Proximate Composition, Carbohydrates and Proteins

Yoshihara and Kajiki (1951) reported that seeds (kernels) of *Rhus succedanea* contain, after extraction of Japan wax, moisture 11.10, crude protein 3.33, crude fiber 30.48, crude fat 0.5, N-free extract 53.36 and ash 1.20%. The seed coats which contributed 50 % of the weight of the whole seeds of sumac (*Rhus hirta*) contain ~ 55% fat, 26 % crude fiber, 3.6% ash and 1.5% protein (Al-Shabibi *et al*., 1982).

D-Glucose and L-rhamnose were identified in the wood of *Rhus trichocarpa* (Yasue and Kato, 1957). The composition of the hemicelluloses (5.3%) from the kernel of *Rhus succedanea* was 18.67 moisture, 3.62 ash, 67.18 crude hemicelluloses, pentosan (corrected for uronic acid) 60.58, methyl pentosan 1.02, uronic acid anhydride 5.48, lignin 8.02 and N (calculated as NH_3) 0.49% (Nikaya and Iwata, 1952). To elucidate the role of the cell wall interaction with gall-inducing organisms, symplastic and apoplastic sugar contents in the different shapes of gall tissue of the sumac (*Rhus chinensis* Mill.) were compared with those of the callus (Yeo *et al*., 1998). The gall tissues with vascular cylinders, intercellular spaces and callus were fractionated into symplastic [methanol, hot water, and starch] fractions and apoplastic [pectin, hemicelluloses, triflouoroacetic acid (TFA)-soluble and cellulose] fractions. Symplastic sugar content of gall tissues was higher than that of callus. In apoplastic (cell wall) fractions, the cellulose content of gall tissues was lower than that of callus, due to large amount of pectin with high ratio of uronic acid (UA) and hemicelluloses with low ratio of UA. Analysis of neutral sugar component of the hemicellulosic, TFA-soluble fraction showed that arabinose (side chain) and galactose (backbone) of arabinogalactan were rich in a gall tissues and callus. The gall tissues had higher glucose and lower xylose contents than the callus (Yeo *et al.*, 1998).

Stellacyanin, a copper protein was purified from *Rhus vernicifera*; its oxidation and reduction activities have been studied (Peisach *et al*., 1967; Nakamura and Ogura, 1968; Morpurgo and Pecht, 1982). The *Rhus vernicifera* blue protein (stellacyanin) is 20% carbohydrate and 20% hexosamine, with the remainder being a polypeptide matrix of 108

amino acid residues, in which is embedded a single cupric atom. The molecule contains no methionine or valine (Peisach *et al*., 1967). Echinulin, a cyclic dipeptide carrying a triprenylated indole moiety was isolated from *Rhus parviflora* fruits (Talaptra *et al*., 2001).

The study of sustaining values of foods that might be useful to bobwhites (*Colinus virginianus*) revealed that smooth sumac (*Rhus glabra*) ranked lowest (Newlon, 1964).

Two poisonous species (*Rhus vernix* and *Rhus radicans*) and 3 nonpoisonous (*Rhus capallina, Rhus glabra* and *Rhus typhina*) were analysed for N, P, K, Ca, Mg, Na, Zn, Cu and Pb to determine if higher concentrations were associated with toxic species. N and P were significantly higher in the fruits of poisonous species. The toxic secondary compound urushiol does not contain N or P and is not the reservoir for the higher concentrations of these elements in the poisonous species. Other elemental differences between the poisonous and nonpoisonous species, however, were not consistent, suggesting that the evolution of poisonous species may be associated with predictably high nutrient concentrations in the tissues (Weathers and Siccama, 1986).

Young stems and leaves of *Rhus* species found in Japan exude about the same amount of latex. Old stems of *Rhus semialata* var. *osbeckii* and *Rhus vernicifera* are the most productive. All the exudates contain more or less rubber, albumin, urushiol and oxidase (Harada, 1940). *Rhus glabra* contains 0.38% (stems), 0.60% (leaves) and 0.61% (roots) rubber (Mitchell *et al*., 1942).

Lipids

The oil from sumac (*Rhus glabra*) compares favourably in properties with cotton seed and corn oil (Baubaker, 1919). The physicochemical properties and fatty acid composition of the Galla Chinese oil and the *Rhus chinensis* oil have been studied. The results showed that the level of oil in *Rhus chinensis* contains 13.78% the level of, unsaturated fatty acids is up to 72.13%, where the content of oleic acid is 12.12%, the level of linoleic acid is 57.92% the level of, and the linolenic acid is 2.09%. Saturated fatty acids is mainly in the Galla Chinese oil, where the content of lauric acid is 44.41%, myristic acid 31.78%, palmitic acid 11.75%. Accordingly, *Rhus chinensis,* whose prospects for the development is lofty, is a kind of new oil sources in the oil tree (Hu *et al*., 2008).

