

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

Viktor M. Bratkov, Aleksandar M. Shkondrov, Petranka K. Zdraveva, Iliana 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.<sup>[1]</sup>

The genus *Astragalus* is the largest in the Fabaceae family and is cosmopolite, with more than 2,500 species grouped in 100 subgenera.<sup>[2]</sup> Moreover, *Astragalus* is considered to be one of the most diverse genera.<sup>[3]</sup> 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).<sup>[4]</sup> In Bulgaria, the genus presents with 29 species.<sup>[5]</sup>

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.<sup>[6,7]</sup> There are other compounds possessing biological activity such as sesquiterpene-flavonolic complexes,<sup>[8]</sup> sterols, lignans, coumarins, and phenolic acids.<sup>[6]</sup> Three toxic groups of phytoconstituents—indolizidine alkaloids, aliphatic nitro compounds, and iron-selenium derivatives have been also discovered.<sup>[6,7]</sup>

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.<sup>[6,7,9–14]</sup> There are review articles concerning only pharmacological properties of *Astragalus membranaceus* and *Astragalus complanatus*, used in traditional Chinese medicine.<sup>[10,15,16]</sup> This review includes full details on the flavonoids isolated from the *Astragalus* species from 1952 (the first report about flavonoid isolated from the genus)<sup>[17]</sup> 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, isoflavanones, and pterocarpanes. 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*.<sup>[18]</sup> 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.<sup>[19]</sup> A glycoside similar to complanatin was isolated together with two other rhamnocitrin glycosides acylated with p-Coumaric and ferulic acid.<sup>[20]</sup> Alaniya *et al.* identified two new flavonol tetraglycosides named falcoside C and falcoside D from the leaves and flowers of *Astragalus falcatus*.<sup>[21]</sup> Information about a new flavonol tetraglycoside isolated from *Astragalus caprinus* was published in 2001.<sup>[22]</sup> In addition, 1 year later four new flavonol glycosides were determined, two of which

### Correspondence:

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

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

Several flavanones were isolated from different *Astragalus* species but only two flavanone glycosides from *Astragalus corniculatus* and *Astragalus ponticus* were reported.<sup>[26,27]</sup> *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.<sup>[28]</sup> New dihydrochalcone derivative named astradurnin together with six known chalcones were found in pathogenic-infected *Astragalus adsurgens*.<sup>[29]</sup> Sulfuretin from *Astragalus microcephalus* is the only one auron isolated from the genus.<sup>[30]</sup>

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.<sup>[31-33]</sup> The first new isoflavan from the the genus – astraciceran was isolated from the fungus-inoculated leaflets of *Astragalus cicer*.<sup>[34]</sup> Another two new isoflavans, astragaluquinone and 8-methoxyvestitol were reported from the roots of *Astragalus alexandrinus* and *Astragalus trigonus*.<sup>[35]</sup> A new isoflavone identified as 7-hydroxy-3',5'-dimethoxyisoflavone was found in the aerial parts of *Astragalus peregrinus*.<sup>[36]</sup>

*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.<sup>[37-41]</sup>

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.<sup>[179]</sup> Total flavonoids, obtained from Radix Astragali demonstrated significant antioxidant activity and inhibited the lipid peroxidation caused by O<sub>2</sub>, H<sub>2</sub>O<sub>2</sub>, and ultraviolet (UV) irradiation.<sup>[180,181]</sup> Protective effect of total flavonoids from *Astragalus* against DNA strand breaks, caused by hydroxyl radicals, was also observed.<sup>[182]</sup> Flavanonols from *Astragalus sinicus* showed potent antioxidant activity determined by 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay.<sup>[28]</sup> 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.<sup>[183]</sup> Flavonoid fraction obtained from the seeds of *Astragalus complanatus* showed significant radioprotective effect against damage induced by  $\gamma$ -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*.<sup>[153]</sup> The isoflavan 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<sup>2+</sup> + and copper-chelating ability.<sup>[184]</sup> 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  $\alpha$ -tocopherol.<sup>[108]</sup> 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.<sup>[185]</sup> 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).<sup>[186]</sup> 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<sub>50</sub>) of 0.027  $\mu\text{g}\cdot\text{mL}^{-1}$ , 0.047  $\mu\text{g}\cdot\text{mL}^{-1}$ , and 0.031  $\mu\text{g}\cdot\text{mL}^{-1}$ , respectively. Pretreatment with those compounds increased the activities of some antioxidant enzymes and prevented the release of lactate dehydrogenase.<sup>[187]</sup> Five compounds from *Astragalus mongholicus* including formononetin, ononin, 9,10-dimethoxypterocarpan-3-O- $\beta$ -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<sub>50</sub> values were found to be 0.05  $\mu\text{g}\cdot\text{mL}^{-1}$ . 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<sub>50</sub> 10 and 50  $\mu\text{g}\cdot\text{mL}^{-1}$ .<sup>[188]</sup> 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.<sup>[189]</sup>

