Revista Brasileira de Farmacognosia
Brazilian Journal of Pharmacognosy
22(5): 1145-1154, Sep./Oct. 2012

A review on phytochemical, ethnomedical and pharmacological studies on genus *Sophora*, Fabaceae

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Abstract: *Sophora* is a genus of the Fabaceae family, contains about 52 species, nineteen varieties, and seven forms that are widely distributed in Asia, Oceanica, and the Pacific islands, in the family Fabaceae of herbaceous (*Sophora flavescens* Aiton) to trees (*Sophora japonica* L.). More than fifteen species in this genus have a long history of use in traditional Chinese medicines. In the last decades the use of this genus in traditional Chinese drugs has led to rapid increase in the information available on active components and reported to posses various pharmacological/ therapeutic properties. The paper reviews the ethnopharmacology, the biological activities and the correlated chemical compounds of genus *Sophora*, Fabaceae. More than 300 compounds has been isolated, among them major are quinolizidine alkaloids particularly matrine and oxymatrine and flavonoids particularly prenylated and isoprenylated flavonoids. Modern pharmacological studies and clinical studies demonstrated that these chemical constituens possess wide reaching pharmacological actions like anti oxidant, anticancer, anti-asthamatic, anti-neoplastic, antimicrobial, antiviral, antidote, anti pyretic, cardiotonic, antinflammatory, diuretic and in the treatment of skin diseases like eczema, colitis and psoriasis.

Review

Received 9 Aug 2011
Accepted 22 Dec 2011
Available online 3 Apr 2012

Keywords:
flavonoids
Sophora
sophoroflavonone G
sophoramine
matrine and oxymatrine alkaloids

ISSN 0102-695X
http://dx.doi.org/10.1590/S0102-695X2012005000043

Introduction

Sophora is a genus of the Fabaceae family, contains about 52 species, nineteen varieties, and seven forms that are widely distributed in Asia, Oceanica, and the Pacific islands, in the family Fabaceae of herbaceous (*Sophora flavescens* Aiton) to trees (*Sophora japonica* L.); its two sub genera are *Sophora* (ultimately dehiscent fruits and incomplete mesocarp) and *Styphnolobium* (fleshy indehiscent fruit and complete mesocarp). *Sophora* sub genus is further divided into three sections, *Disamaea, Pseudosophora*, and *Sophora,* while the sub genus *Styphnolobium* is divided into four sections; *Raphanocarpus, Arizoniate, Agastianus* and *Stypnolobium* (Tsoong & Ma, 1981a, b). More than fifteen species in this genus have a long history of use in traditional Chinese medicines. In the last decades the use of this genus in traditional Chinese drugs has led to rapid increase in the information available on active components and reported to posses various pharmacological/therapeutic properties, in particular *Sophora* alkaloids have been found to be their chief active chemical constituents including matrine, oxymatrine, sophocarpine, sophoramine, sophoridine and others (Liu et al., 2003; Zhang et al., 2008; Hu et al., 1996a,b,c; Lin et al., 1997); along with flavonoids , iso flavonoids isoprenylated flavonoids (Xing et al., 2008), isoflavonones, flavones, flavonols and their glycosides, coumarochromones (Tang et al., 2002), saponins, triterpene glycosides, phospholipids, polysaccharides, oligostilbenes and fatty acids (Bach & Brashler, 1975). A number of quinoline alkaloids, prenylated flavonoids and oligostilbenes, were used as chemotaxonomic markers (Izaddoost, 1975). Several phytochemical researches, *in-vivo* and *in-vitro* experiments and clinical practices have demonstrated that *Sophora* constitutes many phyto-constituents possessing wide-reaching pharmacological actions, including anti-oxidant, anticancer, anti-asthamatic, anti-neoplastic, antimicrobial, antiviral, antidote, anti-pyretic, cardiotonic, antinflammatory, diuretic and in the treatment of skin diseases like eczema, colpitis and psoriasis. In this review we tried to present and assess traditional importance and reported phytochemical constituents along with reported pharmacological actions of some of the species of *Sophora.*

Materials and Methods

The pharmacological activities of compounds

isolated and identified from genus *Sophora* along with their ethnopharmacological uses were searched through many online data bases. An extensive bibliographic search was undertaken to identify works on these medicinal plants published in periodicals, data banks, and rare or current texts stored in public and private libraries during the period between 1970 and 2011, including sources such as Sci-verse/Science direct, Food & Drugs Administration (USA), Pubmed and similar sources. Additionally, we consulted published monographs, thesis, and proceedings of scientific congresses, websites, and technical research publications. The references were consulted for details of the experimental models used for testing the extracts.

