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Original Research Article

Traditional uses, chemical constituents and pharmacological effects of Boschniakia rossica: A systematic review

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Abstract

Purpose: *To undertake a review on the morphology, traditional uses, phytochemistry and pharmacology of Boschniakia rossica, a plant with a long history of usage in Chinese traditional medicine.*
Methods: *Available literature on the ethnopharmacological uses of B. rossica from 1967 to 2018 were selected via various databases, such as ScienceDirect, NCBI, Springerlink, Taylor & Francis and CNKI.*
Results: *A variety of phytochemical studies demonstrated that B. rossica contains more than 100 chemical constituents, among which boschnaside, boschniakine, 7-deoxy 8-epiloganic acid, (4R)-4-hydroxymethyl-boschnialactone are predominant. Studies showed that isolates and crude extracts of B. rossica exhibit a wide spectrum of in vitro and in vivo pharmacological effects such as anti-aging, anti-tumor, anti-oxidant, anti-inflammatory and immune enhancement. It was revealed that iridoids, carbohydrates and glycosides are perhaps responsible for most of the biological activities shown by this plant. However, the bio-active compounds and their underlying mechanisms of action have not yet been investigated in detail.*
Conclusion: *B. rossia has received tremendous research attention. Phytochemical and pharmacological studies have provided scientific bases for validation of the traditional uses of the plant.*

Keywords: *Boschniakia rossica, Traditional herb, Pharmacology, Chemical components, Boschnaside*

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INTRODUCTION

Boschniakia rossica Fedtsch. et Flerov (Figure 1) belongs to O*robanchaceae*. It is a perennial parasitic herb which lives on the roots of plants belonging to the genus *Alnus*, for example *Alnus japonica*. The whole herb is used as medicine which in China, is called “no old herb” because of its medicinal properties. The distribution area of *B. rossica* is a very limited in the world: it is found only in Korea, Japan, Russia’s Siberia Mountains and northeast China. In China, it is distributed mainly at 1350- 2000 m above sea level in the Changbai Mountains and on the northern mountainous area of Daxinganling [1]. *Boschniakia rossica* has rare natural distribution due to its parasitic characteristics, it belongs the

second-class of national protected plants in the list of rare and endangered plants in China [2].

Figure 1: *B. rossica.* (A) fresh whole herb; (B) dry whole herb. The roots are underground, while the stems and spikes are above the ground. The leaves are dense near the base of the stem and sparse upward

B. rossica is a highly parasitic and precious medicinal plant, the aerial parts of which contain boschnialactone, boschnaside, boschniakine and boschnialinic acid. The rhizome contains mannitol and alkaloids. *Boschniakia rossica* is available and collected between May and August every year. After drying by airing or in the sun, it is cut into sections. Most people take *B. rossica* in the form of soup or infuse it into their bodies. It possesses multiple functions which are recorded in Chinese traditional books. These include; kidney invigoration, aphrodisiac qualities, hemostatic activity, and enhancement of longevity [2]. Clinically, *B. rossica* is used to treat kidney problems, chills, waist and knees pain, chronic constipation, cystitis, functional uterine hemorrhage, nephritis, prostatitis, as well as kidney and bladder hemorrhage. Although its dried herb is used as a tonic in China, Korea and Japan, the basic principle involved in this application has not yet been elucidated. Studies have shown that *B. rossica* exhibited free radical scavenging, anti-lipid peroxidation, anti-tumor, anti-inflammatory and immunity-enhancing properties [3].

METHOD

The available literatures on the ethno-pharmacological uses of *B. rossica* from 1967 to 2018 were selected via several databases-such as Science Direct, NCBI, Springer link, Taylor & Francis and CNKI. The main chemical compositions and pharmacological activities were reviewed based on the collected literatures, with the aim of providing beneficial information for the development and clinic applications of *B. rossica***.**

RESULTS AND DISCUSSION

Phytochemistry

Varieties of natural compounds have been isolated from different parts of *B. rossica* through chromatography. These include phenylpropanoid glycosides, iridoids, polysaccharides, organic acids and alkaloids. The main chemical compositions of the plant are shown on Tables 1 and 2. In addition to chemical composition, nutrient and mineral element contents of *B. rossica* have been determined by automatic amino acid analyzer and atomic absorption spectrometry, respectively. The results showed 6.55 % amino acid content, out of which essential amino acids accounted for 36.18 % [4]. In addition, there were 17 amino acids, and more than 7 of these are essential to humans [5]. Inorganic elements include K, Na, Ca, Mg, Fe, Zn, Mn, Cu, Ni and Cr. The contents of first eight inorganic elements were 20.436, 2.275, 0.820,0.994, 0.236, 0.036, 0.034 and 0.016 mg/g, respectively [4,6,7]. Water-soluble polysaccharides have been isolated and purified from *B. rossica*, and their molecular weights and monosaccharide compositions have been studied [8,9].