### 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.<sup>[190]</sup> 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<sup>-1</sup>). Pretreatment of the animals with the flavonoid fraction (100 mg.kg<sup>-1</sup>) resulted in reduction of the death rate to 20% and an obvious dose-dependent decrease in ALT levels and the area of hepatocellular necrosis.<sup>[191]</sup>

### 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  $\mu\text{g}\cdot\text{mL}^{-1}$  to 31.3  $\mu\text{g}\cdot\text{mL}^{-1}$ .<sup>[29]</sup> 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.<sup>[55]</sup> Astragaluquinone and

**Table 1:** Flavonoid aglycones isolated from *Astragalus* species

Flavones						
Name	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	<i>Astragalus</i> sp. <sup>[References]</sup>
Apigenin (5,7,4'-trihydroxyflavone)	H	H	H	H		<i>A. ammodendron</i> <sup>[42]</sup> <i>A. bombycinus</i> <sup>[18]</sup> <i>A. bungeanus</i> <sup>[43]</sup> <i>A. eremophilus</i> <sup>[44]</sup> <i>A. floccosifolius</i> <sup>[45]</sup> <i>A. inopinatus</i> <sup>[46]</sup> <i>A. macropterum</i> <sup>[47]</sup> <i>A. peregrinus</i> <sup>[36]</sup> <i>A. propinquus</i> <sup>[48]</sup> <i>A. sieberi</i> <sup>*,[38]</sup> <i>A. bombycinus</i> <sup>[18]</sup> <i>A. coluteocarpus</i> <sup>[49]</sup> <i>A. cremophilus</i> <sup>[50]</sup> <i>A. kabadianus</i> <sup>[51]</sup> <i>A. peregrinus</i> <sup>[36]</sup> <i>A. propinquus</i> <sup>[48]</sup> <i>A. quisqualis</i> <sup>[52]</sup> <i>A. eremophilus</i> <sup>[44]</sup> <i>A. brachystachys</i> <sup>[53]</sup> <i>A. propinquus</i> <sup>[48]</sup> <i>A. annularis</i> <sup>[54]</sup> <i>A. trimestris</i> <sup>[54]</sup> <i>A. arequipensis</i> <sup>[55]</sup>
Luteolin (5,7,3',4'-tetrahydroxyflavone)	H	H	OH	H		
5,7,4'-trihydroxy-3'-methoxyflavone** Salvigenin (5-hydroxy-4',6,7-trimethoxyflavone)	H OCH <sub>3</sub>	H CH <sub>3</sub>	OCH <sub>3</sub> H	H CH <sub>3</sub>		
Sorbifolin (7-methoxy-4',5,6-trihydroxyflavone)	OH	CH <sub>3</sub>	H	H		
5,7,3'-trihydroxy-4'-methoxyflavone**	H	H	OH	CH <sub>3</sub>		
Zapotinin (5-hydroxy-6,2',6'-trimethoxyflavone) 5,6-dihydroxyflavone**	CH <sub>3</sub> H	OCH <sub>3</sub> H	OCH <sub>3</sub> H	H		<i>A. adsurgens</i> <sup>[56]</sup> <i>A. membranaceus</i> <sup>[57]</sup>
7-hydroxyflavone	H	H	H			<i>A. microcephalus</i> <sup>[58]</sup>
5,7,2'-trihydroxyflavone	OH	OH	H			<i>A. cruciatus</i> <sup>[59]</sup>
5,7,2',4'-tetrahydroxyflavone**	OH	OH	OH			<i>A. bombycinus</i> <sup>[18]</sup>
FLAVONOLS						
Kaempferol (3,5,7,4'-tetrahydroxyflavone)	H	H	H	OH		<i>A. ammodendron</i> <sup>[42]</sup> <i>A. asper</i> <sup>[60]</sup>

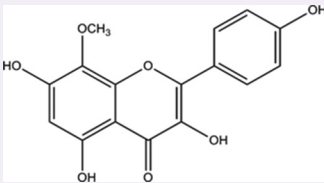
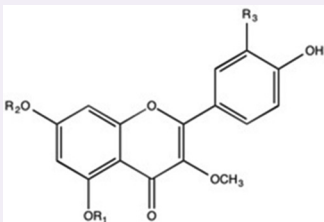
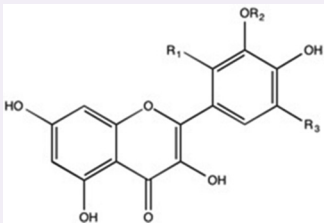
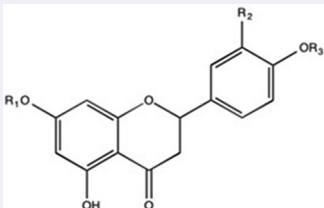
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Table 1: Contd...

