Pharmacogn. Rev.
A multifaceted peer reviewed journal in the field of Pharmacognosy and Natural Products
www.phcogrev.com | www.phcog.net

REVIEW ARTICLE

Flavonoids from the Genus *Astragalus*: Phytochemistry and Biological Activity

Viktor M. Bratkov, Aleksandar M. Shkondrov, Petranka K. Zdraveva, Ilina N. Krasteva

Department of Pharmacognosy, Medical University of Sofia, Sofia, Bulgaria

ABSTRACT

Flavonoids, the most common plant polyphenols are widely distributed in every species and possess a broad range of pharmacological activities. The genus *Astragalus* is the largest in the Fabaceae family with more than 2,500 species spread. They are known to contain different metabolites such as flavonoids, saponins, and polysaccharides. Plants from the genus have been used in the traditional medicine of many countries for centuries. This paper is focused on the large group of flavonoid compounds. Details on structure as well as information about the pharmacological properties of flavonoids, isolated from *Astragalus* species have been discussed. This review is based on publications until the first half of 2014 and includes also the results from our phytochemical investigations of the genus.

Key words: *Astragalus*, biological activity, flavonoids, phytochemistry

INTRODUCTION

Since the existence of humanity, plants have been an inexhaustible source of cure against diseases. Data on traditional plant-derived remedies are found in every culture. The earliest known herbal medicine-based system dates back to the 5000 BC in Mesopotamia.[1]

The genus *Astragalus* is the largest in the Fabaceae family and is cosmopolite, with more than 2,500 species grouped in 100 subgenera.[2] Moreover, *Astragalus* is considered to be one of the most diverse *genera*.[3] The species are spread in Southwestern Asia (the largest area with 1,000–1,500 species), Chinese Himalayan region (500 species), northwestern America and South America (with 400-450 and 100 species, respectively), Europe (133 species).[4] In Bulgaria, the genus presents with 29 species.[5]

Till date, more than 100 species have been investigated. The plants have been intensively analyzed, mainly for three main groups of biologically active compounds–polysaccharides, flavonoids, and saponins.[6,7] There are other compounds possessing biological activity such as sesquiterpene-flavonolic complexes,[8] sterols, lignans, coumarins, and phenolic acids.[6] Three toxic groups of phytoconstituents–indolizidine alkaloids, aliphatic nitro compounds, and iron-selenium derivatives have been also discovered.[6,7]

Flavonoids represent the largest group of polyphenolic compounds occurring in *Astragalus* species. Review papers on the phytochemistry and pharmacology of *Astragalus* genus have been published.[6,7,9-14] There are review articles concerning only pharmacological properties of *Astragalus membranaceus* and *Astragalus complanatus*, used in traditional Chinese medicine.[10,15,16] This review includes full details on the flavonoids isolated from the *Astragalus* species from 1952 (the first report about flavonoid isolated from the genus)[17] to the first half of 2014.

FLAVONOIDS FROM THE GENUS ASTRAGALUS

Many different subclasses of flavonoids have been described from the genus *Astragalus* including flavones, flavonols, flavanones, flavanonols, chalcones, aurones, isoflavones, isoflavanes, and pterocarpans. The number of the flavones from the genus according to our literature survey is 22. Ibrahim *et al*. reported a new flavone, *C*-glycoside from *Astragalus bombycinus*.[18] Flavonols are the most frequently isolated compounds. Among them quercetin, kaempferol, and their glycosides were found in higher number *Astragalus* species. Phytochemical investigation of the seeds of *Astragalus complanatus* revealed the presence of complanatin–a new rhamnocitrin glycoside acylated with acidic type sesquiterpen.[19] A glycoside similar to complanatin was isolated together with two other rhamnocitrin glycosides acylated with p-Coumaric and ferulic acid.[20] Alaniya *et al*. identified two new flavonol tetraglycosides named falcoside C and falcoside D from the leaves and flowers of *Astragalus falcatus*.[21] Information about a new flavonol tetraglycoside isolated from *Astragalus caprinus* was published in 2001.[22] In addition, 1 year later four new flavonol glycosides were determined, two of which

Correspondence:
Prof. Ilina N. Krasteva,
Department of Pharmacognosy, Faculty of Pharmacy, Medical University of Sofia, 2 Dunav Street, Sofia - 1000, Bulgaria.
E-mail: ikrasteva@pharmfac.net

Access this article online

Quick Response Code:

Website: www.phcogrev.com

DOI: 10.4103/0973-7847.176550

Cite this article as: Bratkov VM, Shkondrov AM, Zdraveva PK, Krasteva IN. Flavonoids from the genus *Astragalus*: Phytochemistry and biological activity. Phcog Rev 2016;10:11-32.

were acylated with hydroxymethyl glutaric acid.[23] Those types of acylated compounds are very rare in the plant kingdom.[24] A new acylated isorhamnetin triglycoside together with a new triglycoside of tamarixetin were identified from the aerial parts of *Astragalus armatus*.[25]

Several flavanones were isolated from different *Astragalus* species but only two flavanone glycosides from *Astragalus corniculatus* and *Astragalus ponticus* were reported.[26,27] *Astragalus sinicus* is the only one *Astragalus* species documented to contain flavanonols. Ampelopsin and its 3'-glucoside and 3'-xyloside were obtained from this plant.[28] New dihydrochalcone derivative named astradsurnin together with six known chalcones were found in pathogenic-infected *Astragalus adsurgens*.[29] Sulfuretin from *Astragalus microcephalus* is the only one auron isolated from the genus.[30]

Another large and important group is the isoflavonoids. Its relative number compared to those of the flavonols is smaller. The isoflavonoids are more often described as aglycones than as glycosides. They can be divided into two groups: isoflavones and isoflavanes. Many of the isoflavonoids isolated from *Astragalus* species were new natural compounds.[31-33] The first new isoflavan from the the genus – astraciceran was isolated from the fungus-inoculated leaflets of *Astragalus cicer*.[34] Another two new isoflavans, astragaluquinone and 8-methoxyvestitol were reported from the roots of *Astragalus alexandrinus* and *Astragalus trigonus*.[35] A new isoflavone identified as 7-hydroxy-3',5'-dimethoxyisoflavone was found in the aerial parts of *Astragalus peregrinus*.[36]

Astragalus plants are also an object of *in vitro* cultivation because of their economical and traditional therapeutic significance. Flavonoid production from *Astragalus membranaceus*, *Astragalus edulis*, *Astragalus sieberi*, and *Astragalus missouriensis* is one of the targets in biotechnological process optimization.[37-41]

The isolated flavonoid aglycones and glycosides are summarized in Tables 1 and 2.

BIOLOGICAL ACTIVITY

Antioxidant and radioprotective activities

It is known that flavonoids can neutralize different types of oxidizing species including superoxide anion, hydroxyl radical, or peroxy radicals. They may also act as quenchers of singlet oxygen.[179] Total flavonoids, obtained from Radix Astragali demonstrated significant antioxidant activity and inhibited the lipid peroxidation caused by O_2, H_2O_2, and ultraviolet (UV) irradiation.[180,181] Protective effect of total flavonoids from *Astragalus* against DNA strand breaks, caused by hydroxyl radicals, was also observed.[182] Flavanonols from *Astragalus sinicus* showed potent antioxidant activity determined by 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay.[28] Zhang *et al.* compared the antioxidant activity of several extracts from *Astragalus complanatus* obtained by different extraction conditions. They found that the antioxidant capacity, measured by DPPH test highly correlates to the total phenolic content of the corresponding extracts. The high correlation coefficient (0.9476) suggests that the total phenolics in the extracts were the major free radical scavenging components.[183] Flavonoid fraction obtained from the seeds of *Astragalus complanatus* showed significant radioprotective effect against damage induced by *γ*-irradiation in mice. The flavonoid fraction increased the survival rate of the experimental animals and made the damaged organ recover normal appearance with the mechanism of enhancing immunity and blood-producing function. This activity of the flavonoids could be explained with the reduction of DNA injury and mutation *in vitro*.[153] The isoflavon daidzein and its glycoside daidzin showed inhibitory effect on copper and caused oxidative protein modification *in vitro*. The aglycone showed stronger antioxidative effect, which could be explained by its greater affinity for Cu^2 + and copper-chelating ability.[184] Shirataki *et al.* isolated afrormosin, calycosin, and odoratin from the roots of *Astragalus membranaceus* and found that these compounds were active antioxidants with activity superior or similar to those of butyl-hydroxytoluene and *α*-tocopherol.[108] Calycosin obtained from the same plant inhibited lecithin peroxidation induced by hydroxy radicals while both calycosin and formononetin inhibited lecithin peroxidation induced by superoxide anion. The isoflavonoids afrormosin and odoratin did not have any inhibitory effects. These results showed that the antioxidant properties of some isoflavones are derived from the hydroxy groups at the 7' and 4' positions.[185] It was also found that genistein inhibited lecithin peroxidation induced by hydroxy radicals generated from the interaction of hemoglobin and hydrogen peroxide. Daidzein and formononetin inhibited lecithin peroxidation that was induced by superoxide anion generated by xanthine (XA)-xanthine oxidase (XO).[186] The direct antioxidant and neuroprotective effects of isoflavonoids from *Astragalus mongholicus* were investigated using DPPH assay and pheochromocytoma (PC12) cell model. Formononetin, calycosin, and calycosin-7-*O*-glucoside were found to be active against free radicals generated by DPPH in a dose-dependent manner. Formononetin, ononin, and calycosin inhibited the glutamate-induced cell injury, with an estimated 50% effective concentration (EC_{50}) of 0.027 μg.mL^{-1}, 0.047 μg.mL^{1}, and 0.031 μg.mL^{-1}, respectively. Pretreatment with those compounds increased the activities of some antioxidant enzymes and prevented the release of lactate dehydrogenase.[187] Five compounds from *Astragalus mongholicus* including formononetin, ononin, 9,10-dimethoxypterocarpan-3-*O*-*β*-D-glucoside, calycosin, and calycosin-7-*O*-glucoside were tested for protection against superoxide-induced damage of PC12 cells. The latter two compounds were shown to inhibit XA/XO induced injury to PC12 cells. Their EC_{50} values were found to be 0.05 μg.mL^{-1}. Moreover a decrease in the antioxidant enzymes activities was prevented after treatment with the flavonoids. In a cell free system only calycosin and its 7-glucoside inhibited XO activity with IC_{50} 10 and 50 μg.mL^{-1}.[188] Asgarpanah *et al.* examined the antioxidant activity of total phenolic and flavonoid content of *Astragalus squarrosus* by the DPPH test. They found out that the extract had antioxidant potential for chain-breaking inhibition of lipid peroxidation.[189]

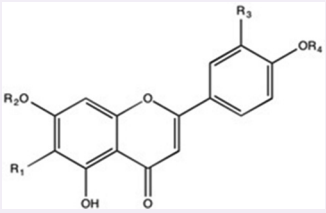
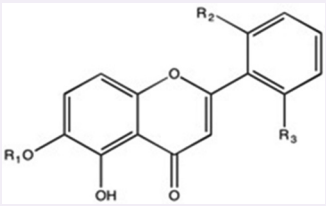
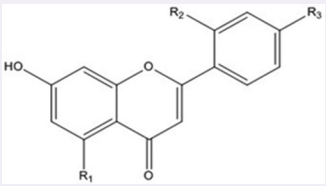
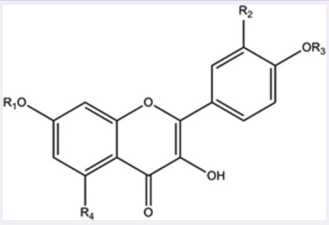
Hepatoprotective and antifibrotic activities

Antifibrotic effect of flavonoids from *Astragalus complanatus* in *in vivo* experiments with rats with induced liver fibrosis was observed. The antifibrotic mechanisms of the flavonoids were related to their influence on lipid peroxidation and collagen synthesis and degradation.[190] Total flavonoid fraction from *Astragalus membranaceus* exerted a protective effect against paracetamol-induced hepatotoxicity in mice. A significant rise in the serum levels of alanine transaminase (ALT) and area of liver necrosis were observed 24 h after paracetamol treatment (400 mg.kg^{-1}). Pretreatment of the animals with the flavonoid fraction (100 mg.kg^{-1}) resulted in reduction of the death rate to 20% and an obvious dose-dependent decrease in ALT levels and the area of hepatocellular necrosis.[191]

Antimicrobial activity

A chalcone and an isoflavan, both isolated from *Astragalus adsurgens*, infected with phytopathogen demonstrated antibacterial activity against five bacterial strains (*Escherichia coli, Bacillus cereus, Staphylococcus aureus, Erwinia carotovora*, and *Bacillus subtilis*) with minimal inhibitory concentrations (MICs) ranging from 7.8 μg.mL^{-1} to 31.3 μg.mL^{-1}.[29] Flavone glycoside, derived from *Astragalus arequipensis* has been shown to possess a wide range of antibacterial activity against both gram-positive and gram-negative bacteria.[55] Astragaluquinone and

Table 1: Flavonoid aglycones isolated from *Astragalus* species

Flavones						
						
Name	**R_1**	**R_2**	**R_3**	**R_4**	**R_5**	***Astragalus* sp.**[References]
Apigenin (5,7,4'-trihydroxyflavone)	H	H	H	H		*A. ammodendron*[42] *A. bombycinus*[18] *A. bungeanus*[43] *A. eremophilus*[44] *A. floccosifolius*[45] *A. inopinatus*[46] *A. macropterum*[47] *A. peregrinus*[36] *A. propinquus*[48] *A. sieberi**[38]
Luteolin (5,7,3',4'-tetrahydroxyflavone)	H	H	OH	H		*A. bombycinus*[18] *A. coluteocarpus*[49] *A. cremophilos*[50] *A. kabadianus*[51] *A. peregrinus*[36] *A. propinquus*[48] *A. quisqualis*[52]
5,7,4'-trihydroxy-3'-methoxyflavone**	H	H	OCH_3	H		*A. eremophilus*[44]
Salvigenin (5-hydroxy-4',6,7-trimethoxyflavone)	OCH_3	CH_3	H	CH_3		*A. brachystachys*[53] *A. propinquus*[48]
Sorbifolin (7-methoxy-4',5,6-trihydroxyflavone)	OH	CH_3	H	H		*A. annularis*[54] *A. trimestris*[54]
5,7,3'-trihydroxy-4'-methoxyflavone**	H	H	OH	CH_3		*A. arequipensis*[55]
						
Zapotinin (5-hydroxy-6,2',6'-trimethoxyflavone)	CH_3	OCH_3	OCH_3			*A. adsurgens*[56]
5,6-dihydroxyflavone**	H	H	H			*A. membranaceus*[57]
						
7-hydroxyflavone	H	H	H			*A. microcephalus*[58]
5,7,2'-trihydroxyflavone	OH	OH	H			*A. cruciatus*[59]
5,7,2',4'-tetrahydroxyflavone**	OH	OH	OH			*A. bombycinus*[18]
FLAVONOLS						
						
Kaempferol (3,5,7,4'-tetrahydroxyflavone)	H	H	H	OH		*A. ammodendron*[42] *A. asper*[60]

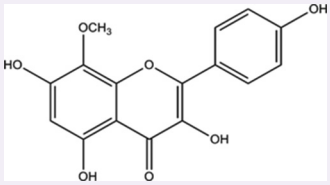
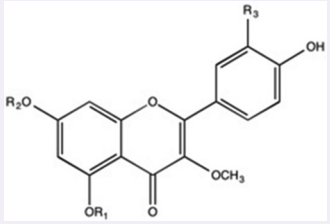
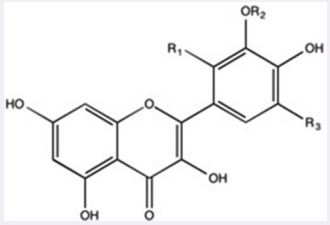
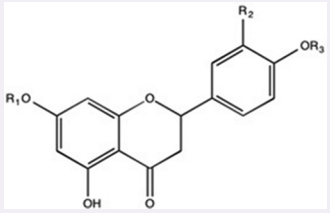
Contd...