The important phytochemical components of *B. rossica* that have received research interest are phenylpropanoid glycosides, iridoids, polysaccharides and the resinous exudates which are dispensed on prescription in the indigenous medicines of China, Japan, Korea. Therefore, the spikes, leaves, bark and stem of *B. rossica* are the most frequently investigated targets for screening active compounds. Figure 2 shows the structures of some chemical constituents of *B. rossica.*

Biological activities

Various studies have reported the anti-aging, anti-tumor and hepatoprotective effects of *B. rossica* extracts in animal models (Table 3). These activities might be related to the anti-inflammatory, free radical scavenging and SOD-enhancing effects of the plant. Other studies have suggested that iridoids, polysaccharides and glycosides are the major bioactive compounds in *B. rossica*.

Immune-enhancing effects

It has been shown that ethanol extracts of *B. rossica* increased immune function *in vitro* and *in vivo*. Mice spleen cells and sheep red blood cells of treatment group increased significantly compared with control group, and two had positive correlation [29]. Rat Kupffer cells cultured *in vitro* and treated with carbon tetrachloride had significantly higher phagocytic rate and phagocytic index when exposed to ethanol extract *B. Rossia* ethanol extract [30]. In another research, three polysaccharides were isolated and purified from the water extract of *B. rossica*, and their effects on macrophage activation were also investigated *in vitro*, including phagocytosis of macrophages, NO production and TNF-α secretion. The results indicated that *B. rossica* polysaccharides mediated macrophage activation and promoted the production NO and TNF-α, thereby contributing to immune-stimulationing [9].

Table 1: Chemical constituents of *B. rossica*

Class	Chemical constituent	Source	References
Volatile oils	All-cis-iridomyrmecin (1)	Whole herb	[10, 11]
	All-cis-iridomyrmecin (2)	Whole herb	[10, 11]
	All-cis-dihydronepetalactone (3)	Whole herb	[10, 11]
	All-cis-isodihydrone petalactone (4)	Whole herb	[10, 11]
	Boschnialactone (5)	Whole herb	[10, 11]
	Neoboschnialactone (6)	Whole herb	[10, 11]
	1-Heanol (7)	Whole herb	[12]
	Cis-8-minthene (8)	Whole herb	[12]
	Pulegine (9)	Whole herb	[12]
	N-hexylvinyl (10)	Whole herb	[12]
	Dihydro-carvone (11)	Whole herb	[12]
	Tetradecane (12)	Whole herb	[12]
	Heptadecane (13)	Whole herb	[12]
	Cis-caryophylene (14)	Whole herb	[12]
	Octodecane (15)	Whole herb	[12]
	Geraniol (16)	Whole herb	[12]
	Lavanduol (17)	Whole herb	[12]
	Ethyl-tren-α-heptanoate (18)	Whole herb	[12]
	4-methyl-azabicyclo(2,2,2)octane acid (19)	Whole herb	[12]
	N-pentadcane (20)	Whole herb	[12]
	3α- acetyloleanolic acid (21)	Whole herb	[13, 14]
	Oleanolic acid (22)	Whole herb	[13, 14]
	β-sitosteryl (23)	Whole herb	[13, 14]
	7-deoxy-8-epiloganic acid (24) (4R)-4-hydroxymethyl-	Root, stem	[15]
	boschnialactone (25)	Root, stem	[16]
	(24S)-3β-hydroxy-24-ethylcholest-5-en-7-one (26)	Whole herb	[16]
	(24R)-3β-hydroxy-24-ethylcholest-5-en-7-one Methyl p-	Whole herb	[16]
	coumarate (27)	Whole herb	[16]
	4,5,6-three hydroxyl odone (28)	Whole herb	[11, 17]
	Boschnialinic acid (29)		[11, 17]
Organic	Decahydronaphthoic acid (30)	Whole herb	[18]
acids	3,5-Dimethoxybenzoic acid (31)	Whole herb	[18]
	Palmitic acid (32)		[18]
	Linoleic acid (33)		[18]
	10-methyl-heptadecanoic acid (34)		[18]
	9,12-octadecadienoic acid (35)		[19]
	9,17-octadecadienoic acid (36)		[19]
	5,8,11-heptadecatrienoic acid (37)		[19]
	Gallic acid (38)		[17, 20]
	Cinnamic acid (39)		[17, 20]
	Caffeic acid (40)		[17, 20]

Table 2: Chemical constituents of *B. rossica* (*contd*)