Name	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	<i>Astragalus</i> sp. <sup>[References]</sup>
						<i>A. austrosibiricus</i> <sup>[61]</sup>
						<i>A. babatagi</i> <sup>[62]</sup>
						<i>A. beckeri</i> <sup>[63]</sup>
						<i>A. bornmüllerianus</i> <sup>[64]</sup>
						<i>A. brachycarpus</i> <sup>[65]</sup>
						<i>A. chinensis</i> <sup>[66]</sup>
						<i>A. coluteocarpus</i> <sup>[49]</sup>
						<i>A. corniculatus</i> <sup>[26]</sup>
						<i>A. cremophilus</i> <sup>[50]</sup>
						<i>A. edulis</i> <sup>[39]</sup>
						<i>A. eupeplus</i> <sup>[67]</sup>
						<i>A. floccosifolius</i> <sup>[45]</sup>
						<i>A. galegiformis</i> <sup>[68]</sup>
						<i>A. gombiformis</i> <sup>[69]</sup>
						<i>A. himalayanus</i> <sup>[70]</sup>
						<i>A. kabadianus</i> <sup>[51]</sup>
						<i>A. leucocephalus</i> <sup>[71]</sup>
						<i>A. macropterum</i> <sup>[47]</sup>
						<i>A. melilotoides</i> <sup>[72]</sup>
						<i>A. membranaceus</i> <sup>[73]</sup>
						<i>A. onobrychis</i> <sup>[74]</sup>
						<i>A. ponticus</i> <sup>[27]</sup>
						<i>A. quisqualis</i> <sup>[52]</sup>
						<i>A. sieberi</i> <sup>[38]</sup>
						<i>A. subrobustus</i> <sup>[75]</sup>
						<i>A. torrentum</i> <sup>[76]</sup>
						<i>A. virgatus</i> <sup>[77]</sup>
5-deoxykaempferol	H	H	H	H		<i>A. beckeri</i> <sup>[63]</sup>
Rhamnocitrin (7-methylkaempferol)	CH <sub>3</sub>	H	H	OH		<i>A. complanatus</i> <sup>[78]</sup>
						<i>A. gombiformis</i> <sup>[69]</sup>
						<i>A. hamosus</i> <sup>[79]</sup>
						<i>A. mongholicus</i> <sup>[80]</sup>
						<i>A. vogelii</i> <sup>[81]</sup>
Kaempferide (4'-methoxykaempferol)	H	H	CH <sub>3</sub>	OH		<i>A. complanatus</i> <sup>[82]</sup>
Quercetin (3,5,7,3',4'-pentahydroxyflavone)	H	OH	H	OH		<i>A. asper</i> <sup>[60]</sup>
						<i>A. babatagi</i> <sup>[62]</sup>
						<i>A. beckeri</i> <sup>[63]</sup>
						<i>A. bornmüllerianus</i> <sup>[64]</sup>
						<i>A. brachycarpus</i> <sup>[65]</sup>
						<i>A. captiosus</i> <sup>[83]</sup>
						<i>A. ciceroides</i> <sup>[84]</sup>
						<i>A. coluteocarpus</i> <sup>[49]</sup>
						<i>A. corniculatus</i> <sup>[26]</sup>
						<i>A. cremophilus</i> <sup>[50]</sup>
						<i>A. edulis</i> <sup>[39]</sup>
						<i>A. eupeplus</i> <sup>[67]</sup>
						<i>A. eximus</i> <sup>[85]</sup>
						<i>A. floccosifolius</i> <sup>[45]</sup>
						<i>A. frigidus</i> <sup>[86]</sup>
						<i>A. himalayanus</i> <sup>[70]</sup>
						<i>A. kabadianus</i> <sup>[51]</sup>
						<i>A. karakuschensis</i> <sup>[87]</sup>
						<i>A. lasiopetatus</i> <sup>[85]</sup>
						<i>A. levieri</i> <sup>[88]</sup>
						<i>A. macropterum</i> <sup>[47]</sup>
						<i>A. membranaceus</i> <sup>[73]</sup>
						<i>A. mongholicus</i> <sup>[80]</sup>
						<i>A. onobrychis</i> <sup>[74]</sup>
						<i>A. ponticus</i> <sup>[89]</sup>
						<i>A. quisqualis</i> <sup>[52]</sup>
						<i>A. schrenckianus</i> <sup>[85]</sup>
						<i>A. sieberi</i> <sup>[38]</sup>
						<i>A. subrobustus</i> <sup>[75]</sup>
						<i>A. tectimundii</i> <sup>[90]</sup>
						<i>A. torrentum</i> <sup>[76]</sup>
						<i>A. virgatus</i> <sup>[77]</sup>
Fisetin (5-deoxyquercetin)	H	OH	H	H		<i>A. beckeri</i> <sup>[63]</sup>