The saturated fatty acids of neutral lipids of the seed coats of sumac (*Rhus hirta*) from Mosul, Arbil and Khoran localities in north of Iraq were 36.31, 29.5, and 27.0% respectively. The major fatty acids were $C_{16:0}$ and $C_{18:2}$. The polar lipid fraction showed more polyunsaturated fatty acids ($C_{18:2}$ and $C_{18:3}$) than the neutral lipids. Arbil and Khoran samples showed 5.9 and 6.4% of $C_{20:4}$ (Al-Shabibi *et al*., 1982). The fatty oil from the seeds of *Rhus succedanea* has been reported to consist of 25.4% palmitic, 46.8% oleic, and 27.8% linoleic acids (Chen, 1950b). However, Bedi and Atal (1971) stated that the linoleic acid content of the seed oil is 52%. The solid fat, extracted from the mesocarp of *Rhus succedanea* var. *dumoutiere* Kudo and Matuura consisted of palmitic (82%), oleic acid (8%), stearic acid (4%), lignoceric acid (2%), heneicoanedicarbonic acid (2%) and small amounts of tetradecenic and hexadecenic acids (Hata and Kuniaski, 1940). The oil from fruits of *Rhus trichocarpa* contains oleic acid, linoleic acid and a saturated acid (Taki and Toyama, 1937). The following fatty acids were identified from the fruits of staghorn sumac (*Rhus typhina*): palmitic, stearic, arachidic, behenic, oleic, elaidic, linoleic, linolenic acids and (3) OH fatty acids tetracosanolic ($C_{24}H_{48}O_3$), docasanolic ($C_{22}H_{44}O_3$), eicosanolic ($C_{20}H_{40}O_3$) and octadecanolic ($C_{18}H_{36}O_3$) acids (Tischer, 1960).

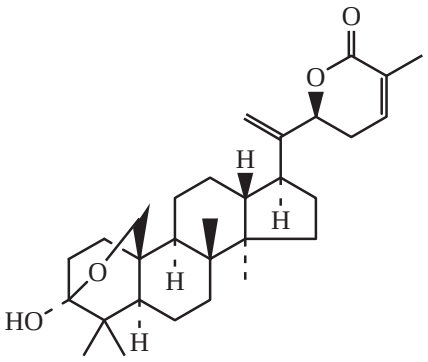
Palmitic, stearic, oleic, linoleic and arachidic acid comprise more than 95% of the total fatty acids of haze wax from *Rhus succedanea* (Xu and Kawashi, 1988). The wax (12%), from seeds of *Rhus trichocarpa* contains palmitic acid and trichocarpinic acid

(monohydroxystearic acid) (Tsukamoto, 1942). The major fatty acid components of haze wax from urushi (*Rhus verniciflua*) were characterized by lower palmitic and higher oleic and linoleic acids (Xu and Kawashi, 1988).

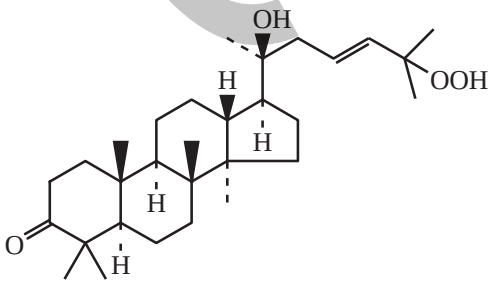
Triterpenes and Sterols

Parveen *et al*. (1989) reported that the triterpenoid semimoronic acid, identified from the leaves of *Rhus alata* Thumb., and others might be useful as a chemotaxonomic marker to establish interspecific relationships in the genus *Rhus*. The following are examples of triterpenes and sterols, isolated from some *Rhus* species:

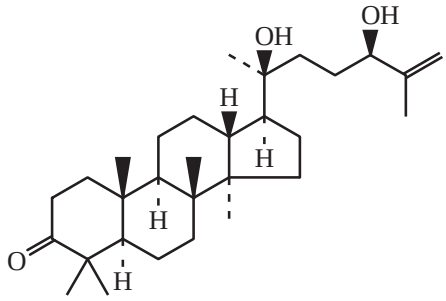
1. *Rhus alata* Thumb.: The leaves contain benulin, semimoronic acid, α-amyrin, fridelin, lupeol, oleanolic acid, taraxerone and β-sitosterol (Parveen *et al*., 1989; Parveena *et al*., 2008).
2. *Rhus chinensis*: Betulin, betulonic acid, moronic acid, 3-oxo-6β-hydroxyolean-12-en-28-oic acid and 3-oxo-6β-hydroxyolean-18-en-28-oic acid, hydroxyl-dammarenone and semialactone were isolated from the stems (Gu *et al*., 2007; Kim *et al*., 2010a).
3. *Rhus javanica*: The plant contains several dammarane-type triterpenes *viz.* rhuslactone, semialactone (**91**), isofouquierone peroxide (**92**), fouquierone (**93**) and semialactic acid (Sung *et al*., 1980; Lee *et al*, 2001c), moronic acid and betulonic acid (Kurokawa *et al*, 1999). β-Sitosterol was identified from the plant (Imamura *et al*., 1967).
4. *Rhus javanica* var. *roxburghiana*: Lantabetulal, lantanolal, lantanolol, lantabetulic acid and lantanolic acid were identified from the roots (Chiu *et al*., 2008).
5. *Rhus semialata*: Semimoronic acid (**94**), lantabetulic acid (Bagchi *et al*., 1985b) and semialatic acid (**95**) (Parveen *et al*., 1991).
6. *Rhus taishanensis*: Moronic acid (Ma *et al*., 1996).
7. *Rhus taitensis*: The leaves contain 3β,20,25-trihydroxylupane, 3,20-dihydroxy-lupane, 20-hydroxylupane-3-one, 20,28-dihydroxylupane-3-one, 3,16-dihydroxy-lup-20(29)-ene and 28-hydroxy-β-amyrone (Yuruker *et al*., 1998). Tetrahydroxy-squalene (**96**), an antimycobacterial compound, was also isoloated from the plant (Noro *et al*., 2008).
8. *Rhus trichocarpa*: β-Sitosterol β-D-glucoside (Yasue and Kato, 1957).
9. *Rhus typhina*: Daucosterol (Tischer, 1960) and 3α,20-dihydroxy-3β,25-epoxy-lupane (Schmidt *et al*., 1998) were isolated from the fruits and flowers respectively.
10. *Rhus wallichi*: β-Sitosterol and β-sitosterol glucoside were isolated from the leaves (Sinha *et al*., 1986).