Class	Chemical constituent	Source	References
Alkaloids	P-coumaric acid (41)		[13]
	Actinidine (42)		[10]
	Boschniakine (43)		[10, 11]
	Trans-2,3-dimethylindoline (44)		[21]
	7-methyl-6,7-dihydro-5H-1-pyridine (45)		[21]
	2-phenyl-5-isopropyl -1,3,4-oxadiazoles (46)		[21]
Glycosides	8-Epi-iridodial glucoside (47)		[22]
	Boschnarol (48)		[14]
	Daucosterol (49)	Whole herb	[14]
	Boschnaloside (50)	Whole herb	[15]
	Bosnarol methylether (51)		[15]
	β-sitosterol-3-O-β-D-glucoside (52)	Whole herb	[17]
	Rossicaside A (53)	Whole herb	[23]
	Rossicaside B (54)		[13]
	Rossicaside C (55)	Whole herb	[13]
	Rossicaside D (56)	Whole herb	[13]
	Rossicaside E (57)	Whole herb	[23]
	Rossicaside F (58)		[24]
	Acteoside (59)	Whole herb	[25]
Carbohydrate	Glucose (60)	Whole herb, stem, root	[8, 9, 26-28]
	Xylose (61)	Whole herb, stem, root	[8, 9, 26]
	Mannose (62)	stem, root, Whole herb	[8, 9]
	Galactose (63)	Stem, root, Whole herb	[8, 9, 28]
	Rhamnose (64)	Whole herb	[26]
	Arabinose (65)	Whole herb	[9, 26, 28]
	Fucose (66)	Whole herb, inflorescence	[27, 28]
	Sucrose (67)	Whole herb	[20]
	Galacturonic acid (68)	Whole herb, inflorescence	[26, 27]
	Glucuronic acid (69)	Whole herb	[9]
	amino acids (70)	Whole herb	[5]
Other components	Mineral elements (71)		[4, 6, 7]

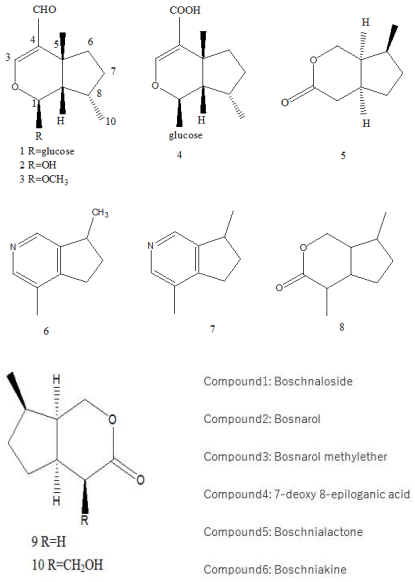

Figure 2: Chemical structure of partial components from *B. rossica*

Anti-aging and memory-enhancing effects

The dried herb and stem of *B. rossica* have been used as anti-senile agents in China for many years. In the past few decades, a series of studies have confirmed the anti-aging and memory-enhancing ability of *B. rossica* extracts, as well as the underlying mechanisms. A 50 % ethanol extract of *B. rossica* was administered to rats whose nucleus basalis of Meynert had been destroyed by the injection of ibotenic acid. This administration resulted in significant mitigation of the decreases in correct responses caused by destruction of the nucleus basalis of Meynert, suggesting that *B. rossica* might be a useful source of therapeutic drug for senility [31].Further studies on the mechanism involved in the invigorating and anti-senile actions of *B. rossica* revealed the 50 % ethanol extract exhibited free radical scavenging activity. The concentrations showing 50 % inhibition of l, l-diphenyl-2-picrylhydrazil radical, superoxide radical and

hydroxyl radical were 0.003, 0.06 and 9.67 %, respectively [32]. The extract increased SOD activity, decreased MDA content, and inhibited the MAO activity in brain tissue. It was observed under microscope that *B. rossica* extract reversed mitochondrial degeneration of mitochondrion and had obvious protective effect on brain tissue of senile rats [33,34]. In addition, *B. rossica* extract has been shown to exert anti-hypoxia and anti-fatigue effects in normal mice [35]. *Boschniakai rossica* extract increased the expression of nestin in hippocampus neural stem cells nestin in AD model rats, and improved learning ability and memory in the AD rats [36]. It reduced the activation of glial cells, thereby protecting the neurons, and it enhanced the ability of learning and memory of rats with Alzheimer's disease [37].

Anti-tumor effects

The water extract of *B. rossica* increased the activities of SOD, GSH-PX and, CAT, and raised TNF-α content of rat liver at the early stage of chemical carcinogenesis; it also reduced GST activity of GST and MDA level arising from increased pre-cancerous lesions [38].

Studies have shown that ethanolic extract of *B. rossica* increased the tumor growth inhibition ratio, and the serum T-AOC, while decreasing serum MDA content [39]. It promoted the apoptosis of tumor cells and inhibited the proliferation of A549 lung carcinoma cells [40]. Further studies showed that the phenylpropanoid glycosides from *B. rossica* extract significantly increased P53, Bax and Fas expressions, and decreased Bcl-2 expression, thus exerting anti-lung cancer effect by inducing cell cycle arrest and apoptosis [41].