Table 1: Contd...

Name	R_1	R_2	R_3	R_4	R_5	*Astragalus* sp.[References]
						A. austrosibiricus[61]
						A. babatagi[62]
						A. beckari[63]
						A. bornmüllerianus[64]
						A. brachycarpus[65]
						A. chinensis[66]
						A. coluteocarpus[49]
						A. corniculatus[26]
						A. cremophilos[50]
						*A. edulis**[39]
						A. eupeplus[67]
						A. floccosifolius[45]
						A. galegiformis[68]
						A. gombiformis[69]
						A. himalayanus[70]
						A. kabadianus[51]
						A. leucocephalus[71]
						A. macropterum[47]
						A. melilotoides[72]
						A. membranaceus[73]
						A. onobrychis[74]
						A. ponticus[27]
						A. quisqualis[52]
						A. sieberi[38]
						A. subrobustus[75]
						A. torrentum[76]
						A. virgatus[77]
5-deoxykaempferol	H	H	H	H		*A. beckari*[63]
Rhamnocitrin (7-methylkaempferol)	CH_3	H	H	OH		*A. complanatus*[78]
						A. gombiformis[69]
						A. hamosus[79]
						A. mongholicus[80]
						A. vogelii[81]
Kaempferide (4'-methoxykaempferol)	H	H	CH_3	OH		*A. complanatus*[82]
Quercetin (3,5,7,3',4'-pentahydroxyflavone)	H	OH	H	OH		*A. asper*[60]
						A. babatagi[62]
						A. beckari[63]
						A. bornmüllerianus[64]
						A. brachycarpus[65]
						A. captiosus[83]
						A. ciceroides[84]
						A. coluteocarpus[49]
						A. corniculatus[26]
						A. cremophilos[50]
						*A. edulis**[39]
						A. eupeplus[67]
						A. eximus[85]
						A. floccosifolius[45]
						A. frigidus[86]
						A. himalayanus[70]
						A. kabadianus[51]
						A. karakuschensis[87]
						A. lasiopetatus[85]
						A. levieri[88]
						A. macropterum[47]
						A. membranaceus[73]
						A. mongholicus[80]
						A. onobrychis[74]
						A. ponticus[89]
						A. quisqualis[52]
						A. schrencianus[85]
						A. sieberi[38]
						A. subrobustus[75]
						A. tectimundi[90]
						A. torrentum[76]
						A. virgatus[77]
Fisetin (5-deoxyquercetin)	H	OH	H	H		*A. beckari*[63]

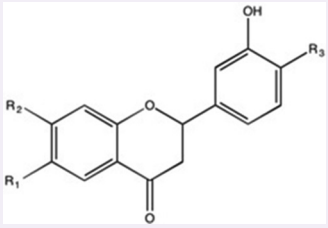
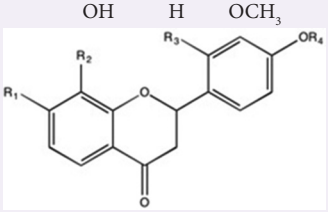
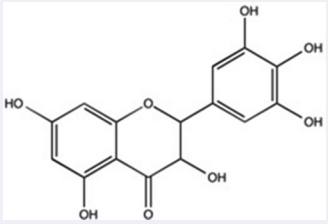
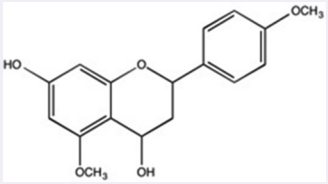
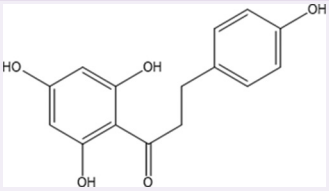
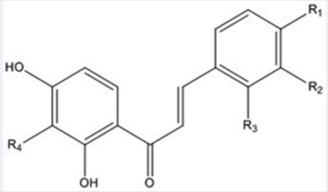
Contd...

Table 1: Contd...

Name	R_1	R_2	R_3	R_4	R_5	*Astragalus* sp.[References]
Rhamnetin (7-methylquercetin)	CH_3	OH	H	OH		*A. floccosifolius*[45]
Isorhamnetin (3,5,7,4'-tetrahydroxy-3'-methoxyflavone)	H	OCH_3	H	OH		*A. adsurgens*[56]
						A. astrosibiricus[61]
						A. corniculatus[26]
						A. dasyanthus[91]
						A. edulis[39]
						A. flexus[92]
						A. floccosifolius[45]
						A. inopinatus[61]
						A. kabadianus[51]
						A. marinus[61]
						A. membranaceus[73]
						A. mongholicus[80]
						A. onobrychis[93]
						A. ponticus[27]
Tamarixetin (4'-methylquercetin)**	H	OH	CH_3	OH		*A. armatus*[25]
						A. miser var. *oblongifolius*[94]
						
8-methoxykaempferol**						*A. spinosus*[95]
						
3-methylqurcetin	H	H	OH			*A. tectimundi*[90]
5,7,4'-trihydroxy-3,3'-dimethoxyflavone	H	H	OCH_3			*A. centralpinus*[96]
4'-hydroxy-3,5,7,3'-tetramethoxyflavone	CH_3	CH_3	OCH_3			*A. centralpinus*[96]
Kumatakenin (5,4'-dihydroxy-3,7-dimethoxyflavone)	H	CH_3	H			*A. centralpinus*[96]
						A. membranceus[97]
						
Myricetin (3,5,7,3',4',5'-hexahydroxyflavone)	H	H	OH			*A. complanatus*[82]
3'-methoxymyricetin (laricitrin)**	H	CH_3	OH			*A. complanatus*[82]
3,5,7,2',3',4'-hexahydroxyflavone**	OH	H	H			*A. complanatus*[98]
FLAVANONES						
						
Naringenin (4',5,7-trihydroxyflavanone)	H	H	H			*A. sinicus*[7]
5-hydroxy-4',7-dimethoxyflavanone	CH_3	H	CH_3			*A. adsurgens*[29]
Eriodictyol (5,7,3',4'-tetrahydroxyflavanone)**	H	OH	H			*A. corniculatus*[26]
Homoeriodictyol (5,7,3'-trihydroxy-4'-methoxyflavanone)	H	OH	CH_3			*A. corniculatus*[27]

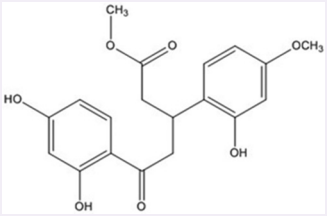
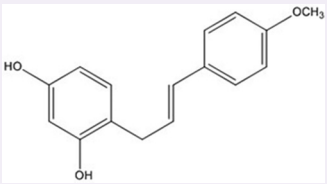
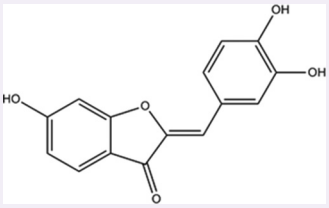
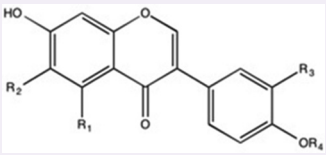
Contd...

Table 1: Contd...

Name	R_1	R_2	R_3	R_4	R_5	*Astragalus* sp.[References]
						
7,3'-dihydroxyflavanone	H	OH	H			*A. centralpinus*[96]
6,3'-dihydroxy-4'-methoxyflavanone	OH	H	OCH_3			*A. adsurgens*[29]
						
Liquiricigenin (7,4'-dihydroxyflavanone)	H	H	H	H		*A. membranceus*[99] *A. microcephalus*[58]
8,2'-dihydroxy-7,4'-dimethoxyflavanone	OCH_3	OH	OH	CH_3		*A. membranaceus*[100]
FLAVANONOLS						
						
Ampelopsin (3',4',5',3,5,7-hexahydroxyflavanonol)						*A. sinicus*[28]
FLAVAN-4-OLS						
						
7-hydroxy-5,4'-dimethoxyflavan-4-ol						*A. centralpinus*[96]
CHALCONES						
						
Phloretin (4-hydroxy-2',4',6'-trihydroxydihydrochalcon)**						*A. ponticus*[27]
						
4,2',4'-trihydroxy-3'-prenylchalcon	OH	H	H	$(CH_3)_2CCHCH_2$		*A. adsurgens*[29]
2',4'-dihydroxy-3,4-dimethoxychalcon	OCH_3	OCH_3	H	H		*A. adsurgens*[29]
4,2',4'-trihydroxychalcon (isoliquiricigenin)	OH	H	H	H		*A. adsurgens*[29] *A. membranaceus*[101]
2',4'-dihydroxy-2,3-dimethoxychalcon	H	OCH_3	OCH_3	H		*A. adsurgens*[29]
2',4'-dihydroxy-4-methoxychalcon	OCH_3	H	H	H		*A. adsurgens*[29]

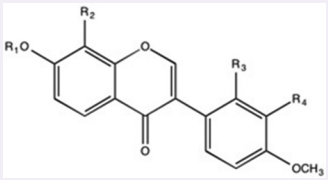
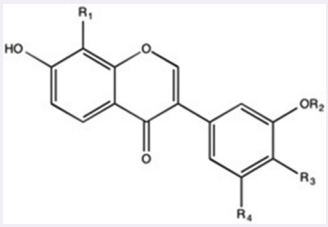
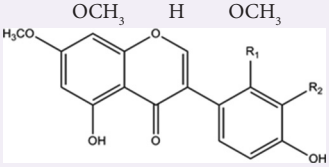
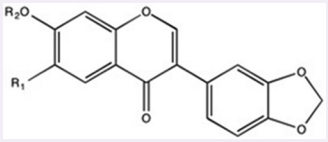
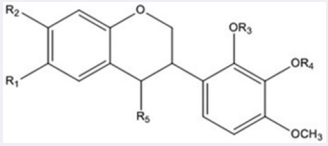
Contd...

Table 1: Contd...

Name	R_1	R_2	R_3	R_4	R_5	*Astragalus* sp.[References]
						
Astradsurnin						*A. adsurgens*[29]
						
2',4'-dihydroxy-4-methoxychalcon						*A. adsurgens*[29]
AURONES						
						
Sulfuretin						*A. microcephalus*[30]
ISOFLAVONES						
						
Genistein (5,7,4'-trihydroxyisoflavone)	OH	H	H	H		*A. membranaceus* var. *mongholicus*[102] *A. peregrinus*[36]
Biochanin A (5,7-dihydroxy-4'-methoxyisoflavone)**	OH	H	H	CH_3		*A. membranaceus* var. *mongholicus*[103]
Daidzein (7,4'-dihydroxyisoflavone)	H	H	H	H		*A. bombycinus*[18] *A. membranceus*[99] *A. peregrinus*[36] *A. sinicus*[7] *A. vogelii*[81]
Formononetin (7-hydroxy-4'-methoxyisoflavone)	H	H	H	CH_3		*A. clucii*[104] *A. complanatus*[78] *A. dahuricus*[105] *A. membranaceus**[37] *A. membranaceus* var. *mongholicus*[106] *A. mongholicus*[107] *A. vogelii*[81]
Cladrin (7-hydroxy-3',4'-dimethoxyisoflavone)	H	H	OCH_3	CH_3		*A. vogelii*[81]
Afrormosin (7-hydroxy-6,4'-dimethoxyisoflavone)	H	OCH_3	H	CH_3		*A. clucii*[104] *A. membranaceus*[108] *A. membranaceus* var. *mongholicus*[100]
Calycosin (7,3'-dihydroxy-4'-methoxyisoflavone)	H	H	OH	CH_3		*A. cicer*[109] *A. complanatus*[98] *A. dahuricus*[105] *A. membranaceus*[110] *A. membranaceus**[37] *A. membranaceus* var. *mongholicus*[106] *A. microcephalus*[58] *A. mongholicus*[107] *A. vogelii*[81]
Odoratin (7,3'-dihydroxy-6,4'-dimethoxyisoflavone)	H	OCH_3	OH	CH_3		*A. membranaceus*[108] *A. mongholicus*[111]

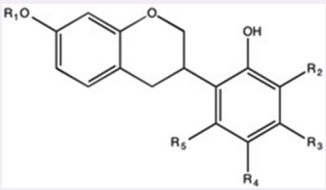
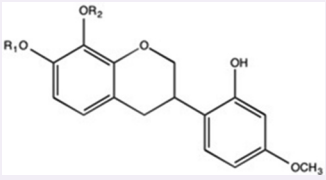
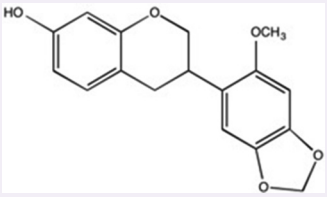
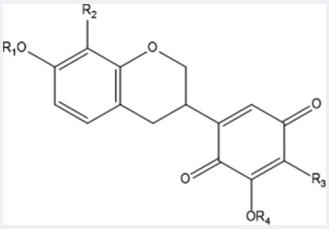
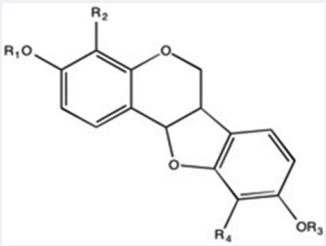
Contd...

Table 1: Contd...

Name	R_1	R_2	R_3	R_4	R_5	*Astragalus* sp.[References]
Pratensein (5,7,3'-trihydroxy-4'-methoxyisoflavone)	OH	H	OH	CH3		*A. membranaceus*[112] *A. membranaceus* var. *mongholicus*[102] *A. verrucosus*[7]
5,7-dihydroxy-4'-methoxyisoflavone	OH	H	H	CH_3		*A. adsurgens*[29]
5,7,4'-trihydroxy-3'-methoxyisoflavone	OH	H	OCH_3	H		*A. abyssinicus*[113] *A. membranaceus* var. *mongholicus*[103]
						
7,4'- dimethoxyisoflavone	CH_3	H	H	H		*A. adsurgens*[29]
7,2'-dihydroxy-3',4'-dimethoxyisoflavone**	H	H	OH	OCH_3		*A. membranaceus* var. *mongholicus*[114]
8,2'-dihydroxy-7,4'-dimethoxyisoflavone	CH_3	OH	OH	H		*A. membranaceus* var. *mongholicus*[114]
8,3'-dihydroxy-7,4'-dimethoxyisoflavone	CH_3	OH	H	OH		*A. membranaceus*[57] *A. membranaceus**[37]
7,3'-dihydroxy-4'-methoxyisoflavone	H	H	H	OH		*A. adsurgens*[29]
						
7,5'-dihydroxy-3'-methoxyisoflavone**	H	CH_3	H	OH		*A. membranaceus*[115]
7-hydroxy-3',5'-dimethoxyisoflavone	H	CH_3	H	OCH_3		*A. peregrinus*[36]
7,3'-dihydroxy-8,4'-dimethoxyisoflavone	OCH_3	H	OCH_3	H		*A. membranaceus*[57]
						
Cajanin (5,2',4'-trihydroxy-7-methoxyisoflavone)	OH	H				*A. cicer*[31]
Santal (5,3',4'-trihydroxy-7-methoxyisoflavone)	H	OH				*A. hoantchy*[116]
						
Acicerone (6-hydroxy-7-methoxy-3',4'-methylenedioxyisoflavone)	OH	CH_3				*A. cicer*[117]
Pseudobartigenin (7-hydroxy-3',4'-methylenedioxyisoflavone)	H	H				*A. cicer*[109]
ISOFLAVANES						
						
Spherosine (7-hydroxy-2',3',4'-trimethoxyisoflavane)	H	OH	CH_3	CH_3	H	*A. alexandrinus*[35] *A. orbiculatus*[118] *A. trigonus*[35]
6,3'-dihydroxy -2',4'-dimethoxyisoflavane**	OH	H	CH_3	H	H	*A. hoantchy*[116]
(3R)-7,2',3'-trihydroxy -4'-methoxyisoflavane	H	OH	H	H	H	*A. membranaceus*[119]
(3R)-2'-hydroxy-7,3',4'-trimethoxyisoflavane	H	OCH_3	H	CH_3	H	*A. membranaceus*[120]
Mucronulatol (3R-(-)-7,3'-dihydroxy-2',4'-dimethoxyisoflavane)	H	OH	CH_3	H	H	*A. adsurgens*[56] *A. cicer*[31] *A. lusitanicus*[121]
(3R,4R)-3-(2-hydroxy-3,4-dimethoxyphenyl)-chroman-4,7-diol**	H	OH	H	CH_3	OH	*A. membranaceus*[33]

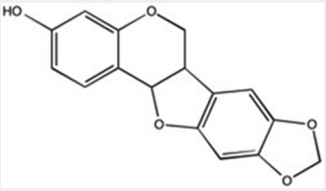
Contd...

