9.2.2. ***Rhus coriaria*** L., Sp. Pl., ed. 1, 265 (1753); Boulos, Fl. Egypt 2: 73 (2000).

Proximate Composition, Carbohydrates, Proteins and Lipids

Sumac (*Rhus coriaria*) is an edible plant. The fruits, collected in Turkey showed the following composition: moisture (9.6%), oil (7.4%), protein (2.6%), fiber (14.6 %), ash (1.8%) and water-soluble extract (63.8%). K, Ca, Mg and P were found to be predominant elements in sumac fruits (Ozcan and Haciseferogullari, 2004). The proximate composition, fatty acids, mineral elements, vitamin content, amino acids and organic acids of *Rhus coriaria* (Syrian sumac) and *Rhus chinensis* (Chinese sumac) fruits collected from Syria and China respectively are shown in Tables 34-38 (Kossah *et al*., 2009). The following elements were found in ten noriental spices (including Sicilian sumac "*Rhus coriaria*"): Mg, Al, Si, P, S, Cl, K, Ca, Ti, Mn, Fe, Cu, and Zn, with varying concentrations (Al-Bataina *et al*., 2003). All the thirty-two plants (including *Rhus coriaria*), used as condiments, contained high amounts of Al, Ba, Ca, Fe, K, Mg, P and S (Ozcan, 2004). Microelement content of the plant has been also reported by Kizil and Turk (2010). The proximate composition, amino acids, minerals and vitamins of Syrian sumac (*Rhus coriaria*) are shown in Tables 34-37 (Kossah *et al*., 2009).

Table 34. Proximate composition of Syrian and Chinese sumac fruits (%, dry weight)*

Components	Syrian sumac	Chinese sumac
Moisture	11.80±0.53	6.64±0.03
Protein	2.47±0.12	4.31±0.27
Fat	7.51±0.44	11.56±0.66
Fiber	22.15±0.14	32.90±0.89
Ash	2.66±0.33	5.37±0.14

* Kossah *et al*. (2009)

Table 35. Amino acid profiles of Syian and Chinese sumac fruits as compared to the FAO/WHO/UNU reference pattern (mg/g protein)*

Amino acids	Syrian sumac	Chinese sumac	FAO/WHO/UNU
Essential			
Leucine	1.25±0.16	3.16±0.19	19
Isoleucine	0.63±0.08	1.79±0.17	13
Lysine	0.98±0.02	2.65±0.07	16
Phenylalanine	0.75±0.13	2.00±0.13	19
Threonine	0.70±0.08	1.57±0.06	9
Methionine	0.15±0.07	0.05±0.02	17
Valine	0.71±0.06	2.24±0.30	13
Tryptophan	0.51±0.18	3.10±0.15	5
Non-essential			
Arginine	1.09±0.10	2.79±0.25	
Histidine	0.68±0.01	1.03±0.12	
Cysteine	0.18±0.04	0.10±0.03	
Aspartic acid	1.70±0.34	3.68±0.49	
Glutamic acid	2.45±0.15	7.46±0.40	
Serine	0.93±0.17	2.26±0.16	
Glycine	0.60±0.26	2.17±0.12	
Alanine	0.96±0.26	1.98±0.18	
Tyrosine	0.51±0.33	1.27±0.19	
Proline	1.43±0.27	2.26±0.24	

* Kossah *et al*. (2009)

Table 36. Mineral elements of Syrian and Chinese sumac fruits (mg/kg)*

Mineral	Syrian sumac	Chinese sumac
K	7441.25±0.07	5576.00±0.68
Na	101.04±0.15	183.00±0.26
Mg	605.74±0.51	871.00±0.42
Ca	3155.53±0.41	3098.00±0.52
Fe	174.15±0.18	180.00±0.67
Cu	42.68±0.45	9.56±0.19
Zn	55.74±0.38	17.20±0.38
Mn	10.57±0.39	11.60±0.35
p	327.70±0.35	1032.00±0.21

* Kossah *et al*. (2009)