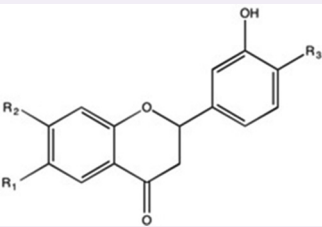
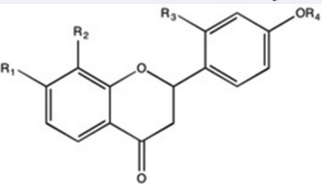
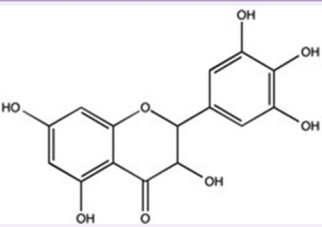
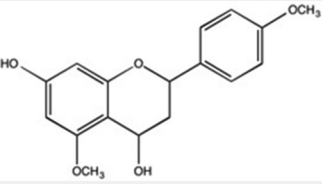
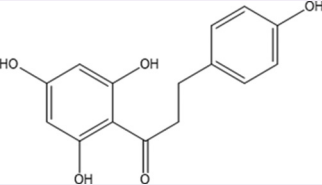
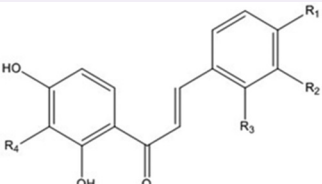
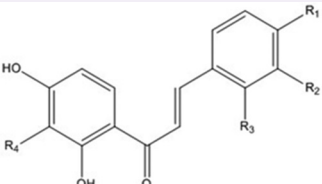
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Table 1: Contd...

Name	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	<i>Astragalus</i> sp. <sup>[References]</sup>
Rhamnetin (7-methylquercetin)	CH <sub>3</sub>	OH	H	OH		<i>A. floccosifolius</i> <sup>[45]</sup>
Isorhamnetin (3,5,7,4'-tetrahydroxy-3'-methoxyflavone)	H	OCH <sub>3</sub>	H	OH		<i>A. adsurgens</i> <sup>[56]</sup> <i>A. astrosibiricus</i> <sup>[61]</sup> <i>A. corniculatus</i> <sup>[26]</sup> <i>A. dasyanthus</i> <sup>[91]</sup> <i>A. edulis</i> <sup>[39]</sup> <i>A. flexus</i> <sup>[92]</sup> <i>A. floccosifolius</i> <sup>[45]</sup> <i>A. inopinatus</i> <sup>[61]</sup> <i>A. kabadianus</i> <sup>[151]</sup> <i>A. marinus</i> <sup>[61]</sup> <i>A. membranaceus</i> <sup>[73]</sup> <i>A. mongholicus</i> <sup>[80]</sup> <i>A. onobrychis</i> <sup>[93]</sup> <i>A. ponticus</i> <sup>[27]</sup> <i>A. armatus</i> <sup>[25]</sup> <i>A. miser</i> var. <i>oblongifolius</i> <sup>[94]</sup>
Tamarixetin (4'-methylquercetin)**	H	OH	CH <sub>3</sub>	OH		
						
8-methoxykaempferol**						<i>A. spinosus</i> <sup>[95]</sup>
						
3-methylquercetin	H	H	OH			<i>A. tectimundi</i> <sup>[90]</sup>
5,7,4'-trihydroxy-3,3'-dimethoxyflavone	H	H	OCH <sub>3</sub>			<i>A. centralpinus</i> <sup>[96]</sup>
4'-hydroxy-3,5,7,3'-tetramethoxyflavone	CH <sub>3</sub>	CH <sub>3</sub>	OCH <sub>3</sub>			<i>A. centralpinus</i> <sup>[96]</sup>
Kumatakenin (5,4'-dihydroxy-3,7-dimethoxyflavone)	H	CH <sub>3</sub>	H			<i>A. centralpinus</i> <sup>[96]</sup> <i>A. membranaceus</i> <sup>[97]</sup>
						
Myricetin (3,5,7,3',4',5'-hexahydroxyflavone)	H	H	OH			<i>A. complanatus</i> <sup>[82]</sup>
3'-methoxymyricetin (laricitrin)**	H	CH <sub>3</sub>	OH			<i>A. complanatus</i> <sup>[82]</sup>
3,5,7,2',3',4'-hexahydroxyflavone**	OH	H	H			<i>A. complanatus</i> <sup>[98]</sup>
<b>FLAVANONES</b>						
						
Naringenin (4',5,7-trihydroxyflavanone)	H	H	H			<i>A. sinicus</i> <sup>[7]</sup>
5-hydroxy-4',7-dimethoxyflavanone	CH <sub>3</sub>	H	CH <sub>3</sub>			<i>A. adsurgens</i> <sup>[29]</sup>
Eriodictyol (5,7,3',4'-tetrahydroxyflavanone)**	H	OH	H			<i>A. corniculatus</i> <sup>[26]</sup>
Homoeriodictyol (5,7,3'-trihydroxy-4'-methoxyflavanone)	H	OH	CH <sub>3</sub>			<i>A. corniculatus</i> <sup>[27]</sup>

Contd...

