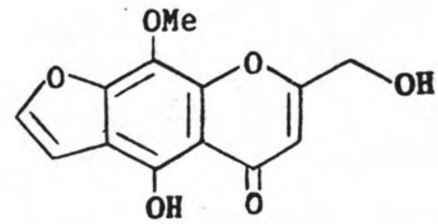
Stigmatellin B (22) R_1 = H R_2 = Me

2.1.4.5 HETEROANNULATED CHROMONES

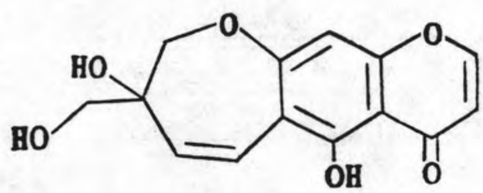
This type of chromones has the ring such as pyran ring, furan ring etc. fused to the benzene ring. eg. methylallopteroxylin (23), norammiol (24), ptaeroglycol (25) (Saengchantara and Wallace, 1986).



Methylallopteroxylin (23)



Norammiol (24)



Ptaeroglycol (25)

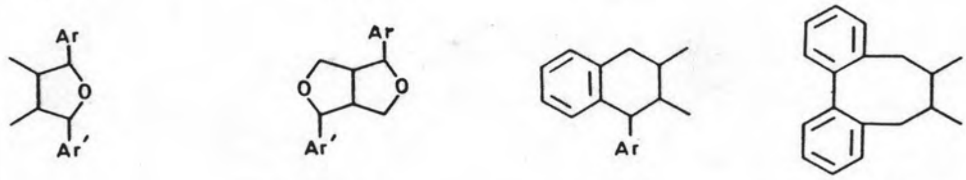
2.2 LIGNANS AND NEOLIGNANS

Lignans and neolignans are groups of natural products whose carbon skeletons are constructed by the linking of C_6-C_3 units (Whiting, 1985).

2.2.1 LIGNANS

The term "lignans", reflecting the woody tissue from which many examples derive, was introduced by Haworth, and implied structures that are composed of two phenylpropane units, linked β-β' (8-8'). The lignans are divided into six groups, based on general structures (**Fig.** 2) (Whiting, 1985).

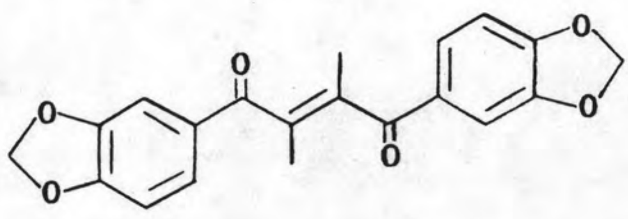
(26) (27) (28) (29)



(30) (31) (32) (33)

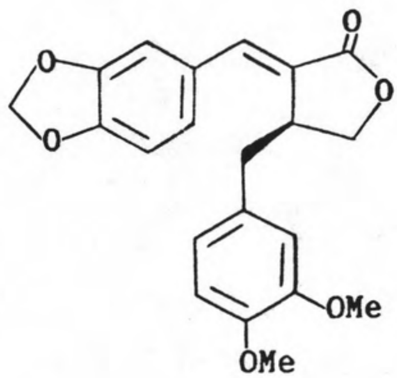
Fig. 2 General structures of lignans

2.2.1.1 DIBENZYLBUTANES (26)



Zuihonin D (34)

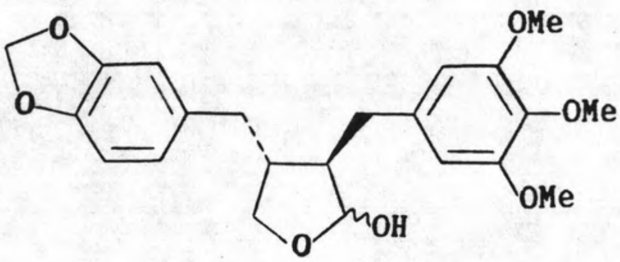
2.2.1.2 DIBENZYLBUTYROLACTONES (27)



Arylidene lactone (35)

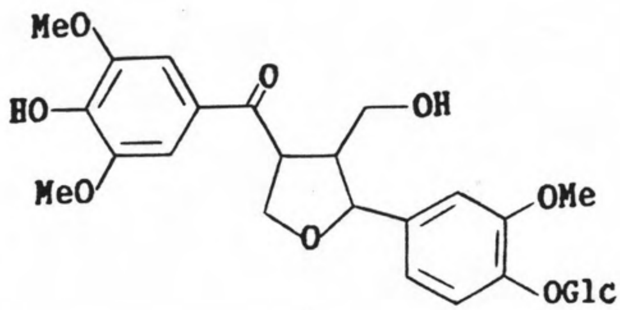
2.2.1.3 SUBSTITUTED FURANS

2.2.1.3.1 TYPE I (28)



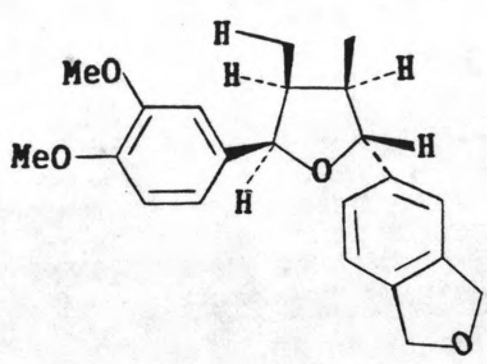
(-) Clusin (36)

2.2.1.3.2 TYPE II (29)



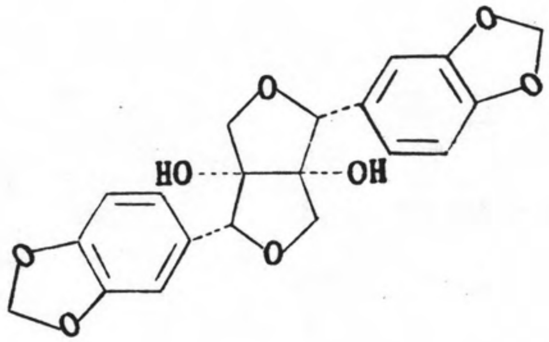
Magnolenin-C (37)

2.2.1.3.3 TYPE III (30)



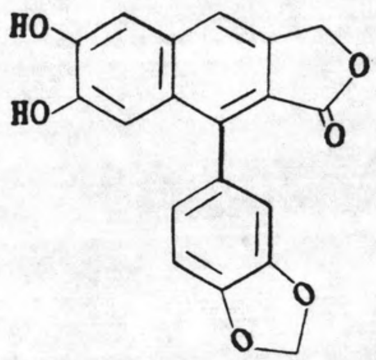
Machilusin (38)

2.2.1.4 FUROFURANS (31)



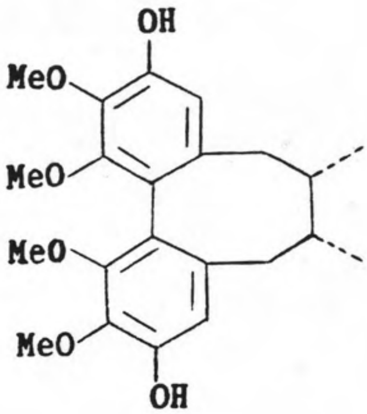
Kigeliol (39)

2.2.1.5 1-ARYLNAPHTHALENES AND RELATIVE (32)



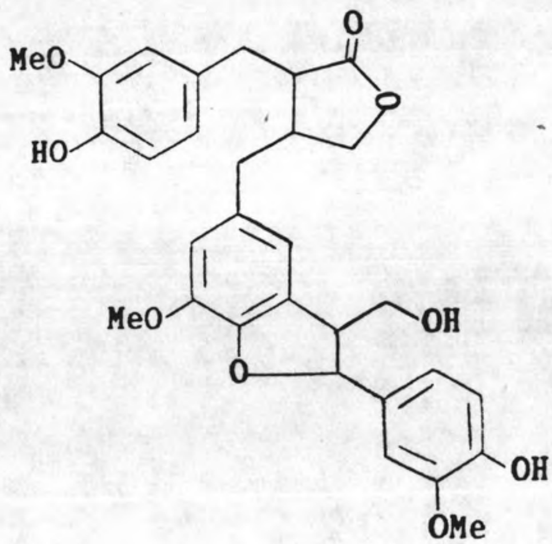
Daurinol (40)

2.2.1.6 O,O'-BRIDGED BIPHENYLS (DIBENZOCYCLO-OCTADIENES) (33)

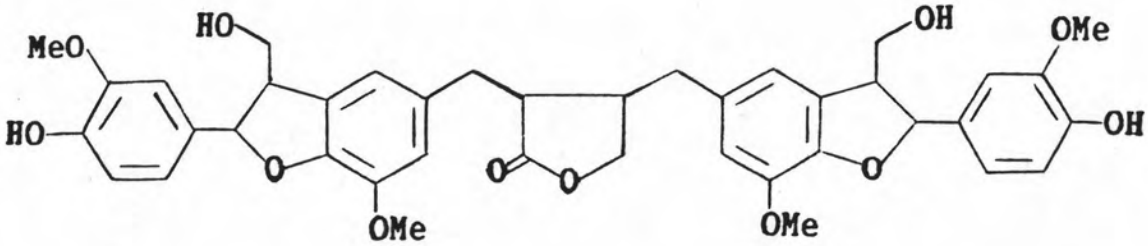


Gomisin J (41)

There is a group of compounds in which three, rather than two, phenylpropane units have been coupled. These have been referred to as "sesquilignans", by analogy to the terpenes eg. lappaol A (42), lappaol F (43) (Whiting, 1985).



Lappaol A (42)

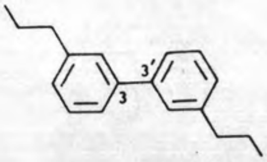


Lappaol F (43)

2.2.2 NEOLIGNANS

Initially, the neolignans were compounds containing two C_6-C_3 units that are linked otherwise than β-β'. More recently, neolignans were redefined as the products of oxidative coupling of allyl - or propenylphenols, while lignans were regarded as the coupling products of cinnamyl alcohol etc.

The neolignans show very varied structures (Fig.3) and are divided into eleven subgroups base on the points of union between the C_6-C_3 units (Whiting, 1985).



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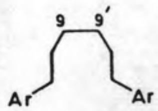

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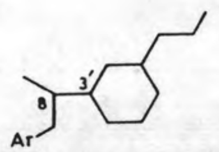

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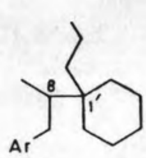

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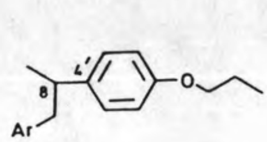

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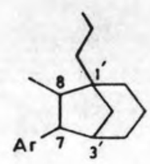

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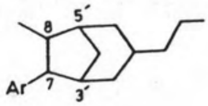

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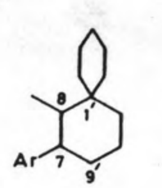

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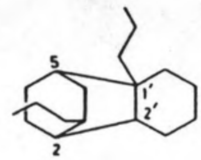

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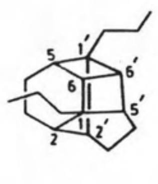

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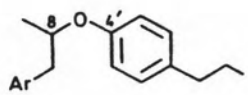

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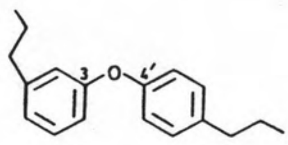

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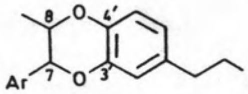

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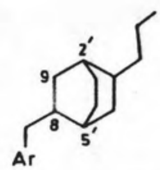

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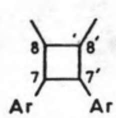
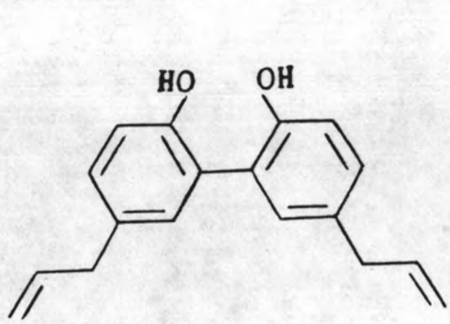


(58)

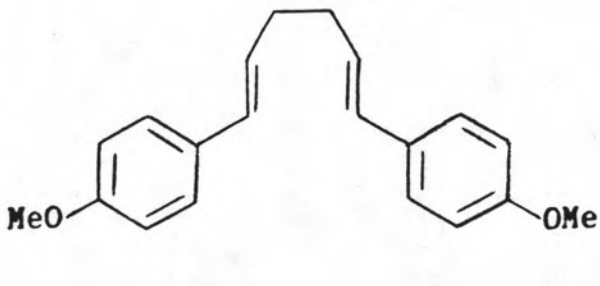
Fig.3 General structures of neolignans

2.2.2.1 (3,3')-NEOLIGNANS (44)



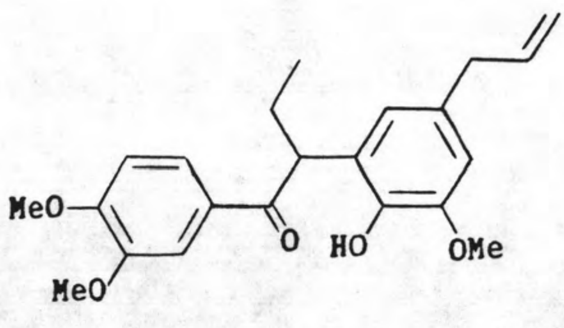
Magnolol (59)

2.2.2.2 (9,9')-NEOLIGNANS (45)



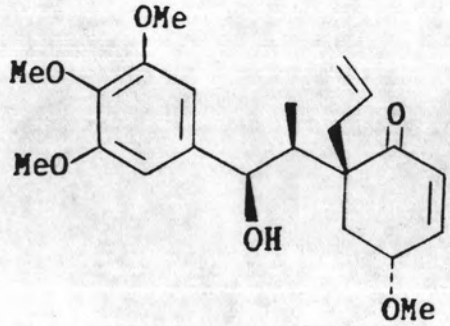
Ocimin (60)

2.2.2.3 (8,3')-NEOLIGNANS (46)



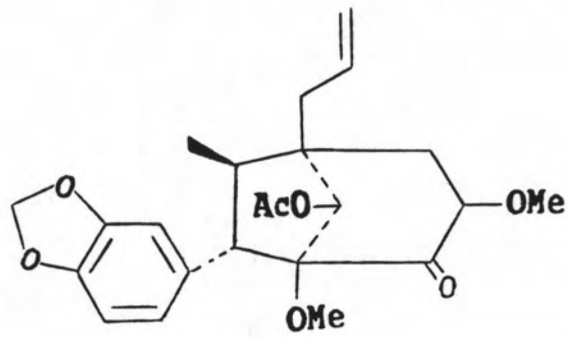
(-) Carinatone (61)

2.2.2.4 (8,1')-NEOLIGNANS (47)



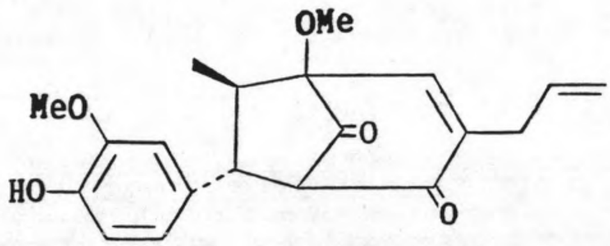
Megaphone (62)

2.2.2.5 (8,1'.7,3')-NEOLIGNANS (49)



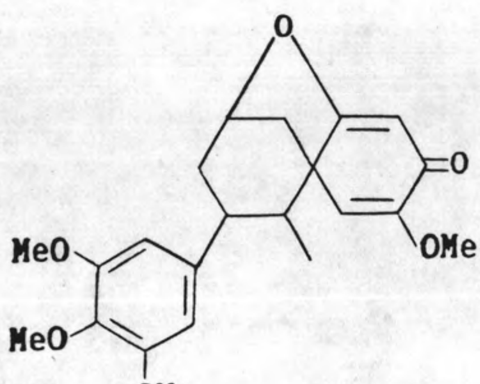
Neolignan from *Licaria armeniaca* (63)

2.2.2.6 (8,5'.7,3')-NEOLIGNANS (50)



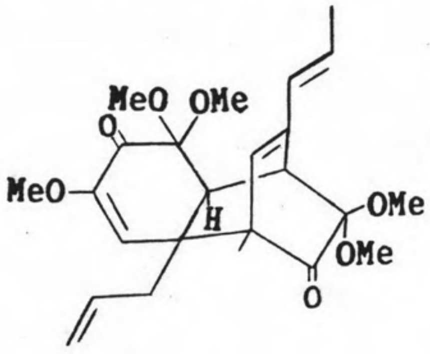
Liliflodione (64)

2.2.2.7 (8,1'.7,9') NEOLIGNANS (51)



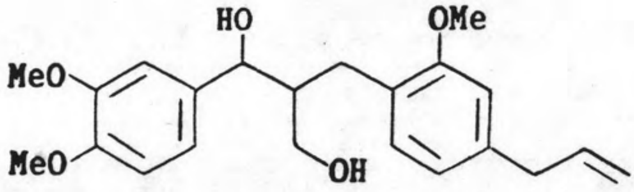
Denudatone (65)

2.2.2.8 (2,2'.5,1') NEOLIGNANS (52)



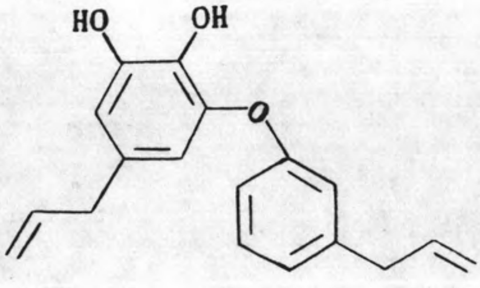
Isoasatone A (66)

2.2.2.9 (8-0-4')-NEOLIGNANS (54)



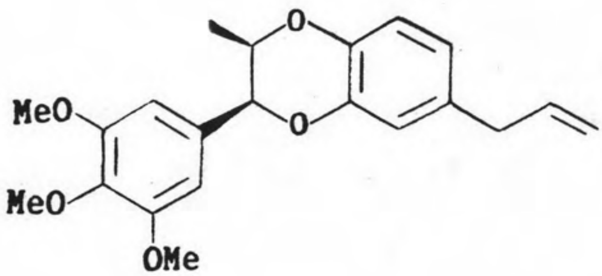
Carinatidiol (67)

2.2.2.10 (3-0-4')-NEOLIGNANS (55)



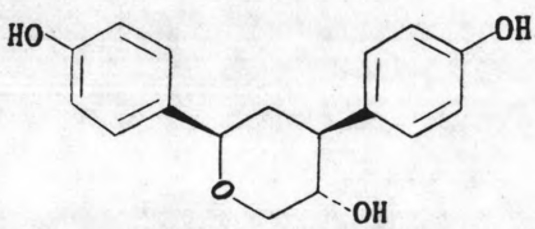
Obovatol (68)

2.2.2.11 (8-O-4'.7-O-3') NEOLIGNANS (56)

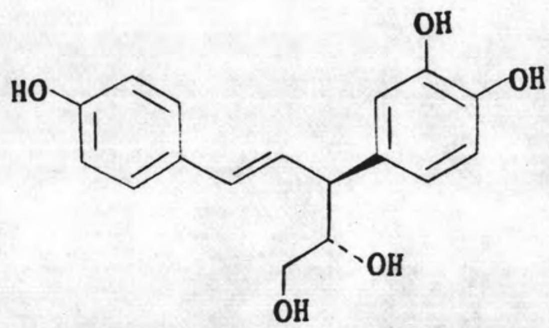


Eusiderin C (69)

A group of natural compounds have a C_{17} core structure. These substances,termed "norlignans", are derived from two C_6-C_3 units but with a loss of one carbon-probably through decarboxylation in most cases. eg. sugiresinol (70), sequirin-C (71) (Whiting, 1987).



Sugiresinol (70)



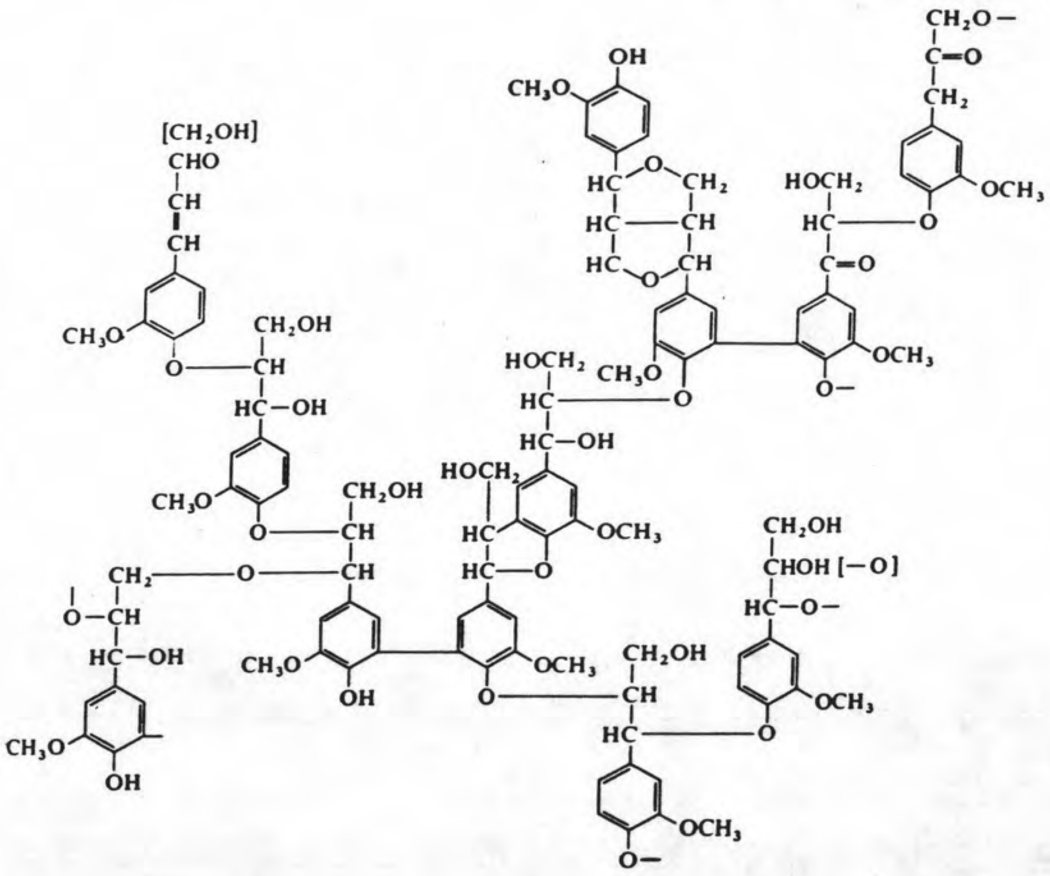
Sequirin - C (71)

2.3 LIGNIN

Lignin is a polymeric component of plant cell walls which is present in supporting and conducting tissues. Botanically, lignin is a metabolite of a growing plant which may be detected by certain color reactions. Enzymologically, lignin is thought of as the end product of a series of enzymatically controlled dehydrogenation reactions of certain monomers of a phenylpropanoid-type structure (Goodwin and Mercer, 1983;Schubert, 1973).