Iridoid glucosides from *B. rossica* in H_{22}-bearing mice significantly reduced xenograft tumor mass, and significantly increased mice spleen index and serum levels of IL-2 and T-AOC, while decreasing the levels of TNF-α and MDA [42]. It has been reported that iridoid glucosides from *B. rossica* inhibited the expression of PCNA of tumor cells, induced tumor cell apoptosis, decreased Bcl-2 protein expression, and increased Bax protein expression, indicating that inhibition of tumor cell proliferation and induction of tumor cell apoptosis may be part of the mechanisms involved in the anti-tumor effect of iridoid glucosides [43].

Rhizome polysaccharide of *B. rossica* [BRP] showed antitumor effect *in vivo* at early metaphase of liver cancer [44]. It was seen that BRP alone or in combination with 5-FU significantly inhibitedsarcoma-180 tumor growth and increased the spleen index in a dose-dependent manner. Asynergistic effect was observed in boosting various immunity functions such as stimulating lymphocytes proliferation, increasing NK cell cytotoxicity, enhancing serum IL-2 and TNF-γ secretions, as well as augmenting CD^{4+} and CD^{8+}spleen T lymphocytes subsets [45,46]. The BRP inhibited the proliferation of Hep2 cells in a time- and dose-dependent manner. Cell cycle analysis revealed that exposure to BRP.

Hepatoprotective effect

Studies on the hepatoprotective effect of *B. rossica* extract have reported that it reduced the formation of thiobarbituric acid- reactive substances, conjugated dienes and old lipofuscin, and restored SOD activity to normal value [48].

Ethanol extract of *B. rossica* protected the liver against chemically-induced injuries in animal models. Using a rat model of pig serum-induced liver fibrosis, it was shown that *B. rossica* extract significantly reduced serum procollagen type III and collagen type IV levels, and RT-PCR revealed that TGF-b1 mRNA expression was also reduced. Thus *B. rossica* prevented rat liver fibrosis by inhibiting the activation of hepatic stellate cells and synthesizing collagen [49]. It has been shown that administration of *B. Rossica* ethanolic extract resulted in an anti-fibrogenic role in DMN-induced liver fibrosis in rats through its anti-oxidative effect and inhibition of hepatic stellate cell activation [50].

In CCl_4-induced liver injury in rats, pre-administration of *B. rossica* extract not only reversed the significant changes hepatic oxidative stress, xenobiotic metabolizing enzymes and pro-inflammatory mediators induced by CCl_4, but it also restored liver cytochrome P450 2E1level and function [51,52].

The iridoid glucosides, phenylpropanoid glycosides and polysaccharides of *B. rossica* extract showed strong activity against D-Gal, LPS and CCl_4-induced liver injury. Iridoid glucosides from *B. rossica* significantly reduced serum ALT and AST levels in LPS-induced liver injury mice, reduce the caspase-3 and caspase-8 activation levels of liver tissue, and decreased liver DNA fractures. These effects may involve mechanisms related to its inhibition of liver cell apoptosis [53,54]. Moreover, the extract increased the anti-oxidative status of the liver, and exerted protective effects on acute liver injury induced by D-galactoamine in mice [55].

Table 3: Pharmacological activities of *B. rossica*

Activity	Extract used	Plant part used	References
Immune-enhancing effect	Ethanol, polysaccharide	Whole herb	[9, 29-30]
Anti-aging and memory-enhancing effect	Ethanol, water	Whole herb	[31-37]
Anti-tumor effect	Water & ethanol, iridoid glucosides, polysaccharide, Phenylpropanoid glycosides	Whole herb root	[38-47]
Hepatoprotective effect	Ethanol, water, n-butanol , phenylpropanoid glycoside, iridoid glucoside, Polysaccharide	Whole herb	[48-60]
Anti-oxidative effect	Polysaccharide, water	Whole herb	[61-64]
Anti-inflammatory effect	Water, CH_2Cl_2	Whole herb	[65-66]
Safety	Polysaccharide	Whole herb	[67, 69]

In addition, activity screening results showed that phenylpropanol glycosides of *B. rossica* inhibited triglyceride accumulation HepG2 cells [56].

Different doses of polysaccharides from *B. rossica* had different degrees of lowering effects in mice blood ALT and AST levels, and they reduced MDA content in liver tissue to varying degrees. They reduced liver tissue NO, and improved the activity of SOD in liver tissue. Histological studies on mice liver using H&E staining showed that the polysaccharides reduced the degree of liver cell swelling and, inflammatory cell infiltration [57].Moreover, these data, *Boschniakia rossica* ethanol extract inhibited the proliferation of rat hepatic stellate cell-T6 cultured *in vitro* in a dose- and time-dependent manner. Flow cytometry analysis showed that the hepatic stellate cell-T6 treated with the *B. rossica* ethanol extract was arrested in Go/G1 [59,60].