Table 1: Contd...

Name	R_1	R_2	R_3	R_4	R_5	*Astragalus* sp.[References]
						
Isomucronulatol (7,2'-dihydroxy-3',4'-dimethoxyisoflavane)	H	OCH_3	OCH_3	H	H	*A. cicer*[34] *A. dahuricus*[105] *A. hoanthy*[116] *A. membranaceus*[99]
5'-hydroxy-isomucronulatol**	H	OCH_3	OCH_3	OH	H	*A. mongholicus*[32]
7-O-methylisomucronulatol	CH_3	OCH_3	OCH_3	H	H	*A. membranaceus*[120]
(3R)-7,2'-dihydroxy-5',6'-dimethoxyisoflavane**	H	H	H	OH	OH	*A. membranaceus*[110]
						
(3S)-8-methoxyvestitol (7,2'-dihydroxy-8,4'-dimethoxyisoflavane)	H	CH_3				*A. alexandrinus*[35]
(3R)-8,2'-dihydroxy-7,4'-dimethoxyisoflavane	CH_3	H				*A. trigonus*[35] *A. trimestris*[54] *A. dahuricus*[105] *A. membranaceus*[119] *A. membranaceus**[37]
						
Astraciceran (7-hydroxy-2'-methoxy-4',5'-methylenedioxyisoflavane)						*A. cicer*[34]
						
Astragaluquinon (1-[(3R)-7,8-dimethoxybenzopyran-3-yl]-3-hydroxybenzoquinone)	CH_3	OCH	H	H		*A. alexandrinus*[35]
Pendulione (7-nydroxy-3',4'-dimethoxyflavanquinone)	H	H	OCH_3	CH_3		*A. trigonus*[35] *A. hoanthy*[116]
PTEROCARPANS						
						
Medicarpin (3-hydroxy-9-methoxypterocarpan)	H	H	CH_3	H		*A. cicer*[109]
Methylnissolin (6aR,11aR)-3-hydroxy-9,10-dimethoxypterocarpan)	H	H	CH_3	OCH_3		*A. membranaceus*[122] *A. membranaceus* var. *mongholicus*[103] *A. mongholicus*[122]

Contd...

Table 1: Contd...

Name	R_1	R_2	R_3	R_4	R_5	*Astragalus* sp.[References]
(6aR,11aR)-10-hydroxy-3,9-dimethoxypterocarpan	CH_3	H	CH_3	OH		*A. membranaceus*[120] *A. membranaceus**[37] *A. membranaceus var. mongholicus*[100]
(6aR,11aR)-3,9,10-trimethoxypterocarpan	CH_3	H	CH_3	OCH_3		*A. membranaceus*[120] *A. mongholicus*[32]
Melilotocarpan B (4,9-dihydroxy-3-methoxypterocarpan)	CH_3	OH	H	H		*A. adsurgens*[29]
						
Maackianin (3-hydroxy-8,9-methylenedioxypterocarpan)						*A. cicer*[31] *A. trojanus*[123]

*Flavonoids isolated from shoot and tissue cultures. **Known only as glycosides

Table 2: Flavonoid glycosides isolated from *Astragalus* species

FLAVONES			
Name	**Ag***	**Sugar moiety**	***Astragalus* sp.**[References]
Cosmosinin	1	7-*O*-*β*-D-glc	*A. ammodendron*[42] *A. bombycinus*[18] *A. cremophillos*[50] *A. glycyphyllos*[124] *A. kadshorensis*[125] *A. macropterum*[47] *A. peregrinus*[79] *A. trimestris*[126]
-	1	7-*O*-*α*-L-rha	*A. trimestris*[126]
Isorhoifolin	1	7-*O*-*α*-L-rha-(1→6)-*β*-D-glc	*A. onobrychis*[74] *A. trimestris*[127]
-	1	7-*O*-*α*-L-rha-(1→2)-*β*-D-glc	*A. peregrinus*[36]
Apiin	1	7-*O*-*β*-D-api-(1→2)-*β*-D-glc	*A. cicer*[128] *A. eremophilus*[44]
Vitexin	1	8-*C*-*β*-D-glc	*A. corniculatus*[26] *A. ponticus*[27]
-	1	7-*O*-*β*-D-glc-(1→3)-*β*-D-glc	*A. trimestris*[54]
-	1	7-*O*-*β*-D-glc-(1→6)-*β*-D-glc	*A. bombycinus*[18]
Cinarozid	2	7-*O*-*β*-D-glc	*A. bombycinus*[18] *A. ciceroides*[84] *A. circassicus*[129] *A. cremophilos*[50]
Skolimozid	2	7-*O*-*α*-L-rha-(1→2)-*β*-D-glc	*A. melilotoides*[72]
Graveobioside A	2	7-*O*-*β*-D-api-(1→2)-*β*-D-glc	*A. eremophilus*[44]
Orientin	2	8-C-*β*-D-glc	*A. corniculatus*[26]
Graveobioside B	3	7-*O*-*β*-D-api-(1→2)-*β*-D-glc	*A. eremophilus*[44]
Baikalin	8	7-*O*-glucuronic acid	*A. membranaceus*[57]
-	11	7-*O*-*β*-D-glc; 8-*C*-*α*-arabinopyranoside	*A. bombycinus*[18]
FLAVONOLS			
-	12	3-*O*-*α*-L-ara	*A. angustifolius*[130]
-	12	3-*O*-*β*-D-xyl	*A. maximus*[131]
Trifolin	12	3-*O*-*β*-D-gal	*A. adsurgens*[129] *A. arguricus*[129] *A. brachycarpus*[65] *A. bungeanus*[129] *A. circassicus*[129] *A. dipelta*[132] *A. galegifolius*[133] *A. goktschaicus*[129] *A. interpositus*[129] *A. lagurus*[134] *A. maximus*[133]

Contd...

Table 2: Contd...

Name	Ag*	Sugar moiety	*Astragalus* sp.[References]
			A. sevangensis[129]
			A. subrobustus[75]
			A. torrentum[76]
Astragalin	12	3-*O*-*β*-D-glc	*A. adsurgens*[56]
			A. aitosensis[135]
			A. ammodendron[42]
			A. angustifolius[136]
			A. arguricus[129]
			A. asper[60]
			A. bornmüllerianus[64]
			A. brachycarpus[137]
			A. bungeanus[129]
			A. captiosus[83]
			A. circassicus[129]
			A. coluteocarpus[49]
			A. complanatus[82]
			A. cremophilos[50]
			A. dipelta[132]
			A. flexus[92]
			A. floccosifolius[45]
			A. galegiformis[85]
			A. galegifolius[133]
			A. glycyphyllos[124]
			A. goktschaicus[129]
			*A. hamosus***[39]
			A. hamosus[138]
			A. interpositus[129]
			A. karakuschensis[87]
			A. lagurus[134]
			A. lasioglottis[137]
			A. levieri[88]
			A. onobrychis[137]
			A. polygala[137]
			A. sevangensis[88]
			A. sieberi[38]
			A. sinicus[17]
			A. spinosus[95]
			A. subrobustus[75]
			A. tana[139]
			A. testiculatus[140]
			A. tectimundi[90]
			A. torrentum[76]
			A. virgatus[77]
Populin	12	7-*O*-*β*-D-glc	*A. dipelta*[132]
			A. floccosifolius[45]
			A. lagurus[134]
			A. polygala[137]
			A. virgatus[77]
-	12	3,7-di-*O*-*β*-D-glc	*A. spinosus*[95]
-	12	3-*O*-*β*-D-glc; 4'-*O*-*β*-D-glc	*A. complanatus*[98]
-	12	3-*O*-*β*-D-xyl-(1→2)-*β*-D-glc	*A. complanatus*[98]
-	12	3-*O*-*α*-L-rha-(1→6)-*β*-D-gal	*A. tana*[139]
Nicotiflorin	12	3-*O*-*α*-L-rha-(1→6)-*β*-D-glc	*A. abyssinicus*[113]
			A. adsurgens[141]
			A. ammodendron[42]
			A. angustifolius[130]
			A. armatus[25]
			A. complanatus[16]
			A. cruciatus[59]
			A. eremophilus[44]
			A. falcatus[142]
			A. onobrychis[74]
			A. ponticus[89]
			A. sieberi[38]
			A. tana[139]
-	12	3-*O*-*β*-D-glc-(1→6)-*β*-D-glc	*A. spinosus*[95]
-	12	3-O-*α*-L-rha-(1→4)-*α*-L-rha-(1→6)-*β*-D-glc	*A. cruciatus*[59]

Contd...

Table 2: Contd...

Name	Ag*	Sugar moiety	*Astragalus* sp.[References]
-	12	3-O-α-L-rha-(1→6)-β-D-glc; 7-*O*-α-L-rha	*A. cicer*[128]
-	12	3-*O*-α-L-rha-(1→2)-β-D-gal; 7-*O*-α-L-rha	*A. shikokianus*[143]
Ascaside	12	3-*O*-[α-L-rha-(1→3)-α-L-rha-(1→4)]-β-D-gal	*A. caucasicus*[144]
			A. galegiformis[131]
-	12	3-*O*-β-D-xyl-(1→2)-α-L-rha	*A. microcephalus*[58]
Robinin	12	3-O-α-L-rha-(1→6)-β-D-gal; 7-O-α-L-rha	*A. adsurgens*[141]
			A. astrosibiricus[145]
			A. dipelta[132]
			A. eupeplus[67]
			A. falcatus[21]
			A. karakuschensis[87]
			A. levieri[88]
			A. polygala[146]
			A. shikokianus[143]
			A. torrentum[76]
-	12	3-*O*-β-D-api-(1→2)-α-L-rha-(1→6)-β-D-glc	*A. sinicus*[28]
-	12	3-*O*-β-D-api-(1→2)-β-D-glc; 4'-β-D-glc	*A. complanatus*[98]
-	12	3-*O*-[β-D-xyl-(1→3)-α-L-rha-(1→6)]-β-D-gal	*A. caprinus***[23]
Astrasikokiosid	12	3-O-[α-L-rha-(1→6)-α-L-rha-(1→2)]-β-D-gal; 7-O-α-L-rha	*A. shikokianus*[143]
-	12	3-*O*-[β-D-xyl-(1→3)-α-L-rha-(1→6)][β-D-api-(1→2)]-β-D-gal	*A. caprinus*[22]
-	12	3-*O*-[β-D-xyl-(1→3)-α-L-rha-(1→6)][α-L-rha-(1→2)]-β-D-gal	*A. caprinus*[147]
-	12	3-*O*-{[β-D-xyl-(1→3)-α-L-rha-(1→6)][α-L-rha-(1→2)]}-β-D-(3-transferuloyl)-gal	*A. caprinus*[147]
-	12	3-*O*-{[β-D-xyl-(1→3)-α-L-rha-(1→6)][α-L-rha-(1→2)]}-β-D-(3-coumaroyl)-gal	*A. caprinus*[147]
-	12	3-*O*-{[β-D-xyl-(1→3)-α-L-rha-(1→6)][α-L-rha-(1→2)]}-β-D-(4-trans feruloyl)-gal	*A. caprinus*[147]
-	12	3-*O*-{[β-D-xyl-(1→3)-α-L-rha-(1→6)][α-L-rha-(1→2)]}-β-D-(4-coumaroyl)-gal	*A. caprinus*[147]
Mauritianin	12	3-O-α-L-rha-(1→2)[α-L-rha-(1→6)]-β-D-gal	*A. armatus*[25]
			A. sieberi[38]
-	12	3-O-α-L-rha-(1→2)[α-L-rha-(1→6)]-β-D-glc	*A. armatus*[25]
-	12	3-O-α-L-rha-(1→2)[6-O-(3-hydroxy-3-methylglutaryl)]-β-D-gal	*A. gombiformis*[69]
-	12	3-O-α-L-rha-(1→4)[α-L-rha-(1→6)]-β-D-glc	*A. abyssinicus*[113]
-	14	3-*O*-β-D-glc	*A. complanatus*[82]
			A. hamosus[126]
			A. membranaceus[148]
			A. turkestanicus[149]
			A. vogelii[81]
-	14	3-*O*-β-D-gal	*A. vogelii*[81]
-	14	3-*O*-α-L-rha-(1→2)-β-D-glc	*A. vogelii*[81]
-	14	3-*O*-α-L-rha-(1→2)-β-D-gal	*A. gombiformis*[69]
-	14	-O-α-L-rha-(1→2)[6-O-(3-hydroxy-3-methylglutaryl)]-β-D-gal	*A. gombiformis*[69]
-	14	3-*O*-β-D-glc-(1→6)-β-D-glc	*A. hamosus*[79]
-	14	3-*O*-β-D-glc-(1→2)-α-L-rha	*A. hamosus*[27]
-	14	4'-*O*-β-D-gal	*A. hamosus*[138]
Propingosid	14	3-*O*-α-L-ara	*A. propinguus*[150]
Complanatosid	14	3-*O*-β-D-glc; 4'-*O*-β-D-glc	*A. complanatus*[151]
-	14	3-*O*-β-D-gal; 4'-*O*-β-D-glc	*A. vogelii*[44]
Neocomplanatosid	14	3-*O*-(6-acetyl)-β-D-glc	*A. complanatus*[82]
-	14	3-*O*-β-D-api-(1→2)-β-D-gal	*A. vogelii*[44]
-	14	3-*O*-β-D-api-(1→2)-β-D-glc	*A. complanatus*[98]
-	14	3-*O*-β-D-api-(1→2)-β-D-glc; 4'-*O*-β-D-glc	*A. complanatus*[98]
-	14	3-*O*-β-D-api-(1→2)-β-D-gal; 4'-*O*-β-D-glc	*A. vogelii*[44]
-	14	3-*O*-[(5-coumaryl)-β-D-api-(1→2)]-β-D-glc	*A. complanatus*[20]
-	14	3-*O*-[(5-feruloyl)-β-D-api-(1→2)]-β-D-glc	*A. complanatus*[20]
Complanatin I	14	3-*O*-β-D-glc; 4'-*O*-(2"-*O*-dihydrofazeoyl)-β-D-glc	*A. complanatus*[6],[19]
Complanatin II	14	3-*O*-β-D-glc; 4'-*O*-(3"-*O*-dihydrofazeoyl)-β-D-glc	*A. complanatus*[6],[20]
-	14	3-*O*-[6-(3-hydroxy-3-methylglutaryl)][β-D-api-(1→2)]-β-D-gal	*A. caprinus*[23]
-	15	3-*O*-β-D-glc	*A. mongholicus*[152]
-	15	3-*O*-α-L-ara	*A. complanatus*[82]
-	15	3-*O*-β-D-glc; 7-*O*-β-D-glc	*A. vogelii*[81]
Isoquercitrin	16	3-*O*-β-D-glc	*A. adsurgens*[56]
			A. angustifolius[136]
			A. arguricus[129]
			A. asper[60]
			A. bornmüllerianus[64]
			A. brachycarpus[65]
			A. bungeanus[129]
			A. captiosus[83]
			A. ciceroides[84]

Contd...