The term lignin covers a group of closely related, high-molecular-weight polymers whose main, if not only, building units are phenylpropane residues. The structural variations of the phenylpropane residues are few but there are numerous ways in which they can be linked together. The order in which the different phenylpropane units and their linkages occur in the polymer is random (Goodwin and Mercer, 1983).

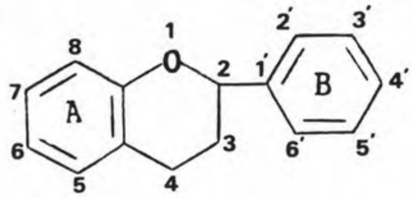
A hypothetical structure of coniferous lignin (72) which depicts the different types of phenylpropane building units and the different ways in which they linked together is shown below (Alder, quoted in Schubert, 1973).



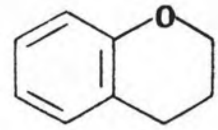
A hypothetical structure of coniferous lignin (72)

2.4 FLAVONOIDS

Flavonoids represent a very widespread group of water-soluble phenylpropane derivatives, many of which are brightly coloured, being red, crimson, purple or yellow. Flavonoids are glycosides and the structure of their aglycones are based on the flavan structure (73) which consists of two aromatic rings joined in a chroman structure (74) by a three carbon unit (C_6-C_3-C_6). Flavonoids are probably derived in plants from the coupling of a phenylpropane unit produced by the shikimic acid pathway and three C_2 acetate units (Goodwin and Mercer, 1983; Harborne, 1973).



Flavane nucleus (73)



Chroman nucleus (74)

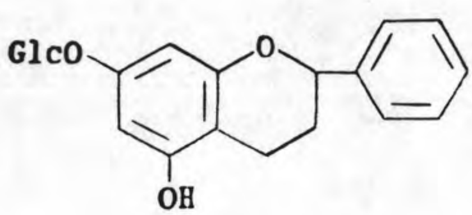
Flavonoids are mostly found in plants but a few has been reported from animal sources. They are 7-hydroxy-5-methoxy-6-methyl flavan (76) and 7-hydroxy-5-methoxyflavan (77) from Dragonfly blood (Sahai and Rastogi, 1983).

Flavonoids which are based on the oxidation state of the C_3 side chain of the phenylpropane unit can be divided in to ten groups; flavans, anthocyanidins, flavonols, flavones, flavanones, dihydroflavonols, chalcones, aurones, isoflavones, neoflavones (Goodwin and Mercer, 1983).

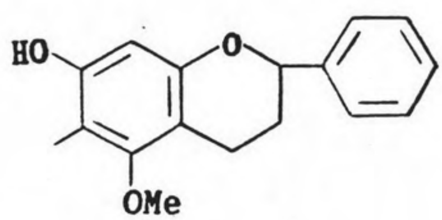
2.4.1 FLAVANS

Flavans can be divided into the following four subgroups on the basis of the substitution pattern in the heterocyclic ring (Sahai and Rastogi, 1983).

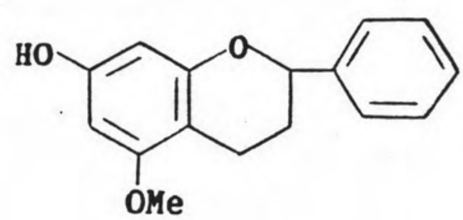
2.4.1.1 FLAVAN UNSUBSTITUTED IN HETEROCYCLIC RING



Koaburanin (75)

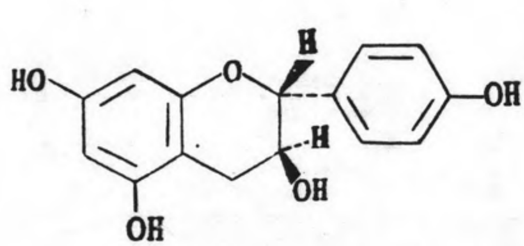


7-Hydroxy-5-methoxy-6-methylflavan (76)



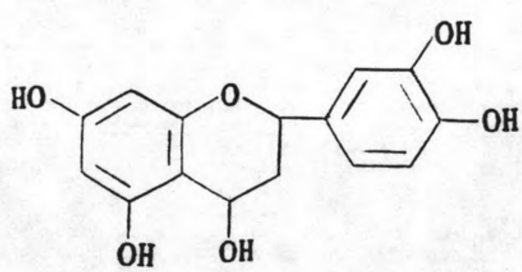
7-Hydroxy-5-methyoxyflavan (77)

2.4.1.2 FLAVAN-3-OLS



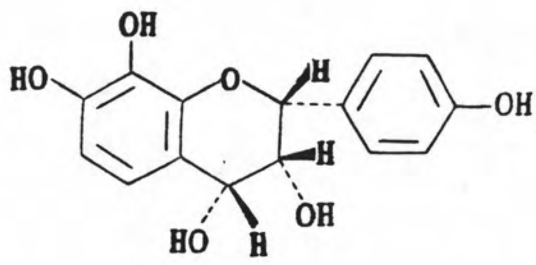
(+) Afzelechin (2R, 3S) (78)

2.4.1.3 FLAVAN-4-OLS



Luteoforol (79)

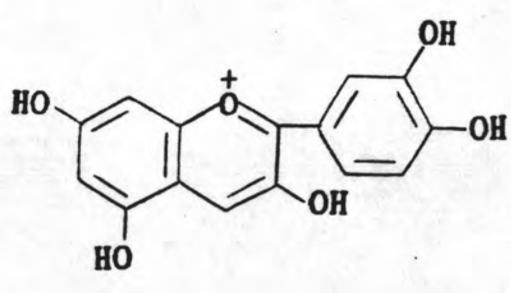
2.4.1.4 FLAVAN-3,4-DIOLS (LEUCOANTHOCYANIDINS OR PROANTHOCYANIDINS)



(-) Teracacidin (2R, 3R, 4R) (80)

2.4.2 ANTHOCYANIDINS

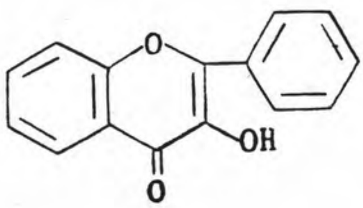
Anthocyanidins as a class are intensely colored substances and their glycosides, the anthocyanins, are responsible for most scarlet red, mauve, purple and blue colors in flowers, fruits and leaves of higher plants. The numbers of hydroxy groups present in B-ring is correlated with color properties (Harborne, 1973).



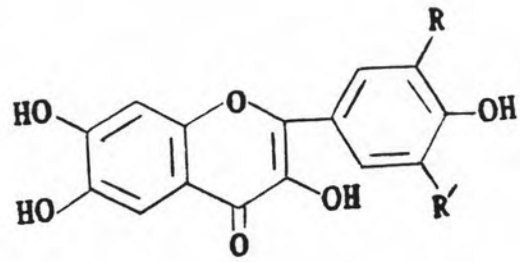
Cyanidin (81)

2.4.3 FLAVONOLS

Flavonols occur with great frequency in leaves. For example, a survey of over 1000 species showed that 48% contained kaempferol (83), 56% quercetin (84), and 10% myricetin (85) (Harborne, 1973).



Flavonol nucleus (82)



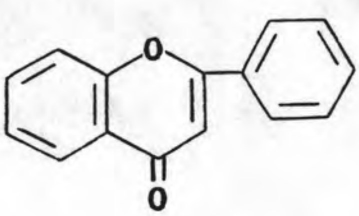
Kaempferol (83) R = R' = H

Quercetin (84) R = OH, R' = H

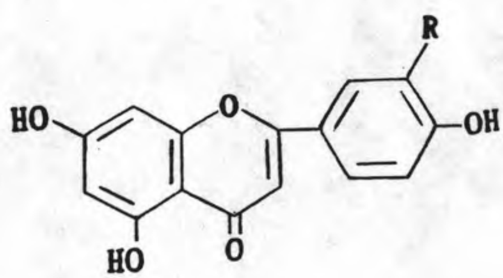
Myricetin (85) R = R' = OH

2.4.4 FLAVONES

Flavones are usually found in plants in place of flavonols, and while flavonols are most abundant in woody angiosperms, flavones occur characteristically in the more herbaceous plant families (Harborne, 1973).



Flavone nuclues (86)

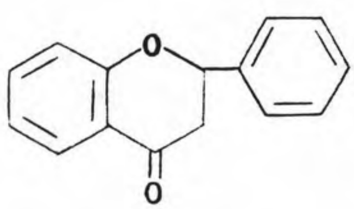


Leuteolin (87) R = OH

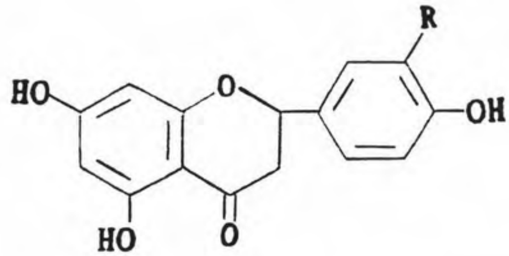
Apigenin (88) R = H

2.4.5 FLAVANONES

Flavanones are colorless substances which are simple reduction products of flavones. The two flavanones, eriodictyol (90) and apigenin (88),occur fairly frequently in plants (Harborne, 1973).



Flavanone nucleus (89)

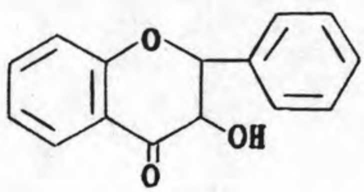


Eriodictyol (90) R = OH

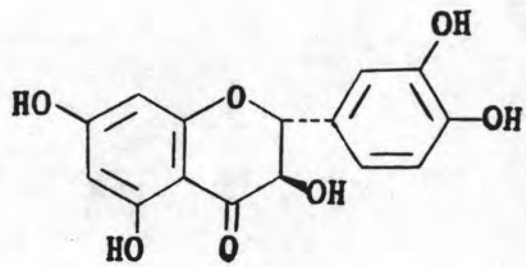
Naringenin (91) R = H

2.4.6 DIHYDROFLAVONOLS

Dihydroflavonols are colorless substances which are simple reduction products of flavonols. They are fairly widespread in nature (Harborne, 1973).



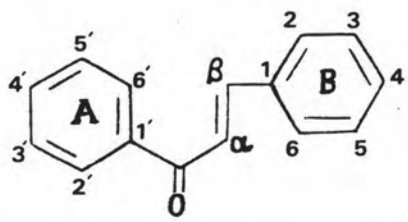
Dihydroflavonol nucleus (92)



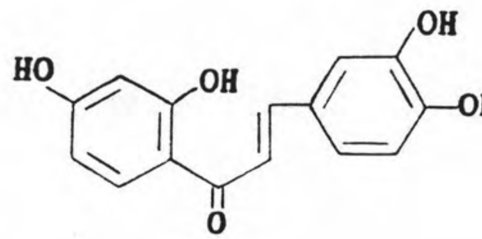
2,3-Dihydroquercetin (93)

2.4.7 CHALCONES

Chalcones have an open chain structure which isomerizes to flavanones by acid treatment (Harborne, 1973).



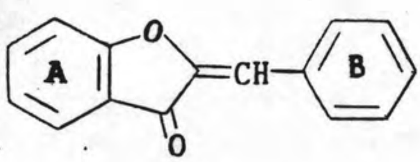
Chalcone nucleus (94)



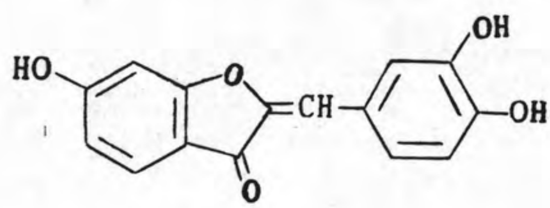
Butein (95)

2.4.8 AURONES

Aurones are formed from chalcones by aerial or enzymic oxidation and are deeper yellow in color (Harborne, 1973).



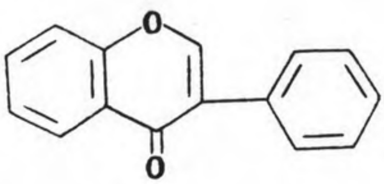
Aurone nucleus (96)



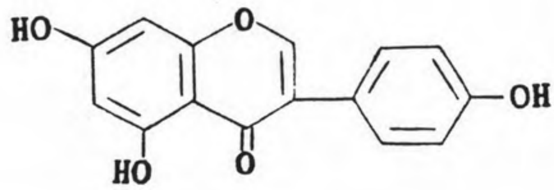
Sulphuretin (97)

2.4.9 ISOFLAVONES

Isoflavones are isomeric with flavones and are derived biosynthetically from the same C_{15} precursor by aryl migration (Harborne, 1973).



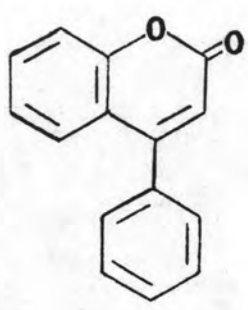
Isoflavone nucleus (98)



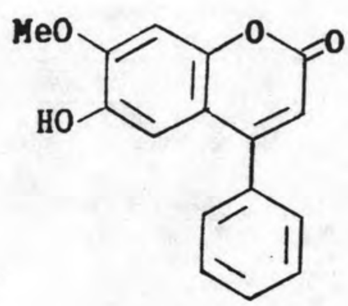
Genistein (99)

2.4.10 <u>NEOFLAVONES</u>

Neoflavones are 4-phenylcoumarins and their existence is probably restricted to the Leguminosae and Guttiferae (Goodwin and Mercer, 1983).

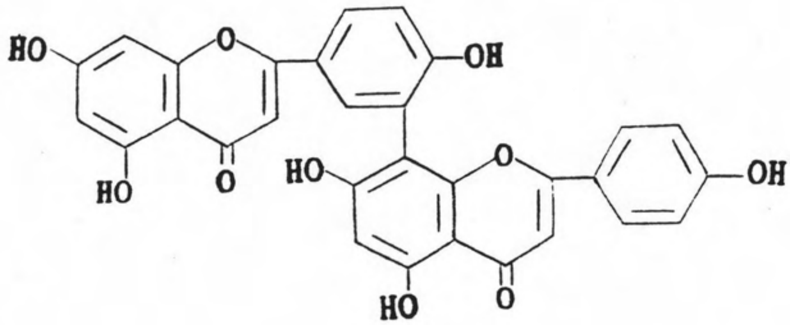


Neoflavone nucleus (100)



Dalbergin (101)

There is a group of compounds in which two flavonoid units have been coupled. These compounds termed "biflavonyls", are presumably formed *in vivo* by oxidative coupling from the monomeric flavones. For example, amentoflavone (102) is a dimer of apigenin (88) (Harborne, 1973).



Amentoflavone (102)

3. BIOSYNTHESIS OF PHENYLPROPANOIDS

The phenylpropanoids except flavonoids and chromones arise from a common biosynthetic intermediate, phenylalanine (116) or its close precursor shikimate (108). In the case of the flavonoids one aromatic ring and its C_3 side chain arises from phenylalanine (116) whilst the other arises from acetyl-CoA *via* the polyketide pathway (Goodwin and Murcer, 1983). In the case of the chromones the biosynthetic pathway should not be concluded that degrade from flavonoids or form from the polyketide pathway (Harborne, 1975;Robeson, Ingham and Harborne, 1980).

The first reaction in the shikimate pathway (Fig. 4) involves the condensation of phosphoenolpyruvate (PEP) (103) with erythrose 4-phosphate (104), is catalysed by the enzyme 3-deoxy-D-*arabino*-heptulosonate-7-phosphate synthase (DAHP synthase). The enzyme 3-dehydroquinate synthase catalyses the conversion of DAHP (105) into 3-dehydroquinate (106). The dehydration of 3-dehydroquinate (106) to 3-dehydroshikimate (107) is catalysed by the enzyme 3-dehydroquinase. Shikimate dehydrogenase is an $NADP^+$-linked dehydrogenase that catalyses the reversible reduction of 3-dehydroshikimate (107) to shikimate (108). The reversible reduction of 3-dehydroquinate (106) to quinate (109) is catalysed by quinate dehydrogenase (Dewick, 1988).

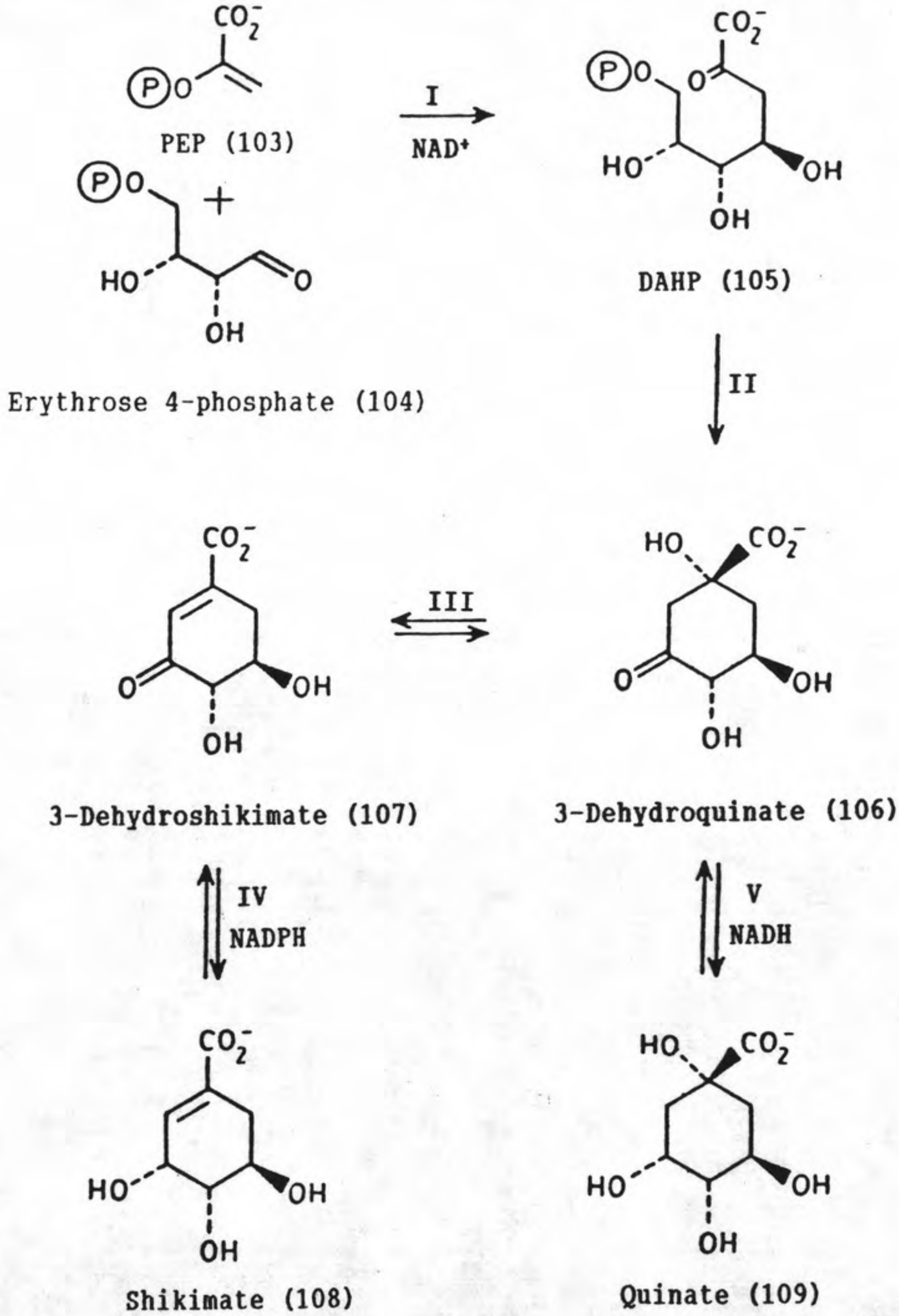


Fig.4 Biosynthesis of shikimate

I : DAHP synthase

II : 3-Dehydroquinate synthase

III : 3-Dehydroquinase

IV : Shikimate dehydrogenase

V : Quinate dehydrogenase

The phosphorylation of shikimate (108) to shikimate 3-phosphate (110) (Fig 5) is brought about by shikimate kinase in the presence of ATP. The condensation of shikimate 3-phosphate (110) with phosphoenolpyruvate to produce 5-enolpyruvylshikimate 3-phosphate (EPSP) (111) is catalysed by EPSP synthase. The elimination of phosphoric acid from EPSP (111) by the enzyme chorismate synthase yields chorismate (112). The Claisen-like rearrangement of chorismate (112) to prephenate (113) is catalysed by chorismate mutase, transferring the phosphoenolpyruvate - derived side-chain so that this becomes directly bonded to the carbocycle and generates the basic skeleton of the phenylpropanoids (Dewick, 1988).