Further investigations are needed to fully elucidate the exact mechanisms.

Anti-oxidative effect

Anti-oxidative effect was exhibited by water extract of *B. rossica* in the early stage of chemical hepato-carcinogenesis in rat livers [61]. *Boschniakia rossica* alleviated pathological changes in myocardial cells infected with coxsackie virus B 3 and significantly reduced MDA content in myocardial cells, while increasing the activity of superoxide dismutase [62]. The anti-lipid peroxidation effect of BRP has been investigated, and it was shown that BRP exerted high total antioxidant capacity in a concentration-dependent manner, and concentration-dependently inhibited lipid peroxidation of liver homogenate and liver mitochondria induced by H_2O_2, Fe^{2+} and ·OH [63,64]. These results suggest that BRP has anti-lipid peroxidation effects *in vitro*.

Anti-inflammatory effect

Aqueous extract of *B. rossica* has strong anti-inflammatory effect. Studies have shown that it inhibited carrageenan-induced foot swelling, controlled the release of inflammatory media PGE, and inhibited mouse celiac capillary permeability induced by acetic acid [65]. Both CH_2Cl_2 and H_2O extracts of *B. rossica* exhibited inhibitory effect in carrageenan-, histamine- and hot scald-induced hind paw edema, adjuvant-induced arthritis in rats and cotton pellet-induced granuloma formation in mice. They exhibited inhibitory effect on formation of preneoplastic hepatic foci in early stage of rat chemical-hepato-carcinogenesis. Both extracts exerted anti-inflammatory effect in rats and mice [66]. It has been reported that BRP inhibited xylene-induced ear swelling in mice, and the number of leukocytes and neutrophil in blood of mice with ear swelling. Dextran-induced rat paw swelling was remarkably reduced by BRP [67].

Anti-atherosclerosis effect

B. rossica significantly reduced the content of cholesterol, triglycerides, low density lipoprotein cholesterol, and MDA in serum of atherosclerosis rats, and increased the activity of high-density lipoprotein cholesterol and, superoxide dismutase. *B. rossica* significantly reduced atherosclerosis-induced damage in rabbit aortic endothelial cells, inhibited smooth muscle cell proliferation, and reduced monocytes adhesion, through a mechanism involving regulation of lipid metabolism, resistance to free radical oxidative damage, and prevention of aortic intima injury [68].

CONCLUDING REMARKS

Boschniakia rossia has received increasing research interest in recent years, and phytochemical and pharmacological studies have

validated its traditional uses. The various organic and aqueous extracts of *B. rossia* possess an array of pharmacological activities, including immune-enhancing, anti-aging, anti-tumor, hepatoprotective and antioxidant effects due to the presence of various iridoids, carbohydrates and glycosides in this plant. These compounds could serve as leads in the search for novel medicinal agents. There is a need to investigate the biochemical and physiological mechanisms underlying the properties of *B. rossia*, especially its cardioprotective, hepatoprotective and neuroprotective activities. Further studies on *B. rossia* should be designed to investigate the molecular mechanism(s) of action of isolated phytoprinciples using specific biological screening models and clinical trials, and also to discover novel leads from them. Moreover, studies should be extended to standardize the various extracts of *B. rossia* for the purpose of their use in specific herbal formulations. Further safety verification and clinical trials should be performed before *B. rossia* can be integrated into medicinal practice.

DECLARATIONS

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Conflict of interest

No conflict of interest is associated with this work.

Contribution of authors

We declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors.