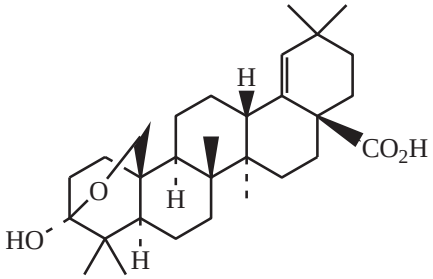
91 Semialactone



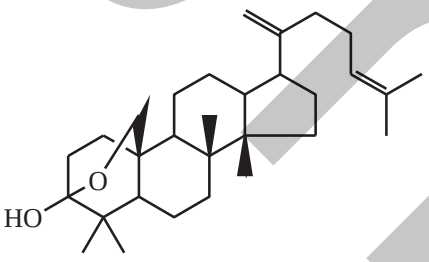
92 Isofouquierone peroxide



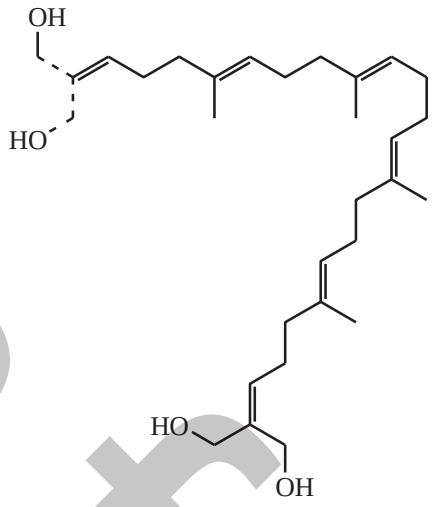
93 Fouquierone



94 Semimoronic acid



95 Semialatic acid



96 Tetrahydroxysqualene

Volatile Constituents

Both the essential oils, obtained from the leaves (L) and flowers (F) of *Rhus mysurensis* Heyne ex Wight & Arn, were found to contain almost the same compounds. The major components of the oils were identified as α-pinene (F, 15.5%, L, 26.8%), limonene (L, 26.2%, F, 51.3%), sabinene (L, 3.8%, F, 4.1%), β-caryophyllene (L, 6.6%, F, 9.4%) and α- and β-eudesmol (L, 7.8%, F, 4.4%) (Srivastava *et al*., 2006). A total of 130 aroma compounds were identified in the aqueous solution of haze (*Rhus succedanea*) honey, including 27 alcohols, 19 aldehydes, 9 ketones, 12 esters, 8 acids, 35 hydrocarbons, 10 furanoids or pyranoids, and 10 miscellaneous compounds. Benzeneacetaldehyde, linalool, phenethyl alcohol, *p*-cresol, *p*-anisaldehyde, methyl-*p*-anisaldehyde, trimethoxybenzene, 5-hydroxy-2-methyl-4*H*-pyran-4-one, and lilac aldehydes seemed to contribute to haze honey aroma (Shimoda *et al*., 1996). More than 70 constituents (including terpenoids, hydrocarbons, aldehydes, fatty acids and *m*-substituted long-chain alkylphenols) were identified in the volatile constituents from leaves of staghorn sumac (*Rhus typhina*) (Bostmann *et al*., 1988). The main volatile constituents of leaves of *Rhus typhina* are 4,6-di(*tert*-butyl)-2-methylphenol, 4-heptanol, 3,7,11-trimethyl-2,6,10-dodecatrien-1-ol, butylated hydroxyl toluene, α-farnesene, 1-octadecene, 4-methyl-1-penten-3-ol, methyl salicylate and ethyl benzoate (Li *et al*., 2009).