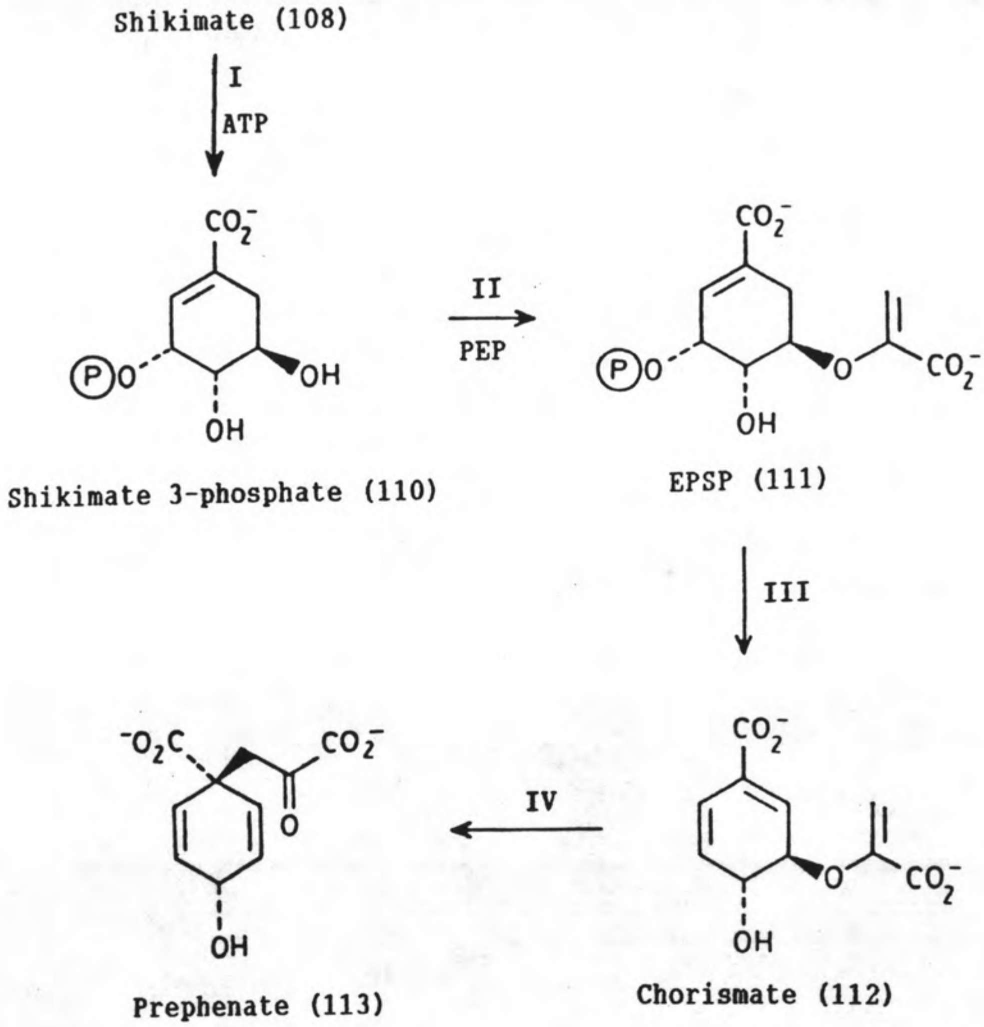


Fig.5 Biosynthesis of prephenate

I : Shikimate kinase

II : EPSP synthase

III : Chorismate synthase

IV : Chorismate mutase

3.1 BIOSYNTHESIS OF L-PHENYLALANINE AND L-TYROSINE

The biosythesis of the aromatic amino acids L-phenylalanine (116) and L-tyrosine (117) from chorismate (112) may occur by several pathways (Fig.6). The pathway that is used is dependent on the organism, and sometimes several routes operate in a particular species. A study of several alkaloids-producing strains of the ergot-producing fungi *Claviceps purpurea* and *C. fusiformis* indicated that all of the strains that were investigated utilize both arogenate (115) and phenylpyruvate (114) as intermediates in the biosynthesis of phenylalanine (116). Cultured cells of *Nicotiana sylvestris* contain arogenate dehydratase but not prephenate dehydratase, thus establishing that phenylalanine (116) in this species is derived from arogenate (115) but not from phenylpyruvate (114) (Dewick, 1988).

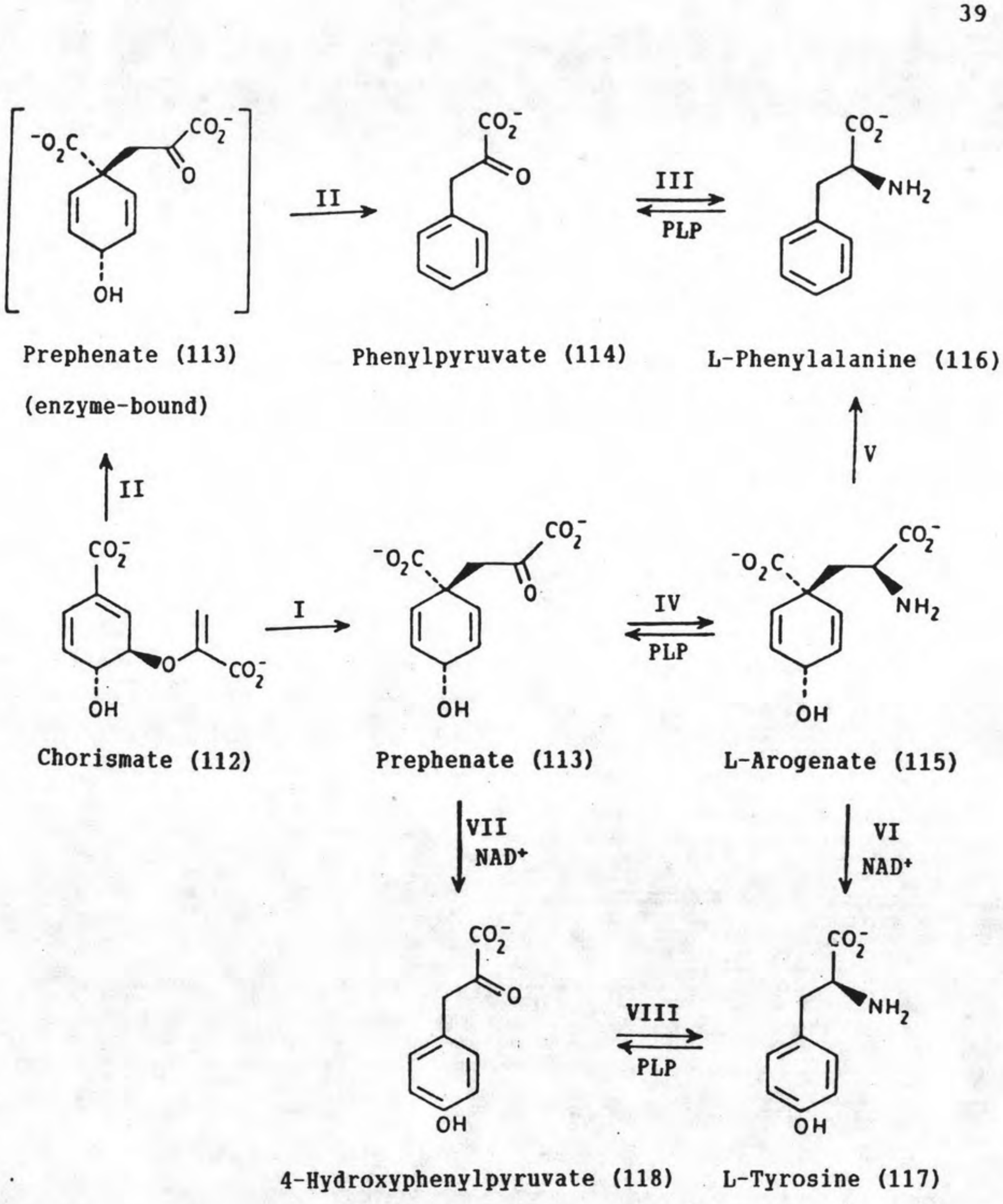


Fig.6 Biosynthesis of L-phenylalanine and L-tyrosine

I : Chorismate mutase (monofunctional)

II : Chorismate mutase-prephenate dehydratase (bifunctional)

III : Phenylpyruvate aminotransferase

IV : Prephenate aminotransferase

V : Arogenate dehydratase

VI : Arogenate dehydrogenase

VII : Prephenate dehydrogenase

VIII : 4-Hydroxyphenylpyruvate aminotransferase

PLP : Pyridoxal 5'-phosphate

3.2 BIOSYNTHESIS OF HYDROXYCINNAMIC ACIDS

The unsubstituted cinnamic acid which originates from phenylalanine (116) by elimination of ammonia is the precursor for the various hydroxycinnamic acids found in nature. The conversion of tyrosine (117) to p-coumaric acid (2) is possible only in the case of the Gramineae. The elimination of ammonia from phenylalanine (116) and tyrosine (117) is catalysed by ammonia lyases which possesses the trivial names, phenylalanine deaminase and tyrase.

The hydroxycinnamic acids shown in Fig. 7 originate from cinnamic acid (119) and p-coumaric acid (2) by hydroxylation and methoxylation reactions. During the formation of p-coumaric acid (2) from cinnamic acid (119), catalysed by a mixed function oxygenase, the hydrogen atom at the p-position is shifted to the m-position in an NIH-shift. Caffeic acid (3), ferulic acid (4) and sinapic acid (5) are widespread. 3,4,5-trihydroxycinnamic acid (120) and 5-hydroxyferulic acid (121), which have not yet been found in nature, are, however, important as precursors in the formation of other natural products, e.g. gallic acid and sinapic acid (5) (Luckner, 1972).

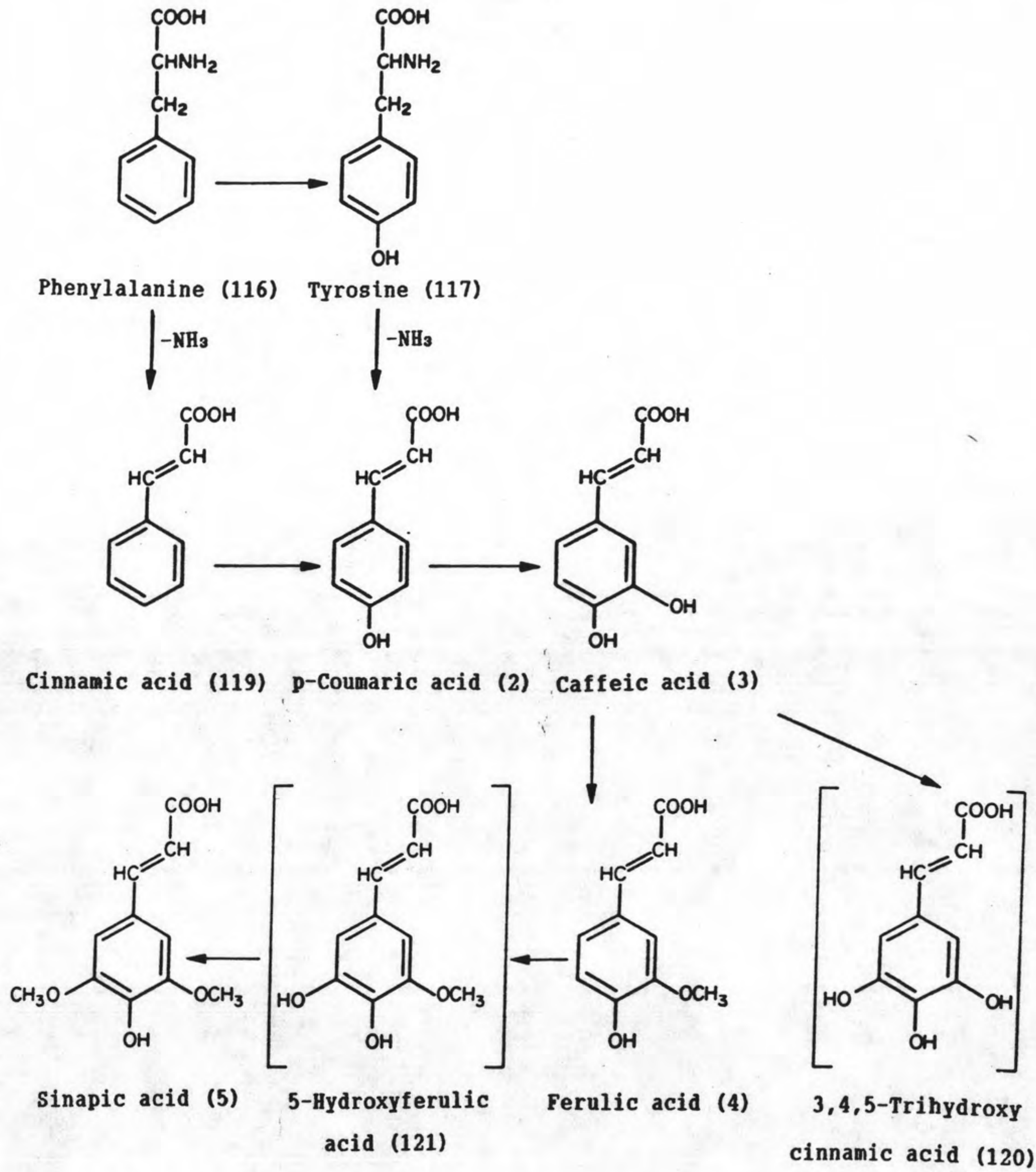
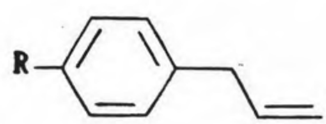


Fig.7 Biosynthesis of hydroxycinnamic acids

3.3 BIOSYNTHESIS OF PHENYLPROPENES

A plausible route for the synthesis of phenylpropenes is by a series of reductive steps from the coresponding cinnamic acid (119) *via* the aldehyde (ArCH=CHCHO) and alcohol ($ArCH=CHCH_2OH$) and its pyrophosphate. Recent studies of the biosynthesis of eugenol (7), chavicol (122), and estragole (123) in *Ocimum basilicum* (Labiatae)



chavicol (122) R = OH

estragole (123) R = OMe

show, howerver, that this scheme must probably be rejected. The biosynthetic pathway is shown in Fig. 8 (Harborne, 1972).

Phenylalanine (116)

↓

Cinnamic acid (3)

↓

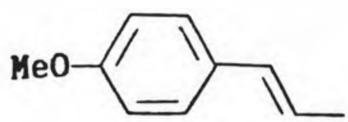
Ferulic acid (4)

↓ decarboxylation

Eugenol (7)

Fig.8 Biosynthesis of eugenol

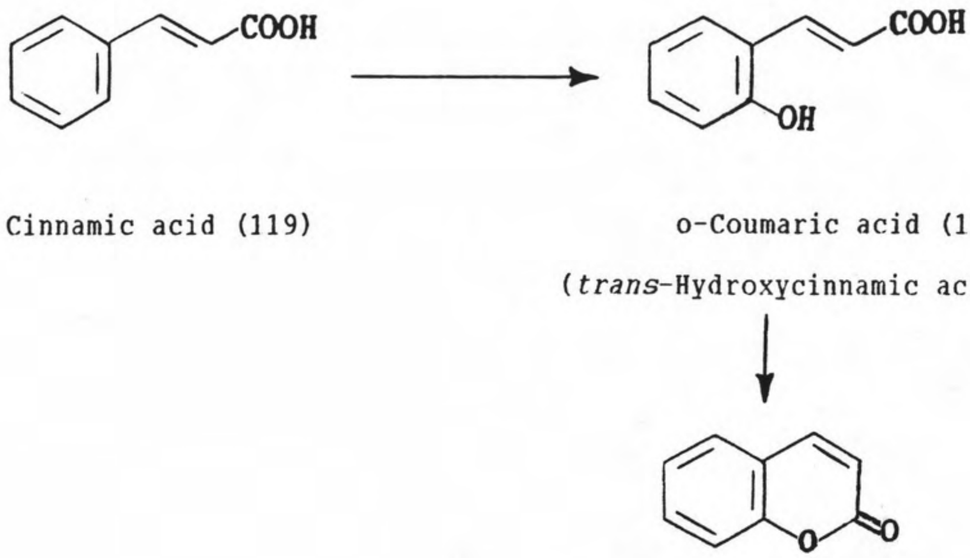
The propenylbenzenes (e.g. anethole (124)) are formed by routes similar to allylbenzenes (e.g.estragole (123)), however, that although these isomers can be interconverted (allyl⟶propenyl) *in vitro*, they are more likely to be formed *in vivo* by independent routes(Harborne, 1972)



Anethol (124)

3.4 BIOSYNTHESIS OF COUMARINS

Coumarins are derived from the shikimate pathway *via* the protoaromatic amino acids phenylalanine (116) and, in a few plants, tyrosine (117). The key step in the biosynthesis of coumarins is the *ortho* (C-2) hydroxylation of a cinnamic acid which is necessary for later lactonization. The enzyme responsible, which is membrane-bound, has been obtained from chloroplasts. The mechanism involved is not yet known (Fig.9) (Brown, 1979;Goodwin and Mercer, 1983).



Cinnamic acid (119)

o-Coumaric acid (125)

(*trans*-Hydroxycinnamic acid)

Coumarin (10)

Fig. 9 Biosynthesis of coumarin

Tracer experiments have clearly shown that p-coumaric acid (2) is a precursor of umbelliferone (11) and demonstrate that in this case at least, p-hydroxylation occurs before o-hydroxylation (Fig.10) (Brown, 1979;Goodwin and Mercer, 1983).

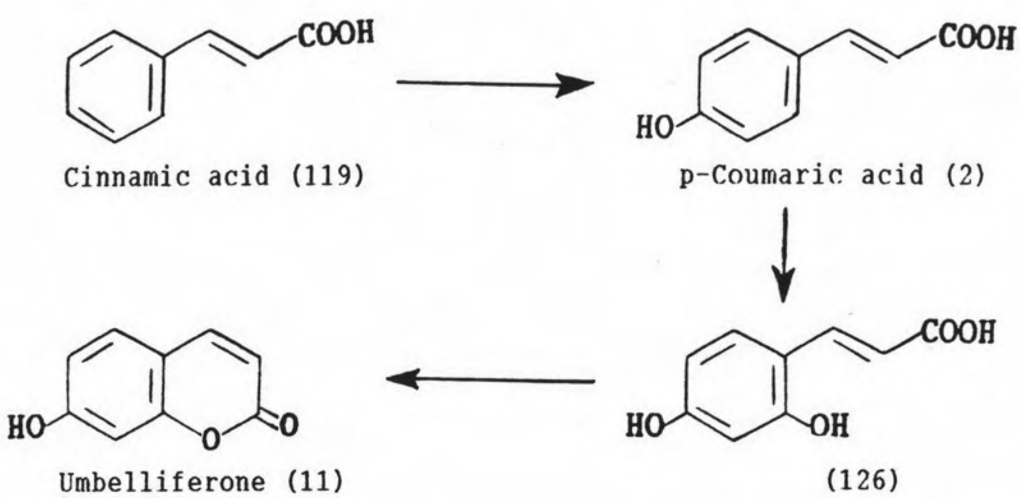


Fig.10 Biosynthesis of umbelliferone

The polyoxygenated coumarins are derived by oxygenation of 7-hydroxycoumarin (umbelliferone(11)). The conversion of umbelliferone (11) into aesculetin (127) shows that hydroxylation can also occur after lactonization. However, the glucosylation may occur before or after the hydroxylation (Fig.11) (Dewick, 1986).

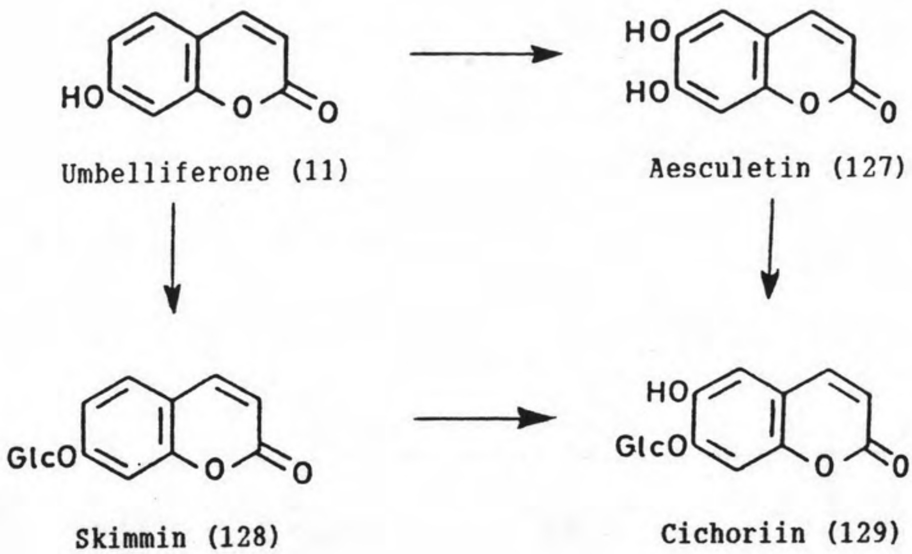


Fig.11 Biosythesis of cichoriin

The biosynthetic pathway to the 6,7,8-trioxygenated coumarin, puberulin (131) in the shoots of *Agathosma puberula* has been proposed in which a prenyl ether is formed at a late stage (Fig. 12). The implication that ferulic acid (4) is not involved contrasts with the known role of this compound as a precursor of scopoletin in tobacco (Dewick, 1985).

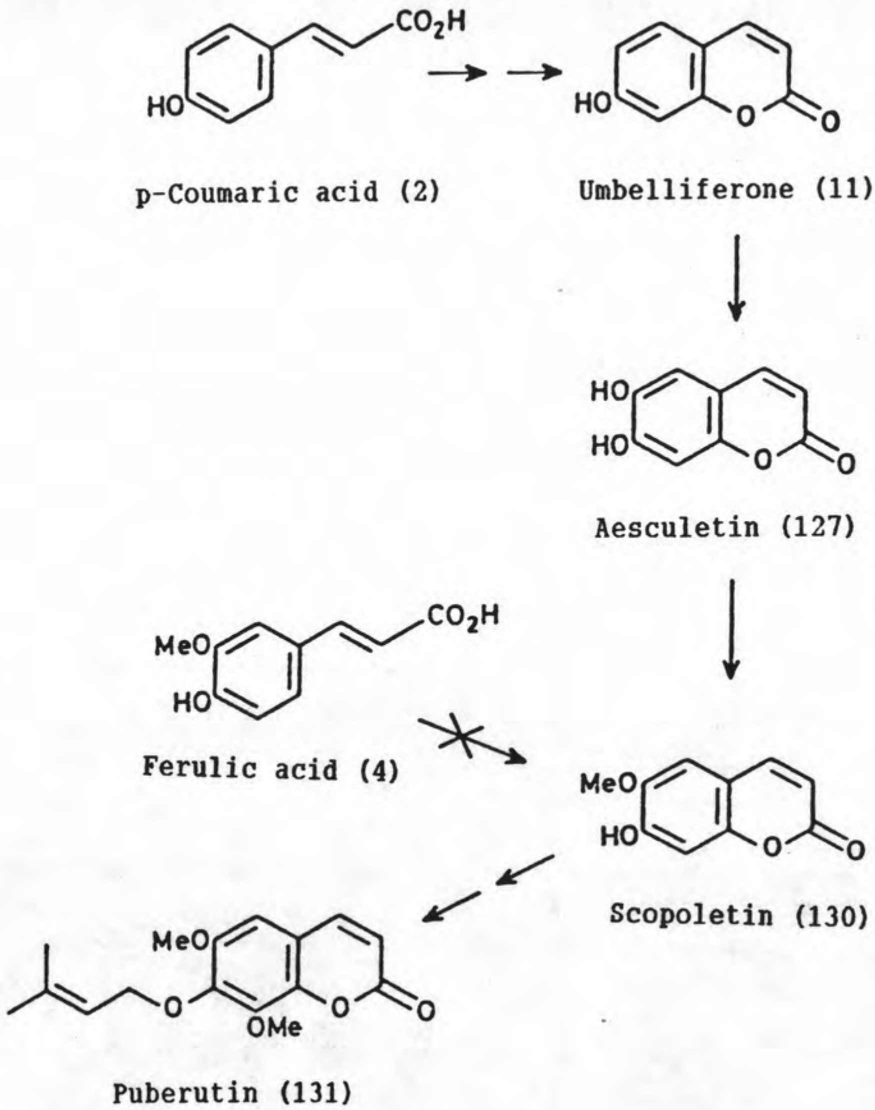


Fig.12 Biosynthesis of puberulin

3.5 BIOSYNTHESIS OF CHROMONES

Chromones have been suggested that could arise biosynthetically *via* degradative pathway from flavonoid, or *via* a polyketide pathway(Harborne, 1975;Robeson et al.,1980).