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REFERENCES

1. *Liu JH, Liang ZY. Advances in studies on active constituents and their pharmacological activities for Boschniakia rossia. Spec Wild Econ Anim Plant Res 2001; 4: 55-58.*
2. *Zhou Y. ChangBai Mountains Plant Resources China. China Forestry press 2010; 3: 1037.*
3. *Song LR, Hu L, Zhang G, Xie Z, Wang X, Xu G, Xiao P, Ling Y, Ding X, Cao C. Chinese Material Medical. Shanghai Sci Tech Publishing House 1998; 1: 495.*
4. *Chen Y, Wang SL, Chen DF. Determination of amino acids and nutrient elements in Boschniakia rossica. Amino Acids & Biotic Resources 2008; 30: 74-76.*
5. *Li SD, Zheng YN. Studies on the chemical constituents of Changbai Mountain Boschniakia rossica. Ⅱ analysis of amino acid components. J Chin Med Mater1987; 1: 39.*
6. *Li SD, Qiu C. Studies on the chemical constituents of Changbai Mountain Boschniakia rossica. Ⅱ analysis of inorganic components. J Chin Med Mater 1988; 5: 40-41.*
7. *Yao YH. Analysis of second speciation of trace elements in Boschniakia rossica. J Yanbian Univ 2012; 38: 75-77.*
8. *Wei M, Zhang LP, Liang ZY, Tian MH. Purification and characterization on water soluble polysaccharides BRT isolated from the stem and the root of wild Boschniakia rossica. J Northeast Normal Univ 2003; 35: 74-77.*
9. *Liu Y, Sheng Y, Yuan GX, Wang Y, Wei HF, Guan M, Pei J. Purification and physicochemical properties of different polysaccharide fractions from the water extract of Boschniakia rossica and their effect on macrophages activation. Int J BiolMacromol 2011; 49: 1007–1011.*
10. *Zheng YN. Studies on the chemical constituents of Boschniakia rossica. J Jilin Agr Univ 1987; 9: 31-37.*
11. *Sakan T, Hayashi Y. Structure and stereochemistry of boschniakine, boschnialactone, and boschnialinic acid, an oxidation product of boschnialactone. Tetrahedron 1967; 23: 4635–4652.*
12. *Li XG, Zeng YL. Study on the chemical constituents of the volatile oil of Boschniakia rossica. Chinese Tradit Patent Med 1985; 5: 29.*
13. *Konishi T, Shoji J. Studies on the constituents of Boschniakia rossica FEDTSCH. et FLEROV. I. isolation and structures of new phenylpropanoid glycosides, rossicasides B, C and D. Chem pharm bull 1981; 29: 2807-2815.*
14. *Gui MY, Zhang HG, Jin YR, Wu GX, Peng WR. Chemical constituents from Boschniakia rossica. Chin Pharm J 1997; 32: 204.*
15. *Yin ZZ, Kim HS, Kim YH, Lee JJ. Iridoid compounds from Boschniakia rossica. Arch Pharm Res 1999; 22: 78-80.*
16. *Yim SH, Kim HJ, Liu YZ, Lee IS. A Novel Iridoid from Boschniakia rossica. Chem PharmBull 2004; 52: 289-290.*
17. *Yi YJ, Cao ZZ. Studies on the chemical constituents of Boschniakia rossica. Acta Pharm Sin1999; 34: 686-689.*
18. *Gui MY. Analysis of fatty acid composition of Boschniakia Rossica. J Norman Bethune Univ Med Sci 1995; 2: 149.*