Long-Chain Phenols

Long-chain phenols have been identified from several *Rhus* species; examples of these are as follows:

1. *Rhus punjabensis*: 3-(Heptadecyl)-catechol semimoronic acid (Parveen *et al.*, 1994).
2. *Rhus semialata*: 2-Hydroxy-6-pentadecylbenzoic acid and 3-(heptadecyl)-catechol (Bagchi *et al*., 1985a; Parveen *et al*., 1994; Ramakrishna *et al*., 2001).
3. *Rhus semialata* var. *roxburghii*: 6-Pentadecylsalicylic acid (Kuo *et al*., 1991).
4. *Rhus striata*: The toxic principle of the plant has been shown to be a mixture of 3-pentadecylcatechol, 1,2-dihydroxy-3-(pentadecenyl-8')-benzene, 1,2-dihydroxy-3-(pentadecadienyl-8',11')-benzene and 1,2-dihydroxy-3-(penta-decatrienyl-8',11',14')-benzene (Nakano *et al*., 1970).
5. *Rhus succedanea*: Three compounds, 10'(*Z*),13'(*E*), 15'(*E*)-heptadecatrienyl-hydroquinone and 10'(*E*),13'(*E*)-heptadecadienylhydroquinone and 10'(*Z*)hepta-decenylhydroquionone were isolated from the sap (Wu *et al*., 2002).
6. *Rhus taishanensis*: The roots contain rhusone (1-(2,3-dihydroxyphenyl)-2-heptyl-1-nonen-3-one) (Ma *et al*., 1996).
7. *Rhus thyrsiflora*: Several cardanols were identified from the plant (Franke *et al*., 2001).
8. *Rhus vernicifera* DC.: Fresh exudates from the lacquer tree contain monomer, dimer, trimer and oligomer fractions of urushiols (13 compounds have been identified) (Harigawa *et al*., 2007).

Tannins

Extracts of sumac (*Rhus hirta*) have been reported to contain tanning agents 23.1%, which produced soft and lightly coloured leathers (Nèmec, 1936). Gedâri (*Rhus oxycantha* Cav.), a common small tree of Cyrenaica (Libya) has been reported to contain tannin in the bark (11.6%), wood (average 11.2%) and root bark (17.2%). The tannin content of the wood is very variable from the white sapwood (5.1%) to the red coloured heart (20.6%). In the tannin of gedâri, protocatechuic acid, phloroglucinol and resorcinol were identified (Bravo, 1940). The trunk bark of *Rhus semialata* contains 10.45% tannins (Ch'in and Wang, 1947), while the leaves of *Rhus typhina* contain 20.74% (Osmolo, 1957). The tannins of several *Rhus* species have been studied as natural tanning materials. Of the 14 species of sumac examined by Russel (1943a), the dwarf sumac (*Rhus copallina* L.) was the most promising as a substitute for Sicilian variety. The tannin content of the cured ground leaf was above 30%. Tests showed that it could be satisfactory in retanning Cr skivers and in full tannage of pickled goat skins and pickled sheep skivers. On the other hand, the tannin content of the leaves and stems (21%) is reported too low (Russel, 1943b). The soluble tannin of Rumanian sumac (*Rhus cotinus*) in May, July, August, September and October was reported as follows: 4.6, 5.8, 6.4, 7.1 and 17.2% respectively (Alexa and Strub, 1948). The average tannin content of wild *Rhus cotinus* leaves in dry years is 18-20%. Blooms contain 3-16, branch wood 0.1-0.4, branch bark 3.7-5.7, root wood 0.5-1.0 and root bark 6-8% tannin (Vágó, 1957). Ferro (1952) reported that the wood of *Rhus cotinus* gives tannin 44.3%, *Rhus cotinus* (occurring wild) contains 16-21% tannic acid (Hollub, 1937). Several studies have been carried out on the production of tannins from *Rhus cotinus* and its use in tanning of sheep and goat skins and of dyeing rayon and cotton fabrics with basic colours (e.g. Ferro, 1952; Strub *et al*., 1956; Murko, 1965). Corilagin (1-galloyl-3,6-hexahydroxydiphenylglucose) was isolated from the fresh leaves of *Rhus*. It is not an artifact but is present in living plants (Hattori and Matsuda, 1961). Corilagin and other tannins have been isolated from several *Rhus* species;

examples of these are as follows:

1. *Rhus alata*: Ethyl gallate from leaves (Perveena *et al*., 2008).
2. *Rhus ambigua*: Corilagin from leaves (Matsuda, 1966).
3. *Rhus aromatica*: Gallotannin, gallic acid, and gallic acid methyl ester from leaves (Buziashvih *et al*., 1973a).
4. *Rhus chinensis*: Tannic acid (Fu *et al*., 1992).
5. *Rhus cotinus*: Gallic acid, pyrogallol, catechol, 3,6-digalloylglucose and pentagalloyl-glucose (Ferro, 1952; Krajčinović *et al*., 1955, Vágó, 1957, Murko, 1965; Biffl, 1974).
6. *Rhus glabra*: Catechin, epicatechin, gallocatechin, epigallocatechin and gallotannin 3,6-bis-*O*-digalloyl-1,2,4-tri-*O*-galloyl-β-D-glucoside (Islambekov *et al*., 1988, 1994; Mavlyanov *et al*., 1995).
7. *Rhus javanica* L.: Gallic acid, gallic acid methyl ester and 1,2,3,4,6-penta-*O*-galloyl-β-D-glucose (Chung *et* al., 1999; Cha *et al*., 2000).
8. *Rhus javanica* var. *roxburghiana*: Gallic acid and 4-methoxygallic acid (Ouyang *et al*., 2007a).
9. *Rhus semialata:* Buziashvili *et al*. (1973b) reported that in the tannins obtained from the leaves, among 7 residues, one is trigalloyl, 1 digalloyl and 3 are monogalloyl. Chienese gallatannin derived from twig galls is a mixture consisting mainly of penta- to undecagalloylglucoses with depside galloyl groups randomly distributed at C-2, C-3 and C-4 on the core of 1,2,3,4,6-penta-*O*-galloyl-β-D-glucose (Nishizawa *et al*., 1982). Ethyl gallate was also identified from the leaves (Parveen and Khan, 1988).
10. *Rhus succedanea*: The mesocarp of the drupes contains ellagic acid (Chen, 1950a). Corilagin (Matsuda, 1966) and gallic acid (Kondo and Imamura, 1985) were identified from the leaves and wood respectively.
11. *Rhus sylvestris*: Corilagin was isolated from the leaves (Matsuda, 1966).
12. *Rhus trichocarpa*: Corilagin (Matsuda, 1966) and gallic acid (Yasue and Kato, 1957) were isolated from the leaves and wood respectively, and 1,2,3,4,6-Penta-*O*- galloyl-β-D-glucose from the stem and leaf (Cho *et al*., 2010).
13. *Rhus typhina*: Gallic acid, tannic acid, *m*-digallic acid, epicatechin, catechin and gallocatechin (Grassmann *et al*., 1957; Tischer, 1960; Islambekov *et al.*, 1988).

Flavonoids, Lignans, Coumarins and Other Phenolics

Flavonoids (including biflavonoids, triflavonoids, aurones, and bichalcones) were isolated from several *Rhus* species. Five biflavonoids and 4 triflavonoids, isolated from the heartwood of *Rhus lancea*, *Rhus leptodictya* and *Schinopsis balansae*, were shown to be condensation products of (2*R*,3*R*,4*S*)-(-)-leucofisetenidin, (2*R*,3*S*)-(+) catechin, and, to a lesser extent, (2*R*,3*R*)-(-)-epicatechin. The unique enantiomeric relationship between the electrophiles and 2 nucleophiles at C-2 is reflected in the biflavonoid metabolites comprising 4 [4,6]- and [4,8]-(+)-fisetinidol-(+)-catechins and [4,8]-(+)fisetinidol-(-)-epicatechin and in the extension of the former group to 4 angular triflavonoid [4,6:4,8]-bi-(+)-fisetinidol-(+)-catechin diastereoisomers (Viviers *et al*., 1983). Examples of flavonoids isolated from some *Rhus* species are shown in Table 33.

Tanchev and Timberlake (1969) reported that the leaves of *Rhus cotinus* (*Cotinus coggygeria*) are pigmented with delphinidin 3-galactoside, cyanidin 3-galactoside, petunidin 3-glucoside and tentatively, delphinidin 7-glucoside and cyanidin 3-glucoside-7-rhamnoside.

Table 33. Flavonoids of some *Rhus* species

Species	Plant part	Flavonoids	References
1. *Rhus alata*	L	Amentoflavone, hinokiflavone, agathisflavone and robustaflavone	Parveen and Khan (1987)
2. *Rhus ambigua*	L	Rhoifolin and myricitrin	Matsuda (1966)
3. *Rhus aromatic*	L	Myricetin 3α-L-rhamnofuranoside, quercetin 3β-glucopyranoside, kaempferol 3β-D-glucopyranoside, myrcietin, quercetin, and kaempferol	Buziashvili *et al*. (1973a)
4. *Rhus chinensis*	L	Myricitrin, myricetin and quercitrin	Matsuda (1966)
	Hw	Pongapin, tetramethoxyfisetin, and dimethoxykanugin	Ahmad *et al.* (1980)
	R,S	3,4′,7-Trihydroxyflavone, 3,3′,4′,7-tetrahydroxyflavone and quercetin	Chen (1981); Zheng and Ji (1982)
5. *Rhus copallina*	L	Myricetin	Sando and Bartlet (1918)
6. *Rhus cotinus* (young fustic)	W	Fisetin	Sando and Bartlet (1918); Korur (1939)
7. *Rhus glabra*	S	6,3′,4- Trihydroxyaurone	Islambekov *et al*. (1994)
8. *Rhus insignis*	L	3,7,3′,4′- and 5,7,3′,4′-tetrahydroxyflavanones, 3,5,7,3′,4′-pentahydroxyflavanone and 5,7,4′- trihydroxyflavanone	Ansari *et al*. (1985)
9. *Rhus javanica*	Hw	Taxifolin (distylin), butein (3,4,2',4'-tetrahydrochalcone), fisetin, fusetin, quercetin, and 3,7,4′-trihydroxyflavone	Imamura *et al*. (1967)
	R	Rhusjavanins, A and B, 2,3-*trans*-3,4-*trans*, 3,4,7,4′-tetrhyroxy-flavan and 2,3-*trans*- 3,4-*cis*, 3,4,7,4′ tetrahydroxyflavan	Wu *et al.* (2010)
10. *Rhus javanicus*	L	Quercitrin	Aritomi *et al*. (1964)
11. *Rhus lancea*	L	Kaempferol, quercetin, myricetin, 3,5,3′,5′-tetrahydroxy-7,4′-dimethoxyflavone (7,4′-di-*O*- methyl myricetin) and its 3-*O*-galactoside	Nair *et al.* (1983)