For example, leptorumol (134) co-occurs with the related flavanone farrerol (132) and also with the dearomatized flavanone (133), which is a possible intermediate in the oxidation of the B-ring of farrerol (132) to give leptorumol (134) (Fig.13) (Harborne, 1975).

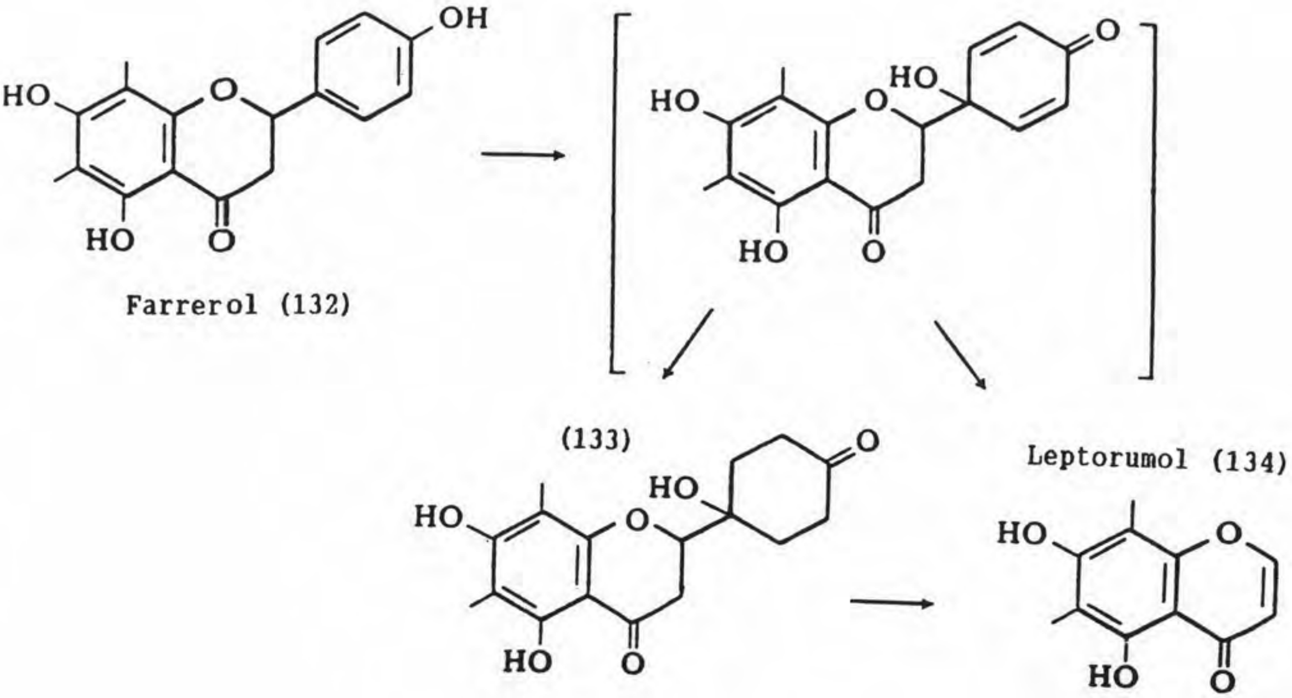
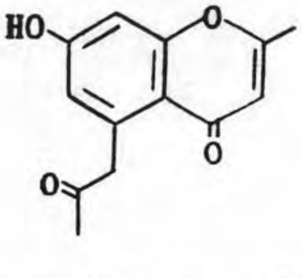


Fig.13 Biosynthesis of leptorumol

Lathodoratin (19) from *Lathyrus odoratus* could have a polyketide origin, the extra carbon fragment required for heterocyclic ring formation being inserted at a late stage in synthesis. Or its possible formation by a degradative pathway from a 2', 5' dihydroxygenated isoflavone (Robeson *et al.*, 1980).

2-Methyl-5-acetonyl-7-hydroxychromone (135) from *Cassia siamea*co-occurs with anthraquinone, which shows that the chromone pathway is probably an offshoot of the anthraquinone biosynthesis from polyketomethylene precursors (Wagner *et al.*, 1978).



2-Methyl-5-acetonyl-7-hydroxychromone (135)

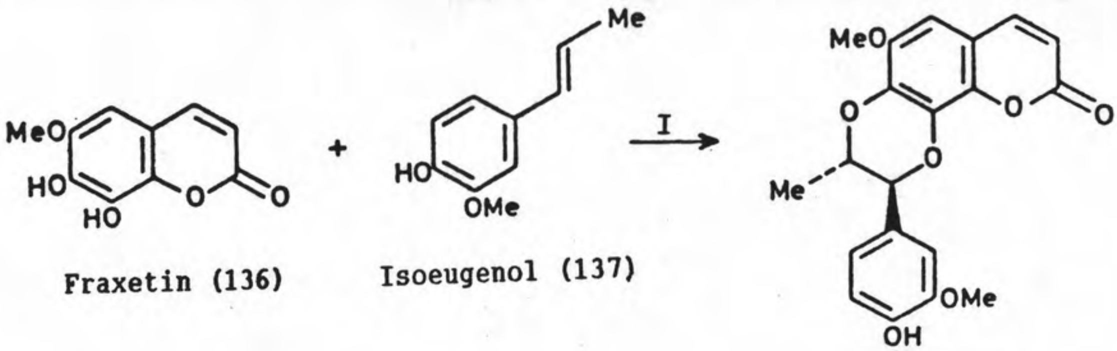
5,7-Dihydroxychromone 7-rutinoside isolated from *Mentha longifolia* was reported as a product of postmortem processes. It is only formed after heating fresh plant material and its production is connected with the degradation of flavonoids, and particularly of eriodictyol 7-rutinoside (Stocker and Pohl, 1976).

However, the biosynthetic pathway of chromones should not be completely ruled out as precedents for such a route have been described.

3.6 BIOSYNTHESIS OF LIGNANS

The biosynthesis of lignans is a rather neglected experimental area. Studies that have been reported to date have concentrated on the demonstration of the incorporation of phenylpropane units into lignans and on the nature of the intermediate products of coupling. The biosynthesis of phenylpropane units is clearly germane to the origin of lignans. It might well be assumed that the carbon skeleton of phenylalanine (116) would be maintained intact in cinnamyl compounds, in allyl-and propenyl-phenol, and in other phenylpropanoids (Whiting, 1985).

The coupling of phenylpropane units most probably occurs by oxidation. The experiment that supports this hypothesis is the synthesis of a range of natural coumarinolignans *via* chemical and enzymic oxidation. The enzymic method employing horseradish peroxidase (with or without H_2O_2) and chloride peroxidase are presumably analogous to the natural processes, and usually result in regioselectivity, in contrast to the corresponding chemical conversion. The production of propacin (138) from the coumarin fraxetin (136) and isoeugenol (137) is shown in Fig. 14(Dewick, 1985).



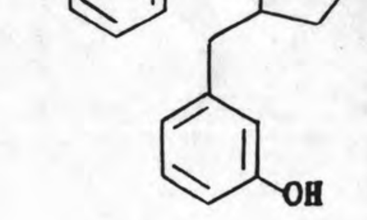
Fraxetin (136) Isoeugenol (137)

Propacin (138)

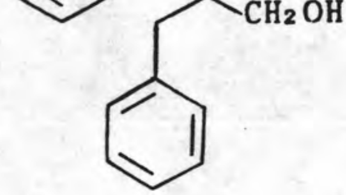
Fig.14 Biosynthesis of propacin

I ; Horseradish peroxidase, H_2O_2

Enterolactone (139) and enterodiol (140) which are two unusual *meta*-hydroxylated lignans that have been discovered in dietary mammalian urine. Microbial dehydroxylation and demethylation are proposed to account for these observations but dietary lignin, rather than lignans. Again, plant material in the diet caused excretion of lignans, but the racemic nature of the products is more in keeping with origins from lignin, and not from optically active plant lignans (Dewick, 1983;Dewick,1984).



Enterolactone (139)



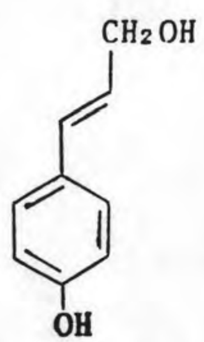
Enterodiol (140)

3.7 BIOSYNTHESIS OF LIGNIN

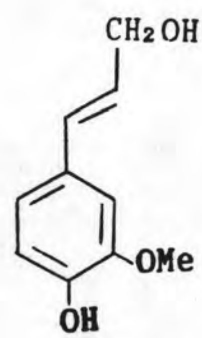
Lignin is a natural polymer that is belived to be derived by phenolic oxidation coupling of monomeric hydroxycinnamyl alcohol units (Dewick, 1985). Lignification often increases dramatically when plant cells are challenged by fungi or bacteria ; as part of a defence mechanism (Dewick, 1984).

The biosynthetic pathway for the formation of lignin in plants may be divided into two distinct phases :

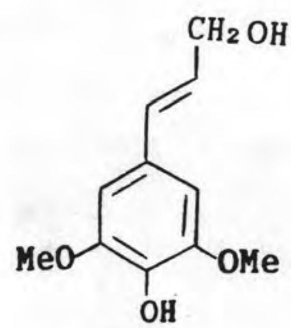
3.7.1 The formation of the lignin monomers, which include p-hydroxycinnamyl alcohol (141), coniferyl alcohol (142), and sinapyl alcohol (143).



p-hydroxycinnamyl alcohol (141)



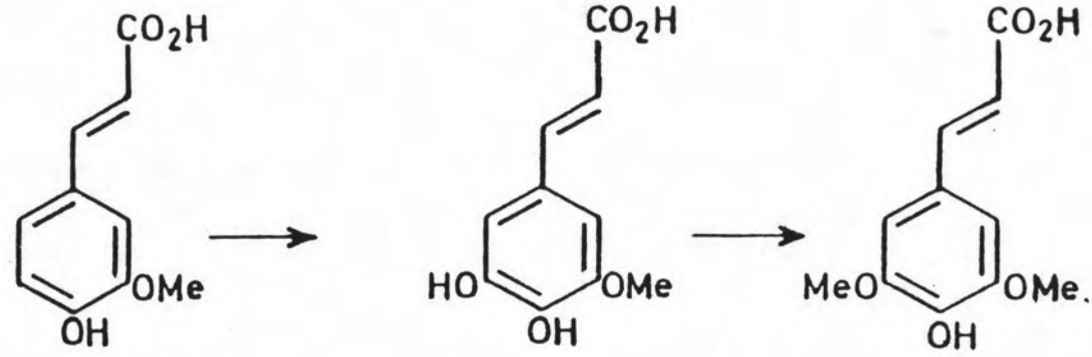
coniferyl alcohol (142)



sinapyl alcohol (143)

3.7.2 The conversion of these monomer into lignin (Dewick, 1985;Schubert, 1973).

These arise from cinnamic acid precursor *via* the corresponding CoA esters and aldehydes (e.g.coniferyl alcohol (142) (Fig.16) (Harborne, 1980)). The formation of sinapic acid (5) from ferulic acid (4) proceeds *via* 5-hydroxyferulic acid (121) (Fig.15) (Dewick, 1985).

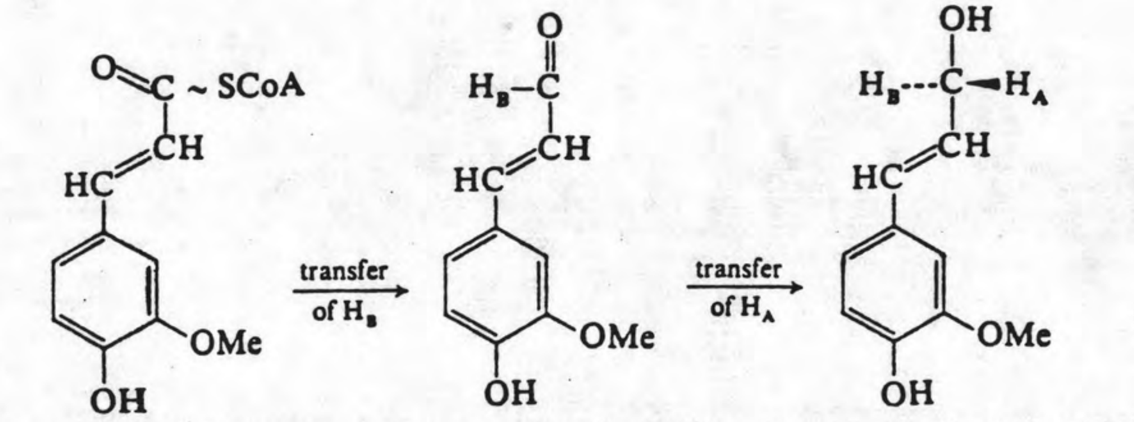


Ferulic acid (4) 5-Hydroxyferulic acid (121) Sinapic acid (5)

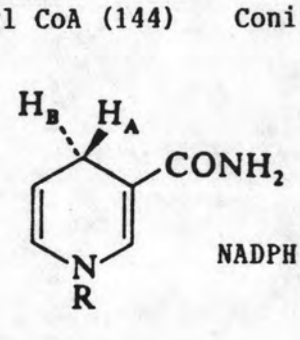
Fig.15 Biosynthesis of sinapic acid

I : Ferulic acid 5-hydroxylase

II : O-Methyltransferase



Ferulyl CoA (144) Coniferyl aldehyde (145) Coniferyl alcohol (142)



NADPH (the donor molecule in both reactions)

Fig.16 Biosynthesis of coniferyl alcohol

The final phase of lignin formation are explainable on the basis of the oxidation and condensation of the cinnamyl alcohol by enzyme (Dewick, 1988;Schubert, 1973).

3.8 BIOSYNTHESIS OF FLAVONOIDS

The key stage in the biosynthesis of all flavonoids is reached with the formation of an intermediate chalcone (94) flavanone (89). Tracer and enzyme evidence points to the formation of chalcones occurring by the condensation of p-coumaryl-coenzyme A. (148) with three malonyl - CoA units (147); chalcones are the first identifiable intermediates (Fig.17) (Goodwin and Mercer, 1983; Harborne, 1973;Herbert, 1981).

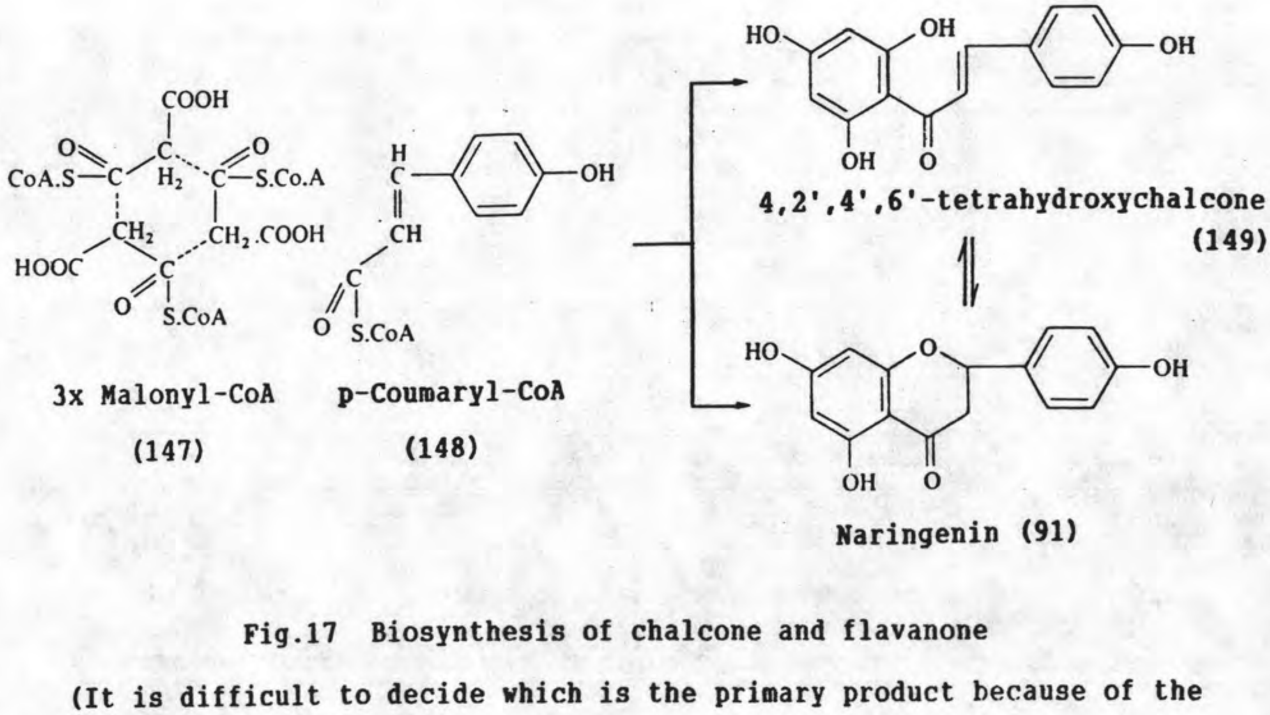


Fig.17 Biosynthesis of chalcone and flavanone

(It is difficult to decide which is the primary product because of the rapid equilibrium established between the chalcone and flavanone).

The hydroxylation of the flavanones in the 3-position giving the dihydroflavonols, which are important intermediates in the biosynthesis of other flavonoids (Dewick, 1988;Herbert, 1981).

The formation of the flavonols as quercetin (84) from the dihydroflavonols as 2,3-dihydroquercetin (93) could be detected in young flower buds of *Matthiola incana* (Dewick, 1985). Flavones can be formed by the oxidation of flavanones by flavanone oxidase which when isolated from young primary leaves of parsley, will oxidize naringenin (91) to apigenin (88). Another possible route to flavones is the oxidation takes place at the chalcone level *via* a hypothetical chalcone epoxide (Goodwin and Mercer, 1983)

Flavan-3,4-diols and flavan-3-ols arise, by successive reduction steps, from dihydroflavonols. The double reduction step has now been demonstrated with an enzyme preparation from maturing grains of barley *(Hordeum vulgare)*. A soluble NPDPH-dependent reductase converted (+)-2,3-dihydroquercetin (93) into the (2R, 3S, 4S) - flavan-3,4-diol(+)-2,3-*trans*-3,4-*cis*-leucocyanidin (150) but was strongly inhibited by the product of the reaction. A second, less-active NADPH-dependent reductase catalysed the reduction of (150) to (+)-catechin (151) (Fig.18) (Dewick, 1988).

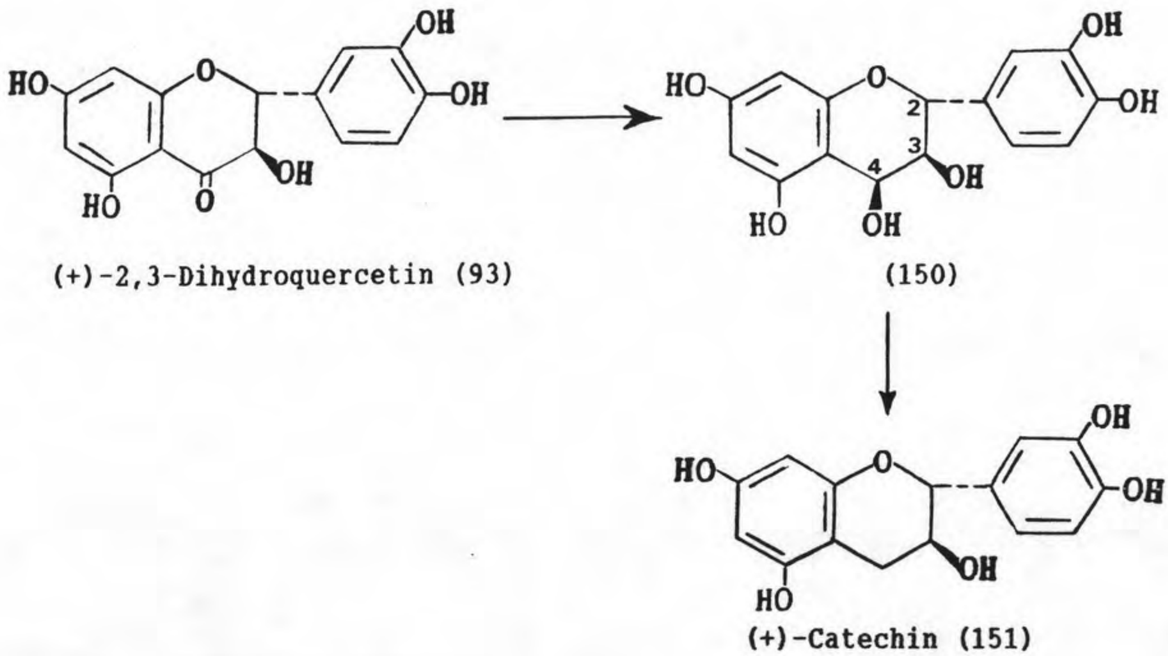
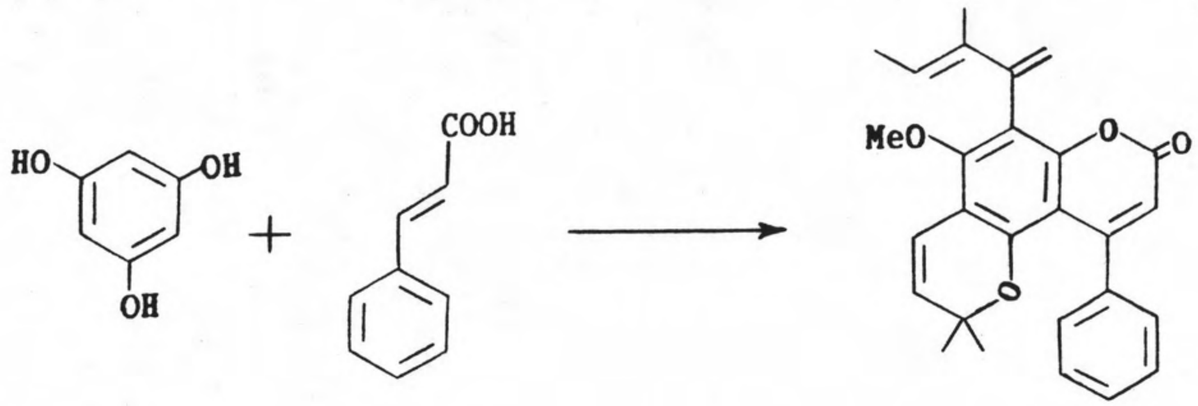


Fig.18 Biosynthesis of flavan -3,4-diol and flavan-3-ol

The anthocyanidins are known to be formed by the main flavonoid pathway, *via* dihydroflavonols and flavan-3,4-diols (Dewick, 1986). The biosynthesis of aurones is derived from chalcones by peroxidase-like enzyme from *Cicer* (Goodwin and Mercer, 1983).