19. Sun QL, Wei CY, Meng XY, Luo WY. Studies on acidic chemical ingredients of Boschniakia rossica. J Jilin Agr Univ 1995; 12: 38-40.
20. Zhou XJ. Studies on chemical constituent and HPLC fingerprint of Boschiniakia rossica. Huhhot: inner Mongolia Med Coll, MS 2008.
21. Wei CY, Zhang J, Shen J, Sun QL. Studies on alkali chemical components of Boschniakia rossica. J Jilin Agr Univ 1994; 16: 145-148.
22. Fujio M, Motoko T. 8-Epi-iridodial glucoside from Boschniakia rossica. Planta Med 1982; 46: 45-47.
23. Wu CH, Wang T, Yamaguchi Y, Deng S, Li CM, Zhang Y. Isolation and identification of rossicaside A-E from Boschniakia rossica Fedtsch et Flerov. J LiaoNing Univ TCM 2013; 15: 55-58.
24. Shyr MH, Tsai TH, Lin LC. Rossicasins A, B and rossicaside F, three new phenylpropanoid glycosides from Boschniakia rossica. Chem PharmBull 2006; 54: 252-254.
25. Wu YT, Lin LC, Sung JS, Tsai TH. Determination of acteoside in Cistanche deserticola and Boschniakia rossica and its pharmacokinetics in freely-moving rats using LC–MS/MS. J Chromatogr B 2006; 844: 89-95.
26. Li SD, Wu C, Zhang JW. Studies on the chemical constituents of Changbai Mountain Reinforcement effects of Boschniakia rossica. Ⅱ analysis of carbohydrate components. J Chin med mater 1987; 2:42-43.
27. Chang GY, Sun C, Jiao YC. Study of water soluble polysaccharide of Boschniakia rossica inflorescence. J Tonghua normal Univ 1997; 6: 51-52.
28. Sun C, Chang GY. Analysis to the Boschniakia rossica polysaccharide extracted with alkailine. Chin J Pharm Anal 2007; 27: 87.
29. Jiang YN, Zheng CX, Li HH, Li YX, We CS. The Effect of Boschniakia rossica on antibody secreting cells of mice. J Med Sci Yanbian Univ 1992; 15: 170-172.
30. Piao YR, Jiang YS, Li YX, Jin MS, Jiang YN. Effects of cellular immune activity against liver injury blight of Boschniakia rossica. Chin Tradit Herbal Drugs 1994; 4: 200-202.
31. Tadashi T, Liu YZ, Sugarya A, Katoh K, Hori K, Tanaka S, Nonura M, Sugaya E. Reinforcement effects of Boschniakia rossica on discrimination learning in cholinergic lesions of rats. J Ethnopharmacol 1994; 44: 67-71.
32. Tsuda T, Sugaya A, Liu YZ, Katoh K, Tanaka H, Kawazura H, Sugaya E, Kusai M, Kohno. Radical scavenger effect of Boschniakia rossica. J Ethnopharmacol 1994; 41: 85-90.
33. Piao L, Zhang XW, Jin XZ, Li SH. Effect of WTHX Boschniakia rossica extract on free radicals in brain of D-galactose induced senile rats. J Chin Integr Med 2003; 1: 125-127.
34. Piao L, Zhang XW, Jin Z, Jin SM. Experimental study on the protective effect of Boschniakia rossica extract on brain tissue of senile rats induced by D-galactose. Chin J Tradit Med Sci Tech 2003; 10: 294.
35. Zhang Y, Ming L, Zhang JS, Li Y, Cao ZZ,Chen MZ. Effects of Boschniakia rossica Fedtsch. et Flerov on increase intelligence. Acta Univ Med Anhui 1994; 29: 181-183.
36. Zhou LS, Zu SX, Wang XY. Effects of Boschniakia rossica extract on hippocampal neurons in Alzheimer's disease model rats learning and memory cells, nestin and stem. Lishizhen Medi MaterMed Res 2008; 19: 2671-2673.
37. Fu AN, Zhou LS, Zu SX. Effect of Boschniakia rossica extract on the microglia cells in the frontal lobe and learning and memory ability of AD rats. Chin J Hospit Pharm 2011; 4: 267-270.
38. Shen MH, Quan JS, Liu MZ, Sun Q, Yin ZZ, Liang CN. Effects of boschniakia rossica extract on the serum antioxidative activities and tumor necrosis factor in initial stage of rat chemical hepato-carcinogenesis in rats. Shandong J Tradit Chin Med 2004; 25: 166.
39. Wang QY, Wang J, Ning Y, Zhao WX, Jin AH, Quan JS. Growth inhibitive effects of aqueous fraction from the ethanolic extract of Boschniakia rossica in H22 bearing mice. J MedScience Yanbian Univ 2012; 35: 107-109.
40. Yin XZ, Xu HX, Xu JP, Jin AH, Quan JS. Inhibitive mechanism of Boschniakia rossica extract on proliferation of lung carcinoma cell. Food Sci Technol 2011; 36: 191-198.
41. Jin YH, Liu CY, Jin AH, Xu HX, Yin XZ. Effect of phenylpropanoid glycosides from Boschniakia rossica on cell cycle distribution and apoptosis of lung carcinoma cell. Chin J Experim Tradit Med Formulae 2011; 17: 213-216.
42. Jin AH, Piao L, Yin XZ, Quan JS. Anti-tumor effect of iridoid glucosides from Boschniakia rossica in H22-bearing mice. Chin Tradit Herbal Drugs 2012; 43: 332-335.
43. Xu HX, Jin YH, Jin AH, Liu CY, Yin XZ. Effects of iridoid glucosides from the Boschniakia rossica on proliferation and apoptosis of transplanted with VX2 tumor cells in rabbits. J Med Sci Yanbian Univ.2011; 34: 169-172.
44. Wu HY, Gong XG, Huang H, Wang BC. Anti-cancer effects and the related mechanism of Boschniakia rossica rhizome polysaccharide. Hainan Med J 2011; 22: 22-24.
45. Wang ZH, Wu BJ, Zhang XH, Xu M, Chang HM, Lu XY, Ren X. Purification of a polysaccharide from Boschniakia rossica and its synergistic antitumor effect combined with 5-Fluorouracil.Carbohyd Polym 2012; 89: 31–35.
46. Zong AZ, Cao HZ, Wang FS. Anticancer polysaccharides from natural resources: A review of recent research. Carbohyd Polym 2012; 90: 1395–1410.
47. Wang ZH, Lu CX, Wu BJ, Wu CQ, Xu M, Luo HN, Li J, Jing G.A polysaccharide from Boschniakia rossica induces apoptosis in Hep2 human laryngeal squamous carcinoma cells. Carbohyd Polym 2013; 6: in press.
48. Yang XW, Lou ZC, Yan ZK. Anti-lipid peroxidative effects of ethanolic extract of Boschniakia rossica on the liver tissue of mice in vivo. Chin Pharm J 1995; 2: 84-86.