Table 37. Vitamin content of Syrian and Chinese sumac fruits (mg/kg)*

Vitamin	Syrian sumac	Chinese sumac
Thiamin (B_1)	30.65±0.57	23.99±0.54
Riboflavin (B_2)	24.68±0.42	24.41±0.33
Pyridoxine (B_6)	69.83±0.31	20.28±0.28
Cyanocobalamin (B_{12})	10.08±0.24	3.51±0.37
Nicotinamide (PP)	17.95±0.28	2.39±0.13
Biotin (H)	4.32±0.23	1.13±0.08
Ascorbic acid (C)	38.91±0.27	13.90±0.20

* Kossah *et al*. (2009)

Table 38. Fatty acid composition of Syrian and Chinese sumac fruits (% total fatty acids)*

Fatty acid	Syrian sumac	Chinese sumac
Myritsic acid ($C_{14:0}$)	0.36±0.07	0.19±0.05
Palmitic acid ($C_{16:0}$)	27.41±0.55	16.28±0.16
Palmitoleic acid ($C_{16:1}$)	0.68±0.23	2.11±0.10
Stearic acid ($C_{18:0}$)	2.92±0.37	2.60±0.13
Oleic acid ($C_{18:1}$)	36.95±0.28	52.31±0.10
Linoleic acid ($C_{18:2}$)	30.38±0.54	25.57±0.20
Linolenic acid ($C_{18:3}$)	1.27±0.15	0.94±0.16
TUFA	69.28±1.20	80.93±0.56
TSFA	30.69±0.99	19.07±0.32

* Kossah *et al*. (2009)
TUFA: Total unsaturated fatty acids
TSFA: Total saturated fatty acids

The seeds of Iraqi sumac (*Rhus coriaria*) contain moisture 5.2% and oil 15.5%. The seed oil contains palmitic, stearic, oleic and linoleic acids (Al-Hamdany and Osman, 1977). Hydroxylated fatty acids (mainly 16-hydroxy and 10,16-dihydroxy-hexadecanoic acids) were identified in the leaf cutin of the plant (Debal *et al*., 1993). The fatty acids of Syrian sumac fruits are shown in Table 38 (Kossah *et al*., 2009). The analysis of seed fat from *Rhus coriaria*, collected from Turkey showed that the triglycerides consist of high quantities of oleic acid (42.20%) and linoleic acid (32.47%) of the total fatty acids. Other fatty acids detected were palmitic (20.00%), palmitoleic (0.40%), stearic (2.55%), linolenic (0.83%), eicosanoic (0.34%) and docosanoic (0.14%) acids, in addition to traces of lauric, myristic and pentadecanoic acids (Brunke *et al*., 1993). The fruits of *Rhus coriaria* are rich in oil, fatty acids and minerals. The main fatty acids are oleic (37.7%), linoleic (27.4%), palmitic (21.1%) and stearic (4.7%) acids (Kizil and Turk, 2010). The main fatty acids of pericarps of the plant (growing wild in ten different regions of Turkey) were oleic (33.78-52.57%), palmitic (16.99-29.76%), linoleic (11.60-21.91%) and linolenic (0.33-1.33%) acids. In addition, linoleic (49.35-60.57%), oleic (24.58-32.05%), palmitic (8.32-13.58%), stearic (1.57-3.03%) and linolenic (0.46-0.74%) acids were established as major fatty acids of sumach seeds (Unver and Ozcan, 2010). Characterstics and fatty acid compositions of *Rhus coriaria*, growing in Turkey, has been also reported by others (Ericyes *et al*., 1989; Dogan and Akgul, 2005). 3-*O*-β-D-Glucopyranosyl-(2'→3")-3"-*O*-stigmast-5-ene, β-sitosterol-β-D-glucoside (Singh *et al*., 2011a), *n*-tetracosane and *n*-pentacosane were identified from the seeds (Singh *et al*., 2011b).

The leaves of the plant, growing in Syria contain raffinose, sucrose, glucose, fructose and rhamnose; the last three also occurred in combination, together with galactose and xylose (El Sissi *et al*., 1966).