Distribution

The plants of this genus distribution range from the temperate to the tropic areas in the world (Iinuma et al., 1993) (Chart 1).

Chart 1. Geographical distribution of genus *Sophora.*

Distribution	Category
China	*S. flavescens, S. japonica, S. subprostrate, S. alopecuroides, S. tonkinensis, S. viciifolia,*
United States of America	*S. davidii, S. lechiana, S. secundiflora, S. tomentosa, S. chrysophylla, S. affinis*
New Zealand	*S. prostrata and S. tetrptera*
Korea	*S. koreensis*
Thailand	*S. exigua*
Australia	*S. fraseri*
India	*S. interrupta*

Ethnopharmacological use

Traditionally *Sophora* species were widely used in the treatment of many diseases and ailments. *Sophora* plants, such as the roots of *S. flavescens* (Chinese name "Kushen"), the roots of *S. tonkinensis* (Chinese name "Shandougen") and the seeds of *S. alopecuroides* (Chinese name "Kudouzi") were commonly used in traditional Chinese medicines for the treatment of eczema, colitis, acute pharyngolaryngeal infection, sore throat, acute dysentery and gastrointestinal haemorrhage (Saito, et al., 1990; Rahman et al., 2000). The principal bioactive constituents of these traditional medicines are the quinolizidine alkaloids, which have been shown to exhibit sedative, depressant, analgesic, hypothermic, anti-tumor, antipyretic, and cardiotonic activities (Kinghorn et al., 1984).

S. subprostrata is a traditional Chinese medicinal plant. Its roots are used as an antipyretic, antidote, analgesic, it has been reported to have antitumour activity (Chen & Jiang, 1994), the roots of *S. subprostrate* have been used as a Korean traditional medicine for the treatment of fever, inflammation, peptic ulcer, cancer and reported that antitumour activity is to be the result of cytotoxicity of its alkaloids (Sakamoto et al., 1992; Zheng et al., 1997).

*Sophora flavescens (*Chinese name "Kushen") were used traditionally for asthma, sores, gastrointestinal hemorrhage, allergy and inflammation antiulcerative effects and is used for the treatment of diarrhoea, gastrointestinal haemorrhage and eczema (Ahn, 1998; Kang et al., 1998). So far, more than twenty alkaloids and fifty flavonoids have been isolated and identified (Miao & Zhang, 2001; Zhao & Sun, 2005). The dried roots of *Sophora flavescens* have various effects like anti-oxidant, anti-inflammation, anti-bacterial, apoptosis modulator properties and anti-tumor activities (Piao et al., 2006; Cheng, et al., 2006; Kuroyanagi et al., 1999; Ko et al., 2000; Zhang & Huang, 2004; Sun et al., 2007).

The seeds of *Sophora alopecuroides* (Chinese name "kudouzi") were used as traditional Chinese medicine as an antibacterial and anti-inflammatory agent and is widely distributed in northwest China (Guan et al., 2009).

S. japonica L. is widely cultivated in China, whose flavones from its buds and fruits have been used as haemostatic agent in traditional Chinese medicine (Ishida et al., 1989; Tang et al., 2001). The seeds of this plants contains phytoconstituents *viz.*, triterpenes, phospholipids, alkaloids, amino acids, polysaccharides and fatty acids (Grishkovets & Gorbacheva, 1995; Mukhamedova & Glushenkova, 1997); Pharmacological and clinical practices revealed that it has anti tumor, anti-fertility and anticancer activities.

S. vicifolia is a bush that grows widely throughout south west china its roots were in use as a Chinese drug Bai-Ci-Hua to treat fever, cystitis, haematuria, edema etc. (Xiao, 1993b). In the Yunnan province of China, many minority races, such as Bai, Yi, Miao etc., have the tradition of eating flower. It is said that eating flower in springtime could eliminate the 'toxin' which had been accumulated in the human body during the previous season. Conventionally, after being dipped in boil water quickly, then soaked and cleaned in water for about 24 h, the flower of *S. viciifolia* is used as a health-giving food, and is cooked with egg, meat, and chicken for the remedy of night sweat, heart stroke, oedema (Gao, 2006). Previous research focused on the analysis of the chemical constituents of the seeds and branches of *S. viciifolia*. Alkaloids and flavonoids isolated from this species showed some bioactivities, such as antiinflammatory, antianaphylaxis, immunological function, antioxidant activity etc. (Wen & Mao, 2006).