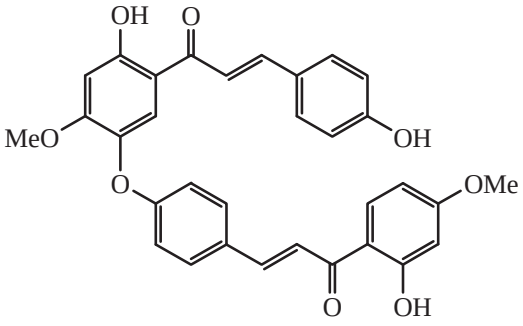
Table 33. Flavonoids of some *Rhus* species (cont.)

Species	Plant part	Flavonoids	References
12. *Rhus mysorensis*	L	Kaempferol, myricetin and quercetin and their 3-*O*- rhamnosides, and hinokiflavone	Sarada and Adinarayana (1984)
13. *Rhus mysurensis*	L	Amentoflavone, cupressuflavone, hinokiflavone, kaempferol, kaempferol 3-*O*-glucoside, quercetin, quercetin 3-*O*-glucoside and quercetin 3-*O*-rhamnoside	Arya *et al*. (1989b)
14. *Rhus parviflora*	L	Myricetin, myricitrin, quercetin, quercitrin, kaempferol and afzelin	Nair *et al*. (1977)
	L,S	Isorhamnetin-3-α-L-arabinoside	Bhakuni *et al*. (1971)
15. *Rhus punjabensis*	L	Agathisflavone, amentoflavone (**32**), hinokiflavone and robustaflavone	Kamil *et al*. (1984)
16. *Rhus pyroides*	T	Rhuschalcone I (bichalcone) (**97**)	Masesane *et al*. (2000)
	Rb	Rhuschalcone I-VI (bichalcones)	Mdee *et al*. (2003)
17. *Rhus retinorrhoea*		Homoeriodictyol, persicogenin, velutin and (2*S*) - 5, 3′, 4′-trihydroxy-7-methoxyflavanone	Mossa *et al*. (1996)
	L	(2*S*,2″*S*)-7,7″-di-*O*-methyltetrahydroamentoflavone (**98**), 7, *O*-methylnaringenin, 7,3′-*O*-dimethylquercetin, 7-*O*-methylapigenin, 7-*O*-methylluteolin and eriodictyol	Ahmed *et al*. (2001)
18. *Rhus rhodanthema*	W	Fisetin	Sando and Bartlet (1918)
19. *Rhus salicifolia*	L	Myricetin, quercetin, kaempferol, myricetin methyl ethers (syringetin, and europetin) and the quercetin methyl ethers (ombuin and rhamnetin)	Wollenweber (1974)
20. *Rhus semialata*	L	(±)- Agathiflavone and other biflavones	Bagchi *et al*. (1985a); Parveen and Khan (1988)
21. *Rhus succedanea* (wax-tree)	L	Rhoifolin (Apigenin 7-rutinoside)	Hattori and Matsuda (1951)
	D	Rhusnetin , rhusnin, amentoflavone, hinokiflavone (**99**), rhusflavone (**100**), rhusflavanone (**101**) and agathisflavone (**102**)	Chen *et al*. (1974a,b); Lin and Chen (1973, 1974a)
	Sk	Robustaflavone (**103**) and succedaneaflavone (**104**)	Lin and Chen (1974b); Chen and Lin (1975)

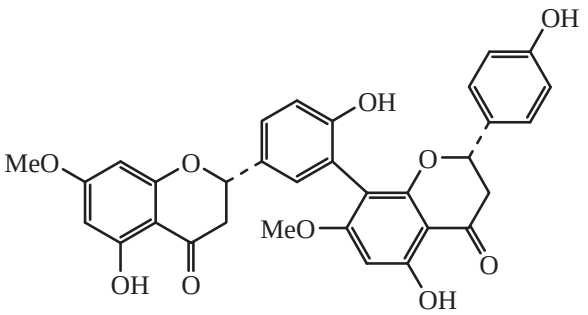
Table 33. Flavonoids of some *Rhus* species (cont.)