Malic, maleic, citric, succinic, tartaric, fumaric and ascorbic acids were identified in *Rhus coriaria*, *Rhus glabra* and *Rhus typhina* (Mavlyanov *et al*., 1997). Syrian sumac (*Rhus coriaria*) contains higher concentrations of organic acids than Chinese sumac (*Rhus typhina*) and malic acid is the most abundant (Table 39) (Kossah *et al*., 2009).

Pharmacognostical studies of *Rhus coriaria* have been reported (Atkin and Marriott, 1921; Bionda, 1942; Marieschi *et al*., 2009).

Table 39. Organic acid content of Syrian and Chinese sumac fruits (mg/kg)*

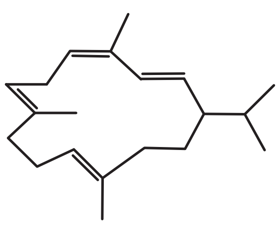
Organic acids	Syrian sumac	Chinese sumac
Malic acid	1568.04±0.05	377.59±0.26
Citric acid	56.93±0.35	30.54±0.54
Tartaric acid	2.15±0.13	1.20±0.06
Fumaric acid	3.40±0.46	0.41±0.07

* Kossah *et al*. (2009)

Essential Oils

Kurucu *et al*. (1993) studied the constituents of the essential oils obtained from the leaf, fruit pericarp and branch/bark of the plant growing in Turkey. Sixty-three constituents in the branch/bark oil, sixty-three constituents in the leaf oil and eight-five constituents in the fruit pericarp oil were identified. The predominant compounds in the pericarp oil were limonene (0.17-9.49%), nonanal (10.77-13.09%) and (*Z*)-2-decanal (9.90-42.35%), while major compounds of the leaf oil were β-caryophyllene (0.33-16.95%) and a sesquiterpene hydrocarbon tentatively identified as patchoulane (3.08-23.87%). The major constituents of the branch/bark oil were β-caryophyllene (12.35-21.91%) and cembrene (10.71-26.50%) (Kurucu *et al*., 1993). The composition of oils from two different regions showed variations. More than 120 substances were identified in the essential oil of the dry fruits of *Rhus coriaria* originating from six Turkish provinces. The qualitative compositions of the individual samples were quite similar, but differences were observed with respect to quantitative ratios of the individual components (Table 40). Within the group of monoterpene hydrocarbons, α-pinene (1-3.8%) and limonene (0.4-1.1%) are present at higher concentrations. Oxygenated monoterpenpoids which contribute to the sensory properties of the fruit material are, for example 1,8-cineole (0.04-0.9%), the linalool oxides (0.2-1%), octanol (0.2-0.6%), borneol (0.2-0.9%) and its acetate (0.1-0.5%), camphor (0.02-0.3%), α-terpineol (0.5-2.5%), terpinen-4-ol (0.2-0.9%), thymol (0.1-0.8%), carvacrol (0.3-10.4%), and cumin aldehyde (0.02-0.6%). The group of sesquiterpene hydrocarbons represented by high amounts of β-caryophyllene (4-14%) is accompanied by greater quantities of functionalized sesquiterpenes with the same basic structure, namely two isomeric caryophyllene oxides (0.4-3%) and β-caryophyllene alcohol (0.8-2.9%). Cembrene (**107**, a diterpene hydrocarbon) was also detected (Brunke *et al*., 1993). Main constituents are terpene hydrocarbons (i.e. α-pinene, β-caryophyllene and cembrene), oxygenated terpenes (i.e. α-terpineol, carvacrol and β-caryophyllene) as well as farnesyl acetone, hexahydrofarnesylacetone and aliphatic aldehydes (Brunke *et al*., 1993).

The study of the flavour characterstics of *Rhus coriaria* showed that malic acid was responsible for the sour taste of sumac. β-Caryophyllene (spicy, woody), cembrene (woody) and caryophyllene oxide (spicy) seem to have an important contribution to sumac flavour (Bahar and Altug, 2009).