The formation of isoflavones is proved to occur by rearrangment of the chalcone skeleton involving a 1,2-aryl shift (Herbert, 1981).

The biosynthesis of neoflavonoids (4-Phenylcoumarins) are thought of as arising from the same basic unit as other flavonoids but in a different manner as calophyllolide (152) in Fig.19 (Herbert, 1981).



Calophyllolide (152)

Fig.19 Biosynthesis of calophyllolide

4. CHEMOTAXONOMY OF PHENYLPROPANOIDS

Phenylpropanoids are widespread in nature, and the veracity of their use as systematic markers. Hydroxycinnamic acids are to be found in greatest abundance in taxa where there has been a shift from the woody to the herbaceous habit, accumulation of hydroxycinnamic acids acting as a sink for surplus metabolism that is no longer required for the formation of condensed tannins or lignin. Phenylpropenes are commonly encountered in plants, as constituents of volatile oils, some being particularly characteristic of the oils that are produced by members of a plant family, e.g. safrole (8) in the Lauraceae. The volatile fragrances of orchids have been examined by gas-liquid chromatography and the patterns of compounds, including eugenol (7) and methyl cinnamate, were useful in delineating these taxonomically complex species. In the Umbelliferae, the phenylpropene, myristicin (6), is found in two closely related genera, *Daucus* and *Pseudorlaya* and distinguishes them from other members of the tribe Caucalideae (Waterman and Gray, 1987).

Simple coumarins such as aesculetin (127) are of widespread occurrence in nature and generally seem to have little systematic significance. However, the more highly substituted prenylated coumarins, dihydrofuranocoumarins, furanocoumarins, and pyranocoumarins are major constituents of the subfamily Apioideae of the Umbelliferae and of the Rutaceae (Waterman and Gray, 1987).

Lignans are commonly encountered in the families Umbelliferae, Compositae, and Rutaceae, but generally little systematic use has been made of them. Sesamin type dioxabicyclic lignans are founded in a large number of species of *Artemisia* (Compositae) and the structures and stereochemistry of the lignans correlate with morphological features and with the geographical distribution of these species. The neolignans, typified by the bicyclo-octanoids and the benzofuranoids are found in the families which comprise the Magnoliideae, most notably in the Lauraceae. From the study of the distribution of neolignans in the complex lauraceous genus *Aniba*, the presence of neolignans are indicative of primitive taxa whereas pyrones are found in more advanced taxa. One interesting observation is that sympatric species tend to exhibit high chemical diversity (Waterman and Gray, 1987).

Flavonoids are a diverse group of phenolic plant pigments. There are many different structural types and their extensive use as taxonomic markers has been widely documented (Harborne, 1973). There is some evidence that they may have some adaptive value under arid conditions because both flavonoids and lignan-type compounds often occur on the cuticular surface of leaves of species that grow in such regions (Waterman and Gray, 1987).

5. BIOLOGICAL ACITVITIES OF PHENYLPROPANOIDS

Biological activities of phenylpropanoids is broad. Various phenylpropanoids are known to have anticoagulant, anti-inflammatory, antimicrobial, antitumor, antiviral activity and a variety of biological activities have been documented. Some phenylpropanoids are used in the treatment of some diseases e.g. eugenol as germicidal and local anesthetic, coumadin (warfarin) as anticoagulant, rutin as decreasing capillary fragility (Havsteen, 1983;MacRae and Towers, 1984;Soine, 1964 ; Youngken,1950).

Lists of phenylpropanoids having biological activities are shown in tables 1 to 6.

Table 1 Biological activities of hydroxycinnamic acids

Chemical Substance	Biological Activity	Reference
Caffeic acid	Abortifacient activity	Zheng *et al.*, 1987
	Antiprogestational action	Zheng *et al.*, 1987
	Bactericidal activity	Paster, Juven and Harshemesh, 1988
	Hepatoprotective activity	Adzet, Camarasa and Carlos Laguna, 1987
	Inhibition of aflatoxin production	Paster *et al.*, 1988
Ferulic acid	Antilipemic activity	Srinivasan and Satyanarayana, 1987
	Inhibition of aflatoxin production	Nandan and Polasa, 1985
	Inhibition of pepsin activity	Racz and Osan, 1987
m-Coumaric acid	Inhibition of pepsin activity	Racz and Osan, 1987
o-Coumaric acid	Inhibition of aflatoxin production	Paster *et al.*, 1988
p-Coumaric acid	Inhibition of aflatoxin production	Nanda and Polasa, 1985
	Inhibition of prostaglandin and thromboxane synthetases	Goda, Shibuya and Sankawa, 1987

Table 2 Biological activities of phenylpropenes

Chemical Substance	Biological Activity	Reference
Plantamajoside	Antibacterial activity	Ravn and Brimer, 1988
Sodium ferulate	Antiplatelet aggregation	Zhang *et al.*, 1987
Allylpyrocatechol	Antifungal activity	Evans, Bowers and Funk, 1984
	Nematocidal activity	Evans *et al.*, 1984
Allylpyrocatechol diacetate	Antifungal activity	Evans *et al.*, 1984
	Nematocidal activity	Evans *et al.*, 1984
Anethol	Antifungal activity	Shukla and Tripathi, 1987
Asarone	Anticholelithogenic activity	Gomez *et al.*, 1987
	Anticholesteremic activity	Gomez *et al.*, 1987
	Inhibition of pepsin activity	Racz and Osan, 1987
Carpacin	Weak sedative activity	Ghosal, Banerjee and Frahm, 1979
Chavibetol	Antifungal activity	Evans *et al.*, 1984
	Nematocidal activity	Evans *et al.*, 1984
Chavibetol acetate	Antifungal activity	Evans *et al.*, 1984
	Nematocidal activity	Evans *et al.*, 1984
Chavicol	Antifungal activity	Evans *et al.*, 1984
	Nematocidal activity	Evans *et al.*, 1984
Elemicin	Psychotropic activity	Trease and Evans, 1978
Eugenol	Antimycotic activity	Pham Chong Thi Tho *et al.*, 1986

Table 2 (Continue)

Chemical Substance	Biological Activity	Reference
Eugenol (continue)	Antipyretic activity	Feng and Lipton, 1987
	Carcinogenic activity	Fukuda, 1987
Isoeugenol	Antimycotic activity	Pham Chong Thi Tho *et al.*, 1986
Methyleugenol	Anesthetic activity	Sell and Carlini, 1976
Myristicin	Psychotropic activity	Trease and Evans, 1978
Sarisan	Antifungal activity	Villegas *et al.*, 1988

Table 3 Biological activities of coumarins

Chemical Substance	Biological Activity	Reference
6-Acetoxy-5,7-dimethoxycoumarin	Cytotoxic activity against L 1210 cells	Kang and Ahn, 1986
Aesculetin	Bacteriostatic activity	Fischer *et al.*, 1976
	Cytotoxic activity against L 1210 cells	Kang and Ahn, 1986
Aesculin	Bacteriostatic activity	Fischer *et al.*, 1976

Table 3 (Continue)

Chemical Substance	Biological Activity	Reference
Ammoresinol	Antibiotic activity	Hodak, Jakesova and Dadak,1967
Apterin	Bacteriostatic activity	Fischer *et al.,* 1976
Athamantin	Antibacterial activity	Tandon and Rastogi, 1979
Bergapten	Cytostatic activity against HeLa cells	Gawron and Glowniak, 1987
	Molluscicidal activity	Schonberg and Latif, 1954
3-(Carbobenzoxyamino)-4, 7-dihydroxy-8-methylcoumarin	Inhibition of Bacterial gyrase	Althaus, Dolak and Reusser, 1988
Calophyllolide	Anticonvulsant activity	Chaturvedi *et al.*, 1974
	Anti-inflammatory activity	Chaturvedi *et al.*, 1974
Chartreusin	Antibacterial activity	Tandon and Rastogi, 1979
Chlorobiocic acid	Inhibition of bacterial gyrase	Althaus *et al.*, 1988
Clorobiocin	Inhibition of the B subunit of DNA gyrase	Tabary *et al.*, 1987

Table 3 (Continue)

Chemical Substance	Biological Activity	Reference
Columbianetin	Antiplatelet aggregation	Wang *et al.*, 1988
Coumarin	Anti-inflammatory and anti edema activity	Foldi-Borcsok *et al.*, 1971
	Antimicrobial activity	Boutibonnes and Fischer, 1978
	Antiplatelet aggregation	Sarkar and Nath, 1979
	Antipyretic activity	Ritschel, Alcorn and Ritschel, 1984
	Antispermatogenic activity	Tyagi, Dixit and Joshi, 1980
	Hypnotic activity	Tandon and Rastogi, 1979
	Induction of liver carcinoma in rat	Griepentrog, 1973 Lake, 1984 Lake *et al.*, 1989
	Supression of DMBA-induced breast adenocarcinoma	Feuer, Kellen and Kovacs, 1975
Coumermycin	Antibacterial activity	Tandon and Rastogi, 1979
Coumosterol	Oestrogenic activity	Tandon and Rastogi, 1979

Table 3 (Continue)

Chemical Substance	Biological Activity	Reference
Daphnetin	Bacteriostatic activity	Fischer *et al.*, 1976
	Cytotoxic activity against L 1210 cells	Kang and Ahn, 1986
Daphnetin analogs	Analgesic activity	Yang *et al.*, 1980
Dauroside D	Hypotensive activity	Aminov and Vakhabov, 1985
	Spasmolytic activity	Aminov and Vakhabov, 1985
Decursinol	Calcium blocking activity	Namba *et al.*, 1988
Dicoumarol	Antibiotic activity	Hodak *et al.*, 1967
	Antiplatelet aggregation	Sarkar and Nath, 1979
	Calcium blocking activity	Namba *et al.*, 1988
Dihydrosamidin	Vasodilatory activity	Tandon and Rastogi, 1979
5,7-Dihydroxycoumarin	Bacteriostatic activity	Fischer *et al.*, 1976
5,7-Dimethoxy-6-hydroxycoumarin	Cytotoxic activity against L 1210 cells	Kang and Ahn, 1986
Fraxetin	Hypotensive activity	Aminov and Vakhabov, 1985
	Spasmolytic activity	Aminov and Vakhabov, 1985

Table 3 (Continue)

Chemical Substance	Biological Activity	Reference
7-O -D-Glucopyranosylcoumarin	Antiarrhythmic activity	Abyshev *et al.*, 1982
Haploperoside A	Hypotensive activity	Aminov and Vakhabov, 1985
	Spasmolytic activity	Aminov and Vakhabov, 1985
Imperatorin	Antifungal activity	Tandon and Rastogi, 1979
Isopimpinellin	Antimicrobial activity	Vichkonova *et al.*, 1973
	Cytostatic activity against HeLa cells	Gawron and Glowniak, 1987
	Molluscicidal activity	Schonberg and Latif, 1954
Khellin	Vasodilatory activity	Tandon and Rastogi, 1979
Licopyranocoumarin	Inhibition of the cytopathic activity of HIV.	Hatano *et al.*, 1988
4-Methylaesculetin	Cytostatic activity against HeLa cells	Gawron and Glowniak, 1987
4-Methyletrahydro benzofurano-(6,7-b) coumarin	Antispermatogenic activity	Tyagi *et al.*, 1980

Table 3 (Continue)

Chemical Substance	Biological Activity	Reference
4-Methyl-7-hydroxycoumarin	Antimicrobial activity	Vichkonova *et al.*, 1973
Nodakenetin	Antimicrobial activity	Wu *et al.*, 1988
	Calcium blocking activity	Namba *et al.*, 1988
Novobiocin	Antibacterial activity	Tandon and Rastogi, 1979
	Inhibition of the B subunit of DNA gyrase	Tabary *et al.*, 1987
Obtusinin	Hypotensive activity	Aminov and Vakhabov, 1985
	Spasmolytic activity	Aminov and Vakhabov, 1985
Obtusoside	Hypotensive activity	Aminov and Vakhabov, 1985
	Spasmolytic activity	Aminov and Vakhabov, 1985
Osthol	Antibacterial activity	Yang and Yen, 1979
	Antiplatelet aggregation	Wang *et al.*, 1988
	Cytostatic activity against HeLa cells	Gawron and Glowniak, 1987
Ostruthin	Antibiotic activity	Hodak *et al.*, 1967
	Antifungal activity	Tandon and Rastogi, 1979

Table 3 (Continue)

Chemical Substance	Biological Activity	Reference
Pimpinellin	Antimicrobial activity	Vichkonova *et al.*, 1973
Prangolarin	Antimicrobial activity	Vichkonova *et al.*, 1973
Pteryxin	Antispasmodic activity	Tandon and Rastogi, 1979
Samidin	Vasodilatory activity	Tandon and Rastogi, 1979
Scoparone	Hypotensive activity	Thakur, Bagadia and Sharma, 1978
Scopolin	Hypotensive activity	Aminov and Vakhabov, 1985
	Spasmolytic activity	Aminov and Vakhabov, 1985
Suksdorfin-A	Antispasmodic activity	Tandon and Rastogi, 1979
Umbelliferone	Antiarrhythmic activity	Abyshev *et al.*, 1982
	Bacteriostatic activity	Fischer *et al.*, 1976
Visnadin	Vasodilatory activity	Tandon and Rastogi, 1979
Xanthotoxin	Antibacterial activity	Yang and Yen, 1979
	Cytostatic activity against HeLa cells	Gawron and Glowniak, 1987

Table 3 (Continue)

Chemical Substance	Biological Activity	Reference
Xanthotoxin (continue)	Molluscicidal activity	Schonberg and Latif, 1954
Xanthotoxol	Cytostatic activity against HeLa cells	Gawron and Glowniak, 1987
Xanthyletin	Antimicrobial activity	Wu *et al.*, 1988

Table 4 Biological activities of chromones

Chemical Substance	Biological Activity	Reference
5,7-Dihydroxychromone	Antihepatotoxic activity	Hikino *et al.*, 1984
3,3-Dimethyl-allyl-spathelia chromene	Antibacterial activity	Gonzalez *et al.*, 1983
	Cytostatic activity against HeLa cells	Gonzalez *et al.*, 1983
Lathodoratin	Antifungal activity	Robeson *et al.*, 1980
Methylalloptaeroxylin	Hypotensive activity	Langenhoven *et al.*, 1988
Methyl-lathodoratin	Antifungal activity	Robeson *et al.*, 1980
5-O-Methylsorbifolin	Cytotoxic activity against 9PS cells	Suwanborirux, Chang and Cassady, 1987

Table 4 (Continue)

Chemical Substance	Biological Activity	Reference
Ptaeroglycol	Cytostatic activity against HeLa cells	Gonzalez *et al.*, 1983
Pulverochromenol	Antibacterial activity	Gonzalez *et al.*, 1983
Spathelia bis chromene	Cytostatic activity against HeLa cells	Gonzalez *et al.*, 1983
	Cytotoxic activity against 9PS cells	Suwanborirux *et al.*, 1987
Stigmatellin	Antibiotic activity	Kunze *et al.*, 1984

Table 5 Biological activities of lignans and neolignans

Chemical Substance	Biological Activity	Reference
Arctiin	Cytotoxic activity against KB cells	Harraz and Amer, 1988
Aschantin	Platelet activating factor antagonist activity	Pan *et al.*, 1987
Austrobailignan-1	Cytotoxic activity	Badawi *et al.*, 1981
Bornylmagnolol	Anti-allergic activity	Pan *et al.*, 1987
Burseran	Antitumor activity	Cole, Bianchi and Trumbull, 1969

Table 5 (Continue)

Chemical Substance	Biological Activity	Reference
Demethoxyaschantin	Platelet activating factor antagonist activity	Pan *et al.*, 1987
4'-Demethyldesoxy-podophyllotoxin	Antimitotic activity	German, 1971
3'-Demethylpodo-phyllotoxin	Antitumor and Cytotoxic activity	Weiss *et al.*, 1975
4'-Demethylpodophy-llotoxin	Cutaneous cytodestructive activity	Von Krogh and Maibach 1982
	Cyotoxic activity	Jackson and Dewick, 1981
Denudatin B	Calcium blocking activity	Chen *et al.*, 1988
Deoxygomisin A	Antihepatotoxic activity in GalN-induced cytotoxicity	Hikino, Kiso, Taguchi and, Ikeya, 1984
Deoxypodophyllo-toxin	Antiviral activity	Bedows and Hatfield, 1982
	Cytotoxic activity	Jackson and Dewick, 1981
		Kupchan, Hemingway and Hemingway, 1967
3-Deoxysilychristin	Antihepatotoxic activity in CCl_4-induced cytotoxicity	Hikino, Kiso, Wagner and Fiebig, 1984

Table 5 (Continue)

Chemical Substance	Biological Activity	Reference
Dihydroguaiaretic acid	Antimicrobial activity	Gisvold and Thaker, 1974
8,9-Dihydroxydihydro-honokiol	Treatment of contact dermatitis	Pan *et al.*, 1987
8,9-Dihydroxydihydro-magnolol	Treatment of contact dermatitis	Pan *et al.*, 1987
(-)-trans-2-3(3",4"-Dimethoxybenzyl)-3-(3',4'-methylenedioxybenzyl) butyrolactone	Antitumor activity	McDoniel and Cole, 1972
Diphyllin	Cytostatic activity against HeLa 299 cells	Gonzalez, Darias and Alonso, 1979
	Inhibition of DNA synthesis in ehrlich ascitic carcinoma	Gonzalez *et al.*, 1979
Enterolactone	Inhibition of cardiac $Na,^{+}K^{+}$-dependent ATPase	Braquet *et al.*, 1986
Epienshicine	Activity aganist leukemia P-388	Liu, Ma and Huang, 1988
Fargesin	Calcium blocking activity	Chen *et al.*, 1988
	Platelet activating factor antagonist activity	Pan *et al.*, 1987
Fargesone A	Calcium blocking activity	Chen *et al.*, 1988

Table 5 (Continue)

Chemical Substance	Biological Activity	Reference
Fargesone B	Calcium blocking activity	Chen *et al.*, 1988
Fargesone C	Calcium blocking activity	Chen *et al.*, 1988
Gomisin C	Antihepatotoxic activity in GalN-induced cytotoxicity	Hikino, Kiso, Taguchi and Ikeya, 1984
Gomisin N	Antihepatotoxic activity in GalN-induced cytotoxicity	Hikino, Kiso, Taguchi and Ikeya, 1984
Isomagnolol	Antimicrobial activity	El-Feraly, Cheatham and Breedlove, 1983
Kasurenone	Platelet activating factor antagonist activity	Pan *et al.*, 1987
Kobusin	Inhibition of the growth of silkworm larvae	Kamikado *et al.*, 1975
Lirioresinol B	Piscicidal activity	Tatematsu *et al.*, 1984
Lirioresinol B dimethyl ether	Calcium blocking activity	Chen *et al.*, 1988
	Platelet activating factor antagonist activity	Pan *et al.*, 1987
Magnolin	Calcium blocking activity	Chen *et al.*, 1988
	Platelet activating factor antagonist activity	Pan *et al.*, 1987
Magnolol	Antimicrobial activity	El-Feraly *et al.*, 1983
	CNS-depressant activity	Whiting, 1985

Table 5 (Continue)

Chemical Substance	Biological Activity	Reference
Magnosalicin	Inhibition of histamine release	Whiting, 1987
	Treatment of nasal allergy	Pan *et al.*, 1987
Nor-isoguaiacin	Antimicrobial activity	Gisvold and Thaker, 1974
(+)-Nortrachelogenin	CNS depressant activity	Kato, Hashimoto and Kidokoro, 1979
α-Peltatin	Antitumor and cytotoxic activity	Weiss *et al.*, 1975
	Cutaneous cytodestructive activity	Von Krogh and Maibach, 1982
β-Peltatin	Antimitotic activity	German, 1971
	Antitumor and cytotoxic activity	Weiss *et al.*, 1975
	Antiviral activity	Bedows and Hatfield, 1982
	Cutaneous cytodestructive activity	Von Krogh and Maibach, 1982
Pinoresinol	Piscicidal activity	Tatematsu *et al.*, 1984
Pinoresinol dimethyl ether	Calcum blocking activity	Chen *et al.*, 1988
	Platelet activating factor antagonist activity	Pan *et al.*, 1987

Table 5 (Continue)

Chemical Substance	Biological Activity	Reference
Podophyllotoxin	Antitumor and cytotoxic acitvity	Weiss *et al.*, 1975
	Antiviral activity	Bedows and Hatfield, 1982
	Cutaneous cytodestructive activity	Von Krogh and Maibach, 1982
	Cytotoxic activity	Jackson and Dewick, 1981
Podophyllotoxone	Cytotoxic activity	Jackson and Dewick, 1981
Prostalidin A	Mild antidepressant activity	Ghosal *et al.*, 1979
Prostalidin B	Mild antidepressant activity	Ghosal *et al.*, 1979
Prostalidin C	Mild antidepressant activity	Ghosal *et al.*, 1979
Schisantherin D	Antihepatotoxic activity in CCl_4-induced cytotoxicity	Hikino, Kiso, Taguchi and Ikeya, 1984
	Antihepatotoxic activity in GalN-induced cytotoxicity	Hikino, Kiso, Taguchi and Ikeya, 1984
Sesamin	Inhibition of the growth of silkworm larvae	Kamikado *et al.*, 1975
Silandrin	Antihepatotoxic activity in CCl_4-induced cytotoxicity	Hikino, Kiso, Wagner and Fiebig, 1984

Table 5 (Continue)

Chemical Substance	Biological Activity	Reference
Silybin	Antihepatotoxic activity in CCl_4-induced cytotoxicity	Gupta, Raj and Rao, 1982
		Hikino, Kiso, Wagner and Fiebig, 1984
Silydianin	Antihepatoxic activity in GalN-induced cytotoxicity	Hikino, Kiso, Wagner and Fiebig, 1984
Silymonin	Antihepatotoxic activity in CCl_4-induced cytotoxicity	Hikino, Kiso, Wagner and Fiebig, 1984
	Antihepatotoxic activity in GalN-induced cytotoxicity	Hikino, Kiso, Wagner and Fiebig,1984
Trachelogenin	Calcium blocking activity	Ichikawa *et al.*, 1986
	Hypotensive activity	Ichikawa *et al.*, 1986
(-)-trans-2-(3",4", 5",-Trimethoxybenzyl)-3-(3',4'-methylenedioxybenzyl) butyrolactone	Antitumor activity	McDoniel and Cole, 1972
Wuweizisu C	Antihepatotoxic activity in CCl_4-induced cytotoxicity	Hikino, Kiso, Taguchi and Ikeya, 1984
	Antihepatotoxic activity in GalN-induced cytotoxicity	Hikino, Kiso, Taguchi and Ikeya, 1984