Table 2: Contd...

Name	Ag*	Sugar moiety	*Astragalus* sp.[References]
			A. circassicus[129]
			A. complanatus[153]
			A. corniculatus[26]
			A. frigidus[86]
			A. goktschaicus[129]
			*A. hamosus***[39]
			A. hamosus[138]
			A. interpositus[129]
			A. karakuschensis[87]
			A. lagurus[129]
			A. membranaceus[148]
			*A. missouriensis***[39]
			A. mongholicus[152]
			A. onobrychis[137]
			A. peduncularis[90]
			A. ponticus[89]
			A. sevangenzis[129]
			A. virgatus[77]
			A. vogelii[81]
Hyperoside	16	3-*O*-*β*-D-gal	*A. arguricus*[129]
			A. babatagi[62]
			A. brachycarpus[154]
			A. bungeanus[129]
			A. circassicus[129]
			A. cicer[27]
			A. coluteocarpus[49]
			A. corniculatus[26]
			A. eupeplus[67]
			A. goktschaicus[129]
			A. hamosus[138]
			A. karakuschensis[87]
			A. lagurus[134]
			A. levieri[88]
			A. macropterum[47]
			A. missouriensis[41]
			A. onobrychis[93]
			A. ponticus[89]
			A. quisqualis[52]
			A. sevangenzis[88]
			A. subrobustus[75]
Quercitrin	16	3-*O*-*α*-L-rha	*A. arguricus*[129]
			A. babatagi[62]
			A. bornmüllerianus[64]
			A. bungeanus[129]
			A. circassicus[129]
			A. corniculatus[27]
			A. cremophilos[50]
			A. floccosifolius[45]
			A. frigidus[86]
			A. goktschaicus[129]
			A. interpositus[129]
			A. lagurus[134]
			A. melilotoides[72]
			A. sevangenzis[129]
-	16	3-*O*-*α*-L-ara	*A. complanatus*[153]
Quercimetrin	16	7-*O*-*β*-D-glc	*A. asper*[60]
			A. flexus[155]
			A. lagurus[134]
Rutin	16	3-O-*α*-L-rha-(1→6)-*β*-D-glc	*A. abyssinicus*[113]
			A. adsurgens[56]
			A. aitosensis[135]
			A. altaicus[156]
			A. angustifolius[136]
			A. arguricus[129]
			A. asper[60]
			A. babatagi[62]
			A. bornmüllerianus[64]

Contd...

Table 2: Contd...

Name	Ag*	Sugar moiety	*Astragalus* sp.[References]
			A. bungeanus[129]
			A. captiosus[83]
			A. ciceroides[84]
			A. cicer[27]
			A. circassicus[129]
			A. coluteocarpus[49]
			A. corniculatus[26]
			A. cremophilos[50]
			A. eupeplus[67]
			A. flexus[92]
			A. floccosifolius[45]
			A. goktschaicus[129]
			A. hamosus[39]
			A. himalayanus[70]
			A. interpositus[129]
			A. kabadianus[51]
			A. karakuschensis[87]
			A. lasioglottis[137]
			A. levieri[88]
			A. macropterum[47]
			A. melilotoides[72]
			A. membranaceus[157]
			*A. missouriensis***[39]
			A. onobrychis[74]
			A. peduncularis[90]
			A. ponticus[89]
			A. quisqualis[52]
			A. rubrivenosum[85]
			A. sevangenzis[88]
			A. tectimundi[90]
			A. torrentum[76]
-	16	3-*O*-*β*-D-glc; 7-*O*-*β*-D-glc	*A. bombycinus*[18]
			A. tectimundi[90]
			A. vogelii[81]
-	16	3-*O*-*β*-D-glc; 7-*O*-*α*-L-rha	*A. bombycinus*[18]
-	16	3-*O*-*β*-D-glc; 7-*O*-*β*-D-glc; 4'-*O*-*α*-L-rha	*A. bombycinus*[18]
-	16	3-*O*-*β*-D-glc-(1→6)-*α*-L-rha	*A. propinguus*[150]
-	16	3-*O*-*β*-D-xyl-(1→2)-*β*-D-glc	*A. sinicus*[28]
-	16	3-O-*α*-L-rha-(1→6)-*β*-D-gal	*A. captiosus*[83]
-	16	3-O-*α*-L-rha-(1→4) [*α*-L-rha-(1→6)]-*β*-D-glc	*A. abyssinicus*[113]
Flagaloside C	16	3-*O*-*β*-D-gal-(6→1)-*O*-*α*-L-rha-(3→1)-*O*-*β*-D-xyl	*A. galegiformis*[68]
Clovin	16	3-*O*-*α*-L-rha-(1→6)-*β*-D-gal; 7-*O*-*β*-D-glc	*A. shikokianus*[143]
-	16	3-*O*-[*β*-D-xyl-(1→3)-*α*-L-rha(1→6)][*β*-D-api-(1→2)]-*β*-D-gal	*A. caprinus*[23]
-	16	3-*O*-*β*-D-glc-(1→6)-*β*-D-glc	*A. vogelii*[81]
Falkozid C	16	3-*O*-[*β*-D-glc-(1→3)-*α*-L-rha(1→6)]-*β*-D-gal;7-*O*-*β*-D-glc	*A. falcatus*[21]
-	22	7-*O*-*β*-D-glc	*A. tectimundi*[90]
-	18	3-*O*-*β*-D-glc	*A. hamosus*[79]
-	18	3-*O*-*β*-D-gal	*A. floccosifolius*[45]
			A. gombiformis[69]
-	18	3-*O*-{[3-hydroxy-3-methylglutaroyl-(1→6)][*β*-D-api-(1→2)]}-*β*-D-gal	*A. caprinus*[23]
-	18	3-*O*-*α*-L-rha-(1→2)-*β*-D-gal	*A. gombiformis*[69]
-	18	3-*O*-*α*-L-rha-(1→2)[6-*O*-(3-hydroxy-3-methylglutaryl]-*β*-D-gal	*A. gombiformis*[69]
-	19	3-*O*-*β*-D-glc	*A. adsurgens*[141]
			A. aitosensis[135]
			A. angustifolius[130]
			A. annularis[54]
			A. astrosibiricus[61]
			A. captiosus[83]
			A. centralpinus[96]
			A. cicer[128]
			A. corniculatus[26]
			A. flexus[92]
			A. floccosifolius[45]
			A. glycyphyllos[124]
			A. kabadianus[51]
			A. karakuschensis[87]
			A. lusitanicus[121]

Contd...

Table 2: Contd...

Name	Ag*	Sugar moiety	*Astragalus* sp.[References]
			A. miser var. *oblongifolius*[94]
			A. mongholicus[152]
			A. onobrychis[93]
			A. ponticus[27]
			A. propinguus[150]
			A. pubiflorus[158]
			A. saganlugensis[84]
			A. tribuloides[159]
			A. virgatus[77]
Cacticin	19	3-*O*-*β*-D-gal	*A. floccosifolius*[45]
			A. kabadianus[51]
-	19	3-*O*-*β*-D-ara	*A. angustifolius*[130]
-	19	7-O-*α*-L-rha	*A. astrosibiricus*[145]
			A. centralpinus[96]
-	19	3-*O*-*β*-D-glc; 7-*O*-*β*-D-glc	*A. galegiformis*[160]
-	19	3-*O*-*β*-D-glc; 7-*O*-*α*-L-rha	*A. adsurgens*[141]
			A. astrosibiricus[61]
Astragaloside	19	3-*O*-*β*-D-glc-(1→6)-*β*-D-glc	*A. altaicus*[156]
			A. brachycarpus[146]
			A. centralpinus[96]
			A. dasyanthus[91]
			A. novoaskanicus[161]
			A. onobrychis[146]
			A. pubiflorus[162]
			A. quisqualis[52]
			A. torrentum[76]
			A. vogelii[81]
Narcissine	19	3-*O*-*β*-D-glc-(1→6)-*α*-L-rha	*A. altaicus*[156]
			A. armatus[25]
			A. centralpinus[96]
			A. cruciatus[59]
			A. dasyanthus[91]
			A. eremophilus[44]
			A. galegiformis[85]
			A. icmadophilus[163]
			A. levieri[88]
			A. lusitanicus[121]
			A. maximus[133]
			A. propinguus[150]
			A. pubiflorus[158]
			A. sevangenzis[88]
			A. torrentum[76]
			A. virgatus[77]
			A. vogelii[81]
Flagaloside D	19	3-*O*-*β*-D-xyl-(2→1)-*β*-D-xyl	*A. galegiformis*[68]
Dactylin	19	3-*O*-*β*-D-glc; 4'-*O*-*β*-D-glc	*A. galegiformis*[160]
			A. lasioglottis[137]
-	19	3-O-*α*-L-rha-(1→6)-*β*-D-glc	*A. annularis*[54]
			A. corniculatus[26]
			A. ponticus[27]
-	19	3-*O*-*α*-L-rha-(1→6)-*β*-D-gal	*A. vulneraria*[164]
-	19	3-O-*β*-D-api-(1→2)-[*α*-L-rha-(1→6)]-*β*-D-glc	*A. vulneraria*[164]
-	19	3-O-*α*-L-ara-*α*-L-rha	*A. angustifolius*[130]
Falkozid D	19	3-*O*-*β*-D-xyl-(1→3)-[*α*-L-rha-(1→6)]-*β*-D-glc; 7-*O*-*α*-L-rha	*A. falcatus*[21]
-	19	3-*O*-[(4‴-p-hydroxy-benzoyl)-*α*-api-(1→2)][*α*-L-rha (1→6)]-*β*-D-gal	*A. armatus*[25]
-	19	3-*O*-*α*-api-(1→2)-[*α*-L-rha-(1→6)]-*β*-D-gal	*A. armatus*[25]
-	19	3-*O*-*α*-L-rha-(1→2)-[*α*-L-rha-(1→6)]-*β*-D-gal	*A. armatus*[25]
Microcephalin I	19	3-*O*-*β*-D-api-(1→3)-*β*-D-glc	*A. microcephalus*[165]
Microcephalin II	19	3-*O*-*α*-L-rha-(1→3)-*β*-D-glc	*A. microcephalus*[165]
-	20	3-*O*-*β*-D-glc	*A. miser var. oblongifolius*[94]
-	20	3-*O*-*α*-api-(1→2)-[*α*-L-rha-(1→6)]-*β*-D-glc	*A. armatus*[25]
-	21	3-*O*-*β*-D-glc; 4'-*O*-D-rha	*A. spinosus*[95]
-	26	3-*O*-*β*-D-glc	*A. complanatus*[98]
-	26	3'-*O*-*β*-D-glc	*A. sinicus*[28]
-	26	3'-*O*-*β*-D-xyl	*A. sinicus*[28]
-	26	3-*O*-*β*-D-xyl-(1→2)-*β*-D-glc	*A. complanatus*[98]
Myricomplanosid	27	5'-*O*-*β*-D-glc	*A. complanatus*[82]

Contd...

Table 2: Contd...

Name	Ag*	Sugar moiety	*Astragalus* sp.[References]
-	27	3-*O*-*β*-D-glc	*A. complanatus*[153]
Cannabiscitrin	28	2'-*O*-*β*-D-glc	*A. complanatus*[98]
FLAVANONES			
-	31	7-*O*-*β*-D-glc	*A. corniculatus*[26]
-	31	7-*O*-*α*-L-rha-(1→6)-*β*-D-glc	*A. corniculatus*[27]
			A. ponticus[27]
FLAVANONOLS			
-	37	3'-*O*-*β*-D-glc	*A. sinicus*[28]
-	37	3'-*O*-*β*-D-xyl	*A. sinicus*[28]
CHALCONES			
Phloridzin	39	2'-*β*-D-glc	*A. ponticus*[27]
			A. corniculatus[27]
ISOFLAVONES			
Ononin	51	7-*O*-*β*-D-glc	*A. complanatus*[98]
			A. membranaceus[33]
			A. membranaceus var. mongholicus[166]
			A. mongholicus[122]
-	51	7-*O*-*β*-D-glc-(6"-acetate)	*A. membranaceus*[112]
			A. membranaceus var. mongholicus[103]
			A. mongholicus[112]
-	51	7-*O*-*β*-D-glc-(6"-malonate)	*A. membranaceus*[122]
Sissotrin	49	7-*O*-*β*-D-glc	*A. membranaceus var. mongholicus*[103]
-	53	7-*O*-*β*-D-glc	*A. membranaceus*[112]
-	53	7-*O*-*β*-D-glc-(6"-malonate)	*A. membranaceus*[112]
-	54	7-*O*-*β*-D-glc	*A. complanatus*[167]
			A. ernestii[168]
			A. membranaceus[57]
			A. membranaceus var. *mongholicus*[166]
			A. mongholicus[122]
-	54	7-*O*-*β*-D-glc-(6"-malonate)	*A. membranaceus*[122]
			A. mongholicus[122]
-	54	7-*O*-*β*-D-glc-(6"-acetate)	*A. membranaceus*[169]
			A. membranaceus var. *mongholicus*[170]
			A. mongholicus[112]
-	54	7-*O*-*β*-D-{6"-[(E)-but-2-enoyl]}-glc	*A. membranaceus var. mongholicus*[171]
-	54	3'-*O*-*β*-D-glc	*A. membranaceus*[172]
-	55	7-*O*-*β*-D-glc	*A. ernestii*[168]
			A. membranaceus[119]
			A. mongholicus[111]
Astroside	57	7-*O*-*β*-D-glc	*A. austriacus*[173]
-	64	7-*O*-*β*-D-glc	*A. membranaceus*[115]
-	56	7-*O*-*β*-D-glc	*A. membranaceus* var. *mongholicus*[114]
			A. membranaceus[112]
-	60	7-*O*-*β*-D-glc	*A. membranaceus* var. *mongholicus*[114]
Daidzin	50	7-*O*-*β*-D-glc	*A. verrucosus*[174]
			A. membranaceus[101]
ISOFLAVANES			
-	72	6-*O*-*β*-D-glc	*A. ernestii*[168]
			A. hoantchy[116]
			A. membranaceus var. *mongholicus*[100]
Astraisoflavanin	75	7-*O*-*β*-D-glc	*A. membranaceus*[175]
-	77	7-*O*-*β*-D-glc	*A. chrysopterus*[176]
			A. dahuricus[105]
			A. membranaceus[176]
			*A. membranaceus***[37]
			A. membranaceus var. *mongholicus*[177]
			A. mongholicus[107]
-	77	7-*O*-*β*-D-glc; 2'-*O*-*β*-D-glc	*A. membranaceus*[99]
			A. mongholicus[32]
-	78	2'-*O*-*β*-D-glc; 5'-*O*-*β*-D-glc	*A. mongholicus*[32]
-	77	7-*O*-*β*-D-glc-(6"-acetate)	*A. membranaceus* var. *mongholicus*[103]
-	77	7-*O*-*β*-D-glc-(6"-malonate)	*A. membranaceus*[122]
			A. mongholicus[122]

Contd...