49. Wu CS, Piao XX, Piao DM, Jin YR, Li CH. Treatment of pig serum-induced rat liver fibrosis with Boschniakia rossica, oxymatrine and interferon-α. World J Gastroenterol 2005; 11: 122-126.
50. Piao XX, Huang HG, Piao DM. Therapeutic role of ethanolic extract of Boschniakia rossica in dimethylnitrosamine-induced liver fibrosis in rats. World Chin J Digestology 2005; 13: 2206.
51. Quan JS, Piao L, Xu HX, Li T, Yin X. Protective effect of iridoid glucosides from Boschniakia rossica on acute liver injury induced by carbon tetrachloride in rats. Biosci, Biotechnol, and Biochem 2009; 73: 849-854.
52. Quan JS, Yin XZ, Xu HX. Boschniakia rossica prevents the carbon tetrachloride-induced hepatotoxicity in rat. Exp Toxicol Pathol 2011; 63: 53-59.
53. Piao L, Yang ZK, Yang Y, Zhang YN, Quan JS, Yin XZ. Protective effect of iridoid glucosides from Boschniakia rossica on lipopolysaccharide-induced hepatocyte apoptosis in D-galactosamine-sensitized mice. Frontier Sci 2011; 5: 11-14.
54. Yang ZK, Yang Y, Zhang YN, Liu CY, Quan JS. Protective effects of butanol soluble and aqueous fractions of Boschniakia rossica on acute liver injury in mice. J Med Sci Yanbian Univ.2011; 34: 105-107.
55. Li D, Shen GY, Zhao W, Zhao WX, Jin AH, Quan JS. Effects of the Boschniakia rossica iridoids on hepatic antioxidative activity in mice with liver injury by D-galactoamine. J Med Sci Yanbian Univ.2012; 35: 98-100.
56. Zhang Y, Wu CH,Guo LL, Chen Y, Han LF, Liu EW, Gao X, Wang T. Triglyceride accumulation inhibitory effects of phenylpropanoid glycosides from Boschniakia rossica Fedtsch et Flerov. Fitoterapia 2013; 85: 69-75.
57. Li Y, Chen LY, Jin MH, Jin M. Antioxidative effect of polysaccharides from Boschniakia rossica. Food Sci Tech 2011; 36: 246-248.
58. Quan JS, Li T, Zhao WX, Xu HX, Qiu DL, Yin XZ. Hepatoprotective effect of polysaccharides from Boschniakia rossica on carbon tetrachloride-induced toxicity in mice. J clinbiochem and nutr 2013; 52: 244-252.
59. Jin CL, Piao XX, Li CH, Jin YR, Jin HY, Huang Y. Effect of ethanol extract from Boschniakia rossica on proliferation and apoptosis of rat hepatic stellate cell-T6 cultured in vitro. Chin J Experim TraditMed Formulae 2012; 18: 246-250.
60. Huang Y, Jin YR, Piao XX, Jin CL. Study on the effects of anti-proliferation and inducing apoptosis of ethanol extract Boschniakia rossica on hepatic stellate cell-T6. Chin J Hosp Pharm 2012; 1: 1-5.
61. Yin ZZ, Jin HL, Shen MH, Li TZ, Quan JS. Inhibitory effect of boschniakia rossica on den-induced precancerous hepatic foci and its antioxidative activities in rats. Chin J Cancer Res 1999; 11: 169-173.
62. Cao HZ, Xuan YH, Zhang CG, Cao DX. Anti-oxidation effects of the Boschniakia rossica Fedtsch on cultured rats myocardial cells infected with coxsackie virus B3. J Medi Sci Yanbian Univ 2001; 24: 182-185.
63. Liu Y. Active constituents and finger analysis of Cistanche deserticola Ma and Boschniakia rossica. Changchun: Jilin Univ. PhD 2013.
64. Jin AH, Chen LY, Quan JS. Protective effects of polysaccharides from Boschniakia rossica on erythrocyte. Chin J Pub Health 2011; 27: 1433-1434.
65. Yu QH, Gao YD, Piao GC, Sun QS, Yang HJ, Niu YF, Liu Y. Study of Boschniakia rossica pharmacological experiments. J Chin medi mater 1993; 16: 34-36.
66. Yin ZZ, Jin HL, Yin XZ, Li TZ, Quan JS, Jin ZN. Effect of Boschniakia rossica on expression of GST-P, p53 and p21ras proteins in early stage of chemical hepatocarcinogenesis and its anti-inflammatory activities in rats. World J Gastroenterol 2000; 6: 812-818.
67. Chi LC. The research of anti-inflammatory effect toxicological assessment form Boschniakia rossica polysaccharide. Changchun: Jilin Univ. PhD 2008.
68. Jin CH. Protective effect of Boschniakia rossica on atherosclerosis. Yanji: Yanbian Univ.MS 2008.
69. Yu Y, Shen MY, Song QQ, Xie JH. Biological activities and pharmaceutical applications of polysaccharide from natural resources: A review. Carbohyd Polym 2018; 183: 91-101.