Table 6 Biological activities of flavonoids

Chemical Substance	Biological Activity	Reference
7-O-Acetylafromosin	Inhibition of skin tumor promotion	Konoshima *et al.*, 1988
7-O-Actylformononetin	Inhibition of skin tumor promotion	Konoshima *et al.*, 1988
Amentoflavone	Inhibition of histamine release	Amellal *et al.*, 1985
Apigenin	Anti-inflammatory activity	Della Loggia *et al.*, 1986
	Inhibition of β-glucuronidase release	Middleton, Drzewiecki and Tatum, 1987
	Inhibition of histamine release	Middleton and Drzewiecki, 1984
		Middleton, Drzewiecki and Tatum, 1987
		Wu *et al.*, 1985
Artemisetin	Antitumor activity against melanoma B 16	Chemesova, Belenovskaya and Stukov, 1987
Avicularin	Inhibition of lens aldose reductase	Shimizu *et al.*, 1984

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
Baicalein	Antithrombic activity	Kubo *et al.*, 1985
	Inhibition of AMV reverse transcriptase	Inouye *et al.*, 1989
	Sialidase inhibitory activity	Nagai, Yamada and Otsuka, 1989
Baicalin	Sialidase inhibitory activity	Nagai *et al.*, 1989
Biochanin A	Hypolipidemic activity	Sharma, 1979
Chalcone	Inhibition of histamine release	Middleton and Drzewiecki, 1984
Chamanetin	Antimicrobial activity	Hufford and Lasswell, 1978
Chrysin	Antithrombic activity	Kubo, *et al.*, 1985
Chrysoeriol	Inhibition of β-glucuronidase release	Middleton, Drzewiecki and Tatum, 1987
	Inhibition of histamine release	Middleton, Drzewiecki and Tatum, 1987
Chrysosplenetin	Antitumor activity against melanoma B 16	Chemesova *et al.*, 1987
Chrysosplenol B	Antiviral activity	Tsuchiya *et al.*, 1985
Chrysosplenol C	Antiviral activity	Tsuchiya *et al.*, 1985
Chrysosplenol D	Antimicrobial activity	Wang *et al.*, 1989
Cirsilineol	Spasmolytic activity	Van den Broucke, 1983

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
Cirsimaritin	Antibacterial activity	Miski *et al.*, 1983
Cosmosiin	Inhibition of lens aldose reductase	Shimizu *et al.*, 1984
Datisetin	Antibacterial activity	Mori *et al.*, 1987
5,4'-Diacetyloxy-3, 7-dimethoxyflavone	Antimicrobial activity	Wang *et al.*, 1989
3',4'-Diacetyloxy-5-methoxy-3,7-dimethoxyflavone	Antimicrobial activity	Wang *et al.*, 1989
7,4'-diacetyloxy-5-methoxy-3,8,3'trime-thoxyflavone	Antimicrobial activity	Wang *et al.*, 1989
Dichamanetin	Antimicrobial activity	Hufford and Lasswell, 1978
6,7-Dihydroxyflavone	Cytotoxic activity against HeLa cells	Mori *et al.*, 1988
7,8-Dihydroxyflavone	Antibacterial activity	Mori *et al.*, 1987
	Cytotoxic activity against HeLa cells	Mori *et al.*, 1988
	Inhibition of AMV reverse transcriptase	Inouye *et al.*, 1989
7,8-Dihydroxy-4'-methoxyisoflavan	Antifungal activity	Weidenborner *et al.*, 1989

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
6,7-Dihydroxy-3'-methylisoflavan	Antifungal activity	Weidenborner *et al.*, 1989
3,3'-dimethylquercetin	Antiviral activity	Van Hoof *et al.*, 1984
3,7'-dimethylquercetin	Antiviral activity	Van hoof *et al.*, 1984
Diosmetin	Inhibition of β-glucuronidase release	Middleton, Drzewiecki and Tatum, 1987
-	Inhibition of histamine release	Middleton, Drzewiecki and Tatum, 1987
Diuvaretin	Antimicrobial activity	Hufford and Lasswell, 1978
DN-24	Inhibition of AMV reverse transcriptase	Inouye *et al.*, 1989
(-)-Epigallocatechin	Antibacterial activity	Mori *et al.*, 1987
Eriodictyol 7-Methyl ester	Antitumor activity against melanoma B 16	Chemesova *et al.*, 1987
Erybraedin A	Antibacterial activity	Mitscher *et al.*, 1988
Erybraedin B	Antibacterial activity	Mitscher *et al.*, 1988
Erybraedin C	Antibacterial activity	Mitscher *et al.*, 1988
Erythrabyssin II	Antibacterial activity	Mitscher *et al.*, 1988

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
Fisetin	Cytotoxic activity against HeLa cells	Mori *et al.*, 1988
	Inhibition of AMV reverse transcriptase	Inouye *et al.*, 1989
	Inhibition of histamine release	Middleton and Drzewiecki, 1984
		Middleton, Fujiki *et al.*, 1987
	Mutagenic activity	Hardigree and Epler, 1978
Flacumin	Antihepatotoxic activity against tetracycline cytotoxicity	Skakun, Shman'ko and Stepanova, 1985
Flamin	Antihepatotoxic activity against tetracycline cytotoxicity	Skakun *et al.*, 1985
Flavodilol	Hypotensive activity	Blosser *et al.*, 1989
Formononetin	Hypolipidemic activity	Sharma, 1979
Galangin	Cytotoxic activity against HeLa cells	Mori *et al.*, 1988
3,5,6,7,8,3',4'-Heptamethoxyflavone	Inhibition of histamine release	Middleton, Drzewiecki and Tatum, 1987
(±)-Hespertin	Cytotoxic activity against HeLa cells	Mori *et al.*, 1988

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
Hispidulin	Antihepatotoxic activity in phalloidin cytotoxicity	Soicke and Leng-Peschlow, 1987
(+)-Homoeriodictyol	Cytotoxic activity against HeLa cells	Mori *et al.*, 1988
6-Hydroxyluteolin	Inhibition of lens aldose reductase	Shimizu *et al.*, 1984
Hypolaetin-8-O-glucoside	Anti-inflammatory activity	Villar *et al.*, 1985
	Antiulcer activity	Villar *et al.*, 1985
Isochamanetin	Antimicrobial activity	Hufford and Lasswell, 1978
Isokaemferide	Antimicrobial activity	Wang *et al.*, 1989
6-Isopentenylnaringenin	Antifungal activity	Mizobuchi and Sato, 1985
Isorhamnetin	Inhibition of β-glucuronidase release	Middleton, Drzewiecki and Tatum, 1987
	Inhibition of histamine release	Middleton, Drzewiecki and Tatum, 1987
Isouvaretin	Antimicrobial activity	Hufford and Lasswell, 1978
Isoxanthohumol	Antifungal activity	Mizobuchi and Sato, 1985
Kaemferide	Antibacterial activity	Mersta and Mersta, 1985

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
Kaemferol	Antibacterial activity	Mersta and Mersta, 1985
	Cytotoxic activity against HeLa cells	Mori *et al.*, 1988
	Inhibition of AMV reverse transcriptase	Inouye *et al.*, 1989
	Inhibition of histamine release	Middleton, Drzewiecki and Tatum, 1987
	Mutagenic activity	Hardigree and Epler, 1978
Kaemferol 3-rhamnoside	Inhibition of lens aldose reductase	Shimizu *et al.*, 1984
Lonicerin	Inhibition of lens aldose reductase	Shimizu *et al.*, 1984
Luteolin	Anti-inflammatory activity	Della Loggia *et al.*, 1986
	Cytotoxic activity against HeLa cells	Mori *et al.*, 1988
	Inhibition of β-glucuronidase release	Middleton, Drzewiecki and Tatum, 1987

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
Luteolin (continue)	Inhibition of histamine release	Amellal *et al.*, 1985 Middleton, Drzewiecki and Tatum, 1987 Meddleton, Fujiki *et al.*, 1987
	Virustatic activity	Mucsi *et al.*, 1978
Luteolin 7-glucuronide	Inhibition of lens aldose reductase	Shimizu *et al.*, 1984
8-Methoxycirsilineol	Spasmolytic activity	Van den Broucke, 1983
3-Methoxylated flavones	Antiviral activity	Tsuchiya *et al.*, 1985
3-Methylquercetin	Antiviral activity	Van Hoof *et al.*, 1984
Morin	Antibacterial activity	Mori *et al.*, 1987
	Inhibition of AMV reverse transcriptase	Inouye *et al.*, 1989
	Mutagenic activity	Hardigree and Epler, 1978
Myricetin	Antibacterial activity	Mersta and Mersta, 1985 Mori *et al.*, 1987

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
Myricetin (continue)	Antiulcer activity	Barnaulov, Manicheva and Komissarenko, 1983
	Inhibition of AMV reverse transcriptase	Inouye *et al.*, 1989
	Mutagenic activity	Hardigree and Epler, 1978
Naringenin	Inhibition of the conversion of PGI_2 and PGF_2 to 6-oxo-PGE_1	Moore, Griffiths and Lofts, 1983
	Inhibition of the microsomal prostaglandin synthesis	Moore *et al.*, 1983
	Inhibition of the spasmogenic effect of PGI_2	Moore *et al.*, 1983
Nobiletin	Inhibition of histamine release	Middleton Drzewiecki and Tatum, 1987 Middleton, Fujiki *et al.*, 1987
Oroxylin A	Antithrombic activity	Kubo *et al.*, 1985
Pelargonidin	Antiviral activity	Mucsi *et al.*, 1978
Pinocembrin	Antimicrobial activity	Metzner *et al.*, 1979
Phloretin	Inhibition of histamine release	Middleton and Drzewiecki, 1984

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
Podoverine A	Anti-inflammatory activity	Arens *et al.*, 1986
Podoverine B	Anti-inflammatory activity	Arens *et al.*, 1986
Procyanidin	Antiviral activity	Mucsi *et al.*, 1978
Quercetagenin	Antibacterial activity	Mori *et al.*, 1987
Quercetin	Antibacterial activity	Mersta and Mersta, 1985
	Anti-inflammatory activity	Arens *et al.*, 1986
	Antiulcer activity	Barnaulov *et al.*, 1983
	Antiviral activity	Mucsi *et al.*, 1978
	Inhibition of AMV reverse transcriptase	Inouye *et al.*, 1989
	Inhibition of histamine release	Middleton and Drzeviecki, 1984
		Middleton, Fujiki *et al.*, 1987
	Inhibition of the microsomal prostaglandin synthesis	Moore *et al.*, 1983
	Mutagenic activity	Hardigree and Epler, 1978
Quercetin 3,3'-dimethyl ether	Inhibition of histamine release	Wu *et al.*, 1985

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
Quercetin 3-methyl ether	Inhibition of histamine release	Wu *et al.*, 1985
Quercitin	Mutagenic activity	Hardigree and Epler, 1978
Rhamnetin	Cytotoxic activity against HeLa cells	Mori *et al.*, 1988
Robinetin	Antibacterial activity	Mori *et al.*, 1987
Rutin	Inhibition of the conversion of PGI_2 and PGF_2 to 6-oxo PGE_1	Moore *et al.*, 1983
	Inhibition of the spasmogenic effect of PGI_2	Moore *et al.*, 1983
	Mutagenic activity	Hardigree and Epler, 1978
	Stimulation of the microsomal prostaglandin synthesis	Moore *et al.*, 1983
Sinensetin	Inhibition of histamine release	Middleton, Drzewiecki and Tatum, 1987
Skullcapflavone II	Antithrombic activity	Kubo et al.,1985
Swertisin	Sedative activity	Shin, Woo and Lee, 1981
Sylluteolin	Antiherpetic activity	Suganda *et al.*, 1984

Table 6 (Continue)

Chemical Substance	Biological Activity	Reference
Taneflon	Antihepatotoxic activity against tetracycline cytotoxicity	Skakun *et al.*, 1985
Tangeretin	Inhibition of histamine release	Middleton, Drzewiecki and Tatum, 1987
5,6,7,4'-Tetramethoxy flavone	Inhibition of histamine release	Middleton, Drzewiecki and Tatum, 1987
Thymonin	Spasmolytic activity	Van den Broucke, 1983
5,7,4'-Trihydroxy-3,3'-dimethoxyflavone	Antimicrobial activity	Wang *et al.*, 1989
5,7,4'-Trihydroxy-3,8-dimethoxyflavone	Antimicrobial activity	Wang *et al.*, 1989
3,7,3'-Trimethyl quercetin	Antiviral activity	Van Hoof *et al.*, 1984
Umuhengerin	Antimicrobial activity	Rwangabo *et al.*, 1988
	Antiviral activity	Rwangabo *et al.*, 1988
Uvaretin	Antimicrobial activity	Hufford and Lasswell, 1978
Uvarinol	Antimicrobial acitvity	Hufford and Lasswell, 1978
Wogonin	Antithrombic activity	Kubo *et al.*, 1985
	Sialidase inhibitory activity	Nagai *et al.*, 1989

Chemical Substance	Biological Activity	Reference
Wogonin glucuronide	Sialidase inhibitory acitivity	Nagai *et al.*, 1989
Xanthohumol	Antifungal activity	Mizobuchi and Sato, 1985

5. CHEMICAL CONSTITUENTS OF *Piper* SPECIES

The piquant flavour of *Piper nigrum* fruits attracted attention of chemists as early as 1819 when Oestred isolated piperine the pungent principle, from this spice. Since that time, the search for active constituents from different *Piper* species has continued and this has been intensified in recent years, particularly because phytochemicals from several *Piper* species have been shown to have interesting biological activities (Sengupta and Ray, 1987) The groups of compounds commonly found in the *Piper* species are alkaloids, amines, phenylpropanoids, lactones, benzenoids, terpenoids, steroids and hydrocarbons.

List of the compounds found in various species of *Piper* is shown in Table 7.

Table 7 Chemical constituents of *Piper* species

Botanical Origin	Chemical Substance	Category	Reference
Piper aduncum (leaves)	Dillapiole	Phenylpropene	Smith and Kassim, 1979
	Piperitone	Monoterpene	Smith and Kassim, 1979
P. aduncum L. (fruits)	1-Allyl-2,3-(methylenedioxy)-4,5-dimethoxy-benzene	Phenylpropene	Burke and Nair, 1986

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P.aduncum L. (fruits) (continue)	2,6-Dihydroxy-4-methoxydihydro-chalcone	Flavonoid	Burke and Nair, 1986
	5-Hydroxy-7-methoxyflavanone	Flavonoid	Burke and Nair, 1986
	4-Methoxy-3-5-bis (3'-methyl-2'-butenyl)-benzoic acid	Phenylpropene	Burke and Nair, 1986
P. aduncum L. (leaves)	2',6'-Dihydroxy-4' -methoxydihydro-chalcone	Flavonoid	Achenbach *et al.*, 1984
P. aduncum L. (stems)	β-Sitosterol	Steroid	Achenbach *et al.*, 1984
P. aduncum L.*	Dillapiol	Phenylpropene	Diaz D. *et al.*, 1984
	Myristicin	Phenylpropene	Diaz D. *et al.*, 1984
	Piperitone	Monoterpene	Diaz D. *et al.*, 1984
P. album (fruits)	*trans, trans* - Piperine	Alkaloid	Glasl, Borup-Grochtmann and Wagner, 1976

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. amalago (bark)	β-Amyrin	Triterpene	Dominguez and Alcorn, 1985
	β-Sitosterol	Steroid	Dominguez and Alcorn, 1985
P. amalago (leaves)	γ-Aminobutyric acid	Amine	Durand *et al.*, 1962
	Dopamine	Amine	Durand *et al.*, 1962
P. amalago (roots)	2-Methoxy-4,5-methylenedioxy-trans-cinnamoyl piperidide	Alkaloid	Dominguez *et al.*, 1986
	2-Methoxy-4,5-methylenedioxy-trans-cinnamoyl piperidide	Alkaloid	Dominguez *et al.*, 1986
P. amalago L. (roots)	Ishwarol	Sesquiterpene	Achenbach, Grob and Portecop, 1984
P. arboricola *	3,4-Dimethoxyphenylpropionic acid	Phenylpropene	Ho *et al.*,1981
	3,4-Dimethoxyphenylpropylamine	Amine	Ho *et al.*,1981

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. argyrophyllum Miq. (whole plants)	Piperine	Alkaloid	Banerji and Nandi, 1988
	N-Iosobutyloctadeca -2E, 4E-dienamide	Alkaloid	Banerji and Nandi, 1988
P. attenuatum (whole Plants)	Aristolactam AII	Alkaloid	Desai *et al.*,1989
	Cepharadione A	Alkaloid	Desai *et al.*,1989
	Cepharadione B	Alkaloid	Desai *et al.*,1989
	Cepharanone B	Alkaloid	Desai *et al.*,1989
	2-Hydroxy-1-methoxy -4,5-dioxoporphine	Alkaloid	Desai *et al.*,1989
	Norcepharadione B	Alkaloid	Desai *et al.*,1989
	Piperadione	Alkaloid	Desai *et al.*,1989
	Piperolactam A	Alkaloid	Desai *et al.*,1989
P. attenuatum Ham. (whole plants)	Crotepoxide	Benzenoid	Desai *et al.*,1975
P. aurantiacum (fruits)	Piperine	Alkaloid	Rao, Subrahamanyam and Rao, 1974
	Piperettine	Alkaloid	Rao *et al.*,1974
	Sylvatine	Alkaloid	Rao *et al.*,1974
	β-Sitosterol	Steroid	Rao *et al.*,1974
P. aurantiacum Wall (fruits)	Cholestanol	Steroid	Singh, Santani and Pani, 1976

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. aurantiacum Wall (fruits) (continue)	Cholesterol	Steroid	Singh, Santani and Pani, 1976
	Linoleic acid	Hydrocarbon	Singh, Santani and Pani, 1976
	β-Sitosterol	Steroid	Singh, Santani and Pani, 1976
	Stearic acid	Hydrocarbon	Singh, Santani and Pani, 1976
	Triacontane	Hydrocarbon	Singh, Santani and Pani, 1976
P. aurantiacum Wall (seeds)	Aurantiamide	Alkaloid	Banerji and Ray, 1981
	Aurantiamide acetate	Alkaloid	Banerji and Ray, 1981
	Epi-friedelanol	Triterpene	Banerji and Das, 1977a
	Friedelin	Triterpene	Banerji and Das, 1977a
	β-Sitosterol	Steroid	Banerji and Das, 1977a

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. auritum H.B.K. (leaves)	β-Bisabolene	Sesquiterpene	Gupta *et al.*,1985
	Borneol	Monoterpene	Gupta *et al.*,1985
	Bornyl acetate	Monoterpene	Gupta *et al.*,1985
	β-Bourbonene	Sesquiterpene	Gupta *et al.*,1985
	Cadina-1,4-diene	Sesquiterpene	Gupta *et al.*,1985
	Δ-Cadinene	Sesquiterpene	Gupta *et al.*,1985
	Camphene	Monoterpene	Gupta *et al.*,1985
	Camphor	Monoterpene	Gupta *et al.*,1985
	Δ^3 -Carene	Monoterpene	Gupta *et al.*,1985
	β-Caryophyllene	Sesquiterpene	Gupta *et al.*,1985
	β-Caryophyllene oxide	Sesquiterpene	Gupta *et al.*,1985
	1,8-Cineole	Monoterpene	Gupta *et al.*,1985
	α-Copaene	Sesquiterpene	Gupta *et al.*,1985
	α-Cubenene	Sesquiterpene	Gupta *et al.*,1985
	p-Cymenene	Monoterpene	Gupta *et al.*,1985
	p-Cymen-8-ol	Monoterpene	Gupta *et al.*,1985
	Δ-Elemene	Sesquiterpene	Gupta *et al.*,1985
	Elemicine	Phenylpropene	Gupta *et al.*,1985
	Eugenol	Phenylpropene	Gupta *et al.*,1985
	n-Hexadecane	Hydrocarbon	Gupta *et al.*,1985
	Humulene	Sesquiterpene	Gupta *et al.*,1985

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. auritum H.B.K. (leaves) (continue)	Limonene	Monoterpene	Gupta *et al.*,1985
	Linalool	Monoterpene	Gupta *et al.*,1985
	Muurolene	Sesquiterpene	Gupta *et al.*,1985
	Myrcene	Monoterpene	Gupta *et al.*,1985
	Myristicine	Phenylpropene	Gupta *et al.*,1985
	Nonanone-2	Hydrocarbon	Gupta *et al.*,1985
	α-Phellandrene	Monoterpene	Gupta *et al.*,1985
	β-Phellandrene	Monoterpene	Gupta *et al.*,1985
	α-Pinene	Monoterpene	Gupta *et al.*,1985
	β-Pinene	Monoterpene	Gupta *et al.*,1985
	Sabinene	Monoterpene	Gupta *et al.*,1985
	cis-Sabinene hydrate	Monoterpene	Gupta *et al.*,1985
	Safrole	Phenylpropene	Gupta *et al.*,1985
	Spathulenol	Sesquiterpene	Gupta *et al.*,1985
	α-Terpinene	Monoterpene	Gupta *et al.*,1985
	γ-Terpinene	Monoterpene	Gupta *et al.*,1985
	Terpinolene	Monoterpene	Gupta *et al.*,1985
	α-Thujene	Monoterpene	Gupta *et al.*,1985
P. auritum H.B.K. (roots)	Cepharadione A	Alkaloid	Hansel and Leuschke, 1975
	Cepharadione B	Alkaloid	Hansel and Leuschke, 1975

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. auritum Kunth. (roots)	1-Allyl-2,3-(methylenedioxy)-5-methoxybenzene	Phenylpropene	Nair, Sommerville and Burke, 1989
	Dillapiole	Phenylpropene	Nair *et al.*,1989
	1-Propenal-3,4-(methylenedioxy)-5-methoxybenzene	Phenylpropene	Nair *et al.*,1989
	Safrole	Phenylpropene	Nair *et al.*,1989
P. banksii Miq. (leaves and stems)	Dillapiole	Phenylpropene	Loder and Nearn, 1972
	Elemicin	Phenylpropene	Loder and Nearn, 1972
	N-Isobutyl-*trans*-2, *trans* 4-octadienamide	Alkaloid	Loder and Nearn, 1972
P. betle (leaves)	Allylpyrocatechol diacetate	Phenylpropene	Rimando *et al.*, 1986
	Allylpyrocatechol monoacetate	Phenylpropene	Rimando *et al.*, 1986
	Camphene	Monoterpene	Rimando *et al.*, 1986
	Cardinene	Sesquiterpene	Dutt, 1956 Nigam and Purohit, 1962

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. betle (leaves) (continue)	Carvacrol	Monoterpene	Dutt, 1956 Nigam and Purohit, 1962
	Caryophyllene	Sesquiterpene	Dutt, 1956 Nigam and Purohit, 1962 Rimando *et al.*, 1986
	Chavibetol	Phenylpropene	Dutt, 1956 Nigam and Purohit, 1962 Rimando *et al.*, 1986
	Chavibetol acetate	Phenylpropene	Rimando *et al.*, 1986
	Chavicol	Phenylpropene	Dutt, 1956 Nigam and Purohit, 1962
	Cineole	Monoterpene	Dutt, 1956 Nigam and Purohit, 1962
	1,8 Cineole	Monoterpene	Rimando *et al.*, 1986