107 Cembrene

Table 40. Qualitative and quantitative composition of the essential oil of *Rhus coriaria* fruits originating from different provinces of Turkey

Substance	%					
	A	B	C	D	E	F
1. Nonane	0.03	-	-	-	-	-
2. 3-Methylbutanal	0.03	0.06	0.06	-	-	-
3. 2-Ethylfuran	-	-	0.01	-	-	-
4. Pentanal	0.03	0.02	0.03	-	<0.03	-
5. Decane	0.04	0.04	0.03	0.02	0.03	0.03
6. Tricyclene	0.01	0.01	0.01	0.01	trace	0.02
7. α-Pinene	3.54	2.73	3.78	1.06	1.50	1.36
8. α-Fenchene	0.02	0.04	0.04	-	-	-
9. Camphene	0.38	0.19	0.21	0.37	0.08	0.05
10. Hexanal	2.43	0.58	1.19	0.35	0.95	0.15
11. β-Pinene	0.24	0.12	0.36	0.04	0.11	0.10
12. 2-Butylfuran	0.03	trace	0.02	-	-	-
13. 3-Carene	0.03	trace	-	0.12	0.05	0.03
14. Myrcene	0.13	0.12	0.23	0.19	0.14	0.10
15. α-Phellandrene	0.06	0.06	0.07	0.36	trace	0.05
16. Heptan-2-one	0.02	-	0.02	-	-	-
17. Heptanal						
18. Isoamyl alcohol	0.05	0.28	0.22	-	0.26	0.11
19. α-Terpinene				0.78	0.04	0.03
20. Limonene	0.83	0.77	1.08	1.10	0.39	0.55
21. (*E*)-Anhydrolinalol oxide	0.02	trace	trace	-	-	0.04
22. β-Phellandrene	0.10	0.09	0.17	0.29	0.08	0.07
23. (*E*)-Hex-2-enal	0.10	0.12	0.17	-	0.07	-
24. 1,8-Cineole	Trace	trace	trace	0.90	0.08	0.04
25. 2-Pentylfuran	0.45	0.13	0.28	0.15	0.33	0.19
26. *cis*-β-Ocimene	0.11	0.07	0.22	0.08	0.16	0.22
27. *n*-Amyl alcohol	0.03	-	0.01	-	-	-
28. (*Z*)-Anhydrolinalol oxide	0.03	trace	0.08	0.01	-	0.02
29. γ-Terpinene	-	0.26	trace			
30. *trans*-β-Ocimene	0.25	trace	0.54	0.62	0.57	0.40
31. Hexyl acetate	0.01	-	-	-	trace	-
32. *p*-Cymene	0.08	0.32	0.26	0.70	0.90	0.09
33. Octan-2-one	0.02	-	-	-	-	-
34. Terpinolene	-	-	0.59	0.42	0.10	0.14
35. Octanal	0.53	0.76	-	0.51	1.10	0.23
36. Isoamyl isovalerate	0.03	-	-	-	-	trace
37. Oct-1-en-3-one	0.17	0.12	0.14	0.05	0.28	0.10
38. (*E*)-Hept-2-enal	2.06	1.47	2.00	0.43	4.35	1.32
39. Pinol	-	-	-	0.08	-	-
40. 6-Methylhept-5-en-2-one	0.14	0.36	0.46	0.07	0.14	0.10
41. Hexanol	0.04	-	0.03	-	-	-
42. Nonanal	11.50	2.99	2.42	4.55	3.57	3.28
43. Oct-3-en-2-one	0.39	0.07	0.18	-	0.17	0.19
44. (*E*)-Oct-2-enal	0.82	0.54	0.78	0.25	1.08	0.65

Table 40. Qualitative and quantitative composition of the essential oil of *Rhus coriaria* fruits originating from different provinces of Turkey (cont.)