Sophora tonkinensis (Shan-Dou-Gan) was also

used in traditionl Chinese medicine, the roots of this species have been used as the Chinese drug Shan-Dou-Gen to treat fever, throat inflammation, haemorrhoids, and tumours (The Pharmacopoeia of the People's Republic of China 1994; Xiao 1993a). Phytochemical investigations have revealed that the plant accumulated isoprenyl-substituted flavonoids and lupin alkaloids as its main constituents (Ding & Chen, 2006, 2007). Pharmacological studies showed that the isoprenylated flavanones isolated from this species could inhibit cell growth and induce apoptosis on various cell lines from human solid tumors and in human leukemia U937 cells (Kajimoto et al., 2002).

Sophora moorcroftiana is an endemic shrub species in Tibet, China, and is mainly distributed in the wide valleys and the middle reaches of several main tributaries of Yalu Tsangbo River (Nianchu and Lhasa Rivers). Its seeds have been used for a long time in Chinese folk medicine. The decoction of the seeds were used in Chinese folk medicine for dephlogistication, detoxication, emetic, infectious diseases and verminosis (Xingming et al., 2004). *Sophora subprostrata* is a traditional Chinese medicinal plant, distributed chiefly in South China. Its roots were used in traditional Chinese medicine as an antipyretic, antidote and analgesic (Chen & Jiang, 1994). It has been known to contain flavonoids, alkaloids, saponins, phenols and lignins. The antitumor activity of *S. subprostrata* crude preparation has been reported and theorized to be the result of cytotoxicity of its alkaloids (Sakamoto et al., 1992; Zheng et al., 1997).

Phytoconstituents

The genus *Sophora* is rich in alkaloids and flavonoids. Alkaloids constituted the majority of compounds like quinolizidine alkaloids, lupine alkaloids particularly matrine, oxy matrine, sophocarpine, sophoramine and sophoridine and others (Liu et al., 2003; Zhang et al., 2008; Hu et al., 1996abc; Lin et al., 1997) along with flavonoids, isoflavonones, flavonol triglycosides, isoprenylated flavonoids, isoflavonones, saponins, triterpene glycosides, phospholipids, polysaccharides, oligostilbenes (Ohyama et al., 1995), fatty acids (Bach & Brashler 1975), and a number of other compounds representing a wide spectrum of secondary metabolite classes have been isolated and identified from the genus *Sophora.* The most phytochemically characterized compounds of this genus are flavonoids and alkaloids and the most prominent compounds are prenylated flavonoids and quinolizidine alkaloids. These phytoconstituents displayed many *in vitro* and *in vivo* bioactivities. These have been confirmed to possess anticancer, antioxidant, antibacterial, antifungal, anti-inflammatory, antiviral and other activities.

Flavonoids

Flavonoids and their derivatives are important constituents of genus *Sophora.* Over 150 flavonoids were isolated *viz*., flavonol, flavone, chalcone, flavanone, isoflavones, isoflavonones, prenylated flavonoids, lavandulyl flavanones and flavonol glycoside, have been found from different species of *Sophora* (Chart 2). The sugar moieties of the glycosides are usually glucose, rhamnose, xylose or their corresponding mono- or di-acetyl sugars. Quercetin and quercetin-3-rutinoside (rutin) from *S. japonica* and isoflavone (genistein) from *S. tonkinensis* is having wide range of antioxidant activity. (Cai et al., 2004; 2006). Lavandulyl flavanones and isoflavonoids from *S. flavescens* is found to have inhibitory activity on SGLT (Na^+-glucose cotransporter), which has the role in the reabsorption of glucose in the kidneys (Sato et al., 2007). Lavandulyl flavanone is also found to inhibit BACE1 which has the crucial role in the development of Alzeimer's disease (Hwang et al., 2008). Kurarinone isolated from *S. flavescens* inhibited MCP-1 induced chemotaxis (Lee et al., 2005). Prenylated flavonoids exhibited wide variety of pharmacological activities which include antioxidant, apoptogenic and antiulcer effects (Ko et al., 2000).