Table 1: Contd...

Name	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	<i>Astragalus</i> sp. <sup>[References]</sup>
7,3'-dihydroxyflavanone 6,3'-dihydroxy-4'-methoxyflavanone		H OH	OH H	H OCH <sub>3</sub>		<i>A. centralpinus</i> <sup>[96]</sup> <i>A. adsurgens</i> <sup>[29]</sup>
Liquiricigenin (7,4'-dihydroxyflavanone) 8,2'-dihydroxy-7,4'-dimethoxyflavanone		H OCH <sub>3</sub>	H OH	H OH	H CH <sub>3</sub>	<i>A. membranceus</i> <sup>[99]</sup> <i>A. microcephalus</i> <sup>[58]</sup> <i>A. membranaceus</i> <sup>[100]</sup>
<b>FLAVANONOLS</b>						
Ampelopsin (3',4',5',3,5,7-hexahydroxyflavanonol)						<i>A. sinicus</i> <sup>[28]</sup>
<b>FLAVAN-4-OLS</b>						
7-hydroxy-5,4'-dimethoxyflavan-4-ol						<i>A. centralpinus</i> <sup>[96]</sup>
<b>CHALCONES</b>						
Phloretin (4-hydroxy-2',4,6'-trihydroxydihydrochalcon)**						<i>A. ponticus</i> <sup>[27]</sup>
4,2',4'-trihydroxy-3'-prenylchalcon 2',4'-dihydroxy-3,4-dimethoxychalcon 4,2',4'-trihydroxychalcon (isoliquiricigenin)		OH OCH <sub>3</sub> OH	H OCH <sub>3</sub> H	H H H	(CH <sub>3</sub> ) <sub>2</sub> CCHCH <sub>2</sub> H H	<i>A. adsurgens</i> <sup>[29]</sup> <i>A. adsurgens</i> <sup>[29]</sup> <i>A. adsurgens</i> <sup>[29]</sup> <i>A. membranaceus</i> <sup>[101]</sup>
2',4'-dihydroxy-2,3-dimethoxychalcon 2',4'-dihydroxy-4-methoxychalcon		H OCH <sub>3</sub>	OCH <sub>3</sub> H	OCH <sub>3</sub> H	H H	<i>A. adsurgens</i> <sup>[29]</sup> <i>A. adsurgens</i> <sup>[29]</sup>

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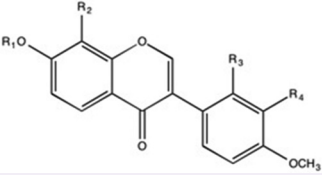
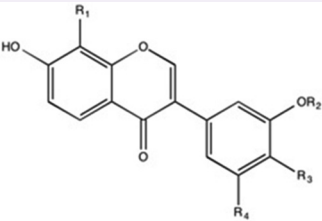
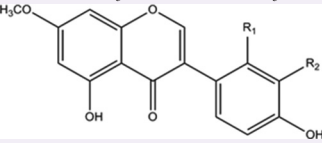
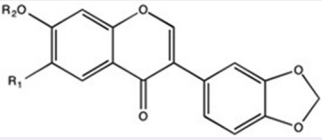
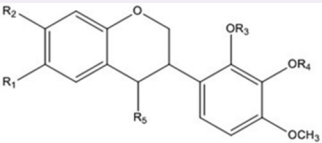
Table 1: Contd...