Species	Plant part	Flavonoids	References
		Neorhusflavanone, mesuaferrone A (**105**) and B (**106**) and cupressuflavone	Chen (1973); Chen *et al.* (1978)
	Hw	Fisetin, fusetin and butein	Kondo and Imamura (1985)
22. *Rhus trichocarpa*		Fusetin, rhoifolin	Yasue and Kato (1957)
	L	Rhoifolin	Matsuda (1966)
23. *Rhus trilobata*		Myricitroside	Plouvier (1970)
24. *Rhys typhina*	S	6,3′,4′-Trihydroxyaurone	Islambekov *et al.* (1994)
	W	Fisetin	Sando and Bartlet (1918)
		Myricitroside	Plouvier (1970)
	L	Rhoifolin and myricitrin	Buziashvili *et al.* (1973a)
25. *Rhus undulata*	R	5-Hydroxy-4′,7-dimethoxyflavone	Fourie and Snyckers (1984)
26. *Rhus vernicifera*	L	Luteoloside (Cynaroside)	Plouvier (1970)
	Hw	Fisetin, garbazanol and sulfuretin	Hasegawa and Shirato (1951)
27. *Rhus verniflua*		Fisetin, fusetin and 3′,4,7-trihydroxyflavone	Park *et al.* (2000); Kim *et al.* (2010d)
28. *Rhus wallichi*	L	Kaemperol, quercetin, amentoflavone, quercitrin, quercetin 3-*O*-glucoside, quercetin 3-*O*-arabinoside, quercetin 3-*O*-galactoside, quercetin 3-*O*-xyloside and myricetin	Khatoon *et al.* (1985); Sinha *et al.* (1986)

D: drupes; Hw: heartwood; L: leaves; R: roots; Rb: root bark; S: stems; Sk: seed kernel; W: wood



97 Rhuschalcone-1



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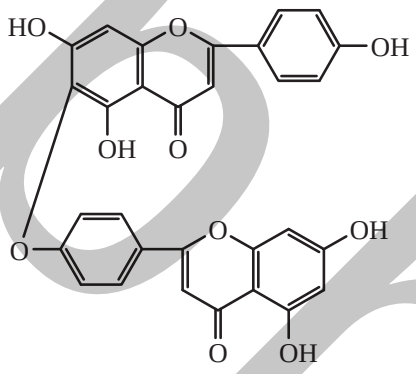
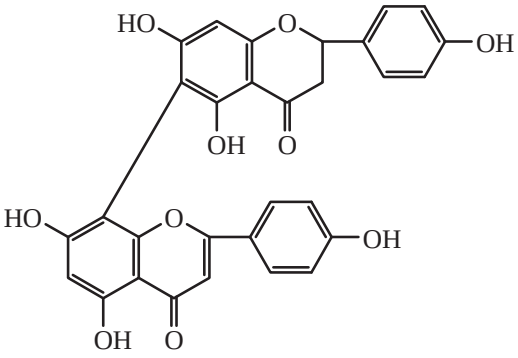
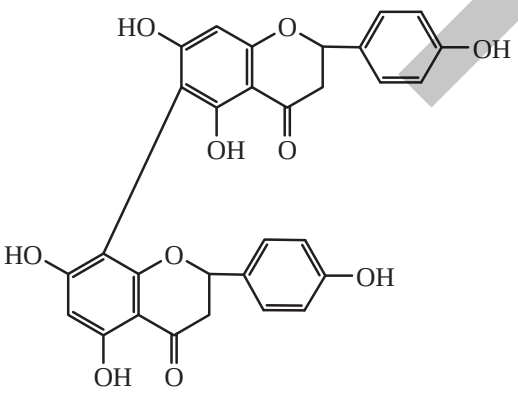