Chart 2. The flavonoids isolated from the genus *Sophora.*

Compounds	Species	Part	References
alopecurone A-F (flavonostilbenes), alopecurone G (flavanone), vexibidin (lechianone A), vexibinol (sophoraflavanone G)	*S. alopecuroides*	Roots	Iinuma et al., 1995c
sulfuretin, dihydrophaseic acid, ferulic acid, butein, 7-hydroxy-3′,4′-methylenedioxyisoflavone, 7,3′,4′-trihydroxyflavone, matrine sophoridine, piscidic acid, sophoramine, butein-4-*O*-β-D-glucopyranoside, cytosine, luteolin, quercetin, vicenin-2, saponarin, 3',5,7-trihydroxy-4'-methoxyflavone-3-*O*-α-L-rhamnopyranosyl (1-6)-β-D-glucopyranoside.	*S. alopecuroides*	Seeds	Guan et al., 2009
arizonicanol A-D, derrone (isoflavone)	*S. arizonica*	Roots	Tanaka et al., 1997
leachianone A, ophoraflavanones G,H and I, miyabenol C, α-viniferin, ε-viniferin, davidols A-C (stilbene oligomers)	*S. davidii*	Roots	Tanaka et al., 2000
davidol D (resvaretrol pentamer)	*S. davidii*	Roots	Ohyama et al., 1996

kuraridin, kurarinone	*S. flavescens*	Roots	Kang et al., 2000;Kim et al., 2002; Yagi et al., 1989
kurarinol	*S. flavescens*	Roots	Kang et al., 2000
5-methylsophoraflavanone B sophoraflavonone G	*S. flavescens*	Roots	Kang et al., 2000;Kim et al., 2002
variabillin, kushenol N and K	*S. flavescens*	Roots	Sato et al., 2007
kushenol E, B, M, L and H, trifolirhizin	*S. flavescens*	Roots	Kang et al., 2000
maackiain	*S. flavescens*	Roots	Yagi et al., 1989
pterocarpin	*S. flavescens*	Roots	Kang et al., 2000
formononetin	*S. flavescens*	Roots	Kang et al., 2000
kuraridin	*S. flavescens*	Roots	Sato et al., 2007
trifolirhizin	*S. flavescens*	Roots	Yagi et al., 1989
daidzein	*S. flavescens*	Roots	Kang et al., 2000
umbelliferone	*S. flavescens*	Roots	Yagi et al., 1989
(2*S*)-7,4'-dihydroxy-5-methoxy-8-(γ, γ-dimethylallyl)-flavonone	*S. flavescens*	Roots	Kang et al., 2000
unaniisoflavan, (-)-maackiain, medicalpin, 3-hydroxy-8,9-methoxypterocarpan, secundiflorol B, C, liquirtigenin (flavonone), isoliquirtigenin (chalcone)	*S. gypsophila*	Roots	Tanaka et al., 1997
flavonol tetraglycoside	*S. japonica*	Seeds	Wang et al., 2003
sophorabioside, sophoraflavonoloside, genistein 7,4'-di-*O*-β-D-glucopyranoside	*S. japonica*	Seeds	Watanabe et al., 1993
1,6-di-*O*-β-D-glucose	*S. japonica*	Seeds	Kashiwada et al., 1988
isoscutellarein	*S. japonica*	Seeds	Terashina et al., 1991
sissotrin, tectoridin	*S. japonica*	Seeds	Xu et al., 1999
7-*O*-α-L-rhamnopyranoside	*S. japonica*	Seeds	Liu et al., 1994.
sophororicoside	*S. japonica*	Seeds	Wang et al., 2003.
rutin	*S. japonica*	Flower buds	Paniwnyk et al., 2001
quercetin, orobol, 3'-methylquercetin	*S. japonica*	Flower buds	Lo et al., 2009
genistein-7-*O*-β-D-glucopyranoside-4'-*O*-[(α-L-rhamnopyranosyl)-(1-2)-β-D-glucopyranoside, kaempferol 3-*O*-α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranosyl-(1→2)-β-D-glucopyranoside, genistein-7-*O*-β-D-glucopyranoside, kaempferol-3-*O*-β-D-sophoroside, genistein-4'-β-L-rhamnopyranosyl-(1→6)-α-D-glucopyranoside, kaempferol-3-*O*-β-L-rhamnopyranosyl-(1→6)-β-D-glucopyranoside	*S. japonica*	Pericarp	Qi et al., 2007
kenusanone H, flavanone, isoflavanone and few flavonoids, kenusanon F	*S. koreensis*	Root	Iinuma et al., 1992. 1991b, 1992a, b, 1993a.
leachianols C-G (oligostilbenes)	*S. lechiana*	Roots	Ohyama et al., 1995
α- and ε-viniferin	*S. moorcroftianaa*	Roots	Ohyama et al., 1995
prostratol, A-C (isoflavanones), prostratols D-G, maackiain (pterocarpan derivative), isoneorautenol (pterocarpan derivative), ficifolinol (pterocarpan derivative), erythrabyssin II (pterocarpan derivative), glabrol (flavanone), 3-hydroxyglabrol (flavanone), 3'-γ, γ-dimethylallyl-4-2'-4'-trihydroxychalcone, 3'-γ, γ-dimethylally-4-2'-dihydroxy-4'-methoxychalcone, caffeic acid octadecyl ester	*S. prostrata*	Roots	Iinuma et al., 1995b
secondifloran, secundiflorol A	*S. secundiflora*	Stems, Roots	Tanaka et al., 1998, Iinuma et al., 1995d
formononetin, genistein	*S. secundiflora*	Stems	Tanaka et al., 1998
geraldol	*S. secundiflora*	Roots	Shirataki et al., 1997
prunetin, biochanin A	*S. secundiflora*	Stems	Tanaka et al., 1998
gancaonin, pratensin	*S. secundiflora*	Roots	Iinuma et al., 1995d
pseudobaptigenin	*S. secundiflora*	Roots	Shirataki et al., 1997