Table 2: Contd...

Name	Ag*	Sugar moiety	*Astragalus* sp.[References]
-	80	7-*O*-*β*-D-glc	*A. membranaceus*[110]
Astraganoside	76	7-*O*-*β*-D-glc	*A. membranaceus*[33]
PTEROCARPANS			
-	87	3-*O*-*β*-D-glc	*A. dahuricus*[105] *A. membranaceus*[120] *A. membranaceus* var. *mongholicus*[178] *A. mongholicus*[107]
-	87	3-*O*-*β*-D-(6”-acetyl)-glc	*A. membranaceus*[169] *A. membranaceus* var. *mongholicus*[103]
-	87	3-*O*-*β*-D-{6”-[(*E*)-but-2-enoyl]}-glc	*A. membranaceus*[169]
-	87	3-*O*-*β*-D-(6”-malonate)-glc	*A. membranaceus*[122] *A. mongholicus*[122]

Ag* Flavonoid aglycon. **Flavonoids isolated from shoot and tissue cultures

8-methoxyvestitol from the roots of *Astragalus alexandrinus* and *Astragalus trigonus* demonstrated weak antimicrobial activity against Gram-positive microorganisms and fungi.[35] Isoflavonoids possessing antibacterial activity were obtained from the roots of *Astragalus memranaceus*.[57,119,120] Calycosin-7-*O*-*β*-D-glucoside significantly suppressed the growth of certain pathogenic bacteria from the human intestinal microbiota such as Enterobacter, Enterococcus, Clostridium, and Bacteroides. The effect was weaker against probiotic strains such as Lactobacillus and Bifidobacterium. This indicates that calycosin-7-*O*-*β*-D-glucoside has significant effects on the intestinal environment by modulation of the intestinal bacterial population.[192] Different extracts obtained from the areal and underground parts of *Astragalus gombiformis* were tested for antibacterial activity. It was concluded that extracts rich in total phenols and flavonoids possessed the highest inhibitory activity on bacteria *in vitro*.[193]

Cytotoxic activity

The antiproliferative effects of rhamnocitrin 4'-D-galactopyranoside obtained from *Astragalus hamosus* were tested in a panel of human tumor cell lines, using the MTT-dye reduction assay. The highest activity was registered against T-cell leukemia (SKW-3) cells.[194] Nine flavonoids obtained from pathogenic-infected *Astragalus adsurgens* were found to possess cytotoxic activity against human leukemia cell (HL-60) and human hepatoma cell (SMMC-7721). Among them, the chalcones 4,2′,4′-trihydroxychalcone and 2′,4′-dihydroxy-2,3-dimethoxychalcone exhibited the highest activity with IC_{50} between 5 μg.mL^{-1} and 10 μg.mL^{-1}.[29] Flavonoids extracted from the seeds of *Astragalus complanatus* inhibited the growth of human hepatocarcinoma (SMMC-7721 and HepG2) cells by inducing apoptosis via mitochondria-dependent and death receptor-dependent apoptotic pathways.[195] Apigenin and quercetin, isolated from *Astragalus verrucosus* were reported to have cytotoxic activity against HCT116 (human colon carcinoma) and MCF7 (human Caucasian breast adenocarcinoma) cancer cell lines. Apigenin showed higher cytotoxic activity than quercetin with average IC_{50} values of 4.0 μg.mL^{-1} for HCT116 cells and 4.6 μg.mL^{-1} for MCF7 cells.[196] Formononetin from *Astragalus membranaceus* was reported to inhibit the growth of HCT116 colon cancer cells. Activation of apoptosis, caspase activation, and downregulation of the antiapoptotic proteins Bcl-2 and Bcl-x_L were observed.[197] Total flavonoids extracted from the roots of *Astragalus mambranaceus* and calycosin itself were both investigated for cytotoxic activities on human erythroleukemia cells. The data showed that both could inhibit proliferation of K562 cells in IC_{50} of 98.63 μg.mL^{-1} (total flavonoids) and 130.32 μg.mL^{-1} (calycosin) without apoptosis induction but by increasing the number of cells in G (0)/G (1) phase.[198] Wang *et al*. concluded that total flavonoids from *Astragalus membranaceus* could significantly reduce cyclophamide-induced miconucleolus number and gene mutagenesis *in vitro*.[199]

Activity on the cardiovascular system

Paskov and Marechkova reported that intravenous injection of flavonoids isolated from *Astragalus centralpinus* could generate continuous decrease of the arterial blood pressure in experiments with cats under urethane narcosis.[200] The polyphenolic compounds (flavonoids and phenolic acids) obtained from the aerial parts of *Astragalus karakuschensis* demonstrated stronger blood pressure decreasing effect than papaverine hydrochloride.[87] A similar effect was observed for the flavonoid mixture extracted from *Astragalus virgatus*.[77] Total flavonoid fraction derived from *Astragalus complanatus* (TFAC) caused antihypertensive effect in conscious spontaneously hypertensive rats without any influence on cardiac rate and cardiac output. The observed hypotensive effect was due to a significant decrease in the total peripheral resistance.[201] These effects of TFAC were investigated again by Li *et al*. in 2005 and they found that it could decrease the plasma levels of angiotensin II.[202] Moreover, the antihypertensive action of TFAC was reported to be similar to those of Valsartan.[203] Wu *et al*. discovered that calycosin could generate endothelium-independent vasorelaxant effects due to its action as noncompetitive Ca^{2+} channel blocker.[204] Formononetine was also mentioned as a vasorelaxant. It caused vascular relaxation via endothelium/NO-dependent mechanism and endothelium-independent mechanism in experiments with isolated rat aorta.[205] Sodium formononetin 3′-sulphonate showed protective effects in *in vivo* model of cerebral ischemia and reperfusion injury.[206] Calycosin and formononetin from Radix Astragali upregulated neuronal nitric oxide synthase and dimethylarginine dimethylaminohydrolase. This resulted in enhancement in NO production, antihypertensive effect, and improved endothelial and cardiovascular dysfunction.[207] Total flavonoid mixture from the aerial pats of *Astragalus lasioglotis* decreased cholesterol and triglyceride levels in animals with experimentally caused hyperlipidemia.[208] Flavonoid mixture obtained from *Astragalus mongholicus* was studied in *in vivo* model of diet-induced atherosclerotic rabbits. The experiments showed that total flavonoids from the species significantly reduced plasma levels of total cholesterol and low density lipoproteins ($P < 0.05$ to 0.01), increased high density lipoproteins levels ($P < 0.01$), and reduced the aortic fatty streak area by 43.6–63.6% ($P < 0.01$).[209]

Activity on the respiratory system

Total flavonoids from *Astragalus complanatus* were found to attenuate lung injury resulted from Paraquat poisoning in Sprague-Dawley rats. This effect was due to inhibition of excessive endoplasmatic reticulum stress and the c-Jun N-terminal kinase pathway.[210] Alteration in antioxidant status was investigated in mice treated with 4 $mg.kg^{-1}$ b.wt. flavonoids from *Astragalus complanatus* after exposure to 10-Gy thoracic radiation. The results exhibited that flavonoids could be excellent candidates as protective agents against radiation-induced lung injury.[211]

Activity on the nervous system

Formononetin displayed neuroprotective effects in N-methyl-D-asparate-induced neurotoxicity in primary-cultured cortical neurons in dose of 10 μM for 12 h.[212]

Activity on the urinary system

Calycosin and calycosin-7-*O*-*β*-D glucoside from Radix Astragali showed inhibition of high glucose-induced mesangial cell early proliferation. The treatment of glomerular endothelial cells with the same compounds (1–100 μM) showed their significant therapeutic potential to modulate the development and/or progression of diabetic nephropathy.[213]

Antidiabetic activity

Formononetin and calycosin from *Astragalus membranaceus* have been reported to possess antidiabetic properties. They exerted significant activation of peroxisome proliferator-activated receptors *α* and *γ*, peroxisome proliferator-activated receptor (PPAR) *α*/*γ*. Formononetin showed higher activity comparable to what was observed for some synthetic dual PPAR-activating compounds.[214] The therapeutic potential of active fraction containing calycosin, formononetin, ononin and calycosin-7-*O*-*β*-D-glucoside from the same plant was validated. Continuous administration of the fraction considerably improved the glycemic control, reduced the levels of serum triglyceride, and also alleviated insulin resistance and glucose intolerance in db/db obese mice. These effects were result of its anti-inflammatory activity.[215] A recent review paper by Ng *et al.* discusses the antidiabetic effects of *Astragalus membranaceus* and the pharmacological action of its chemical constituents in relation to diabetes mellitus types 1 and 2.[16]

Anti-inflammatory activity

Choi *et al.* suggested that calycosin-7-*O*-*β*-D-glucoside could be a promising drug for the treatment of osteoarthritis. Rabbits with induced osteoarthritis-like lesions were injected with the compound once a week. A significant reduction of the total synovial fluid volume and alleviation of the osteoarthritis-induced accumulation of prostaglandin were registered after 4 weeks of treatment.[216] Formononetin has been found to generate positive effects on the metabolic activity of human normal osteoblasts (Obs) and osteoarthritis subchondral osteoblasts (OA Obs). After culturing with the compound the levels of interleukin (IL)-6, vascular endothelial growth factor (VEGF), bone morphogenic protein-2 (BMP-2), osteocalcin (OCN), type I collagen (Col 1), and alkaline phosphatase (ALP) activity in OA Obs were dose-dependently decreased. In the normal Obs, ALP activity and the levels of vascular endothelial growth factor (VEGF), bone morphogenetic protein-2 (BMP-2), osteocalcin (OCN), and Col 1 were markedly increased. Stronger remodeling effect on the osteogenic markers and inflammatory mediators was observed in the OA Obs.[217] Li *et al.* isolated 12 flavonoids (isoliquiritigenin, liquiritigenin, calycosin, calycosin-7-*O*-*β*-D-glucoside, formononetin, formononetin 7-*O*-*β*-D-glucoside, daidzein, daidzein-7-*O*-*β*-D-glucoside, methylnissolin, methylnissolin-3-*O*-*β*-D-glucoside, isomucronulatol, and isomucronulatol-7-*O*-*β*-D-glucoside) from the roots of *Astragalus membranaceus* and observed their anti-inflammatory effects. Isoliquritigenin and liquiritigenin exhibited significant inhibitory effects on lipopolysaccharide (LPS)-induced interleukins, IL-6 and IL-12 production, with IC_{50} values ranging from 2.7 μM to 6.1 μM. Isoliquiritigenin also showed a moderate inhibitory effect on LPS-stimulated production of TNF-*α* with an IC_{50} value of 20.1 μM.[101]

Other activities

Flavonoid complex obtained from *Astragalus centralpinus* had a well-pronounced spasmolytic effect on the smooth muscles of the gastrointestinal tract.[200] Shen *et al.* observed protective effect of flavonoids of *Astragalus membranaceus* against reperfusion-induced hepatic injury in hemorrhagic shock.[218] Fourteen flavonoids isolated from the aerial parts of *Astragalus quisqualis* and *Astragalus floccosifolius* were tested for their effects on the development of experimental lesions in the stomach of mice. Among them, quercetin and myricetin showed the highest antiulcer activity in immobilized or reserpinized mice. Moreover, luteolin prolonged the relaxant effect of adrenaline in isolated rabbit intestine preparations.[219] Ethyl acetate extract from the aerial parts of *Astragalus corniculatus*, containing flavonoids, was found to be practically nontoxic (acute oral toxicity > 5 $g.kg^{-1}$ in mice). Also, a significant dose-dependent antihypoxic activity of the extract was established in the experimental model of hemic and circulatory hypoxia in mice. The antihypoxic effect was especially well-pronounced in the model of circulatory hypoxia.[220] Astrapterocarpan inhibited proliferation of vascular smooth muscle cells in rats [A10 cells, induced by platelet-derived growth factor (PDGF)-BB] in a concentration-dependent manner. The investigators suggested that one of the mechanisms of antiproliferative effect involves inhibition of PDGF-BB-induced phosphorylation of the mitogen-activated protein kinases (MAPKs) 1 and 3, also known as extracellular-signal regulated kinases 1 and 2.[221] The isoflavonoids formononetin, ononin, calycosin, and calycosin-7-*O*-*β*-D-glucoside from Radix Astragali were reported to enhance the hematopoietic functions. Dose-dependent stimulation of the expression of erythropoietin in cultured human embryonic kidney fibroblasts was observed and calycosin-7-*O*-*β*-D-glucoside showed the highest activity.[222] The same compound was considered and as anti-human immunodeficiency virus (HIV)-1 agent with a therapeutic index above 28.49. It exerted low cytotoxicity on human T-cell line (C8166 cells) with 50% cytotoxic concentration value above 200 $\mu g.mL^{-1}$ while its 50% inhibitory concentration value against HIV-1-induced cytopathic effects was 7.02 $\mu g.mL^{-1}$.[223] Huh *et al.* investigated the fracture healing properties of formononetin in rats with produced femoral fractures. In the early stage of chondrogenesis, formononetin significantly increased the number of vessels and expression of vascular endothelial growth factor. In the later stages, formononetin stimulated gene expression of mesenchymal progenitors such as alkaline phosphatase, osteocalcin, osteopontin, and collagen type I, indicating osteogenic differentiation.[224] The same flavonoid accelerated wound closure rate was found in wound animal model. The underlying mechanism of this action involves endothelial repair due to the over-expression of early growth response factor-1 through the regulation of the MAPK pathways.[225] Immunoregulatory effects of flavonoids from *Astragalus membranaceus* were reported. After 6 weeks of oral administration, the flavonoids ameliorated the aberrant cytokine production and the reduced spleen cell proliferation in rats with induced chronic fatigue syndrome.[226]

CONCLUSION

The review on the phytochemistry and pharmacology of flavonoids from species of genus *Astragalus* L. represented their possible medicinal use and phytochemical significance. Plants from the genus will stand for the future as a source of inexhaustible structural diversity of flavonoids and corresponding pharmacological action.

Acknowledgment

Financial support from by Grant No. 25/2014 r. from the Council of Medical Science at Medical University of Sofia is acknowledged.