Name	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	<i>Astragalus</i> sp. <sup>[References]</sup>
Astradsurnin						<i>A. adsurgens</i> <sup>[29]</sup>
2,4'-dihydroxy-4-methoxychalcon						<i>A. adsurgens</i> <sup>[29]</sup>
<b>AURONES</b>						
Sulfuretin						<i>A. microcephalus</i> <sup>[30]</sup>
<b>ISOFLAVONES</b>						
Genistein (5,7,4'-trihydroxyisoflavone)	OH	H	H	H		<i>A. membranaceus</i> var. <i>mongholicus</i> <sup>[102]</sup> <i>A. peregrinus</i> <sup>[36]</sup>
Biochanin A (5,7-dihydroxy-4'-methoxyisoflavone)**	OH	H	H	CH <sub>3</sub>		<i>A. membranaceus</i> var. <i>mongholicus</i> <sup>[103]</sup> <i>A. bombycinus</i> <sup>[18]</sup>
Daidzein (7,4'-dihydroxyisoflavone)	H	H	H	H		<i>A. membranaceus</i> <sup>[99]</sup> <i>A. peregrinus</i> <sup>[36]</sup> <i>A. sinicus</i> <sup>[7]</sup> <i>A. vogelii</i> <sup>[81]</sup> <i>A. clucii</i> <sup>[104]</sup>
Formononetin (7-hydroxy-4'-methoxyisoflavone)	H	H	H	CH <sub>3</sub>		<i>A. complanatus</i> <sup>[78]</sup> <i>A. dahuricus</i> <sup>[105]</sup> <i>A. membranaceus</i> * <sup>[37]</sup> <i>A. membranaceus</i> var. <i>mongholicus</i> <sup>[106]</sup> <i>A. mongholicus</i> <sup>[107]</sup> <i>A. vogelii</i> <sup>[81]</sup>
Cladrin (7-hydroxy-3',4'-dimethoxyisoflavone)	H	H	OCH <sub>3</sub>	CH <sub>3</sub>		<i>A. vogelii</i> <sup>[81]</sup> <i>A. clucii</i> <sup>[104]</sup>
Afrormosin (7-hydroxy-6,4'-dimethoxyisoflavone)	H	OCH <sub>3</sub>	H	CH <sub>3</sub>		<i>A. membranaceus</i> <sup>[108]</sup> <i>A. membranaceus</i> var. <i>mongholicus</i> <sup>[100]</sup>
Calycosin (7,3'-dihydroxy-4'-methoxyisoflavone)	H	H	OH	CH <sub>3</sub>		<i>A. cicer</i> <sup>[109]</sup> <i>A. complanatus</i> <sup>[98]</sup> <i>A. dahuricus</i> <sup>[105]</sup> <i>A. membranaceus</i> <sup>[110]</sup> <i>A. membranaceus</i> * <sup>[37]</sup> <i>A. membranaceus</i> var. <i>mongholicus</i> <sup>[106]</sup> <i>A. microcephalus</i> <sup>[58]</sup> <i>A. mongholicus</i> <sup>[107]</sup> <i>A. vogelii</i> <sup>[81]</sup>
Odoratin (7,3'-dihydroxy-6,4'-dimethoxyisoflavone)	H	OCH <sub>3</sub>	OH	CH <sub>3</sub>		<i>A. membranaceus</i> <sup>[108]</sup> <i>A. mongholicus</i> <sup>[111]</sup>

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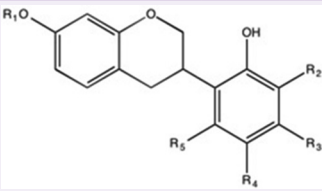
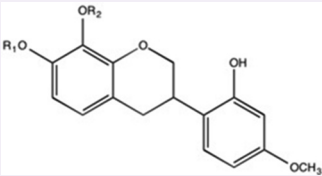
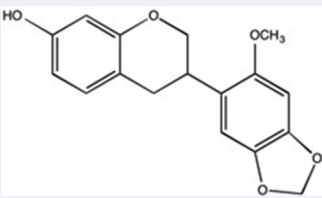
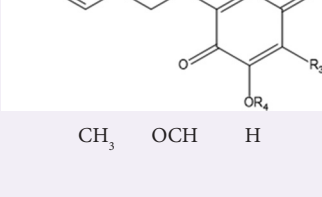
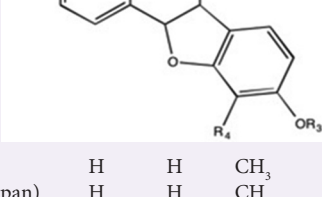

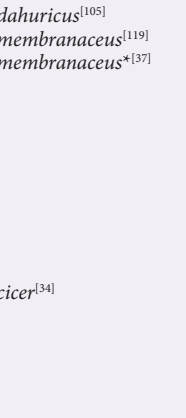
Table 1: Contd...

Name	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	<i>Astragalus</i> sp. <sup>[References]</sup>
Pratensein (5,7,3'-trihydroxy-4'-methoxyisoflavone)	OH	H	OH	CH <sub>3</sub>		<i>A. membranaceus</i> <sup>[112]</sup> <i>A. membranaceus</i> var. <i>mongholicus</i> <sup>[102]</sup> <i>A. verrucosus</i> <sup>[7]</sup>
5,7-dihydroxy-4'-methoxyisoflavone	OH	H	H	CH <sub>3</sub>		<i>A. adsurgens</i> <sup>[29]</sup>
5,7,4'-trihydroxy-3'-methoxyisoflavone	OH	H	OCH <sub>3</sub>	H		<i>A. abyssinicus</i> <sup>[113]</sup> <i>A. membranaceus</i> var. <i>mongholicus</i> <sup>[103]</sup>
						
7,4'-dimethoxyisoflavone	CH <sub>3</sub>	H	H	H		<i>A. adsurgens</i> <sup>[29]</sup>
7,2'-dihydroxy-3',4'-dimethoxyisoflavone**	H	H	OH	OCH <sub>3</sub>		<i>A. membranaceus</i> var. <i>mongholicus</i> <sup>[114]</sup>
8,2'-dihydroxy-7,4'-dimethoxyisoflavone	CH <sub>3</sub>	OH	OH	H		<i>A. membranaceus</i> var. <i>mongholicus</i> <sup>[114]</sup>
8,3'-dihydroxy-7,4'-dimethoxyisoflavone	CH <sub>3</sub>	OH	H	OH		<i>A. membranaceus</i> <sup>[57]</sup> <i>A. membranaceus</i> * <sup>[37]</sup>
7,3'-dihydroxy-4'-methoxyisoflavone	H	H	H	OH		<i>A. adsurgens</i> <sup>[29]</sup>
						