Substance	%					
	A	B	C	D	E	F
45. 4-Isopropenyltoluene	0.09	0.16	0.20	0.29	0.15	-
46. Oct-1-en-3-ol	0.62	0.18	0.30	0.29	0.31	0.26
47. *cis*-Linalool oxide	0.15	0.11	0.63	-	0.20	0.14
48. Furfural	0.15	0.04	0.03	-	trace	-
49. 2(*E*).4(*Z*)-Heptadienal	0.26	trace	0.12	0.02	0.04	0.04
50. *trans*-Linalool oxide	0.07	0.13	0.44	-	0.14	0.19
51. 2(*E*),4(*E*)- Heptadienal	0.21	0.04	0.17	-	0.07	0.11
52. Decanal	0.31	0.19	0.30	-	0.27	0.32
53. Benzaldehyde	0.04	0.03	0.04	-	0.05	-
54. Camphor	0.02	0.03	0.03	0.25	0.07	0.09
55. (*E*)-Non-2-enal	1.59	0.67	1.32	0.50	1.10	0.86
56. Linalol	-	-	-	-	-	trace
57. Octanol	0.52	0.36	0.30	0.40	0.63	0.23
58. Linalyl acetate	-	-	0.11	0.03	-	0.06
59. Fenchol	0.10	0.24	0.77	0.31	0.04	0.02
60. Bornyl acetate	0.12	0.34	0.29	0.47	-	0.20
61. 2-(*E*),4(*E*)-Octadienal	0.16	0.29	0.30	-	0.09	0.11
62. Terpinen-4-ol	0.25	-	0.33	0.92	0.38	-
63. Oct-2-enol	1.02	0.43	0.09	-	-	-
64. β-Caryophyllene	8.39	10.03	8.83	4.02	9.72	13.79
65. Phenylacetaldehyde	0.19	0.03	-	0.01	0.03	-
66. (*E*)-Dec-2-enal	4.22	9.67	6.97	2.87	22.21	5.04
67. Methylchavicol	-	0.05	0.15	0.30	trace	0.11
68. α-Humulene	0.94	1.11	1.01	0.81	1.00	1.46
69. α-Terpineol	0.54	1.28	2.42	1.32	0.54	0.93
70. 2(*E*),4(*E*)-Nonadienal	0.81	-	-	-	0.37	0.24
71. Borneol	trace	0.48	0.84	0.43	0.18	0.50
72. β-Bisabolene	-	-	-	0.47	0.23	-
73. Carvone	0.85	0.17	0.21	trace	2.02	trace
74. Naphthalene	0.14	0.12	0.11	3.58	trace	1.30
75. (*E*)-Undec-2-enal	1.02	1.49	1.72	0.31	2.26	1.13
76. 2(*E*),4(Z)-Decadienal	2.36	0.40	1.76	0.57	0.85	1.82
77. δ-Cadinene	0.34	0.13	0.16	-	0.11	-
78. γ-Cadinene	0.16	0.11	0.09	-	-	-
79. *ar*-Curcumene	-	-	-	0.59	-	-
80. Cuminaldehyde	0.13	trace	-	0.57	0.02	0.35
81. Myrtenol	0.05	0.05	0.10	-	-	-
82. 2(*E*),4(*E*)-Decadienal	5.83	0.97	4.17	1.30	1.98	4.17
83. *trans*-Anethole	-	-	-	2.06	0.19	2.42
84. Caproic acid	0.22	-	0.20	-	-	-
85. Calamenene	0.07	trace	-	-	trace	-
86. Geranylacetone	0.94	0.93	0.57	0.53	0.90	1.21
87. Methylnaphthalene	0.03	-	-	0.23	trace	-
88. Safrole	-	-	-	0.23	-	-

Table 40. Qualitative and quantitative composition of the essential oil of *Rhus coriaria* fruits originating from different provinces of Turkey (cont.)