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. betle (leaves) (continue)	p-Cymene	Monoterpene	Dutt, 1956 Rimando *et al.*, 1986
	Estragole	Phenylpropene	Nigam and Purohit, 1962
	Eugenol		Dutt, 1956 Nigam and Purohit, 1962 Rimando *et al.*, 1986
	Eugenol methyl ether (Chavibetol methyl ether)	Phenylpropene	Dutt, 1956 Rimando *et al.*, 1986
	α-Limonene	Monoterpene	Rimando *et al.*, 1986
	α-Pinene	Monoterpene	Rimando *et al.*, 1986
	β-Pinene	Monoterpene	Rimando *et al.*, 1986
	Safrole	Phenylpropene	Rimando *et al.*, 1986
	Terpinene	Monoterpene	Nigam and Purohit, 1962

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. betle L. (leaves)	Allylpyrocatechol	Phenylpropene	Evans *et al.*, 1984
	Allylpyrocatechol diacetate	Phenylpropene	Evans *et al.*, 1984
	Chavibetol	Phenylpropene	Evans *et al.*, 1984
	Chavibetol acetate	Phenylpropene	Evans *et al.*, 1984
	Chavicol	Phenylpropene	Evans *et al.*, 1984
P. boehimerifolium (whole plants)	Aristolactam AII	Alkaloid	Desai *et al.*,1989
	Cepharadione A	Alkaloid	Desai *et al.*,1989
	Cepharadione B	Alkaloid	Desai *et al.*,1989
	Cepharanone B	Alkaloid	Desai *et al.*,1989
	2-Hydroxy-1-methoxy-4,5-dioxoaporphine	Alkaloid	Desai *et al.*,1989
	Norcepharadione B	Alkaloid	Desai *et al.*,1989
	Piperolactam A	Alkaloid	Desai *et al.*,1989
	Piperolactam B	Alkaloid	Desai *et al.*,1989
	Piperolactam C	Alkaloid	Desai *et al.*,1989

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. brachystachyum[a]	Apiole	Phenylpropene	Singh and Atal, 1969a
	Caryophyllene epoxide	Sesquiterpene	Thappa *et al.*,1970
	Crotepoxide	Benzenoid	Singh and Atal, 1969a
	β-Sitosterol	Steroid	Singh and Atal, 1969a
	Triacontane	Hydrocarbon	Singh and Atal, 1969a
	Triacontanol	Hydrocarbon	Singh and Atal, 1969a
P. brachystachyum Wall. (Aerial Parts)	Brachystamide A	Alkaloid	Banerji and Das, 1989
	Brachystamide B	Alkaloid	Banerji and Das, 1989
P. brachystachyum Wall. (fruits)	Asarinine	Lignan	Koul *et al.*,1988
	Fargesin	Lignan	Koul *et al.*,1988
	Guineensine	Alkaloid	Koul *et al.*,1988
	Pipataline	Benzenoid	koul *et al.*,1988
	Pipercide	Alkaloid	Koul *et al.*,1988
	Pluviatilol	Lignan	Koul *et al.*,1988

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. brachystachyum Wall. (fruits) (continue)	Retrofractamide A	Alkaloid	Koul *et al.*,1988
	Sesamine	Lignan	Koul *et al.*,1988
	β-Sitosterol	Steroid	Koul *et al.*,1988
	E-2,4,5-Trimethoxy cinnamic acid	Cinnamic acid derivative	Koul *et al.*,1988
	Z-2,4-5-Trimethoxy cinnamic acid	Cinnamic acid derivative	Koul *et al.*,1988
	E-2,4-5-Trimethoxy methyl cinnamate	Cinnamic acid derivative	Koul *et al.*,1988
P. brachystachyum Wall. (seeds)	(+)-Asarinin	Lignan	Dutta and Banerjee, 1976
	Sessamin	Lignan	Dutta and Banerjee, 1976
	Sylvatine	Alkaloid	Dutta and Banerjee, 1976
P. callosum Ruiz & Pavon (roots)	Pipercallosidine	Alkaloid	Pring, 1982
	Pipercallosine	Alkaloid	Pring, 1982
	Piperovatine	Alkaloid	Pring, 1982
*P. cavalcantei**	Methyleugenol	Phenylpropene	De Alencar *et al.*, 1972
	Safrole	Phenylpropene	De Alencar *et al.*, 1972

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. chaba Hunter. (stems)	Piperine	Alkaloid	Mishra and Tewari, 1964
	Piplartine	Alkaloid	Mishra and Tewari, 1964
	β-Sitosterol	Steroid	Mishra and Tewari, 1964
P. chaba Hunter*	Piperine	Alkaloid	Bose, 1935
P. clusii Cass DC. (leaves)	Piperine	Alkaloid	Koul *et al.*,1983
	Sesamin	Lignan	Koul *et al.*,1983
P. clusii Cass DC.*	Asaronaldehyde	Benzenoid	Koul *et al.*,1983
	(-)-Clusin	Lignan	Koul *et al.*,1983
	(-)-Cubebin	Lignan	Koul *et al.*,1983
	(-)-Deoxypodorhizone	Lignan	Koul *et al.*,1983
	(-)-Dihydrocubebin	Lignan	Koul *et al.*,1983
	(-)-Hinokinin	Lignan	Koul *et al.*,1983
	Sitosterol	Steroid	Koul *et al.*,1983
	(153) (Fig.20)	Lignan	Koul *et al.*,1984
	(154) (Fig.20)	Lignan	Koul *et al.*,1984
	(155) (Fig.20)	Lignan	Koul *et al.*,1984
	(156) (Fig.20)	Lignan	Koul *et al.*,1984

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. cubeba (fruits)	Aschantin	Lignan	Haensel and Zander, 1961
	Cadalene	Sesquiterpene	Razdan and Bhattacharyya, 1952
	Cadinol	Sesquiterpene	Razdan and Bhattacharyya, 1952
	Copaene	Sesquiterpene	Razdan and Bhattacharyya, 1952
	(-)-Clusin	Lignan	Prabhu and Mulchandani, 1985
	(-)-Cubebin	Lignan	Prabhu and Mulchandani, 1985
	(-)-Cubebinin	Lignan	Prabhu and Mulchandani, 1985
	(-)-Cubebininolide	Lignan	Badheka, Prabhu and Mulchandani, 1986
	(-)-Cubebinone	Lignan	Badheka *et al.*,1986

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. cubeba (fruits) (continue)	(-)-Dihydroclusin	Lignan	Prabhu and Mulchandani, 1985
	(-)-Dihydrocubebin	Lignan	Prabhu and Mulchandani, 1985
	α-O-Ethyl cubebin	Lignnan	Badheka, Prabhu and Mulchandani, 1987
	β-O-Ethyl cubebin	Lignan	Badheka *et al.*, 1987
	Hemiariensin	Lignan	Badheka *et al.*, 1987
	Heterotropan	Neolignan	Badheka *et al.*, 1987
	(-)-Hinokinin	Lignan	Prabhu and Mulchandani, 1985
	(-)-Isoyatein	Lignan	Badheka *et al.*, 1986
	Magnosalin	Neolignan	Badheka *et al.*, 1987
	5-Methoxyhinokinin	Lignan	Badheka *et al.*, 1987

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. cubeba (fruits) (continue)	2-(3",4"-Methylene-dioxybenzyl)-3-(3',4'-dimethoxybenzyl) butyrolactone	Lignan	Badheka *et al.*, 1986
	(-)-di-O-Methyl thujaplicatin methyl ether	Lignan	Badheka *et al.*, 1986
	Piperine	Alkaloid	Hadorn and Jungkunz, 1951
	(+)-Sesamin	Lignan	Haensel and Zander, 1961
	2,4,5-Trimethoxy-benzaldehyde	Benzenoid	Badheka *et al.*,1987
	(-)-Yatein	Lignan	Badheka *et al.*,1986
P. cubeba L. (fruits)	Bicyclosesqui-phellandrene	Sesquiterpene	Terhune *et al.*, 1974
	Cardinene	Sesquiterpene	Opduke, 1976
	d-Δ^4-Carene	Monoterpene	Rao, Shintre and Simonsen, 1928
	Cineole	Monoterpene	Opdyke, 1976
	1,4-Cineole	Monoterpene	Rao *et al.*, 1928
	α-Cubebene	Sesquiterpene	Opdyke, 1976
	β-Cubebene	Sesquiterpene	Opdyke, 1976

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. cubeba L. (fruits) (continue)	p-Cymene	Monoterpene	Opdyke, 1976
	d-Limonene	Monoterpene	Opdyke, 1976
	Myrcene	Monoterpene	Opdyke, 1976
	Ocimene	Monoterpene	Opdyke, 1976
	α-Phellandrene	Monoterpene	Opdyke, 1976
	β-Phellandrene	Monoterpene	Opdyke, 1976
	α-Pinene	Monoterpene	Opdyke, 1976
	β-Pinene	Monoterpene	Opdyke, 1976
	Sabinene	Monoterpene	Opdyke, 1976
	α-Terpinene	Monoterpene	Opdyke, 1976
	γ-Terpinene	Monotepene	Opdyke, 1976
	d- Δ^1-Terpinen-4-ol	Monoterpene	Rao *et al.*, 1928
	Terpinolene	Monoterpene	Opdyke, 1976
	α-Thujene	Monoterpene	Opdyke, 1976
P.demeraranum **(Miq) C.DC.(aerial parts)**	**Dihydrocinnamoyl-2-pyrrolinone amide**	**Alkaloid**	**Maxwell and Rampersad, 1989 a**
	2-Geranylgeranyl-3, 4-dihydroxybenzoic acid	**Benzenoid**	**Maxwell and Rampersad, 1989 a**
	5-Geranylgeranyl -3,4-dihydroxy-benzoic acid	**Benzenoid**	**Maxwell and Rampersad, 1989 a**
	3-Geranylgeranyl-4-hydroxybenzoic acid	**Benzenoid**	**Maxwell and Rampersad, 1989 a**

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. fadyenii	5,6-*E*-Fadyenolide	Lactone	Pelter *et al.*,1981
(roots)	5,6-*Z*-Fadyenolide	Lactone	Pelter *et al.*,1981
P. futokadzura	Camphene	Monoterpene	Takahashi, 1969
Sieb. et Zucc.	Crotepoxide	Benzinoid	Takahashi, 1969
(leaves and	(futoxide)		
stems)	Futoamide	Alkaloid	Takahashi, 1969
	Futoenone	Benzenoid	Takahashi, 1969
	Futoquinol	Neolignan	Takahashi, 1969
	Isoasarone	Phenylpropene	Takahashi, 1969
	Limonene	Monoterpene	Takahashi, 1969
	α-Pinene	Monoterpene	Takahashi, 1969
	β-Pinene	Monoterpene	Takahashi, 1969
	Sabinene	Monoterpene	Takahashi, 1969
	β-Sitosterol	Steroid	Takahashi, 1969
	Stigmasterol	Steroid	Takahashi, 1969
P. futokadsura	Kadsurenone	Neolignan	Chang *et al.*,1985
Sieb. et Zucc.	Kadsurin A	Neolignan	Chang *et al.*,1985
(stems)	Kadsurin B	Neolignan	Chang *et al.*,1985
P. guayranum C.DC.	Alatamide	Alkaloid	Maxwell and
(aerial parts)			Rampersad,1989 b
	Tembamide acetate	Alkaloid	Maxwell and
			Rampersad,1989 b

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. quineense (fruits)	Aschantin	Lignan	Haensel, Leuckert and Schulz, 1966
	4,5-Dihydro-2'-methoxypiperine	Alkaloid	Okogun, Sondengam and Kimbu, 1977
	N-Isobutyl-*trans*-2-*trans*-4-eicosadienamide	Alkaloid	Addae-Mensah, Torto, Oppong *et al.*, 1977
	Piperine	Alkaloid	Haensel *et al.*,1966
	(+)-Sesamin	Lignan	Haensel *et al.*,1966
	Yangambin	Lignan	Haensel *et al.*,1966
P. guineense (roots)	$\Delta^{\alpha\beta}$-Dihydropiperine	Alkaloid	Addae-Mensah, Torto, Dimonyeka *et al.*,1977
	4,5-Dihydropiperine	Alkaloid	Okogun *et al.*, 1977
	N-Isobutyl-*trans*-2-*trans*-4-eicosadienamide	Alkaloid	Addae-Mensah, Torto, Dimonyeka *et al.*,1977
	Piperine	Alkaloid	Addae-Mensah, Torto, Dimonyeka *et al.*,1977

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. guineense (roots) (continue)	Wisanidine	Alkaloid	Addae-Mensah, Torto, Dimonyeka *et al.*, 1977
	Wisanine	Alkaloid	Addae-Mensah, Torto, Dimonyeka *et al.*, 1977
P. guineense (root bark)	Piperx	Alkaloid	Addae-Mensah *et al.*, 1981 Woode *et al.*,1984
	Wisanine	Alkaloid	Addae-Mensah *et al.*, 1981 Woode *et al.*,1984
P. guineense (seeds)	$\Delta^{\alpha\beta}$-Dihydrowasanine	Alkaloid	Sondengam and Kimbu, 1977
	$\Delta^{\alpha\beta}$-Dihydrowisani-dine	Alkaloid	Sondengam Kimbu and Connolly, 1977
	Wisanidine	Alkaloid	Sondengam *et al.*, 1977
P. guineense (stems)	2-Methoxypiperine	Alkaloid	Okogun *et al.*, 1977

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. guineense Schum. & Thonn. (fruits)	$\Delta^{\alpha\beta}$-Dihydropiperine	Alkaloid	Dwuma-Badu, Ayim and Dabra, 1976
	$\Delta^{\alpha\beta}$-Dihydropiper-longuminine	Alkaloid	Dwuma-Badu *et al.*, 1976
	Eudesmin	Lignan	Sondengam and Kimbu, 1976
	Guinneensine	Alkaloid	Okogun and Ekong, 1974
	N-Isobutyl-*trans*-2-*trans*-4-eicosa-dienamide	Alkaloid	Okogun and Ekong, 1974
	N-Isobutyl-*trans*-2-*trans*-4-hexadeca dienamide	Alkaloid	Okogun and Ekong, 1974
	N-isobutyloctadeca-*trans*-2-*trans*-4-dienamide	Alkaloid	Dwuma-Badu *et al.*, 1976
	Piperine	Alkaloid	Dwuma-Badu *et al.*, 1976 Okogun and Ekong, 1974

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. guineense Schum. & Thonn (fruits) (continue)	Piperlonguminine	Alkaloid	Okogun and Ekong, 1974
	Sesamin	Lignan	Okogun and Ekong, 1974
	Sylvatine	Alkaloid	Dwuma-Badu *et al.*, 1976
	Trichostachine	Alkaloid	Dwuma-Badu *et al.*, 1976 Okogun and Ekong, 1974
P. guineense Schum. & Thonn. (leaves)	Dihydrocubebin	Lignan	Dwuma-Badu *et al.*, 1976
P. guineense Schum.& Thonn. (roots)	$\Delta^{\alpha\beta}$-Dihydropiperine	Alkaloid	Dwuma-Badu *et al.*, 1976
	Piperine	Alkaloid	Dwuma-Badu *et al.*, 1976
	Tetrahydropiperine	Alkaloid	Dwuma-Badu *et al.*, 1976
	Trichostachine	Alkaloid	Dwuma-Badu *et al.*, 1976

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. hancei Maxim *	Crotepoxide	Benzenoid	Li and Han, 1987
	Hancinone B	Neolignan	Li and Han, 1987
	Hancinone C	Neolignan	Li and Han, 1987
	β-Sitosterol	Steroid	Li and Han, 1987
P. hamiltonii (whole plants)	Aristolactam AII	Alkaloid	Desai *et al.*,1989
	Cepharadione A	Alkaloid	Desai *et al.*,1989
	Cepharadione B	Alkaloid	Desai *et al.*,1989
	Piperadione	Alkaloid	Desai *et al.*,1989
	Piperolactam A	Alkaloid	Desai *et al.*,1989
	Norcepharadione B	Alkaloid	Desai *et al.*,1989
P. hispidinervum (leaves)	Eugenol methyl ether	Phenylpropene	Gottlieb *et al.*, quoted in Likhitwitayawuid, 1988
	Safrole	Phenylpropene	Gottlieb *et al.*, quoted in Likhitwitayawuid, 1988
P. hispidum Sw. (fruits)	1-Allyl-2,3-(methylenedioxy)-4,5-dimethoxybenzene	Phenylpropene	Burke and Nair, 1986
	2,6-Dihydroxy-4-methoxydihydrochalcone	Flavonoid	Burke and Nair, 1986

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. hispidum Sw. (fruits) (continue)	5-Hydroxy-7-methoxyflavanone	Flavonoid	Burke and Nair, 1986
	4-Methoxy-3,5-bis (3'-methyl-2'-butenyl)-benzoic acid	Phenylpropene	Burke and Nair, 1986
P. hispidum Sw. var. *obliquum* Tr. Yunker (branches and leaves)	2,3'-dihydroxy-4' 6'-dimethoxychalcone	Flavonoid	Vieira *et al.*, 1980
	4-(5'E-n-Hexadecenyl) -phenol	Benzenoid	Vieira *et al.*, 1980
	6-Hydroxy-5-7-dimethoxyflavanone	Flavonoid	Vieira *et al.*, 1980
	8-Hydroxy-5,7-dimethoxyflavanone	Flavonoid	Vieira *et al.*, 1980
	2'-Hydroxy-3',4',6'-trimethoxychalcone	Flavonoid	Vieria *et al.*, 1980
	5,7,8-Trimethoxy-flavanone	Flavonoid	Vieira *et al.*, 1980
P. hookeri (stems)	Crotepoxide	Benzenoid	Singh, Dhar and Atal, 1969a

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. hookeri L. (leaves)	1-Phenylethanol benzoate	Benzenoid	Singh and Atal, 1969b
	Pipoxide	Benzenoid	Singh, Dhar and Atal, 1970
	β-Sitosterol	Steroid	Singh and Atal, 1969b
	Triacontane	Hydrocabon	Singh and Atal, 1969b
	Triacontanol	Hydrocabon	Singh and Atal, 1969b
P. hookeri Miq (whole plants)	Sitosterol	Steroid	Desai *et al.*,1975
P. interruptum Opiz. (stems)	Crotepoxide	Benzenoid	Thebpatiphat, Pengprecha and Ternai, 1988
	Eupomatene	Benzenoid	Thebpatiphat *et al.*, 1988
	Pipercallosine	Alkaloid	Thebpatiphat *et al.*, 1988
P. kadsura *	Germacrene D	Sesquiterpene	Yoshihara *et al.*, 1969
P. lenticellosum *	Thymol	Monoterpene	Calle and Ferreira, 1973

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. lenticellosum CDC. (leaves)	γ-Asarone	Phenylpropene	Diaz, Ramos and Matta, 1986
	Elimicin	Phenylpropene	Diaz *et al.*,1986
	Eugenol methyl ether	Phenylpropene	Diaz *et al.*,1986
	trans-2-Methoxy -4,5-methylene dioxycinnamaldehyde	Phenylpropene	Diaz *et al.*,1986
	2-Methoxy-4,5- methylene dioxy benzaldehyde	Benzenoid	Diaz *et al.*,1986
	Sarisan	Phenylpropene	Diaz *et al.*,1986
P. longum (roots)	Aristolactam AII	Alkaloid	Desai, Prabhu and Mulchandani, 1988
	Cepharadione A	Alkaloid	Desai *et al.*,1988
	Cepharadione B	Alkaloid	Desai *et al.*,1988
	Cepharanone B	Alkaloid	Desai *et al.*,1988
	2-Hydroxy-1-methoxy -4,5-dioxoaporphine	Alkaloid	Desai *et al.*,1988
	Norcepharadione B	Alkaloid	Desai *et al.*,1988
	Piperadione	Alkaloid	Desai *et al.*,1988
	Piperolactam A	Alkaloid	Desai *et al.*,1988
	Piperolactam B	Alkaloid	Desai *et al.*,1988

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. longum (roots) (continue)	Piperolactam C	Alkaloid	Desai *et al.*,1988
P. longum (stems)	Piplartine	Alkaloid	Atal and Banga, 1963
P. longum *	N-Isobutyldeca-*trans* -2-*trans*-4-dienamide	Alkaloid	Dhar and Atal,1967
P. longum L. (fruits)	Dihydropiperlongu-minine	Alkaloid	Tabuneng, Bando and Amiya, 1983
	Guineensine	Alkaloid	Tabuneng *et al.*, 1983
	(2E,4E)-N-Isobutyl-eicosa-2,4-dienamide	Alkaloid	Tabuneng *et al.*, 1983
	(2E,4E,8Z)-N-Isobutyl -eicosa-2,4,8-trienamide	Alkaloid	Tabuneng *et al.*, 1983
	(2E,4E)-N-Isobutyl -octadeca-2,4dienamide	Alkaloid	Tabuneng *et al.*, 1983
	Pipercide	Alkaloid	Tabuneng *et al.*, 1983
	Piperlonguminine	Alkaloid	Tabuneng *et al.*, 1983
	Pipernonaline	Alkaloid	Tabuneng *et al.*, 1983

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. longum L. (fruits) (continue)	Piperine	Alkaloid	Tabuneng *et al.*, 1983
	Piperundecalidine	Alkaloid	Tabuneng *et al.*, 1983
P. longum Linn. (roots)	Methyl 3,4,5-trimethoxycinnamate	Cinnamic acid derivative	Dutta, Banerjee and Sil, 1977
	Piperlongine	Alkaloid	Chatterjee and Dutta, 1967
	Piperlongumine	Alkaloid	Chatterjee and Dutta, 1967
	Piperlonguminine	Alkaloid	Chatterjee and Dutta, 1967
	Piperine	Alkaloid	Chatterjee and Dutta, 1967
	Piplartine	Alkaloid	Joshi, Kamat and Saksena, 1968
	Sesamin	Lignan	Dutta *et al.*,1977
	β-Sitosterol	Steroid	Chatterjee and Dutta, 1967
P. longum Linn. (stem bark)	Piplartine	Alkaloid	Joshi *et al.*,1968

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. longum Linn. (seeds)	(+)-Diaeudesmin	Lignan	Dutta, Banerjee and Roy, 1975
	Sesamin	Lignan	Dutta *et al.*,1975
	Sylvatin	Alkaloid	Dutta *et al.*,1975
P. marginatum Jacq. (aerial parts)	3-Farnesyl-4-hydroxybenzoic acid	Benzenoid	Maxwell and Rampersad, 1988
P. marginatum Jacq. (leaves)	Anethole	Phenylpropene	Foungbe *et al.*, 1976
	p-Cymene	Monoterpene	De Diaz and Gottlieb,1979
	Eugenol methyl ether	Phenylpropene	Foungbe *et al.*, 1976
	2-Hydroxy-4,5 methylenedioxy propiophenone	Benzenoid	De Diaz and Gottlieb, 1979
	Marginatoside	Flavonoid	Tillequin *et al.*, 1978
	2-Methoxy-4,5-methylenedioxy propiophenone	Benzenoid	De Diaz and Gottlieb, 1979
	3,4-Methylenedioxypropiophenone	Benzenoid	De Diaz and Gottlieb, 1979