Financial support and sponsorship

Financial support from by Grant No. 25/2014 r. From the Council of Medical Science at Medical University of Sofia is acknowledged.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Sumner J. The Natural History of Medicinal Plants. 1st ed. Portland: Timber Press; 2001. p. 110-5.
2. Boissier PE. Flora Orientalis: Sive, enumeratio plantarum in Oriente a Graecia et Aegypto ad Indiae fines hucusque observatarum. Vol. 2. Genevae et Basileae: Bibliopola; p. 1872.
3. Chaudhary LB, Rana TS, Anand KK. Current status of the systematics of *Astragalus* L. (Fabaceae) with special reference to the Himalayan Species in India. Taiwania 2008;53:338-55.
4. Heywood VH, Ball PW. Leguminosae. In: Tutin TG, Heywood VH, Burges NA, Mooze DM, Valeutine DH, Walters SM, editors. Flora Europea. Vol. 2. Cambridge: Cambridge University Press; p. 1972.
5. Pavlova D. A Taxonomic Investigation of *Astragalus* Species Represented in Bulgaria, Biol. D Thesis, Faculty of Biology, Sofia University, Sofia, Bulgaria. 1988.
6. Pistelli L. Secondary metabolites of genus *Astragalus*: Structure and biological activity. In: Atta-Ur-Rahman, editor. Studies in Natural Products Chemistry (Bioactive Natural Products, Part H). Amsterdam: Elsevier Science; 2002. p. 443-545.
7. Verotta L, El-Sebakhy N. Cycloartane and oleanane saponins from *Astragalus* sp. In: Atta-Ur-Rahman, editor. Studies in Natural Products Chemistry (Bioactive Natural Products, Part F). Karachi: Elsevier Science; 2001. p. 179-234.
8. Cui B, Nakamura M, Kinjo J, Nohara T. Chemical studies on *Astragali Semen*. Tennen Yuki Kagabutsu Toronkai Koen Yoshishu 1991;33:377-84.
9. Rios JL, Waterman PG. A review of the pharmacology and toxicology of *Astragalus*. Phytother Res 1997;11:411-8.
10. Krasteva I, Benbassat N, Nikolov S. Flavonoids from genus *Astragalus* L. Pharmacia 2000;47:20-5.
11. Khan GA, Khan AR, Khan IR, Khan H, Khan MN. Flavonoids from *Astragalus* species. J Chem Soc Pak 2003;25:259.
12. Mamedova RP, Isaev MI. Triterpenoids from *Astragalus* plants. Chem Nat Comp 2004;40:303-52.
13. Yang LP, Shen JG, Xu WC, Li J, Jiang JQ. Secondary metabolites of the genus Astragalus: Structure and biological-activity update. Chem Biodivers 2013;10:1004-54.
14. Ionkova I, Shkondrov A, Krasteva I, Ionkov T. Recent progress in phytochemistry, pharmacology and biotechnology of *Astragalus* saponins. Phytochem Rev 2014;13:343-74.
15. Agyemang K, Han L, Liu E, Zhang Y, Wang T, Gao X. Recent Advances in Astragalus Membranaceus Anti-Diabetic Research: Pharmacological Effects of its Phytochemical Constituents. Evid Based Complement Alternat Med 2013;2013:1-9.
16. Ng YF, Tang PC, Sham TT, Lam WS, Mok DK, Chan SW. *Semen Astragali complanati*: An ethnopharmacological, phytochemical and pharmacological review. J Ethnopharmacol 2014;155:39-53.
17. Nakabayashi TA. A flavonoids pigment astragalin (kaempferol-3-glucoside) in *A. sinicus*. J Agr Chem Soc Jpn 1952;26:539-41.
18. Ibrahim LF, Marzouk MM, Hussein SR, Kawashty SA, Mahmoud K, Saleh NA. Flavonoid constituents and biological screening of *Astragalus bombycinus* Boiss. Nat Prod Res 2013;27:386-93.
19. Cui B, Kinjo J, Nakamura M, Nohara T. A novel acylated flavonoid glycoside from *Astragalus complanatus*. Tetrahedron Lett 1991;32:6135-8.
20. Cui BL, Nakamura M, Kinjo J, Nohara T. Structures of three new acylated flavonol glycosides from *Astragalus complanatus* R. Br Chem Pharm Bull 1992;40:1943-5.
21. Alaniya MD, Kavtaradze NS, Skhirtladze AV, Sutiashvili MG. Flavonoid oligosides from Georgian *Astragalus falcatus*. Chem Nat Compd 2011;47:377-81.
22. Semmar N, Fenet B, Lacaille-Dubois MA, Gluchoff-Fiasson K, Chemli R, Jay M. Two new glycosides from *Astragalus caprinus*. J Nat Prod 2001;64:656-8.
23. Semmar N, Fenet B, Gluchoff-Fiasson K, Hasan A, Jay M. Four new flavonol glycosides from the leaves of *Astragalus caprinus*. J Nat Prod 2002;65:576-9.
24. Porter EA, van den Bos AA, Kite GC, Veitch NC, Simmonds MS. Flavonol glycosides acylated with 3-hydroxy-3-methylglutaric acid as systematic characters in *Rosa*. Phytochemistry 2012;81:90-6.
25. Khalfallah A, Karioti A, Berrehal D, Kabouche A, Lucci M, Kabouche Z, *et al*. Flavonoid triglycosides from *Astragalus armatus*. Planta Med 2011;77:47.
26. Krasteva I, Nikolov S. Flavonoids in *Astragalus corniculatus*. Quim Nova 2008;31:59-60.
27. Krasteva NI. Phenolic compounds in four *Astragalus* species. Eur J Med Plants 2013;3:616-23.
28. Yeom SH, Kim MK, Kim HJ, Shim JG, Lee JH, Lee MW. Phenolic compounds from seeds of *Astragalus sinicus* and its antioxidative activities. Saengyak Hakhoechi 2003;34:344-51.
29. Chen J, Li Y, Yang LQ, Li YZ, Nan ZB, Gao K. Biological activities of flavonoids from pathogenic-infected *Astragalus adsurgens*. Food Chem 2012;131:546-51.
30. Alaniya MD, Kavtaradze NS, Lavoi S, Pichette A, Mshvildadze VD. Aurone from *Astragalus microcephalus* stems. Chem Nat Compd 2009;45:455-6.
31. Martin SS, Townsend CE, Lenssen AW. Induced isoflavonoids in diverse populations of *Astragalus cicer*. Biochem Syst Ecol 1994;22:657-61.
32. Subarnas A, Oshima Y, Hikino H. Isoflavans and a pterocarpan from *Astragalus mongholicus*. Phytochemistry 1991;30:2777-80.
33. Liu W, Chen J, Zuo WJ, Li X, Wang JH. A new isoflavane from processed *Astragalus membranaceus*. Chin Chem Lett 2007;18:1092-4.
34. Ingham JL, Dewick PM. Astraciceran: A new isoflavan phytoalexin from *Astragalus cicer*. Phytochemistry 1980;19:1767-70.
35. El-Sebakhy NA, Asaad AM, Abdallah RM, Toaima SM, Abdel-Kader MS, Stermitz FR. Antimicrobial isoflavans from *Astragalus species*. Phytochemistry 1994;36:1387-9.
36. Abd El-Latif RR, Shabana MH, El-Gandour AH, Mansour RM, Sharaf M. A new isoflavone from *Astragalus peregrinus*. Chem Nat Compd 2003;39:536-7.
37. Zheng Z, Song C, Liu D, Hu Z. Determination of 6 isoflavonoids in the hairy roots cultures of Astragalus membranaceus by HPLC. Yao Xue Xue Bao 1998;33:148-51.
38. Abd El-Mawla AM, Attia AA. Production of flavonoids in cell cultures of *Astragalus sieberi* DC. Bull Pharm Sci Assiut Univ 2002;25:79-83.
39. Ionkova I. *Astragalus* species: *In vitro* culture and the production of saponins, astragalin, and other biologically active compounds. In: Bajaj YP, editor. Biotechnology in Agriculture and Forestry, Medicine and Aromatic Plants. Berlin, Heidelberg: Springer Verlag; 1995. p. 97-138.
40. Ionkova I. Optimization of flavonoid production in cell cultures of *Astragalus missouriensis* Nutt. (Fabaceae). Phcog Mag 2009;5:92-7.
41. Ionkova I, Sasheva P, Ionkov T. Enhanced production of flavonoids in *Astragalus missouriensis*, using bioreactor by model based control of the bioprocess. In: Stevanović ZD, Radanović D, editors. Proceedings of the 7th Conference on Medicinal and Aromatic Plants of Southeast European Countries. Subotica, Serbia: 2012. p. 332-7.
42. Khozhambergenova P, Blinova KF. Flavonoids of *Astragalus ammodendron*. Khim Prir Soedin 1980;16:566-7.
43. Alaniya MD, Kavtaradze NS, Lavoi S, Pichette A, Mshvildadze VD, Apakidze ZZ. Chemical constituents of the aerial part of *Astragalus bungeanus*. Chem Nat Compd 2011;46:1001-3.
44. Perrone A, Masullo M, Plaza A, Hamed A, Piacente S. Flavone and flavonol glycosides from *Astragalus eremophilus* and *Astragalus vogelii*. Nat Prod Commun 2009;4:77-82.
45. Yasinov RK, Syrovezhko NV, Yakovlev GP, Ovcharenko SN. Flavonoids of *Astragalus floccosifolius*. Khim Prir Soedin 1984;20:523-4.
46. Gromova AS, Lutsky VI, Cannon JG, Li D, Owen NL. Secondary metabolites of *Astragalus danicus* Retz. and *A. inopinatus* Boriss. Russ Chem Bull 2001;50:1107-12.
47. Yasinov RK. Flavonoids of *Astragalus macropterum*. Chem nat Compd 1986;22:483-4.
48. Chaturvedula VS, Prakash I. Flavonoids from *Astragalus propinquus*. J Chem Pharm Res 2013;5:261-5.
49. Yasinov RK, Aripova ET. Flavonoids of *Astragalus coluteocarpus*. Khim Prir Soedin 1987;23:454-5.
50. Makboul MA, El-Shanawany MA, Abdel-Baky AM. Study of the lipid and flavonoid contents of *Astragalus cremophilos Boiss*. growing in Egypt. Bull Pharm Sci Assiut Univ 1984;7:380-8.
51. Yasinov RK, Khaitov IK. Flavonoids of *Astragalus kabadianus*. Chem Nat Compd 1988;24:386.
52. Yasinov RK, Syrovezhko NV, Yakovlev GP. Flavonoids of *Astragalus quisqualis*. Khim Prir Soedin 1983;19:368.
53. Jassbi AR, Zamanizadehnajari S, Azar PA, Tahara S. Antibacterial diterpenoids from *Astragalus brachystachys*. Z Naturforsch C 2002;57:1016-21.
54. El-Hawiet AM, Toaima SM, Asaad AM, Radwan MM, El-Sebakhy NA. Chemical constituents from *Astragalus annularis* Forssk. and *A. trimestris* L., Fabaceae. Rev Bras Farmacogn 2010;20:860-5.
55. Melgarejo MM, Castro P, Vila J. Antibacterial activity of four natural products from a Bolivian highlands plant. Rev Bol Quim 2006;23:40-3.
56. Sun L, Zeng S, Sheng X. Studies on flavonoids of *Astragalus adsurgens*. Xibei Shifan Daxue Xuebao, Ziran Kexueban 1994;30:52-4.
57. Song CQ, Zheng ZR, Liu D, Hu ZB. Antimicrobial isoflavans from *Astragalus membranaceus* (Fisch.) Bunge. Acta Botanica Sinica 1997;39:486-8.
58. Kavtaradze NS, Alaniya MD, Mshvildadze VD, Skhirtladze AV, Lavoie S, Pichette A. Flavonoids from *Astragalus microcephalus*. Chem Nat Compd 2011;46:971-3.
59. Benchadi W, Haba H, Lavaud C, Harakat D, Benkhaled M. Secondary metabolites of *Astragalus cruciatus* link and their chemotaxonomic significance. Rec Nat Prod 2013;7:105-13.
60. Guzhva NN. Flavonoids and hydroxycinnamic acids from *Astragalus asper*. Chem Nat Compd 2010;46:303-4.
61. Kadyrova RB. Flavonoid composition of some Siberian species of *Astragalus* L. species. Rastit Resur 1989;25:552-7.
62. Yasinov RK, Yakovlev GP. Flavonoids of *Astragalus babatagi*. Chem Nat Compd 1986;22:349.
63. Hasan A, Sadiq A, Abbas A, Mughal E, Khan KM, Ali M. Isolation and synthesis of flavonols and comparison of their antioxidant activity. Nat Prod Res 2010;24:995-1003.