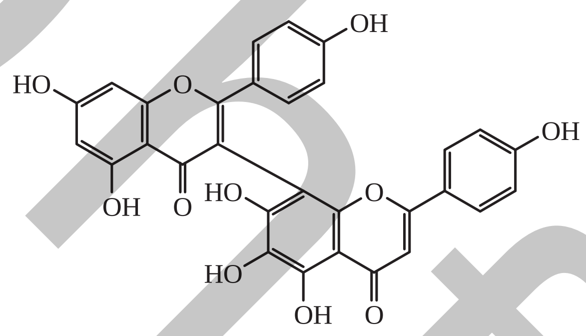
Substance	%					
	A	B	C	D	E	F
89. α-Calacorene	0.25	0.35	-	-	0.06	-
90. Caryophyllene oxide α+β	0.63	0.39	0.66	3.06	0.64	1.27
91. Eugenol methyl ether	0.09	-	-	0.59	-	1.03
92. Nerolidol	-	0.29	0.39	0.15	-	0.22
93. Humulene oxide	0.08	0.08	0.07	0.14	-	0.18
94. Caprylic acid	0.18	0.27	0.18	-	-	-
95. β-Caryophyllene alcohol	0.75	1.79	2.90	-	0.88	-
96. Hexyl benzoate	-	0.39	0.19	-	-	-
97. Heneicosane	0.10	0.15	-	-	-	-
98. Hexahydro-farnesylacetone	2.76	1.87	1.04	0.93	0.51	0.65
99. Cedrol	0.11	0.17	0.11	-	-	-
100. Pelargonic acid	2.63	1.18	1.12	1.82	0.05	0.40
101. Eugenol	-	-	-	1.12	-	0.89
102. Thymol	-	0.13	-	0.77	0.50	trace
103. γ-Eudesmol	-	-	0.28	0.26	-	-
104. *T*-Cadinol	0.11	0.15	-	-	-	-
105. Carvacrol	0.26	2.81	0.24	2.72	10.35	-
106. Cembrene	9.17	7.40	11.50	1.47	6.50	15.37
107. Heptadecan-2-one	0.41	0.29	0.05	0.60	0.29	1.08
108. Capric acid	0.35	-	-	-	-	-
109. Caryophylla-1(12),8(15)-dienol-(9) (?)	3.53	-	-	-	0.37	-
110. Undecanoic acid	trace	trace	0.17	-	-	-
111. Farnesylacetone	0.44	0.81	0.61	0.86	0.42	0.98
112. Nonadecan-2-one	0.15	0.51	0.14	0.16	0.45	0.33
113. Methyl oleate	-	0.56	-	0.45	-	-
114. Luric acid	0.16	0.13	0.22	-	-	-
115. Methyl linoleate	-	0.36	-	-	-	-
116. Pentacosane	0.60	0.70	0.39	1.33	-	0.91
117. Benzyl benzoate	-	0.05	0.10	-	-	trace
118. Myristic acid	0.47	0.66	0.84	0.45	-	-
119. Heptacosane	2.15	3.51	1.83	5.69	0.86	3.81
120. Octacosane	0.12	0.23	0.16	0.12	-	0.12
121. Palmitic acid	1.09	5.11	0.84	3.99	2.25	3.17
122. Nonacosane	2.41	1.28	1.52	3.97	-	3.84

(A)Province Adana, (B) Province Sanliurfa, (C) Province Diyabkir, (D) Province Hatay, (E) Province Gaziantep, (F) Province Kahramanmaras.
* Brunke *et al*. (1993)

Flavonoids

The leaves of Syrian sumac (*Rhus coriaria*) has been reported to contain myricetin, quercetin, kaempferol and isoquercitrin (Perkin, 1902; El Sissi *et al*., 1966, 1971, 1972). The following flavonoids were isolated fom the leaves of Venetian sumac (*Rhus coriaria*): myricetin and quercetin 3-*O*-α-L-rhamnofuranosides, avicularin (quercetin 3-*O*-α-Larabinofuranoside), astragalin (kaempferol 3-*O*-β-D-glucopyranoside) (Buziashvili *et al*., 1970). The biflavonoids, agathisflavone (**102**), amentoflavone (**32**), hinokiflavone (**99**) and sumaflavone (**108**), were also identified from the plant (Van Loo *et al*., 1988). The main flavonoid glycosides of the Venetian sumac and sumac (*Cotinus coggygria*) were the myricetin group (75-80%); the amount of quercetin group was lower (18-23%) and those of kaempferol were present only in traces (Buziashvili *et al*., 1973c). Myricetin was found to be the major flavonoid of *Rhus coriaria*, followed by minor quantities of quercetin and kaempferol (Mehrdad *et al*., 2009). Isoquercitrin, myricetin 3-*O*-α-L-rhamnoside, kaempferol and quercetin were identified in the fruits of genetically related *Rhus coriaria*, known as sumac obtained from a herbalist shop in Cairo (Shabana *et al*., 2011).