medicapin, calycosin, cladrin, 6-γ, γ-dimethylallyl-5,7,3',4',-tetrahydroxyflavanone	*S. secundiflora*	Roots	Iinuma et al., 1995d
orobol	*S. secundiflora*	Stems	Tanaka et al., 1998
secundiflorol B, secundiflorol C	*S. secundiflora*	Stems, Roots	Tanaka et al., 1998; Iinuma et al., 1995d
secundiflorol F	*S. secundiflora*	Stems	Tanaka et al., 1998.
(-)-maackiain3-sulfate (pterocarpan), trifolirhizin, lupeol, ononin, 7,4'-dihydroxyflavone, (+)-syringaresinol	*S. subprostrata*	Roots	Park et al., 2003
tetrapterols-A-E (isoflavonones) (with geranyl or isoprenyl group)	*S. tetraptera*	Roots	Iinuma et al., 1995a
tetrapterols-F-I (isoflavanones), lupinifolin, 8-*O*-methylretusin, 5,7,4'-trihydroxy-6-3'-di(γ, γ-dimethylallyl)isoflavone, sophoracarpan A, medicagol, 2-(2,4-dihydroxypfenyl)-5,6-methylenedioxybenzofuran	*S. tetraptera*	Roots	Shirataki et al., 1999
phenolic compounds, cajanone, kenusanone A, lespedeol B, euchenone a_9, lonchocarpol, isoneorautenol, pentacosanyl caffeate	*S. tetraptera*	Roots	Iinuma et al., 1995a
irisolidone, 3'isoprenylgenistein, glabranin	*S. tomentosa*	Stem, Roots	Tanaka et al., 1997
tomentosanol A (isoflavanone), tomentosanol B, iristeorigenin A, des-*O*-methylanhydroicaritin, tomentosanol C, (8-geranylkaempferol), tomentosanol D (naringenin), tomentosanol E (isoprenyl flavanone)	*S. tomentosa*	Root	Tanaka et al., 1997
tonkinochromanes J, K and L, 2',4',7-trihydroxy-6-8,-bis(3-methyl-2-butenyl)flavonone, 2-(2',4'-dihydroxy-phenyl)-8,8-dimethyl-10-(3-methyl-2-butenyl)-8H-pyrano[2,3-d]chroman-4-one, 6-[3-(2',4'-dihydroxyphenyl)acrylolyl]-7-hydroxy-2,2-dimethyl-8-(3-methyl-2-butenyl)-2H-benzopyran, kushenol E	*S. tonkinensis*	Roots	Xing et al., 2008

Alkaloids

About forty alkaloids mainly quinolizidine type are isolated from the genus *Sophora* which includes matrine and oxymatrine which has variety of pharmacological effects (Kinghorn et al., 1984). These are reported to exhibit sedative, inotropic, antipyretic, anti tumor, antihepatitis B virus (Zhou et al., 2008a,b; Ma et al., 2008; Zhang et al., 2006; Ding et al., 2006) (Chart 3).