7,5'-dihydroxy-3'-methoxyisoflavone**	H	CH <sub>3</sub>	H	OH		<i>A. membranaceus</i> <sup>[115]</sup>
7-hydroxy-3',5'-dimethoxyisoflavone	H	CH <sub>3</sub>	H	OCH <sub>3</sub>		<i>A. peregrinus</i> <sup>[36]</sup>
7,3'-dihydroxy-8,4'-dimethoxyisoflavone	OCH <sub>3</sub>	H	OCH <sub>3</sub>	H		<i>A. membranaceus</i> <sup>[57]</sup>
						
Cajanin (5,2',4'-trihydroxy-7-methoxyisoflavone)	OH	H				<i>A. cicer</i> <sup>[31]</sup>
Santal (5,3',4'-trihydroxy-7-methoxyisoflavone)	H	OH				<i>A. hoantchy</i> <sup>[116]</sup>
						
Acicerone (6-hydroxy-7-methoxy-3',4'-methylenedioxyisoflavone)	OH	CH <sub>3</sub>				<i>A. cicer</i> <sup>[117]</sup>
Pseudobartigenin (7-hydroxy-3',4'-methylenedioxyisoflavone)	H	H				<i>A. cicer</i> <sup>[109]</sup>
<b>ISOFLAVANES</b>						
						
Spherosine (7-hydroxy-2',3',4'-trimethoxyisoflavane)	H	OH	CH <sub>3</sub>	CH <sub>3</sub>	H	<i>A. alexandrinus</i> <sup>[35]</sup> <i>A. orbiculatus</i> <sup>[118]</sup> <i>A. trigonus</i> <sup>[35]</sup>
6,3'-dihydroxy-2',4'-dimethoxyisoflavane**	OH	H	CH <sub>3</sub>	H	H	<i>A. hoantchy</i> <sup>[116]</sup>
(3R)-7,2',3'-trihydroxy-4'-methoxyisoflavane	H	OH	H	H	H	<i>A. membranaceus</i> <sup>[119]</sup>
(3R)-2'-hydroxy-7,3',4'-trimethoxyisoflavane	H	OCH <sub>3</sub>	H	CH <sub>3</sub>	H	<i>A. membranaceus</i> <sup>[120]</sup>
Mucronulatol (3R)-(-)-7,3'-dihydroxy-2',4'-dimethoxyisoflavane	H	OH	CH <sub>3</sub>	H	H	<i>A. adsurgens</i> <sup>[56]</sup> <i>A. cicer</i> <sup>[31]</sup> <i>A. lusitanicus</i> <sup>[121]</sup>
(3R,4R)-3-(2-hydroxy-3,4-dimethoxyphenyl)-chroman-4,7-diol**	H	OH	H	CH <sub>3</sub>	OH	<i>A. membranaceus</i> <sup>[33]</sup>

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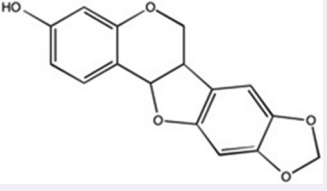


Table 1: Contd...

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

Contd...

Table 1: Contd...

Name	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	<i>Astragalus</i> sp. <sup>[References]</sup>
(6aR,11aR)-10-hydroxy-3,9-dimethoxypterocarpan	CH <sub>3</sub>	H	CH <sub>3</sub>	OH		<i>A. membranaceus</i> <sup>[120]</sup> <i>A. membranaceus</i> * <sup>[37]</sup> <i>A. membranaceus</i> var. <i>mongholicus</i> <sup>[100]</sup>
(6aR,11aR)-3,9,10-trimethoxypterocarpan	CH <sub>3</sub>	H	CH <sub>3</sub>	OCH <sub>3</sub>		<i>A. membranaceus</i> <sup>[120]</sup> <i>A. mongholicus</i> <sup>[32]</sup>
Melilotocarpan B (4,9-dihydroxy-3-methoxypterocarpan)	CH <sub>3</sub>	OH	H	H		<i>A. adsurgens</i> <sup>[29]</sup>
						
Maackianin (3-hydroxy-8,9-methylenedioxypterocarpan)						<i>A. cicer</i> <sup>[31]</sup> <i>A. trojanus</i> <sup>[123]</sup>

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

Table 2: Flavonoid glycosides isolated from *Astragalus* species

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

Contd...

Table 2: Contd...

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

Contd...

Table 2: Contd...

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

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Table 2: Contd...

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

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Table 2: Contd...

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

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Table 2: Contd...

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

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Table 2: Contd...

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

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Table 2: Contd...