The leaves in autumn contained chrysanthemin (anthocyanin), and the fruits contained 3 anthocyanin glycosides (Karimdzhanov *et al*., 1986). Three anthocyanins *viz.* chrysanthemin, myrtillin and delphinidin were identified in *Rhus coriaria*, *Rhus glabra* and *Rhus typhina* (Mavlyanov *et al*., 1998). The anthocyanins of the plant were reported as safe and stable food colourants for confectionery products, cakes, and beverages (Kasumov, 1991). Cyanidin, peonidin, pelargonidin, petunidin and delphinidin glucosides and coumarates were also identified from the anthocyanin fraction of *Rhus coriaria* (Kosar *et al*., 2007).



108 Sumaflavone

Tannins

Lidoff (1888) reported that the leaves of *Rhus coriaria* contain 15.31% and the stalks 3.4% of tannic acid and 11% gallic acid. Sumac (*Rhus coriaria*) leaves were early used by the tanner and dyer because of their high values in tannins and colouring matters (Collin, 1907).

Yakimov and Ulman (1932) reported that *Rhus coriaria* contains 17-26% tannides and 13-25% nontanning substances; the tannides can be used for the preparation of technical and pharmaceutical tannin of 75 and 95%, respectively, in addition to technical and pure gallic acid. The leaves were reported a suitable substitute for gallotannin from nutgalls for use by the ink, dye and wine industries (Carrara, 1951). The leaves of *Rhus coriaria* (from Sicily, Italy) contains 25% tannins (Giglioli, 1937). In leaves of *Rhus coriaria, Rhus glabra* and *Rhus typhina* (cultivated in USSR), the concentration of tannins reached maximum in the period from blossoming to the appearance of reddish-coloured leaves, the yield being 15-22% (Sverdlina, 1970). The leaves of the plant, growing in Syria contained 23.55% tannins or polyphenolics (El Sissi *et al*., 1966). Kossah *et al*. (2010) found that the polyphenols content was 159.32 and 150.68 mg gallic acid/g of *Rhus coriaria* and *Rhus typhina* (Chinese sumac) fruits respectively.

The possibility of using the leaves of the plant, growing in Hungary as a source of tanning material was early reported (Hollub, 1943). Also, the plant growing in Yugoslavia, has been proposed as a raw material for obtaining medicinal tannins (Ramic and Devetak, 1964). In the three species (*Rhus coriaria*, *Rhus glabra* and *Rhus typhina*) investigated by

Karimdzhanov *et al*. (1986), the tannin content was highest in the foliage. The tannins of leaves and petioles of *Rhus coriaria*, collected from two regions in Turkey showed quantitative differences (Guvenc and Koyuncu, 1994).

The stem and petioles of three *Rhus* species (*Rhus coriaria*, *Rhus glabra* and *Rhus typhina*) contained 3 and 1 catechin respectively (Karimdzhanov *et al*., 1986). The gallotannin, prepared from the plant growing in Syria appeared to be an octa- or monogallolyted glucose (El Sissi *et al*., 1971). In tannin from *Rhus coriaria*, among 6 galloid residues, 2 are digalloyl and 2 monogalloyl (Buziashvili *et al*., 1973b). Pyrogallol (or a derivative) was identified in the leaves (Vágó, 1957; Durio *et al*., 1959). Gallic acid, its methyl and ethyl esters, *m*-digallic acid and ellagic acid were identified from the leaves of the plant growing in Syria (El Sissi *et al*., 1966,1972). According to Balansard *et al*. (1976), the methyl and ethyl esters of gallic acid were not observed in the leaves, but were formed during extraction.

The study of the structure of hydrolysable tannins from commercial sumac revealed a more complex mixture of glucose oligomers up to 13 repeating units (Pizzi *et al*., 2009). *Rhus coriaria*, that grow in Mediterranean regions, best known in the Cordovan and Moroccan tanning products; the sumac tannins comprise pyrogallols, and gallic acid, glucose, green dyes, and inorganic salts (Berthet, 2001).