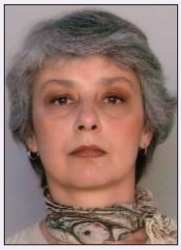
64. Yasinov RK, Syrovezhko NV, Yakovlev GP. Flavonoids of *Astragalus bornmüllerianus*. Khim Prir Soedin 1986;22:781-2.
65. Alaniya MD, Kemertelidze ÉP. Chemical study of *Astragalus brachycarpus* MB. Izv Akad Nauk Gruz SSR 1981;7:125-30.
66. Xu Y, Wei L. Chemical constituents of *Astragalus chinensis* L. Zhongguo Zhong Yao Za Zhi 1995;20:296-7, 320.
67. Yasinov RK. Flavonoids of *Astragalus eupeplus*. Chem Nat Compd 1986;22:353.
68. Alaniya MD, Kavtaradze NS, Bassarello C, Skhirtladze AV, Pizza C, Kutateladze I. Flavonoid glycosides from *Astragalus galegiformis* leaves. Chem Nat Compd 2006;42:681-5.
69. Montoro P, Teyeb H, Masullo M, Mari A, Douki W, Piacente S. LC-ESI-MS quali-quantitative determination of phenolic constituents in different parts of wild and cultivated *Astragalus gombiformis*. J Pharm Biomed Anal 2013;72:89-98.
70. Gupta RK, Singh J, Santani DD. Non alkaloidal constituents of some *Astragalus* species. Fitoterapia 1995;66:376.
71. Rao YJ, Reddy CR, Gangadhar N, Krupadanam GL. Phytochemical investigation of the whole plant of *Astragalus leucocephalus*. Indian J Chem 2009;48:1329-32.
72. Makbul MA, Blinova KF. Flavonoids of *Astragalus melilotoides*. Chem Nat Compd 1979;15:640-1.
73. Cheshuina AI. Flavonol aglycons of *Astragalus membranaceus*. Chem Nat Compd 1990;26:712.
74. Benbassat N, Nikolov S. Flavonoids from Astragalus onobrychis. Planta Med 1995;61:100.
75. Guzhva NN, Luk'yanchikov MS, Dranik LI. Phenolic compounds of *Astragalus subrobustus*. Chem Nat Compd 1987;23:455.
76. Guzhva NN, Dzhumyrko SF, Kazakov AL. Flavonoids of *Astragalus torrentum*. Chem Nat Compd 1984;20:496-7.
77. Guzhva NN, Luk'yanchikov MS, Kazakov AL. Flavonoids of *Astragalus virgatus*. Chem Nat Compd 1987;23:765-6.
78. Gu Y, Huang ZD, Lui YH. Studies on the efficacious components of *Astragalus complanatus*. Yao Xue Xue Bao 1997;32:59-61.
79. Shabana MH, Mansour RM, Sharaf M, Abd-El-Latif RR, El Ghandour AH. A comparative morphological, phytochemical and biological study of *Astragalus hamosus* L. and *Astragalus peregrinus* Vahl subsp. *peregrinus*. B-FOPCU 2006;44:175-84.
80. Dungérdorzh D, Petrenko VV, Deryugina LI. Aglycone composition of the flavonoid glycosides of *Astragalus mongolicus*. Nat Compd 1974;10:260.
81. Shabana MH, Saleh NA, Mansour RM, Shabana MM. Chemical constituents and biological activity of some Egyptian members of the *Leguminosae*. Bull Nat Res Cent 2005;30:45-55.
82. Cui BL, Lu YR, Wei LX. Studies on chemical constituents of *Astragalus complanatus* R. Br. Yao Xue Xue Bao 1989;24:189-93.
83. Guzhva NN, Luk'yanchikov MS, Ushakov VB, Sarkisov LS. Flavonoids of *Astragalus captiosus*. Chem Nat Compd 1986;22:729.
84. Kazakov AL, Luk'yanchikov MS, Turubarov VD, Guzhva NN. Phenols compounds of *Astragalus ciceroides* and *A. stragalus saganlugensis*. Chem Nat Compd 1987;23:122.
85. Tsepkova NA, Svechnikova AN, Bandyukova VA, Khalmatov KH. A study of the polyphenol compounds of *Astragalus* species of the flora of the northern Caucasus and Uzbekistan I. Chem Nat Compd 1972;8:638.
86. Makbul MA, Blinova KF. Quercetin glycosides from *Astragalus frigidus*. Khim Prir Soedin 1980;16:252.
87. Guzhva NN, Sarkisov LS, Dzhumyrko SF, Prudnik YV. Polyphenolic compounds of *Astragalus karakuschensis*. Chem Nat Compd 1990;26:339-40.
88. Guzhva NN, Luk'yanchikov MS, Kazakov AL. Flavonoids of *Astragalus levieri* and *A. sevangensis*. Chem Nat Compd 1983;19:501-2.
89. Krasteva I, Nikolov S, Pavlova D. Flavonoids from *Astragalus ponticus* Pall. (Fabaceae). Farmatsiya (Sofia) 1999;46:6-7.
90. Imomnazarov BA, Bandyukova VA. Polyphenolic compounds from *Astragalus* species in the flora of Western Pamir III. Khim Prir Soedin 1988;24:876-7.
91. Khoron'ko AT, Glyzin VI. Flavonoids of *Astragalus dasyanthus*. Chem Nat Compd 1973;9:403.
92. Khozhambergenova P, Blinova KF. Flavonoids of *Astragalus flexus*. Chem Nat Compd 1979;15:358.
93. Guzhva NN. Caucasian *Astragalus onobrychis* biologically active substances. Khim Rastit Syr 2009;3:123-32.
94. Norris FA, Stermitz FR. 4'-O-methylquercetin 3-glucoside from *Astragalus miser* var. *oblongifolius*. Phytochemistry 1970;9:229-30.
95. Shabana MH. New flavonol glycoside from *Astragalus spinosus Forssk*. Egypt J Pharm Sci 2002;43:19-27.
96. Marechkova L, Kumanova B. Isolation of flavonoids and some accompanying substances from the above-ground part of *Astragalus centralpinus* family Leguminosae. Probl Pharm 1981;9:63-74.
97. Dungérdorzh D, Petrenko VV. Kumatakenin from *Astragalus membranaceus*. Chem Nat Compd 1972;8:382.
98. Cui B, Nakamura M, Kinjo J, Nohara T. Chemical constituents of *Astragali Semen*. Chem Pharm Bull 1993;41:178-82.
99. Lee EJ, Yean MH, Jung HS, Kim JS, Kang SS. Phytochemical studies on *Astragalus* root (2)-flavonoids and a lignan. Nat Prod Sci 2008;14:131-7.
100. Bian Y, Guan J, Bi Z, Song Y, Ping L. Studies on chemical constituents of *Astragalus membranaceus* (Fisch.) Bge. var. *mongholicus* (Bge.) Hsiao. Zhongguo Yaoxue Zazhi 2006;41:1217-21.
101. Li W, Sun YN, Yan XT, Yang SY, Kim S, Lee YM, *et al.* Flavonoids from *Astragalus membranaceus* and their inhibitory effects on LPS-stimulated pro-inflammatory cytokine production in bone marrow-derived dendritic cells. Arch Pharm Res 2014;37:186-92.
102. Du X, Bai Y, Liang H, Wang Z, Zhao Y, Zhang Q, *et al.* Solvent effect in 1H NMR spectra of 3'-hydroxy-4'-methoxy isoflavonoids from *Astragalus membranaceus* var. *mongholicus*. Magn Reson Chem 2006;44:708-12.
103. Zhang YZ, Xu F, Liang J, Tang JS, Shang MY, Wang X, *et al.* Isoflavonoids from roots of *Astragalus membranaceus* var. *mongholicus*. Zhongguo Zhong Yao Za Zhi 2012;37:3243-8.
104. Marco JL, Sanz I, Rodriguez B. Phenol compounds from *Astragalus clusii*. An Quim Ser C 1983;79:94-5.
105. Wang JL, Xu HM, Li WH, Hua Z, Zhang SJ. Studies on chemical constituents of *Astragalus dahuricus*. Zhongguo Zhong Yao Za Zhi 2008;33:414-6.
106. Ma X, Tu P, Chen Y, Zhang T, Wei Y. Preparative isolation and purification of calycosin and formononetin from *Astragalus membranaceus* var. *mongholicus* (Bge.) Hsiao by high-speed counter-current chromatography. Se Pu 2005;23:299-301.
107. Lu G, Lu S. Isolation and identification of flavones like constituents from Mongolian milkvetch (*A. mongholicus*). Zhongcaoyao 1984;15:452-4.
108. Shiratаki Y, Takao M, Yoshida S, Toda S. Antioxidative components isolated from the roots of *Astragalus membranaceus* Bunge *(Astragali Radix)*. Phytother Res 1997;11:603-5.
109. Lenssen AW, Townsend CE, Martin SS. Clonal-by-environment interactions influence isoflavonoid accumulation in *Cicer* milkvetch. Crop Sci 1995;35:756-63.
110. Yu Z, Liu X. Active constituents of *Astragalus membranaceus* (Fich.) Bunge. Zhiwu Ziyuan Yu Huanjing 1993;2:40-3.
111. Bi ZM, Yu QT, Li P, Lin Y, Gao XD. Flavonoids from the aerial parts of *Astragalus mongholicus*. Chin J Nat Med 2007;5:263-5.
112. Zhang X, Xiao HB, Xue XY, Sun YG, Liang XM. Simultaneous characterization of isoflavonoids and astragalosides in two *Astragalus* species by high-performance liquid chromatography coupled with atmospheric pressure chemical ionization tandem mass spectrometry. J Sep Sci 2007;30:2059-69.
113. El Dib RA, Soliman HS, Hussein MH, Attia HG. Two new flavonoids and biological activity of *Astragalus abyssinicus* (Hochst.) Steud. ex A. Rich. Aerial Parts. Drug Res (Stuttg) 2015;65:259-65.
114. Ma X, Tian X, Chen Y, Tu P. Flavonoid constituents of *Astragalus membranaceus* var. *mongholicus*. Zhongcaoyao 2005;36:1293-6.
115. Cao ZZ, Cao Y, Yi J, Wu YP, Len ZK, Li D, *et al.* A new isoflavone glucoside from *Astragalus membranaceus*. Chin Chem Lett 1998;9:537-8.
116. Zhao M, Duan J, Huang W, Zhou R, Che Z. Isoflavans and isoflavone from *Astragalus hoanchy*. Zhongguo Yaoke Daxue Xuebao 2002;33:274-6.
117. Lenssen AW, Martin SS, Townsend CE, Hawkins B. Acicerone: An isoflavone from *Astragalus cicer*. Phytochemistry 1994;36:1185-7.
118. Tadzhibaev MM, Lutfullin KL, Mirzamatov RT. Phenolic compounds of *Euphorbia ferganensis* and *Astragalus orbiculatus*. Chem Nat Compd 1988;24:394.
119. Song C, Zheng Z, Liu D, Hu Z, Sheng W. Isoflavones from *Astragalus membranaceus*. Zhiwu Xuebao 1997;39:764-8.
120. Song C, Zheng Z, Liu D, Hu Z, Sheng W. Pterocarpans and isoflavans from *Astragalus membranaceus* Bunge. Acta Botanica Sinica 1997;39:1169-71.
121. De Pascual TJ, Aubauell JCH, Grande M. Components of *A. lusitanicus* Lam. II. Flavonoids. An Quim 1979;75:1005-7.
122. Lin LZ, He XG, Lindenmaier M, Nolan G, Yang J, Cleary M, *et al.* Liquid chromatography-electrospray ionization mass spectrometry study of the flavonoids of the roots of *Astragalus mongholicus* and *A. membranaceus*. J Chromatogr A 2000;876:87-95.
123. Bedir E, Calis I, Aquino R, Piacente S, Pizza C. Trojanoside H. A cycloartane-type glycoside from the aerial parts of *Astragalus trojanus*. Phytochemistry 1999;51:1017-20.
124. Nikolov S, Elenga P, Panova D. Flavonoids of the *Astragalus glycyphyllos*. Farmatsiya (Sofia) 1984;34:26-9.
125. Alaniya MD, Komissarenko NF, Kemertelidze ÉP. An apigenin glucoside from *Astragalus kadshorensis*. Chem Nat Compd 1971;7:507.
126. Toaima SM. Flavonoidal glycosides of some *Astragalus* species. Alex J Pharm Sci 2002;16:135-8.
127. Tang W, Eisenbrand G. Chinese Drugs of Plant Origin. Chemistry Pharmacology and use in Traditional and Modern Medicine. Berlin: Springer-Verlag; 1992. p. 191-7.
128. Alaniya MD, Aneli DN, Patudin AV, Komelin RV. Flavonoid glycosides of *Astragalus cicer*. Chem Nat Compd 1983;19:500-1.
129. Guzhva NN, Luk'yanchikov MS, Kazakov AL. Flavonoids of the Onobrychium section of the genus *Astragalus*. Chem Nat Compd 1985;21:4387.
130. Panova D, Nikolov S, Ionkova I. *Astragalus angustifolius* Lam. Flavonoids. Probl Pharm 1983;11:21-5.
131. Alaniya MD, Komissarenko NF. Phytochemical study of *Astragali* of the flora of Georgia. Izv Akad Nauk Gruz SSR Ser Khim 1976;2:31-8.
132. Luk'yanchikov MS, Guzhva NN, Elisevich DM. Kaempferol glycosides from *Astragalus dipelta*. Chem Nat Compd 1987;23:378-9.
133. Alaniya MD, Komissarenko NF, Kemertelidze ÉP. Flavonoids from *Astragalus galegifolius* and *A. maximus*. Chem Nat Compd 1972;8:784.
134. Guzhva NN, Kazakov AL, Dzhumyrko SF, Sarkisov LS. Flavonoids of *Astragalus lagurus*. Chem Nat Compd 1984;20:627-8.
135. Ionkova I. Isolation and HPLC-TLC analyses of the major flavonoids from *Astragalus aitosensis* MB (Fabaceae). Planta Med 1990;56:581.
136. Panova D, Nikolov S, Elmazova L, Ionkova I. Flavonoids from *Astragalus angustifolius* Lam. Farmatsiya (Sofia) 1981;3:98-103.
137. Kazakov VA, Luk'yanchikov MS, Dzumirko SF, Kompanchev VA. Flavonoids of some *Astragalis* species Part I. Khim Prir Soedin 1981;17:388-9.
138. Krasteva I, Platikanov S, Nikolov S, Kaloga M. Flavonoids from *Astragalus hamosus*. Nat Prod Res 2007;21:392-5.
139. Alaniya MD, Chkadua NF. Flavonoids of *Astragalus tana*. Chem Nat Compd 2000;36:537.