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

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.<sup>[35]</sup> Isoflavonoids possessing antibacterial activity were obtained from the roots of *Astragalus membranaceus*.<sup>[57,119,120]</sup> 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.<sup>[192]</sup> 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*.<sup>[193]</sup>

### 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.<sup>[194]</sup> 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<sub>50</sub> between 5 μg.mL<sup>-1</sup> and 10 μg.mL<sup>-1</sup>.<sup>[29]</sup> 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.<sup>[195]</sup> 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<sub>50</sub> values of 4.0 μg.mL<sup>-1</sup> for HCT116 cells and 4.6 μg.mL<sup>-1</sup> for MCF7 cells.<sup>[196]</sup> 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<sub>L</sub> were observed.<sup>[197]</sup> Total flavonoids extracted from the roots of *Astragalus membranaceus* 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<sub>50</sub> of 98.63 μg.mL<sup>-1</sup> (total

flavonoids) and 130.32 μg.mL<sup>-1</sup> (calycosin) without apoptosis induction but by increasing the number of cells in G (0)/G (1) phase.<sup>[198]</sup> Wang *et al.* concluded that total flavonoids from *Astragalus membranaceus* could significantly reduce cyclophamide-induced micronucleolus number and gene mutagenesis *in vitro*.<sup>[199]</sup>

### 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.<sup>[200]</sup> The polyphenolic compounds (flavonoids and phenolic acids) obtained from the aerial parts of *Astragalus karakuschensis* demonstrated stronger blood pressure decreasing effect than papaverine hydrochloride.<sup>[87]</sup> A similar effect was observed for the flavonoid mixture extracted from *Astragalus virgatus*.<sup>[77]</sup> 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.<sup>[201]</sup> 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.<sup>[202]</sup> Moreover, the antihypertensive action of TFAC was reported to be similar to those of Valsartan.<sup>[203]</sup> Wu *et al.* discovered that calycosin could generate endothelium-independent vasorelaxant effects due to its action as noncompetitive Ca<sup>2+</sup> channel blocker.<sup>[204]</sup> Formononetin 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.<sup>[205]</sup> Sodium formononetin 3'-sulphonate showed protective effects in *in vivo* model of cerebral ischemia and reperfusion injury.<sup>[206]</sup> 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.<sup>[207]</sup> Total flavonoid mixture from the aerial parts of *Astragalus lasioglottis* decreased cholesterol and triglyceride levels in animals with experimentally caused hyperlipidemia.<sup>[208]</sup> 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% ( $P < 0.01$ ).<sup>[209]</sup>

## 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 endoplasmic reticulum stress and the c-Jun N-terminal kinase pathway.<sup>[210]</sup> Alteration in antioxidant status was investigated in mice treated with 4 mg.kg<sup>-1</sup> 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.<sup>[211]</sup>

## Activity on the nervous system

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

## 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.<sup>[213]</sup>

## 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.<sup>[214]</sup> 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.<sup>[215]</sup> 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.<sup>[16]</sup>

## 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.<sup>[216]</sup> 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 morphogenic 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.<sup>[217]</sup> 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, methylnissoin, methylnissoin-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. Isoliquiritigenin and liquiritigenin exhibited significant inhibitory effects on lipopolysaccharide (LPS)-induced interleukins, IL-6 and IL-12 production, with IC<sub>50</sub> 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<sub>50</sub> value of 20.1 μM.<sup>[101]</sup>

## Other activities

Flavonoid complex obtained from *Astragalus centralpinus* had a well-pronounced spasmolytic effect on the smooth muscles of the gastrointestinal tract.<sup>[200]</sup> Shen *et al.* observed protective effect of flavonoids of *Astragalus membranaceus* against reperfusion-induced hepatic injury in hemorrhagic shock.<sup>[218]</sup> 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.<sup>[219]</sup> Ethyl acetate extract from the aerial parts of *Astragalus corniculatus*, containing flavonoids, was found to be practically nontoxic (acute oral toxicity > 5 g.kg<sup>-1</sup> 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.<sup>[220]</sup> 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.<sup>[221]</sup> 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.<sup>[222]</sup> 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 μg.mL<sup>-1</sup> while its 50% inhibitory concentration value against HIV-1-induced cytopathic effects was 7.02 μg.mL<sup>-1</sup>.<sup>[223]</sup> 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.<sup>[224]</sup> 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.<sup>[225]</sup> 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.<sup>[226]</sup>

## 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.

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## Conflicts of interest

There are no conflicts of interest.

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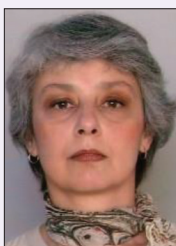
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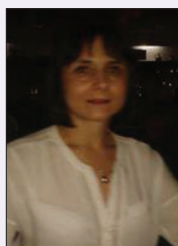
Viktor M. Bratkov



Aleksandar M. Shkondrov



Petranka K. Zdraveva



Iliana 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.

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