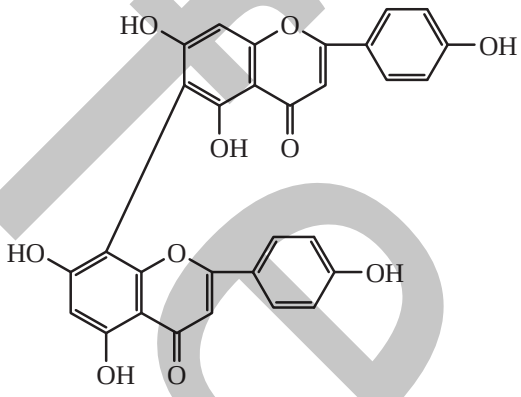
99 Hinokiflavone



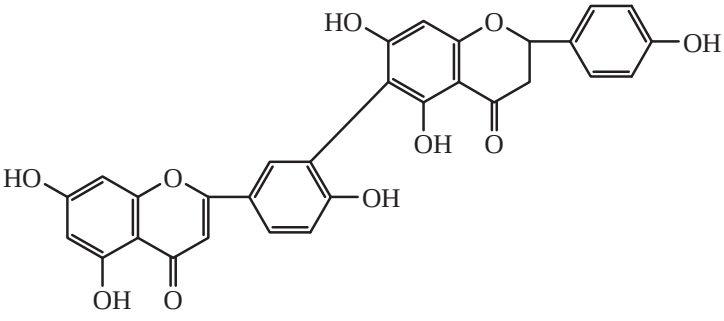
100 Rhusflavone



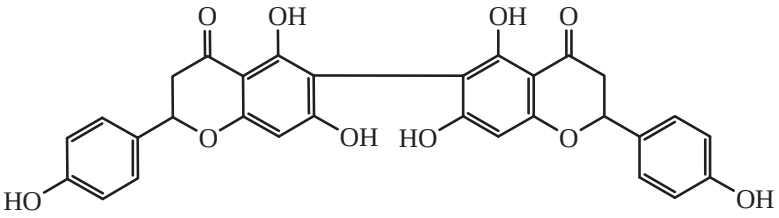
101 Rhusflavanone



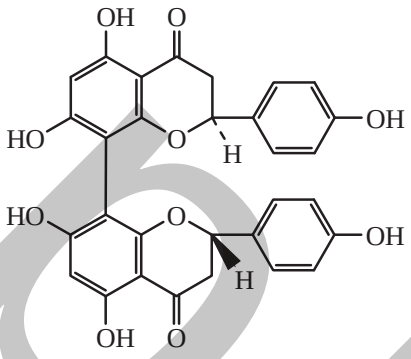
102 Agathisflavone



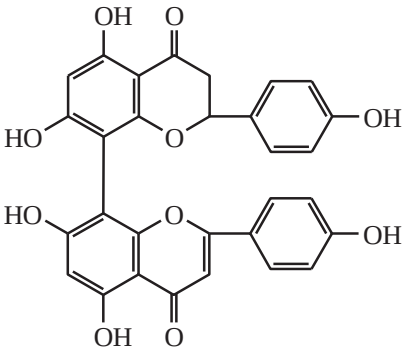
103 Robustaflavone



104 Succedaneaflavanone



105 Neorhusflavanone



106 Mesuaferrone B

Young, mature and autumn red leaves of *Rhus succedanea* contained chrysanthamin and peonidin 3-monoglucoside (Ishikura, 1972). Leucoanthocyanidins have been detected in *Rhus parviflora* (Verma and Bokadia, 1965).

Three cyclolignan esters, rhusemialins A-C (Ouyang *et al*., 2007a), tortoside B and other five lariciresinol-based lignan glycosides (Ouyang *et al*., 2007b) were isolated from the roots of *Rhus javanica* var. *roxburghiana*. Scopolin, scopoletin, orcinol (methyl resorcinol "3,5-dihydroxy-toluene") and orcinol β-D-glucoside were also identified from the stem bark of *Rhus javanica* (Chung *et al*., 1999).

Sulfuretin (2-benzylidene-3',4',6-trihydroxycoumarinone) was isolated from *Rhus cotinus* (King and White, 1961), heartwoods of *Rhus javanica* (Imamura *et al*., 1967) and *Rhus succedanea* (Kondo and Imamura, 1985).

Rhuscholide A (a benzofuran lactone, 5-hydroxy-3-(propan-2-ylidene)-7-(3,7,11,15-tetramethylhexadeca-2,6,10,11-tetraenyl)-2(3*H*)-benzofuranone,) and 5-hydroxy-7-(3,7,11, 15-tetramethylhexadeca-2,6,10,11-tetraenyl)-2(3*H*)benzofuranone) were isolated from the stems of *Rhus chinensis* (Gu *et al*., 2007). A benzofuranoic acid named (2*E*)-3-(4-hydroxy-5,7-dimethylbenzo[3,4-b]furan-6-xyloxy)prop-2-enoic acid was identified from the leaves of *Rhus alata* (Parveena *et al*., 2008). *Rhus undulata* has been reported to contain stilbenes (Ryu *et al*., 1988). *p*-Coumaric acid, caffeic acid (Nair *et al*., 1977), syringic acid and protocatechuic acid (Cha *et al*., 2000) were isolated from *Rhus parviflora* and *Rhus javanica* respectively.

Two phenol glycosides, 3,4,5-trimethoxyphenol-1-*O*-β-D-glucopyranosyl-4',6'-*O*-(*E*)-diferuloyl ester and 3,5-dimethoxy-4-hydroxyphenylmethanol-4-*O*-β-D-glucopyranosyl-4',6'-*O*-(*E*)-diferuloyl ester were identified from the roots of *Rhus javanica* var. *roxburghiana* (Ouyang *et al*., 2008). The principal dermatitant, lobinol, of the poison oak (*Rhus diversiloba*) have been early reported to be probably a polyhydric phenol (McNair, 1921).

Vanillin, methyl ferulate and 4-hydroxy-3,5-dimethoxybenzaldehyde were identified from *Rhus javanica* var. *roxburghiana* (Ouyang *et al*., 2007a). 2-Hydroxy-4-methoxybenzaldehyde was characterized as the principal tyrosinane inhibitor from the roots of *Rhus vulgaris* (Kubo and Kinst-Hori, 1999). Three antioxidant compounds were isolated

from *Rhus verniciflua* and identified as 1,2,3-trihydroxybenzene, Me 3,4,5-trihydroxybenzoate and 3,4,5-trihydroxybenzoic acid (Choi *et al*., 2002).

Other Constituents

The fruits of *Rhus semialata* contain citric, malic and tartaric acids (Uota and Nisida, 1941). Malic acid was also identified from the fruits of *Rhus typhina* L. (Tisher *et al*., 1941). A natural citric acid derivative identified as 2-hydroxy-1,2,3-propanetricarboxylic acid methyl ester (citric acid 2-methyl ester) was isolated from the fruits of *Rhus parviflora* (Talaptra *et al*., 1993,2001).

myo-Inositol was identified from *Rhus typhina* (Plouvier, 1960). Nonacosane 5-diol was found in the epicuticular wax of *Rhus cotinus* leaf (Hunt and Baker, 1979). *Rhus copallina* contains acetylcholine (Miura and Shih, 1984).