Grassmann (1956) detected glucose, rhamnose and arabinose in addition to gallic acid in the tannin hydrolysate. The sugar component in one of the tannin fractions seems to be a tetrasaccharide containing 2 molecules glucose, 1 molecule arabinose and 1 molecule rhamnose. A tannase-producing strain of *Aspergillus niger* efficiently hydrolyzes the gallotannins of *Rhus coriaria* to pure gallic acid (Pourrat *et al*., 1987).

There are several other reports about the tannins of *Rhus coriaria*, concerning their occurrence, stability, analysis, in addition to the tanning capacity and uses in carpet industry, wool and others (*e.g.* Perkin and Allen, 1896; Perkin, 1897; Perkin and Wood, 1898; Mesheninov, 1929; Haddaway, 1956; Laiseca *et al*., 1957; Kasumov, 1974; Zalacain *et al*., 2000, 2001). The study of Seriozli and Kivanc (2009) revealed that some strains of *Aspergillus niger* may be used not only for gallic acid but also tannase production from tannin rich plant materials such as gall nuts. Their high yields and short incubation periods are also remarkable.

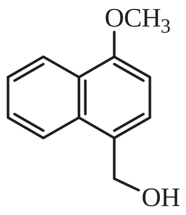
Air-dried leaves of 8 species of *Rhus* (sumac) and of *Cotinus* (smoke tree) were studied for seasonal variations of their content of medicinal tannin (I), flavonoid glycosides (II) and gallic acids (III). The highest level of I (22.5 to 25.3% of wt. of dried leaves) was found for *Cotinus* from near Tbilisi at the end of June to the middle of July (flowering phase). The highest levels of II and III (~2 to 5%) were before flowering. The greatest yield of I from *Rhus* species were *Rhus coriaria* (20), *Rhus typhina* (18), and *Rhus aromatica* (16%) (Buziashvili *et al*., 1972). Total phenolic content of *Rhus coriaria* amounted to 497.87 mg GAE/g and may be used in different applications to preserve food and human health (Unver *et al*., 2009).

Xanthones, Quinones and Other Constituents

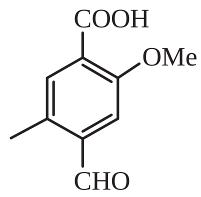
The following four xanthones were isolated from the seeds of *Rhus coriaria*: 2,3-dihydroxy-7-methyl xanthone, 2,3,6-trihydroxy-7-hydroxymethylene xanthone-1-carboxylic acid, 2-methoxy-4-hydroxy-7-methyl-3-O-β-D-glucopyranosyl xanthone-1,8-dicarboxylic acid, and 2-hydroxy-7-hydroxymethylene xanthone-1,8-dicarboxylic acid (Singh *et al*., 2011a).

The seeds also contain 1-methoxy-4-hydroxy-methylene naphthalene (**109**, coriarianaphthyl ether), 2-methoxy-5-methyl benzen-4-al-1-oic acid (**110**, coriariaoic acid) and 1-dodecanoxy-2,8-dihydroxy-anthracene-15-oic acid (**111**, coriarianthracenyl ester) along with anise alcohol, *p*-hydroxybenzyl alcohol, methyl lawsone and 2-hydroxymethylene naphthaquinone (Singh *et al*., 2011b).

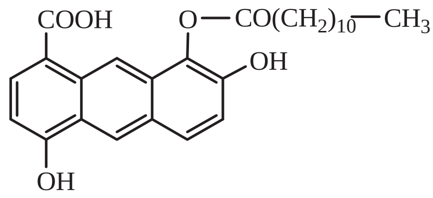
The detection of an anthraquinone in the stems (Karimdzhanov *et al*., 1986) and protocatechuic acid in the fruits (Shabana *et al*., 2011) has been reported.



109 Coriarianaphthyl ether



110 Coriariaoic acid



111 Coriarianathracenyl ester