Matrine acts as kappa opioid receptor agonist and shown to have antinociceptve activity (Higashiyama et al., 2005).

Polysaccharides

Polysaccharides are isolated from the roots of *S. subprostrata* (Chart 4), particularly heteroxylon, and several water extractable amylopectins and pectins. Starch is another reserved polysaccharide of its roots, along with arabinogalactans attached to small amount of rhamnogalacturonan core which has immunopharmacological and antioxidant properties (Dong et al., 1998). galactomann was isolated from seeds of *S. japonica* (Bourbon et al., 2010).

Fatty acids

Fatty acids from the seeds of *Sophora flavescen*s are reported, particularly polyunsaturated fatty acids which is dragging the attention of researchers due to their pharmacological properties. More than 31 compounds are isolated from the lipids of the species mainly palmitic, linoleic, oleic and steric acids (Olennikov et al., 2009).

Pharmacological potentials

Anticancer

Root extract of *S. flavescens* shown anti proliferative effect on cultured HaCaT cells (Tse et al., 2006). Traditionally, Chinese herbal medicine has been extensively used to treat psoriasis and produced promising clinical results. However, its underlying mechanisms of action have not been systematically investigated. Treatment with ethanolic extract of seeds of *Sophora moorcroftiana* at a dose of 800 mg/kg/d has a marked inhibiting effect on S_{180} sarcoma development in mice *in-vivo* (Xingming et al., 2009a). Ethanolic extracts from *S. moorcroftiana* seeds significantly inhibited the proliferation of human stomach cancer cells and its activity was in dose- as well as time-dependent manner (Xingming et al., 2009b); Root extract of *Sophora japonica* inhibit the proliferation Hep G_2 cells (Bassem et al., 2009).

Induction of apoptosis

A mannaose binding lectin from *S. flavescens* shows a strong cytotoxic effect against HeLa cells and induced apoptosis in time and dose dependent manner and it typically has caspase-dependent mechanism (Liu et al.,

Chart 3. The alkaloids isolated from genus *Sophora.*

Compounds	Species	Part	References
sophocarpine	*S. alopecuroides*	Root and aerial parts	Movsumov et al., 2006
matrine, sophoridine, sophoramine	*S. alopecuroides*	Seeds	Guan et al., 2009
9α-hydroxy-7,11-dehydromatrine, flavascensine, (+)-matrine, (-)-sophoridine, (+)-isomatrine, (+)-allomatrine, (-)-sophocarpine, (+)-7,11-dehydromatrine (leontalbinine), (+)-sophoramaine, (+)-oxymatrine, (+)-oxysophocarpine, (+)-5α-hydroxymatrine, (-)-9α-hydroxysophocarpine, (-)-9α-hydroxysophoramine, (-)-14β-hydroxymatrine, (-)-*N*-methylcytisine	*S. flavescens*	Roots	Liu et al., 2010
(+)-12α-hydroxysophocarpine, (+)-lehmannine, (-)-13,14-dehydrosophoridine, (-)-anagyrine	*S. flavescens*	Roots	Ding et al., 2006
matrine, oxymatrine	*S. subprostrata*	Roots	Bai et al., 1982
tonkinensis A and B (cystine type)	*S. tonkinensis*	Roots	Li et al., 2008
(+)-matrine	*S. vicifolia*	Roots	Xiao et al., 1999
(+)-matrine *N*-oxide	*S. vicifolia*	Roots, Seeds	Xiao et al., 1999
(-)-sophocarpine, (+)-sophocarpine, *N*-oxide(-)-sophoridine, (+)-sophoramine	*S. vicifolia*	Roots,Seeds	Xiao et al., 1999
(-)-14β-hydroxysophoridine, (-)-12β-hydroxysophocarine, (-)-9α-hydroxysophocarpine, (+)-9α-hydroxymatrine, (-)-14β-hydroxymatrine, (+)-lupanine, (-)-5,6-dehydrolupanine, (-)-cystine	*S. vicifolia*	Seeds	Xiao et al., 1999

Chart 4. Other compound isolated from genus *Sophora.*

Compounds	Species	Part	References
xyloglucan, heteroxylan, amylopectins (SSa1 & SSa2), Pectins (SSa3 & SSa4)	*S. subprostrata*	Roots	Dong et al., 1998

2008). Sophoranone, extracted from *Sophora flavescens* induces apoptosis in human leukemia u937 cells *Via* formation of reactive oxygen species and opening of Mitochondrial permeability transition pores (Kajimoto et al., 2002).