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. marginatum Jacq. (leaves) (continue)	Piperonal	Benzenoid	De Diaz and Gottlieb, 1979
	Safrole	Phenylpropene	De Diaz and Gottlieb, 1979
	Stearic acid	Hydrocarbon	De Diaz and Gottlieb, 1979
	Vitexin	Flavonoid	Tillequin *et al.*, 1978
P. methysticum (leaves)	Desmethoxyyangonin	Lactone	Smith, 1983
	Dihydrokawain	Lactone	Smith, 1983
	Dihydromethysticin	Lactone	Smith, 1983
	Kawain	Lactone	Smith, 1983
	Pipermethystine	Alkaloid	Smith, 1983
	Tetrahydroyangonin	Lactone	Smith, 1983
	Yangonin	Lactone	Smith, 1983
P. methysticum (rhizomes)	Cinnamylideneacetone	Benzenoid	Jossang and Molho, 1967
	5,6-Dehydrokawain	Lactone	Duve, 1981
	7,8-Dihydrokawain	Lactone	Duve, 1981
	7,8-Dihydromethysticin	Lactone	Duve, 1981
	Kawain	Lactone	Duve, 1981

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	References
P. methysticum (rhizomes) (continue)	[3,4-(Methylenedi-oxy) cinnamylidene] acetone	Benzenoid	Jossang and Molho, 1967
	Methysticin	Lactone	Duve, 1981
	5,6,7,8-Tetrahydro-yangonin	Lactone	Duve, 1981
	Yangonin	Lactone	Duve, 1981
P. methysticum (roots)	5,6-Dehydrokawain	Lactone	Duve, 1981
	Desmethoxyyangonin	Lactone	Smith, 1983
	7,8-Dihydrokawain	Lactone	Duve, 1981;Smith, 1983
	7,8-Dihydromethys-ticin	Lactone	Duve, 1981;Smith, 1983
	Kawain	Lactone	Duve, 1981;Smith, 1983
	Methysticin	Lactone	Duve, 1981;Smith, 1983
	5,6,7,8-Tetrahydro-yangonin	Lactone	Duve, 1981;Smith, 1983
	Yangonin	Lactone	Duve, 1981
P. methysticum (stems)	Desmethoxyyangnin	Lactone	Smith, 1983
	Dihydrokawain	Lactone	Smith, 1983
	Dihydromethysticin	Lactone	Smith, 1983

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. methysticum	Kawain	Lactone	Smith, 1983
(stems)	Pipermethystine	Alkaloid	Smith, 1983
(continue)	Tetrahydroyangonin	Lactone	Smith, 1983
	Yangonin	Lactone	Smith, 1983
*P. methysticum**	11,12-Dimethoxydihydrokawain	Lactone	Achenbach, Karl and Regal, 1972
	11-Hydroxy-12-methoxydihydrokawain	Lactone	Achenbach *et al*., 1972
	(+)-5,6,7,8-Tetrahydroyangonin	Lactone	Achenbach, Karl and Smith, 1971
P. methysticum Forst. (leaves)	Pipermethystine	Alkaloid	Smith, 1979
P. methysticum	Flavokawain C	Flavonoid	Dutta *et al*.,1972
Forst. (roots)	Kawain	Lactone	Dutta *et al*.,1972
	Methysticin	Lactone	Dutta *et al*.,1972
	Yangonin	Lactone	Dutta *et al*.,1972
P. methysticum	Desmethoxyyangonin	Lactone	Young *et al*.,1966
Forst*	Dihydrokawain	Lactone	Young *et al*.,1966
	Dihydrokawain-5-ol	Lactone	Achenbach and Wittmann, 1970
	Dihydromethysticin	Lactone	Young *et al*.,1966
	Flavokawain A	Flavonoid	Som *et al*.,1985
	Flavokawain B	Flavonoid	Som *et al*.,1985

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. methysticum Forst.* (continue)	Flavokawain C	Flavonoid	Som *et al.*,1985
	Kawain	Lactone	Som *et al.*,1985 Young *et al.*,1966
	Methysticin	Lactone	Som *et al.*,1985 Young *et al.*,1966
	Yangonin	Lactone	Som *et al.*,1985 Young *et al.*,1966
P. nepalense Miq. (stems)	Caryophyllene oxide	Sesquiterpene	Gupta, Atal and Gaind, 1972a
	N-Isobutyl-deca-*trans*-2-*trans*-4 dienamide (Pellitorine)	Alkaloid	Gupta *et al.*,1972a
	Piperine	Alkaloid	Gupta *et al.*,1972a
	Piperlonguminine	Alkaloid	Gupta *et al.*,1972a
	Sitosterol	Steroid	Gupta *et al.*,1972a
	Triacontanol	Hydrocarbon	Gupta *et al.*,1972a
P. nigrum (fruits)	(2E,4E)-N-Isobutyl -2,4-decadienamide	Alkaloid	Ohigashi, Nishimuro and Koshimizu, 1983
	Piperettine	Alkaloid	Spring and Stark, 1950
	Piperine	Alkaloid	Ohigashi *et al.*, 1983

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
	Piperoleine B	Alkaloid	Ohigashi *et al.*, 1983
	Piperonal	Benzenoid	Ohigashi *et al.*, 1983
P. nigrum *	Caryophyllene oxide	Sesquiterpene	Hasselstrom *et al.*, 1957
	Cryptone	Monoterpene	Hasselstrom *et al.*, 1957
	Dihydrocarveol	Monoterpene	Hasselstrom *et al.*, 1957
	Piperonal	Benzenoid	Hasselstrom *et al.*, 1957
	Sesquisabinene	Sesquitepene	Terhune *et al.*, 1975
P. nigrum L. (fruits)	(E,E,E)-13-(1,3-Benzodioxol-5-yl)-N-(2-methylpropyl)-2,4,12-trideca-trienamide	Alkoloid	Su and Horvat, 1981
	(E,E,E)-11-(1,3-Benzodioxol-5-yl)-N-(2-methylpropyl)-2,4,10-undeca-trienamide	Alkoloid	Su and Horvat, 1981

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. nigrum L. (fruits) (continue)	Dihydroferuperine	Alkaloid	Inatani, Nakatani and Fuwa, 1981
	N-*trans*-Feruloyl tyramine	Alkaloid	Nakatani, Inatani and Fuwa, 1980
	N-*trans*-Feruloyl piperidine	Alkaloid	Inatani *et al.*, 1981
	Feruperine	Alkaloid	Inatani *et al.*, 1981
	Guineensine	Alkaloid	Nakatani and Inatani, 1981
	N-5-(4-Hydroxy-phenyl)-2E,4E-pentadienoyl piperidine	Alkaloid	Nakatani *et al.*, 1980
	N-Isobutyl eicosa-*trans* 2-*trans*-4-dienamide	Alkaloid	Raina, Dhar and Atal, 1976
	N-Isobutyl -2E,4E, 8Z-eicosatrienamide	Alkaloid	Nakatani and Inatani,1981
	N-Isobutyl -2E,4E, -octadecadienamide	Alkaloid	Nakatani and Inatani,1981

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
	(E,E)-N-(2-Methyl-propyl)-2,4,-deca-dienamide	Alkaloid	Su and Horvat, 1981
	Pellitorine	Alkaloid	Nakatani and Inatani, 1981
P. nigrum L. (leaves)	(-)-Cubebin	Lignan	Sumathykutty and Rao, 1988
	(-)-3,4-Dimethoxy-3,4-desmethylene dioxycubebin	Lignan	Sumathykutty and Rao, 1988
	(-)-3',4'-Dimethoxy -3',4'-desmethylene-dioxycubebin	Lignan	Sumathykutty and Rao, 1988
P. nigrum L. *	Camphene	Monoterpene	Ikeda *et al.*,1962
	δ-Cadinene	Sesquiterpene	Alencar, Craveiro and Matos, 1984
	Δ^3-Carene	Monoterpene	Ikeda *et al.*,1962
	Eugenol	Phenylpropene	Alencar *et al.*, 1984
	Eugenol methyl ether	Phenylpropene	Alencar *et al.*, 1984
	α-Humulene	Sesquiterpene	Alencar *et al.*, 1984

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. nigrum L. * (continue)	Isorhamnetin	Flavonoid	Voesgen and Herrmann, 1980
	Kaempferol	Flavonoid	Voesgen and Herrmann, 1980
	d-Limonene	Monoterpene	Ikeda *et al.*,1962
	Myrcene	Monoterpene	Ikeda *et al.*,1962
	Ocimene	Monoterpene	Ikeda *et al.*,1962
	α-Phellandrene	Monoterpene	Ikeda *et al.*,1962
	β-Phellandrene	Monoterpene	Ikeda *et al.*,1962
	α-Pinene	Monoterpene	Ikeda *et al.*,1962
	β-Pinene	Monoterpene	Ikeda *et al.*,1962
	Quercetin	Flavonoid	Voesgen and Herrmann, 1980
	Ramnetin	Flavonoid	Voesgen and Herrmann, 1980
	Sabinene	Monoterpene	Ikeda *et al.*,1962
	α-Terpinene	Monoterpene	Ikeda *et al.*,1962
	γ-Terpinene	Monoterpene	Ikeda *et al.*,1962
	α-Thujene	Monoterpene	Ikeda *et al.*,1962
P. novae-hollandiae (wood)	Δ^{α}-Dehydropiperine	Alkaloid	Loder, Moorhouse and Russell, 1969
	Dillapiole	Phenylpropene	Loder *et al.*,1969
	Fagaramide	Alkaloid	Loder *et al.*,1969

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. novae-hollandiae (wood) (continue)	ω-Hydroxyisodillapiole	Phenylpropene	Falkiner *et al.*, 1972
	N-Isobutyl-*trans*-2-*trans*-4-decadienamide	Alkaloid	Loder *et al.*, 1969
	N-Isobutyl-*trans*-2-*trans*-4-octadienamide	Alkaloid	Loder *et al.*, 1969
	3,4-Methylenedioxycinnamoylpiperidide	Alkaloid	Loder *et al.*,1969
	Piperine	Alkaloid	Loder *et al.*,1969
	Piperlongumine	Alkaloid	Loder *et al.*,1969
P. officinarum Cas. DC (fruits)	N-Isbutyl docosa-*trans*-2-*trans*-4-*cis*-10-trienamide	Alkaloid	Gupta *et al.*,1976
	N-Isobutyl eicosa-*trans*-2-*trans*-4-*cis*-8-trienamide	Alkaloid	Gupta *et al.*,1977
	N-Isobutyl-trideca-13-(3,4 methylenedioxyphenyl)-2,14,12-trienamide	Alkaloid	Gupta, Dhar and Atal, 1976

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. officinarum Cas. DC (fruits) (continue)	Methyl piperate	Benzenoid	Gupta, Atal and Gaind, 1972b
	Piperine	Alkaloid	Boit, quoted in Gupta *et al.*,1972b
P. peepuloides Roxb. (fruits)	N-Isobutyl-dodeca-*trans*-2-*trans*-4-dienamide	Alkaloid	Dhar and Raina, 1973
	5-Hydroxy-4'7-dimethoxyflavone	Flavonoid	Dhar, Atal and Pelter, 1970
	5-Hydroxy-3',4',7-trimethoxyflavone	Flavonoid	Dhar *et al.*,1970
	Pipataline	Benzenoid	Dhar and Raina, 1973
	Piperine	Alkaloid	Dhar and Raina, 1973
	Sesamin	Lignan	Dhar and Raina, 1973
P. peepuloides Roxb. (leaves)	2-Methoxy-4,5-methylenedioxy cinnamoyl piperidine	Alkaloid	Gupta *et al.*,1978
	Peepuloidin	Alkaloid	Atal and Moza, 1968

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. retrofractum Vahl. (aerial parts)	Retrofractamide A	Alkaloid	Banerji *et al.*,1985
	Retrofractamide B (pipericide)	Alkaloid	Banerji *et al.*,1985
	Retrofractamide C	Alkaloid	Banerji *et al.*,1985
	Retrofractamide D	Alkaloid	Banerji *et al.*,1985
	Sesamin	Lignan	Banerji *et al.*,1985
	3,4,5-Trimethoxy-dihydrocinnamic acid	Cinnamic acid derivative	Banerji *et al.*,1985
P. ribesoides Wall.(aerial parts)	(-)-Cubebin	Lignan	Kijjoa *et al.*,1989
	(+)-3,7-Dimethyl-3 hydroxy-4-(p-coumaryloxy)-1,6-octadiene	Monoterpene	Kijjoa *et al.*,1989
	(-)-Hinokinin	Lignan	Kijjoa *et al.*,1989
	N-Isobutyl-2E,4E-deca-2,4-dienamide	Alkaloid	Kijjoa *et al.*,1989
	Methyl 2E,4E,6E-7 -phenyl-2,4,6-heptatrienoate	Benzenoid	Kijjoa *et al.*,1989
	Methyl piperate	Benzenoid	Kijjoa *et al.*,1989
	Palmitic acid	Hydrocarbon	Kijjoa *et al.*,1989
	β-Sitosterol	Steroid	Kijjoa *et al.*,1989

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. ribesoides Wall.(aerial parts) (continue)	Stearic acid	Hydrocarbon	Kijjoa *et al.*,1989
P. saltuum C.DC (aerial parts)	2-Geranylgeranyl-3, 4,-dihydroxybenzoic acid	Benzenoid	Maxwell and Rampersad, 1989 c
	5-Geranylgeranyl-3,4-dihydroxybenzoic acid	Benzenoid	Maxwell and Rampersad, 1989 c
	3-Geranylgeranyl-4-hydroxybenzoic acid	Benzenoid	Maxwell and Rampersad, 1989 c
P. sanctum (roots)	4,5-Dimethoxy-6-(3,4-methylenedioxystyryl)-2-pyrone	Benzenoid	Haensel, Beer and Schulz, 1973
P. sanctum (roots and stems)	7,8-Epoxypiperolide	Lactone	Pelter and Haensel, 1972
	Piperolide	Lactone	Pelter and Haensel, 1972
P. sanctum (Miq)Schlecht	Methylenedioxypiperolide	Lactone	Hansel and Pelter, 1971
(subterranean parts)	Piperolide	Lactone	Hansel and Pelter, 1971

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. sarmentosum Roxb. (fruits)	Asaronaldehyde	Benzenoid	Likhitwitayawuid *et al.*,1988
	α-Asarone	Phenylpropene	Likhitwitayawuid *et al.*,1988
	1-(3,4-Methylene-dioxyphenyl)-1E-tetradecene	Benzenoid	Likhitwitayawuid *et al.*,1987
	Pellitorine	Alkaloid	Likhitwitayawuid *et al.*,1987
	N-(3-Phenylpropanoyl) pyrrole	Alkaloid	Likhitwitayawuid *et al.*,1987
	Sarmentine	Alkaloid	Likhitwitayawuid *et al.*,1987
	Samentosine	Alkaloid	Likhitwitayawuid *et al.*,1987
	β-Sitosterol	Steroid	Likhitwitayawuid *et al.*,1987
P. sarmentosum Roxb. (leaves)	Hydrocinnamic acid	Cinnamic acid derivative	Niamsa and Chantrapromma, 1983
	β-Sitosterol	Steroid	Niamsa and Chantrapromma, 1983

Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. sylvaticum Roxb. (roots)	Piperine	Alkaloid	Banerji and Dhara, 1974
	Piperlongumine	Alkaloid	Banerji and Dhara, 1974
	Sesamin	Lignan	Banerji and Dhara, 1974
P. sylvaticum Roxb. (seeds)	(+)-Diaeudesmin	Lignan	Benerji and Das, 1977b
	3',5-Dihydroxy-4',7-dimethoxyflavone	Flavonoid	Banerji and Pal., 1982a
	5-Hydroxy-7-methoxy flavone	Flavonoid	Banerji and Das, 1977b
	5-Hydroxy-3',4',7-trimethoxyflavone	Flavonoid	Bznerji and Das, 1977b
	Pipataline	Benzenoid	Banerij and Das, 1977 b
	Sylvamide	Alkaloid	Banerji and Pal, 1982 b
	Sylvatesmin	Lignan	Banerji and Pal, 1982 a
	Sylvone	Lignan	Banerji *et al.*, 1984

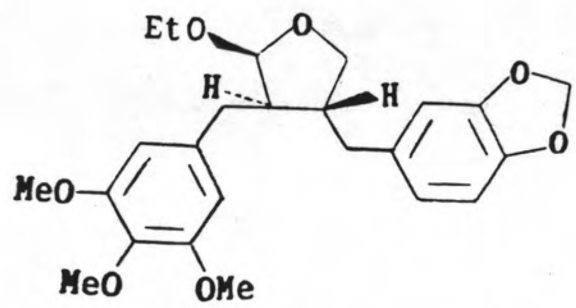
Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. trichostachyon (leaves)	Trichonine	Alkaloid	Singh, Dhar and Atal, 1971
	Trichostachine	Alkaloid	Singh, Dhar and Atal, 1969b
P. trichostachyon (stems)	Tricholein	Alkaloid	Singh, Santani and Dhar, 1976
*P. trichostachyon**	Cyclopiperstachine	Alkaloid	Joshi, Viswanathan, Gawad, Balakrishnan and Von Philipsborn, 1975
	Cyclostachine A	Alkaloid	Joshi, Viswanathan, Gawad, Balakrishnan and Von Philipsborn, 1975
	Cyclostachine B	Alkaloid	Joshi, Viswanathan, Gawad, Balakrishnan and Von Philipsborn, 1975
P. trichostachyon C.DC (stems)	Piperstachine	Alkaloid	Joshi, Viswanathan, Gawad, and Von Philipsborn, 1975

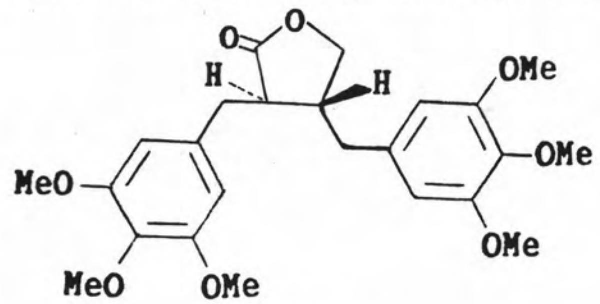
Table 7 (Continue)

Botanical Origin	Chemical Substance	Category	Reference
P. trichostachyon DC (fruits)	(-)-Cubebin	Lignan	Koul *et al.*,1988
	(-)-Dihydrocubebin	Lignan	Koul *et al.*,1988
	(-)-Hinokinin	Lignan	Koul *et al.*,1988
	(157) (Fig.21)	Lignan	Koul *et al.*,1988
	(158) (Fig.21)	Lignan	Koul *et al.*,1988
	(159) (Fig.21)	Lignan	Koul *et al.*,1988
P. tuberculatum (leaves)	3,4-Methylenedioxycinnamic acid	Cinnamic acid derivative	Simmonds and Stevens, 1956
P. tuberculatum Facq. (root bark)	Piplartine	Alkaloid	Braz Filho, De Souza and Mattos, 1981
	Piplartine-dimer A	Alkaloid	Braz Filho *et al.*, 1981
	3,4,5-Trimethoxycinnamic acid	Cinnamic acid derivative	Braz Filho *et al.*, 1981
P. wallichii *	Flavone II	Flavonoid	Li and Huang, 1985

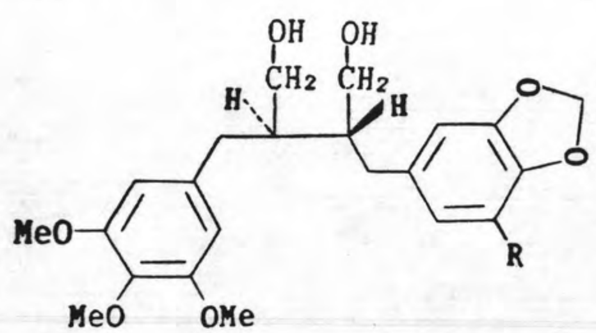
* : Unclassified Part



2S,3R,4R,2-Ethoxy-3-(3,4,5-trimethoxyphenyl) methyl 4-(1,3 benzodioxol-5-yl) methyl tetrahydrofuranol (153)



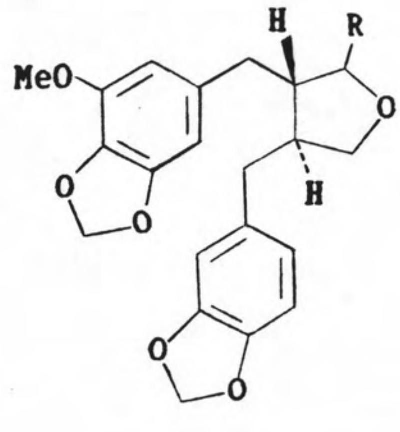
3R,4R-*bis*-3,4-(3,4,5-trimethoxyphenyl) methyl tetrahydrofuran-2-one (154)



2R,3R,2-(7-methoxy 1,3-benzodioxol-5-yl) methyl 3-(3,4,5-trimethoxy phenyl) methyl butan-1,4-diol (155) R = OMe

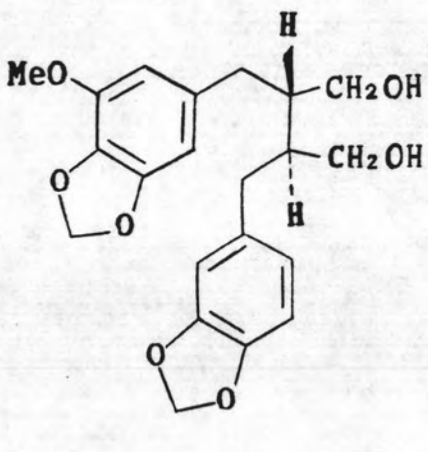
2R,3R,2-(1,3-benzodioxol-5-yl) methyl 3-(3,4,5 trimethoxyphenyl) methyl butan-1,4-diol (156) R = H

Fig.20 Some lignans of *Piper clusii* Cass DC*



2S,3S,3-(6-methoxy 1,3-benzodioxol 5-yl) methyl 4-(1,3-benzodioxol 5-yl) methyl tetrahydrofuran -2-one (157) R = =O

3S,4S,3-(6-methoxy 1,3-benzodioxol 5-yl) methyl 4-(1,3-benzodioxol 5-yl) methyl tetrahydrofuran-2-ol (158) R = OH



2S,3S,2-(6-methoxy 1,3-benzodioxol 5-yl) methyl 3-(1,3-benzodioxol 5-yl) methyl butan 1,4-diol (159)

Fig.21 Some lignans of *Piper trichostachyon* DC (fruits)