140. Sidel'nikova VI. A flavonol glycoside from *Astragalus testiculatus*. Chem Nat Compd 1978;14:333.
141. Komissarenko NF, Polyakova LV. Flavonoids of *Astragalus adsurgens*. Chem Nat Compd 1987;23:256-7.
142. Alaniya MD. Flavonoids from *Astragalus falcatus*. Soobshch Akad Nauk Gruz SSR 1972;68:357-60.
143. Yahara S, Kohjyouma M, Kohoda H. Flavonoid glycosides and saponins from *Astragalus shikokianus*. Phytochemistry 2000;53:469-71.
144. Alaniya MD, Komissarenko NF, Kemertelidze ÉP. Ascaside - a new flavonoid glycoside of *Astragalus caucasicus*. Khim Prir Soedin 1975;11:351-4.
145. Polyakova LV, Yarshova EA. Flavonoids of *Astragalus anstrosibiricus* Schischk. In matural populations of the Altai. I. Intrapopulational variability in steppe communities. Rastit Resur 1996;32:81-7.
146. Kazakov VA, Dzumirko SF, Sergeeva TA, Kompanchev VA. Flavonoids of some *Astragalis* species Part II. Khim Prir Soedin 1981;17:391-2.
147. Semmar N, Fenet B, Gluchoff-Fiasson K, Comte G, Jay M. New flavonol tetraglycosides from *Astragalus caprinus*. Chem Pharm Bull (Tokyo) 2002;50:981-4.
148. Ma Y, Tian Z, Fan C, Meng R. Constituents of stems and leaves of *A. membranaceus* Bunge. Shenyang Yaoxueyuan Xuebao 1991;8:121-3.
149. Svechnikova AP, Bandyukova VA, Khalmatov Kk. The polyphenol compounds of *Astragalus* species of the flora of the Northern Caucasus and Uzbekistan. II. Chem Nat Compd 1976;12:338.
150. Dungérdorzh D, Petrenko VV. Flavonol glycosides of *Astragalus propinquus*. Chem Nat Compd 1973;9:259-60.
151. Chen MH, Liu FS. Studies on chemical constituents of *Astragalus complanatus* R. Brown. II. Yao Xue Xue Bao 1988;23:218-20.
152. Lu S, Zhu I, Wu S. Flavonoid constituents of stems and leaves of Mongolian milkvetch (*A. mongholicus*). Zhongcaoyao 1990;21:249-50.
153. Qi L, Liu CY, Wu WQ, Gu ZL, Guo CY. Protective effect of flavonoids from *Astragalus complanatus* on radiation induced damages in mice. Fitoterapia 2011;82:383-92.
154. Alaniya MD. Phenolic compounds of *Astragalus brachycarpus* I. Chem Nat Compd 1976;12:813.
155. Khozhambergenova P, Blinova KF. Quercetin glycosides from *Astragalus flexus*. Khim Prir Soedin 1980;16:251-2.
156. Yang C, Yang Y, Aisa HA, Xin X, Ma H, Yili A, *et al.* Bioassay-guided isolation of antioxidants from *Astragalus altaicus* by combination of chromatographic techniques. J Sep Sci 2012;35:977-83.
157. Matkowski A, Wożniak D, Lamer-Zarawska E, Oszmiański J, Leszczyńska A. Flavonoids and phenol carboxylic acids in the oriental medicinal plant *Astragalus membranaceus* acclimated in Poland. Z Naturforsch C 2003;58:602-4.
158. Deryugina LI, Krivenchuk PE, Maksyutina NP. Chemical study of the flavonoids from *Astragalus pubiflorus*. Farm Zh. (Kiev) 1966;21:41-5.
159. El-Sebakhy NA, Asaad AM, Abdallah RM, Toaima SM, Verotta L, Orsini F. Constituents of Egyptian *Astragalus tribuloides* Del. Nat Prod Sci 2000;6:11-5.
160. Alaniya MD, Komissarenko NF. Chemical structure of flavonol glycosides of *Astragalus galegiformis*. Soobshch Akad Nauk Gruz SSR 1975;80:625-8.
161. Deryugina LI, Maksyutina NP, Krivenchuk PE. An isorhamnetin glycoside from the flowers of *Astragalus novoascanicus*. Chem Nat Compd 1968;4:218.
162. Deryugina LI, Maksyutina NP, Krivenchuk PE. The flavonoids of *Astragalus*. Khim Prir Soedin 1966;2:394-9.
163. Horo I, Bedir E, Perrone A, Ozgökçe F, Piacente S, Alankuş-Calişkan O. Triterpene glycosides from *Astragalus icmadophilus*. Phytochemistry 2010;71:956-63.
164. Bedir E, Calis I, Piacente S, Khan IA. A new flavonol glycoside from the aerial parts of *Astragalus vulneraria*. Chem Pharm Bull (Tokyo) 2000;48:1994-5.
165. Fathiazad F, Movafeghi A, Khosropanah MK. Flavonol glycosides from the leaves of *Astragalus microcephalus*. Int J Biosci 2012;7:23-8.
166. Ma X, Tu P, Chen Y, Zhang T, Wei Y, Ito Y. Preparative isolation and purification of two isoflavones from *Astragalus membranaceus* Bge. *var. mongholicus* (Bge.) Hsiao by high-speed counter-current chromatography. J Chromatogr A 2003;992:193-7.
167. Yamaki M, Kashihara M, Takagi S. Flavone glucosides from seeds of *Astragalus complanatus*. Shoyakugaku Zasshi 1991;45:261-2.
168. Sun LM, Wang XL, Deng WL, Ding LS, Peng SL. Chemical constituents from *Astragalus ernestii*. Chin J Nat Med 2011;9:38-41.
169. Zhang LJ, Liu HK, Hsiao PC, Kuo LM, Lee IJ, Wu TS, *et al.* New isoflavonoid glycosides and related constituents from *astragali radix* (*Astragalus membranaceus*) and their inhibitory activity on nitric oxide production. J Agric Food Chem 2011;59:1131-7.
170. Xiao W, Han L, Shi B. Isolation and purification of flavonoid glucosides from *Radix Astragali* by high-speed counter-current chromatography. J Chromatogr B Analyt Technol Biomed Life Sci 2009;877:697-702.
171. Pei Y, Li R, Fu H, Wang J, Zhou Y. A new isoflavone glucoside from *Astragalus membranaceus* var. *mongholicus*. Fitoterapia 2007;78:602-4.
172. Liu XH, Zhao LG, Liang J, Guo L, Yang YL, Hu F, *et al.* Component analysis and structure identification of active substances for anti-gastric ulcer effects in *Radix Astragali* by liquid chromatography and tandem mass spectrometry. J Chromatography B Analyt Technol Biomed Life Sci 2014;960:43-51.
173. Deryugina LI. Astroside-new isoflavone glycoside from *Astragalus austriacus*. Chem Nat Compd 1966;2:256-8.
174. Pistelli L, Giachi I, Lepori E, Bertoli A. Further saponins and flavonoids from *Astragalus verrucosus* Moris. Pharm Biol 2003;41:568-72.
175. He ZQ, Wang BQ. Isolation and identification of chemical constituents of *Astragalus* root. Yao Xue Xue Bao 1990;25:694-8.
176. Wang HHK, He K, Xu HX, Zhang ZL, Wang YF, Kikuchi T, *et al.* The structure of astrachrysosid A and the study of 2D-NMR on astrasiversianin XV and 7,2'-dihydroxy-3',4'-dimethoxy-isoflavan-7-O-beta-D glycoside. Yao Xue Xue Bao 1990;25:445-50.
177. He ZQ, Findlay JA. Constituents of *Astragalus membranaceus*. J Nat Prod 1991;54:810-5.
178. Ma X, Tu P, Chen Y, Zhang T, Wei Y, Ito Y. Preparative isolation and purification of isoflavan and pterocarpan glycosides from *Astragalus membranaceus* Bge. var. *mongholicus* (Bge.) Hsiao by high-speed counter-current chromatography. J Chromatogr A 2004;1023:311-5.
179. Harborne JB, Williams CA. Advances in favonoid research since 1992. Phytochemistry 2000;55:481-504.
180. Wang D, Shen W, Tian Y, Sun Z, Yuan S, Jiang C. The effects of the three components isolated from *Astragalus mongholicus* bunge on scavenging free radicals. Chin Pharmacol Bull 1994;10:129-32.
181. Wang D, Shen W, Tian Y, Sun Z, Jiang C, Yuan S. Protective effect of active components extracted from radix *Astragali* on human erythrocyte membrane damages caused by reactive oxygen species. Zhongguo Zhong Yao Za Zhi 1996;21:746-8, 763.
182. Wang D, Shen W, Tian Y, Liu G, Yang S, Zhou S, *et al.* The protective effect of total flavonoids *Astragalus* on DNA strand break in V_(79) cell caused by hydroxyl radicals. Chin Pharm Bull 1995;11:311-3.
183. Zhang QA, Fan XH, Zhang ZQ, Li T, Zhu CP, Zhang XR, *et al.* Extraction, antioxidant capacity and identification of *Semen Astragali complanati* (*Astragalus complanatus* R.Br.) phenolics. Food Chem 2013;141:1295-300.
184. Toda S, Shirataki Y. Comparison of antioxidative and chelating effects of daidzein and daidzin on protein oxidative modification by cooper *in vitro*. Biol Trace Elem Res 2001;79:83-9.
185. Toda S, Shirataki Y. Inhibitory effects of isoflavones in roots of *Astragalus membranaceus* Bunge (*Astragali Radix*) on lipid peroxidation by reactive oxygen species. Phytother Res 1998;12:59-61.
186. Toda S, Shirataki Y. Inhibitory effects of isoflavones on lipid peroxidation by reactive oxygen species. Phytother Res 1999;13:163-5.
187. Yu D, Duan Y, Bao Y, Wei C, An L. Isoflavonoids from *Astragalus mongholicus* protect PC12 cells from toxicity induced by L-glutamate. J Ethnopharmacol 2005;98:89-94.
188. Yu DH, Bao YM, An LJ, Yang M. Protection of PC12 cells against superoxide-induced damage by isoflavonoids from *Astragalus mongholicus*. Biomed Environ Sci 2009;22:50-4.
189. Asgarpanah J, Motamed SM, Farzaneh A, Ghanizadeh B, Tomraee S. Antioxidant activity and total phenolic and flavonoid content of *Astragalus squarrosus* Bunge. Afr J Biotechnol 2011;10:19176-80.
190. Liu CY, Gu ZL, Zhou WX, Guo CY. Effect of *Astragalus complanatus* flavonoid on anti-liver fibrosis in rats. World J Gastroenterol 2005;11:5782-6.
191. Wang DQ, Ding BG, Ma YQ, Zhao HL, Neil TG, Brian T, *et al.* Studies on protective effect of total flavonoids of *Astragalus* on liver damage induced by paracetamol. Zhongguo Zhong Yao Za Zhi 2001;26:483-6.
192. Zhang W, Jiang S, Qian D, Shang EX, Duan JA. Analysis of interaction property of calycosin-7-O- β-D- glucoside with human gut microbiota. J Chromatogr B Analyt Technol Biomed Life Sci 2014;963:16-23.
193. Teyeb H, Houta O, Najjaa H, Lamari A, Neffati M, Douki W, *et al.* Biological and chemical study of *Astragalus gombiformis*. Z Naturforsch C 2012;67:367-74.
194. Krasteva I, Momekov G, Zdraveva P, Konstantinov S, Nikolov S. Antiproliferative effects of a flavonoid and saponins from *Astragalus hamosus* against human tumor cell lines. Phcog Mag 2008;4:269-72.
195. Hu YW, Liu CY, Du CM, Zhang J, Wu WQ, Gu ZL. Induction of apoptosis in human hepatocarcinoma SMMC-7721 cells *in vitro* by flavonoids from *Astragalus complanatus*. J Ethnopharmacol 2009;123:293-301.
196. Buhagiar JA, Bertoli A, Camilleri-Podesta MT, Pistelli L. *In vitro* apoptotic activity of flavonoids from *Astragalus verrucosus* Morris. Nat Prod Commun 2008;3:2007-12.
197. Auyeung KW, Ko JK. Novel herbal flavonoids promote apoptosis but differentially induce cell cycle arrest in human colon cancer cell. Invest New Drugs 2010;28:1-13.
198. Zhang D, Zhuang Y, Pan J, Wang H, Li H, Yu Y, *et al.* Investigation of effects and mechanisms of total flavonoids of *Astragalus* and calycosin on human erythroleukemia cells. Oxid Med Cell Longev 2012;2012:209843.
199. Wang DQ, Tian YP, Song SZ, Wang L. Anti-mutagenesis effects of total flavonoids of Astragalus. Zhongguo Zhong Yao Za Zhi 2003;28:1164-7.
200. Paskov D, Marechkova L. Flavonoids of *Astragalus centralpinus* and their effect on the muscle of the gastrointestinal tract. Probl Pharm 1983;11:36-72.
201. Xue B, Li JX, Chen LB. Depressive effect of total flavonoid fraction of *Asttragalus complanatus* R.Br. and its influence upon hemodynamics in SHR. Zhongguo Zhong Yao Za Zhi 2002;27:855-8.
202. Li JX, Xue B, Chai Q, Liu ZX, Zhao AP, Chen LB. Antihypertensive effect of total flavonoid fraction of *Astragalus complanatus* in hypertensive rats. Chin J Physiol 2005;48:101-6.
203. Xue B, Lib J, Chaic Q, Liuc Z, Chen L. Effect of total flavonoid fraction of *Astragalus complanatus* R.Brown on angiotensin II-induced portal-vein contraction in hypertensive rats. Phytomedicine 2008;15:759-62.
204. Wu X, Wang Y, Cheng J, Zhao Y. Calcium channel blocking activity of calycosin, a major active component of *Astragali Radix*, on rat aorta. Acta Pharmacol Sin 2006;27:1007-12.
205. Wu JH, Li Q, Wu MY, Guo DJ, Chen HL, Chen SL, *et al.* Formononetin, an isoflavone, relaxes rat isolated aorta through endothelium-dependent and endothelium-independent pathways. J Nutr Biochem 2010;21:613-20.
206. Zhu H, Zou L, Tian J, Lin F, He J, Hou J. Protective effects of sulphonated formononetin in a rat model of cerebral ischemia and reperfusion injury. Planta Med 2014;80:262-8.
207. Bai F, Makino T, Kono K, Nagatsu A, Ono T, Mizukami H. Calycosin and formononetin from *Astragalus* root enhance dimethylarginine dimethylaminohydrolase 2 and nitric oxide

synthase expressions in Madin Darby Canine Kidney II cells. J Nat Med 2013;67:782-9.
208. Luk'yanchikov MS. Quantitative determination of flavonoids in some representatives of the family Fabaceae. Checm nat Compd 1984;20:40-1.
209. Wang D, Zhuang Y, Tian Y, Thomas GN, Ying M, Tomlinson B. Study of the effects of total flavonoids of *Astragalus* on atherosclerosis formation and potential mechanisms. Oxid Med Cell Longev 2012;2012:282383.
210. Zhang Z, Dong Y, Li X, Peng L. Total flavonoids from *Astragalus complanatus* attenuates lung injury following paraquat poisoning in rats through inhibiting excessive endoplasmic reticulum stress and c-Jun N-terminal kinase pathway. Zhonghua Wei Zhong Bing Ji Jiu Yi Xue 2014;26:383-7.
211. Wang J, Xu HW, Li BS, Zhang J, Cheng J. Preliminary study of protective effects of flavonoids against radiation-induced lung injury in mice. Asian Pac J Cancer Prev 2012;13:6441-6.
212. Tian Z, Liu SB, Wang YC, Li XQ, Zheng LH, Zhao MG. Neuroprotective effects of formononetin against NMDA-induced apoptosis in cortical neurons. Phytother Res 2013;27:1770-5.
213. Tang D, He B, Zheng ZG, Wang RS, Gu F, Duan TT, *et al.* Inhibitory effects of two major isoflavonoids in *Radix Astragali* on high glucose-induced mesangial cells proliferation and AGEs-induced endothelial cells apoptosis. Planta Med 2011;77:729-32.
214. Shen P, Liu MH, Ng TY, Chan YH, Yong EL. Differential effects of isoflavones, from *Astragalus membranaceus* and *Pueraria thomsonii*, on the activation of PPARalpha, PPARgamma, and adipocyte differentiation *in vitro*. J Nutr 2006;136:899-905.
215. Hoo RL, Wong JY, Qiao C, Xu A, Xu H, Lam KS. The effective fraction isolated from *Radix Astragali* alleviates glucose intolerance, insulin resistance and hypertriglyceridemia in db/db diabetic mice through its anti-inflammatory activity. Nutr Metab (Lond) 2010;7:67.
216. Choi SI, Heo TR, Min BH, Cui JH, Choi BH, Park SR. Alleviation of osteoarthritis by calycosin-7-O-beta-D-glucopyranoside (CG) isolated from *Astragali radix* (AR) in rabbit osteoarthritis (OA) model. Osteoarthritis Cartilage 2007;15:1086-92.
217. Huh JE, Seo DM, Baek YH, Choi DY, Park DS, Lee JD. Biphasic positive effect of formononetin on metabolic activity of human normal and osteoarthritic subchondral osteoblasts. Int Immunopharmacol 2010;10:500-7.
218. Shen WM, Wang CB, Wang DQ, Tian YP, Yan GT, Hao XH. The protective effects of TFA on reperfusion induced hepatic injury in hemorrhagic shock. Zhongguo Yaolixue Tongbao 1997;13:532-4.
219. Barnaulov OD, Manisheva OA, Yasinov RR, Yakovlev GP. Evaluation of the effect of the flavonoids from the aerial parts of *Astragalus quisqualis* Bunge and *Astragalus floccosifolius* Summ. on the development of experimental lesions in mouse stomach. Rastit Resur 1985;21:85-90.
220. Krasteva I, Nikolova I, Danchev N, Nikolov S. Phytochemical analysis of ethyl acetate extract from *Astragalus corniculatus* Bieb. and brain antihypoxic activity. Acta Pharm 2004;54:151-6.
221. Ohkawara S, Okuma Y, Uehara T, Yamagishi T, Nomura Y. Astrapterocarpan isolated from *Astragalus membranaceus* inhibits proliferation of vascular smooth muscle cells. Eur J Pharmacol 2005;525:41-7.
222. Zheng KY, Choi RC, Cheung AW, Guo AJ, Bi CW, Zhu KY, *et al.* Flavonoids from *Radix Astragali* induce the expression of erythropoietin in cultured cells: A signaling mediated *via* the accumulation of hypoxia-inducible factor-1α. J Agric Food Chem 2011;59:1697-704.
223. Ma CH, Wang RR, Tian RR, Ye G, Fan MS, Zheng YT, *et al.* Calycosin 7-O-β-D-glucopyranoside, an anti-HIV agent from the roots of *Astragalus membranaceus* var. *mongholicus*. Chem Nat Compd 2009;45:282-5.
224. Huh JE, Kwon NH, Baek YH, Lee JD, Choi DY, Jingushi S, *et al.* Formononetin promotes early fracture healing through stimulating angiogenesis by up-regulating VEGFR-2/Flk-1 in a rat fracture model. Int Immunopharmacol 2009;9:1357-65.
225. Huh JE, Nam DW, Baek YH, Kang JW, Park DS, Choi DY, *et al.* Formononetin accelerates wound repair by the regulation of early growth response factor-1 transcription factor through the phosphorylation of the ERK and p38 MAPK pathways. Int Immunopharmacol 2011;11:46-54.
226. Kuo YH, Tsai WJ, Loke SH, Wu TS, Chiou WF. *Astragalus membranaceus* flavonoids (AMF) ameliorate chronic fatigue syndrome induced by food intake restriction plus forced swimming. J Ethnopharmacol 2009;122:28-34.


Viktor M. Bratkov


Aleksandar M. Shkondrov


Petranka K. Zdraveva


Ilina N. Krasteva

ABOUT AUTHORS

Viktor M. Bratkov, PhD student, Department of Pharmacognosy, Medical University of Sofia, Sofia, Bulgaria.

Aleksandar M. Shkondrov, PhD student, Department of Pharmacognosy, Medical University of Sofia, Sofia, Bulgaria.

Petranka K. Zdraveva, PhD, Ass. Professor, Department of Pharmacognosy, Medical University of Sofia, Sofia, Bulgaria.

Ilina N. Krasteva, PhD, Full Professor, Department of Pharmacognosy, Medical University of Sofia, Sofia, Bulgaria.