Antioxidant effects

In recent years, there is a tremendous interest in the possible role of nutrition in prevention of disease. In this context, antioxidants especially derived from natural sources such as Chinese medicinal plants, Indian medicinal plants and herbal drugs derived from them require special attention. Antioxidants neutralize the toxic and 'volatile' free radicals. Antioxidants have many potential applications, especially in relation to human health, both in terms of prevention of disease and therapy. Cellular damage induced by oxidative stress has been implicated in the etiology of a large number (>100) of human diseases as well as the process of ageing.

Anti-HBV and anti-entroviruses activity was reported (Ding & Chen 2006; Gao et al., 2006); It also suppressed the proliferation of hl-60 cells (Ding & Chen 2007); The roots of *S. tonkinensis* contain alkaloids that possess broad biological activities, for example-(-) 14-β-hydroxyoxymatrine, (+)-sophoranol and (-)-cytisine showed anti-HBV activity (Ding et al., 2006).

Effects on hair growth

S. flavescens methanol-extract has promising hair growth promoting effect in addition the extract has shown regulatory role on the expression of growth factors and the inhibitory effect on type II 5 α-reductase, which has an important role in hair growth regulation (Roh et al., 2002). RT-PCR analysis showed that *S. flavescens* extract induced mRNA levels of growth factors such as IGF-1 and KGF in dermal papilla cells, suggesting that the effects of *S. flavescens* extract on hair growth may be mediated through the regulation of growth factors in dermal papilla cells.

Antimicrobial activity

Traditionally plant extracts such as roots of *S. flavescens* have been used for microbial infections which strongly reflecting that natural products are the major source of important antimicrobial agents. Prenylated flavonoids are chemical entities which have an isoprenyl, a geranyl, a 1,1-dimethylallyl, and/or lavandulyl moiety as part of flavonoid backbone structure which was isolated from *Sophora* species. Sophoraflavanone G isolated from

S. exigua showed strong antimicrobial activity against methicillin resistant *Staphyllococcus aureus* with 3.13-6.25 µg/mL of MIC (Sato et al., 1995); Kurarinone, sophoraflavanone G and kuraridin also showed strong antimicrobial activity against Staphyllococcus aureus and *Streptococus mutans* (Yamaki et al., 1990). Kuraridin, sophoraflavanone D and sophoraisoflavanone A has the anti microbial activity against fungi (*C. albicans* and *S. cerevisiae*), gram negative bacteria (*E. coli* and *S. typhimurium*) and gram positive bacteria *S. epidermis* and *S. aureus*) (Sohn et al., 2004).

Antiviral activity

Traditional Chinese medicinal herbs in the form of hot water extracts orally have been used as remedies against infectious viral diseases in china. Anagyrine, oxymatrine, and sophoranol isolated from *S. flavescens* have potent antiviral activity against respiratory syncital virus (RSV) with IC50 values of 10.4 µg/mL and SI (CC50/IC50) values of 24.0, 12.0, and 24.0 respectively (Ma et al., 2002). But it showed less significant activity against herpes simplex virus type 1 and type 2. Quinolizidine alkaloids from *S. alopecuroides* have very weak activity against HSV 1, coxsackie B2, measles, polio, semliki forest virus and vesicular stomatitis virus (Zheng et al., 1997).

Conclusion

Phytochemical and pharmacological studies of the compounds isolated from the genus *Sophora* have reached much interest in recent times but most of the species under this genus yet to be explored. So far the pharmacological studies have been performed *in vitro* and *in vivo* with animals, therefore clinical trials in humans are needed to prove their traditional phytotherapy. According to the literature most of the pharmacological activities of *Sophora* plants can be explained by the presence of alkaloids and flavonoids. The crude extracts mainly the roots of these plants possess bioactive constituents which has wide reaching pharmacological actions. The bioactive constituents of *Sophora* especially matrine, oxy matrine alkaloids along with flavonoids such as prenylated flavonoids, flavanones, flavonols, isoflavonones and isoflavonols from various species were isolated and characterized. In the view of their therapeutic efficacy the active ingredients might be developed into new drugs for the treatment of various diseases. So, their pharmacological and toxicity profiles should be further investigated with both *in vitro* and in vivo along with the clinical trials.

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